HISTORICAL ECOLOGY OF BISON MOVEMENT CORRIDORS, WESTERN CORDILLERA, NORTH AMERICA:
A Cross Watershed Comparison

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Douglas Leighton photo

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Summary

Based upon historic literature, bison movement from the North American plains into the northern areas of the Western Cordillera is conceptualized as a 3-phase dispersal process consisting of: 1) an annual migratory pattern of large numbers of bison from the central plains towards the mountains and foothills each fall and winter, and back on the plains into the spring: 2) dispersal events westward through corridors into the mountains that occurred generally when bison were most numerous at the edge of the Cordillera (fall and winter); 3) the persistence or demise of small herds that penetrated the mountains due to interactions with human predation, terrain, forest cover, and snowpack conditions. This conceptual model is tested using data from first person journal accounts of wildlife observations, wallow densities (in northern regions), and terrain and historic vegetation conditions along potential bison movement corridors into the Cordillera.

Preliminary analysis of this data suggests that bison's movement pattern into the mountains varies for by 3 broad regions:

Montane Valleys- Movement routes on to the upper Snake River (South Pass) and upper Missouri (Bozeman Pass) where open grass-shrub vegetation and wide corridors (particularly South Pass) allowed large herds to move over 1000 km into the mountains from the plains;

Mountain Wall- The region from the Great Falls of the Missouri north to the Bow River where relatively open terrain, but very narrow corridors into the mountains resulted in highly effective communal hunting by native Americans, and bison rarely reaching >10 km into the mountains;

Forested Foothills and Boreal Plains- A broad region north of the Bow River, reaching to the boreal plains where dense forest cover resulted in low densities of bison that were difficult to hunt, and small herds reached 50-150 km into the mountains (e.g. , over Howse Pass) and >1000 km northwards into the boreal forest (Peace-Athabasca-Slave river areas).

These historical bison movement patterns could be mathematically evaluated using biophysical and cultural covariates with least cost and friction models.

Acknowledgements:

Thank you to Susan Decaen and Pamela Workman from the Glenbow Ranch Park Foundation, and Leanne Alison and Heather Dempsey from the Bow Valley Naturalists for inviting me to do presentations on bison movements into Rocky Mountains. This helped me better organize my thinking and get some graphics together on how bison movements westward might have worked.

Ted Binnema, Charles Kay, Cormack Gates have been great mentors in encouraging the integration of the disciplines of history and ecology. One way of viewing ecosystems is that they are the product of long-term historical ecology on the landscape, and these researchers have greatly advanced our understanding on bison in north-western biomes.

Doug Leighton, who recently passed away, was a strong advocate for doing this type of research, and his detailed analysis of historical North American grizzly bear observations and human interactions has been an excellent model for the type of information needed to understand species' distribution. Doug's work is now archived at the Whyte Museum of the Canadian Rockies in Banff, and I encourage anyone interested in the large ecology of large mammals to utilize his archival fonds.

Thank you to Charles Kay and Peter White for reviewing a draft of the 2018-10-04 version of this report. Peter is working with the amazing Parks Canada team led by Bill Hunt and Karsten Heuer bringing bison back to Banff National Park. As with many generations of people before them, I suspect the Parks Canada's restoration team's first daily thought is:

"It's a good thing to keep some of those buffalo contained within the mountains where we can find them."

I will update this report periodically (see Appendix B), so comments are always appreciated.

Contents

1. INTRODUCTION

“buffaloe have come here and even further but they are killed at once and do not get wonted”
(wonted meaning habitual, fur trader Andrew Wyeth describing bison bones on the lower Bitterroot River, near Missoula Montana, on April 29, 1833)

Consider that the biogeography of northwestern North America was for millennia, largely created by the interaction between species of great abundance: salmon from the Pacific Ocean, and bison from the Great Plains (Figure 1.1). Humans were the key component linking these great bodies of biomass. The intricate, age-old patterns of human movements to fish, hunt, burn, and occupy the land were intimately connected to bison and salmon. Through these linkages, people, for the more than ten millennia since deglaciation, regulated the patterns and abundance of the great masses of these fish and grazers.

Traditional and current cultures can easily understand the general movement patterns of salmon to and from the Pacific Ocean. The importance of the lakes and streams as nurseries for the young fish, and for the great rivers such as the Fraser and the Columbia, as a route to and from the Pacific Ocean waters has long been comprehended. How waterfalls and canyons function to restrict salmon movements is obvious. Clearly salmon from the Pacific could not, through the ages, leave streams to walk across the passes through the mountain cordillera that drain to the Atlantic or Arctic. Moreover, people well know the importance of preserving the nursery stocks returning to spawn in the headwater stream gravels. These are the essence of a life cycle that nurtured the valuable fisheries that sustained human cultures. (Goble 1999).

A more complicated ecological approach is required to fathom the abundance and distribution of the nomadic North American bison (Gates et al. 2010), especially in areas along the Rocky Mountains (Figure 1-1). From traditional hunters to modern ecologists, people have found the bison wanderings and habitat use patterns an enigma. Why did bison occupy the Great Plains in the millions, yet were rarely found on the rich Palouse Prairie of Washington? How could bison permeate the woodlands and deep snows to occupy vast areas of the boreal forest north of the Great Plains, yet were usually not found on extensive valley bottom grasslands only a short distance into the mountains to the west of the Rocky Mountains at the headwaters Columbia and Fraser rivers?

