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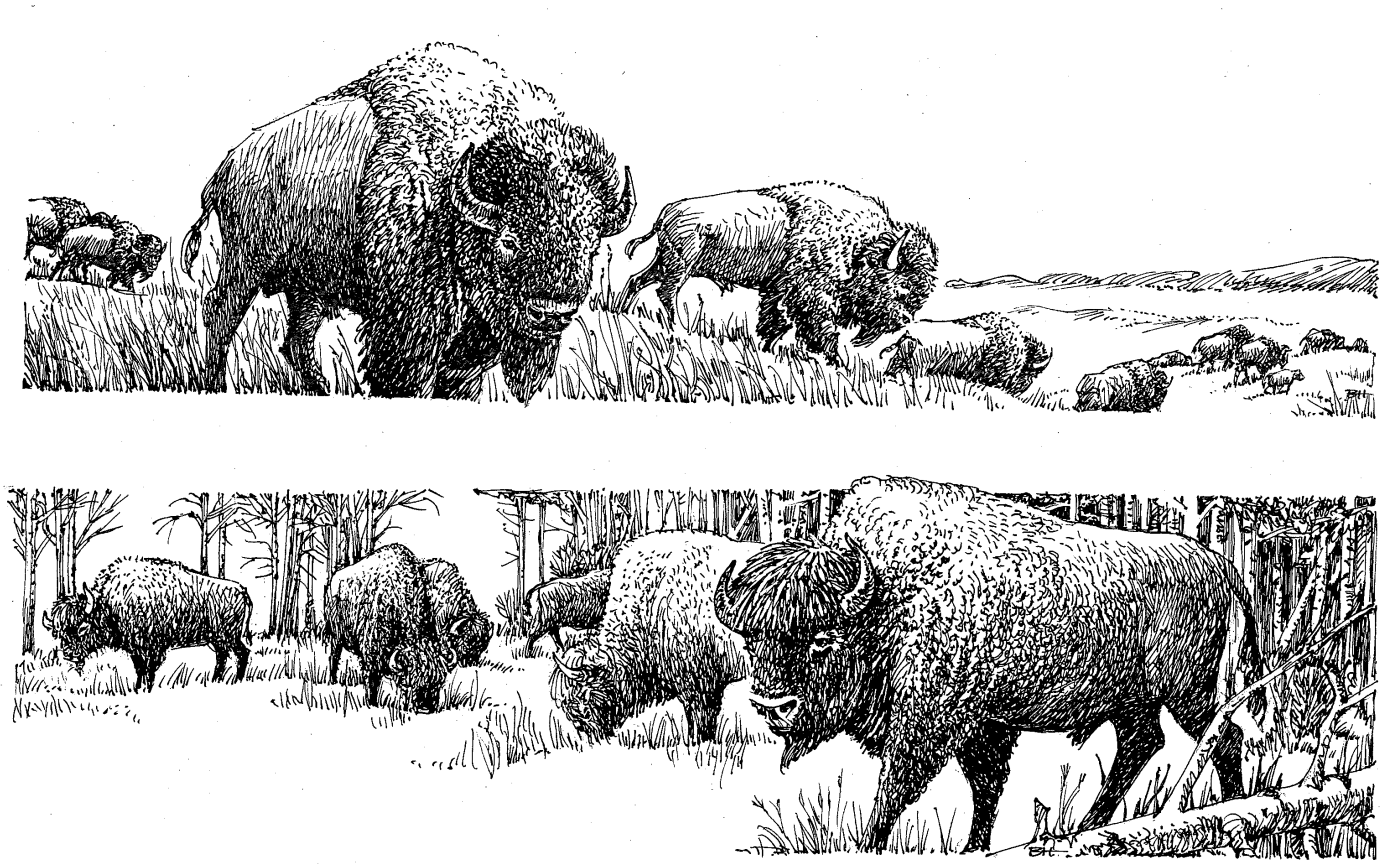
Status of the American Bison (*Bison bison*) in Alberta:

Update 2017



Alberta Wildlife Status Report No. 38 (Update 2017)

Alberta Conservation Association

Alberta Government

Status of the American Bison (*Bison bison*) in Alberta:

Update 2017

Prepared for:
Alberta Environment and Parks (AEP)
Alberta Conservation Association (ACA)

Update prepared by:
John S. Nishi

This report includes some information from the original status report on wood bison prepared by Jonathan A. Mitchell and C. Cormack Gates in 2002.

This report has been reviewed, revised, and edited prior to publication.
It is an AEP/ACA working document that will be revised and updated periodically.

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PREFACE

Every five years, Alberta Environment and Parks reviews the general status of wildlife species in Alberta. General status assessments have been conducted in 1991 (*The Status of Alberta Wildlife*), 1996 (*The Status of Alberta Wildlife*), 2000, 2005, 2010, and 2015 (available in a searchable database at http://aep.alberta.ca/fish-wildlife/species-at-risk/ since 2000). The general status process assigns individual species "ranks" that reflect the perceived level of risk to populations that occur in the province. Such designations are determined from extensive consultations with professional and amateur biologists, and from a variety of readily available sources of population data. The 2015 general status assessments for vertebrates used the same methodology as assessments from 2000 to 2010, and adopted methodology from NatureServe (http://www.natureserve.org/) for invertebrates and plants. A key objective of general status assessment is to identify species that may be considered for more detailed status determinations.

The Alberta Wildlife Status Report Series is an extension of the general status exercise, and provides comprehensive current summaries of the biological status of selected wildlife species in Alberta. Priority is given to species that are considered at some level to be at risk or potentially at risk (e.g., general status of *At Risk* or *May Be At Risk*, NatureServe rank of S1, Committee on the Status of Endangered Wildlife in Canada [COSEWIC] rank of *Endangered/Threatened* at a national level), and species that are of uncertain status (e.g., general status of *Undetermined*).

Reports in this series are published and distributed by Alberta Conservation Association and Alberta Environment and Parks. They are intended to provide up-to-date information that will be useful to resource professionals for managing populations of species and their habitats in the province. The reports are also designed to provide detailed information that will assist Alberta's Endangered Species Conservation Committee in identifying species that may be formally designated as *Endangered* or *Threatened* under Alberta's *Wildlife Act*. To achieve these goals, the reports have been authored and/or reviewed by individuals with unique local expertise in the biology and management of each species.

EXECUTIVE SUMMARY

The American bison (*Bison bison*) is the largest terrestrial mammal in North America and is represented by two subspecies. Under the *General Status of Alberta Wild Species*, wood bison (*B. b. athabascae*) and plains bison (*B. b. bison*) are considered *At Risk* and *Extirpated/Extinct*, respectively. Within a designated management area in northwestern Alberta, bison are listed as *Endangered* under Alberta's *Wildlife Regulation*, and can only be legally hunted through a limited entry draw in a designated hunting zone and season. In another defined area adjacent to the southeastern border of Wood Buffalo National Park (WBNP), bison are designated as Subject Animals under the *Wildlife Regulation*, which prohibits bison hunting by non-Aboriginals. Elsewhere in the province (outside of WBNP and wildland provincial parks), free-ranging bison do not have status under the *Wildlife Act*.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed wood bison as *Special Concern* and plains bison as *Threatened* in 2013. Wood bison remain listed as *Threatened* under the *Species At Risk Act* and plains bison are unlisted; a decision on the recommendation to down-list wood bison to *Special Concern* remains pending. Wood bison and plains bison are aggregated under the taxonomic designation *B. bison* by the Canadian Endangered Species Council, which lists the species as *At Risk* in Canada.

The non-migratory wood bison was historically distributed from northern Alberta to Alaska, whereas the migratory plains bison was vastly more abundant and its main distribution was on the grasslands from the Great Plains continuously to present-day Mexico. In Alberta, the historical range of the plains bison was centred on the Grasslands Natural Region, extending north into the Parklands and west into the foothills of the Rocky Mountains. The historical range of the wood bison reached from the northern extent of the Central Parklands (just north of present-day Edmonton), and extended north throughout the Boreal Forest Natural Region. Widespread market hunting nearly eliminated both wood and plains bison by the end of the 19th century. Indeed, plains bison were extirpated from the province by the late 1800s.

Currently, the provincial wood bison population comprises an estimated 3866 mature animals in six subpopulations that range wholly or partially within Alberta. The largest subpopulation is in the Greater Wood Buffalo National Park (GWBNP) area, which represents approximately 72% of the provincial population and comprises six spatially disjunct local populations (herds) with some demographic or genetic connection among them. The GWBNP subpopulation is also enzootic with the cattle diseases bovine tuberculosis (*Mycobacterium bovis*) and brucellosis (*Brucella abortus*). Ronald Lake and Harper Creek are two subpopulations considered not to be infected with cattle diseases, which were likely established from WBNP in the past but are genetically differentiated from the GWBNP subpopulation; they represent approximately 3% and less than 1% of the provincial population, respectively. Elk Island National Park (EINP) is a managed (fenced) subpopulation representing 9% of the population; it was founded in 1965 through capture and translocation of bison from WBNP. Wood bison from EINP were used to reintroduce healthy bison subpopulations in the Hay-Zama area in northwestern Alberta and a subpopulation that has expanded into Alberta from its reintroduction site near Etthithun Lake in northeast British Columbia. The Hay-Zama and Etthithun subpopulations represent approximately 12% and 3% of Alberta wood bison, respectively.

Presence of cattle diseases in the GWBNP subpopulation is the most significant factor limiting recovery of wood bison, because it has implications for conservation and management of healthy

extant bison subpopulations in northern Alberta. To reduce the risk of disease transmission, the Hay-Zama subpopulation is managed within a target population size of 400–600. The strategy for containing growth and distribution of healthy wood bison will likely apply to Etthithun bison if they expand in range and merge with Hay-Zama. The Government of Alberta has established a health surveillance and population monitoring program between the Hay-Zama range and WBNP, with focus on the Wentzel Lake herd, Harper Creek and Ronald Lake subpopulations.

Future prospects for recovery of free-ranging wood bison on its original range in northern Alberta are limited primarily by the presence of bison infected with cattle diseases in the GWBNP subpopulation. Expansion and impacts of industrial and agricultural land uses will also affect future potential for recovery.

EINP and McCusker River subpopulations make up the Alberta plains bison population, which is estimated to be approximately 442–504 mature bison. The EINP plains bison are descendants of the Pablo-Allard herd in Montana, which was purchased by Canada in 1907. Of the two plains bison subpopulations, EINP is larger and stable, and represents about 95% of the provincial population. The McCusker subpopulation was established from EINP bison in 1969 and ranges mostly in Saskatchewan and the Cold Lake Air Weapons Range, with only about 7% of its defined range in Alberta. The McCusker subpopulation is small in size (approximately 51–113 mature animals in Saskatchewan and Alberta combined) and likely stable.

Future prospects for restoration and recovery of free-ranging plains bison on its original range in southern and central Alberta are limited by the amount of available intact grassland habitats in today's predominantly anthropogenic landscape. Parks Canada Agency initiated the reintroduction of plains bison into Banff National Park in 2017.

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*Note that some affiliations may have changed since 2002.

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INTRODUCTION

Alberta lies within what was known as the "Great Bison Belt" that extended across Eurasia, through Beringia and southward across North America, from central Alaska to central Mexico (Guthrie 1980, 1990). During the Holocene, bison were widely distributed throughout North America, from the eastern woodlands to northwestern Canada and Alaska (Soper 1941, Dary 1989, Stephenson et al. 2001). The phenomenon of large, migratory populations was unique to the Holocene Great Plains, with its vast expanse of contiguous grasslands (Guthrie 1980, 1982, 1990). Prior to European settlement of North America, plains bison (*Bison bison bison*) occurred extensively across the Great Plains (Figure 1) and were estimated to number in the tens of millions (Shaw 1995). It is likely that the last free-roaming plains bison in Alberta were shot near the Hand Hills in 1889 (Cotton 1948). In contrast to plains bison, wood bison (*B. bison athabascae*) were scattered in small, non-migratory herds from northern Alberta to Alaska (Figure 1) (Gates et al. 1992, Stephenson et al. 2001). Like the plains bison, the wood bison was pushed close to extinction late in the 19th century (Gates et al. 1992, Isenberg 2000).

The bison was an important element of the fauna of Alberta for nearly 10,000 years, since the end of the Wisconsin glacial period (Reynolds et al. 2003). Bison provided sustenance and materials for many of Alberta's first human residents, and shaped seasonal rounds and social ties, as well as the kinship, culture, spirituality, and technological advancement of indigenous societies (Guthrie 1980, Morgan 1980, Bamforth 1987, 2011, Vickers 1991, Bryan 2005, Nicholson 2011). Bison were a source of food for early explorers and a staple for the fur trade and early European settlements (Colpitts 2015).

At present, the general status of wood bison and plains bison in Alberta is *At Risk* and *Extirpated/Extinct*[*], respectively (Alberta Environment and Parks [AEP] 2017). Within a designated management area in the northwestern section of the province, wood bison are listed as *Endangered* under Alberta's *Wildlife Regulation* (Government of Alberta [GOA] 2014a) (Figure 2). In another defined area adjacent to the southeastern boundary of Wood Buffalo National Park (WBNP), bison are designated as *Subject Animals* under Alberta's *Wildlife Regulation* (Figure 2). Elsewhere in the province, bison do not have status under the *Wildlife Act*.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) lists the wood bison as *Special Concern* and the plains bison as *Threatened* (Government of Canada 2017). Currently, under the federal *Species At Risk Act*, wood bison remain listed as *Threatened* and plains bison are unlisted.

Reintroduction efforts have been undertaken in five locations within the wood bison's original range in Canada (Gates et al. 2001c), with only one initial reintroduction location occurring in northwestern Alberta near Chateh (also known as Assumption). The presence of cattle diseases in the bison population around WBNP is one of the greatest threats to the recovery and maintenance of healthy wood bison populations in northern Canada (Gates et al. 2001c, Environment and Climate Change Canada [ECCC] 2016), and is the most significant factor limiting further recovery in Alberta. Other threats include habitat loss, resulting from the expansion of agriculture (including commercial bison ranching), forestry and petroleum development activities in northern Alberta (Lee et al. 2009a, 2009b, ECCC 2016).

This report summarizes the history and ecology of the wood and plains bison, causes for their decline, current threats, recovery and conservation efforts, and will be used to update the status of the species in Alberta.

[*] See Appendix 1 for definitions of selected status designations.

Figure 1. Historical (pre-European contact circa 1500) range of wood (2.5 M km^2) and plains bison (6.9 M km^2) in North America, based on available zooarchaeological, paleontological, oral and written historical documentation. Modified from Reynolds et al. (2003), Sanderson et al. (2008), and Gates et al. (2010), with polygons provided by COSEWIC (2013a).

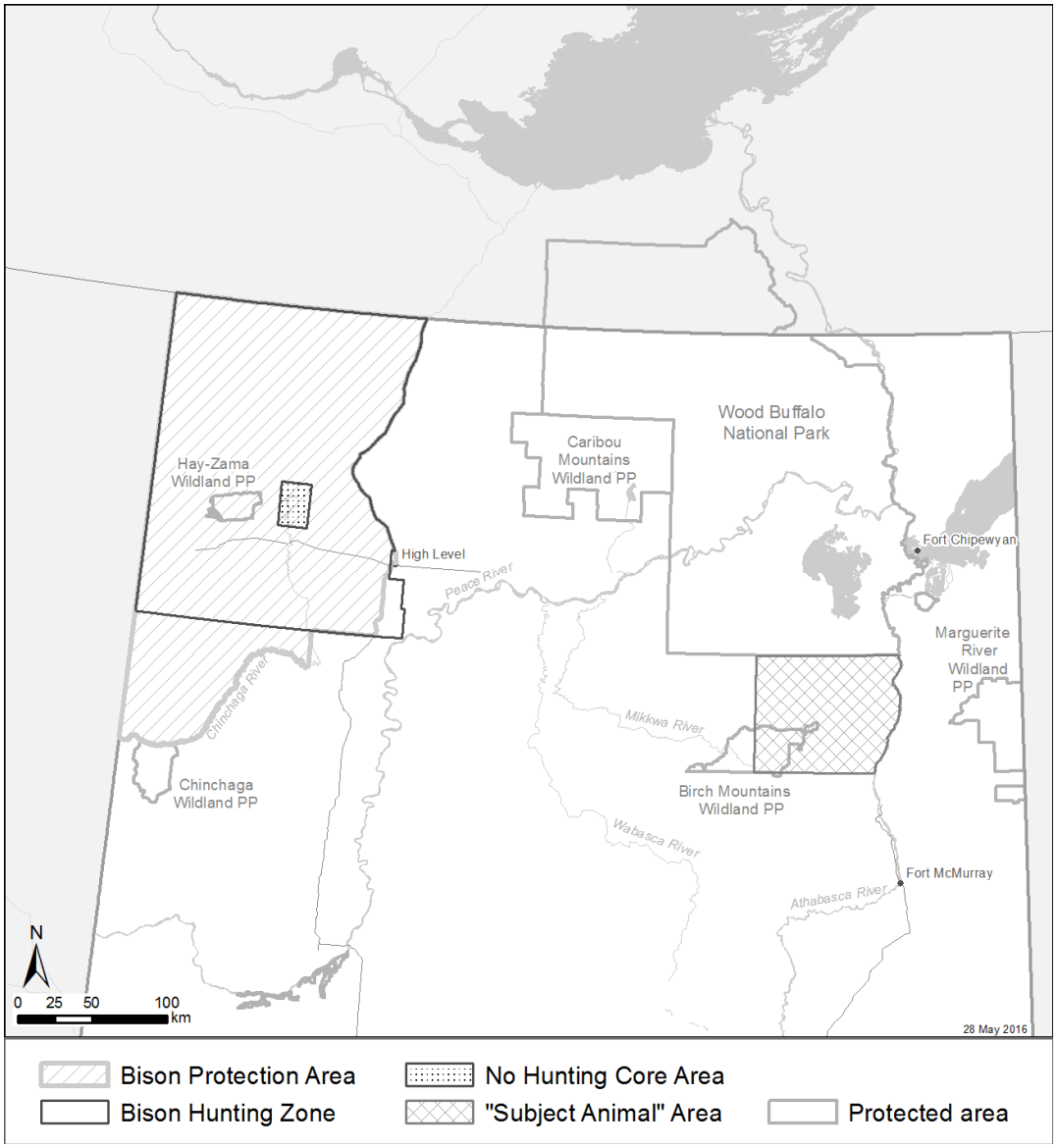


Figure 2. Wood bison management areas in northern Alberta, including the Alberta Bison Protection Area, the Alberta Bison Hunting Zone, the Subject Animal Area and key provincial (PP) and national parks.

SPECIES TAXONOMY

American bison are even-toed, large ruminant ungulates that belong to the family Bovidae, subfamily Bovinae and the tribe Bovini. Within the ox-like tribe Bovini, there are five genera including *Bubalus* (Asian water buffalo), *Syncerus* (African buffalo), *Bos* (domestic cattle and wild relatives), *Pseudoryx* (forest dwelling Saola of Vietnam and Laos), and *Bison* (Grubb 2005, International Union for Conservation of Nature [IUCN] 2015). Although some taxonomists view that cattle (*Bos*) and bison should be united in a single genus (Simpson 1961, Van Gelden 1977, Douglas et al. 2011, Hassanin 2014) because of close morphological and genetic similarity, others suggests that *Bos* and *Bison* are evolutionary divergent units that shared a common ancestor 1.0 – 1.4 million years ago (Hartl et al. 1988, Loftus et al. 1994). Despite the lack of consensus on taxonomic nomenclature, and in keeping with the naming conventions for mammals used for both the 1996 IUCN Red List of Threatened Species

and the 2008 Red List (Wilson and Reeder 1993, 2005), the IUCN American Bison Specialist Group and IUCN European Bison Specialist Group have adhered to the genus *Bison* with two extant species (European bison or wisent [*B. bonasus*] and American bison [*B. bison*]), in the respective status survey and conservation plans (Pucek at al. 2004, Boyd et al. 2010, Gates et al. 2010). The naming convention used by IUCN was also adopted by COSEWIC (2013a) in its status assessment of American Bison in Canada. Similarly, this status report on the American bison in Alberta also adheres to the genus *Bison*.

1. Subspecies - There are two recognized subspecies of American bison: the plains bison (*B. bison bison*) and the larger wood bison (*B. bison athabascae*) (Gates et al. 2010, COSEWIC 2013a, IUCN 2015). Reynolds et al. (2003) and COSEWIC (2004, 2013a) provide comprehensive reviews of the distinction between wood and plains bison—the two putative subspecies. Following the initial type description by Rhoads (1897), the wood bison has been recognized as a separate subspecies from plains bison (Raup 1933, Soper 1941, Skinner and Kaisen 1947, Banfield and Novakowski 1960, Flerov 1965, Karsten 1975, Geist and Karsten 1977, McDonald 1981, Cook and Muir 1984, van Zyll de Jong 1986). Quantifiable differences between plains bison and wood bison in cranial and skeletal morphology were reported by van Zyll de Jong (1986).

When the depopulation and replacement of tuberculosis and brucellosis-infected bison in WBNP was recommended (see Connelly et al. 1990), questions were raised about the validity of the wood bison as a subspecies. Geist (1991) suggested that subspecies status is not warranted and that observed differences between plains bison and wood bison are environmentally induced.

Strobeck et al. (1993) compared sequence divergence in a section of D-loop in the mitochondrial DNA (mtDNA) of a small number of what were putatively considered wood and plains bison, and found that differences between the two subspecies were approximately the same as, or less than, differences within plains bison. The rate of sequence divergence in mtDNA is on the order of 1% to 2% per million years (Wilson et al. 1985). These findings supported the view that wood and plains bison existed as reproductively isolated populations during the last 5000–10,000 years, a relatively short time in evolutionary terms, and that there was introgression of plains bison mtDNA into remnant wood bison populations following the translocation of over 6000 plains bison into WBNP during the 1920s (see Section 1.2, p. 39). Although Cronin et al. (2013) concluded that subspecies ranking of plains and wood bison as a formal taxonomic category was not supported on the basis of phylogenetic distinctiveness, they suggested that plains bison and wood bison should be considered geographic populations and could be managed as such.

Work on morphological (van Zyll de Jong et al. 1995) and genetic differences (Wilson and Strobeck 1999) between wood and plains bison indicate that wood bison continue to function as a genetic entity separate from plains bison, despite the introduction of plains bison into WBNP in the 1920s. As suggested by Wilson and Strobeck (1999), Gates et al. (2001c), Reynolds et al. (2003), and COSEWIC (2004, 2013a), these findings support the view that wood bison and plains bison are sufficiently distinctive to consider their conservation as separate entities.

2. Designatable Units - COSEWIC (2013a) concluded that wood and plains bison satisfy the criteria for discrete and evolutionarily significant designatable units (DU), whether or not they are classified as subspecies or geographic variants (see COSEWIC 2015a). In this context, DUs are biological diversity-based units that are a) guided by the general policy objective of preventing irreplaceable

units of biodiversity from becoming extinct or extirpated from a jurisdiction; b) defined based on hierarchical guidelines that consider established taxonomy, direct or inferred genetic evidence (including morphology, life history and behaviour), range disjunction, and biogeographic distinction, coupled with consideration of conservation status (Green 2005); and c) established in accordance with Canada's *Species at Risk Act*, which provides a legal mandate to manage and define wildlife as a "*species, subspecies, variety or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature"...* (*Species at Risk Act*, SC 2002, c 29, s 2).

The basis for establishing wood and plains bison as distinct DUs is succinctly discussed by COSEWIC (2013a) and summarized here based on the following lines of evidence: 1) despite the introduction of plains bison to WBNP in the 1920s, there is genetic distinctiveness of wood and plains bison based on genetic markers (Wilson and Strobeck 1999) and inherited traits, including skeletal and external morphology (van Zyll de Jong et al. 1995); 2) a natural break in distribution occurred between original ranges of wood and plains bison, such that movement and interaction of bison between the separated ranges was limited (van Zyll de Jong 1986); and 3) the distribution in original ranges of wood and plains bison were separate based on occupation of different biogeographic areas or ecoregions in North America (i.e., the boreal forest versus grasslands; Olson et al. 2001).

An underlying premise of distinguishing between wood and plains bison as separate DUs is to manage their genetic integrity as discrete entities and to not knowingly mix the two subspecies in future conservation and management actions: "*That genetic and morphological differences exist suggests that these subspecies are distinct and should be managed separately. As evidenced by the hybridization at Wood Buffalo National Park, any mixing of these animals will be irreversible, and should not be undertaken lightly"* (COSEWIC 2004; p. 71).

3. Wild by Nature - This assessment applies the conservation-based concept of "wild by nature" to define wood and plains bison as wildlife in Alberta. This concept was applied in the *Species at Risk Act* (SC 2002, c 29), and was subsequently used by COSEWIC (2013a) in its status assessment of wild bison populations in Canada. Gates (2014) provided a detailed discussion and application of the concept, and proposed that a bison population that is "wild by nature" is fundamentally subject to the primary evolutionary process of natural selection and, by corollary, the degree to which humans control breeding, population size and structure, nutrition, health, survival, movements, and predation. White et al. (2015, p. 161) succinctly defined a wild bison population as "*one that roams freely within a defined conservation area that is large and heterogeneous enough to sustain ecological processes such as migration and dispersal, has sufficient animals to mitigate the loss of existing genetic variation, and is subject to forces of natural selection."*

Although there are thousands of wood and plains bison in privately owned commercial herds in Alberta and Canada (Alberta Agriculture and Rural Development [AARD] 2014, Statistics Canada 2011), those bison are not considered to be "wild by nature" or contributing to ecological recovery under the national recovery program (Gates et al. 2001c, COSEWIC 2013a, Gates 2014, ECCC 2016). Despite the numerical abundance of ranched bison, the industry is influenced heavily by consumer preferences and marketing strategies, and actions of the bison industry have generally grown increasingly disparate (McDonald 2001, Sanderson et al. 2003, Lulka 2008) from the broader goals of ecological restoration (Sanderson et al. 2008). Consequently, commercially ranched bison are not considered in this assessment.

DISTRIBUTION

The historical range (circa 1500) of the American bison was an area estimated at 9.4 million km^2 (Sanderson et al. 2008; Figure 1); it spanned from Alaska, through northwestern Canada and into Mexico while including areas as far east as New York and as far west as California.

WOOD BISON

The transition between the Boreal Forest and Parkland natural regions of Alberta (Natural Regions Committee [NRC] 2006) is generally considered to demarcate the contiguous historical ranges of wood and plains bison in North America (van Zyll de Jong 1986; Figure 1). Based on multiple archeological, paleontological, historical and traditional ecological knowledge sources (van Zyll de Jong 1986, Gates et al. 1992, Lotenberg 1996, Stephenson et al. 2001, Farnell et al. 2004, Heffner 2008, Kennedy and Bouchard 2011, and see Gates et al. 2010, COSEWIC 2013a), the historical range of wood bison in North America extended north and west as a wide swath through the boreal forests of northern Alberta, northwestern Saskatchewan, northeastern British Columbia, the western Northwest Territories, most of the Yukon and the central portion of Alaska. The historical range within Alberta was estimated to occupy an area of 432,000 km^2, which was approximately 17% of the historical continental range of wood bison, an area of approximately 2.5 million km^2 (Figure 1).

Wood bison were widely distributed throughout the northern portions of the province (van Zyll de Jong 1986, Gates et al. 2001c). Early accounts of wood bison were provided by explorers and indigenous peoples for many areas (see reviews by Rhoads 1897, Allen 1900, Preble 1908, Gates et al. 1992), including WBNP (Soper 1941), the Fort Vermillion area, the Birch Mountains, and the Fort McMurray area (Roe 1951) in northern Alberta. Depletion of wood bison numbers and contraction of their range was noted locally during the period 1820 to 1830 and was recognized as part of a widespread pattern of game depletion across the Peace-Athabasca area from 1830 to 1840 (Ferguson 1993, Kennedy and Bouchard 2011). By the late 1890s, only small numbers persisted in northern Alberta (McCormack 2010b, Map 9.2; p. 239). Wood Buffalo National Park was established in 1922 to protect remaining wood bison in Canada from further decline and possible extinction (Ogilvie 1979) (see *Population Size, Trends, and Health Status* section for a discussion of the challenges this park has faced).

1.Wood Bison in Alberta

1.1 Population Structure - The current distribution of wood bison in Alberta is based on six subpopulations (*sensu* COSEWIC 2015b, IUCN 2016) that occur wholly or in part within the province (Figure 3). The largest subpopulation occurs in the Greater Wood Buffalo National Park (GWBNP) area, which from a population ecology perspective can be considered a metapopulation (*sensu* Wells and Richmond 1995) that comprises a set of spatially disjunct groups of individuals (i.e., local populations) with some demographic or genetic connection among them. The local populations that compose the GWBNP subpopulation include Garden River, Nyarling, Slave River Lowlands, Hay Camp, Delta, and Wentzel Lake. In this assessment, the Wentzel Lake local population is considered part of the GWBNP subpopulation but summarized separately because it is monitored separately from WBNP and is a herd that is under management authority of Alberta. Ronald Lake and Harper Creek are two wood bison subpopulations that were likely naturally established from WBNP in the past, but are genetically differentiated from the GWBNP metapopulation (Ball et al. 2016). Elk Island National Park (EINP) is a managed, fenced subpopulation that was founded by capturing and translocating bison from WBNP, and has been subsequently used

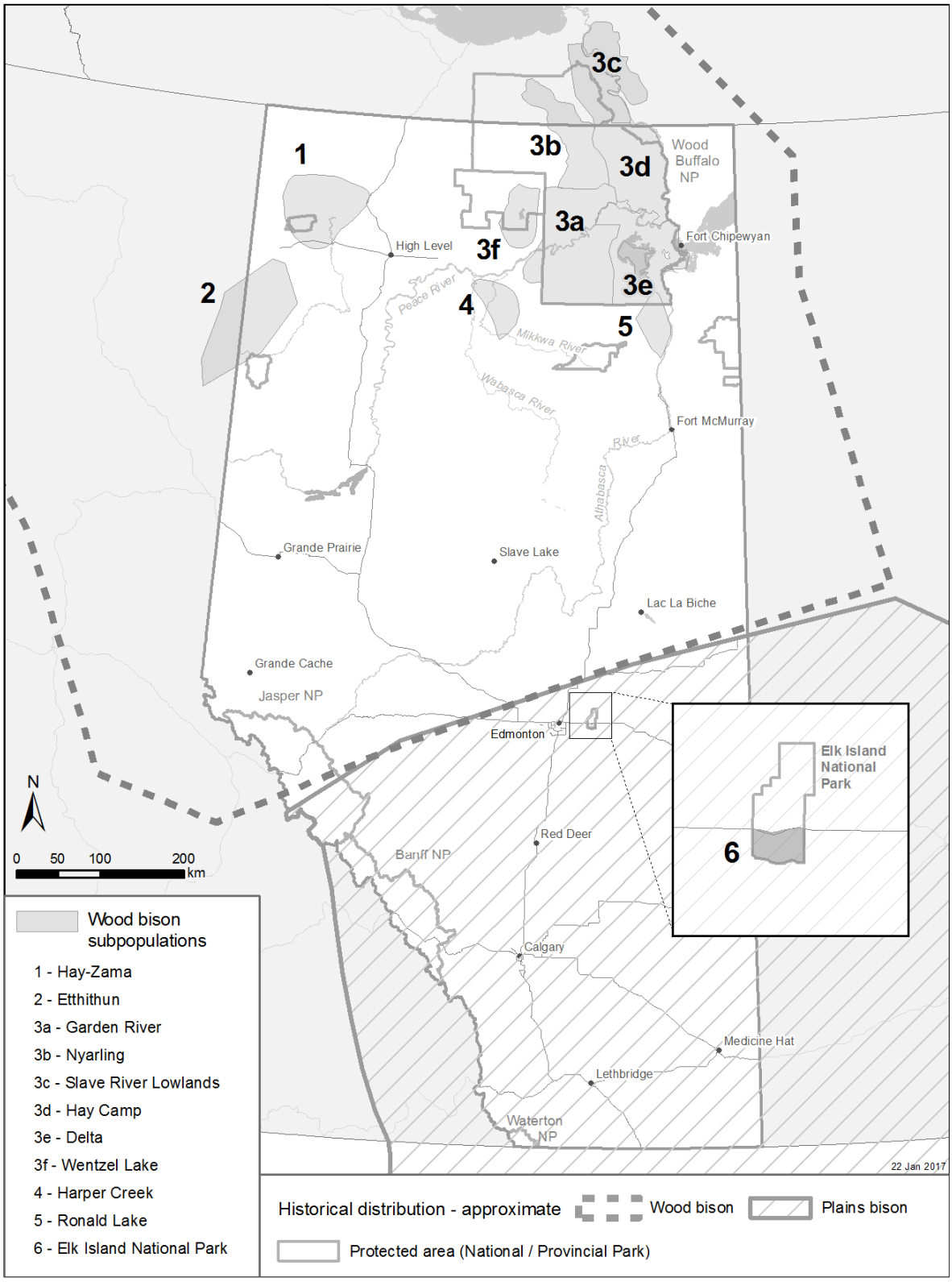


Figure 3. Wood bison subpopulations (herds) in northern Alberta. Bison range polygons adapted from COSEWIC (2013a), and updated based on recommendations from Alberta Environment and Parks staff.

to reintroduce bison subpopulations in the Hay-Zama area of northwestern Alberta and a subpopulation that has expanded in to Alberta from its reintroduction site near Etthithun Lake in northeast British Columbia.

1.2 Provincial Extent of Wood Bison Occurrence - The extent of occurrence (EO) of wood bison in Alberta is about 246,132 km^2 (Appendix 2), although much of this area is unoccupied and unsuitable habitat. Based on a 2-km x 2-km grid, the cumulative Index of Area of Occupancy (IAO) for wood bison subpopulations within the geographic boundaries of Alberta is considerably smaller at about 51,428 km^2 (Table 1), and represents approximately 21% of the EO within the province. Only 38% (19,746 km^2) of the cumulative IAO within the geographic boundary of the province falls within direct management authority of the Government of Alberta (Table 1).

For this assessment, spatial delineation of ranges for wood bison subpopulations and the Wentzel Lake herd was based on a variety of data sources, including public sightings (Figure 4), aerial surveys (Figure 5), and point locations of radio-collared bison (Figure 6). Available information from traditional ecological knowledge was also used to substantiate and define bison range distributions adjacent to WBNP (see Schramm and Krogman 2001, Schramm et al. 2002, Schramm 2005, Candler et al. 2011 and 2015).

1.3 Greater Wood Buffalo National Park (GWBNP) Subpopulation - The GWBNP subpopulation is a metapopulation composed of six genetically panmictic (randomly interbreeding) local populations occurring within WBNP and in adjacent areas of the Northwest Territories and Alberta (Figure 3). With the exclusion of the Wentzel Lake herd, the occupied range of the GWNP metapopulation extends over an area of approximately 41,224 km^2 (based on the number of 2 km x 2 km grid cells that cover the defined range) (Table 1, Figure 3). In accordance with COSEWIC (2013a), the GWBNP metapopulation is considered a single subpopulation. An assumption underlying the premise of a GWBNP metapopulation is that local populations are spatially defined and that there is some level of individual exchange and interaction between adjacent herds that

Table 1. Summary of range areas for wood bison subpopulations in Alberta.

Wood Bison Subpopulation Range Areas					
Alberta	**Subpopulation (Herd) Name**	**Management Jurisdictions**	**Index of Area of Occupancy - IAO[†] (km^2)**	**IAO in Alberta[#] (km^2)**	**IAO in Alberta & GOA Mgmt[##] (km^2)**
Free-ranging	Hay-Zama	AB	6,920	6,920	6,920
	Etthithun	AB, BC	9,624	5,572	5,572
	Ronald Lake	AB, CA	2,020	2,020	1,798
	Harper Creek	AB	2,488	2,488	2,488
Free-ranging Infected*	• Wood Buffalo National Park (WBNP)	CA	41,224	31,376	0
	• Wentzel Lake	AB	2,968	2,968	2,968
Captive	Elk Island National Park (EINP)	CA	84	84	0
			65,328	**51,428**	**19,746**

[†] Calculated by totalling the area of 2x2 km grid cells that cover the subpopulation range (*sensu* COSEWIC 2013a). [#] Refers to the area of a bison subpopulation range that occurs within Alberta. [##] Area of a bison subpopulation range that is under management authority of the Government of Alberta, and not within national parks or federal military reserve lands. Subpopulations preceded by a • indicate they occur within the Greater WBNP metapopulation. *Indicates a subpopulation infected with bovine TB &/or brucellosis.

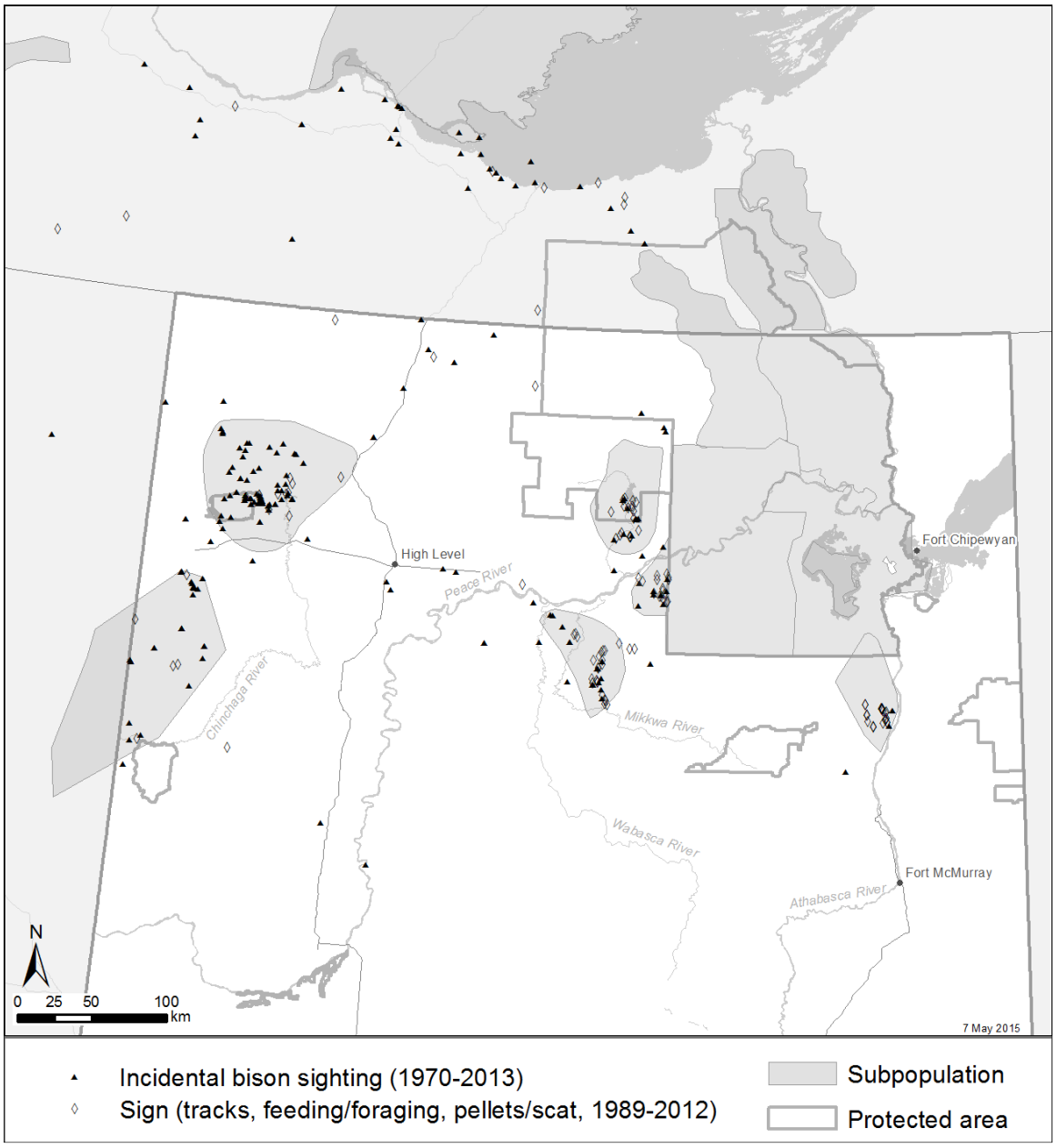


Figure 4. Reported public sightings and observations of bison sign. Data were amalgamated from the Alberta Fisheries and Wildlife Management Information System (FWMIS) database (AEP 2015), and information from the Northwest Territories Wildlife Management Information System (Environment and Natural Resources 2015).

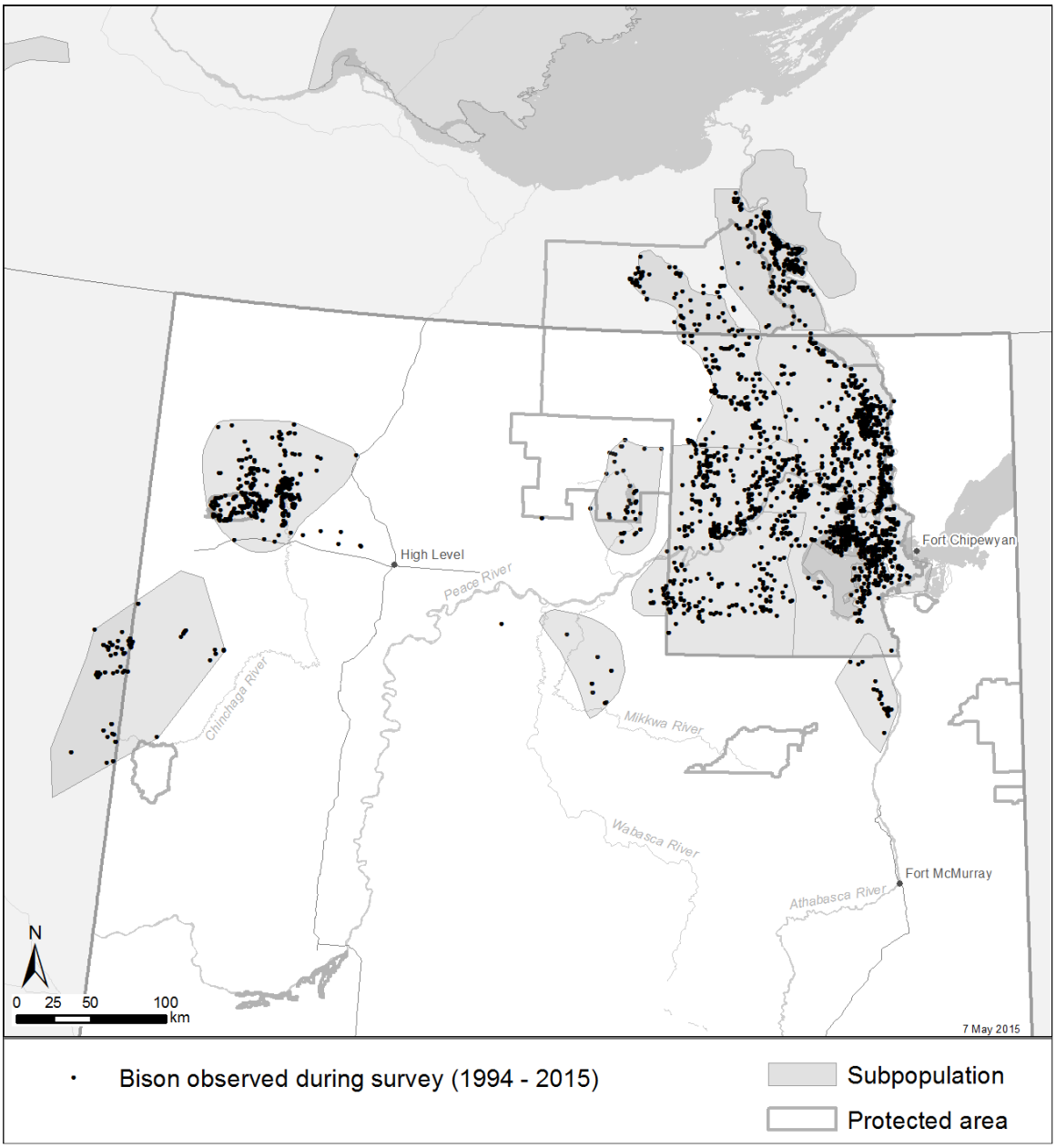


Figure 5. Observations of bison from aerial surveys designed to monitor distribution and abundance of bison, and flown within bison subpopulation ranges in and immediately adjacent to Alberta. Data sources were Parks Canada Agency – Wood Buffalo National Park (WBNP unpubl. data 2003, Zimmer and Macmillan 2005, Vassal and Kindopp 2007, 2010, Cortese and McKinnon 2015), Alberta Fisheries and Wildlife Management Information System (AEP 2015, AEP unpubl. data) and British Columbia Ministry of Environment (unpubl. data).

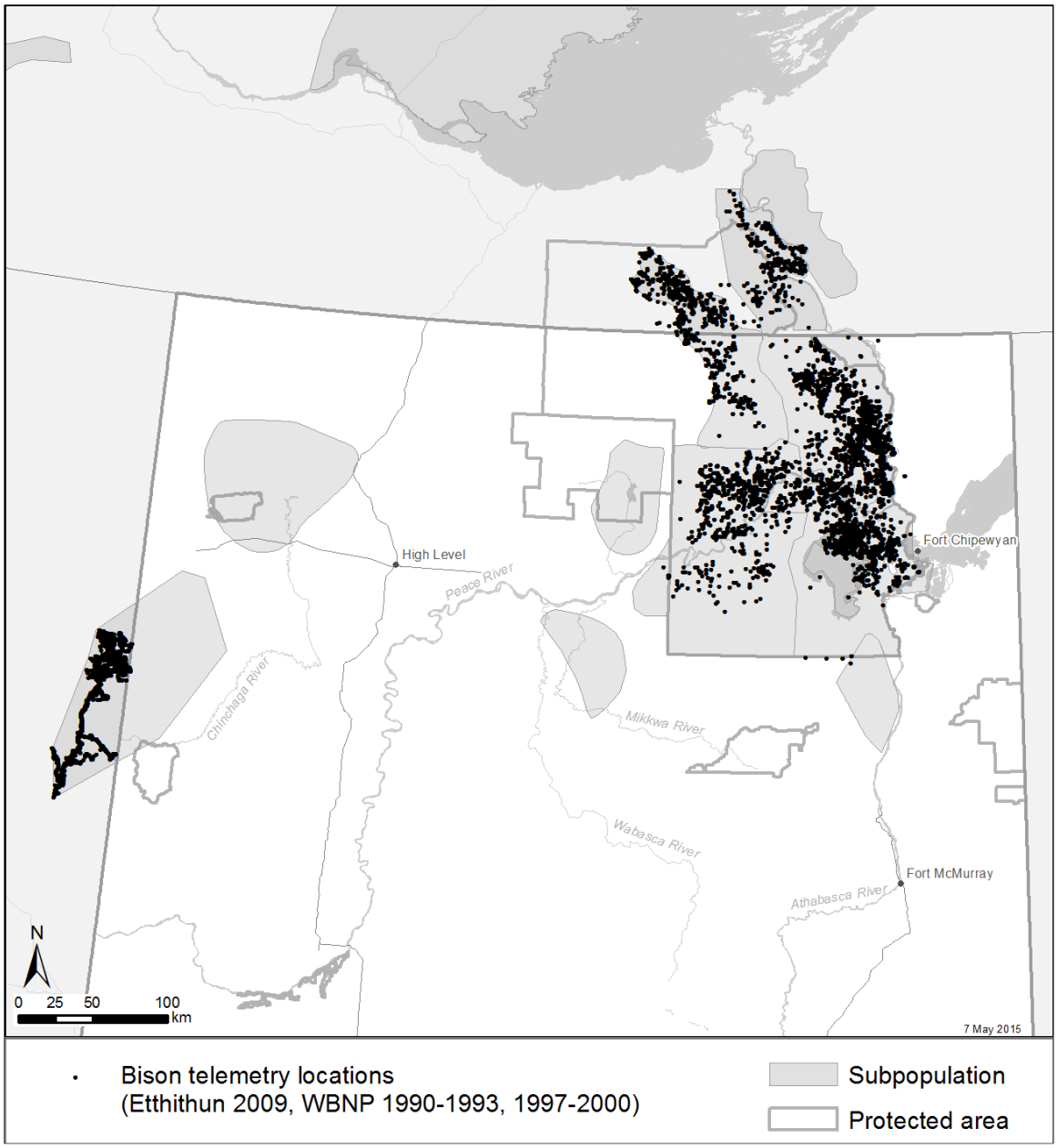


Figure 6. Very high frequency (VHF) and global positioning system (GPS) radio-telemetry locations of collared wood bison in relation to bison subpopulation ranges in and immediately adjacent to Alberta. Data sources were WBNP (1995), Joly (2001), and British Columbia Ministry of Environment (D. Lirette pers. comm.).

either occurs at present, or did occur in the past. Spatial delineation of herd ranges within WBNP was based on data from point locations of radio-collared bison. Cluster analyses by Joly (2001) on geographic point data from studies of radio-collared bison in WBNP from 1993–1995 (WBNP 1995) and 1997–2000 (Joly 2001) (Figure 6), showed that there were five distinct groups of bison in WBNP: Garden River, Nyarling, Little Buffalo (Slave River Lowlands), Hay Camp, and Peace Athabasca Delta (Figure 3). Aerial surveys of bison in WBNP (see Zimmer and Macmillan 2005, Vassal and Kindopp 2007, 2010, Cortese and McKinnon 2015) have also provided information on the distribution of bison in the park. The local populations or herds that occur predominantly outside WBNP are monitored and managed separately by the Northwest Territories (i.e., Slave River Lowlands) and Alberta (i.e., Wentzel Lake) (Figure 3).

1.4 Wentzel Lake Herd (GWBNP) - The Wentzel Lake herd is considered part of the GWBNP metapopulation (see Ball et al. 2016) and occurs north of the Peace River and adjacent to the southwest border of WBNP. The range of the Wentzel Lake bison herd (Figure 3) is derived from direct observations of bison from aerial surveys, as well as reported incidental sightings of bison groups and bison sign (Figures 4 and 5). The delineated occupied range (IAO) is approximately 2968 km^2 (Table 1, Figure 3). It includes consistently used areas identified by Gates et al. (2001b), core bison habitat identified by Little Red River Cree elders (Schramm et al. 2002), anecdotal sightings (Figure 4) and survey observations (Figure 5). The Wentzel Lake area has been included in recent WBNP bison surveys, but has only been covered using non-systematic "spaghetti" flight lines. In contrast, recent systematic surveys by Fullerton (2011 and 2015a) have documented bison occurrence over a larger and more extensive area including areas north of Wentzel Lake in the Caribou Mountains Wildland Provincial Park.

Although it is not known how long bison have been established in the Wentzel Lake area, Fuller (1950) remarked that existence of a bison herd west of the Park and generally occurring in the narrow plain between the Peace River to the south and the Caribou Mountains to the north had been known since 1926. With respect to the Caribou Mountains, Soper (1941, p. 365) indicated that "*there appears to be no evidence that the bison in historic times, at least, ever resorted to this plateau, though they inhabited the prairie benches along the base of the high southern and eastern escarpments*."

Since the 1990s, the Wentzel Lake bison herd had generally occupied the southeastern part of the Caribou Mountains from the Wentzel Lake area and extending southwards towards the Peace River (Figure 3). Local knowledge indicated that Wentzel Lake bison occasionally moved in and out of the park, but that the herd had become more resident in the area because of the placement of supplemental winter feed and mineral licks (Gates et al. 2001b). At the time, provision of supplemental feed and minerals was conducted by Little Red River Cree Nation and Tall Cree First Nation as a means to monitor the herd and initiate a biological research project on the Wentzel herd (Mitchell 2002); this effort was initiated in the early 1990s over a 10-year period, with the goal of developing a community-based bison disease eradication and recovery strategy (Stevenson and Webb 2003), which has not been implemented.

In January 2011, Fullerton (2011) surveyed the area west of WBNP, north of the Peace River and well into the Caribou Mountains. In addition to sightings within the expected range, Fullerton (2011) observed bison tracks over an extensive area in the upper Wentzel River and Buffalo River areas, on the plateau of the Caribou Mountains, along with several small groups of bison. He also noted that bison had traveled up to 14 km in 48 hours to use various riparian and wetland areas. The northern extent

of the Wentzel Lake bison herd was recently confirmed by Fullerton (2015a), who observed 10 groups of bison, totalling over 160 animals, distributed along those same areas of the upper Wentzel and Buffalo rivers (Figure 5).

1.5 Harper Creek (Wabasca-Mikkwa) Subpopulation - The Harper Creek subpopulation occurs to the south and west of WBNP, and has also been referred to as the Wabasca-Mikkwa bison herd (GOA 2013b, Ball et al. 2016); it comprises small groups of resident bison that occur in the area south of the Peace River with their western distribution along the Wabasca River, and their southern distribution associated with the upper Mikkwa River and Harper Creek drainages that flow from the Birch Mountains. The Harper Creek subpopulation is genetically differentiated from the GWBNP metapopulation (Ball et al. 2016). The subpopulation has a current occupied range of 2488 km^2 (Table 1, Figure 3), which was delineated based on expert knowledge (L. Fullerton and D. Moyles pers. comm.), direct observations of bison from aerial surveys, as well as reported incidental sightings of bison groups and bison sign (i.e., tracks, feeding craters, kill sites and fecal pats) (Figures 4 and 5). The identified subpopulation range is also consistent with mapped areas identified by Gates et al. (2001b) and important habitat areas identified by Little Red River Cree elders (Schramm et al. 2002).

Relative to WBNP, the genetic differentiation and discrete distribution of the Harper Creek subpopulation reflects previous accounts that bison groups would occasionally range outside of the southwest region of the park along the south Peace River lowlands and disperse as far west as Fort Vermillion. Tessaro (1987, p.122) indicated that *"Novakowski (1957) and Soper (1941) mention that bison had left the park and established a population in the Wabasca River / Fort Vermillion area as early as 1926, although Novakowski failed to find any animals in that area during a 1957 survey."* Soper (1941, p. 381) suggested that once the small herd dispersed to Vermillion it did not return back to WBNP and that it had become permanently located (i.e., resident to the area), because various reports of bison in the district were received in the following years; he also suggested that dispersal followed by residency out of the park was a rare occurrence.

Tessaro's (1987) observations of 33 bison carcasses between the Wabasca River and Fox Lake Reserve in March 1985 (see Figure 2 in Tessaro et al. 1990) and Gainer's (1985) estimate of 65–120 bison being shot west of the park during that spring suggest that survival and distribution of bison groups that dispersed out of the park were strongly influenced by human access and hunting pressure. Unregulated hunting of bison outside of WBNP has likely influenced dispersal out of the park and subsequent range use and abundance of bison in the Harper Creek area over recent decades; and it is likely that hunting pressure in the area (Gates et al. 2001b, Moyles 2010) continues to be an important factor affecting population distribution and abundance of this herd.

1.6 Ronald Lake Subpopulation - The Ronald Lake subpopulation (also known as the Firebag herd) is strongly genetically differentiated from WBNP bison, which still suggests a founding origin from the park but relative isolation from any further interchange (Ball et al. 2016). The range occurs largely in Alberta, beyond the southern boundary of WBNP and in the lowlands west of the Athabasca River that lie to the north and east of the Birch Mountains. The current range distribution for the Ronald Lake subpopulation (Figure 3) is based on locations collected from bison fitted with satellite collars (GOA 2013c, GOA 2014a, Tan et al. 2015). The defined range is approximately 2020 km^2 (Table 1) and is a minimum convex polygon that includes observations of bison from recent aerial surveys, field collections (Figures 4 and 5) (GOA 2013a, 2013b) and telemetry data (J. Skilnick pers. comm.).

In 1984, S. Tessaro (pers. comm. in Gates et al. 1992) reported seeing 20 bison in the Firebag River area, which suggested that the Ronald Lake subpopulation may have been established relatively recently over the past 30 years. However, traditional knowledge of Athabasca Chipewyan First Nation (ACFN) elders acknowledged the importance of winter bison hunts in that area prior to the 1960s (Candler 2012). Traditional knowledge of ACFN elders was also used to map important bison habitat that extended from Ronald Lake to Eaglenest Lake in the Birch Mountains and east along both sides of the Athabasca River, with inclusion of the lower reaches of the Firebag River valley (Figure 17 in Candler et al. 2011). Indeed, an observation by Fuller (1950, p. 449) suggested that what is considered the Ronald Lake bison subpopulation today may have been re-established and persisted as a small herd by at least the mid-1940s: *"For many years a small herd has been reported between the Athabasca River and Lake Claire as it made its way to winter grounds south of the park on the upper McIvor River. This herd was known to be south of the park at the time of survey* [February 1949]*, but on a later trip a group of about 30 was seen just southeast of Lake Claire."* Similarly, Soper (1941, p. 380) also indicated that "*there are two small herds composed of about 40 individuals which live between Lake Claire and Birch Mountain.*"

It is also worth noting that, in the broader context of historical wood bison occurrence in that area, bison had ranged along the west and east side of the Athabasca River, both below and above Fort McMurray, and were relatively abundant along the Clearwater River valley in the 1830s (Soper 1941). But by the early 1900s, the range had contracted to an extent *"that only a few individuals are now to be met with in open spaces and patches of prairie in sections on the west side of the Athabasca River, between Fort McMurray and the Birch Mountain…"* (MacFarlane 1905, cited in Soper 1941, p. 361).

In 2016, a large area comprising the range occupied by the Ronald Lake subpopulation was protected from hunting by non-Aboriginal people, through designating all bison within this area as *Subject Animals* under the Alberta *Wildlife Regulation* (Figure 2).

1.7 Hay-Zama Subpopulation - In the late 1970s and early 1980s, the Hay-Zama lowlands in northwestern Alberta were selected as a potential site for reintroduction of wood bison (Reynolds et al. 1982). In 1981, a program was initiated to re-establish a disease-free, free-ranging herd of wood bison within original range in northwestern Alberta. In cooperation with the Dene Tha First Nation, a 3-km^2 holding corral was constructed northeast of Habay, Alberta and, in February 1984, 29 wood bison were transported to the site from EINP. Despite some early challenges with flooding and severe winter weather that required supplementary feeding and resulted in poor reproduction and calf survival, 10 calves were born on site in 1990 (see Gates et al. 1992). Although the release of wood bison to northern Alberta was initially scheduled to occur in 1988, the risk of infection with bovine tuberculosis and brucellosis from free-ranging bison in the greater WBNP area resulted in a delay of this activity. The number of bison increased to 49 animals in 1993, after which the animals became a free-roaming population when portions of the fence surrounding the enclosure collapsed.

To enable management of Hay-Zama wood bison, in 1995 the Government of Alberta created a wildlife management area of approximately 40,000 km^2 in the northwestern corner of the province (see Bison Protection Area in Figure 2) and classified bison within this area as *Endangered* animals; elsewhere in the province (outside of WBNP, wildlife provincial parks, and designated *Subject Animal* areas), free-ranging bison are not categorized as wildlife under Alberta's *Wildlife Act,* and may be hunted at all times of the year,

without limit. In addition, the High Level Tribal Council (now called the North Peace Tribal Council) supported a motion under which they agreed to not hunt bison in this area (Morton 1999). In a 1985 agreement, the Government of Alberta (Alberta Fish and Wildlife Division), the Canadian Wildlife Service, and the Dene Tha First Nation agreed that the subpopulation would be maintained through hunting, to a size of approximately 250–400 animals, until the WBNP disease issue was resolved (Gates et al. 2001c).

During its initial growth phase, the free-ranging subpopulation had generally occurred within suitable habitat near the Chinchaga River and the Hay-Zama Lakes complex. As the subpopulation increased numerically, the extent of its range also expanded, with bison from the Hay-Zama subpopulation occasionally wandering westward into the Hay River drainage in northeastern British Columbia (Gates et al. 2001c). The northern extent of the range reached into the upper Steen River drainage south of Bistcho Lake, while the southern distribution extended to Highway 58, which links the community of Rainbow Lake to High Level (GOA 2011a). There were also frequent reports of bison moving east along the Zama road to and beyond Highway 35 (GOA 2011a). By 2008, the Hay-Zama subpopulation was using an area estimated at 11,264 km^2 (GOA 2011a).

The currently delineated annual range (Figure 3) is 6920 km^2 (Table 1) and reflects the subpopulation's maximum range extent based on reported public sightings and observations from aerial surveys (Figures 4 and 5). It is important to note, however, that the distribution of Hay-Zama wood bison has changed following initiation of an annual hunt in 2008 (also see *Population Size, Trends and Health Status*). Although there are no comparable data on annual home range estimates for subpopulation distribution (i.e., see Figure 2 in GOA 2011a), the trend in the area encompassing annual surveys (i.e., defined as a minimum convex polygon [MCP]) shows a marked reduction in size after hunting was initiated in 2008 (Figure 7). Combined with high mortalities of bison observed in winter 2013 (GOA 2013b), the

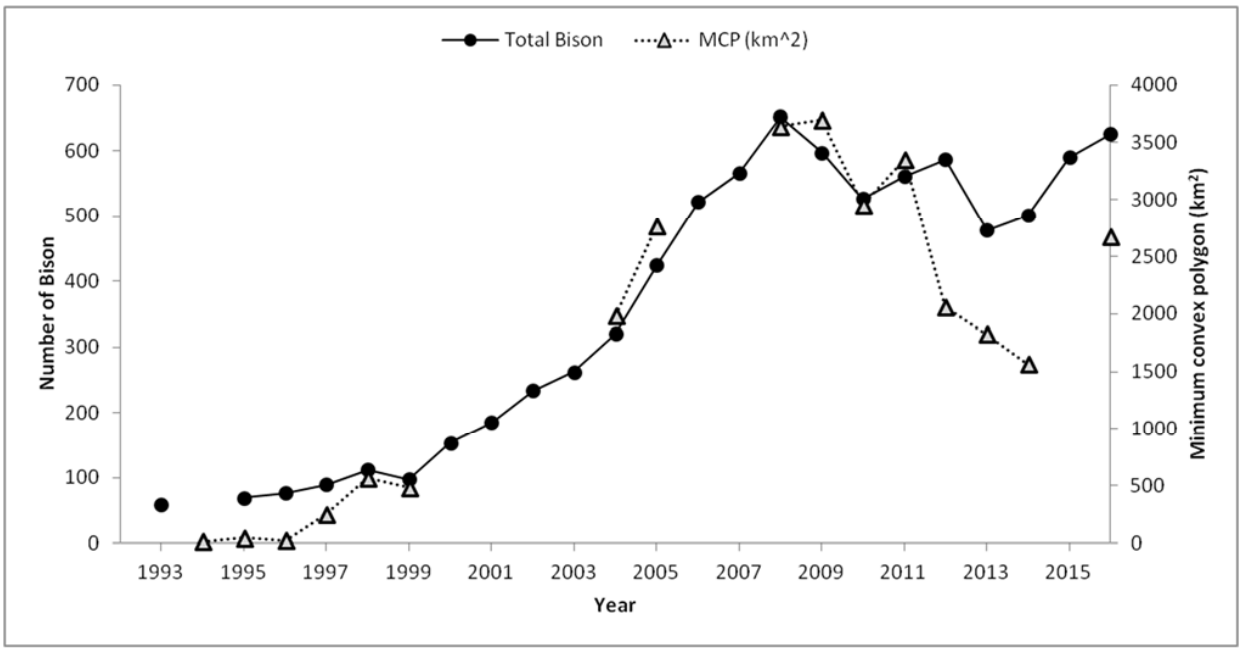


Figure 7. Trend in area (expressed as the minimum convex polygon [MCP] of bison observations during an aerial survey) shown in comparison to patterns in numerical abundance of Hay-Zama bison subpopulation, 1993 – 2016 (data sources: Alberta FWMIS, L. Fullerton pers. comm., Melnycky and Moyles 2016).

annual range of the Hay-Zama subpopulation has declined in recent years.

1.8 Etthithun Subpopulation - Following a previously unsuccessful attempt in 1996–1997 to establish a wood bison subpopulation in northeastern British Columbia near Etthithun and Kantah lakes, a second effort was initiated. In March 1999, 19 wood bison from EINP were released into a newly constructed 850-ha paddock (Harper et al. 2000, Harper and Gates 2000). The goal was to use a "soft" release strategy (see Safronov et al. 2012, Alaska Department of Fish and Game [ADFG] and United States Fish and Wildlife Service [USFWS] 2013, van de Vlasakker 2014, Parks Canada Agency [PCA] 2016a), whereby the young bison would be held for about five years to allow breeding females to calve in the area and the herd to become imprinted to the future release site. The intent was to prevent widespread dispersal of individuals and groups, especially to agricultural lands to the south. Previous experiences with "hard" releases of mature bison had frequently led to haphazard long-distance dispersals, which eventually resulted in failed introductions (see Harper et al. 2000). After an additional shipment of bison from EINP in 2000, the Etthithun bison paddock near Strom Lake held 43 calf and yearling bison (Rowe and Backmeyer 2006). The paddock fence was breached in 2003. Although the free-roaming subpopulation established in the area, it increased numerically and expanded its distribution.

The first aerial surveys of Etthithun bison by British Columbia in March 2006 and 2009 showed that the subpopulation's range extended into Alberta. In 2006, two groups totaling 23 bison were observed in Alberta, within 3 km of the British Columbia-Alberta border. Those bison represented 18.5% of the Etthithun subpopulation count of 124 (Rowe and Backmeyer 2006). In 2009, two groups totaling 40 bison were observed just within Alberta, representing 25.6% of the total count of 156 (Thiessen 2009). In subsequent years, sightings of bison increased in Alberta, extending from around the northwest boundary of Chinchaga Wildland Provincial Park to around Rainbow Lake (58°17'N; 119°15'W) (Vander Vennen and Fullerton 2015) (Figures 4 and 5).

In 2013, 121 bison were observed during an aerial survey in Alberta that was focused on the area between Chinchaga Wildland Provincial Park and the area south of the town of Rainbow Lake, Alberta (Wildlife Management Units – WMU 524 and 536; L. Fullerton and P. Temoin unpubl. data). During the most recent survey in January of 2015, 167 bison were observed in nine groups. Of these, only three groups occurred within Alberta, comprising 51 bison, or 30.5% of the total bison counted. The remaining 116 bison (69.5%) occurred in British Columbia within nine kilometers of the British Columbia-Alberta border (Vander Vennen and Fullerton 2015).

If the observed distribution of bison between British Columbia and Alberta was primarily a reflection of dispersal patterns of the Etthithun subpopulation, then apparent declines observed from surveys in British Columbia between 2011 and 2013 may have simply been an artifact of distributional changes. In February 2009, five adult female Etthithun bison were captured along the Fontas Road in British Columbia and fitted with Global Positioning System (GPS) collars (Thiessen 2010). Analysis of available data from four GPS collars estimated that annual home range of collared cows from 2009–2010 was 3388 km^2. Seasonal range use and movements were strongly associated with roads and other linear disturbances in British Columbia, and collared cows did not range into Alberta (Leverkus 2012). Although those data showed that individual home ranges occurred primarily in British Columbia, a plausible interpretation of patterns in subpopulation trend and distribution incorporates the increased sightings of bison in adjacent parts of Alberta and attributes those occurrences to an eastward

and northern dispersal pulse of Etthithun bison and a likely overall numerical increase. This is consistent with a dynamic pattern of pulsed dispersal observed following the reintroduction of wood bison in the Mackenzie range (Gates and Larter 1990, Larter et al. 2000), but needs to be evaluated empirically for the Etthithun subpopulation.

The current estimated range of the Etthithun subpopulation is approximately 9624 km^2, of which about 5572 km^2 (58%) is in Alberta (Table 1). Most of the defined range of Etthithun bison in Alberta occurs within the Bison Protection Area (Figures 2 and 3). Incidental sightings (Figure 4) and observations from aerial surveys (Figure 5) illustrate the relative proximity of Etthithun and Hay-Zama ranges, and highlight that the two subpopulations will likely connect in the near future.

1.9 Elk Island National Park (EINP) Subpopulation - Elk Island National Park is located about 50 km east of Edmonton, Alberta, and is 194 km^2 in total area. The park is bisected by the four-lane Trans-Canada Highway so the northern and southern areas of the park are managed separately, with each area enclosed by a 2.2-m high perimeter fence. Wood bison occur in the 60-km^2 southern portion of the park, which was added in 1947.

In 1965, 40 wood bison captured in northern WBNP were moved to a holding facility near Fort Smith, NT (Gates et al. 1992). Twenty-seven bison that tested negative for bovine brucellosis and tuberculosis were translocated to an isolation facility in the southern portion of EINP (Figure 3). Twenty-one of these animals survived to become the breeding herd (Gates et al. 1992, Blyth 1995). Despite the one-time testing and translocation of test-negative animals from the Fort Smith facility, tuberculosis and brucellosis were detected in EINP wood bison in 1968 (Blyth 1995). In 1969, the wood bison herd was divided in two, with animals from WBNP in one group, and EINP-born calves in another (Blyth 1995). After the pregnant females calved, all original WBNP bison were euthanized, and nine orphaned calves were hand-reared (Blyth 1995). Following removal of the founders in 1970, remaining captive-born bison had negative diagnostic test results for tuberculosis and brucellosis, and the EINP herd was declared free of the diseases in 1971 (Nishi et al. 2002c).

Wood bison at EINP are considered to be wild by nature and functioning as a wild population with limitations; i.e., confined to a small area that is less than 200 km^2, small population size, and unnaturally low predation rate—although a pack of wolves (*Canis lupus*) recently moved into the park and wolves have been observed in the adjacent Blackfoot Grazing Reserve (COSEWIC 2013a). The fenced EINP wood bison population is maintained for conservation purposes (ECCC 2016), and has been the cornerstone for wood bison recovery in Canada. Since 1976, this subpopulation has provided disease-free founding stock for eight free-ranging populations, other captive breeding herds, zoo and park specimens, and private commercial herds (Gates et al. 2001c, Safronov et al. 2012, COSEWIC 2013a, USFWS 2014).

2. Wood Bison in Other Areas (National) - The current distribution of wood bison in Canada reflects extensive recovery actions initially undertaken in the 1960s to capture founder stock from WBNP and establish healthy populations in the Mackenzie Bison Sanctuary (Northwest Territories) and EINP (Alberta). All subsequent reintroductions of wood bison to establish free-ranging subpopulations in Canada have been founded directly or indirectly from EINP. EINP wood bison have also been used to establish extant subpopulations in Alaska (see Stephenson et al. 2007, USFWS 2014, ADFG 2015, Alaska Wood Bison Management Planning Team [AWBMPT] 2015,) and Russia (Gates et al. 2001d, Safronov et al. 2012).

Figure 8 shows the distribution of wood bison subpopulations that occur outside of Alberta, and Table 2 summarizes the sizes of their respective delineated range areas. Appendix 3 provides a brief summary of the recent history of wood bison, and the reader is referred to the following key references for more details (Connelly et al. 1990, Gates et al. 1992, McCormack 1992, Carbyn et al. 1993, Gates et al., 2001c, Gates et al. 2010, Nishi 2010, Pybus and Shury 2012, COSEWIC 2013a).

3. Wood Bison Search Effort - As suggested by COSEWIC (2013a), bison are large terrestrial animals and herds (subpopulations) are conspicuous on the landscape and unlikely to go unnoticed. Bison behaviour also increases the likelihood that herds will be detected on a landscape: bison aggregate into large groups, particularly during calving and the rut; their preferred forage habitats are large open meadows; and their foraging and trailing behaviour is clearly evident under winter snow conditions. Although the sightability of individual bison may be low in forested areas as a result of variable canopy closure, the likelihood of there being unknown viable wild subpopulations of wood or plains bison in Alberta is low to negligible (COSEWIC 2013a).

PLAINS BISON

Prior to European settlement, the historical distribution of plains bison was associated with the Great Plains grasslands of North America, extending southward from present-day Alberta,

Table 2. Summary of wood bison subpopulations outside of Alberta and within Canada. See COSEWIC (2013a) for further information. Note that the transboundary Etthithun subpopulation, which is partly found in British Columbia, is included in Table 1.

Other Areas	Subpopulation (Herd) name	Management jurisdictions	Other information (subpopulation size, health status, etc.)	References
Free-ranging	Aishihik	YT	Core range is ~11,000 km^2	Reynolds 1982, Yukon Department of Renewable Resources 1998, Gates et al. 2001c, Government of Yukon 2012
	Nordquist	BC, YT	Estimated range is 4,735 km^2 along the Alaska Highway corridor	Harper and Gates 2000, Harper et al. 2000, Rowe 2007, Leverkus 2011, 2012, Thiessen 2009, 2010
	Nahanni	NT, BC, YT	Estimated range is 11,713 km^2	Reynolds et al. 1980, Harper et al. 2000, Larter and Allaire 2007, 2013, SARC 2016
	Mackenzie	NT	Estimated range is 21,695 km^2	Novakowski 1963, Gates and Larter 1990, Larter et al. 2000, Gates et al. 2001, Dragon and Elkin 2001, SARC 2016
	Chitek Lake	MB	Estimated range is ~ 3800 km^2	Payne 1987, Broughton 1990, Joynt 2010,
Free-ranging Infected	Slave River Lowlands	GWBNP, NT	Considered part of GWBNP metapopulation; bovine TB, brucellosis and anthrax are present; 2 herds: Grand Detour (W side Slave R.) - estimated range 4915 km^2; Hook Lake (E side Slave R.) - estimated range 5105 km^2	Fuller 1950, Broughton 1987, Van Camp 1989, Gates et al. 1992, Joly 2001, Wilson et al. 2005, Dragon and Elkin 2001, SARC 2016

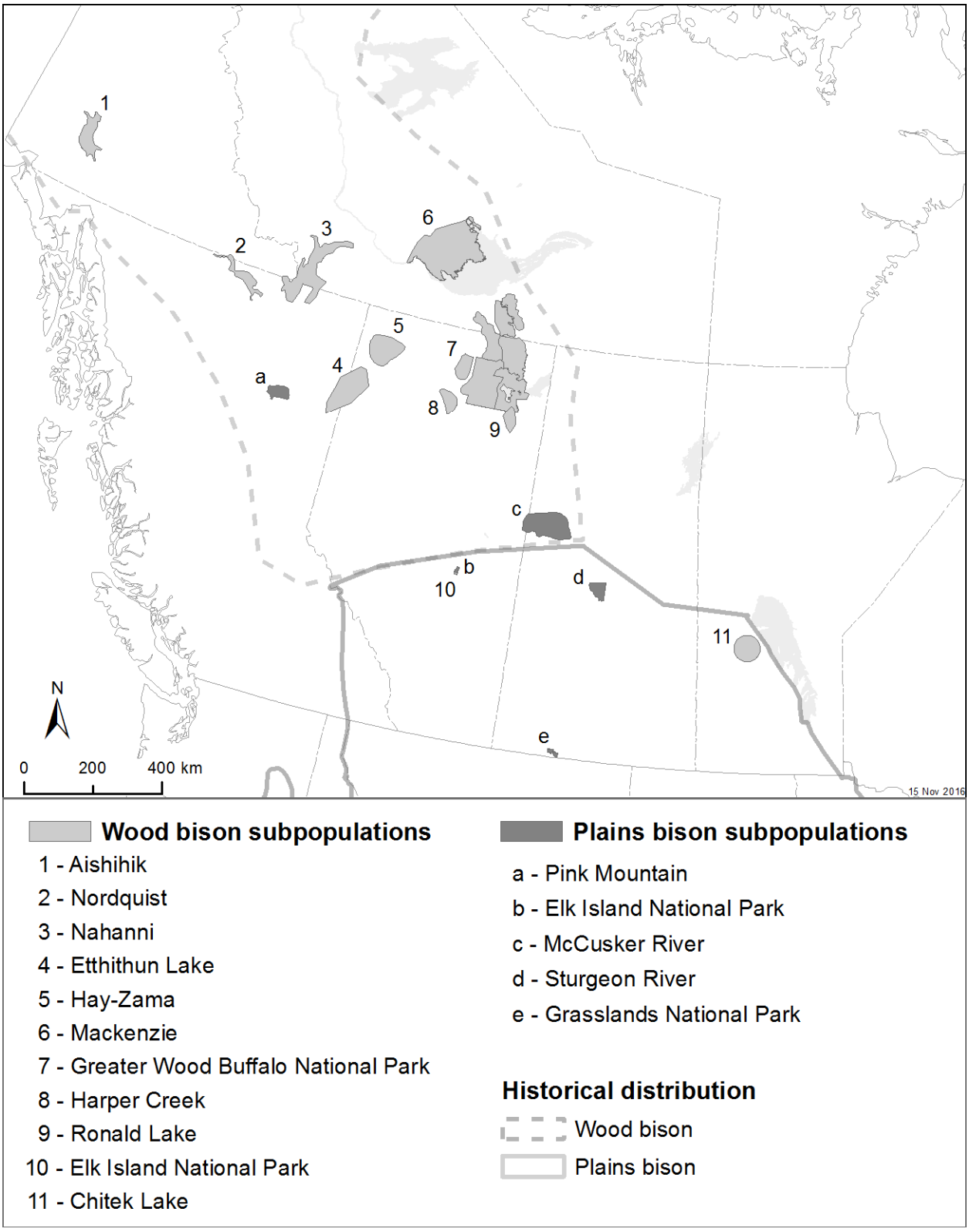


Figure 8. Distribution of wood and plains bison in western Canada. Bison range polygons adapted from COSEWIC (2013a), with wood bison subpopulation ranges in Alberta adjusted based on recommendations from Alberta Environment and Parks staff.