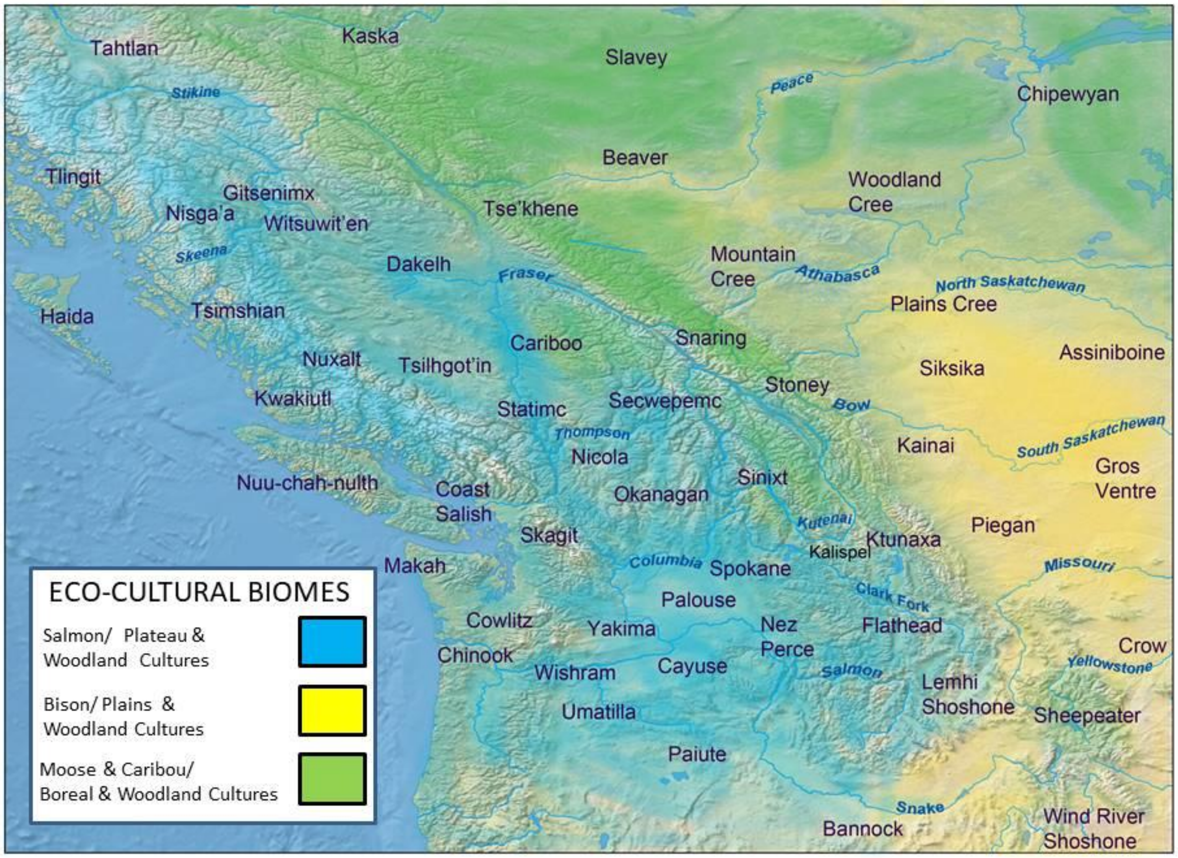

Figure 1-1: Eco-cultural biomes in the Pacific Northwest showing the general location of select Native American groups.

1.1 "Clearly a Long Established Process"

"It is probable that had the bison remained unmolested by man and uninfluenced by him he would have crossed the Sierra Nevada and the Coast Range and taken his abode in the fertile valleys of the Pacific Slope." William T. Hornaday, 1889.

Since the time of the "moccasin telegraph", the density and distribution of bison along its western range limits of bison must have been a topic of serious human contemplation. While today the discussion numbers is mostly confined to debates in academic papers or in the bowels of park administration buildings, in past times a good understanding of how far the bison moved to the west, or how far hunters would have to travel to the east , often into their neighbor's territory, was clearly a matter of survival. No animal rivalled the bison as a provider of food, clothing, and shelter. While the record of First Nation's campfire discussions are mostly lost to us today, the early white travelers in the west faced similar problems on how and where they could procure bison, and their journals of contain numerous records of feast or famine along the western edge of the range. On August 14, 1805 Lewis and Clark were forewarned by the Shoshone of the lack of game to the west of the mountains. Lewis recorded that "*They informed me that there was no buffalo on the West side of these mountains; that the game consisted of a few Elk deers and Antelopes, and that the natives subsisted on fish and roots principally.*" This proved true, and after the expedition moved into the valleys of the Columbia River, they often subsisted on roots, or the meat from dogs and horses (Moulton 1993; Kay 1994, 2007; Martin and Szuter 1999; Laliberte and Ripple 2003).

For the next several decades, the journals of fur traders, trappers and other early travelers provide the intricate details of where bison were, and where they were not. They describe passes across the mountains that were easily passable to bison, and those where bison were rare on not present. They describe herd sizes, and through their discussion with Native Americans and knowledge of the habitat, we are given a reasonable record of the cultural and ecological influences on bison behavior and abundance. Early historians and bio-geographers synthesized these records and put the story together. As we can see from Hornaday's explanation above, by 1887 a scientific perspective on the causes of the bison's range boundaries was developing. In 1932, historian Ceylon Kingston further compiled these observations. He surmised:

The distribution of the buffalo over the continental area depended on a number of factors. Among these were the normal length of life of the species, and the rate of reproduction; the amount of available food as affected by soil, temperature and rainfall; such major obstacles as mountain chains, dense forests, deep canyons and areas of extreme desert type; predator animals and human enemies. In considering the range of the buffalo the Columbia Basin presents a curious and rather intricate problem and biological distribution in which the hunting by the Indians and physiographic difficulties explain in the most part the scarcity or absence of the buffalo. (Kingston 1932).

Some two decades later, in 1951 Frank Gilbert Roe first published his seminal work "The North American Buffalo." In nearly 1000 pages of small-font text, he condenses over 4 centuries of observations on bison. Similar to earlier compilations, he explained that:

"Even before the advance of the white men into the Rocky Mountain territory, the westward advance of the buffalo must have been much impeded by the 'economic pressure' of the Indian tribes beyond the actual buffalo range. For many Indians journeyed through the passes to procure bison meat and hides, either by hostile forays or by trade. This is attested by the earliest (European) observers and by many others, and was ***clearly a long-established process****."* (Roe 1972, p. 259, emphasis added).

This is the basic description of an important long-term eco-cultural interaction, and one that is much interest to researchers studying wildlife movements today. We can visualize the opposing human versus bison use of these "wildlife corridors" for several networks of passes and trails across the Rocky Mountains as shown in Figure 1.1-1.