Saskatchewan and southwestern Manitoba through the United States and into the northern regions of Mexico. Most bison occupied the area between the Rocky Mountains in the west and the Mississippi River in the east (see Reynolds et al. 2003, Sanderson et al. 2008, Potter et al. 2010, COSEWIC 2013a, Plumb et al. 2014) (Figure 1). The extent of the historical range of plains bison was estimated at 6.9 million km^2, of which approximately 230,000 km^2 (~3%) occurred in Alberta (Figure 1).

Bison in the eastern United States, from Florida to the Great Lakes, were extirpated by the late 1700s as a result of Euro-American colonization (Plumb et al. 2014). The once-vast herds of plains bison, numbering in the tens of millions, were reduced to a few hundred in scattered remnant herds and individual animals (Hornaday 1889). In the United States, a few hundred bison survived under the foresight of private individuals and ranchers (Ogilvie 1979, Lueck 2002), and a small group of fewer than 25 animals found refuge and eventual protection in the newly established (1872) Yellowstone National Park (Meagher 1973). In the northern Great Plains of western Canada, bison range rapidly shrank as the large herds were hunted out (Foster 1994, MacEwan 1995, Colpitts 2015). "*Between 1870 and 1880 the last remnants of these herds on the northern plains huddled in the Cypress Hills, near the American border, along with various desperate Native and Métis peoples still seeking to make a living in the traditional way*" (MacDonald 2009, p. 102).

In Alberta, the historical range of plains bison was tied primarily to the Grassland Natural Region (*sensu* NRC 2006), extending into adjacent parts of the Central and Foothills Parkland subregions especially during winter (Moodie and Ray 1976, Morgan 1980, Campbell et al. 1994, MacDonald 2009). The plains bison range also extended up into the eastern slopes of the Rocky Mountains (Quigg 1978, Reeves 1978, Kay and White 2001, White et al. 2001). It is likely that the last free-ranging plains bison were shot in Alberta near the Hand Hills in 1889 (Cotton 1948, but see MacEwan 1995), the same area that fur trader Peter Fidler travelled through in 1793 and passed a single herd that "*numbered some millions… as no ground could be seen* [between] *them in that compleat* [sic] *semicircle and extending at least 10 miles…"* (Arthur 1975, in Colpitts 2015, p. 63). Following its extirpation in the late 1800s, the reintroduction and conservation of plains bison in Alberta is interwoven with the establishment and early management actions of national parks: Banff National Park (1885), EINP (1906), Wainwright Buffalo National Park (1908) and WBNP (1922) (Anonymous 1925, Lothian 1987, Brower 2008, Locke et al. 2016; and see Nishi 2010, Pybus and Shury 2012).

1. Plains Bison in Alberta - In Alberta today, there are no free-ranging wild plains bison subpopulations within the Grassland Natural Region, and there are two subpopulations in the Boreal Forest Natural Region. One subpopulation ranges within a fenced area of Elk Island National Park that occurs in plains bison historical range within the Boreal Forest Natural Region. The second is the McCusker River subpopulation, which ranges in a part of the Boreal Forest Natural Region that is outside of plains bison historical range; this small free-ranging subpopulation has extended its range into Alberta and the Cold (Primrose) Lake Air Weapons Range following a translocation of EINP bison into northern Saskatchewan (Figure 9).

Although the reintroduction of plains bison into Banff National Park has been initiated (Parks Canada Agency 2016a, 2016b), the prospects for re-establishing free-ranging plains bison across their original range in the province are constrained by the lack of available habitat and the potential for conflict with human populations and agricultural land use practices.

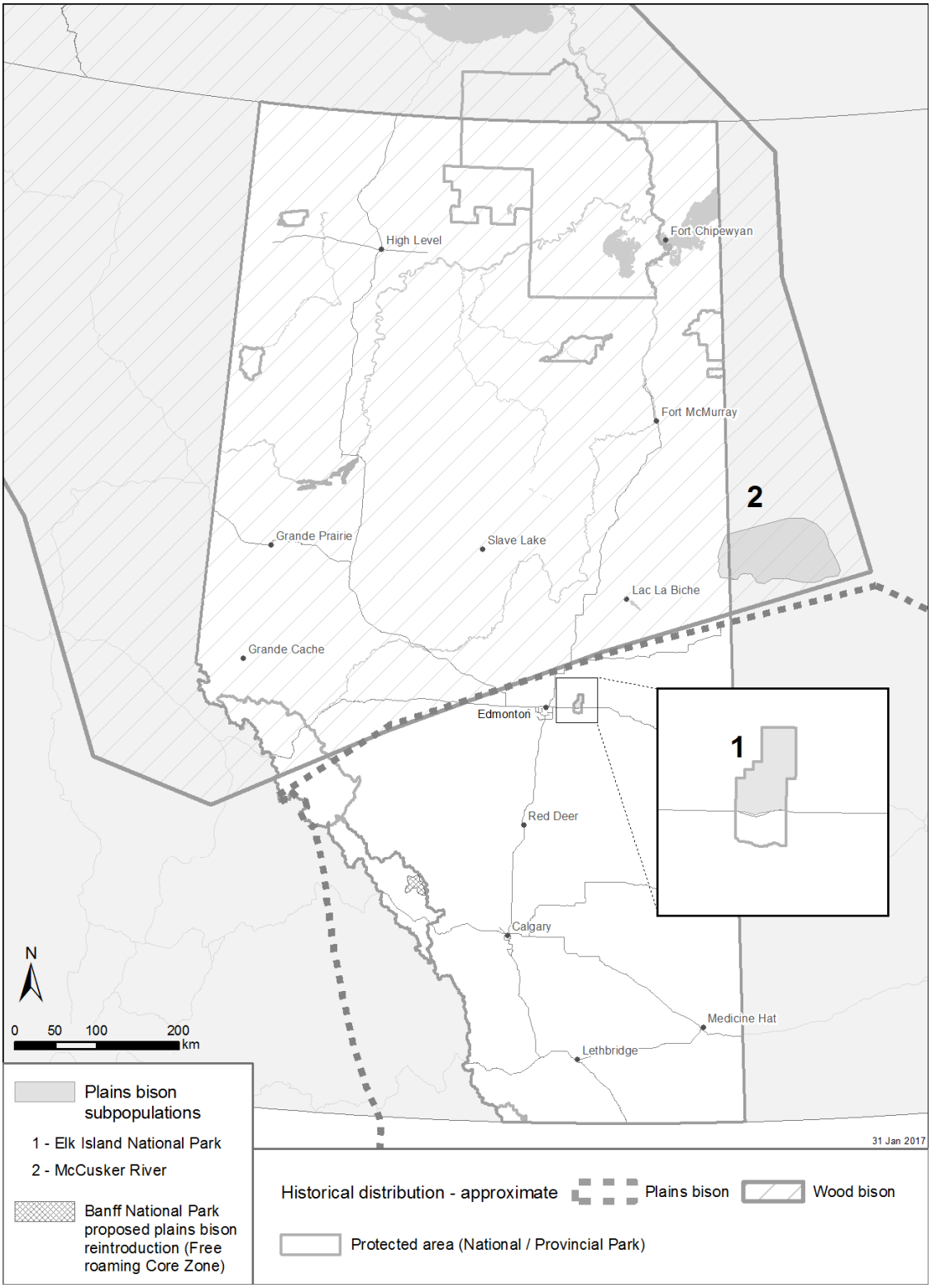


Figure 9. Plains bison subpopulations (herds) in Alberta. Bison range polygons are from COSEWIC (2013a) and Parks Canada Agency (2016b). The historical range of wood bison is indicated, to show the McCusker River plains bison subpopulation relative to those boundaries.

1.1 Provincial Extent of Plains Bison Occurrence - The EO of plains bison within Alberta is about 7241 km^2 (Appendix 4). The EO encompasses the McCusker and EINP subpopulations, and occurs across the transition area between the original ranges of wood and plains bison. Based on a 2-km x 2-km grid, the IAO of the two subpopulations in Alberta is 872 km^2, which represents 12% of the EO (Table 3). The IAO of the McCusker plains bison range that occurs within Alberta, and under management authority of the Government of Alberta, is only 80 km^2, with the remainder of the IAO occurring within the Cold Lake Air Weapons Range (600 km^2) and Saskatchewan (8892 km^2) (Table 3). The McCusker subpopulation is considered to be outside of original plains bison range within Alberta (Figure 9).

1.2 McCusker River Subpopulation - In 1969, 50 plains bison from EINP were translocated to an area 60 km north of Prince Albert National Park (PANP), Saskatchewan and released near Meyakumew Lake (Sturgeon River Plains Bison Stewards [SRPBS] et al. 2013, Saskatchewan Ministry of Environment [SME] 2014). The bison dispersed following the release, and one group of 10–15 animals settled in the southwest part of PANP to become Saskatchewan's Sturgeon River subpopulation. This subpopulation now ranges primarily within the park and adjacent private lands (SRPBS et al. 2013). Several bison also moved to the Big River Community Pasture northwest of PANP, where between 11 and 17 animals were re-captured by the Department of Natural Resources and re-located to the Vermette-Upper Cummings Lake region. These animals eventually settled in the McCusker River area within the Cold Lake Air Weapons Range (Bergeson 1993, COSEWIC 2004 and 2013a, SME 2014).

The McCusker River bison range occurs along the northern extent of original plains bison range and is situated primarily within Saskatchewan, in the McCusker River area of the Cold Lake Air Weapons Range. These bison have also been observed to the west, in Alberta (COSEWIC 2013a) (Figure 9), with the first evidence of this noted in the late 1980s (H. Reynolds pers. comm. in COSEWIC 2004). In 1988, an aerial survey of the Primrose area observed 17 bulls, while 25 cows were estimated to be in the area for a total estimate of 42 bison (W. Runge pers. comm. in Bergeson 1993). There have been no bison surveys conducted in and around Primrose Lake and Cold Lake Air Weapons Ranges to estimate distribution and abundance.

Table 3. Summary of range areas for plains bison subpopulations in Alberta.

Plains Bison Subpopulation Range Areas					
Alberta	**Subpopulation (Herd) Name**	**Management Jurisdictions**	**Index of Area of Occupancy - IAO[†] (km^2)**	**IAO in Alberta[#] (km^2)**	**IAO in Alberta & GOA Mgmt[##] (km^2)**
Free-ranging	McCusker River	SK, CA, AB	9,572	680	80
Free-ranging Infected*	n/a	-	-	-	-
Captive	Elk Island National Park (EINP)	CA	192	192	-
			9,764	**872**	**80**

[†] Calculated by totalling the area of 2x2 km grid cells that cover the subpopulation range (*sensu* COSEWIC 2013a). [#] Refers to the area of a bison subpopulation range that occurs within Alberta. [##] Area of a bison subpopulation range that is under management authority of the Government of Alberta, and not within national parks or federal military reserve lands. *Indicates a subpopulation infected with bovine TB &/or brucellosis.

In recent years, there have been more reports of bison on Saskatchewan Provincial Forest lands outside the Cold Lake Air Weapons Range, which suggests the subpopulation range has increased (R. Tether pers. comm.). McCusker River bison are free-ranging and subject to natural ecological factors, including wolf predation. The current occupied range is estimated to be 9572 km^2, of which 680 km^2 (7%) is in Alberta (Table 3).

1.3 Elk Island National Park (EINP) Subpopulation - Elk Park was established in 1906 (later renamed to Elk Island Park in 1908, and Elk Island National Park in 1913) and was the first "prairie" park in Alberta (Figure 9). It was established because of a concern for diminishing elk *(Cervus elaphus)* herds in the Beaver Hills area, which were under threat by hunters and wildfires (Brower 2008, MacDonald 2009, Pybus and Shury 2012). Once the perimeter fence was completed in 1907, Elk Park received the first shipments from the Pablo-Allard holdings of plains bison in Montana (see Locke et al. 2016). By 1909, most of the remaining Pablo-Allard bison that had been temporarily held at Elk Island Park were shipped to Wainwright National Buffalo Park. However, up to 71 plains bison remained at EINP, which *"is described in park records as "42" plus "6 in the bush" and "23 unaccounted for"* (Blyth 1995, p. 23).

Despite the initial rapid growth of what appeared to be a healthy population, brucellosis was detected in the park bison (Blyth 1995) and by the mid-1950s prevalence in the main herd had increased to 32%, and the disease had spilled over into elk (Corner and Connell 1958). An intensive disease eradication program was established, with large-scale population reduction, followed by vaccination (strain 19 *Brucella* vaccine) of young age classes, test-and-slaughter of seropositive and non-vaccinated bison, and twice-yearly herd testing was also initiated (Blyth 1995). In 1972, EINP plains bison were declared free of brucellosis (Blyth 1995).

EINP comprises northern and southern areas that are each enclosed by 2.2-m high perimeter fences. Plains bison in EINP are a managed subpopulation that is confined to the fenced northern area of the park, which is 134 km^2. The subpopulation is maintained for conservation purposes and is managed directly through whole-herd round-ups every two years, where animals are disease-tested and surplus animals are removed. The EINP subpopulation is an important source of healthy plains bison for reintroduction projects in Canada and internationally, as well as private commercial herds (when surplus animals go to auction) and captive/fenced conservation herds. The EINP plains bison subpopulation is considered to be wild by nature and functioning as a population with limitations; i.e., confined to a small area that is less than 200 km^2, small population size and no predation (COSEWIC 2013a).

1.4 Banff National Park Proposed Reintroduction - Parks Canada Agency has developed, and consulted on, a proposal to reintroduce plains bison into Banff National Park. In March 2015, the proposal was approved with the required financial commitment to proceed (i.e., $6.4 million over five years) (PCA 2016a). The vision for the project is to "restore a wild, free-roaming bison population to Banff National Park in a way that supports ecosystem integrity, enriches and is compatible with other visitor experiences, facilitates cultural connections with the landscape and wildlife, and enhances learning and stewardship opportunities, both in the park and from afar" (PCA 2016a). The proposal seeks to reintroduce bison using a phased approach over five years. In February 2017, a group of 16 EINP plains bison (12 pregnant 2-year-old females and four 2-year-old bulls) was translocated to an 18-ha soft-release paddock in a remote area of the park—the Panther River Valley (Figure 9). The reintroduced herd will be released from the paddock into the 1892-km^2 reintroduction zone in July 2018, with extensive follow-

up monitoring and evaluation (PCA 2016b). A long-term population target remains to be developed, but the maximum population will likely be in the range of 600–1000 individuals (Steenweg et al. 2016).

2. Plains Bison in Other Areas (National and International) - COSEWIC (2013a) provides the current assessment of the distribution and status of plains bison subpopulations in the rest of Canada, and Gates et al. 2010 provide the most recent review of plains bison subpopulations throughout the United States and Mexico. Outside of Alberta and within Canada, there are four plains bison subpopulations that meet the criteria for "wild by nature" (COSEWIC 2013a): McCusker River (transboundary between Alberta and Saskatchewan), Pink Mountain, Sturgeon River, and Grasslands National Park (Figure 8). Table 4 summarizes the delineated range areas for plains bison subpopulations in Canada that occur outside of Alberta.

3. Plains Bison Search Effort - There has been no reported systematic search effort across the known and presumed range of the McCusker River bison subpopulation. There are no free-ranging subpopulations of wild plains bison within their historical range in central and southern Alberta. The likelihood of unknown and undetected populations of plains bison within historical range in Alberta is negligible (COSEWIC 2013a).

HABITAT

Selection and use of habitat by large herbivores occurs within a spatial and ecological hierarchy, which at the broadest scale is reflected by a species' geographic range, and at the finest scale by selection of feeding sites and food items (Johnson 1980, Senft et al. 1987). Prior to European contact, the continental distribution of American bison, from the arid grasslands of northern Mexico through the Great Plains and boreal forest of northern Canada and Alaska, illustrates the bison's adaptability to thrive in a variety of habitats throughout the year (Sanderson et al. 2008, Plumb et al. 2014). The historical range of American bison encompassed 22 major habitat types across North America (derived by Sanderson et al. 2008 by combining the eco-regions mapped by Ricketts et al. 1999), and illustrated that although bison are grassland specialists (Hudson and Frank 1987), they were not confined to grasslands, but also inhabited forests, steppes, and tundra. Contemporary biological studies of bison habitat use across North America are well summarized by Reynolds et al. (2003), Gogan et al. (2010), COSEWIC (2013a), and Plumb et al. (2014).

Table 4. Summary of plains bison subpopulations outside of Alberta and within Canada. See COSEWIC (2013a) for more information. Note that the transboundary McCusker subpopulation, which is partly found in Saskatchewan, is included in Table 3.

Other Areas	Subpopulation (Herd) name	Management jurisdiction	Other information (herd size, disease status, etc.)	References
Free-ranging	Pink Mountain (Sikanni-Halfway)	BC	Estimated range is between 1513 and 2176 km^2 (2006)	Harper et al. 2000, Rowe 2006
	Sturgeon River	SK	Estimated range is ~786 km^2, 87% in SW Prince Albert National Park remainder on adjacent private lands; anthrax	Bergeson 1993, SRPBS et al. 2013, SME 2014, Kelly 2007, Shury et al. 2009
Fenced	Grasslands National Park	SK	Target population is 300-350 bison within 181 km^2 fenced enclosure.	PCA 2010

As grassland specialists, the bison's diet is dominated by grasses (Gramineae), sedges (Cyperaceae) and rushes (Juncaceae) (Reynolds et al. 2003, Gogan et al. 2010, Jung 2015, Jung et al. 2015b). As large ruminant grazers (*sensu* Hofmann 1989), a prerequisite for population viability of bison, at a range scale, is sufficient biomass of grasses and sedges to meet their dietary needs. Recent studies have shown the importance of understanding the mechanistic role of bison foraging behaviour to better predict patterns of bison distribution and habitat use. Foraging behaviour in bison reflects strategies to a) minimize daily foraging time (Bergman et al. 2001), b) maximize instantaneous intake of digestible energy (Fortin et al. 2002, Courant and Fortin 2010, 2012, Babin et al. 2011), and c) minimize risks from exposure to predation. This manifests in bison eating large plants that allow for rapid intake and fast satiation, but often have lower digestibility than small plants (Fortin and Fortin 2009, Harvey and Fortin 2013, Fortin et al. 2015). An understanding of the bison's foraging objective(s) may provide a reliable basis for forecasting bison distributions in new and dynamic environments (Babin et al. 2011).

Bison are highly mobile and capable of travelling considerable distances as part of their daily and seasonal range use. Plains bison in Yellowstone National Park, for example, occasionally travel over 30 km in a day and annually range over areas of between 100 km^2 and 750 km^2 (Meagher 1989, Geremia et al. 2011, 2014). Wood bison in WBNP roam up to 50 km from their centre-of-activity (Chen and Morley 2005), and adult female wood bison in the Mackenzie subpopulation had average home ranges of 897 $km^2 \pm 118$ km^2 (Larter and Gates 1990). Within a home range, multi-scale patterns of bison movement, behaviour, and habitat use are influenced by seasonal quality and quantity of vegetation, forage patch size and dispersion, presence and abundance of predators, biting insect activity, breeding activity, availability of water, snow depth and winter severity (Melton et al. 1989, Larter and Gates 1991, Komers et al. 1993, Fortin et al. 2002, 2003, 2009, Fortin and Fortin 2009, Garrott et al. 2009a, Courant and Fortin 2010, 2012, Geremia et al. 2011, Harvey and Fortin 2013, White et al. 2015).

WOOD BISON

For contemporary wood bison subpopulations that primarily occur within the boreal forest biome, wetland-associated meadows, open savanna-like shrublands, and dry grassland areas are the most important habitat types (Reynolds et al. 1978, Larter and Gates 1991). They may use a wider range of habitats, however, outside of winter. In summer, wood bison in the Mackenzie population occupy grass and/or sedge meadows until mid- to late-summer when they form small herds and move to coniferous and mixed forests (Larter and Gates 1991). In addition to grasses and sedges, the early to mid-summer diet may contain a large quantity of willow leaves (Reynolds et al. 1978, Reynolds and Hawley 1987, Larter and Gates 1991). Lichens were found to be an important dietary component for a short time in the fall, if they were available in open canopy forests surrounding meadows or grasslands (Larter and Gates 1991). In the mountainous range of Yukon's Aishihik subpopulation, wood bison preferred flat terrain, with graminoid or shrub-dominated plant communities, over coniferous woodland and open shrub communities. Bison here also showed particularly strong selection for lakeshores (water/emergent vegetation) and adjacent wet sedge–shrub meadow vegetation (Fischer and Gates 2005, Jung 2015).

The best-described wood bison habitat that is currently occupied occurs in the lowlands of the Peace, Athabasca and Slave rivers (Reynolds 1987, Hamilton 2005, Jensen 2005). The wet meadows here are dominated by sedge (*Carex* spp.) and reed grass (*Calamagrostis* spp.). Moss (1953) described wet meadows as being widely scattered over northern Alberta, where they are maintained by periodic flooding events

that constrain survival of dry meadow species. Zonation of vegetation within these wet meadows reflects a moisture gradient related to elevation change away from water bodies. Hogenbirk and Wein (1991) described three zones in wet meadows in northern Alberta, including sedge marsh in the wettest sites, an adjacent bluejoint (*Calamagrostis canadensis*) meadow upslope, followed by a willow (*Salix* spp.) savanna in the driest zone. This zonation corresponds with habitats used by bison in the Slave River Lowlands (Reynolds et al. 1978) and in the Mackenzie wood bison range in the Northwest Territories (Larter and Gates 1991).

The Boreal Forest Natural Region of Alberta also contains dry grasslands, which include some plant species (*Stipa spartea, Artemisia frigida, Danthonia intermedia*) (Wilkinson and Johnson 1983) that are representative of communities in the Grassland Natural Region located further south. The largest patches of these grasslands occur on productive soils of the Peace River District in the Dry Mixedwood Natural Subregion, which has been heavily influenced by conversion to agricultural land use (Schieck et al. 2014). Smaller patches of dry grasslands, however, occur as far north as WBNP (Raup 1935, Moss 1952, Redmann and Schwarz 1986). Of particular importance are the grasslands and meadows of the Peace and Athabasca rivers, especially the delta at their confluence near Lake Claire, within WBNP. It also appears that significant grassland habitat occurred in the Fort McMurray area, along the tributaries of the Clearwater River, and west towards the Birch Mountains (Roe 1951). These prairies were historically associated with dark, solonetzic soils in the region, whereas forested areas tended to correlate with lighter soils (Wilkinson and Johnson 1983). Encroachment of boreal forest trees onto dark soils is evidence of the historical occurrence of prairie grasslands here and their subsequent disappearance (Wilkinson and Johnson 1983).

The succession of these prairies to forest may be attributed to the disappearance of bison from the northern regions of the province, as well as to active fire suppression in the region. Campbell et al. (1994) offered similar explanations regarding the disappearance of the plains bison and aspen expansion in western Canada. Although there were large prairies in the boreal region of Alberta in the Peace River and Grande Prairie areas, many other small prairies and meadows were scattered from the Rockies to the Canadian Shield (Gates et al. 1992). A range assessment conducted in the Hay-Zama lakes area indicated that there was a significant amount of good bison habitat with the potential to support as many as 2000 animals (Reynolds et al. 1982). The presence of excellent habitat in the Hay-Zama lakes area was also confirmed through a habitat-mapping project conducted in 2000 (Wright and Markiewicz 2000). The affinity that wood bison exhibit for relatively small, widely dispersed graminoid habitat patches likely means that they existed as a metapopulation consisting of many connected subpopulations scattered widely throughout northern Alberta.

In the northern boreal forests of Alberta, early inhabitants used fire to maintain meadows prior to the advent of modern forest management (Lewis 1977, 1980, Lewis and Ferguson 1988). In the High Level–Fort Vermillion area, for example, large areas were still being burned by indigenous peoples just prior to World War II (Lewis 1977). Burning typically took place in early spring, just after snowmelt when grasses were dry in open areas, but the forest understory was still wet. The most common reason for burning was to provide better forage for herbivores, including horses and bison. Meadows were burned west of WBNP to attract bison so that they could be legally hunted outside the park (Lewis 1977).

Currently, in the Boreal Forest Natural Region of the province, agricultural footprint (~11%) is the largest contributor of human footprint

and occurs mainly in the Dry Mixedwood Subregion (Schieck et al. 2014). Forest harvest accounts for approximately 3% of current human footprint in the Boreal, with mines, well sites and other energy features comprising another 2% (Schieck et al. 2014). Over the last 10 years, the rate of native habitat converted in the Boreal was 1.7%, of which forest harvest contributed about 1% and energy features about 0.3% (Schieck et al. 2014).

In addition to human footprint and habitat changes resulting from fire suppression, climate change is expected to have major impacts on northern vegetation, through stressors, such as increased temperature and evapotranspiration (Pastor and Post 1988) (see *3. Climate Change* in *Threats* section). These changes, as well as human interference with flood regimes, reduce important wet meadow habitat in the Boreal, through increased invasion by willows (Timoney et al. 1997) and exotic species (Hogenbirk and Wein 1991, 1992).

PLAINS BISON

In general, the most important habitats for plains bison are prairie grasslands and open meadow habitat types (Reynolds et al. 2003). If available, forested areas are used to varying degrees for escape and thermal cover, as well as for calving (Reynolds et al. 2003). Prior to European contact, plains bison in the Northern Great Plains portion of present-day southern Alberta occupied the Grasslands Natural Region (*sensu* NRC 2006) throughout spring, summer and fall, moving into forested areas of the Central Parkland, Foothills Parkland, and Foothills Fescue natural subregions in winter (Moodie and Ray 1976, Quigg 1978, Morgan 1980, Chisholm et al. 1986, Kay and White 2001, Macdonald 2009). The parkland and montane regions of southwestern Alberta were considered to be part of the winter range of plains bison, subject to grazing primarily during the dormant season (Morgan 1980). Foothills fescue grasslands had likely provided fall forage at a time when summer range was declining in nutritional value. The dormant grasslands would have also provided access to substantial forage in winter and early spring, given occasional chinooks in these areas.

The seasonal movements and migrations of bison were likely localized and flexible, with substantial inter-annual variation as a result of seasonal rainfall patterns, drought, prairie fires, localized overgrazing, blizzards and human hunting pressure (Hanson 1984). It was also likely that bison occupied higher elevation, mountainous ranges in southwestern Alberta in summer and fall, moving to lower elevation grasslands and floodplains in the Waterton and Crowsnest valleys in winter (Reeves 1978; and see Meagher 1973, van Vuren and Bray 1986, Frank and McNaughton 1992, Garrott et al. 2009a, and Geremia et al. 2014, who describe seasonal altitudinal migrations of plains bison in Yellowstone National Park and the Henry Mountains).

Within the original plains bison range of Canada, recent field studies have provided insight into habitat use patterns by plains bison re-introduced to boreal forest (Prince Albert National Park, SK) and grassland environments (Grasslands National Park, SK). In Prince Albert National Park (PANP), the distribution of plains bison in meadows is strongly associated with the spatial distribution of wheat sedge (*Carex atherodes)*, which dominated summer and winter diet (Fortin et al. 2002, 2003, Courant and Fortin 2010). Food intake and habitat selection also reflect trade-offs arising from seasonal dynamics of social group size, and predation risk from wolves—primarily in winter (Fortin et al. 2009, Courant and Fortin 2012, Harvey and Fortin 2013). Free-ranging bison in PANP also regularly move back and forth between habitat within the park and adjacent farmlands, especially during fall when they graze in fields planted to timothy (*Phleum pratense*) (Fortin et al. 2015). Given human activity during daylight hours, however, bison used farmlands primarily at

night and then retreated to the park during the day, minimizing disturbance from people and mortality risk from hunting (Fortin et al. 2015).

Distribution of plains bison in Grasslands National Park (GNP) was strongly influenced by physical habitat characteristics (i.e., bison occurred more on sloped terrains and tended to stay near fences, but away from roads); however, their selection of grassland communities was mostly based on maintaining high instantaneous intake of digestible energy (Babin et al. 2011). In winter, GNP bison selected for upland plant communities dominated by invasive crested wheatgrass (*Agropyron cristatum*); in spring, they selected crested wheatgrass communities as well as upland grasslands dominated by needle-and-thread grass (*Stipa comata*) with subdominant amounts of western wheatgrass (*Pascopyrum smithii*) (Babin et al. 2011, Fortin et al. 2015). Despite the markedly different environments and plant species comprising meadow and grassland habitats in PANP and GNP, food resources that offer rapid digestible energy intake were the common basis for habitat and forage selection by plains bison in both areas.

Prior to European settlement of the northern Great Plains, the Canadian prairies portion spanned about 615,000 km^2. During the settlement era—a span of 50-90 years—crop agriculture cultivated about 500,000 km^2, thus destroying over 80% of Canada's native grassland ecosystem (Bailey et al. 2010a). Relative to pre-settlement conditions, the Grassland Natural Region in Alberta (just under 96,000 km^2) has been transformed dramatically through human settlement and land use (Bailey et al. 2010a and 2010b, Willms et al. 2011, GOA 2014d, Wang et al. 2014). Schieck et al. (2014) showed that about 54% of Alberta's grassland natural region has been converted to human footprint, of which the majority (~48%) is due to agricultural land use; they also revealed that the rate of native habitat converted in the grassland region was about 1.2% during the last 10 years, with agriculture as the largest contributor (~0.7%).

Bailey et al. (2010a) found that of the 57,000 km^2 of natural grassland that remained in Alberta, 53,000 km^2 (~93.3%) were grazed by domestic livestock and wildlife; another 3000 km^2 (~5.3%) were under management for military training and about 810 km^2 (~1.4%) were grazed by wildlife within provincial and national parks. At present, the majority of public and private native grasslands in Alberta are predominantly managed for seasonal grazing by cattle. Restoration of wild plains bison to Alberta native grasslands at a scale that could meet or exceed criteria for a modest contribution to ecological recovery (*sensu* Sanderson et al. 2008) would likely be met with strong institutional, historical and cultural barriers (COSEWIC 2013a, Kohl et al. 2013).

Grazing intensity, fire, and drought were key natural disturbances that shaped the evolution of North American grasslands. Prior to European settlement on the Great Plains, indigenous peoples used fire as a means to improve hunting success, recognizing that new grass growing on a freshly burned area would attract bison. Thus, "fire hunting"—the strategy of surrounding or driving the principal grazers of a region by fire—was a landscape management tool extensively used by indigenous peoples across North America (Pyne 1986) and in other parts of the world (Middleton 2013). By applying fire to grasslands, indigenous peoples could influence large-scale movements of bison herds by managing their food resources (Pyne 1986). It is important to recognize, however, that the effect of large fires would have been highly variable, given the various meteorological, climatological, hydrological, biological, and other factors influencing the frequency, magnitude, and character of grass fires (Nelson and England 1971). At the landscape-scale, anthropogenic and wild fires played an important role in clearing treed vegetation communities to allow for expansion

of grasslands and in maintaining existing grasslands in early successional stages. Through the settlement era, large-scale anthropogenic fires were increasingly viewed as hazards. The risk of fire to destruction of property, forage, crops and settlements was reflected through changing attitudes, management practices and legislation for fire suppression (Nelson and England 1971, Pyne 1986, Bailey 2010a).

BIOLOGY AND ECOLOGY

This section focuses primarily on aspects of plains and wood bison biology that are relevant to their conservation, management and status.

1. Physical Description - The American bison is the largest terrestrial mammal in North America (Reynolds et al. 1987, 2003). Among the two subspecies, the wood bison is larger based on body size and mass. Comparative data from bison at EINP (Table 5) show that mature male wood bison are 18%–19% heavier than plains bison; they reach average adult (asymptotic) body mass by the time they are 8–9 years old, and continue to grow to reach maximum body mass by year 13. Adult female wood bison are approximately 23%–25% heavier compared to plains bison (Table 5). Adult female bison reach mature body size by the time they are 6–7 years of age, and attain maximum body size at 10–12 years of age.

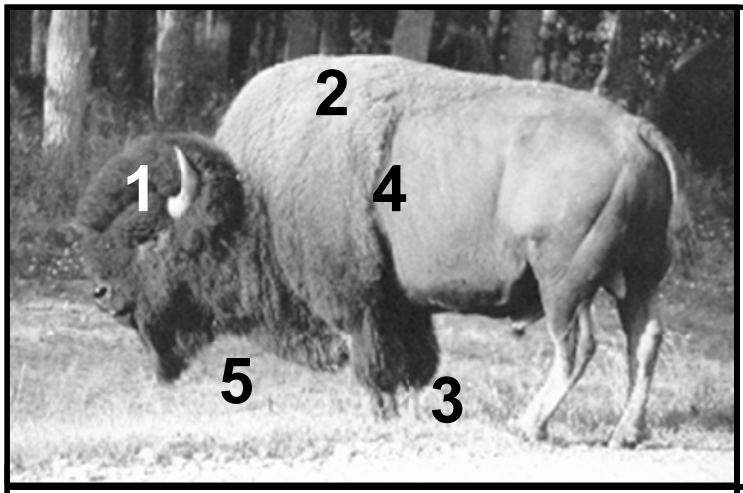
Bison of both subspecies are sexually dimorphic. Males have a massive triangular head, large shoulders with a prominent hump, and dense, shaggy, dark brown and black hair around the head and neck (van Zyll de Jong et al. 1995; see Olson [2005] for photos and drawings distinguishing different sex and age classes of bison based on physical characteristics). They possess short, thick, black horns that end in an upward curve. Females possess thinner, more curved horns (Fuller 1966, Olson 2005). Bison pelage varies in length over the body and is composed of long, coarse guard hairs, with a woolly undercoat (Banfield 1974). Hair on the head is darker than on the remainder of the body. Bison moult twice annually, in both spring and fall (Reynolds et al. 1987). They have a thick dermal shield between the horns and on the forehead and thick skin on the neck, which provides protection during sparring. There is also marked sexual dimorphism in body size and mass; in wood bison, mature males are approximately 60%–63% heavier than mature females, while in plains bison the males are approximately 68%–69% heavier (Table 5).

Comparing subspecies, wood bison have longer hair on their head and the hair is less woolly than on plains bison. The beard, throat mane, cape and chaps are typically less pronounced in wood bison than in plains bison (Figure 10).

2. Reproductive Biology - Bison have a polygamous breeding system organized through dominance relationships. Mature males compete for opportunities to tend and copulate with estrous females during the rut

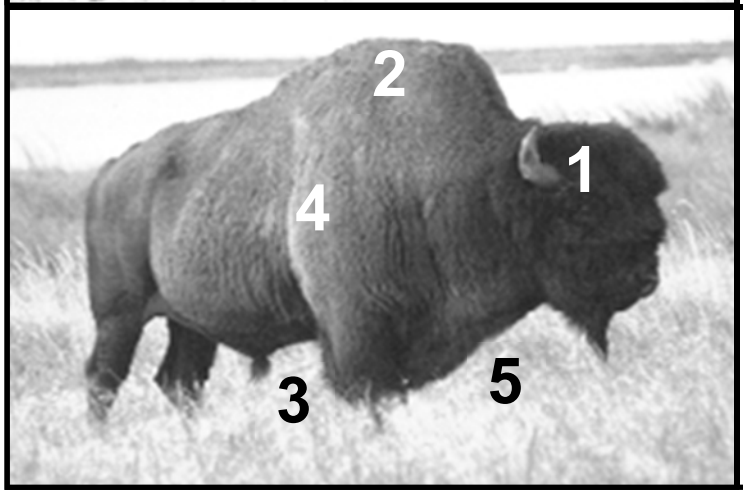
Table 5. Average body mass of male and female wood and plains bison at Elk Island National Park, Alberta. Data were summarized from age-specific growth curves in Reynolds et al. (2003).

	Male				Female			
	Asymptotic mean body mass (kg)	Age (yr)	Maximum mean body mass (kg)	Age (yr)	Asymptotic mean body mass (kg)	Age (yr)	Maximum mean body mass (kg)	Age (yr)
Wood Bison	880 $\pm$ 15.1	8	910	13	540 $\pm$ 5.7	7	567	12
Plains Bison	739 $\pm$ 10.0	8-9	769	13	440 $\pm$ 2.1	6	454	10



Male Plains Bison

1. Horn covered by dense woolly bonnet
2. Flat back
3. Well-developed chaps
4. Distinct cape
5. Well-developed beard and throat mane



Male Wood Bison

1. Horn clear, bonnet not woolly
2. Hump large, centered forward of leg axis
3. Reduced chaps
4. No clear cape
5. Smaller beard and throat mane

Figure 10. Physical differences between wood and plains bison.