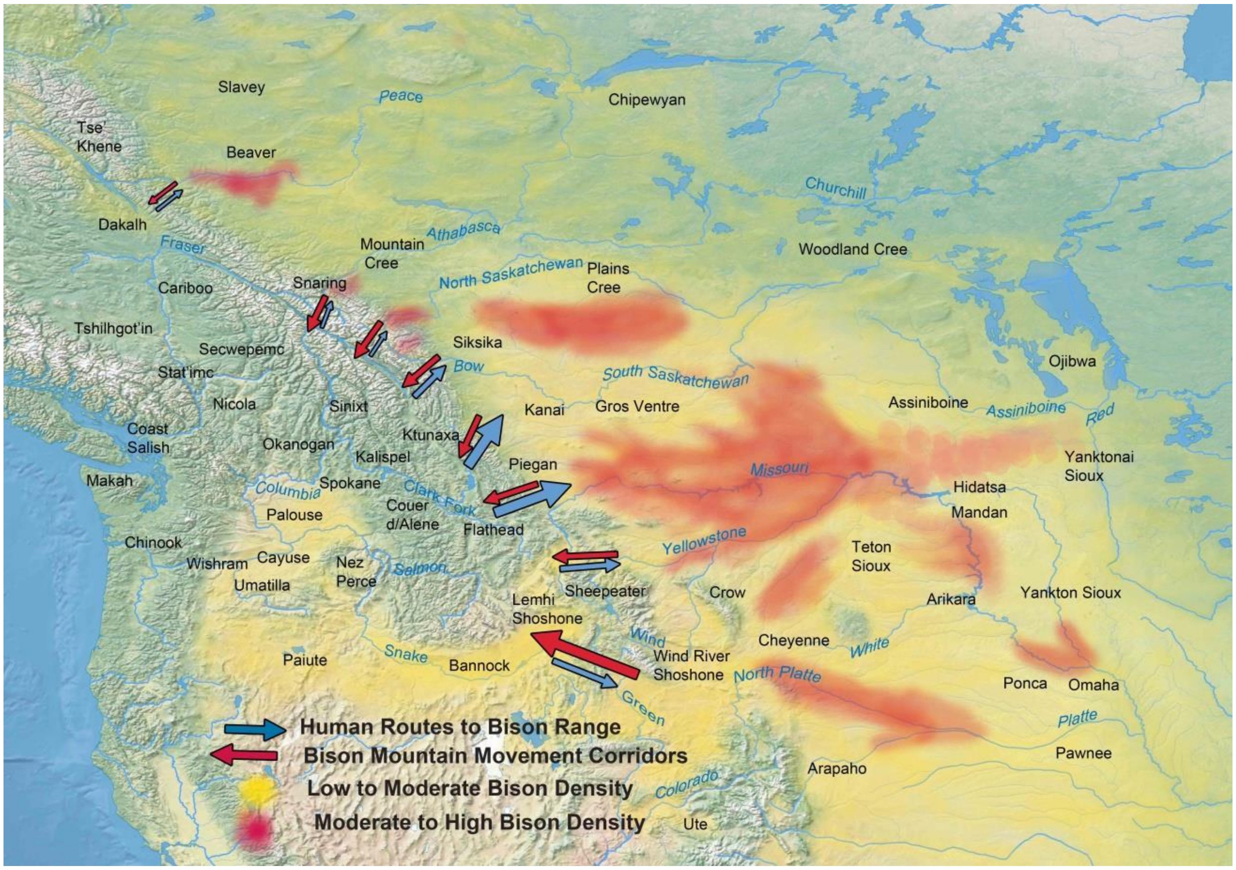

Figure 1.1-1: Locations of selected Native American groups, potential summer bison density, and the relative importance of several bison and human movement routes across the Rocky Mountains in northwestern North America for the period of approximately 1800 to 1830. The map shows only one of many potential scenarios for summer conditions of moderate to high densities of mixed male and female herds on the Great Plains. This pattern would change each year as bison followed unique seasonal patterns of forage created by precipitation and burning, and avoided predation by human groups and other carnivores. In general, in late spring bison had moved away from woodlands and out on the open plains. Here they may have been found near sources of water, and avoided human predation by favouring zones between tribes at war.

1.2 Recent Reviews of Bison Westward Movements

Since the latter 1980s, researchers from numerous disciplines have been integrating Kingston's and Roe's thinking into the distribution and abundance of bison and other large terrestrial mammals in the Pacific Northwest. Multi-disciplinary ecologists such as Dirk Van Vuren (1987), Charles Kay (1994) and others (Martin and Szuter 1999; Laliberte and Ripple 2003; Lyman 2004; Grayson 2006, Bailey 2016) have more fully considered these eco-cultural processes. Some potential considerations for humans, bison, and other factors could have interacted are:

- Given relatively low numbers of bison west of Rockies, and intense hunting by Native Americans, routine recolonization from bison from the Great Plains might be required to maintain larger western herds such as along the Snake River, or most small herds within the Rocky Mountains. The argument that bison in or west of the Rocky Mountains were essentially "sink" populations was most recently proposed by Kay (1994) in part of his "Aboriginal Overkill" hypothesis, and by White et al. (2001), and Langemann (2002). An alternate perspective that mountain bison could be self-supporting "source populations" is provided by Plumb et al. (2009), and Lyman (2004) provides a critique of the overkill hypothesis.
- Large herds of bison moving westwards might be required to overwhelm groups of human hunters moving eastward. This would most often occur in wide gaps such as the South Pass;
- Large herds of bison in or near the passes across the Rockies would most likely be found where Great Plains grasslands most closely approach the mountains such as at the head of the Platte River (South Pass), or along the Missouri River where the Sun River provides access to Lewis and Clark and Cadotte passes (Farr 2003; Scott 2015).
- Mountain grasslands and relatively unbroken terrain might be required to facilitate large herds in the mountains, with the dry, windy South Pass area linking the North Platte, Green, and Snake headwaters having the most ideal conditions. Other bison movement corridors in the mountains might require very high frequencies of burning to keep them timber free for summer use, and snow depths in winter would limit bison use (White et al. 2001b, 2011);
- The number of native peoples travelling eastward to hunt bison could also be important. For example, the presence of bison in the upper Snake River may have reduced the need for human movements across South Pass, whereas high densities of people in the upper Columbia and Fraser watersheds, and a dearth of bison may have favoured high use of passes by people travelling east to hunt to on the Great Plains and eastern foothills and river headwaters (Schaffer 1940, Anastasio 1985, Reeves 2003).
- Tribal relations might be important influences on bison abundance and movements (Kay 1994, 2007; West 1995, Flores 2007). Within the mountains passes that lay within intertribal warfare zones might be less frequently used by hunters, allowing bison numbers to increase in these corridors. For example, Kootenay Plains, on the headwaters of the North Saskatchewan was historically a buffer zone between warring tribes, and was historically a noted location for finding bison in abundance (Kay et al. 1999);

- The importance of salmon in supporting complex hunter-gatherer societies west of the continental divide could be of special significance. These peoples could form dedicated groups of hunters and traders to travel eastwards for long periods of time focussed on in early times on resources provided by the bison (robes, hide, and meat), and after 1700, also trading horses with plains peoples (Anastasio 1985, Josephy 1997, Farr 2003).

After a detailed analysis of historical observations of bison in the American Rocky Mountains, and reviewing the evidence above, Bailey (2016) concluded:

These observations provide compelling evidence that human predation was a major, perhaps preponderant, factor limiting bison distribution in the Rocky Mountains. While other factors varied geographically and temporally, Native American predation was more persistent, mobile and widespread.

1.3 Need for Further Interdisciplinary Research on Long-term Bison Movement Patterns at the Western Edge of Historic Range

Since the near extirpation of bison in the latter 1800s, there has been an ongoing international effort to restore wild bison populations at a continental level. By 2010 there were several existing and proposed initiatives to restore bison in Canada, United States and Mexico (Gates et al. 2010). Some of these projects such as the American Prairie Reserve in Montana occur in core historic bison habitat (Freese et al. 2007, Sanderson et al 2008). In these locations it is a reasonable hypothesis that bison occurred at relatively high densities (Figure 1.2), and may have been a keystone species in the long-term development and maintenance of plant communities (Kohl 2012). However, other high profile projects lie in the Rocky Mountains at the long-term edge of occupied bison habitat. These include ongoing projects in Jackson Hole (USDI 2007), Yellowstone National Park (USDI 2000, Plumb et al. 2009), and Banff National Park (Parks Canada 2017). These restored bison herds occur at the edge of bison range, in rugged terrain, where bison densities were possibly low and highly variable over space and time. Given they were at the edge of the range, for long-term management, it may be necessary to understand wildlife movement corridors that provided connectivity to core populations to the east. Most importantly, these bison restoration efforts are centred in national park or wildlife refuges that have objectives of maintaining not just bison, but all other long-term ecosystem components and processes (Sellars 1997, Parks Canada 2000, Woodley 2010, White et al. 2013), and this will not be possible without some understanding, and perhaps restoration of the movement processes that sustained bison, possibly at variable and low densities in the mountains (White et al. 2001; Kay and White 2001).
As a first example where these processes remain poorly understood with potentially serious implications, consider the ongoing changes in plant communities on Yellowstone’s northern winter range, one of the continent’s longest experiments in bison restoration (Figure 1.3-1).

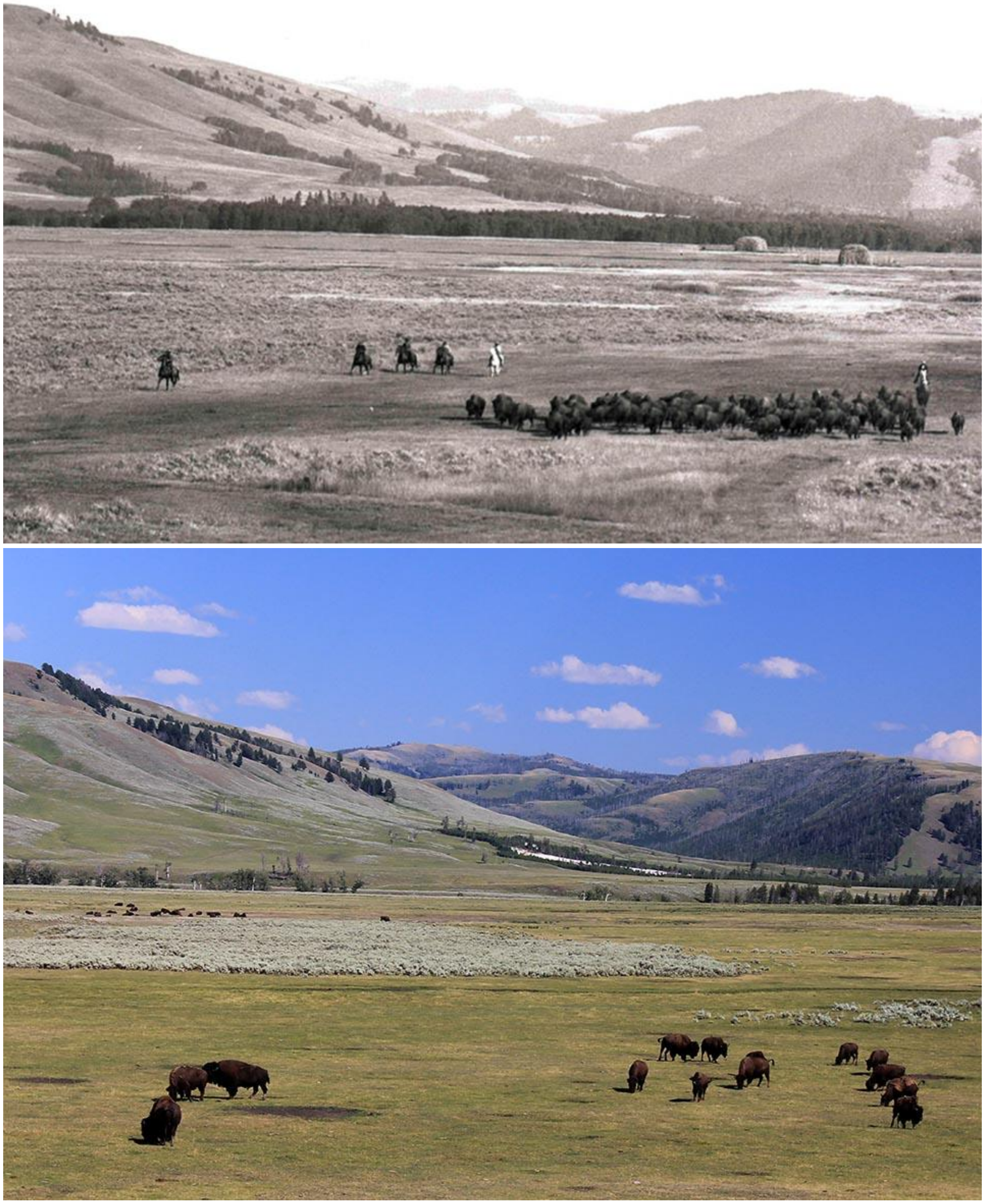

Figure 1.3-1: Lamar valley bison c. 1924 (Yellowstone National Park Archives NPS-YELL-27818) and in 2016 (CW-2016-07-24-090). In the 1920s, Yellowstone National Park wranglers stampeded a domesticated herd of bison across the Lamar valley grasslands to thrill park visitors (Sellars 1997, Franke 2005). Yellowstone's total bison numbers have increased from a few hundred in the 1960s to over 5000 by the year 2005 (Plumb et al. 2009). High densities of herbivores and the 1988 wildfires altered sagebrush cover in the foreground, riparian cottonwoods in the mid-ground, and trembling aspen groves on the background slopes. (Kay 1990, 2002; Wagner 2006; Kauffman et al. 2010; Beschta and Ripple 2014, 2016; Keigley 2018).

The observed decline in coverage in diverse and valued plant communities such as sagebrush, riparian cottonwoods, and aspen in Yellowstone, the world's first national park and a World Heritage Site has been highly controversial (Wagner 2006, Keigley 2018). When wolves were restored to the ecosystem in 1995, and preyed heavily on elk, biologists predicted the potential recovery of some plant communities as elk herbivory rates declined (White et al. 1998, Ripple et al. 2001). However, although elk numbers and herbivory rates did decline, concurrently bison numbers increased (Plumb et al. 2007), and some scientists detected increased use of bison of low elevation plant communities (Beschta and Ripple 2014, 2016; see current conditions in Figure 1.3-1).

The potentially increasing detrimental effects of bison on the Yellowstone ecosystem clearly demonstrate the need for a rigorous scientific analysis of landscape-level processes influencing bison numbers and movements in the national park area. Possibly, in contrast to a current description (Plumb et al. 2007), Yellowstone was not a high density, food-regulated bison population that annually migrated seasonally from a core summer use area at upper elevations within the current park to lower elevations on surrounding lands. Possibly the upper elevations of Yellowstone were a low density population sink area, with abundant forage, but infrequently visited from herds dispersing (or driven by humans) up the narrow valleys to from higher density populations on the surrounding lower elevation plains. In this landscape this bison were at high predation risk, and down-valley movement was infrequent.

A further example for research comes from Banff National Park. Parks Canada (2017) described potential ecological processes for a recently implemented, experimental bison restoration in the eastern section of the park. In the project' early inception, a group of interdisciplinary researchers and stakeholders including biologists, historians, archaeologists, and First Nations recognized that to achieve Parks Canada's policies for "ecological integrity" and First Nation's traditional use (Parks Canada 2001) restored bison in Banff would be a "sink population" at the edge of their range, regulated at low numbers by indigenous hunting (Fleener et al. 2000, Shury 2000, White et al. 2001, Kay and White 2001). However, similar to the Yellowstone's management model, wildlife biologists and managers currently guiding the restoration program (now numbering over 30 bison "on-the-ground") describe how restored bison could reach relatively high numbers, dispersed throughout reintroduction area in summer, and each fall moving to lower elevations in areas within or adjacent to the park as the snowpack increased at upper elevations (Steenweg et al. 2016, Parks Canada 2017). Similar to Yellowstone, this viewpoint demonstrates limited understanding of long-term bison populations, their movements, and potential impacts on ecosystem attributes (White 2016).

Thus, to meet their agency policy and legal objectives for maintaining all components of national park ecosystems, both these high-profile, ongoing bison restoration programs may require substantial modifications to integrate the long-known human understanding of bison population at the western edge of its range described above. This requires a new initiative to use interdisciplinary approaches integrating information from archaeology, history, traditional knowledge, wildlife biology, animal movement patterns driven by both food and human predation risk.

2. BACKGROUND FOR A CONCEPTUAL MODEL OF BISON WESTWARD MOVEMENTS

2.1 The "Abundant Center Distribution" Hypothesis for Bison

The long-term range of bison may approximate a classic "abundant center distribution" model (Sagarin et al. 2006), where a species' numbers are generally highest in the center of the range and declined towards areas of more unfavorable habitat or intense predation condition (Holt and Keitt 2000). In the historic record for bison these types of population density processes may have partially influenced areas most susceptible to outer range boundaries fluctuations as human predation intensity fluctuated during the period 1400 to 1885 (Figure 2.1-1). First a period of reduced predation due to human population declines, particularly along the Mississippi Valley as early as 1400 (Woods 2004) may have allowed a major bison population expansion south and east (Mann 2005: 318-321). By the mid-1700s, bison range had expanded greatly, with early European settlers observing the date of their arrival in various regions (Allen 1886, Hornaday 1889) Bison historian F. G. Roe (1972: 228-256) describes this range expansion in detail, remarking that in the southeast:

"… there was no reason inherent in the region why buffalo should not have advanced to the shores of the Gulf of Mexico, as they actually did on the western side of the Mississippi, in Texas. The only probable explanations that suggest themselves are that the species had not occupied the Southeast for a sufficiently long time, or in numbers great enough to withstand the attack of Indian hunting tribes." (Roe 1972: p. 240).