(breeding season) (Lott 1974), which typically occurs from the middle of July through to the end of August; an extended late rut occurs from September to early October (Komers et al. 1994b).

Female bison are physically mature at two years of age and most calve for the first time at three years old. Ninety-five per cent of cows mate only once with conception generally occurring at the first or second estrus (Goodrowe et al. 2007). Observed calving and pregnancy rates for mature bison cows under free-ranging and semi-wild conditions has ranged from 35% to 88% (Reynolds et al. 2003). Most calves are born from late April to early June, after a gestation of approximately 270 to 300 days (Banfield 1974, Rutberg 1984, Jones et al. 2010). Typically, only one calf is born (Lott and Galland 1985). Neonates are light reddish brown in colour without the distinctive body shape of adults (Olson 2005).

Male bison reach reproductive maturity at one to two years of age. In the presence of older males, juvenile (1–3 years) and sub-adult bulls (3–6 years) participate only infrequently in breeding (Komers et al. 1994a, 1994b). During the late rut, older bulls decrease their involvement in competition for mates, providing limited mating opportunities for younger bulls (Komers et al. 1994b, Wolff 1998). Male reproductive effort increases throughout their lifetime (Komers et al. 1994b).

The typical generation length for bison was estimated to be eight years, based on a range of rates for survival and fecundity for various

bison populations reported in the scientific literature (see Appendix 5 for this calculation). Both sexes can live for up to 20 years in the wild and have been known to live longer than 30 years in captivity (Reynolds et al. 1982). Some evidence suggests that bison in the wild can also live beyond 20 years: a 27-year-old female bison (born Oct. 29, 1968, died Nov. 3, 1995) was killed by a vehicle east of Habay, Alberta, and became the oldest on record in the wild (K. Morton pers. comm. in 2000).

3. Ecological Relationships - Impacts of bison on their local environment are manifested through herbivory, wallowing, rubbing and horning trees and vegetation, and nutrient recycling through deposition of feces and urine. Grazing by bison influences the structure of plant communities and cycling of nutrients (Frank and McNaughton 1992, Frank and Evans 1997) with effects cascading to other animals, such as grassland birds, prairie dogs (*Cynomys* spp.), and dung beetles (Scarabaeidae) (Gates et al. 2010, Tiberg and Floate 2011). Bison also physically influence the landscape; their wallows and trails disturb the ground, providing microhabitat sites for plant species that favour disturbed sites (Polley and Collins 1984). It has also been postulated that bison play a role in maintaining meadow habitat and overall biodiversity of the regions they inhabit (Campbell et al. 1994, Zimov et al. 1995, Knapp et al. 1999, Powell 2006, Askins et al. 2007).

Bison are ruminant herbivores (i.e., cud-chewers) and are a primary grazer of coarse grasses and sedges. They occupy a niche that is not used by other native North American herbivores (Reynolds et al. 1978, Larter and Gates 1991), and there is little dietary overlap between bison and other ungulates. The potential for direct competition for food resources**,** therefore**,** is minimal (Fischer and Gates 2005, Jung et al. 2015a, 2015b). Bison may influence other ungulate species through apparent competition, which may occur through increased predation risk, as wolves (their primary predator) respond numerically to an increased abundance of bison as prey (Larter et al. 1994, Garrott et al. 2009b). Bison provide a source of food for wolves (Carbyn and Trottier 1988), and may also provide an important source of food for other animals including bears (*Ursus* spp.), ravens and crows (*Corvus* spp.), foxes (*Vulpes vulpes*) that scavenge on bison carcasses (Green et al. 1997). Wolves are thought to regulate small bison populations (Van Camp and Calef 1987, Carbyn and Trottier 1988, Carbyn et al. 1993, 1998), and predation may have a synergistic effect on mortality rates in bison populations infected with brucellosis and tuberculosis (Messier 1989, Gates 1993, Joly and Messier 2004b, 2005, Heisey et al. 2006; and see Bradley and Wilmshurst 2005).

POPULATION SIZE, TREND AND HEALTH STATUS

For this report, bison subpopulations in Alberta are categorized into three classes (see Gates et al. 2001c): 1) free-ranging subpopulations; 2) free-ranging subpopulations infected with bovine tuberculosis and/or brucellosis; and 3) fenced subpopulations with conservation objectives. Subpopulations in these three classes play different roles in the conservation of bison in Alberta.

WOOD BISON

1.Wood Bison in Alberta - Size and trend for each wood bison subpopulation in Alberta is summarized in Table 6. The estimated total number of mature bison in all Alberta subpopulations is 3866. Approximately 19% of mature bison are represented in four free-ranging subpopulations that are considered not to be infected with bovine tuberculosis and brucellosis (i.e., Hay-Zama, Etthithun, Harper Creek, and Ronald Lake). The majority of mature individuals (72%) occur within the GWBNP subpopulation, which includes the Wentzel Lake herd. The remaining 9% of mature bison occur within EINP. Survey information for

Table 6. Summary of wood bison subpopulations in Alberta. Note that a portion of the transboundary Etthithun subpopulation occurs in British Columbia; therefore, only approximately one-third (in 2015 survey) of this subpopulation is found in Alberta.

Wood Bison								
Alberta	Subpopulation (Herd) Name	Jurisdictions	Population Size (± 90% CI)	Adults ≥ 2 years (%)*	Survey Year	Survey Type†	Trend (%) (3 Generations)#	Sources
Free-ranging	Hay-Zama	AB	626	470 (75%)	2016	MC	1097%	1
	Etthithun	AB, BC	167	117 (70%)	2015	MC	1124%	2
	Ronald Lake	AB, CA	186	145 (78%)	2013	MC	unknown	3
	Harper Creek	AB	15	11 (75%)	2014	MC	unknown	4
Free-ranging Infected**	• Wood Buffalo National Park (WBNP)	CA	3,363 (± 893)	2,616 (78%)	2014	MC & ST	-0.4%	5
	• Wentzel Lake	AB	160	120 (75%)	2015	MC	unknown	6
Fenced	Elk Island National Park (EINP)	CA	494	352 (71%)	2014	MC	34%	7
			5011	3866				

*In absence of a specific empirical estimate, a mean value of 75% adult animals in a wood bison subpopulation was used (SARC 2016). Subpopulations preceded by a • indicate they occur within the Greater WBNP Ecosystem. †Survey type where MC = minimum count, MC & ST = combination of minimum count and strip transect. Estimates of precision provided where available; minimum counts did not have estimates of precision. #Trend (%) over 3 generations calculated using CriterionA_Workbook.xls (IUCN 2016) with exponential assumption and only 2 years of data. **Subpopulation infected with bovine TB &/or brucellosis. Data Sources: 1) L. Fullerton pers. comm. 2015, Melnycky and Moyles 2016; 2) Rowe and Backmeyer 2006, Thiessen 2010, Vander Vennen and Fullerton 2015; 3) Gates et al. 2001b, Powell and Morgan 2010, GoA 2013b; 4) Fullerton 2014; 5) Carbyn et al. 1993, Cortese and McKinnon 2015; 6) Gates et al. 2001b, Fullerton 2015a; 7) P. Robinson pers. comm.

Harper Creek, Ronald Lake and Wentzel Lake was insufficient to estimate subpopulation- or herd-specific numerical trends, because the data were not collected using comparable survey methodologies over a sufficient period of time. Nevertheless, available trend data illustrate that wood bison subpopulations do not incur "extreme fluctuations" (*sensu* IUCN 2016), where population size (or distribution area) varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude.

1.1 Free-Ranging

1.1.1 Hay-Zama Subpopulation - During early establishment of the Hay-Zama subpopulation, causes of mortalities of individual animals included predation (three), bison-vehicle collisions (eight), euthanization from bison-people conflicts (eight) and other causes (nine) (K. Morton pers. comm. in 2001; Table 1 in Mitchell and Gates 2002). From 1993 to 2008, the free-ranging Hay-Zama subpopulation increased by approximately 18% annually and peaked at 652 bison (Figure 11).

To address ongoing concerns over the increase in abundance and distribution of the Hay-Zama subpopulation, and its potential exposure to bovine tuberculosis and brucellosis from infected WBNP bison, the Alberta government implemented a strategy in 2008 to manage and monitor abundance, distribution, and health of Hay-Zama bison (GOA 2011a). A principal goal of this strategy is to "*maintain the Hay-Zama wild bison recovery herd free of bovine tuberculosis and brucellosis by limiting their numbers and distribution, particularly east towards Highway 35, thereby reducing the opportunity for exposure to diseased bison from the vicinity of Wood Buffalo National Park* (GOA 2011a)". With an objective to maintain this subpopulation between 400 and 600 bison[1], Alberta initiated an annual Hay-Zama bison hunt (GOA 2010). From 2008 to 2012, a total of 523 bison were killed during these hunts, of which 60% were bulls, 1% were subadults, and 39% were cows (Fullerton 2015b). In 2013,

1 The lower population management objective of 400 is consistent with the recommendation by the former National Wood Bison Recovery Team (Gates et al. 2001c) for a minimum viable population. Similarly, McFarlane et al. (2006) suggested that bison populations should be maintained above a minimum size (i.e., ≥ 400-500) to minimize the loss of heterozygosity.

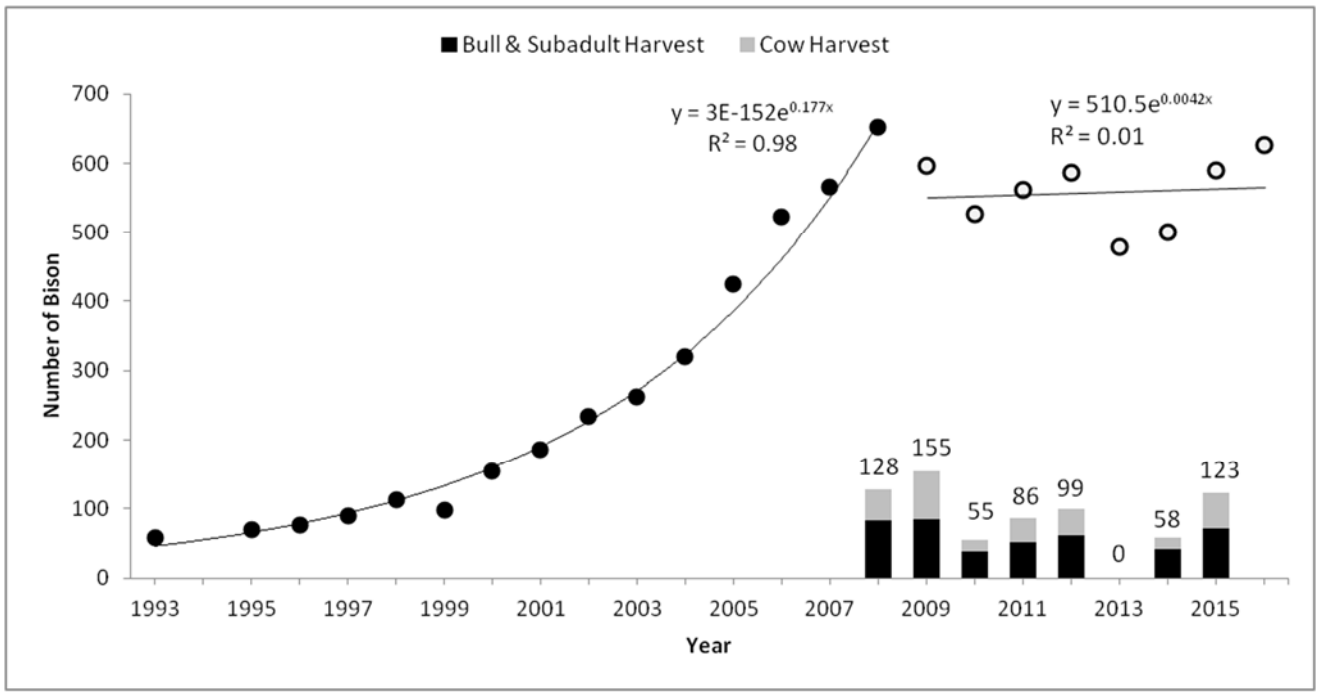


Figure 11. Population trend (based on aerial survey counts that include calves) and annual harvest of Hay-Zama wood bison subpopulation, 1993–2015. Population data from 1993 to 2008 (closed circles) show population trend prior to initiation of an annual hunt, with a regression indicating an average exponential rate of growth (r) = 0.177. Population data after initiation of an annual hunt in winter 2008 (open circles) shows a stable trend, based on regression. Numbers above stacked bars indicate the total annual hunt. Data sources: Alberta FWMIS, L. Fullerton and D. Moyles pers. comm., Melnycky and Moyles (2016).

the hunt was temporarily suspended because of population concerns related to extreme winter conditions. Aerial surveys indicated that almost all calves (~95%) and approximately 10% of adults had likely died as a result of deep snow across their winter range, and the pre-season population estimate of 410 was at the lower range of the population objective for the subpopulation (GOA 2014c). In 2014, however, based on a subpopulation estimate of 501 bison and expected recruitment of calves (~11%), the bison hunt was reinstated for the 2014/2015 season, with a harvest goal of 65–70 bison (GOA 2014c). Reported harvests for the 2014/2015 and 2015/2016 seasons were 58 and 123 bison, respectively (Figure 11). Since the annual bison hunt was established in 2008, the population trend of the Hay-Zama subpopulation has been stable (Figure 11) with an average total population size (i.e., including calves) of 558 (± 52 SD), based on surveys from 2009–2016. The most recent aerial surveys in 2015 and 2016 resulted in total counts of 590 and 626 bison, respectively (L. Fullerton pers. comm., Melnycky and Moyles 2016).

The annual Hay-Zama bison hunt has provided hunting opportunities for both indigenous and resident hunters, and has facilitated monitoring of herd health through collection of blood and/or tissue samples from hunter-killed bison. Of the reported total of 553 bison harvested between 2008 and 2012, 56.6% were taken by indigenous hunters and the remaining 43.4% were taken by resident hunters (Fullerton 2015b). Hunters provided a total of 279 samples that subsequently tested negative for brucellosis and tuberculosis, providing evidence that the Hay-Zama subpopulation has not been exposed and infected with either pathogen (Ball 2009,

GOA 2013b) or, alternatively, that the true prevalence is too low to detect (i.e., prevalence is < 1% at a 95% confidence level).

1.1.2 Etthithun Subpopulation - The Etthithun subpopulation started off as a captive herd of 43 calf and yearling bison and became free-roaming in 2003. By 2004, the population comprised 70 bison. An aerial survey in March 2006 showed that the reintroduced subpopulation in British Columbia had grown to 124 animals, with a ratio of 34 calves:100 cows, reflecting strong population growth potential (Rowe and Backmeyer 2006). Subsequent surveys in British Columbia showed that the number of Etthithun bison increased to 181 animals by March 2011 (D. Lirette pers. comm.), followed by an apparent decline to 117 bison in the survey area by March 2013 (BC Forest Lands and Natural Resources unpubl. data; D. Lirette pers. comm) (Figure 12). Regression analysis of bison counts, constrained to the data points between 2002 and 2011 (i.e., the period when Etthithun bison were free-ranging and their distribution occurred mostly in BC), suggested that the subpopulation increased by an estimated 16% annually during that period (Figure 12).

As described previously (see *Distribution*), during the first aerial surveys in 2006 and 2009, Etthithun bison had been observed to use habitat within Alberta, and in subsequent years there were increased reports of bison occurring in Alberta. In 2013, British Columbia (A. Goddard unpubl. data) and Alberta (L. Fullerton and P. Temoin unpubl. data) conducted separate and partially overlapping aerial surveys in Etthithun bison range and observed 117 and 121 bison, respectively. If interpreted independently, these results suggest a decline in Etthithun bison in British Columbia and an increasing trend in the adjacent range in Alberta (Figure 12). Interpreted through the lens of density-dependent, pulsed dispersal from initial core range, however, a more likely explanation is that the overall range extent has increased (Figures 4 and 5), and is concomitant with an increasing numerical trend. Thus, true abundance for the entire Etthithun subpopulation is likely larger

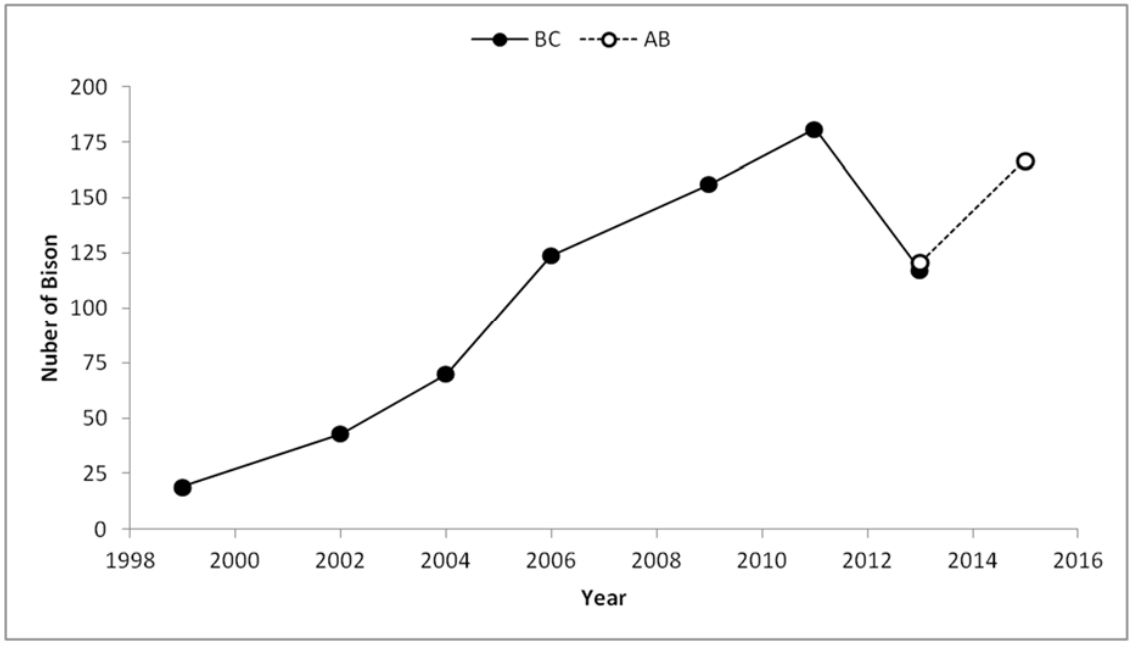


Figure 12. Observed trend in abundance of Etthithun bison subpopulation, based on minimum counts from aerial survey results in British Columbia (solid circles) and Alberta (open circles). Data sources: Harper et al. (2000), Rowe and Backmeyer (2006), Thiessen (2010), Vander Vennen and Fullerton (2015).

than the 167 animals (51 within Alberta) suggested by the most recent survey in January 2015, which occurred mostly in Alberta and therefore may have under-detected animals in British Columbia (Vander Vennen and Fullerton 2015).

Etthithun wood bison are assumed to be free from infection with bovine tuberculosis and brucellosis, principally because the founding animals were from EINP, which was recognized as free of tuberculosis and brucellosis (Koller-Jones 2008, US Department of Agriculture [USDA] 2008). Secondly, there are no known sylvatic or domestic animal reservoirs of either *M. bovis* or *B. abortus* in northeastern British Columbia or northwestern Alberta, and the recent testing of 279 hunter-killed Hay-Zama bison confirms the absence of infection in that subpopulation, at least above an approximately 1% detectable prevalence threshold. So there is support for the assumption that Etthithun bison are free from infection with bovine tuberculosis and brucellosis. Health monitoring of the Etthithun subpopulation across its range in British Columbia and Alberta remains an important effort, however, and will likely require evidence based on direct sampling, especially when range overlap occurs with the Hay-Zama subpopulation.

1.1.3 Harper Creek (Wabasca-Mikkwa) Subpopulation - Although bison were known to occur in the Wabasca-Mikkwa area as early as the mid-1920s, there were few efforts to systematically survey bison herds contiguous with the southwest corner of WBNP. In 1996, Alberta Fisheries and Wildlife Management Division observed two groups, totalling 51 bison, while conducting aerial moose surveys. These bison ranged near the Mikkwa and Wabasca rivers, south of the Peace River and near the boundary of WBNP (Gates et al. 2001c) (Figure 13).

In 2009, the Alberta Beef Producers requested that the GOA determine number and distribution of free-ranging bison outside of WBNP (Moyles 2010). Subsequently in February 2010, Moyles (2010) conducted the initial systematic aerial

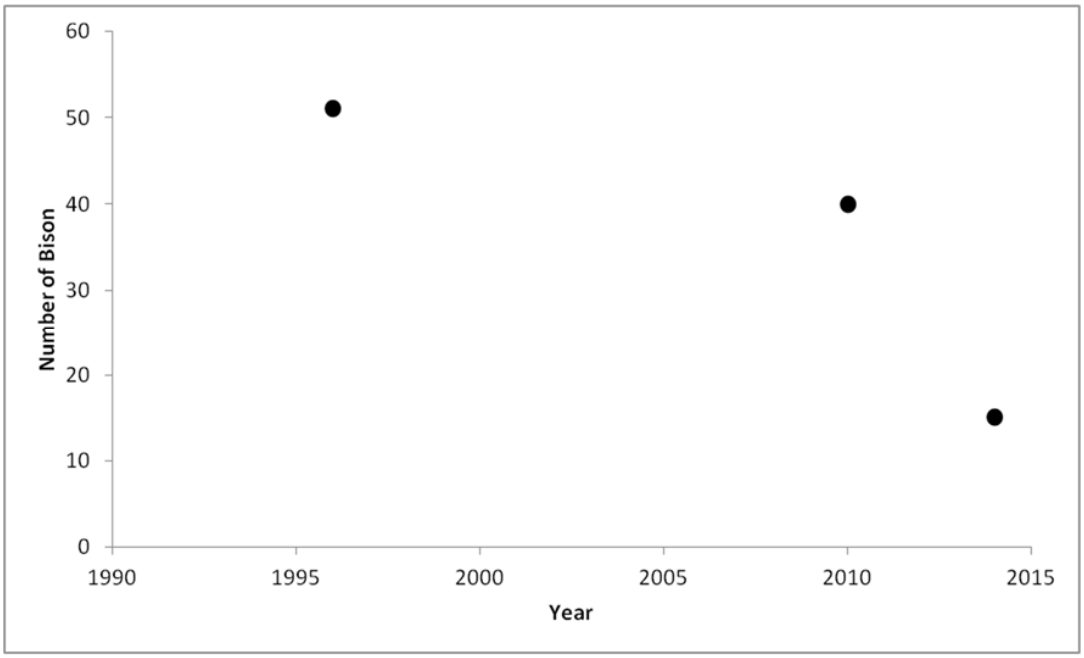


Figure 13. Minimum counts of bison observed during aerial surveys of Harper Creek, Wabasca-Mikkwa area (1996–2014). Data sources: Gates et al. (2001c), Moyles (2010), and Fullerton (2014).

survey of an extensive area south of the Peace River and between the Wabasca River and WBNP (identified as Surveillance Area 2, Figure 7, p. 9 in GOA 2011a), and estimated 30–40 bison there (Figure 13). The survey found bison in two main areas, including the wetlands between the Mikkwa and Wabasca rivers, and the wetlands extending along Harper Creek and its tributaries. Based on the localized distribution of tracks associated with the observed bison, Moyles (2010) inferred that bison were resident in those areas. He also noted that there was evidence of snowmobile tracks through the surveyed area, with the carcass remains of four hunter-killed bison about 10 km east of the community of Fox Lake. Extensive sightings of bison tracks in the area between Fox Lake and WBNP indicated that bison had been freely moving in and out of the park.

In March 2014, Fullerton (2014) flew a systematic aerial survey of Surveillance Area 2 (see Figure 14) and observed a total of 71 bison in the survey area; five groups totaling 56 animals occurred in the area between Fox Lake and WBNP were attributed to the Garden River herd, and another four groups comprising 15 bison occurred in an extensive area of wetlands between the Mikkwa River and the upper reaches of Harper and Lambert creeks—the Harper Creek subpopulation. The relatively low densities of bison observed during surveys in 1996, 2010, and 2014, combined with recent known removals of at least 24 individual animals since 2011 (see below), suggests that bison abundance has declined in the Harper Creek area (Figure 13). Most reports of Harper Creek bison before 2010 were based on anecdotal or incidental observations (Figure 4). Historical knowledge and recent surveys suggest there are fewer than 50 animals in the group (L. Fullerton pers. comm. in Ball et al. 2016). The small size of the Harper Creek subpopulation puts it at possible risk of extirpation, especially given the unregulated hunting (see *4. Hunting* in *Threats* section).

Between 1983 and 1985, Tessaro (1987) examined 164 bison carcasses in and around WBNP and necropsied 72 that were suitable for post-mortem analysis to test for infection with brucellosis and/or tuberculosis. Of the six bison that were located west of WBNP and south of the Peace River, *B. abortus*, the bacterium that causes brucellosis, was cultured from one animal (Tessaro 1987; p. 147). Based upon this positive test and local information indicating transboundary movements into and out of WBNP, the groups of bison south of the Peace River with individual animals occasionally moving outside the Park and west towards Fox Lake (i.e., the Garden River herd) were considered to be infected with brucellosis (and tuberculosis) (Tessaro 1987).

In contrast to Tessaro's (1987) opportunistic sampling of found-dead bison outside of WBNP, recent health surveillance of bison in the Wabasca-Mikkwa area has been based on a combination of approaches, including opportunistic blood and tissue samples from hunter-kills, blood testing of live-captured bison, and post-mortem tissue and blood sampling from field collections. From 2011–2014, a total of 24 bison were collected from Surveillance Area 2, and all animals tested from the interior of Area 2 (i.e., the Harper Creek subpopulation) have had negative test results for bovine brucellosis (GOA 2014c), suggesting that if the diseases were present, the true disease prevalence was below 12% (Ball et al. 2016).

1.1.4 Ronald Lake Subpopulation- Soper (1941) and Fuller (1950) suggest that what is considered the Ronald Lake subpopulation today may have been re-established and persisted as a small herd by at least the mid-1940s (see *Ronald Lake subpopulation* in *Distribution* section). Candler (2012) also reported that traditional knowledge of ACFN elders acknowledge the importance of winter bison hunts in the area prior to the 1960s. Early reports of a small bison herd in the

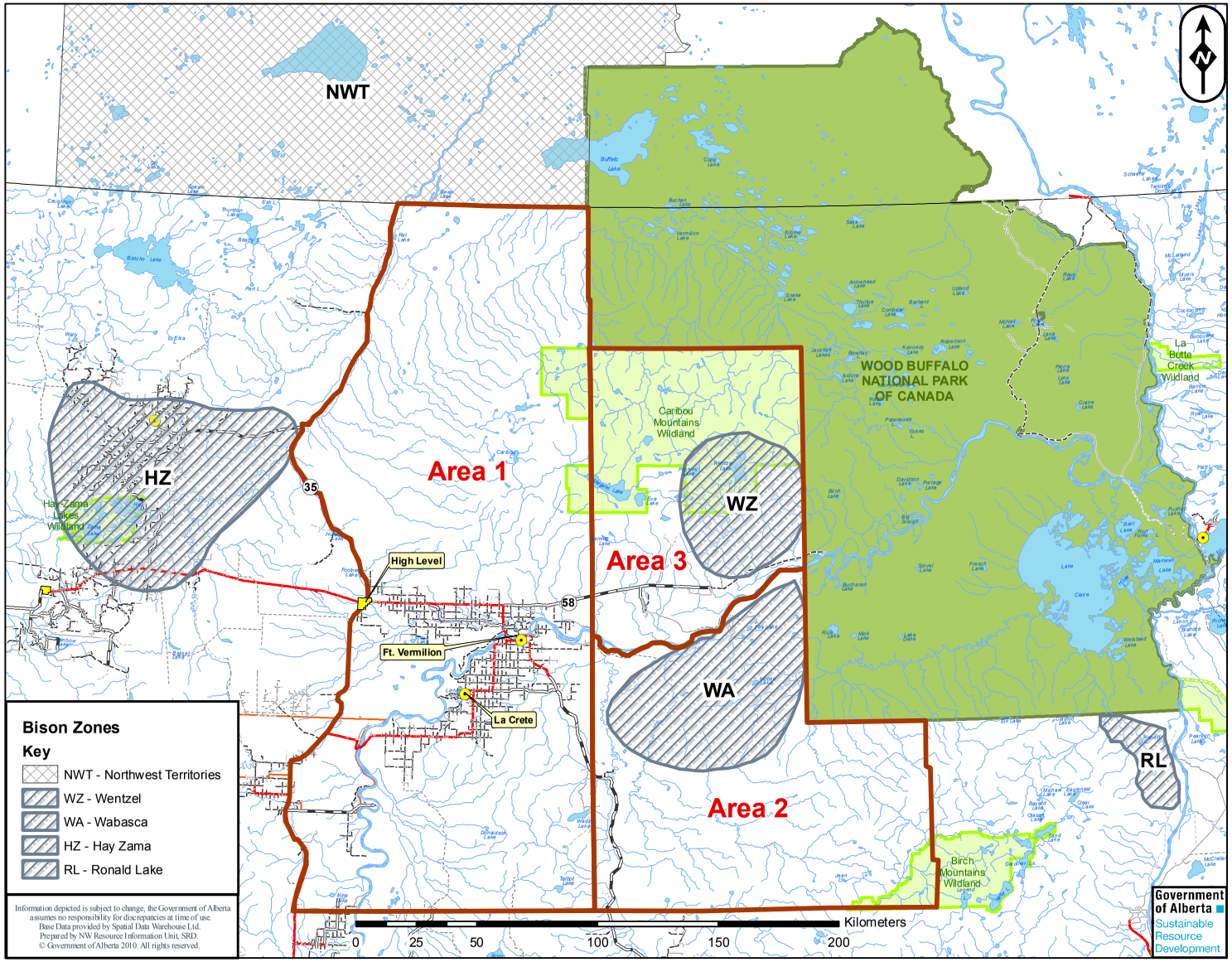


Figure 14. Aerial survey areas for surveillance monitoring of bison in northern Alberta (Areas 2 and 3 were designated high priority areas) (figure used with permission from GOA 2011a).

Firebag River area north of Fort McMurray and along the Athabasca River were substantiated by three separate anecdotal sightings of bison groups totaling 20, 65, and 42 animals in 1984, 1990, and 1991, respectively (Gates et al. 1992) (Figure 15). Following these anecdotal sightings, bison were reported in the Firebag area by Alberta Government staff in winter 2001, when they saw a group of 52 animals in January, and a group of two bulls in February (Gates et al. 2001b).

In February 2010, Powell and Morgan (2010) conducted an aerial survey using a mark-resight methodology and estimated 101 bison (90% CI = 74–159) in the Ronald Lake area. Subsequent scouting flights in December 2012 and March 2013 reported minimum counts of 169 and 186 bison, respectively (GOA 2013b). Although there have been aerial surveys of the Ronald Lake range in 2010, 2012, and 2013, the survey methods were not comparable so it is not possible to reliably estimate trend. Interpreting trend in those recent survey data is challenged by the large confidence intervals associated with the 2010 visual mark-and-recapture survey (Powell and Morgan 2010), and the fact that the 2012 and 2013 surveys were not designed to estimate bison abundance, but were scouting flights to locate bison groups prior to subsequent capture, disease sampling and/or application of radio collars (GOA 2013b) (Figure 15). Recent surveys since 2010 suggest the subpopulation may be stable to slightly increasing.

Between 2010/2011 and 2013/2014, a total of 72 bison were sampled in the Ronald Lake area and subsequent diagnostic tests were negative for bovine brucellosis and tuberculosis (M. Ball pers. comm.). The test results to date suggest the absence of bovine tuberculosis or brucellosis, based on a sample size sufficient to detect prevalence at 12% (Ball et al. 2016). Results of these tests are consistent with traditional knowledge sources that suggests

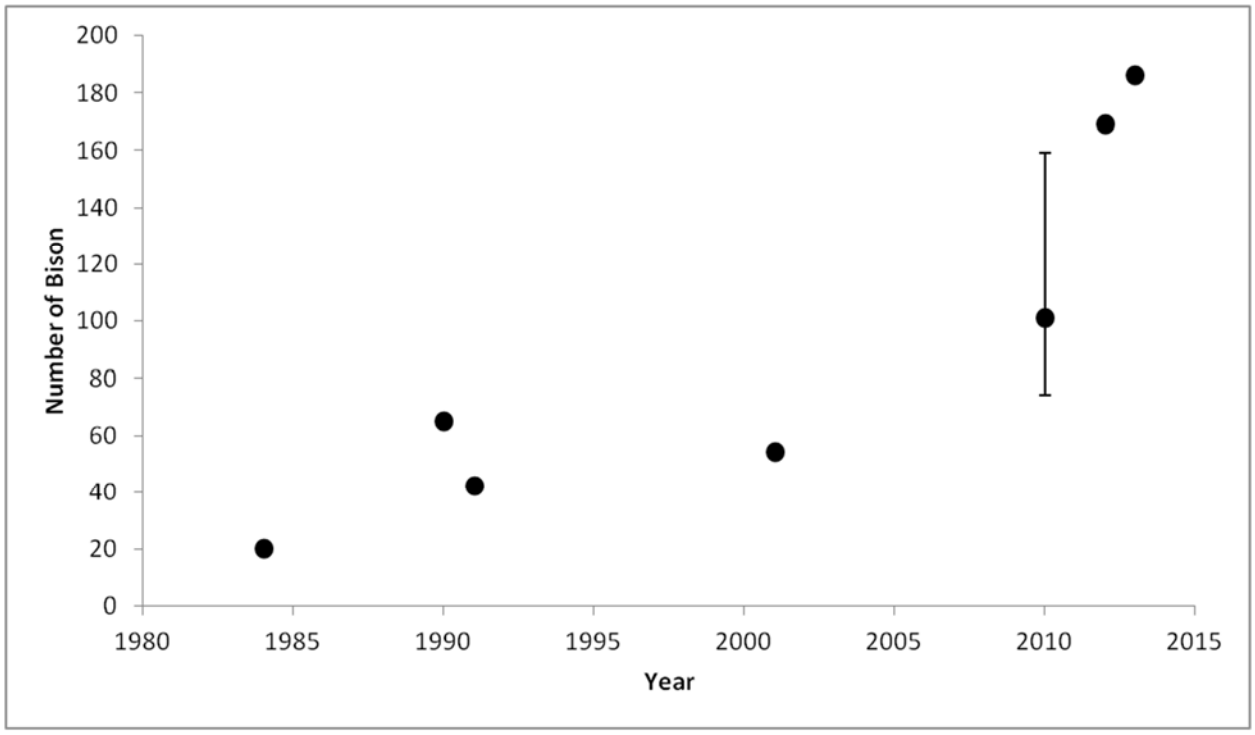


Figure 15. Number of bison observed and counted in Ronald Lake (Firebag) area, 1982–2013. Data sources: Gates et al. (1992), Gates et al. (2001b), Powell and Morgan (2010) (mark and re-sight estimate), GOA (2013b).

these bison are disease-free and comprised of "pure" wood bison (Candler et al. 2015).

1.2 Free-Ranging and Infected (with bovine tuberculosis and/or brucellosis)

1.2.1 Greater Wood Buffalo National Park (GWBNP) Subpopulation - Wood Buffalo National Park was created in 1922 to protect the remaining wood bison in northern Canada from further decline and possible extinction (Ogilvie 1979). Relative to its nadir of approximately 250 animals in the late 1890s (Allen 1900, Preble 1908, Gates et al. 1992), by 1922 the wood bison population increased to 1500–2000 animals (Soper 1941, Carbyn et al. 1993). However, between 1925 and 1928, that initial recovery of wood bison was forever changed after the Government of Canada translocated 6673 plains bison by rail and barge from Buffalo National Park near Wainwright, Alberta to the southern part of WBNP (Ogilvie 1979, Carbyn et al. 1993, MacEwan 1995, Fuller 2002, Sandlos 2002, Reynolds et al. 2003, Brower 2008). That translocation resulted in the irreversible introgression of plains bison genes (Wilson and Strobeck 1999, and see SARC 2016, p. 219-220 for discussion of factors likely affecting extent of introgression). It also introduced the cattle diseases, bovine tuberculosis and brucellosis, to the indigenous wood bison population (Connelly et al. 1990, Fuller 2002, Nishi et al. 2006, Wobeser 2009). Tuberculosis was first recognized in a single WBNP bison in 1937 and in another in 1946 (Connelly et al. 1990). Brucellosis was first noted in 1956 (Fuller 1966). WBNP bison are a reservoir of infection, as both disease pathogens have become established and are unlikely to disappear without management intervention. Joly and Messier (2004a) observed apparent prevalence rates of 31% and 45% for brucellosis and tuberculosis, respectively, which is consistent with prevalence data from Tessaro (1987) who tested bison in and around WBNP between 1983 and 1985.

Following the introduction of plains bison to WBNP, the population increased rapidly, and by 1934 there were approximately 12,000 bison in the park (Soper 1941) (Figure 16). Bison numbers remained between 10,000 and 12,000 until the 1970s and were largely affected by management actions including the poisoning, shooting and trapping of wolves, commercial slaughters, and vaccine roundups (Dragon and Elkin 2001, Fuller 2002, and see Carbyn et al. 1993 for a detailed overview of factors affecting WBNP bison population dynamics from the 1920s to the 1990s).