Whatever the processes of bison range expansion during early European colonization period, it did not last long, with bison generally disappearing out of the newly occupied areas to the east the earliest (Allen 1886, Hornaday 1889, Roe 1972). Although core high densities of bison survived in the central and northern plains, large area range contractions occurred particularly on the east, south, and southwest edges of historical range. These areas generally had lower density bison numbers in past times (Lott 2002). The bison extirpation process involved increased predation at range edges, fragmentation of habitats by increased human travel (Oregon Trail, railroads etc.), and ultimately large scale killing in core high density population areas (Hornaday 1889, Isenberg 2000, Colpitts, 2015).

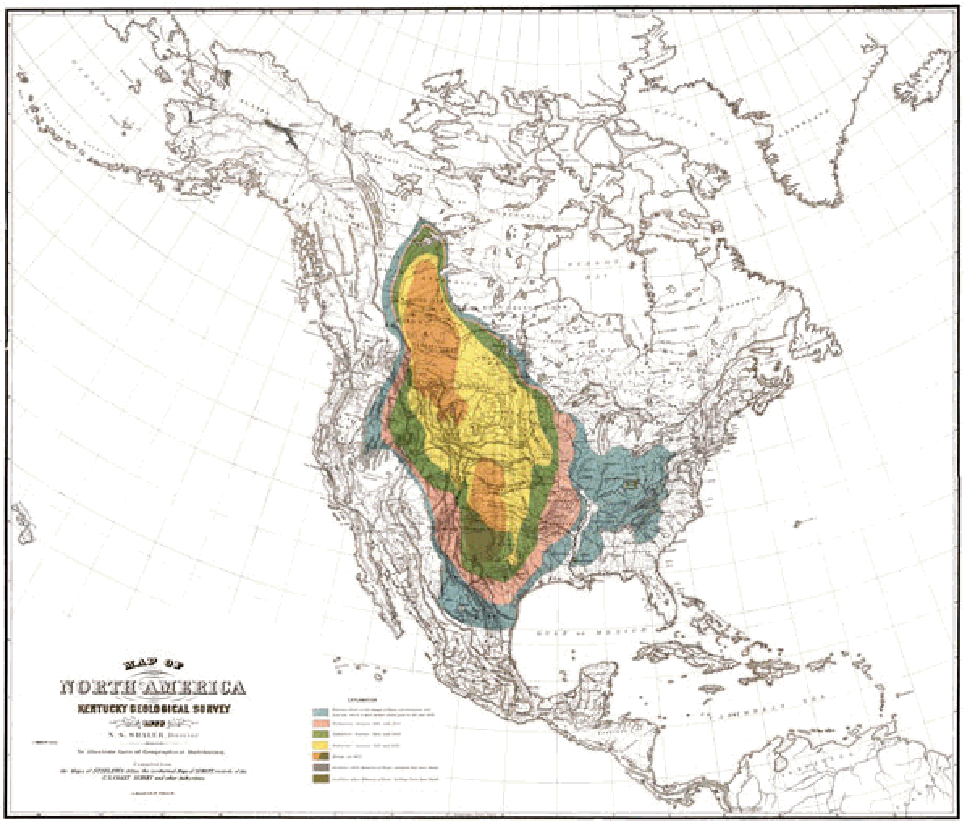

Figure 2.1-1: The spatial process of bison extirpation in North America (1700 to 1880) that indicates the population generally followed an "abundant center distribution" during this period (from Allen 1886). The areas in blue shading indicate the maximum extent of bison range in the 1700s. Areas in the southeast had only been occupied by bison for few decades at this time. The orange areas in the center of the range had persistently high densities of bison until 1850s.

Interdisciplinary research over the last century provides further general support for the abundant center distribution model. Native peoples and early European travelers in the west recognized that depending on the season or location, bison tended to one of two interacting behavior patterns, either low-density "spacers" on the periphery of bison range with limited annual movements or, on the central plains, high density large groups that routinely travel longer distances (Epp 1988). This is typical of other non-territorial migrant ungulates like the African wildebeest or barren-ground caribou-- one behavior strategy is to space and hide, often in woodlands or rough terrain whereas the other behavior mode is to form large groups and routinely move, usually in open smooth terrain (Fryxell et al., 1988). In North America, human hunters saw migratory bison in the thousands on the open plains, but as they travelled through the foothills, mountains, boreal woodlands, bison were secretive and seldom sighted. Some historians estimate that similar to other species with this dual dispersal pattern, the migrant bison herds were more abundant, and if conditions on the plains were favorable, they might outnumber bison spacing in wooded and mountainous terrain by ratios of up to 4 to 1 (Epp 1988, Epp and Dyck 2002).

2.2 The Three-Phase Movement Pattern Hypothesis: A Conceptual Model

For considering potential bison movement patterns into the Western Cordillera, we can view this typical dual state of population conditions as Phase 1 in a three-phase model below where bison, in abundant herds on the plains routinely interact with lower density bison in peripheral areas (Figure 2.2-1). described by .

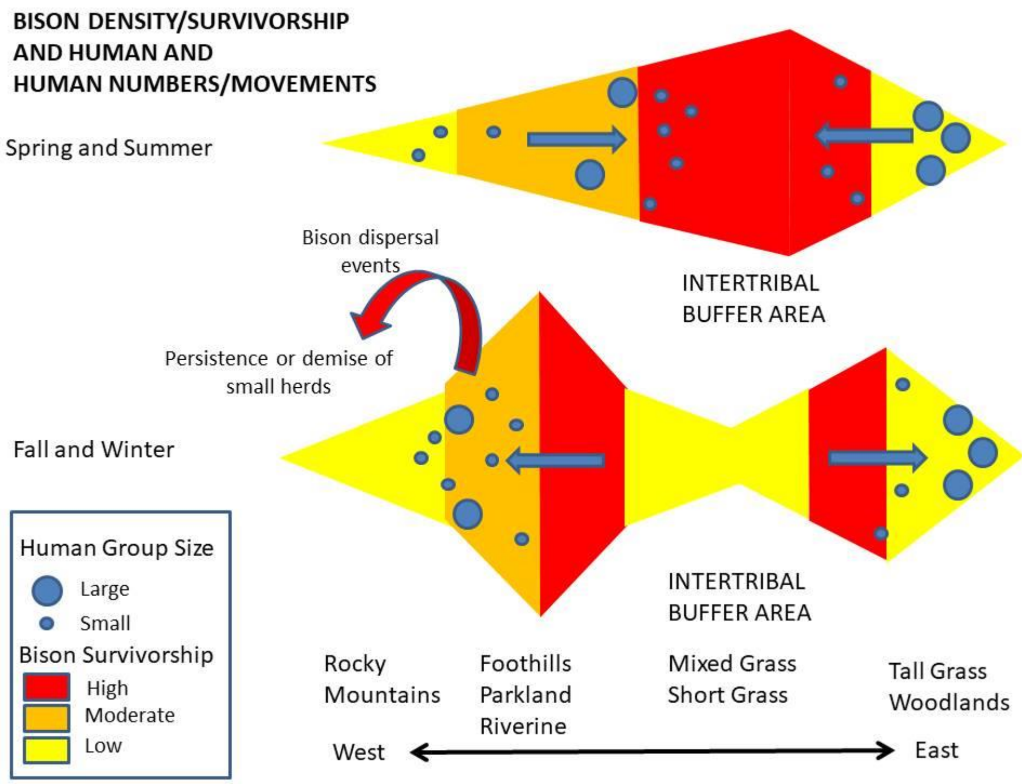

Figure 2.2-1: Three phase model of bison movements showing characteristics of regular bison movements between plains and immediately peripheral areas (modified from Binnema 2001). This annual pattern of movement (Phase 1) provides conditions favorable for periodic dispersals into the mountains or northern woodlands (Phase 2), followed by persistence or demise of these small herds (Phase 3).