Spring floods during 1958 to 1961 and in 1974 resulted in mass drowning events (Carbyn et al. 1993) and were followed by a long-term population decline for the next 30 years. Coincident with the start of the decline was the cessation of wolf-control practices by the park (Carbyn et al. 1993). From 1972 to 1999, the population declined at an average rate of approximately 5% per year (Figure 16; WBNP unpubl. data, and see Carbyn et al. 1998, Joly and Messier 2004b, Bradley and Wilmshurst 2005). The combined effect of wolf predation and disease (i.e., bovine brucellosis and tuberculosis) was hypothesized to have driven the decline and maintained the low density of WBNP bison (Gates 1993, Messier and Blyth 1996, Joly and Messier 2005, Heisey et al. 2006; but see Bradley and Wilmshurst 2005).

Abundance of WBNP bison appeared to be approximately stable to slowly increasing (r = 0.025) from 1990–2014, which is a period of approximately three generations up to and including to the most recent survey. During this period, however, the population has ranged in abundance from a low of 2232 in 1999 to a high of ca. 5641 in 2005 (Zimmer and Macmillan 2005). Subsequent surveys in winter 2007 and 2009 resulted in counts of 4065 and 3942, respectively (Vassal and Kindopp 2007, 2010) (Figure 16). Although the WBNP population had increased relative to the low estimate from winter 1999, Vassal and Kindopp (2010)

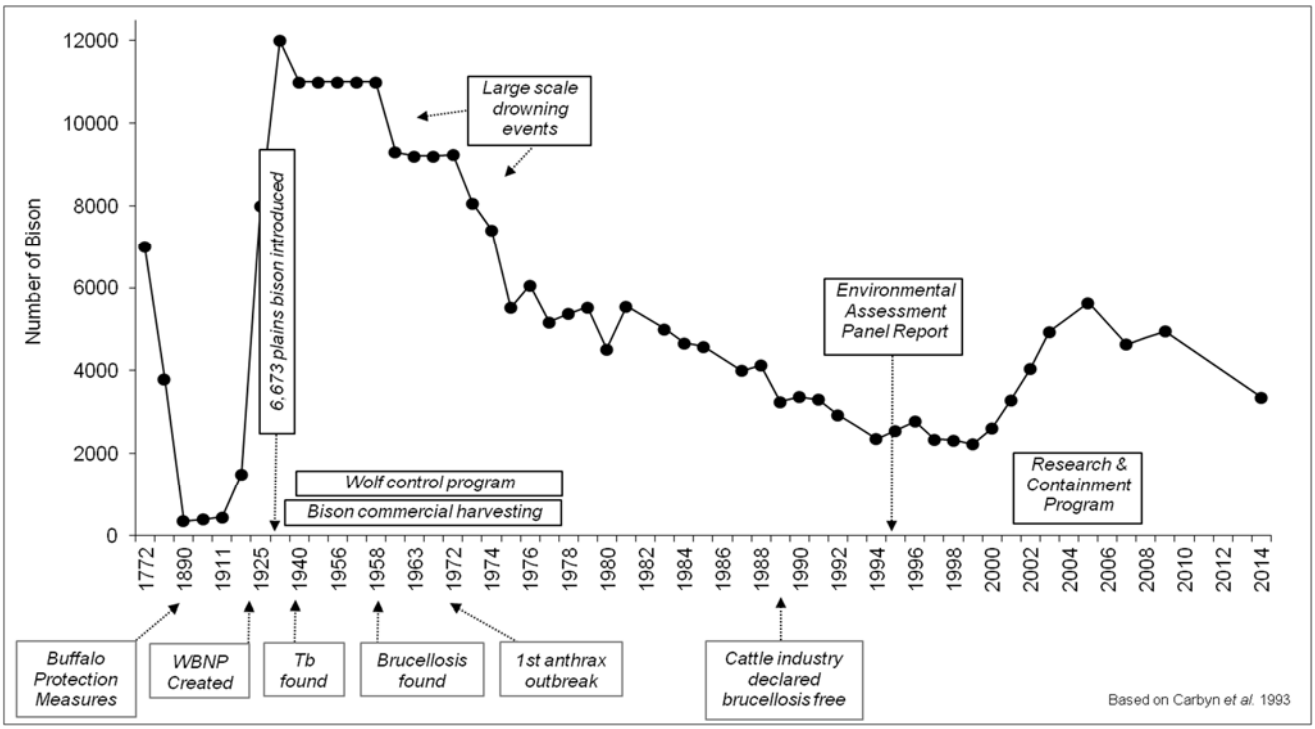


Figure 16. Population trend of bison in Wood Buffalo National Park (data source: WBNP – Parks Canada Agency). Data since 1975 are presented as buffered minimum counts to allow for comparison of survey results based on variable census techniques (see Bradley and Wilmshurst 2005, Zimmer and Macmillan 2005, Vassal and Kindopp 2007, 2010, and Cortese and McKinnon 2015).

concluded that bison estimates from surveys conducted in 2003, 2005, 2007, and 2009 were not significantly different from each other. The most recent survey in March 2014 resulted in a minimum count of 2573, and the corresponding population estimate (3363 $\pm$ 893 [90% CI]) was considered to be significantly lower than the previous surveys from 2003–2009 (Cortese and McKinnon 2015). In contrast to the longer term trend over three generations, regression analysis of recent WBNP population counts from 2005–2014 suggest an exponential rate (*r)* of -0.07, which is a 7% annual rate of decrease.

1.2.2 Wentzel Lake Herd (GWBNP) - Bison in Alberta that range outside of either the designated bison management zone in the northwest corner of the province, the *Subject Animal* zone south of WBNP, or WBNP itself (Figure 2) are not considered wildlife under Alberta's *Wildlife Act* and are subject to unregulated hunting (Gainer 1985, Tessaro 1987, Moyles 2010). This has generally facilitated an unmonitored buffer area within which unregulated hunting has deterred establishment and movement of bison herds, and thereby reduced the probability of disease transmission to the Hay-Zama subpopulation.

There are relatively few population estimates derived from a consistent survey methodology available for the Wentzel Lake bison herd. Based on local knowledge, Gates et al. (2001b) estimated that population size ranged up to 110 animals. A similar perspective on abundance was provided by Schramm et al. (2002), who interviewed Little Red River Cree Nation elders and indicated that the Wentzel Lake herd comprised 60 bison with up to 100 counted in summer. During recent bison surveys

of WBNP, park staff surveyed the Wentzel Lake area using non-systematic "spaghetti" reconnaissance flights and observed 28 bison in March 2005 (Zimmer and Macmillan 2005), 12 and 19 bison during the February-March surveys in 2007 and 2009, respectively (Vassal and Kindopp 2007 and 2010), and 71 bison in March 2014 (Cortese and McKinnon 2015).

As part of Alberta's disease management strategy of bison herds outside of WBNP, Fullerton (2011) conducted an extensive systematic aerial survey of Area 3 in January 2011, which included the Wentzel Lake area, and observed a total of 200 bison. Over half of these bison (i.e., 107 animals), however, were found just west of WBNP (Townships 112 and 113 Range 1 West of 5th Meridian), and were more likely to be associated with the Garden River herd, which occurs primarily within WBNP (WBNP 1995). The remaining 93 bison were distributed south and north of Wentzel Lake, along the Wentzel River drainage and along the upper Buffalo River drainage. A recent survey by Fullerton (2015a) in February 2015 documented 198 bison, primarily in the vicinity of Wentzel Lake and north along the upper Wentzel and Buffalo River drainages on the plateau of the Caribou Mountains. Relative to 2011, the 2015 survey indicated an average annual rate of increase of 13.5% (Figure 17), which could be attributed to a numerical increase, dispersal of animals from within WBNP, missed detection of animals in 2011, or a combination of those factors (Fullerton 2015a).

Health surveillance and disease testing programs for herds adjacent to WBNP are currently being conducted by AEP, through direct field sampling of live or euthanized bison, along with voluntary submission of bison samples from hunters. In 2011/2012, samples from 10 Wentzel Lake bison were subjected to diagnostic testing; all samples were negative for tuberculosis and three samples were test positive for brucellosis (GOA 2014c).

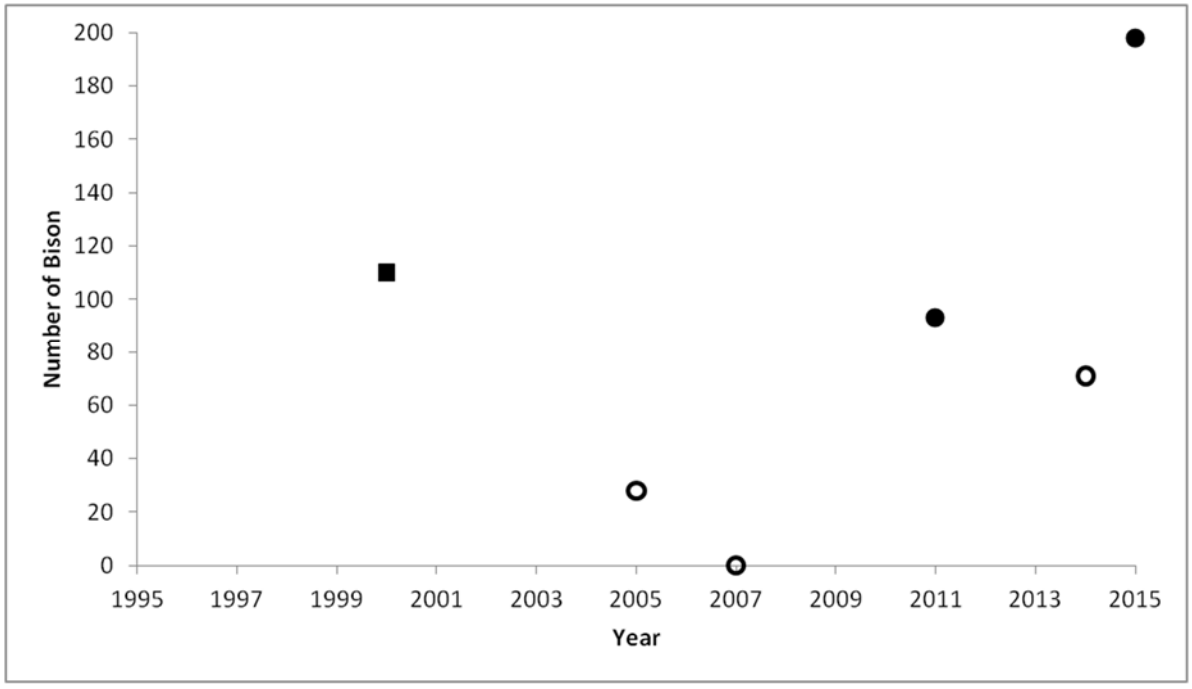


Figure 17. Minimum counts of bison observed in Wentzel Lake area (2000–2015). Data sources: solid square is an estimate from Gates et al. (2001b); open circles are observations from WBNP bison surveys (Zimmer and McMillan 2005, Vassal and Kindopp 2007, Cortese and McKinnon 2015); solid circles are results from aerial surveys by Fullerton (2011 and 2015a).

1.3 Fenced subpopulation with Conservation Objectives

1.3.1 Elk Island National Park (EINP) Subpopulation - As a result of the 2.1-m high perimeter game fence and relative absence of large predators (i.e., wolves), EINP is a fairly closed ecosystem that requires active management of large herbivores to regulate overall population health and impacts to forest habitat (PCA 2011). The health and abundance of bison are monitored through biennial "round-ups", and population size is managed by removal of animals to ensure the subpopulation does not grossly exceed targets for habitat carrying capacity. Of the bison that are removed from the park population, 20% of the annual removals are subject to post-mortem inspection by the Canadian Food Inspection Agency (CFIA) at an abattoir (P. Robinson pers. comm.), and the remainder are sold at auction or translocated as founder stock to establish new or augment existing conservation herds.

Based on its population size at the time (Figure 18), Wilson and Zittlau (2004) recommended that wood bison in EINP be managed above a minimum threshold of 245 animals, to meet long-term conservation objectives of retaining 90% of genetic diversity over 200 years. Correspondingly, recommended population size for wood bison in EINP is 260–300 (PCA 2011). Observed trends in population size for wood bison are shown in Figure 18, and are largely reflective of the dynamics between population productivity in the absence of predation, and removals of bison imposed through park management. The most recent population count in winter 2014 was 494 bison, of which 352 (71.3%) were estimated to be mature animals (Table 6) (Parks Canada Agency unpubl. data). Over approximately the last three generations (1992–2014), mean total population size for wood bison was 363 (SD = 57), with a minimum of 281 and a maximum of 494.

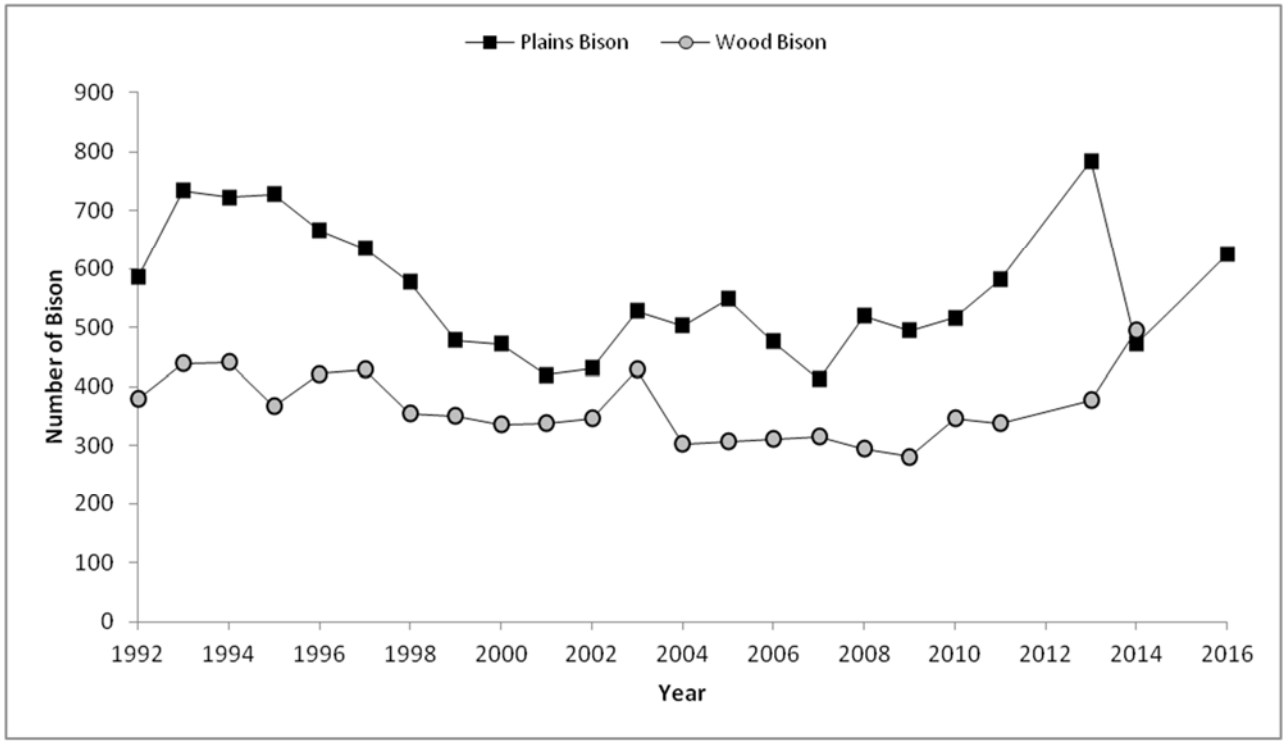


Figure 18. Abundance of wood and plains bison in Elk Island National Park (1992–2016). Data sources: EINP, Parks Canada Agency, P. Robinson (pers. comm.).

With respect to health status, wood and plains bison at EINP are subjected to the testing requirements imposed on ranched bison in Canada. Both bison subpopulations are tested regularly for bovine tuberculosis and brucellosis and there have been no positive reactors since the 1970s (Nishi et al. 2002c and 2016). Prior to shipment of EINP bison to Alaska in 2008, extensive reviews of EINP herd health data were conducted by the CFIA and the United States Department of Agriculture. Koller-Jones (2008, p. 1) reviewed available evidence and concluded with "*the CFIA's determination that the wild wood bison population at EINP, together with the other wild ungulate species (plains bison, elk, moose, and deer) at EINP is free from bovine tuberculosis and brucellosis*." The USDA (2008, p. 7) similarly concluded results of its analysis, which *"revealed that the likelihood of the presence of either brucellosis or tuberculosis in 1 percent or more of the combined elk and wood bison population of the Wood Bison Area of EINP is extremely low (less than 0.01 percent) given the exit testing surveillance results to date."*

2. Wood Bison in Other Areas - Table 7 summarizes the size and trend for five wood bison subpopulations in Canada that occur outside of Alberta, as well as the Slave River Lowlands herd that is part of the GWBNP metapopulation and occurs in the Northwest Territories. The estimated total number of mature bison outside of Alberta and within Canada is 3063-3100, and the majority (~74%) occur in five healthy subpopulations that are considered free from infection with bovine tuberculosis and brucellosis.

3. Rescue Potential - Rescue potential is the likelihood that immigration by individuals from a separate subpopulation (herd) would mitigate potential extirpation or decline in a subpopulation or population in Alberta. Based on observed patterns of range expansion since its reintroduction to northeastern British Columbia, the Etthithun Lake wood bison subpopulation will likely become a source of migrants to the Hay-Zama subpopulation. Rescue potential of other healthy bison subpopulations (i.e., free from infection with bovine tuberculosis and brucellosis) outside of Alberta is low to negligible, because of the distances between subpopulation ranges and the actions being undertaken to manage distribution and abundance of subpopulations.

Table 7. Summary of wood bison subpopulations elsewhere in Canada. Note that the transboundary Etthithun subpopulation, which is partly found in British Columbia, is included in Table 6.

Wood Bison								
Other Areas (in Canada)	**Subpopulation (Herd) Name**	**Jurisdictions**	**Population Size (± 90% CI)**	**Adults ≥ 2 years (%)***	**Survey Year**	**Survey Type†**	**Trend (%) (3 Generations)#**	**Sources**
Free-ranging	Aishihik	YK	1,470	1,103 (75%)	2014	MR	2840%	1
	Nordquist	BC, YK	108	79 (73%)	2010	MC	306%	2
	Nahanni	NT, BC, YK	431 (± 106 SE)	323 (75%)	2011	ST	1177%	3
	Mackenzie	NT	714 (± 156 SE)	558 (78%)	2013	DS	-52%	4
	Chitek Lake	MB	250-300	188-225 (75%)	2009	MC	2329%	5
Free-ranging Infected**	• Slave River Lowlands	NT	1,083 (± 414 SE)	812 (75%)	2014	DS	76%	6
Fenced	Hook Lake Wood Bison Recovery Project (HLWBRP)	NT	0	-	2006	-	depopulated	7
			4056-4106	3063-3100				

*In absence of an empirical estimate, a mean value of 75% adult animals in a wood bison population was used (SARC 2016). Subpopulations preceded by a • indicate they occur within the Greater WBNP metapopulation. †Survey type where DS = distance sampling, MC = minimum count, MR = mark-recapture, ST = strip transect. Estimates of precision provided where available; minimum counts did not have estimates of precision. #Trend (%) over 3 generations calculated using CriterionA_Workbook.xls (IUCN 2016) with exponential assumption and only 2 years of data. **Subpopulation infected with bovine TB &/or brucellosis.
Data Sources: 1) Jung and Egli 2014, % adult estimated as average of empirical estimates for free-ranging wood bison (Ettithun, Nordquist, Mackenzie); 2) Thiessen 2010; 3) Larter and Allaire 2013, SARC 2016; 4) Larter et al. 2000, Armstrong and Cox 2013; 5) COSEWIC 2013a, MCWS 2014; 6) Armstrong 2014, SARC 2016; 7) Nishi 2010

For example, the bison-free management areas in the Northwest Territories and in northern Alberta are designed to minimize the likelihood of bison migrants between subpopulation ranges including WBNP.

PLAINS BISON

1. Plains Bison in Alberta - There are two subpopulations of plains bison (i.e., McCusker River and EINP) in Alberta, with respective size and trends summarized in Table 8. Based on available data for the two subpopulations, the total estimated number of mature plains bison in Alberta is close to 400, with the uncertainty in the estimate arising from the lack of a systematic survey or minimum count of bison in the McCusker subpopulation. Thus, the majority of plains bison in the province (approximately 95%) occur within EINP. The available trend data show that plains bison subpopulations are not subject to "extreme fluctuations" (*sensu* IUCN 2016), where population size (or distribution area) varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude.

1.1 Free-Ranging

1.1.1 McCusker River Subpopulation - The McCusker River subpopulation ranges mostly in Saskatchewan within the Primrose Lake Air Weapons Range, but extends west into Alberta. This subpopulation has not been monitored or systematically surveyed since it was established in 1969, so there are no direct estimates of abundance. Based on observations of biologists, COSEWIC (2004) estimated that subpopulation size was between 70 and 100 individuals, and may be increasing in abundance and extent of occupied range. More recently, COSEWIC (2013a) considered anecdotal observations of bison from observers flying over the Primrose Lake Air Weapons Range, as well as reported ground sightings of bison outside the air weapons range in Saskatchewan, and estimated the subpopulation size to be 100–150 bison. This is still considered an appropriate guess-estimate, given there has been no further information suggesting an increase or decrease of the population (R. Tether pers. comm.). The estimate of mature animals was approximated at 51–113, through the application of lower and upper limit estimates from other plains bison subpopulations (51%–75%) (COSEWIC 2013a). The proportion of McCusker bison that occur in Alberta is not known; however, a simple extrapolation based on the proportion of the peripheral subpopulation range that occurs within Alberta (~7%), suggests that there are likely few bison (i.e., an extrapolated range of 4–8 mature bison) that occur within the province. In the last two years, there has been an increase in bison hunting outside the

Table 8. Summary of plains bison subpopulations in Alberta. Note that the transboundary McCusker River subpopulation largely occurs in Saskatchewan; therefore, only a small (and unmeasured) proportion of that subpopulation is found in Alberta.

			Plains Bison					
Alberta	**Subpopulation (Herd) Name**	**Jurisdictions**	**Population Size (± 90% CI)**	**Adults ≥ 2 years (%)***	**Survey Year**	**Survey Type†**	**Trend (%) (3 Generations)#**	**Sources**
Free-ranging	McCusker River	SK, CA, AB	100-150	51-113 (51-75%)	2012	GE	unknown (likely stable)	1
Free-ranging Infected**	n/a	-	-	-	-		-	-
Fenced	Elk Island National Park (EINP)	CA	625	391 (63%)	2016	MC	7%	2
			725-775	442-504				

*In absence of an empirical estimate, the proportion of mature individuals was approximated by applying lower and upper limit estimates from other Plains Bison subpopulations (51-75%) (COSEWIC 2013a). †Survey type where GE = guess estimate, and MC = minimum count. Guess estimates and minimum counts did not have estimates of precision. **Subpopulation infected with bovine TB &/or brucellosis. #Trend (%) over 3 generations calculated using CriterionA_Workbook.xls (IUCN 2016) with exponential assumption and only 2 years of data.

Data Sources: 1) COSEWIC 2013a, R. Tether pers. comm.; 2) Parks Canada Agency, P. Robinson pers. comm.

air weapons range, primarily by local First Nation hunters. This is likely a result of new and improved access associated with newly logged forest cutblocks adjacent to the air weapons range on the Saskatchewan side (R. Tether pers. comm.).

There have been no health studies conducted on the McCusker River subpopulation, although the source EINP subpopulation is considered to be free from infection with bovine tuberculosis and brucellosis and there are no known reservoirs of infection for either pathogen in Saskatchewan wildlife. It is noteworthy, however, that the translocation of 50 EINP plains bison to north central Saskatchewan in 1969 occurred before the plains bison subpopulation in the park was officially declared free of brucellosis in 1972 (Blyth 1995).

1.2 Fenced Subpopulation with Conservation Objectives

1.2.1 Elk Island National Park (EINP) Subpopulation - Plains bison at EINP occur within the main fenced area (134 km^2) of the park. Based on the population size of plains bison in EINP (Figure 18), Wilson and Zittlau (2004) recommended that it should not decline below 175 animals in order to meet long-term conservation objectives of retaining 90% of genetic diversity over 200 years. Correspondingly, the population target is 250–275 animals (PCA 2011). Although the population of plains bison has increased slightly over the past 3 generations (reported as 7% in Table 8), the dynamics of population size (Figure 18) largely reflect the interaction between population productivity in the absence of predation, and removals of bison imposed through park management. The most recent population count in winter 2016 was 625 bison (Table 8). Over approximately the past three generations (1992–2016), the mean total population size for plains bison in EINP was 561 bison (SD = 108), with a minimum of 411 and a maximum of 784 (Figure 18). The proportion of mature animals (≥ 2 years old) in the population was estimated at 62.6% based on composition data collected in 2016 (Parks Canada Agency unpubl. data), which resulted in an estimate of 391 mature EINP plains bison (Table 8).

Plains bison at EINP have been subjected to the testing requirements imposed on ranched bison in Canada. The population has been tested regularly for bovine tuberculosis and brucellosis and there have been no positive reactors since the 1970s (Nishi et al. 2002c and 2016). In a review of animal health data and history of EINP, Koller-Jones (2008) concluded that the plains (and wood) bison populations at EINP, together with the other wild ungulates at EINP including elk, moose and deer, were free from bovine tuberculosis and brucellosis.

2. Plains Bison in Other Areas - Gates et al. (2010) provide a thorough and extensive overview and status of plains bison conservation herds throughout North America, and the COSEWIC (2013a) bison status report provides the most recent update on status of other plains bison subpopulations in Canada. Table 9 summarizes size and trend for three plains bison subpopulations in Canada that occur outside of Alberta (see Figure 8). The total number of mature bison outside of Alberta and within Canada is estimated to be 1119, with the majority (66%) occurring in the Pink Mountain subpopulation in British Columbia.

3. Rescue Potential - There is negligible rescue potential for plains bison subpopulations in Alberta. Plains bison at EINP are managed as a closed population and are enclosed by a perimeter fence. McCusker River bison comprise an isolated subpopulation that has a transboundary range across Saskatchewan and Alberta. Although there is a theoretical potential for migrants from the Sturgeon River subpopulation in PANP, the practical likelihood is negligible because of the approximately 120 km straight-line distance between the two subpopulation ranges across a predominantly

Table 9. Summary of plains bison subpopulations elsewhere in Canada. Note that the transboundary McCusker River subpopulation, which is partly found in Saskatchewan, is included in Table 8.

Plains Bison								
Other Areas (in Canada)	**Subpopulation (Herd) Name**	**Jurisdictions**	**Population Size (± 90% CI)**	**Adults ≥ 2 years (%)**	**Survey Year**	**Survey Type†**	**Trend (%) (3 Generations)#**	**Sources**
Free-ranging	Pink Mountain (Halfway-Sikanni)	BC	1013	734 (73%)	2014	SB	62%	1
	Sturgeon River (Prince Albert National Park - PANP)	CA	223 (± 14 SE)	166 (74%)	2013	MR	27%	2
	Grasslands National Park (GNP)	CA	310	219 (71%)	2015	MC	4993%	3
Free-ranging Infected*	n/a	-	-	-	-		-	-
Fenced	n/a	-	-	-	-		-	-
			1323	1119				

*Subpopulation infected with bovine TB &/or brucellosis. †Survey type where DS = distance sampling, GE = guess estimate, MC = minimum count; MC & ST = combination of minimum count and strip transect; MR = mark-recapture, SB = stratified block, ST = strip transect. Minimum counts and guess estimates did not have estimates of precision. Estimates of precision provided where available; minimum counts and guess estimates did not have estimates of precision. #Trend (%) over 3 generations calculated using CriterionA_Workbook.xls (IUCN 2016) with exponential assumption and only 2 years of data
Data Sources: 1) D. Lirette unpubl. data; 2) Merkle and Fortin 2014, Merkle et al. 2015; 3) Parks Canada Agency, S. Liccioli pers. comm.

agricultural landscape. More importantly, the Government of Saskatchewan would likely implement a targeted hunt if the Sturgeon River subpopulation increased above the upper threshold of 430 in the management plan (SRPBS 2013) in conjunction with increased landowner conflicts, or if the McCusker subpopulation increased and moved out of the air weapons range (R. Tether pers. comm.).

THREATS

This section focuses on threats that have an anthropogenic origin, as well as other factors that occur naturally if they are amplified by human activities and result in increased pressures on a bison subpopulation. Threats are generally listed in order of importance (i.e., beginning with recent/current/imminent threats that are well documented and have caused/are causing/will cause population-scale harm).

1. Types of Threats

1.1 Disease - Enzootic diseases affecting wood bison in northern Alberta present important challenges to management and recovery of affected subpopulations (and herds), because of their influence on population vital rates and the potential risk of disease transmission to non-infected wild bison subpopulations as well as commercial bison and cattle herds. Bovine tuberculosis and brucellosis are discussed together because both disease pathogens originated in domestic cattle and were introduced into wild bison. Their effects on birth and death rates in infected wild bison are synergistic and interactive with predation. Anthrax is discussed separately because its effects on wild bison populations occur primarily as direct mortalities that occur during epizootic outbreaks (primarily in summer), are linked to climatic and environmental conditions that increase susceptibility and exposure of bison to anthrax spores that persist in the environment, and are also highly variable with respect to inter-annual frequency and magnitude of mortality.

1.1.1 Bovine tuberculosis and brucellosis - Wood bison in the GWBNP metapopulation are infected with the bacterial pathogens that cause bovine tuberculosis (*M. bovis*) and bovine brucellosis (*B. abortus*). These pathogens likely originated in domestic

cattle, spilled-over into plains bison herds at Wainwright, and were introduced to WBNP with the translocation of infected bison in the 1920s (Brower 2008, Wobeser 2009). The pathobiology of each disease is considered similar in bison and cattle (Tessaro 1989) (see Appendix 6 for more information).

In the greater WBNP ecosystem, bison are the host reservoir for these zoonotic, reportable[2] cattle diseases and are capable of maintaining infection under a broad range of population densities. In the absence of management intervention, the pathogens will likely be maintained indefinitely in the ecosystem (Connelly et al. 1990, Joly and Messier 2004a). With maintenance of bovine tuberculosis and brucellosis in the GWBNP metapopulation, there is continued risk that these pathogens can infect healthy bison subpopulations, farmed livestock (cattle and bison), and people who hunt and consume wild bison from infected herds (Connelly et al. 1990). The persistence of these two reportable cattle diseases in GWBNP bison presents the most difficult issue facing management and recovery of wood bison in Alberta (Gates et al. 2001c, Nishi 2010, Pybus and Shury 2012, Shury et al. 2015, ECCC 2016). Appendix 7 provides a brief overview of the history of the two diseases and the northern diseased bison issue.

Infected wood bison in the GWBNP metapopulation are negatively impacted by these diseases, through increased mortality, reduced fecundity, and increased susceptibility to predation (Gates et al. 1992, Joly and Messier 2004b, 2005). Joly and Messier (2004a) found overall prevalence rates in WBNP bison of 49% and 31% for tuberculosis and brucellosis, respectively, which was consistent with prevalence data from Tessaro (1987) on bison tested from 1983 to 1985. Bison that tested positive for both tuberculosis and brucellosis showed reduced survival and pregnancy rates compared to bison positive for one or neither disease (Joly and Messier 2005). Concurrent modeling showed this to be sufficient to cause a shift from a high density, food-regulated equilibrium to a low density equilibrium regulated by predation by wolves (Joly and Messier 2004b). The combined and synergistic effect of wolf predation and disease (bovine brucellosis and tuberculosis) are hypothesized as playing key roles in the decline and persistent low densities of bison in WBNP (Gates 1993, Joly and Messier 2004b; but see Bradley and Wilmshurst 2005).

In addition to being a concern for recovery of healthy wood bison in wild populations, these diseases are of concern to the commercial cattle and bison industry (Connelly et al. 1990, and see MacArthur 2012, Farkas 2014, and Appendix 6 and 7). One estimate of the economic consequences of an outbreak in cattle in Canada reported a potential cumulative loss of $1 billion over a 20-year period (Connelly et al. 1990). In response to these concerns and at the request of the Canadian Bison Association (CBA), the Animal, Plant and Food Risk Analysis Network (APFRAN) of the Canadian Food Inspection Agency conducted a risk assessment in the late 1990s. The risk assessment estimated the probability of: 1) invasion by diseased bison into an area containing susceptible bison and cattle herds, 2) contact between an infected and non-infected animal in that region once invasion had occurred, and 3) disease transmission to an individual animal in each risk group upon contact. The economic consequence of such a disease transmission was also estimated (APFRAN 1999). The risk assessment estimated the 95% probability of at

2 A reportable disease—also referred to as a notifiable or listed disease—is designated in the *Reportable Diseases Regulations* (SOR/91-2) under authority of law by Canada's *Health of Animals Act* (SC 1990, c. 21), and when suspected, the case must be reported by the owners (or animal caretakers) to the Canadian Food Inspection Agency (CFIA). The CFIA responds by either controlling or eradicating the disease. Bovine tuberculosis, brucellosis, and anthrax are listed as "reportable diseases" because they may pose serious threats to international trade in livestock, and may have important socioeconomic and human health consequences.

least one animal becoming infected (APFRAN 1999) in an "At Risk" group (Table 10). Disease-free, free roaming (wild) bison in the Hay-Zama and Mackenzie populations were at the highest risk of infection, at one in eight years for brucellosis and one in six years for tuberculosis.

Additional research was conducted for the APFRAN risk assessment to include biogeographical factors that may influence bison movement, as well as local knowledge of bison distribution in the "At Risk" regions. The results defined probable movement corridors of bison: "*the highest density corridors paralleled the Peace River in the vicinity of Fort Vermillion and another cluster ran from WBNP southwest across the south end of the Buffalo Head Hills*" (Gates et al. 2001b, Mitchell 2002). The findings also highlighted the fact that distances between susceptible herd locations and documented wild bison sightings were much shorter than distances generated by either the movement model or assumptions used in the APFRAN (1999) risk assessment (Gates et al. 2001b, Mitchell 2002). The implication was that some susceptible herds may have already come into contact with wild bison and that there was considerable risk potential for transmission of diseases to healthy wood bison subpopulations and bison ranches in the vicinity of the diseased herds (Gates et al. 2001b, Mitchell 2002).

With a focus on risk of disease transmission to commercial cattle pasturing in Municipal District Mackenzie No. 23 southwest of WBNP, the CFIA (2016) updated the APFRAN (1999) risk assessment. The CFIA (2016) estimated that on average the introduction of bovine brucellosis and tuberculosis into the cattle population from free-ranging bison in WBNP and surrounding area would occur not more frequently than once every 555 years and once every 107 years, respectively. It estimated that the economic impact of an outbreak of bovine brucellosis or tuberculosis to the livestock industry in Canada would be moderate and low, respectively.

Table 10: Risk assessment results indicating infection probabilities and economic consequences based on 1998 conditions (APFRAN 1999).

Disease	Risk parameter	Wild bison	Commercial bison	Cattle
	Probability of invasion	1/10 yrs*	1/ 29.9 yrs	1/ 2.7 yrs
Brucellosis	**Probability of infection**	1/8 yrs	1/229 yrs	1/1276 yrs
	Cost/outbreak	$5,400,000	$6,500,000	$632,000
	Annual cost	$668,750	$28,384	$495
Tuberculosis	**Probability of infection**	1/6 yrs	1/173 yrs	1/1764 yrs
	Cost/outbreak	$5,400,000	$8,200,000	$832,000
	Annual cost	$891,667	$47,399	$472

* Annual probability of one bison from GWBNP meeting a free-ranging bison from another population based on bi-directional movement.

Proposals to eliminate bovine tuberculosis and brucellosis raised concern about the importance of conserving (Connelly et al. 1990, Wilson and Strobeck 1999) and managing genetic diversity of wood bison in recovering disease-free populations (Gates et al. 2001c, and see Shury et al. 2006). Subsequent work on genetic salvage of wood bison from tuberculosis and brucellosis infected subpopulations in the Slave River Lowlands (Gates et al. 1998, 2001c, Nishi et al. 2001, 2002b, Wilson et al. 2005) was followed by development of strategic approaches for managing genetic diversity of healthy subpopulations (Wilson and Zittlau 2004, McFarlane et al. 2006). The proposed national recovery strategy for wood bison (ECCC 2016) outlines further approaches to address genetic management issues (and see Shury et al. 2015).

1.1.2 Anthrax - Anthrax is a naturally occurring, reportable disease that is enzootic in northern populations of wood bison (see Appendix 8). If untreated it is an infectious, often-fatal disease of wild and domestic animals (and humans), caused by an endospore-forming bacterium *Bacillus anthracis*. The pathogen relies on a suitable mammalian host (bison) to complete its life cycle and produce infectious endospores that contaminate a carcass site and persist in the environment (Dragon and Rennie 1995, Dragon et al. 2005). Anthrax in other species of free-ranging wildlife is rare and only occurs in conjunction with outbreaks in bison (or cattle) (Hugh-Jones and de Vos 2002).

Anthrax has likely been present in northern bison populations for a longer period of time than is the case for bovine tuberculosis or brucellosis. As early as July 1821, records in Fort Chipewyan and oral tradition in the Fort Smith area acknowledged sudden death among bison during summer that was consistent with anthrax mortality (Ferguson and Laviolette 1992). Between 1962 and 2015, there have been eight documented outbreaks in the Slave River Lowlands, eleven in WBNP, and three in the Mackenzie subpopulation, resulting in the deaths of at least 2267 animals (Gates et al. 1995, Dragon et al. 1999, Dragon and Elkin 2001, Nishi et al. 2002a, Elkin et al. 2013, New 2014). Because of the role of climatic and environmental conditions, anthrax outbreaks may also occur at a broader geographic scale that extends beyond defined ranges of individual subpopulations. Most recently, in summer 2015, anthrax killed at least 60 bison in Wood Buffalo National Park, 5 bison on the Beaver Creek Wood Bison Ranch (MacArthur 2015) located 50 km north of Fort McMurray, and there were at least 10 confirmed cases of anthrax in beef cattle on two separate farms in the Fort Vermillion area (Kienlen 2015).