Phase 1, or the annual ebb and flow of bison to the western edge of the plains, is the mainspring of bison population dynamics—the routine movement pattern from large herds to the plains in the spring and early summer, and returning to wooded or sheltered areas along the plain's periphery in the late summer, fall and winter (Reeves 1990; Morgan 1979; Binnema 2001, 2016; Peck 2001). The second step involves periodic bison dispersal events from this peripheral zone into the mountains, foothills, or northern forests. A third phase is the persistence or demise of these smaller herds depending on biophysical or cultural conditions. Below, I describe each of these three steps in turn, but some summary points on how this process could facilitate bison dispersal into the mountains are as follows:

- Bison populations persist in core areas with adequate predictable resources for reproducing bison, but not for humans;

- Bison populations may grow substantially when herd size reaches levels where human encounters do not result in high mortality rates;
- Where predictable high density bison source population areas become sought after by two or more antagonistic human groups, this may result in large, intertribal buffer areas rarely entered by large family hunting groups of the conflicting tribes. This can further reduce human encounter rates and cause a positive feedback loop with phase 2 above further increasing bison numbers, thus further increasing intertribal strife and population growth in the source area;
- Population growth and expansion results in bulls, sometimes followed by cow ranging widely beyond the core population area. High human-caused mortality rates around the periphery of these areas may balance population growth within the source population source area;
- Periodically, a pulse of dispersal may occur out the source areas, with high numbers of bison effectively overwhelming predation around the perimeters, and result in bison moving long distances into infrequently used habitats. Causes of this dispersal could include weather events (snowstorms, drought), wide ranging fires that remove grasses outside the growing season, or a response to intense predation;
- Depending on conditions in the locations where bison disperse to, new source populations may grow, persist at low densities, or eventually die out.

2.2.1 Phase 1: Regular Bison Movements between Plains and Peripheral Areas

The first phase of conceptual model focuses on the interactions between core source and peripheral areas that sustained bison populations. Several studies (summarized by Binnema 2016) provide a relatively consistent perspective element of historic bison behavior. Figure 2.2-1 (modified from Binnema 2001) illustrates general annual movement patterns and numbers for bison and humans across a stylized landscape that runs from the Rocky Mountains on the west to the woodlands along the Missouri River and its tributaries to the east. Annually, bison would aggregate in large herds on the Great Plains in spring and summer then disperse in smaller groups to the woodlands and foothills surrounding the plains in winter. Bison bulls were often in the vanguards of these movements, followed by cows and calves (Binnema 2001, Peck 2001). Humans and other predators followed this pattern as closely as possible, but were restrained by their need for wood, shelter, and multiple sources of food, particularly in winter (Epp and Dyck 2002). Through this movement pattern, bison cows would drop their calves in late April and May, and early calf growth would occur while the bison were moving in large, mixed sex groups towards their safest habitats from predation on the short and mixed grass prairies in the centre of the plains (Epp 1988, Geist 1996).

During a period of relatively stable environmental and ecological conditions, the spring and summer center of bison populations would be an optimal location that provided grass, sources of water, and a minimal threat from predation. Then, after the mating season in late July and early August, and the calves were larger and could travel longer distances, bison might begin move back outwards from these driest areas to other habitats. In extreme winters, or very dry summers, bison might be forced outwards into forested habitats routinely used by humans. (Binnema 2001, 2016; Peck 2001).

When we consider that bison numbers on the Great Plains possibly exceeded 10 million during many periods (even as a low estimate), and population growth in favourable years could reach 10%, it is possible that this annual pattern of aggregation for calving and mating in the center of the plains, followed by outward movement might result in up to over one million bison a year being available for dispersal into lightly used habitats on the periphery of bison range.

2.2.2 Phase 2: Bison Dispersals from the Plains into the Cordilleran and Foothill Forests

January 11, 1755: *Moderate freezing weather, travelled none, killed 2 beaver; the winter has set in in earnest…*
January 13: *Travelled none. Indians employed hunting: killed 6 buffalo, saw many going Westward*…
January 17: *… this day pitcht 10 M to ye westward, here we travel as the Cattle Goes*
(From the journals of Anthony Henday as he trapped in the Canadian Rockies foothill forest, Belyea 2000: 142-143).

The second phase of the conceptual model (Figures 2.2-1) is the process bison dispersal pulses, or events, from peripheral areas into the mountains or northern forests. Phase 1, described above, describes an annual pattern of bison production that could result in relatively predictable large numbers of bison reaching peripheral areas of the core population zone. Once here, less predictable stimuli might create a dispersal event where bison would move further west. These events could overwhelm human hunters surrounding the plains, and allow numbers of bison to move relatively long distances into previously lightly used ranges. The location of a dispersal pulse would depend on annually unique climatic, terrain, or predation risk conditions. The location of late summer or fall fires that removed forage would be particularly important in channelling bison movements. These dispersal events helped drive a fascinating ecology of interaction with humans and other species, not just the plains, but in a wide range of habitats around them. Although the focus of this work is on the western edge of bison range westwards into the Rocky Mountains and northwestwards into the boreal foothills, these periodic waves of movements likely also occurred northwards into the parklands and boreal mixed-wood, eastwards into the Red and Missouri river woodlands, and southwards into the dry southern plains.

Our understanding of the phase of the conceptual model is very poor. In fact, there are few descriptions from any of the main disciplines—archaeology, history, or traditional knowledge- of bison dispersal pulses into the foothills, mountains and forests surrounding the core population zone, or what factors drove or drew them into this terrain. Here is list of how some preliminary ideas on how this step of the process could have worked:

- As described above, the regular movements of bison herds on the plains and the periphery of the plains may under some conditions result in large numbers of bison reaching foothills areas. These conditions might include weather, burning or predation patterns on the plains that push bison westwards in high numbers (Binnema 2001, 2016; Peck 2001);
- Because these dispersals come from the edge of the range, historical and archaeological evidence should indicate they are dominated by males that predominate in these range edge

areas and may be the leaders in exploiting unfamiliar terrain (Gates and Larter 1990, Gates et al. 2005);

- In areas where bison encounter higher predation (for example corridors heavily used by humans), dispersal numbers and distances could be most limited. For example, the "Road to the Bison" between today's Missoula and Great Falls, Montana was heavily used by native hunters going to the plains (Scott 2015), thus bison use of these valleys could be low;
- Periodically, bison moving westward from the plains might enter intertribal buffer zones, lightly used by hunters, where low risk of predation allows bison to move long distances into the foothills and mountains. For example, in the 1800s the Kootenay Plains area along the North Saskatchewan River was described as a neutral ground between the Secwepemc (Salish) peoples of the west, and Siksika and Cree on the east (Kay et al. 1999). This area might then be expected to have higher bison use than other areas;
- Another scenario is that if bison enter Cordilleran valleys or passes, they may be contained or pursued by humans and other predators that push them even further westwards into the mountains. In narrower valleys, humans could actually drive bison very deep into the rugged terrain. Again for the North Saskatchewan valley, David Thompson gives in his 1814 account of a trip over Howse Pass an example of his group potentially herding bison westwards down the Blaeberry River in British Columbia (Belyea 1994). In most situations, traditional knowledge might be paraphrased as: "*"It's a good thing to keep those buffalo contained within the mountains."* The corollary of this idea is: "*Only an idiot would chase bison out of the mountains*." Of course, this perspective depends on unique terrain features, and relationships with neighboring human groups.
- Weather conditions (drought, deep snows etc.) in foothills areas might further drive bison further into the mountains, or actually result in bison herds being trapped within the mountains. Archaeologists Kornfeld, Frison and Larson (2010) describe how winter snow accumulation around Colorado's Middle Park might have been important in "providing ready access to winter 'storage-on-the-hoof' resource procurement" for small bison herds and other wildlife.
- Interactions between terrain and vegetation conditions could be very important. Wide valleys with open forests would favor high numbers of bison moving westward. Conversely, narrow constrained terrain with heavy forest cover could limit the number of bison moving west. There may be evidence of native burning to create conditions favoring bison movement into the mountains (White et al. 2001, 2011).
- Given the distance involved in these movements from core plains populations, it is possible that the bones of bison found in the mountains may have bone isotope compositions indicating different forage sources that local conditions (Langemann 2002).

These variables could be evaluated by studying historic bison movements across a range conditions on the plains, in areas peripheral to the plains, and in the mountain travel corridors themselves.

2.2.3 Phase 3: Persistence or Demise of Low Density Bison Populations in Mountains and Forests

After a dispersal event occurs, it is necessary to consider bison persistence along corridors or at the end of corridors over the following winter, or several winters when snow depths will have an important role in the Cordillera or more northern regions. Figure 5.3-1 is a simple hypothetical model of how terrain and snow depth may interact to influence bison mortality rates in the presence of human communal hunting. When snow depths are low, both low density herds on boreal forest plains, or higher density herds on the prairies are well adapted to winter conditions, can avoid human hunting, and will have relatively low mortality. In fact, in the boreal forest, frozen lakes and muskegs could, when snow depths are low, actually increase bison movement rates and reduce predation risk. However, under conditions of higher snow depths and more constrained terrain, bison mortality risk increases sharply. Combining all three phases of bison movement (annual in source areas, dispersal events, persistence in sink areas) from a regional perspective could ultimately greatly help in understanding historical range boundaries.

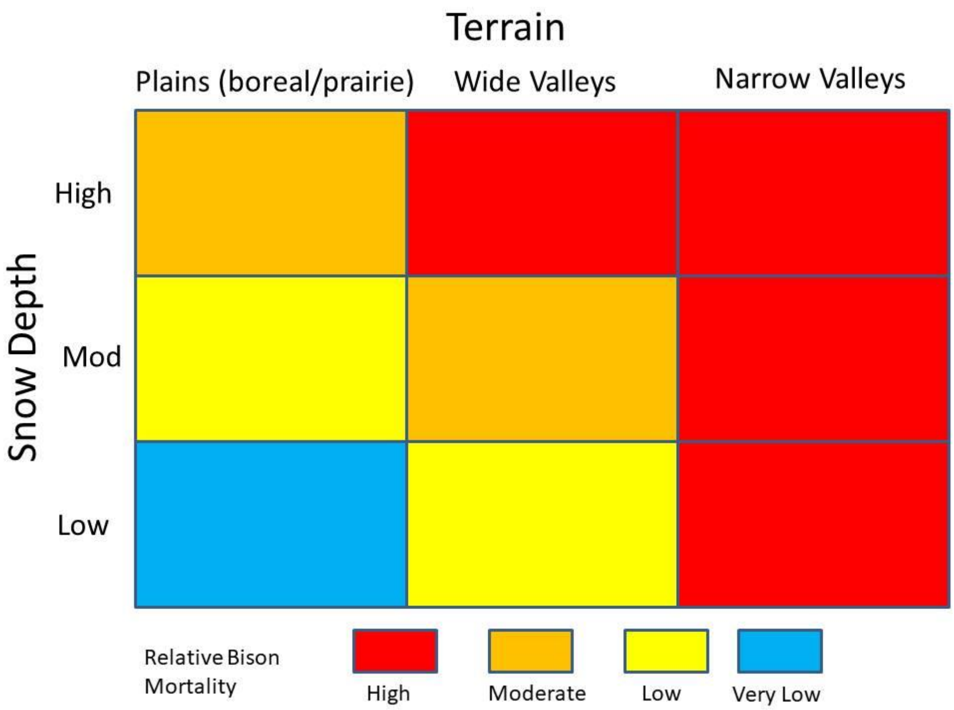

Figure 2.2.3-1. A hypothetical model of how terrain and snow depth may influence bison predation mortality rates over multiple years in low density areas at the western or northern edges of the range.

2.3 Interacting Causes for Dynamics in Bison Movement and Dispersal Patterns

The three-step bison dispersal model described above is theoretically massive “source and sink” bison spatial ecosystem across the Great Plains that likely influenced, at its periphery, bison density, movements, and dispersal into the mountains. The development of these patterns has clearly taken time. North American bison likely shared their most common ancestor with Eurasian bison about 22,000 and 15,000 years B.P. before the last advances of Wisconsin continental glaciation (Wilson 1996, Shapiro *et al.* 2004). After this, southern bison on the continent had distinctive phenotypes (van Zyll de Jong 1993), rapidly developing from *B. antiquus* to an intermediate form *B. occidentalis*, then to the modern form *B. bison* (Wilson et al. 2008). Southern bison moved northwards as the continental ice-sheets retreated, with a gradient between two variants morphologically, but not genetically evident: smaller plains bison in the south, and larger wood bison in the northern forests (Geist 1991, Wilson et al. 2008). Over time, bison have undergone strong morphological change. Ten millennia ago, they were much larger, with horns facing more forward. Some ecologists believe this may have been a response to living at lower densities, moving less, and “facing-down” large predators that did not have communal hunting skills. After arrival of humans in North America, bison have become smaller and more adapted to movement in herds. For southern bison, mobility in large groups became the favored response for bison to minimize predation from humans (Geist 1996).

Thus, living in groups, and particularly large herds on the Great Plains, may have be one of bison’s most resilient traits for persistence over time. Low density populations in adjacent woodlands and foothills, possibly quite ephemeral and “winking in and winking out” depending predation conditions, would then be periodically recharged from herds from large source populations moving from the core to the periphery of the plains. For these source populations, we can view the three sets of factors influencing bison abundance and movement as a continually interacting, evolving process over time as shown in Figure 2.3-1: weather and forage, predator avoidance by bison, and human social patterns.