To date, most observed anthrax outbreaks primarily affect mature male bison and were generally considered not to play a significant role in population dynamics (Elkin et al. 2013). However, the demographic effect of anthrax epizootics on a bison population is linked to the frequency of outbreaks, and the number and sex-age composition of dead bison during an outbreak. Relative to previously observed patterns, therefore, an increase in outbreak frequency combined with a proportional increase in mortality rates of adult females from anthrax may result in reduced growth rates of affected bison populations (see Joly and Messier 2001). The outbreak of anthrax in 2012 in the Mackenzie bison subpopulation should provide a natural test of this hypothesis, given at least 451 bison died that summer 2012 (New 2014). This reduced the pre-outbreak population of 1531 animals by approximately 53% to a post-outbreak estimate of 714 bison (Armstrong and Cox 2013). Of the bison carcasses classified during the outbreak, 73% (293/400) were adults and 47% (158/336) were female (New 2014).

Anthrax is difficult to control because of its ability to persist in soil as a highly resistant endospore (Dragon and Rennie 1995, Gates et al. 1995). Vaccination is an effective tool

to prevent anthrax mortalities in livestock and captive wildlife, but mass vaccination is not practical in free-ranging bison (Dragon and Elkin 2001, Elkin et al. 2013). Targeted surveillance for carcass detection, minimization of scavenging, and effective carcass disposal are key management responses that may limit the amount of environmental contamination with anthrax spores, thereby reducing the total number of spores available to cause future cases or outbreaks (Hugh-Jones and de Vos 2002, Nishi et al. 2002a, Nishi et al. 2007, Shury et al. 2009, Elkin et al. 2013, Morris et al. 2015).

1.2 Anthropogenic Land Use - Alberta's landscapes have changed significantly over the last 100 years, as a result of the cumulative effects of settlement and land use (Schieck et al. 2014). The growing human population depended on a thriving economy that was based primarily on natural resource development in the energy, agriculture, forestry and mining sectors (Stelfox and Wynes 1999, Bailey et al. 2010b, Stelfox 2013). Although the economy today has diversified to include manufacturing and a growing service industry, it is still heavily dependent on resource extraction, which will continue to influence the land base through development of infrastructure and associated footprint (roads, pipelines, seismic lines, well-sites, transmission lines, surface mines, cutblocks, etc.).

The cumulative effect of human activity and incremental increase in anthropogenic footprint over time has impacted wildlife species, landscapes and natural ecological processes — from the boreal forests in the north to the grasslands in the south. With respect to bison conservation and management in Alberta, human activity and land use ultimately determine habitat availability and represent the key factors that:

- contributed to the range contraction and extirpation of plains bison from the province in the late 19th century;
- shifted the composition of natural landscapes in the province to reflect human settlement and economic land use priorities (Schieck et al. 2014), which has resulted in irreversible loss of bison habitat within its original range and is especially evident in the Parkland and Grassland Natural Regions; and
- establish priorities for current and future human land-uses, which are incompatible or conflict with the behaviours and habitat requirements of free-ranging bison.

At a provincial scale, outside of national parks, a pervasive limiting factor for recovery of free-ranging wild bison populations is habitat availability. Habitat availability is dependent on the suite of regional land-use issues and priorities, and also reflects the acceptance of people (i.e., a socially-determined carrying capacity) for reintroduced free-ranging bison (Government of Yukon 2012, Clark et al. 2016). Potential habitat availability for bison on public lands in the province is affected by a suite of land-uses including agriculture, forest harvesting, and energy development. For wood bison recovery in northern Alberta, habitat availability is also constrained by the presence of cattle diseases in the GWBNP bison metapopulation. For plains bison recovery in the southern portion of the province, habitat availability is the key limiting factor.

1.2.1 Agriculture: Wild Bison and Agricultural Livestock (commercial bison and cattle) - In northern Alberta, the concerns about transmission of bovine tuberculosis and/or brucellosis to healthy free-ranging wood bison, and farmed bison and cattle are focused on the GWBNP metapopulation as the source of disease transmission (Gates et al. 2001b, ECCC 2016). For wild bison, the risk of contact for the Hay-Zama subpopulation is managed through hunting, as well as monitoring the area between Highway 35 and WBNP to detect and remove any bison present (GOA 2011a, 2014c). Management strategies

for the Etthithun subpopulation may need to be defined and implemented to address potential issues that arise from its continued expansion, and associated risk of contact with wild bison or commercial livestock. In the context of disease risk management, it is important to consider the bi-directional risk of exposure and pathogen transfer between wild bison and commercial livestock herds.

In addition to risk of disease transmission, there is a wider range of issues that may potentially occur through the interaction between wild bison, and commercial bison and cattle herds including:

- genetic mixing of escaped commercial bison with wild wood bison;
- escape of bison from commercial herds leading to establishment of feral bison herds;
- agricultural fences causing habitat fragmentation for wild herbivores (including wild bison);
- agricultural encroachment into existing management areas and ranges of wild bison;
- crop damage by wild bison and/or forage competition with livestock; and
- damage of private property by wild bison

1.2.1 Agriculture: Agricultural Expansion - Based on available census data (1996, 2001, 2006, and 2011), the number of farmed bison in Alberta represented an average of 50.2% of all farmed bison in Canada (Statistics Canada 2011). The number of farmed bison in Alberta more than tripled from 22,782 in 1996 to 79,731 in 2001 (Figure 19). During this initial growth phase (1991–2001), the number of farmed bison in Alberta grew exponentially at an average annual rate of increase (r) of 0.261, which corresponds to a doubling time of 2.7 years. Between 2001 and 2006, the rate of increase (r) slowed to 0.04 and the population peaked at just over 97,000. In 2011, Alberta still reported the largest number of farmed bison in Canada with 57,483 head, which was a 41.0% decrease since 2006. The average annual rate of change from 2006 to 2011 was (r) = -0.105 (Figure 19).

Of the total number of farmed bison in 2011 in Alberta (AARD 2014), 2057 animals (3.7%) occurred in 28 bison farms in the Lower Peace Region of northern Alberta, with most of the bison occurring in the Northern Lights County (Table 11 and Figure 20). In comparison to farmed bison, in 2011 (AARD 2014) there were 44,293 cattle on 460 farms in the Lower Peace Region (~0.9% of the provincial cattle population), with 16,701 cattle on 247 farms in Mackenzie County and 18,662 cattle on 161 farms in the Northern Lights County (Table 11). At the municipal scale (i.e., counties), Figure 20 (and see Figures 4 and 5) highlights the potential risk of future contact between free-ranging wood bison and agricultural livestock (Table 11), if abundance and range occupancy of one or both expands in the future.

Progressive expansion of agricultural lands within the northern Alberta landscape (Hamley 1992, Bowen 2002, GOA 2013a) could potentially influence the nature of conflicts with wild bison, and increase their likelihood. This may not contribute directly to increased risk of transmission of bovine tuberculosis or brucellosis to livestock, but wild bison use of agricultural lands may increase exposure of people to bison and/or expose bison to outbreaks of anthrax in human-dominated landscapes (e.g., Shury et al. 2009, Aune et al. 2010). Thus, the perceived risk of these events may further influence distribution and range of wood bison subpopulations in northern Alberta.

As part of the amendment to the Alberta *Public Lands Act* (RSA 2000, c P-40) in 2003, the definition of "livestock" was revised to "include horses, sheep, cattle and, to the extent permitted by the regulations, bison." The accompanying *Public Lands Administration*

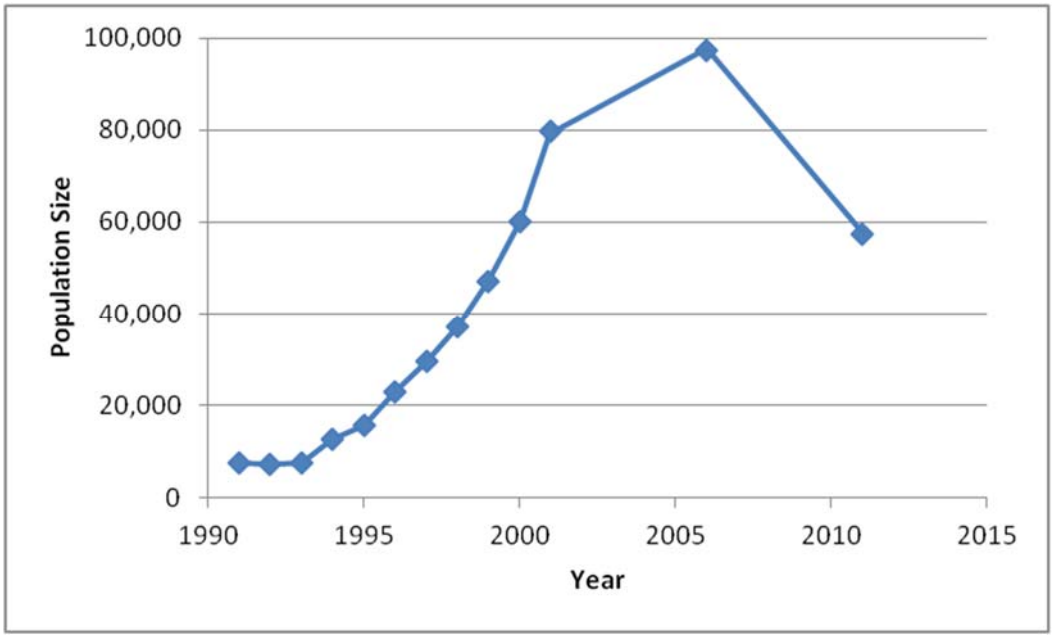


Figure 19. Trend in population size of commercial bison in Alberta, 1991–2011. Data sources: Nixdorf (2002); Statistics Canada (2011); Alberta Historical Landuse & Landscape Data Library, Online [URL] www.abll.ca/tables/Livestock/Population_Speciality.

Table 11. Characteristics of bison and cattle farms, and farmed bison and cattle in Alberta, 2011. Data Source: AARD 2014.

A) **Provincial Regions**	**# Bison Farms**	**# Farmed Bison**	**# Cattle Farms**	**# Cattle**
Lower Peace	28	2,057	460	44,293
Lower Athabasca	14	1,522	564	81,436
Upper Peace	112	11,500	1,441	205,335
Upper Athabasca	64	4,660	2,505	397,406
North Saskatchewan	194	18,733	6,929	1,128,420
Red Deer	95	11,333	4,959	1,097,930
South Saskatchewan	64	5,320	5,030	2,149,785
Total	**571**	**55,125**	**21,888**	**5,104,605**
Average # Animals / Farm		97		233
B) **Lower Peace Region**				
Mackenzie County	7	67	247	16,701
Northern Lights County	12	1,386	161	18,662
Northern Sunrise County	9	604	52	8,930
Total	**28**	**2,057**	**460**	**44,293**
Average # Animals / Farm		73		96
C) **Upper Peace Region**				
Clear Hills	11	882	198	22,149
Average # Animals / Farm		80		112

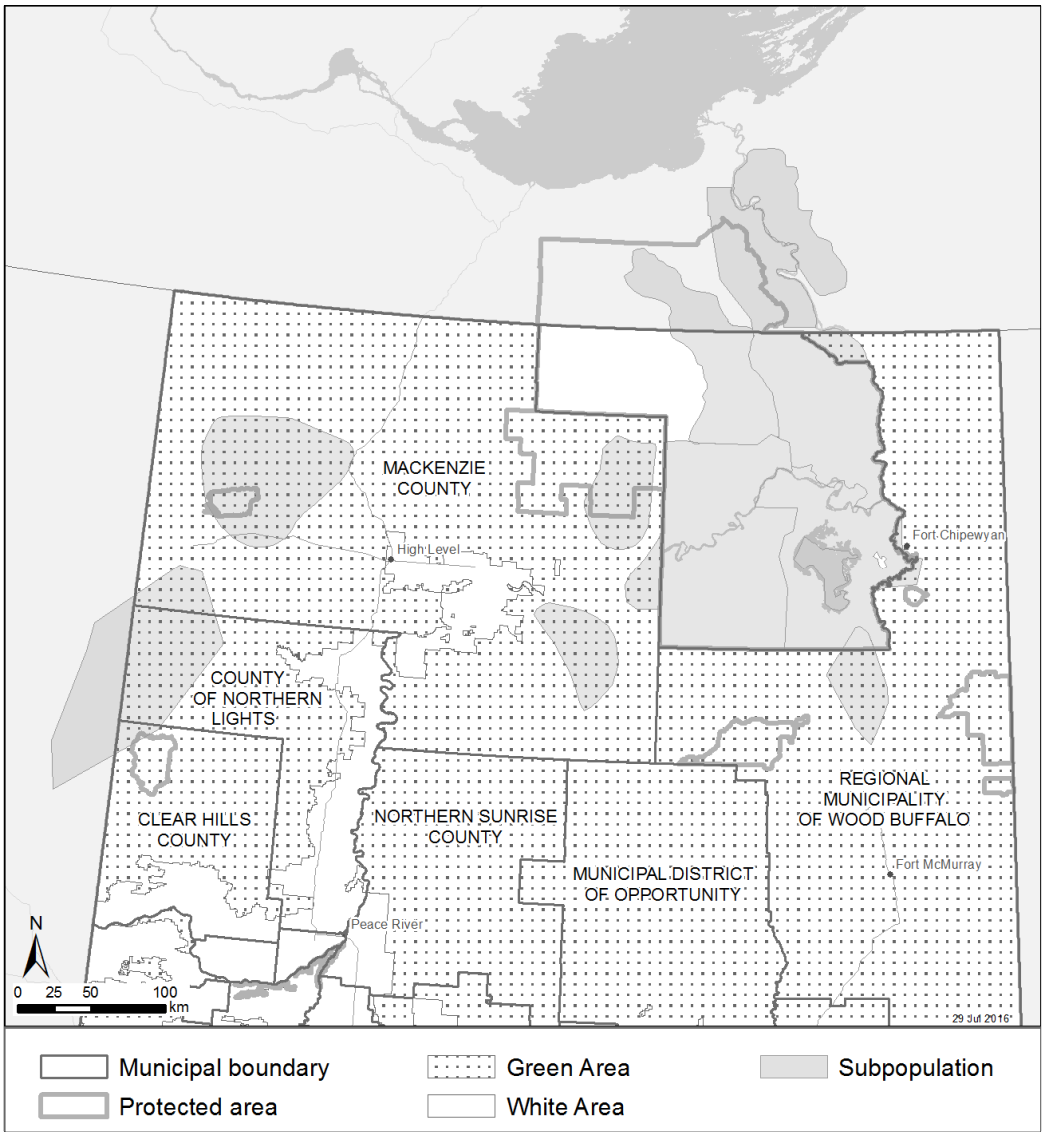


Figure 20. Wood bison subpopulation (herd) ranges and management zones (including key protected areas) shown relative to municipal boundaries in northern Alberta. The Green and White Areas represent the forested and settled portions of the province, respectively. In the Green Area, public land is managed for multiple uses including timber production, oil and gas production, wildlife and fisheries, recreation and other uses. In the White Area, public land is part of the agricultural landscape and is managed for agriculture, recreation, soil and water conservation, fish and wildlife habitat, and other uses.

Regulation (AR 187/2011) established that authorization to graze bison on public lands would not be granted in the northern part of the province (specifically the area north of township 95, west of the Peace River and north of township 88, east of the Peace River). For the remainder of the province, a disposition holder could apply to graze bison on public agricultural land, with the main enforceable conditions being requirements for a) wildlife-friendly fencing (Gates 2006), b) disease-testing of all bison entering the land under the disposition, and c) implementation of a system for marking the bison. Currently, 56 grazing

dispositions (with a total of 16,639 Animal Unit Months[3]) have been authorized for bison grazing on public lands in the province (Figure 21). On average over the past five years, 13 dispositions have been used annually for bison grazing with an average utilization of 1855 AUMs (M. Schumacher pers. comm.).

1.2.2 Natural resource extraction - Extractive resource development may increase meadow and grassland habitat in boreal Alberta, and it has been suggested that recovery potential for wood bison could benefit from these activities (Gates et al. 2001c). A demonstration project was initiated in 1993 by Syncrude Canada and the community of Fort McKay, in cooperation with the Canadian Wildlife Service and the Government of Alberta, to establish a captive population of wood bison founded from EINP on an oil sands lease area north of Fort McMurray (Gates et al. 2001c). The project now spans about 500 hectares of reclaimed land and is operated as a commercial ranch with 300 wood bison. Currently, the Beaver Creek Wood Bison Ranch is a joint venture between Syncrude Canada Ltd. and the Fort McKay First Nation (Fort McKay Environment LP 2016). Although the joint venture has successfully demonstrated use of reclaimed habitat by captive bison at a small scale, the potential benefit to the recovery of free-ranging bison will vary with the spatial scale and long-term productivity and availability of reclaimed habitat.

In contrast, the free-ranging Ronald Lake bison subpopulation has become a focus of attention, as a result of concerns about the effects of proposed oil sands mine projects on the bison and its habitat (Teck Resources Ltd. 2011, Alberta Energy Regulator 2013, Shell Canada Ltd. 2013, Tan et al. 2015, D'lorio 2016, Noseworthy 2016, Teck Resources Ltd. 2016). Principal among these concerns is the potential cumulative effects of direct habitat loss, reduced habitat effectiveness, and displacement of bison from the direct footprint of an oil sands mine and its associated activity. These factors may cause behavioural disturbance and changing seasonal movement patterns in this subpopulation (Candler et al. 2012, Alberta Energy Regulator 2013). For the Ronald Lake subpopulation, the potential impacts of industrial land use are tied primarily to extraction of bitumen within or adjacent to its annual range and the associated footprint of this activity (i.e., open pit mining versus *in situ* extraction technologies).

For the Hay-Zama and Etthithun subpopulations, the potential cumulative impacts of industrial land uses to bison and bison habitat are a reflection of a broader suite of disturbance footprints and activities related to forestry, conventional oil and gas exploration and development (Stelfox and Wynes 1999, Lee et al. 2009a), and more recent activity associated with an emerging interest in unconventional hydrocarbon reserves (i.e., shale gas in the Montney and Muskwa formations) (Rokosh et al. 2012, AER 2015). The spatial pattern and trend in the cumulative disturbance to forested landscapes in northwest Alberta is well documented by Lee et al. (2009a), with Smith and Cheng (2016) illustrating the recent and marked degradation of large intact forest landscapes in the region between 2010 and 2013. Despite the observed landscape-level impacts of industrial disturbance to forest intactness, no field studies have evaluated if there may be long-term negative consequences of disturbance to bison or bison habitat from combined industrial land uses in northwestern Alberta. Preliminary analyses by Leverkus (2012) on a small sample of GPS-collared

3 An Animal Unit Month (AUM) is the amount of forage required by an "animal unit" in one month. The standard animal unit is defined as one mature 1000 lb cow with or without a calf, and is based upon the average daily intake of 25 lb of dry matter forage per day. That consumption, combined with a factor for trampling and waste of about 25%, results in an estimate of about 1000 lb of dry matter forage to supply one animal unit for one month. Compared to a 1000 lb domestic cow, a bison cow is an equivalent of 1.5 AUMs. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq6722/

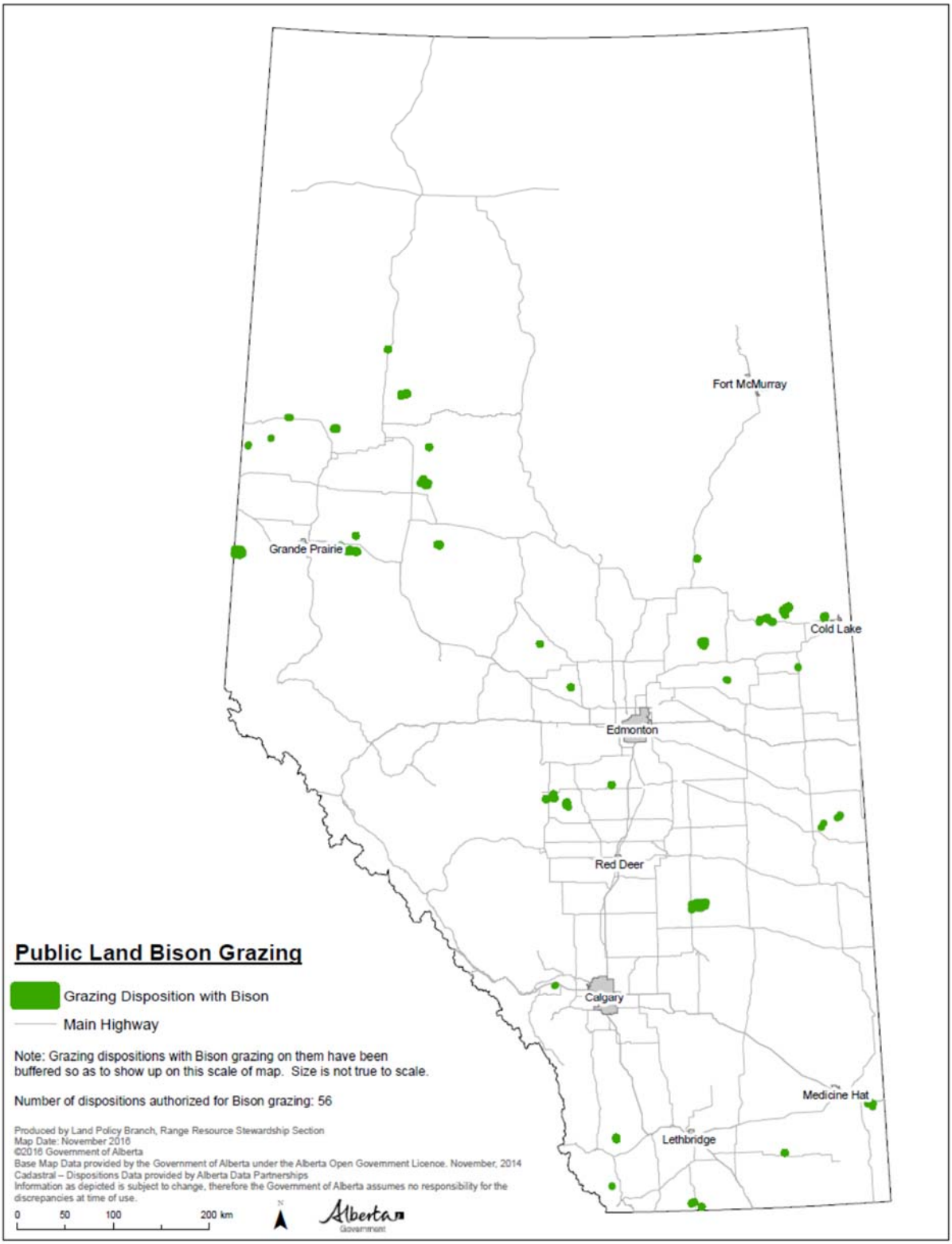


Figure 21. Grazing dispositions (n = 56) authorized for bison grazing on public land (figure used with permission from Land Policy Branch, Range Resource Stewardship Section).

Etthithun bison cows in BC—an unhunted subpopulation—showed that those individuals have a strong association with roads and other linear features, which is likely explained by their use of forage growing in association with these features. One outcome of an association of bison distribution with roads is an increase in occurrence of bison-vehicle collisions.

1.3 Climate Change - *Climate change is occurring, is caused largely by human activities, and poses significant risks for—and in many cases is already affecting—a broad range of human and natural systems* (Matson et al. 2010).

Over the last 100 years, Alberta's mean annual temperature has increased by approximately 1.4° C, with much of the increase occurring since 1970 (Figure 4.2 in Schneider 2013). Between 1912 and 2011, mean annual temperature in the southern half of the province increased by 1.1°C (0.1 per decade), and in the north the rate was double that (2.3°C or 0.2 per decade) (Shank and Nixon 2014). The pace of warming in Alberta has accelerated since 1970 at a rate of 0.3°C per decade in both the north and the south (Figure 1 in Shank and Nixon 2014). In comparison, precipitation has declined in central Alberta by 5% over the past ca. 100 years (1900–2004), but has increased in the north by as much as 20% (Figure 2.1.1 in Rodenhuis et al. 2009).

At a regional scale, successional changes in Alberta's northern boreal forest will likely transition according to projected increases in mean annual temperature and precipitation. It is likely that the ecological changes in the Boreal Forest Natural Region will substantially lag behind climatic changes. Individual ecosystem types will respond in different ways and at different rates, and peatlands and aspen forests will become dominant features (Schneider et al. 2015). The extensive occurrence of peatlands across the boreal region provides a buffer against climate-induced changes in forest ecosystems, largely owing to their capacity for water retention (Schneider et al. 2015).

Using NatureServe's Climate Change Vulnerability Index (CCVI) (Young et al. 2011), Shank and Nixon (2014) conducted a preliminary assessment of how a range of terrestrial plant and animal species in Alberta, including wood bison, might respond to projected climate change in the 2050s. In comparison to other ungulates in the Boreal Forest Natural Region, wood bison and moose (*Alces alces*) were assessed as having Medial Vulnerability, boreal caribou (*Rangifer tarandus)* as having High Vulnerability, and mule (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*), as having Low Vulnerability with respect to climate change.

Although the initial systematic assessment of vulnerability (Shank and Nixon 2014) was useful, providing a relative ranking with other mammals, the future implications of climate change to bison subpopulations in Alberta are uncertain, complex, scale-dependent, and to some extent herd-specific. At a broad regional scale, a warming trend and expected increase in variability of climatic conditions will interact with industrial and agricultural land uses, as well as natural disturbance regimes such as wildfires. At a finer scale, the impacts of future climatic conditions will also depend on the biophysical characteristics of subpopulation ranges. For example, future habitat changes within the Peace-Athabasca Delta of WBNP will likely be affected by both changing climate and upstream river flow regulation (i.e., hydroelectric dams and drawdowns by industrial land use) that influence hydrological processes, floodplain dynamics (Wolfe et al. 2012), and successional changes between wet meadows, willow communities and forests (Timoney 2008a, 2008b, Timoney 2013). In comparison, the effects of climate change on Hay-Zama, Etthithun and Ronald Lake subpopulations are likely to manifest more through an interaction of climate, wildfire, and

disturbance to lowland and upland habitats from anthropogenic land use. Some plausible and cumulative impact pathways of climate change on bison, which may interact with effects of human land use on habitat loss and behavioural disturbance, include:

- directional trend and/or increased variability in extent and quality of habitat as a result of hydrologic influence of drought and flooding events; i.e., in the absence of flooding, some riparian meadow areas are lost to willow invasion (Timoney et al. 1997, Timoney and Argus 2006), and there may be increased expansion of noxious weeds (see *5. Invasive weeds*);
- increased frequency and magnitude of wildfires in boreal forest vegetation communities (Weber and Flannigan 1997, Flannigan et al. 2005, Krawchuk et al. 2009); and
- increased frequency and/or severity of weather-related stochastic mortality events including starvation from severe winter snow conditions, drowning as a result of thin and variable ice conditions, and anthrax epizootics.

1.4 Hunting - During 1820 to 1830, the depletion of wood bison numbers and contraction of their range was noted locally and recognized as part of a widespread pattern of game depletion across the Peace-Athabasca area from 1830 to 1840 (Ferguson 1993, Kennedy and Bouchard 2011). Although different causal factors are debated (i.e., severe winter conditions, hunting and predation; see Preble 1908), the expanding fur trade and economy built around acquisition and supply of pemmican was likely the key driver in the range contraction and virtual extirpation of bison in Canada (Ferguson 1993, Ray 2008, McCormack 2010b, Colpitts 2015).

By the late 1800s, plains bison across the range were pushed to the brink of extinction as a result of widespread market hunting and accumulated years of systematic slaughter. In the United States, unsustainable market hunting of bison was driven by the demand for robes and hides (Hornaday 1889, Isenberg 2000, Lueck 2002). From the 1870s to the 1880s, innovations in hide-tanning technology and a very high European demand for industrial leather accelerated the bison decline to the precipice of extinction (Taylor 2011). Political motivations also contributed, as the commercial "destruction of the buffalo" was aided and abetted by the United States army as part of a strategy to conquer the "Plains Indians" (Smits 1994).

In Canada, the rapid expansion of the fur trade was the impetus for fueling an unsustainable and accelerated demand for bison meat and fat (the raw materials for pemmican) (Colpitts 2015). The demand for robes and hides occurred later, and was additive to the robust and growing pemmican trade (MacEwan 1995, Colpitts 2015). Clearing bison from the plains was considered to be a necessary condition to allow for the settlement, colonization and industrialization of North America (Isenberg 2000, Lueck 2002).

Regulated and unregulated hunting of bison has a direct influence on distribution and abundance of several free-ranging bison subpopulations (herds) in northern Alberta, including Hay-Zama, Ronald Lake, Wentzel Lake, and Harper Creek. Except in the designated Bison Management and *Subject Animal* areas (Figure 2), bison roaming outside a national park or a wildland provincial park in Alberta are not recognized or protected as wildlife under the *Wildlife Act.* In combination with the increased access created by linear features (roads, seismic lines, and pipelines), unregulated hunting of bison may be an important factor in limiting abundance and distribution of bison that range outside WBNP and other designated management areas. In effect, these policies limit re-establishment of wood bison populations in a large section of original wood

bison range in northern Alberta. On the one hand, re-establishment or growth of existing free-ranging bison herds in the area adjacent to WBNP may not be a desirable outcome unless the potential spread of bovine tuberculosis and brucellosis is resolved. On the other hand, the policies contribute to generating conflict between First Nation and Métis communities, resident hunters, and guide-outfitters.

One example of this emergent conflict has been occurring between the Little Red River Cree Nation/Tall Cree First Nation and non-indigenous hunters who attempt to hunt bison in the Wentzel River area. These First Nations have wanted to protect the Wentzel Lake herd to facilitate studies on disease prevalence, movement patterns and habitat requirements, and have expressed a desire to hunt disease-free, free-roaming bison herds here over the long term (Gates et al. 2001b, Stevenson and Webb 2003). Although the issue was identified in a previous version of the national recovery strategy for wood bison (Gates et al. 2001c), a management plan has not been developed to achieve these objectives.

A second example occurs to the south of WBNP in the range of the Ronald Lake subpopulation. In addition to concerns regarding the impacts of industrial development here, there has been a similar underlying conflict between First Nation and Métis communities, who have traditionally subsisted on this subpopulation, and non-indigenous hunters, who have been able to more easily access and hunt the same bison (Willow Springs Strategic Solutions Inc. 2014, Candler et al. 2015, Dertian-Loubert 2015). At the end of the 2015–2016 hunting season, on March 31, 2016, Alberta established a new *Subject Animal* zone for wood bison surrounding the Ronald Lake subpopulation that restricted non-indigenous hunting.

Previously, the only free-ranging bison populations that were subject to regulated hunting in Canada (quotas and permits) were the Aishihik wood bison subpopulation, the Mackenzie wood bison subpopulation, the Slave River Lowlands subpopulations, and the Pink Mountain plains bison subpopulation (Gates et al. 2001c). Since 2008, the Hay-Zama subpopulation has also been managed with an annual hunt. From 2008–2015, a total of 704 bison have been harvested, with about 57% accrued to indigenous hunters and 43% to non-indigenous hunters (based on available data from 2008–2012).

1.5 Invasive Weeds - ECCC (2016) identified Canada thistle (*Cirsium arvense*) as an aggressive noxious weed that has been spreading in the Peace-Athabasca region of WBNP in recent decades. Canada thistle is able to invade a site following disturbances caused by wildfire or drying conditions. Once established, the colony-forming perennial weed spreads mainly through its creeping root system, allowing it to out-compete native plants. Bison do not eat thistle and are observed to avoid previously used meadow habitats once they have been invaded by thistles (Candler et al. 2015). The predicted increase in wildfires and drying conditions as a result of climate change and/or basin drawdown from increased upstream anthropogenic water use will favour continued expansion of weeds such as Canada thistle (Timoney 2013), which in turn would reduce forage availability and suitable habitat for bison (ECCC 2016).

Timoney (2013) described the spread of weeds in the Peace-Athabasca Delta over the past 80 years and associated the initial incursion of weeds with the northward spread of agriculture and a variety of early management actions in the delta related with the introduction of plains bison, including repeated haying of sloughs, trucking of hay into the Sweetgrass area, and associated heavy bison use. Wein et al. (1992) first noted the occurrence of dandelion (*Taraxacum officinale*), perennial sow-thistle (*Sonchus arvensis*), and Canada thistle in the delta proper based on their plant collections

in 1986–1988. Most recently, Mikisew Cree First Nation knowledge holders observed and reported that thistles have invaded the Sweetgrass area and the south end of Lake Claire, and attribute the increase to lower water levels and the lack of seasonal flooding in the Athabasca Delta (Candler et al. 2015).

1.6 Fire Suppression - Fire suppression has likely contributed to habitat change in northern Alberta (Cumming 2005) through conversion of meadow habitat to aspen-dominated forests, reducing available forage and overall carrying capacity for bison populations in the region (McCormack 1992). It has been postulated that the combination of human use and management of fire during the last 50 years, and the historical decline or absence of grazing by bison may have contributed to a reduction in habitat (Campbell et al. 1994, Gates et al. 2001c).

2. Locations - "Locations" are geographically or ecologically distinct areas vulnerable to a single plausible threatening event, either natural (e.g., disease outbreak, habitat loss, fire, etc.) or anthropogenic (e.g., hunting, culling, etc.) (as defined by IUCN 2012). COSEWIC (2013a, p. 72) identified nine such locations for wood bison in Canada with the most serious plausible threats being: 1) disease (anthrax), 2) management response to brucellosis and tuberculosis, and 3) severe winter or unusual spring weather event leading to widespread starvation or drowning. Application of the COSEWIC (2013a) criteria to Alberta results in four locations of vulnerability to wood bison in the province: Hay-Zama, Etthithun Lake, WBNP, and EINP. With the recent genetic studies indicating the apparent reproductive isolation of the Ronald Lake and Harper Creek subpopulations from WBNP (Ball et al. 2016), as well as their presumed health status (i.e., free from infection with bovine tuberculosis and brucellosis), these subpopulations may qualify as additional locations of vulnerability. Although the smaller subpopulations are relatively isolated, the total population of wood bison in Alberta may not meet the criteria of "severely fragmented" (sensu IUCN 2016) because a majority (~ 61%) of the occupied area (IAO) in the province occurs within WBNP (Table 1) and represents about 2623 mature individuals or 68% of the population (Table 6).

There are two discrete locations for plains bison in Alberta: McCusker River and EINP. Both subpopulations are small and unhunted, with the most plausible serious threats including severe weather-related mortalities and disease (anthrax). Plains bison may meet the definition of "severely fragmented" (*sensu* IUCN 2016), because at least 78%–88% of mature individuals (approximately 391 animals) in the province occur within EINP (Table 8). However, it is important to note that based on the small proportion of the McCusker River bison range that occurs in Alberta (~7%), it is more likely that EINP represents 95% or more of all plains bison in Alberta. A perimeter fence encloses the EINP subpopulation within an area that represents approximately 22% of the area occupied (IAO) in the province. This small area is a fraction of the area historically occupied by plains bison.

STATUS DESIGNATIONS*

1. Alberta - The general status of wood bison in Alberta is *At Risk*, and plains bison are *Extirpated/Extinct* (AEP 2017). Based on NatureServe conservation status ranks, wood and plains bison in Alberta have the S1 (critically imperiled) and SNR (unranked) designations, respectively (Table 12).

Legislation in Alberta generally considers bison as livestock (Livestock Market Regulation, AR 133/2014; *Animal Health Act*, SA 2007, c A-40.2). There are, however, two geographically explicit exceptions, under

* See Appendix 1 for definitions of selected status designations.

Table 12. Heritage status ranks for bison in Canada (NatureServe 2015a). See Appendix 1 for definitions of status ranks.

Region	Status		
	American Bison	Wood Bison	Plains Bison
Canada	N3N4	N2N3	N3N4
Alberta	SNR	S1	SNR
British Columbia	S3	S2	SX
Manitoba	SX	SNA	SX
Saskatchewan	S3	SX	S3
Northwest Territories	S2	S2	
Yukon	S2S3	S2S3	

the Wildlife Regulation (AR 143/1997) and pursuant to the *Wildlife Act* (RSA 2000, c W-10).

In 1995, the Government of Alberta established the Bison Protection Area in the northwest portion of the province (Figure 2). Bison that are found or killed on or captured from the lands within the Bison Protection Area are categorized as *Endangered* (Wildlife Regulation, AR 143/97). This status was conferred to provide regulatory authority in managing the Hay-Zama wood bison population and protect it as a conservation herd. Since 2008, as part of the strategy to manage distribution and abundance of the Hay-Zama subpopulation, bison here may be lawfully hunted under authorization of a bison special licence, during designated periods and within the designated Bison Hunting Zone (Figure 2) (Wildlife Management Units 536 and 539).

Most recently in 2016, the Alberta Wildlife Regulation (AR 143/97 Sched.7) established an area comprising the known range of the Ronald Lake bison subpopulation, and conferred *Subject Animal* status to all bison occurring within its boundaries (Figure 2). This status effectively prohibits hunting of this subpopulation by non-indigenous people. The regulation does not affect the hunting of bison for subsistence by persons who hold a constitutional right to do so in this area.

The resulting situation is that any free-ranging bison in Alberta, occurring outside of the Bison Protection area, the *Subject Animal* area and WBNP, have no status under Alberta's *Wildlife Act* and are thus not legislatively protected. Bison may not be hunted in wildland provincial parks because their lack of status precludes the establishment of a hunting season for these animals. On all other lands, the lack of status for bison facilitates passive disease control, given that any free-roaming bison can be killed without limit at any time of the year. It is important to note that, although the Wildlife Regulation created under Alberta's *Wildlife Act* recognizes four subspecies of elk as *Big Game* and two subspecies of caribou as *Threatened*

species, it does not recognize wood bison as a subspecies separate from plains bison.

In 2003, legislative amendments (Public Lands Administration Regulation, AR 187/2011) were made to the *Public Lands Act* (RSA 2000, c P-40) to provide bison producers with an opportunity to seasonally graze bison on public lands in the province.

2. Canada - The legal designations for bison vary throughout the country. In 2003, wood bison was listed as *Threatened* under Schedule 1 of the *Species at Risk Act* (SC 2002, c. 29). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-examined wood bison in November 2013 and assessed it as *Special Concern*. However, a decision on the recommendation to list wood bison as *Special Concern* under the *Species at Risk Act* remains pending (ECCC 2016). In 2004, plains bison was designated *Threatened* in Canada by COSEWIC. This status was re-examined and confirmed in November 2013 (COSEWIC 2013a). A decision by the Governor in Council is still pending on whether or not plains bison will be listed under the *Species at Risk Act*. Wood bison and plains bison are aggregated under the taxonomic designation *Bison bison* by the Canadian Endangered Species Council, which lists the species as *At Risk* in Canada. The national and provincial/territorial heritage status ranks for bison (both subspecies) are summarized in Table 12 (NatureServe 2015a).

In Yukon, wood bison were "initially considered a *Specially Protected Species* under the Yukon *Wildlife Act*, but once the Aishihik subpopulation reached a population goal of 500 animals in about 1998, they were removed from the *Specially Protected Species* list and added to the list of *Big Game Species"* (Government of Yukon 2012, p. 8). Harvest management is a principal means of influencing the size of the Aishihik subpopulation (Yukon Department of Renewable Resources 1998); hunting of wood bison is enabled through Wildlife Regulation (YOIC 2012/84) under the *Wildlife Act* (RSY 2002, c 229). Under the Umbrella Final Agreement, Yukon First Nations do not have subsistence hunting rights because wood bison are considered a transplanted species (Government of Yukon 2012).

In the Northwest Territories, wood bison were designated as *Game in Danger of becoming Extinct* through an Order-In-Council in 1960 (CRC, c 1236), which was enabled by the *Northwest Territories Act* (RSC, 1985, c. N-27) and established legal protection from unrestricted hunting. When the new *Wildlife Act* (SNWT 2014, c 31) came into force in November 2014, bison were prescribed as *Big Game* under the Wildlife General Regulations (NWT Reg 115-2014) and managed through quotas established in the Big Game Hunting Regulations (NWT Reg 019-92). Wood bison in the Northwest Territories were recently assessed as *Threatened* (SARC 2016). The Nuisance Bison Control Regulations (NWT Reg 070-92) establish the policy by which bison found in the designated Bison Control Area are declared to be nuisance wildlife and may be legally removed by any Northwest Territories resident. The Bison Control Area Program is implemented as a management strategy to prevent the transmission of bovine brucellosis and tuberculosis from infected populations in and around WBNP to the Mackenzie and Nahanni bison populations (see Nishi 2002).

In British Columbia, bison are defined as *Big Game* under the *Wildlife Act* (RSBC 1996, c 488) and are also an eligible species of *Game* identified in the Game Farm Regulation (BC Reg 5/2015) pursuant to the *Animal Health Act* (SBC 2014, c 16). As wildlife, wood bison and plains bison are *Red Listed* under the provincial conservation status ranking and are ranked S2 (imperiled) and SX (presumed extirpated), respectively (Table 12) (BC Conservation Data Centre 2016). There is no hunting of wood bison in the province; however, this has been allowed in the past for the Etthithun

subpopulation (by Doig River First Nation; Thiessen 2010), and is being considered again as an option for Etthithun bison (M. Bridger pers. comm.). Hunting of plains bison from the introduced Pink Mountain population is facilitated through the Limited Entry Hunting Regulation (BC Reg 134/93).

In Saskatchewan, the definition of *Big Game* in the Wildlife Regulations (RRS c W-13.1 Reg 1) includes bison, other than domestically raised bison. There is no specific legislation or protection for wood bison populations. Under the Open Seasons Game Regulations (RRS c W-13.12 Reg 3), however, there is a provision to establish plains bison open seasons in four Wildlife Management Zones (53, 66, 67 and 69) in the general area between Prince Albert National Park and the Cold Lake (or Primrose Lake) Air Weapons Range. The provision to create a hunting season has not been used, but it permits the Ministry to establish a limited draw hunting quota if the Sturgeon River subpopulation increases above the upper threshold in the management plan or if the McCusker subpopulation increases and moves out of the air weapons range (R. Tether pers. comm.). With respect to commercial production, bison are also listed as livestock under the Livestock Dealer Regulations (RRS c A-20.2 Reg 9), which is pursuant to the *Animal Products Act* (RSS 1978 (Supp), c A-20.2).

Under the Manitoba *Wildlife Act* (CCSM c W130), wood bison are listed as a protected species. Plains bison are designated as an extirpated species under the *Endangered Species and Ecosystems Act* (CCSM c E111). In 2001, wood and plains bison were also prescribed as livestock in accordance with the *Livestock and Livestock Products Act* (CCSM c L170) to facilitate commercial production by private producers. In 2014, Manitoba established the 1003 km^2 Chitek Lake Anishinaabe Provincial Park, which encompasses the primary range of the introduced Chitek Lake wood bison herd and the core of the Skownan First Nation's traditional use area.

3. Other Areas - The Convention on the International Trade in Endangered Species (CITES) listed the wood bison on Appendix I in 1977, and downlisted it to Appendix II in 1997 (Gates et al. 2001c). This international agreement regulates the import and export of animals for commercial purposes. In 2016, Canada proposed (successfully) that CITES remove wood bison from Appendix II (CITES 2016). The International Union for Conservation of Nature (IUCN) recognized the wood bison as *Conservation Dependent* in 1996 (Recovery of Nationally Endangered Wildlife [RENEW] 1998), and since 2008 American bison have been listed as *Near Threatened* (IUCN 2015). The United Nations Educational, Scientific and Cultural Organization (UNESCO) identified WBNP as a World Heritage Site in 1983, predominantly because of the wildlife populations (UNESCO 2016). This World Heritage designation becomes important when considering options for management of the disease issue. The Global Heritage Status Rank for wood bison was determined to be G4T2T3Q, because remnant and reintroduced, managed populations occur in several Canadian parks and preserves, range expansion is limited by agricultural development, and there is a risk of disease transmission and genetic contamination from contact with plains or hybrid bison (NatureServe 2015a). Plains bison are ranked as G4TU (NatureServe 2015a).

A summary of heritage ranks for bison in the United States is provided in Table 13. In the United States, wood bison were included in a list of foreign endangered species under the *Endangered Species Conservation Act*, which was published in 1970. Wood bison were subsequently listed as *Endangered* under the 1973 *Endangered Species Act* (ESA). In 2012, wood bison were reclassified from *Endangered* to *Threatened* based on the success of recovery efforts (USFWS 2012). In 2014, wood bison

Table 13. Heritage status ranks for bison in the United States (NatureServe 2015a). See Appendix 1 for definitions of status ranks.

Region	Status		
	American Bison	Wood Bison	Plains Bison
United States	N4	NNR	NNR
Montana	S2		
Wyoming	S1		S1
South Dakota	S3		
Utah	S2		
All other states in its former range	SX		

in Alaska were designated a "nonessential experimental population" under the ESA (USFWS 2014), to allow hunting and support conservation and implementation of its wood bison reintroduction program (AWBMPT 2015).

RECENT MANAGEMENT AND RESEARCH IN ALBERTA

1. Wood Bison - In early 2011, the Government of Alberta confirmed its goal for management of northern diseased bison, and initiated a plan to address the ongoing risk of disease transmission from infected bison subpopulations in and around WBNP to domestic livestock and free-ranging healthy wood bison (i.e., free from infection with bovine tuberculosis and brucellosis): *Alberta's long-term goal is to eliminate the disease risk. This would remove the risk to Alberta's livestock industry and would allow the restoration of wild populations of wood bison across northern Canada. The restoration of wood bison populations would fill a key ecological role and provide substantial cultural and economic benefits to Alberta. Until this long-term goal can be achieved, the interim approach is to prevent the spread of tuberculosis and brucellosis from diseased wild bison to domestic livestock and disease-free wild bison* (GOA 2011a).

The geographic area of focus was between the Hay-Zama subpopulation in the west and WBNP to the east (Figure 14), and the interim management plan comprised three main components (GOA 2011a):

- manage distribution and abundance of the Hay-Zama subpopulation through a highly regulated annual hunting season, which had been initiated in 2008;
- manage wood bison east of Highway 35 through active aerial surveillance, public reporting, and removal of all wild bison found on private agricultural lands in the Fort Vermillion and La Crete areas; and
- monitor distribution, abundance, and health status of wild bison based on a) regular and targeted aerial surveillance within three survey areas west of WBNP (Figure 14) based on likelihood of bison occurrence, and b) ante- and post-mortem

disease testing of animals to determine if herds are infected with bovine tuberculosis and/or brucellosis.

Since 2011, the interim disease risk management program has resulted in regular and active aerial surveillance and animal health testing of bison in the region (Fullerton 2011, GOA 2011a, 2011b, 2012, Fullerton 2013, GOA 2013b, 2013c, 2014c, Fullerton 2015a and 2015b; and see Ball 2009, GOA 2010, Moyles 2010, Powell and Morgan 2010). In 2012, the Ronald Lake bison subpopulation was added to the program to ensure bison management objectives in Alberta (GOA 2014c) were consistent with the proposed National Recovery Strategy for Wood Bison in Canada (ECCC 2016), and to also address data gaps and emerging concerns and issues regarding potential impacts of the proposed Frontier Oil Sands Mine Project (Canadian Environmental Assessment Agency [CEAA] 2015) to the Ronald Lake subpopulation and its habitat (Candler 2012, GOA 2014a, 2014b, 2014c, Management and Solutions in Environmental Science 2014). Alberta's objectives for the Ronald Lake monitoring program (GOA 2013c) are to determine population size and range distribution; disease status of the subpopulation; movements of bison relative to local bison populations within Wood Buffalo National Park; and genetic relatedness of the subpopulation to other provincial subpopulations. In 2014, the Ronald Lake Bison Herd Technical Team was established with representatives from government, industry, indigenous groups, and academia to collaborate and contribute to field research on the subpopulation (GOA 2014a, 2014b).

Two key results from the interim disease risk management program have been an assessment of genetic characteristics and an evaluation of health status of bison herds (subpopulations) adjacent to WBNP. Genetic analyses by Ball et al. (2016) showed that the Hay-Zama subpopulation is not differentiated from EINP wood bison (its founding source), and that Harper Creek and Ronald Lake bison were strongly differentiated from WBNP, which indicates that individuals from those subpopulations have not been interacting and breeding with bison from the GWBNP metapopulation. Genetic characteristics of the Ronald Lake subpopulation showed it to be differentiated from WBNP, but likely founded from WBNP with relatively recent isolation and limited genetic exchange (Ball et al. 2016). The Harper Creek subpopulation showed genetic differentiation from WBNP, although its uniqueness may derive from hybridization with domestic plains bison and warrants further study (Ball et al. 2016). Samples from the Wentzel Lake herd confirmed that those animals were genetically connected to WBNP (Ball et al. 2016).

Disease testing of bison outside of WBNP showed that the Wentzel Lake herd was positive for brucellosis, further supporting the hypothesis that the herd is both genetically and epidemiologically connected to WBNP. Based on diagnostic test results of 279 samples, the Hay-Zama subpopulation is considered to be free from infection with bovine tuberculosis and brucellosis, or that prevalence is less than 1% at a 95% confidence level (Ball 2009, GOA 2013b). Similarly, diagnostic samples for Ronald Lake (n = 73) (GOA 2014c) and Harper Creek (n = 22) (M. Ball pers. comm.) have not tested positive for cattle diseases, which suggests the absence of infection, or that true prevalence is less than 12% at the 95% confidence level (Ball et al. 2016). Those disease test results are well below the prevalence rates observed by Joly and Messier (2004a) who reported that 49% and 31% of captured WBNP bison tested positive for tuberculosis and brucellosis, respectively. Thus, it is more than likely that the two subpopulations have not been in contact with WBNP bison, or if exposure to the cattle diseases has occurred it

has happened very recently and affected only a small proportion of the subpopulation.

In addition to determining health status and genetic characteristics of wood bison subpopulations in northern Alberta, recent scientific and traditional knowledge research has focused on the Ronald Lake subpopulation to address the potential direct, indirect and cumulative impacts of the proposed Frontier Oil Sands Mine Project (CEAA 2015). The proposed project footprint would overlap the annual range of the Ronald Lake subpopulation and the proposal includes construction, operation and reclamation of a "truck and shovel" oil sands surface mine with a production capacity of about 44,000 m^3 / day (277,000 bpd) of bitumen. Concern for the potential impacts of the winter exploration program on bison distribution and behaviour, and potential impacts of the full mine proposal on viability of the bison subpopulation have resulted in additional empirical and community-based studies.

Tan et al. (2015) provide a summary analysis of one year of data collection from GPS radio-collars on 10 adult female bison in the Ronald Lake subpopulation. The study is focused on describing home range occupation, seasonal movements, habitat selection, and responses to natural and anthropogenic disturbances, and is scheduled to continue to 2020. Candler et al. (2015) describe results of a study completed by the Mikisew Cree First Nation (MCFN), conducted to document and recognize indigenous knowledge of the MCFN on wood bison (*Sakâw mostos*, literally translated as "bush" or "woods" bison) in the areas south of Lake Claire and WBNP. The study was based on a review of existing MCFN information and interviews with focus-groups and knowledge holders in Fort McMurray and Fort Chipewyan. It highlighted the importance of wood bison to culture, traditions, and way of life for the MCFN, and the essential role and need for continued access for hunting healthy bison (i.e., free of cattle diseases) as a means of maintaining food security, and the cultural practices and knowledge of land and animals that are tied to bison hunting.

Following its reintroduction in 2003 in British Columbia, the Etthithun subpopulation has increased in abundance and expanded its range into Alberta. Surveys to date, however, appear to have focused on either the British Columbia or Alberta portions of the range. Consequently, it is important for the two provinces to collaborate directly—as suggested by both Thiessen (2010), and Vander Vennen and Fullerton (2015)—in order to design and conduct future population monitoring programs that will more accurately track and distinguish changes in distribution and abundance.

2. Plains Bison - On September 23, 2014, leaders of 11 First Nations from Alberta and Montana signed the "Northern Tribes Buffalo Treaty," which embodies a vision to establish intertribal alliances for restoring American bison and conserving native grasslands on Tribal/First Nations Reserves or co-managed lands:
"The historic signing, the first of its kind in more than 150 years, brought together members of the Blackfeet Nation, Blood Tribe, Siksika Nation, Piikani Nation, the Assiniboine and Gros Ventre Tribes of Fort Belknap Indian Reservation, the Assiniboine and Sioux Tribes of Fort Peck Indian Reservation, the Salish and Kootenai Tribes of the Confederated Salish and Kootenai Indian Reservation, and the Tsuu T'ina Nation. Collectively, these Tribes/First Nations own and manage approximately 6.3 million acres of grassland and prairie habitat throughout the United States and Canada" (Wildlife Conservation Society North America 2016).

The long-term vision of the Buffalo Treaty is to restore the central role of bison in the food, culture, spirituality and economies of signatory American Indian Tribes, and First

Nations in Canada. Although there were no formal timelines established with the signing, Montana has coincidentally completed a draft Environmental Impact Statement (EIS) to "determine if bison restoration is appropriate and if so, what potential opportunities are feasible and consistent within Montana's laws, policies, rules, and regulations" (MFWP 2015).

See *Distribution* (*Plains Bison in Alberta* subsection) for a discussion of Parks Canada Agency's plans and initial steps taken to reintroduce plains bison into Banff National Park in 2017.

3. Research on Assisted Reproductive Technology in Bison - Research on the development and application of assisted reproductive technologies in bison has advanced profoundly since work was conducted by Thundathil et al. (2007) on *in vitro* production and cryopreservation of bison sperm, oocytes, and embryos, which occurred in conjunction with the depopulation phase of the Hook Lake Wood Bison Recovery Project (Himsworth et al. 2010). The respective research advancements by the Veterinary Colleges at the Universities of Calgary and Saskatoon culminated recently in the successful and healthy production of three bison calves that were born using *in vitro* fertilization (IVF) at the University of Saskatoon in early July 2016 (G. Adams pers. comm., Neufeld 2016).

Over the past decade, detailed research was conducted at the Universities to develop optimal techniques for collecting and preserving viability of semen from bison bulls (Aurini et al. 2009, Lessard et al. 2009, Pegge et al. 2009, Krishnakumar et al. 2011, Krishnakumar et al. 2013, Krishnakumar et al. 2015). Concomitant research on the reproductive biology of bison cows at the University of Saskatchewan detailed the seasonal and annual characteristics of reproductive (estrous) cyclicity (McCorkell et al. 2013), which was necessary for development of bison-specific protocols for controlling ovarian function and reliably inducing ovulation (Palomino et al. 2013, Palomino et al. 2015, Palomino et al. 2016)—a prerequisite for artificial insemination (Adams et al. 2009), or superovulation and collection of bison oocytes (Palomino et al. 2014). Detailed research was conducted to develop protocols for superovulation, artificial insemination, embryo collection, and embryo transfer resulting in production of live offspring by recipient bison cows (Toosi et al. 2013). Recent studies by Cerventes et al. (2016, 2017) have further advanced protocols for maturing oocytes to provide more robust *in vitro* embryos following IVF. With the recent successful production of viable calves being born using IFV protocols, this body of research may be readily applied to salvage genetic diversity of diseased bison populations in North America and conserve and manage the genetic diversity of wild bison across isolated subpopulations.

SYNTHESIS

There are an estimated 3866 mature wood bison in Alberta, in six subpopulations including Hay-Zama, Etthithun, Ronald Lake, Harper Creek, GWBNP (including the Wentzel Lake herd), and EINP. The GWBNP subpopulation and associated Wentzel Lake herd are infected with bovine tuberculosis and brucellosis and account for approximately 72% (2772) of the provincial population. Over the past three generations, the number of wood bison in the GWBNP metapopulation has been approximately stable, although the population has fluctuated from a low count of 2232 to a high of 5641 within that timeframe. The reintroduced Hay-Zama subpopulation comprises 12% of the provincial population (470 mature animals), and is the largest subpopulation of free-ranging wood bison that is considered to be free from infection with bovine tuberculosis and brucellosis. Since its reintroduction in the mid-1980s, the Hay-Zama subpopulation increased exponentially at an average annual rate of about 17%, and is now managed through hunting at an upper

population size between 400 and 600 animals to reduce risk of exposure to diseased GWBNP bison. Ronald Lake is the second largest healthy extant subpopulation and includes an estimated 145 mature wood bison and represents about 4% of the provincial population. The trend of the Ronald Lake herd is not well known because of a lack of comparable surveys, but may be stable to slightly increasing. The Etthithun subpopulation was reintroduced in British Columbia and has increased and expanded its range into Alberta since it became free-ranging in 2003; it comprises an estimated 117 mature bison and accounts for approximately 3% of the provincial population. It is likely that the Etthithun subpopulation will merge with the Hay-Zama subpopulation range in the near future. The Harper Creek subpopulation accounts for less than 1% of the provincial population. There are no comparable survey data, but Harper Creek bison have persisted as a small population of less than 50. And finally, EINP is a subpopulation managed within a fenced national park and comprises 351 mature animals or about 9% of the wood bison in Alberta. The EO that encompasses the six known wood bison subpopulations within Alberta is 246,132 km^2, and the sum of the subpopulation IAOs in the province is 51,428 km^2 (~21%).

EINP and McCusker River are the two plains bison subpopulations in Alberta. EINP likely comprises 95% or more of a provincial population of approximately 400 mature individuals. In winter 2016, there were an estimated 391 mature plains bison in EINP. In contrast, the McCusker River bison may only contribute an estimated 10 mature bison to the provincial population, based on a simple area-weighted extrapolation (i.e., 7% of the range occurs in Alberta and the guess-estimate is that the subpopulation comprises ~ 51–113 mature animals). The EINP subpopulation is managed through regular removals so it does not exceed the carrying capacity of the fenced area it ranges within. Over the past three generations, the average population count was 560 bison, ranging between 411 and 784. Compared to EINP, there is a dearth of empirical population data for the McCusker River subpopulation. However, since the reintroduced subpopulation was established in Saskatchewan in 1969 from 11–17 individuals, it has persisted and grown to approximately 100–150 bison (~ 51–113 mature animals). McCusker River is a transboundary subpopulation with most its presumed annual range in Saskatchewan (~93%). The EO that encompasses the two known plains bison subpopulations within Alberta is 7241 km^2, and the sum of the subpopulation IAOs in the province is 872 km^2 (~12%).

Future research activities that would be most useful to more clearly define the status of wood and plains bison in Alberta should be initially focussed on developing consistent methodologies and implementing regular surveys of subpopulations and herds. Survey methods for bison in Alberta have included: 1) minimum counts based on spaghetti flight lines over known areas of bison occupancy and new areas thought to be attractive to bison (e.g., Morton 2003, Moyles 2009), or systematically spaced strip transects to cover the total presumed area of bison occupancy (e.g., Rowe and Backmeyer 2006, Fullerton 2015a, Melnycky and Moyles 2016); and 2) estimates of abundance based on a mark-resight aerial survey (e.g. Powell and Morgan 2010). Survey methods should be reviewed, followed by adoption of standardized methodologies to ensure consistency of technique and comparability of data within a subpopulation, and ideally across multiple subpopulations. Although survey precision is a desirable parameter to estimate uncertainty in population estimates (and therefore requires a statistical sampling methodology to be used), for small populations of bison where clumped distributions are the rule and not the exception, it may be appropriate and suitable to collect baseline population data from minimum counts

along systematic survey lines and consistent effort.

An additional consideration is that the distribution of bison across provincial borders necessitates inter-agency collaboration and coordination to conduct robust population surveys. The Etthithun wood bison subpopulation represents one example whereby the initial reintroduction occurred in British Columbia, but the animals have since expanded their range into Alberta. Future surveys of this subpopulation should be designed and conducted to estimate bison abundance across their range in British Columbia and Alberta. This approach should help ensure consistency in survey coverage and comparability of results. Without coordination between jurisdictions, it will be difficult to explain the relative contribution of dynamics in numerical abundance versus spatial distribution to the observed patterns in trend. Similarly, coordination of management strategies through recovery action planning between the two provincial governments will help define consistent and specific objectives for distribution, abundance and health of the subpopulation. A second example is found in the McCusker plains bison subpopulation, which will require at least similar levels of interagency coordination and collaboration between Alberta, Saskatchewan, and Canada to monitor bison distribution and abundance in the future. An issue for monitoring the McCusker subpopulation is that a large portion of the defined range occurs in the Cold Lake Air Weapons Range, which has controlled air space.

Prospects for recovery and management of healthy wood bison subpopulations are constrained by the need to manage risk of infection with bovine tuberculosis and brucellosis from diseased bison in the GWBNP metapopulation, which requires ongoing management to limit the size and distribution of healthy subpopulations, as well as disease surveillance and monitoring. Prospects for recovery of plains bison in the province are restricted by habitat availability. Potential impacts of human land use (i.e., energy development, forest harvest, and agriculture) on wood and plains bison habitat will require ongoing management and mitigation. Although outside of original plains bison range, the McCusker River subpopulation represents potential for a viable extant population, if it is supported through appropriate monitoring and research studies, underpinned by collaborative consultation with Saskatchewan, Canada, indigenous communities, and other stakeholders. The initiation of the reintroduction of plains bison to Banff National Park, which is within original plains bison range, represents strong potential for long-term establishment of a managed and viable extant subpopulation.

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Appendix 1. Definitions of status ranks and legal designations.

A. General Status of Alberta Wild Species Categories (used in 2000, 2005, 2010, and 2015 General Status exercises) (Government of Alberta 2011c)

Rank	Definitions
At Risk	Any species known to be *At Risk* after formal detailed status assessment and legal designation as *Endangered* or *Threatened* in Alberta.
May Be At Risk	Any species that may be at risk of extinction or extirpation, and is therefore a candidate for detailed risk assessment.
Sensitive	Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk.
Secure	Any species that is not *At Risk, May Be At Risk* or *Sensitive*.
Undetermined	Any species for which insufficient information, knowledge or data is available to reliably evaluate its general status.
Not Assessed	Any species that has not been examined during this exercise.
Exotic/Alien	Any species that has been introduced as a result of human activities.
Extirpated/Extinct	Any species no longer thought to be present in Alberta (Extirpated) or no longer believed to be present anywhere in the world (Extinct).
Accidental/Vagrant	Any species occurring infrequently and unpredictably in Alberta, i.e., outside its usual range.

B. Alberta Species at Risk Formal Status Designations
Species designated as *Endangered* under Alberta's *Wildlife Act* include those listed as *Endangered* or *Threatened* in the Wildlife Regulation (in bold).

Endangered	**A species facing imminent extirpation or extinction.**
Threatened	**A species likely to become endangered if limiting factors are not reversed.**
Species of Special Concern	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Data Deficient	A species for which there is insufficient scientific information to support status designation.

C. Committee on the Status of Endangered Wildlife in Canada (after COSEWIC 2013b)

Extinct	A species that no longer exists.
Extirpated	A species that no longer exists in the wild in Canada, but occurs elsewhere.
Endangered	A species facing imminent extirpation or extinction.
Threatened	A species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern	A species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk	A species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient	A category that applies when the available information is insufficient to (a) resolve a wildlife species' eligibility for assessment, or (b) permit an assessment of the wildlife species' risk of extinction.

D. United States Endangered Species Act (U.S. Fish & Wildlife Service 2005)

Endangered	Any species that is in danger of extinction throughout all or a significant portion of its range.
Threatened	Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Appendix 1 continued:

E. Heritage Status Ranks:

Subnational (S) ranks in Alberta (after Alberta Conservation Information Management System 2016)

S1	Known from five or fewer occurrences or especially vulnerable to extirpation because of other factors.
S2	Known from 20 or fewer occurrences or vulnerable to extirpation because of other factors.
S3	Known from 100 or fewer occurrences, or somewhat vulnerable due to other factors, such as restricted range, relatively small population sizes, or other factors.
S4	Apparently secure. Taxon is uncommon but not rare. Potentially some cause for long-term concern because of declines or other factors.
S5	Secure. Taxon is common, widespread, and abundant.
SX	Taxon is believed to be extirpated from the province. Not located despite intensive searches of historical sites and other appropriate habitat. Virtually no likelihood that it will be rediscovered.
SH	Known from only historical records but still some hope of rediscovery. Evidence that the taxon may no longer be present but not enough to state this with certainty.
S?	Not yet ranked, or rank tentatively assigned.
S#S#	A numeric range rank is used to indicate any range of uncertainty about the status of the taxon. Example: S2S3 or S1S3. Ranges cannot skip more than two ranks.
SU	Taxon is currently unrankable because of a lack of information or substantially conflicting information. Example: native versus non-native status not resolved.
SNR	Not ranked. Conservation status not yet assessed.
SNA	Not applicable. A conservation status rank is not applicable because the species or ecosystem is not a suitable target for conservation activities. Example: introduced species.
S#?	Inexact numeric rank. Applied when a specific rank is most likely appropriate but for which some conflicting information or unresolved questions remain.

Global (G), National (N) and other Subnational (S) ranks (after NatureServe 2015b)

G1/N1/S1	Critically Imperiled. At very high risk of extinction or elimination due to very restricted range, very few populations or occurrences, very steep declines, very severe threats, or other factors.
G2/N2/S2	Imperiled. At high risk of extinction or elimination due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
G3/N3/S3	Vulnerable. At moderate risk of extinction or elimination due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
G4/N4/S4	Apparently Secure. At fairly low risk of extinction or elimination due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
G5/N5/S5	Secure. At very low risk or extinction or elimination due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats.
GX/NX/SX	Presumed Extinct/Extirpated. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood of rediscovery.
GH/NH/SH	Possibly Extinct/Extirpated. Known from only historical occurrences but some hope of rediscovery.
G?/N?/S?	Inexact Numeric Rank. Denotes inexact numeric rank.
G#G#/ N#N#/S#S#	A numeric range rank (e.g., G2G3, G1G3) is used to indicate the range of uncertainty about the exact status of a taxon or ecosystem type. Ranges cannot skip more than two ranks.
GU/NU/SU	Unrankable. Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
GNR/NNR/ SNR	Unranked. Conservation status not yet assessed.
GNA/NNA/ SNA	Not Applicable. A conservation status rank is not applicable because the species is not a suitable target for conservation activities

Appendix 2. Extent of occurrence (EO) of wood bison in Alberta (246,132 km2), calculated using a minimum convex polygon encompassing known wood bison subpopulations within Alberta. The EO is the area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a wildlife species (COSEWIC 2013b).

Appendix 3. Timeline summarizing the history of bison in Alberta and northern Canada.

Pre-1800: Bison were plentiful within their original range in Canada. Soper (1941) estimated 168,000 animals prior to European arrival.

1890s: Wood bison in the WBNP area reached an estimated low of 250.

1889: The last plains bison in Alberta is killed in Hand Hills.

1897: S.N. Rhoads identified the wood bison as a subspecies, creating two taxa within North America, plains bison (*Bison bison bison*), and wood bison *(Bison bison athabascae*).

1906: The Canadian government agrees to purchase a herd of endangered plains bison, known as the Pablo-Allard herd, from Montana rancher Michel Pablo; 310 plains bison were transported to Elk Island National Park (EINP) and approximately 750 plains bison were brought to the enclosed Buffalo National Park (BNP) at Wainwright, Alberta.

1921: BNP plains bison rapidly outgrowing the capacity of their range, and population size exceeds 5000 animals.

1922: WBNP was established. Wood bison population was estimated to be approximately 1500–2000 animals.

1925-1928: 6673 plains bison (yearlings, 2 and 3 year olds) were transported from BNP in Wainwright to Hay Camp in WBNP; however, it is unclear how many survived to be released. At the time the wood bison population in the park is estimated at 2000 animals.

Late 1930s: The bison population of the WBNP was estimated as 12,000, which is lower than the perceived regional carrying capacity. Wolves were subsequently poisoned and trapped in an attempt to increase the number of bison.

1940: The "pure" wood bison was believed to be extinct as a result of crossbreeding with the introduced plains bison.

1959: Approximately 200 bison were discovered near the Nyarling River in the northwest corner of WBNP. Anatomical comparisons indicated that they represented wood bison, although comparative studies were not carried out.

1963: 18 disease-free wood bison from the Nyarling River area were transported to what became the Mackenzie Bison Sanctuary (MBS).

1965/68: 23 wood bison were transported from the Nyarling River herd to EINP.

(**Appendix 3** continued:)

1969: Following a failed reintroduction of 50 plains bison from EINP to an area north of Prince Albert National Park, SK, 11-17 plains bison were re-captured by the Department of Natural Resources and located to the Vermette-Upper Cummings Lake region, SK where they eventually settled in the McCusker River area within the Cold Lake Air Weapons Range.

1970: The bison population in the Greater WBNP area began to decline.

1974: Approximately 3000 bison drowned when they fell through the ice of the flooded Peace-Athabasca Delta.

1977: Wood bison listed on Appendix I of the Convention on International Trade in Endangered Species (CITES) controlling exportation and importation of endangered wildlife species and products (subsequently downlisted to Appendix II in 1997).

1978: The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed the wood bison as *Endangered* (subsequently down-listed to *Threatened* in 1988). The governments of Alberta and the Northwest Territories protect bison; however, "hybrid" animals outside of the Park were subject to regional hunting. In Alberta, there were no regulations governing the hunting of bison outside of the park, excepting the Hay-Zama herd.

Late 1980s: First evidence of McCusker River bison occurring in Alberta.

1980-1991: Wood bison herds were started from EINP animals: Nahanni National Park in 1980 (Nahanni population), Interlake region of Manitoba in 1991 (Chitek Lake herd), Hay-Zama lakes of Alberta in 1984 (Hay-Zama herd), and the Nisling River of Yukon in 1988 and 1992 (Aishihik herd).

1995-1996: 50 wood bison were reintroduced to the Upper Liard River valley in British Columbia (Nordquist herd) and 18 wood bison from Northern Lights College in Dawson Creek were released near Etthithun and Kantah Lakes, BC (Etthithun Lake herd).

1996: The Hook Lake Wood Bison Recovery Project was initiated in Fort Resolution, NT, to salvage genetic diversity of wood bison from the GWBNP subpopulation. Over three years, 60 calves were captured from the Hook Lake herd in the Slave River Lowlands, monitored for disease, and used to establish a healthy captive breeding herd.

2001: Collaborating agencies forming the National Wood Bison Recovery Team published a National Recovery Plan for the Wood Bison. The primary goal is to remove the wood bison from

(**Appendix 3** continued:)

Threatened status by establishing at least four self-sustaining populations, each at or above a minimal viable population of 400 in original range.

2006: The Hook Lake Wood Bison Recovery Project was depopulated following confirmation of infection with bovine tuberculosis, and unsuccessful funding request to complete a final salvage effort.

2013: Status assessment on plains and wood bison in Canada conducted by COSEWIC.

2016: Draft National Wood Bison Recovery Strategy released for public review by Environment and Climate Change Canada. Canada proposed (successfully) that CITES remove wood bison from Appendix II.

2017: Sixteen plains bison from EINP released into a fenced area in Banff National Park, as part of a reintroduction plan.

Appendix 4. Extent of occurrence (EO) of plains bison in Alberta (7241 km2), calculated using a minimum convex polygon encompassing known plains bison subpopulations within Alberta. The EO is the area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a wildlife species (COSEWIC 2013b).

Appendix 5. Summary of a range of calculated estimates of generation length for American bison ($\bar{x}$ = 8 years), based on different assumptions for survival and fertility/fecundity and the IUCN Microsoft Excel spreadsheet calculator "Generation Length". Data assumptions highlighted in the table below along with published sources. (Generation Length spreadsheet available from:http://s3.amazonaws.com/iucnredlist-newcms/staging/public/attachments/3157/generation_length.xls).

Estimated Generation Length (yr)	**9.0**		**9.0**		**8.8**		**7.5**		**7.4**		**6.6**	
Assumptions - Survival	average age-specific survivorship values of female plains bison in NBR, GTNP, and WMWR (Brodie 2008: Table 2)		proportion female bison surviving by year class in YNP, 1996-2012 (White et al. 2015: Table 5.1)		average age-specific survivorship values of female plains bison in NBR, GTNP, and WMWR (Brodie 2008: Table 2)		expected female survivorship from WMWR plains bison based on fitted logistic functions (Brodie 2008: Figure 1)		average age-specific survivorship values of WMWR female plains bison (Brodie 2008: Table 2)		average age-specific survivorship values for female bison in YNP (Udevitz and Gogan 2012: Figure 2)	
Assumptions - Fertility / Fecundity	average values of age-specific calving percentage for EINP (wood bison), and plains bison in NBR, and BNP (Brodie 2008: Table 5		proportion of female bison calving by year class in YNP, 1996-2012 (White et al. 2015: Table 5.1)		expected values of age-specific female plains bison reproduction for BNP from a fitted logistic function (Brodie 2008: Figure 3B)		expected values of age-specific female wood bison reproduction for EINP (Wilson et al. 2002) from a fitted logistic function (Brodie 2008: Figure 3A)		average values of age-specific plains bison pregnancy rates for WMWR (Brodie 2008: Table 5)		average values of age-specific pregnancy rates for YNP bison (Gogan et al. 2013)	
Age class (YEARS)	**Survival rate**	**Fertility or fecundity**	**Survival rate**	**Fertility or fecundity**	**Survival rate**	**Fertility or fecundity**	**Survival rate**	**Fertility or fecundity**	**Survival rate**	**Fertility or fecundity**	**Survival rate**	**Fertility or fecundity**
i	*S(i)*	*F(i)*	*S(i)*	*F(i)*	*S(i)*	*F(i)*	*S(i)*	*F(i)*	*S(i)*	*F(i)*	*S(i)*	*F(i)*
0	0.89	0	0.80	0	0.89	0	0.78	0	0.96	0	0.80	0
1	0.80	0	0.83	0	0.80	0	0.80	0	0.55	0	0.80	0.05
2	0.91	0.07	1.00	0.00	0.91	0.28	0.82	0.28	0.76	0.08	0.98	0.59
3	0.96	0.63	0.97	0.57	0.96	0.40	0.83	0.40	0.89	0.75	0.98	0.45
4	0.98	0.60	0.97	0.72	0.98	0.51	0.83	0.52	0.95	0.93	0.91	0.60
5	0.96	0.72	0.95	0.70	0.96	0.61	0.84	0.62	0.89	0.93	0.91	0.72
6	0.95	0.69	0.95	0.61	0.95	0.67	0.84	0.70	0.86	0.93	0.80	0.72
7	0.96	0.72	0.96	0.70	0.96	0.72	0.83	0.75	0.91	0.93	0.80	0.72
8	0.95	0.77	0.96	0.88	0.95	0.75	0.82	0.79	0.87	0.93	0.80	0.72
9	0.91	0.76	0.92	0.79	0.91	0.76	0.81	0.81	0.76	0.92	0.80	0.72
10	0.93	0.78	0.81	0.75	0.93	0.75	0.79	0.81	0.82	0.92	0.80	0.72
11	0.92	0.76	0.83	0.81	0.92	0.73	0.77	0.81	0.77	0.92	0.80	0.72
12	0.84	0.79	0.81	0.73	0.84	0.69	0.74	0.80	0.54	0.92	0.40	0.72
13	0.84	0.72	0.83	0.71	0.84	0.63	0.70	0.77	0.57	0.92	0.40	0.72
14	0.84	0.53	0.75	0.75	0.84	0.54	0.65	0.73	0.55	0.8	0.40	0.72
15	0.55	0.48	1.00	0.50	0.55	0.43	0.59	0.66	0.64	0.8		0.72
16	0.57	0.50	0.78	0.50	0.57	0.31	0.53	0.57	0.57			
17	1.00	0.42	0.78	0.50	1.00	0.20	0.45	0.46	1.00			
18	0.50	0.40	0.78	0.50	0.50	0.11	0.38	0.34	0.50			
19	1.00	0.31			1.00	0.05	0.30	0.22	1.00			
20		0.39				0.02	0.23	0.13				

BNP = Badlands National Park; EINP = Elk Island National Park; GTNP = Grand Teton National Park; NBR = National Bison Refuge; WMWR = Wichita Mountains Wildlife Refuge; YNP = Yellowstone National Park

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Udevitz, M. S., and P. J. P. Gogan. 2012. Estimating survival rates with time series of standing age-structure data. Ecology 93:726-732.

Appendix 6. Transmission, pathology, and disease management implications of bovine tuberculosis and brucellosis in bison.

Bovine tuberculosis *(Mycobacterium bovis)*

Bovine tuberculosis is primarily a respiratory disease with inhalation being the principle route of infection, although oral transmission through ingestion is also important (Phillips et al. 2003, Kaneene and Pfeifer 2006). In livestock and wild ungulates, infected animals shed the bacteria in body secretions and transmission is usually through direct contact via inhalation of droplets expelled by infected animals or consumption of contaminated feed (Phillips et al. 2003). Transmission may also occur from mother to fetus through the placenta and umbilicus, or when the newborn offspring consumes its mother's infectious milk (Phillips et al. 2003). Bovine tuberculosis primarily affects the respiratory system with lesions commonly found in cranial and thoracic lymph nodes and in the alimentary canal (O'Reilly and Daborn 1995, Kaneene and Pfeiffer 2006). In bison, the disease may reduce fertility, weaken infected animals and in advanced cases result in death. Fuller (1966) and Tessaro (1987) estimated that advanced tuberculosis may result in 4%–6% adult mortality in WBNP bison; both authors suggested a link between infection with tuberculosis and increased susceptibility to predation by wolves. Studies by Joly and Messier (2005) in Wood Buffalo National Park showed that survival and reproduction rates were reduced in female bison that tested positive for both tuberculosis and brucellosis. Heisey et al. (2006) further demonstrated reduced survival in tuberculosis-positive bison.

Bovine brucellosis *(Brucella abortus)*

The pathogenicity of brucellosis in bison is similar in most aspects to that in cattle (Davis et al. 1990, Williams et al. 1993, Rhyan et al. 2001, Thorne 2001, Rhyan et al. 2009). The main clinical features of brucellosis are a high incidence (approximately 90%) of abortion during the first pregnancy following infection; the second pregnancy exhibits a 20% abortion rate, and subsequent pregnancies result in less than a 1% abortion rate due to naturally acquired immunity (Davis et al. 1991). In female bison, brucellosis results in infertility, uterine infections, premature abortions, retained placenta, or weak calves that die soon after birth (Davis et al. 1991, Thorne 2001). The risk of disease transmission is greatest during or immediately after an infected female calves or aborts. In males, the disease causes inflammation of the testes and epididymides

(**Appendix 6** continued)

(Tessaro 1987, Williams et al. 1997). The disease may also cause arthritis and hygroma in which inflammation of leg joints may be severe enough to result in crippling or increased susceptibility to predation (Tessaro 1987). Transmission occurs primarily through direct contact when the pathogen is shed in high concentrations by infected females during abortion or parturition and is found in placental and uterine fluids. Susceptible animals are infected through contact with infectious uterine fluids, aborted fetuses, or food, water, or soil contaminated by those materials. Calves may become infected through ingestion of infected milk from their dam (Williams et al. 1997, Olsen et al. 2003). Venereal transmission of B. abortus from bovine males to females is not considered important in the epidemiology of brucellosis, and is therefore not considered an important route of transmission in bison (Thorne 2001).

Disease management

Owing to the importance of tuberculosis and brucellosis as reportable, zoonotic diseases communicable from animals to humans, the pathogens have been the subject of intensive, long-term eradication programs in livestock populations in Canada and the United States. Efforts to control tuberculosis in Canadian cattle began in 1896 (Wobeser 2009) and Canada initiated a national eradication programs for tuberculosis in cattle in 1923 (CFIA 2015). By 2005, the occurrence of bovine tuberculosis had been virtually eliminated except for a small area of Manitoba (Wobeser 2009) and rare cases in domestic animals (CFIA 2015). Canada initiated an eradication program for bovine brucellosis in livestock in the 1940s, and was declared free of the disease in 1985 (CFIA 2015). Bison in the Greater Wood Buffalo National Park area represent the last known reservoir of the pathogens in Canada; although wapiti (*Cervus elaphus*) and white-tailed deer (*Odocoileus virginianus*) are reservoir hosts for bovine tuberculosis in Riding Mountain National Park, Manitoba (Lees et al. 2003, Nishi et al. 2006, Wobeser 2009, Shury and Bergeson 2011).

Appendix 7. Brief timeline of bovine tuberculosis and brucellosis research and management and the northern diseased bison issue in Canada (key references: Connelly et al. 1990, McCormack 1992, BRCP 1996, Gates et al. 2001, Nishi et a. 2006, Nishi 2010).

Year	Event
1917	A Wainwright bison died from tuberculosis thought to have been contracted from local cattle herds.
Mid-1920s	Plains Bison infected with cattle diseases released into WBNP.
Late 1930s	Tuberculosis symptoms observed in bison in WBNP, disease presence confirmed in 1947.
1956	Brucellosis first tested for and confirmed in WBNP
1980s	Agricultural grazing increases in the region, within 70 km of the WBNP boundary, creating a concern of disease transmission to domestic animals (cattle, bison and elk).
1985	Canadian domestic cattle herd is declared 'bovine brucellosis-free' and tuberculosis has almost been eliminated in the domestic stock. Sporadic tuberculosis outbreaks have continued to occur, one in Quebec in 1989 and another in Manitoba in 1997 (D. Scott pers. comm. 1999), but can be traced to imported stock.
1987 - present	Bison Control Area Program initiated in Northwest Territories to conduct aerial surveys in area between WBNP and Mackenzie bison range, and remove any bison found in control area.
1988	Elimination or control of the diseases in the bison is listed as a management priority.
1989-1990	Federal Environmental Assessment of disease issue – replacement with healthy wood bison recommended.
1991-1992	Northern Buffalo Management Board established to develop a management plan – concluded with recommendation for more research.
1995-2000	Bison Research and Containment Program (BCRP) initiated by Parks Canada. Funding provided to: research project by University of Saskatchewan (disease prevalence and impact on bison survival and

pregnancy); research project by University of Calgary (bison movements and distribution); support NWT Bison Control Area Program. BCRP committee requests additional funding to complete recommended research but program is terminated.

1996-1999 Canadian Bison Association (CBA) requested Agriculture and Agri-Food Canada to conduct a risk assessment on the potential spread of bovine tuberculosis and brucellosis from bison in and around Wood Buffalo National Park. Risk assessment completed by Animal, Plant and Food Risk Analysis Network in 1999.

1996-2001 University of Saskatchewan conducts research project on the effects of brucellosis and tuberculosis on bison in Wood Buffalo National Park.

1996-2006 Government of Northwest Territories and Deninu Kue First Nation initiate the Hook Lake Wood Bison Recovery Project (HLWBRP)—a genetic salvage and disease eradication project in the Slave River Lowlands. HLWBRP is terminated in 2006 after bovine tuberculosis is discovered in herd.

1997 Canada recognized by the United States Department of Agriculture (USDA) as having "TB free" status; USDA no longer required cattle to be TB tested prior to import.

1999-2001 University of Calgary completes a project on landscape evaluation of bison movements and distribution, models bison movement corridors, and develops recommendations for risk management.

2000 Peace Country Bison Association and the Government of Alberta initiate a northern Alberta commercial bison grazing experiment at Fort Vermillion.

2000-2001 Little Red River Cree Nation develop a research proposal and project to establish a wood bison recovery herd north of the Peace River in the Wentzel Lake watershed; the proposal is not funded.

2001-2002 CBA requests that a diseased bison management process be developed. A Federal Interdepartmental Steering Committee is established to develop a federal position and prepare a strategy for implementing a consultation

	and management process. However, no progress was made on engaging stakeholders and emphasis shifts to National Disease Strategy.
2003-2004	Parks Canada CEO and three Alberta Deputy Ministers invite Northwest Territories and Canadian Food Inspection Agency to establish an intergovernmental committee to develop risk mitigation options for diseased bison with focus in northern Alberta. Interim Measures Technical Committee develops recommendations and completes report.
2005	Parks Canada Agency and Environment Canada facilitated a Bison Diseases Technical Workshop to address the question: "Could bovine tuberculosis and brucellosis be eliminated from free-roaming herds of bison in the region centered on Wood Buffalo National Park, through a program of depopulation and subsequent repopulation?" Workshop participants were unanimous in their agreement that disease eradication through a depopulation/repopulation scenario as discussed and laid out was technically feasible, provided that adequate resources, funding and a management infrastructure able to carry out a twenty-year program would be available.
2008 - ongoing	Alberta implements interim management approach to prevent spread of tuberculosis and brucellosis from diseased wild bison to domestic livestock and disease-free wild bison based on 1) Hay-Zama wild bison herd management (bison hunt), 2) disease surveillance and risk reduction east of Highway 35, and 3) monitoring populations of wild bison east of Highway 35.
2012 – ongoing	Alberta initiates a multi-year study on Ronald Lake bison herd to determine health status, distribution, seasonal movements, and habitat selection. A Ronald Lake Bison Herd Technical Studies Team is established in 2014.
2016	Canadian Food Inspection Agency releases an updated assessment on "Risk of Bovine Brucellosis and Tuberculosis to Cattle from Bison of Wood Buffalo National Park and Area".

Appendix 8. Epizootiology of anthrax (*Anthracis bacillus)* in bison

The life history of *B. anthracis* is very different from most other infectious pathogenic bacteria. Its persistence in the environment depends on extreme virulence, death of its host, and survival of highly resistant, infectious endospores during prolonged periods of time outside the host (Gates et al. 2001a). Once a bison is infected, the bacteria replicate rapidly and cause mortality of the host generally within 3-5 days. In an intact carcass, natural putrefaction destroys the anthrax bacilli within a few days of death. However, if vegetative cells of anthrax are physically released from a carcass due to scavenging and encounter suitable aerobic conditions of temperature, humidity, and nutrient depletion, the cells can form resistant spores; sporulation is a response to low nutrient conditions or dehydration (Bengis and Frean 2014). Scavengers are often partially responsible for dispersing anthrax spores through disarticulation and physical movement of the carcass. Depending on soil and environmental conditions, anthrax spores can persist in the environment for a number of years and remain viable to infect another suitable host animal.

Anthrax epizootics (outbreaks affecting many individuals of a species) typically occur during drought conditions in summer that follow a wet spring, and end with the onset of cooler conditions in early fall. There are two hypotheses that have been proposed to explain the initiation of anthrax outbreaks in bison: the modified host resistance hypothesis (Gainer and Saunders 1989), and the wallow concentrator hypothesis (Dragon et al. 1996). The modified host resistance hypothesis proposes that stress factors associated with drought conditions coupled with breeding stress during the late summer rut predispose bulls to infection. Alternatively, the wallow concentrator hypothesis proposes that anthrax spores in the environment are carried by water action and concentrated in the environment into low lying wallows preferentially utilized by bulls (Dragon et al. 1999, Hugh-Jones and Blackburn 2009).

Anthrax epizootics ranging from large-scale (hundreds of dead bison) to localized (tens of dead bison) continue to occur throughout northern Alberta and the original range of wood bison. These epizootics have been observed in bison with no apparent link to livestock and, similarly, outbreaks in livestock have been documented in the region with no definitive link to wild bison. The interface between anthrax outbreaks in wild bison and domestic livestock, however, may become more important during larger-scale outbreaks. This is especially

(**Appendix 8** continued:)

pronounced where there is overlap in space use on landscapes supporting persistence of anthrax spores, while environmental conditions favour epizootics (Bengis et al. 2002, Morris et al. 2015). Because of the persistence of anthrax spores in the environment, the spatial overlap between wild and domestic animals need not occur closely in time. The significance of large or sporadic outbreaks in wild bison is that they provide enough new animal cases for the bacteria to multiply and maintain an environmental pool of viable endospores (Elkin et al. 2013).

Appendix 9. Historical overview on hunting of wood bison in and around Wood Buffalo National Park.

Indigenous people in the Canadian northwest have a long tradition of association with bison, both having inhabited the region for millennia. Traditionally, indigenous people hunted wood bison for food, clothing, and for use in spiritual ceremonies (Guthrie 1980, Bigstone Cree Nation and Métis People of Kituskeenow 1999, Stephenson et al. 2001, McCormack 2010b, Candler et al. 2015). Wood bison represent an important animal in their cultural system of beliefs and values. The relationship between indigenous people and bison, however, was changed by a series of policies established as early as 1894, when the federal government enacted the *Unorganized Territories Game Preservation Act* (SC 1894 [57-58 Vict.], c 31) to prohibit any hunting of the endangered wood bison. The prohibition on hunting wood bison was enforced by "buffalo rangers" and subsequently maintained through both the federal *Northwest Game Act* of 1906 and the *Alberta Game Act* of 1907 (McCormack 2010b). In 1922, WBNP was created to both protect the northern wood bison and, "secondarily, to protect the Indian inhabitants of the buffalo range from competition with outside trappers" (McCormack 1992; p 369). The ongoing prohibition on bison hunting in WBNP by indigenous people continues under current park regulation (see Table 4 in Candler et al. 2015), and is in contrast to policy establishment for newly created national park reserves that emphasize co-management and continuance of traditional harvesting by Aboriginal peoples with a historical relationship to the region (PCA 2015).

Appendix 10a: Wood Bison Technical Summary

A summary of information contained within this status report, and used by the Scientific Subcommittee of Alberta's Endangered Species Conservation Committee for the purpose of status assessment based on International Union for Conservation of Nature (IUCN) criteria. For definitions of terms used in this technical summary, go to: http://www.iucnredlist.org/technical-documents/categories-and-criteria and http://www.cosewic.gc.ca.

Scientific Name*: Bison bison athabascae*
Common name: **Wood Bison**
Range of occurrence in Alberta: Wood bison occur within the northern portion of the province, from Elk Island National Park (EINP) (located east of Edmonton), north and west to the Northwest Territories and British Columbia borders respectively. Wood bison in EINP are enclosed within a large fenced area (~60 km^2); whereas free-ranging subpopulations occur within and adjacent to Wood Buffalo National Park in the northeast region of the province, as well an extensive area in the northwest, which occurs west of Highway 35 (Paddle Prairie – High Level – AB/NWT border) and extends from the northern part of Chinchaga Wildland Provincial Park to the Hay-Zama Wildland Provincial Park.

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time as indicated in the most recent IUCN guidelines is being used) Appendix 5 (p. 109) provides a range of estimates of generation length based on published estimates for survival and pregnancy rates. A generation time of 8 years is the average value from six estimates. See Biology and Ecology (p. 29).	~ 8 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Free-ranging bison subpopulations (Hay-Zama and Etthithun) have increased by 1097% and 1124%, respectively (extrapolated to 3 generation lengths) since they were reintroduced in northern Alberta. Recent surveys suggest that Ronald Lake has increased, but there are insufficient long-term data to estimate trend. Free-ranging infected subpopulations – in WBNP – have fluctuated but have declined by < 1% relative to abundance three generations ago. See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32)	No

(**Appendix 10a** [Wood Bison] continued)

[Observed, estimated, inferred, or suspected] percent reduction or increase in total number of mature individuals over the last 3 generations. Total population has been increasing by approximately 30% in the last 3 generations. Although the largest subpopulation in WBNP (i.e., represents ~68% of the total subpopulation) has been comparatively stable. See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32).	30% increase
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 3 generations. Overall population trend over next 3 generations is likely to be stable to increasing. This is based on following key assumptions: - WBNP fluctuates between 2000–5000 bison, and any large dispersal of infected animals into the agricultural area west of the park is detected and managed through hunting and coordinated removals. - Healthy free-ranging bison (Hay-Zama, Etthithun, and Ronald Lake) are maintained as 'disease-free' with objectives for distribution and abundance achieved through regulated hunting and coordinated removals. - Abundance of EINP wood bison is maintained according to Parks Canada management objectives, and subpopulation is managed through regular removals See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32).	Uncertain (but likely stable to increasing based on assumed disease & subpopulation management strategies)
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any 3-generation period, over a time period including both the past and the future. See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32).	Increasing in last 3 generations; uncertain in future 3 generations.

(**Appendix 10a** [Wood Bison] continued)

Estimated percent of continuing decline in total number of mature individuals within 2 generations Stability in the largest subpopulation (i.e., WBNP) is partially offset by free-ranging healthy (infection-free) subpopulations, which are, or will likely be actively managed to reduce risk of disease transmission through establishment of objectives for distribution and abundance. See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32).	Total population has increased in recent past; uncertain in future 2 generations.
Have the causes of the decline ceased? Are they understood? Are they clearly reversible?	N/A
Are there extreme fluctuations in number of mature individuals? Mortality events (anthrax outbreaks and mass drowning) have removed up to half of some subpopulations. The Mackenzie subpopulation in the Northwest Territories has fluctuated approximately threefold in the last 3 generations. In WBNP, the maximum population size has been ~2.5 times the minimum estimate (based on available data from 1992-2014 where minimum count was 2232 and maximum was 5641). Fluctuations do not exceed one order of magnitude. See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32).	No
Is the species subject to [actual, potential] exploitation? Subpopulations in WBNP and EINP are not hunted. There is a limited entry draw hunting season established for the Hay Zama subpopulation and managed by the Government of Alberta. The Ronald Lake subpopulation is only accessible for subsistence hunters from local First Nations and Métis communities. Etthithun bison may be hunted if they occur in the Bison Hunting Area during the season established for the Hay Zama subpopulation. Bison in subpopulations occurring outside of WBNP (i.e., Wentzel Lake, and Harper Creek) are subject to year-round unregulated hunting. See Threats, 3. Hunting (p. 57).	Yes

Is the decline in the number of mature individuals affected by [introduced taxa, hybridisation, pathogens, pollutants, competitors, parasites]? Several subpopulations are infected with introduced bacterial disease pathogens—bovine tuberculosis and brucellosis (i.e., WBNP, Wentzel Lake, and Harper Creek); those endemic diseases reduce pregnancy and increase mortality rates in infected subpopulations, and are hypothesized to interact synergistically with predation to reduce population growth potential in bison. Anthrax is an enzootic bacterial disease that also affects northern bison. It is a pathogen that can persist as a dormant spore in suitable soils and infects bison under environmental conditions that typically present as wet springs with high precipitation followed by hot dry conditions in summer. Anthrax epizootics directly kill bison that become infected. See Threats, 1. Disease (p. 46).	Yes

Extent and Occupancy Information

Estimated extent of occurrence See 1.2 Provincial Extent of Wood Bison Occurrence (p. 8)	246,132 km²
Index of area of occupancy Hay-Zama 6920 km² Etthithun 5572 km² Ronald Lake 2020 km² Harper Creek 2488 km² Wood Buffalo National Park (WBNP) 31,376 km² Wentzel Lake 2968 km² Elk Island National Park (EINP) 84 km² See Table 1 (p. 8). Note that for the transboundary Etthithun subpopulation, the area of occupancy of only the Alberta portion is indicated here.	51,428 km²

(**Appendix 10a** [Wood Bison] continued)

Is the total population severely fragmented? Approximately 72% of the population occurs within the Greater WBNP ecosystem (i.e., WBNP and Wentzel Lake), and comprises ~2736 mature individuals. The remaining subpopulations in northern Alberta that are considered free of infection with bovine tuberculosis and brucellosis are managed to prevent contact with the infected WBNP metapopulation. Disease management actions are conducted through active surveillance and removal of bison from bison-free management areas in northwest Alberta. However, the total population of wood bison in Alberta is likely not severely fragmented because ~ 61% of the IAO in the province occurs within WBNP, which represents about 68% of the population. See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32).	No
Number of locations There are currently six locations of wood bison considered in the province: Hay-Zama, Etthithun Lake, Ronald Lake, Harper Creek, WBNP (including Wentzel Lake), and EINP. In the future, however, the number will very likely be counted as five locations, once the Hay-Zama and Etthithun subpopulations merge; this could happen within three generations. See 2. Locations (p. 59).	6
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of subpopulations? Subpopulations outside WBNP are small and potentially subject to local extirpation depending on whether hunting is managed through restrictions on authorization or access. For example, Wentzel Lake and Harper Creek subpopulations are subject to unregulated hunting. The Ronald Lake subpopulation range occurs largely within a recently defined "Subject Animal" area which restricts hunting except by those exercising Aboriginal harvesting rights. See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32); and Status Designations, Alberta (p. 59).	Possibly

(**Appendix 10a** [Wood Bison] continued)

Is there an [observed, inferred, or projected] continuing decline in number of locations? See comments above for decline in number of subpopulations. Locations are defined by threats, which influence (and are influenced by) how humans manage subpopulations (i.e., via hunting/control measures to manage disease). Therefore, decline in the number of locations would be possible, if management were to change. See 2. Locations (p. 59).	Possibly
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Concerns have been voiced by communities over potential industrial impacts to range of Ronald Lake subpopulation. Habitat disturbance due to human land uses (forestry and energy sector) has also increased in the range of the Hay-Zama and Etthithun subpopulations, but a quantitative assessment has not been done. See Habitat (p. 24) and Threats, 2. Anthropogenic Land Use (p. 50).	Possibly
Are there extreme fluctuations in number of subpopulations? See Population Size, Trend and Health Status; Wood Bison in Alberta (p. 31) and Table 6 (p. 32).	No
Are there extreme fluctuations in number of locations? See 2. Locations (p. 59).	No
Are there extreme fluctuations in extent of occurrence? See Distribution, 1.2 Provincial Extent of Wood Bison Occurrence (p. 8).	No
Are there extreme fluctuations in index of area of occupancy? See Distribution, 1.2 Provincial Extent of Wood Bison Occurrence (p. 8).	No

Number of Mature Individuals (in each subpopulation)

Population	**N Mature Individuals**
Hay-Zama	470
Etthithun	117
Ronald Lake	145

(**Appendix 10a** [Wood Bison] continued)

Harper Creek	11
Wood Buffalo National Park	2,616
Wentzel Lake	120
Elk Island National Park	352
Total	**3,866**
See Table 6 (p. 32). Note that the number of individuals indicated for the transboundary Ethhithun subpopulation includes a portion that occurs in British Columbia; therefore, this total is slightly overestimated.	

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Probability of extinction has not been quantitatively assessed.

Threats (See Threats section p. 46)
(Actual or imminent threats, to subpopulations or habitats. List from highest to least impact, as per IUCN Threats Calculator [http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme]. Rate immediacy, scope and severity.)

One of the highest-impact threats (rated high-medium) comes from a variety of cattle-borne and native (anthrax) pathogens, which have generated high mortality events within various subpopulations both historically and recently. The presence of these diseases can also increase predation rate by wolves.
Another high-medium impact threat is hunting (both controlled and unregulated), used to manage growth, prevent range expansion, and reduce bison-human conflicts, including discouraging bison use of agricultural areas and roadsides.
A medium-low impact threat comes from agricultural activity, both cropland and ranching. These activities prevent natural expansion of existing subpopulations into historical habitat.
An additional medium-low impact threat is represented by anthropogenic activity in the form of energy production and mining: e.g., oil and gas installation/functioning and existing/proposed oil sands. These activities have generated or are expected to generate mortality within various subpopulations.
A third medium-low impact threat comes from severe weather events exacerbated by climate change; these have generated high mortality events within various subpopulations both historically and recently.
Lower but locally significant threats include road mortality, dams and water management and genetic introgression from cattle and privately owned bison.

(**Appendix 10a** [Wood Bison] continued)

Rescue Effect (immigration from outside Alberta)

Status of outside population(s) most likely to provide immigrants to Alberta? See Population Size, Trend and Health Status, Wood Bison, 3. Rescue Potential (p. 43).	
Is immigration known or possible? Immigration is inferred for Etthithun wood bison subpopulation, which was re-introduced in British Columbia. Other subpopulations outside of Alberta are generally too far away for immigration to be expected and in many cases there is active management aimed at preventing movement between subpopulations. See Population Size, Trend and Health Status; Wood Bison, 1.1.2 Etthithun subpopulation (p. 34).	Yes - limited
Would immigrants be adapted to survive in Alberta? See Population Size, Trend and Health Status; Wood Bison, 1.1.2 Etthithun subpopulation (p. 34).	Yes
Is there sufficient habitat for immigrants in Alberta? There is habitat for existing subpopulations; however, habitat for immigrants into other areas of northern Alberta may be limited due to conflicting land uses such as agriculture (and associated disease control activities, including hunting), which now occur within original range in Alberta. See Population Size, Trend and Health Status; Wood Bison, 1.1.2 Etthithun subpopulation (p. 34).	Yes
Are conditions deteriorating in Alberta? See Threats; 1.2 Anthropogenic Land Use (p. 50).	Likely
Are conditions for the source population deteriorating? Land use in northern British Columbia is also subject to disturbance from forestry and energy sectors. See Threats; 1.2 Anthropogenic Land Use (p. 50).	Likely

(**Appendix 10a** [Wood Bison] continued)

Is the Alberta population considered to be a sink? The Hay-Zama and Etthithun bison subpopulations are managed as sustainable subpopulations. Hay-Zama is subject to management through implementation of a harvest season. Etthithun bison may also be hunted during this season because they may occur within the Alberta Bison Hunting Zone. See Threats; 1.2 Anthropogenic Land Use (p. 50).	No
Is rescue from outside populations likely? The Ettithun bison range extends from BC in to Alberta. It is likely that the Etthithun subpopulation will continue to grow numerically and extend its range in to the Hay Zama annual range. However, it is likely that the Etthithun subpopulation on the Alberta side will be subject to management objectives for distribution and abundance of bison in the northwest part of the province. Any potential rescue effect will be limited geographically to the northwest region of the province because of disease management objectives, which are designed to ensure isolation between Hay-Zama – Etthithun subpopulations, and bison infected with bovine tuberculosis in and around WBNP. See Population Size, Trend and Health Status, Wood Bison, 3. Rescue Potential (p. 43).	No

Current Status (unless specified otherwise, status designations listed here refer specifically to wood bison). See Status Designations (p. 59).

Provincial: *Endangered* in defined area that contains the Hay-Zama subpopulation; identified as a *Subject Animal* in defined area that contains the Ronald Lake subpopulation; elsewhere not categorized as "Wildlife" under the *Wildlife Act.*

National: *SARA: Threatened*; COSEWIC: *Special Concern* (2013); British Columbia: all bison are *Big Game* but wood bison are also on Red List of species at risk, also S2; Yukon: *Big Game Species* (population size managed by hunting), also S2S3; NWT: *Threatened*, also S2; Saskatchewan: all bison are *Big Game* (but not currently hunted), also SX; Manitoba: designated a *Protected Species*, also SNA.

Elsewhere: IUCN: American bison are *Near Threatened*; CITES: removed from Appendix II in 2016; US *Endangered Species Act*: *Threatened in Canada*; Global Heritage Status Rank: G4T2T3Q

Author of Wood Bison Technical Summary: John Nishi, Robin Gutsell

Appendix 10b: Plains Bison Technical Summary

Scientific Name: *Bison bison bison*
Common name: **Plains Bison**
Range of occurrence in Alberta: There are two plains bison subpopulations in Alberta. The McCusker subpopulation is extralimital to the original range of plains bison because it occurs in the Boreal Natural Subregion. The subpopulation occurs primarily in Saskatchewan, with its range extending in to Alberta in the area of the Cold (Primrose) Lake Air Weapons Range. Only ~7% of the documented range of the McCusker subpopulation occurs within Alberta. The second subpopulation of plains bison occurs in the northern portion of Elk Island National Park (EINP) (located east of Edmonton), and is enclosed within a large fenced area (~134 km^2). In February 2017, 16 plains bison (primarily females) were reintroduced to a fenced area in the Panther Valley of Banff National Park. The intent is to release the herd in to a larger ~1200 km^2 reintroduction zone in summer 2018.

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time as indicated in the most recent IUCN guidelines is being used) Appendix 5 (p. 109) provides a range of estimates of generation length based on published estimates for survival and pregnancy rates. A generation time of 8 years is the average value from 6 estimates. See Biology and Ecology (p. 29).	~ 8 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	No

(**Appendix 10b** [Plains Bison] continued)

[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last 3 generations. Based on available data for the McCusker and EINP subpopulations, plains bison in EINP (which make up ~95% of the Alberta population) have increased by ~7% over the last 3 generations; however, this largely reflects the interaction between population productivity in the absence of predation, and removals of bison through park management. What little is known about McCusker suggests that it has increased since its reintroduction. See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	7% increase
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next 3 generations. Overall population trend over next 3 generations is likely to be stable to increasing. This is based on following key assumptions: - EINP, which represents ~95% of the population, is managed as a stable population within management targets identified in a park management plan. - McCusker River subpopulation will continue to grow with no substantial impact of disease, to the point where direct management of distribution and abundance is required. To date, there are few empirical data on trend in subpopulation size and range use. See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	Expected to remain stable (and possibly increasing in McCusker)

(**Appendix 10b** [Plains Bison] continued)

[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any 3-generation period, over a time period including both the past and the future. The fenced EINP subpopulation is managed to be stable. Population growth is anticipated for the McCusker River subpopulation because there do not appear to be any strong limiting factors affecting the subpopulation. See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	Increasing in last 3 generations; uncertain (but likely stable to increasing) in future 3 generations.
Estimated percent of continuing decline in total number of mature individuals within 2 generations Based on available data for the McCusker and EINP subpopulations, plains bison in Alberta have increased over the last 3 generations (all in EINP), and are expected to be stable to increasing in the future. See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	None; stable to increasing
Have the causes of the decline ceased? Are they understood? Are they clearly reversible There is very limited monitoring of the McCusker subpopulation.	N/A
Are there extreme fluctuations in number of mature individuals? See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	No
Is the species subject to [actual, potential] exploitation? There is no hunting in EINP, and no reports of hunting for bison in the McCusker River subpopulation. However, this may change in the future if the McCusker River subpopulation grows to a point where management of is size is desired. See Threats, 3. Hunting (p. 57).	No

(**Appendix 10b** [Plains Bison] continued)

Is the decline in the number of mature individuals affected by [introduced taxa, hybridisation, pathogens, pollutants, competitors, parasites]? The Sturgeon River plains bison subpopulation in Saskatchewan experienced an anthrax outbreak in summer 2008; and there have been frequent outbreaks of anthrax in and around WBNP and in the Slave River Lowlands, Northwest Territories. It is possible that anthrax will affect the McCusker River subpopulation in the future. See Threats, 1. Disease (p. 46).	No

Extent and Occupancy Information

Estimated extent of occurrence See 1.1 Provincial Extent of Plains Bison Occurrence (p. 22)	7,241 km²
Index of Area of occupancy (AO) McCusker River (Alberta portion) 680 km² Elk Island National Park 192 km² See Table 3 (p. 22)	872 km²
Is the total population severely fragmented? Approximately 95% of plains bison in Alberta are isolated as a small (i.e., $\leq$ 400 mature individuals) subpopulation. This subpopulation within a fenced area of ~192 km^2 (EINP) represents only 22% of the IAO for plains bison in Alberta. The McCusker River subpopulation (~51-113 mature individuals, with only a portion of those entering Alberta) occurs in a remote location on the edge of original range for plains bison. There is no possibility for interchange, and expansion of the populations is highly constrained. See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	Possibly

(**Appendix 10b** [Plains Bison] continued)

Number of locations There are two locations of plains bison considered in the province: EINP and McCusker Lake. See Threats, 2. Locations (p. 59)	2
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of subpopulations? Although the McCusker subpopulation is very small, it is currently slowly expanding into Alberta. See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	No
Is there an [observed, inferred, or projected] continuing decline in number of locations? See comment above for decline in number of subpopulations. See 2. Locations (p. 59).	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Within the current ranges of the two subpopulations there is no continuing decline in habitat. However, habitat within original range (Grassland Natural Region) and outside current subpopulations ranges in the province is highly constrained due to human land uses primarily agricultural crops and livestock grazing. See Habitat (p. 24) and Threats, 2. Anthropogenic Land Use (p. 50).	No

(**Appendix 10b** [Plains Bison] continued)

Are there extreme fluctuations in number of subpopulations? See Population Size, Trend and Health Status; Plains Bison in Alberta (p. 44) and Table 8 (p. 44).	No
Are there extreme fluctuations in number of locations? See 2. Locations (59).	No
Are there extreme fluctuations in extent of occurrence? See Distribution, 1.1 Provincial Extent of Plains Bison Occurrence (p. 22).	No
Are there extreme fluctuations in index of area of occupancy? See Distribution, 1.1 Provincial Extent of Plains Bison Occurrence (p. 22).	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
McCusker subpopulation	51-113 (includes SK bison)
Elk Island National Park subpopulation	391
Total See Table 8 (p. 44).	< 442-504

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Probability of extinction has not been quantitatively assessed.

(**Appendix 10b** [Plains Bison] continued)

Threats (See Threats section p. 46)
(Actual or imminent threats, to subpopulations or habitats. List from highest to least impact, as per IUCN Threats Calculator [http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme]. Rate immediacy, scope and severity.)

The highest impact threat (rated high) is hunting (both controlled and unregulated), used to manage growth, prevent range expansion, and reduce bison-human conflicts, including discouraging bison use of agricultural areas and roadsides. For the free-ranging McCusker subpopulation, this threat is likely only to occur in the future, but the EINP herd is currently managed below a certain population size by regular removals of individuals, most of which are moved out of Alberta, domesticated, or killed.
An additional high-medium impact threat comes from a variety of cattle-borne, sheep-borne and enzootic (anthrax) pathogens, which have generated high mortality events within various subpopulations of wood bison, and also threaten plains bison subpopulations.
A medium-low impact threat comes from droughts and temperature extremes exacerbated by climate change; these have generated high mortality events within various subpopulations of wood bison both historically and recently.
Lower but locally significant threats include agriculture (through both crop growing and ranching), mortality from oil and gas drilling and genetic introgression from cattle and privately owned bison.

Rescue Effect (immigration from outside Alberta)

Status of outside population(s) most likely to provide immigrants to Alberta?

The McCusker River subpopulation is a transboundary subpopulation with its range extent occurring primarily in Saskatchewan (93%), but with a small proportion (7%) in Alberta. This subpopulation is presumed to be free from bovine tuberculosis and brucellosis based on the health status of its source subpopulation (EINP) and the absence of any known reservoirs for either disease within its range. The McCusker subpopulation was introduced in 1969, and in 2012 was estimated to comprise 100-150 animals (51-113 mature individuals); available data suggest it has increased by ~200% over the past 3 generations. Aside from the McCusker River subpopulation, the other free-ranging plains bison subpopulations in Canada are considered to be too far from Alberta for natural dispersal to occur, with a high probability of management intervention to prevent immigration to Alberta.

See Population Size, Trend and Health Status, Plains Bison; 3. Rescue Potential (p. 45).

(**Appendix 10b** [Plains Bison] continued)

Is immigration known or possible? The McCusker subpopulation range occurs mostly in SK, and partially in AB. The status of the subpopulation in AB will depend largely on growth and immigration / dispersal from SK See Population Size, Trend and Health Status; Plains Bison, 1.1.1 McCusker subpopulation (p. 44).	Yes
Would immigrants be adapted to survive in Alberta? Plains bison from EINP were the source of founders for the McCusker River and Sturgeon River subpopulations in Saskatchewan. EINP plains bison have been translocated successfully in Canada. See Population Size, Trend and Health Status; Plains Bison, 1.1.1 McCusker subpopulation (p. 44).	Yes
Is there sufficient habitat for immigrants in Alberta? There is likely sufficient habitat in Alberta for the McCusker bison to disperse into. However, habitat for immigrants in the southern regions of Alberta is limited because of the predominance of agricultural land use within original range in Alberta. The proposal for reintroduction to plains bison in to Banff National Park has identified a suitable habitat area. See Population Size, Trend and Health Status; Plains Bison, 1.1.1 McCusker subpopulation (p. 44).	Yes (in McCusker range)
Are conditions deteriorating in Alberta? Conditions within the two current ranges of plains bison subpopulations in the province are likely not deteriorating. However, at a provincial scale, there is limited suitable habitat for large scale restoration of free-ranging bison within original range, which includes the Grassland Natural Region, and Central and Foothills Parkland Natural Subregions. See Threats; 1.2 Anthropogenic Land Use (p. 50).	No

(**Appendix 10b** [Plains Bison] continued)

Are conditions for the source population deteriorating? However, there has not been any detailed assessment of habitat in the McCusker River subpopulation range (within Alberta or Saskatchewan). See Threats; 1.2 Anthropogenic Land Use (p. 50).	Likely not
Is the Alberta population considered to be a sink? See Threats; 1.2 Anthropogenic Land Use (p. 50).	No
Is rescue from outside populations likely? At a broad provincial scale, there is negligible rescue potential for plains bison subpopulations to provide immigrants to southern Alberta. The McCusker River subpopulation is a transboundary subpopulation with its range extent occurring largely in Saskatchewan (93%), with potential for further expansion into Alberta. Plains bison at EINP are managed as a closed population and are enclosed by a perimeter fence. See Population Size, Trend and Health Status; Plains Bison; 3. Rescue Potential (p. 45).	No (not at a provincial scale and beyond the McCusker River subpopulation)

Current Status (unless specified otherwise, status designations listed here refer specifically to plains bison). See Status Designations (p. 59).

Provincial: No status; SNR (unranked) National: SARA: no status; COSEWIC - *Threatened* (2013); British Columbia: all bison are *Big Game* but plains bison are also on Red List of species at risk, also SX; Saskatchewan: all bison are *Big Game* (but not currently hunted), also S3; Manitoba: designated an *Extirpated Species*, also SX. Elsewhere: IUCN: American bison are *Near Threatened*; Global Heritage Status Rank: G4TU; plains bison are assigned no CITES or US *Endangered Species Act* status.

Author of Plains Bison Technical Summary: John Nishi, Robin Gutsell

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