Clearly through processes such as climate change or changing human behavior patterns, these interactions could change bison numbers greatly over time. In terms of weather and forage, a period of moist summers and warm winters in a certain region of the plains would likely stimulate high bison population growth. Growth of human populations due to the increasing use of agricultural foods such as corn would likely influence bison numbers. Or consider the paradoxical proposition that what if the adoption of more deadly weapons such as the bow and arrow may have in some places actually favored the hunted, not the hunters? This could occur for not only could these weapons kill bison, but they also made warfare within the buffer zones more deadly and thus reduced human hunter use. Possibly the adoption of the horse also have expanded some zones because required tribes to space apart even further to avoid raids from their enemies.

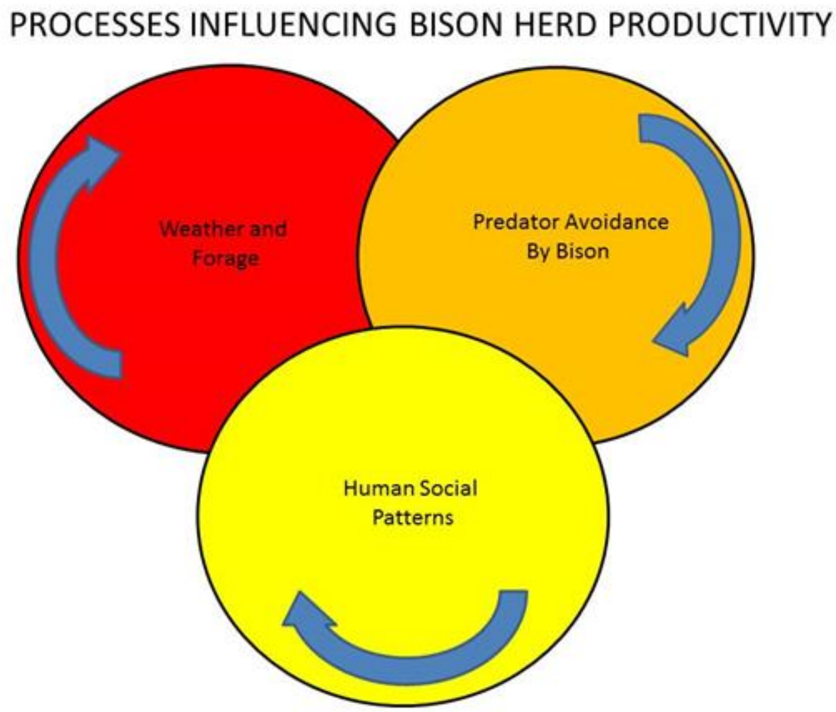

Figure 2.3-1: Three interacting groups of processes influencing bison abundance and movement patterns.

How can we evaluate how these and other factors may have changed bison population density and distributions over time? Archaeologist Judith Cooper (2008) analysed the study results from over 900 provincial and state archeological sites where bison hunting or processing was inferred from bone material. The abundance of bone matter was plotted by site for the Great Plains, and smoothed for three time periods after A.D. 500 to show general abundance patterns (Figure 2.3.2).

This evaluation technique appears to demonstrate great changes in the abundance of bison bone assemblages in archaeological sites over time. If this is representative of relative bison populations, the upper Missouri and North Platte river area may have consistently had high bison densities over the last 1500 years, but other areas such as the upper Powder River, or the plains of Texas and New Mexico may have only had high densities of bison in the last few hundred years (Cooper 2008). Understanding these potential changes in regional bison densities over time requires more research. These patterns may be tied to changing climate, changing extents of tribal buffer zones and settlement effects by Europeans (Roe 1972, Kay 1994, Geist 1996, Cooper 2008). Most important may be the general collapse of native human populations across Americas due to pandemics such as smallpox (Dobyns 1983, Denevan 1992, Mann 2005). These depopulations likely began to occur on the southeast North American plains as early as the 1600s (Ramenofsky and Galloway 1997, Calloway 2005). Smallpox reached the middle Missouri and lower Saskatchewan rivers in the 1730s (Daschuk 2013) and spread across the plains in the 1780s (Fenn 2001, Calloway 2005). Numerous pandemics occurred thereafter.

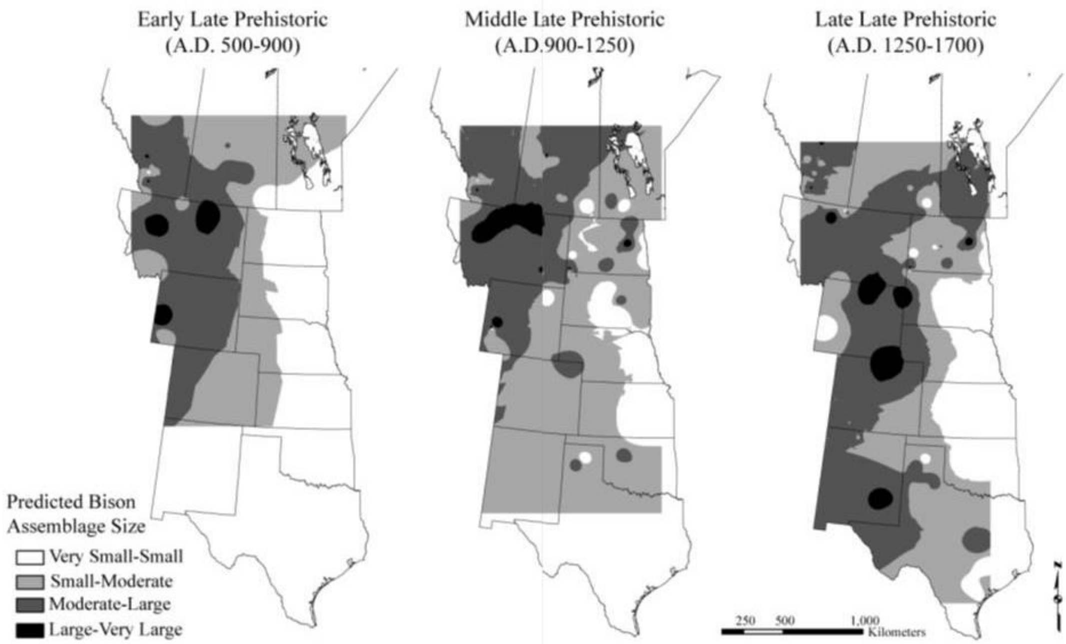

Figure 2.3-2. Patterns of bison populations inferred from predicted bone assemblage for archaeological sites for 3 time periods from A.D. 500 to A.D. 1700 (from Cooper 2008).

The key aspect of the three-phase bison movement model described above is that its key driving factors-- weather and forage availability, bison predation avoidance, and human cultural patterns—are all continually interacting. The plains could be a difficult environment for survival, even by hardy bison. Changing weather patterns, forage growth, winter severity, and water availability were thus the primary, but highly variable “bottom up” influence on where and when bison could exist, particularly large numbers (Bamforth 1988, Beaudoin 2016). In some areas, water sources would strongly influence where and when bison could forage and safely avoid predators—where water sources were few, humans and other predators could wait in ambush knowing that bison must come for water routinely. Thus, drought effects on bison productivity would be exacerbated by predators increasingly reduced bison survivorship as water sources became fewer and more predictable. Interactions between predation and drought may account for the near absence of bison in the archaeological record around 1000 AD (Isenberg 2000:27, Cooper 2008, Figure 2.3.2 above). In addition, humans could greatly alter forage availability through the use of fire. Finally, the major overarching interacting “top-down” process was the human cultural interactions hunting such as communal hunting or the location of tribal buffer zones, for this clearly influenced the spatial use by humans, bison’s primary hunter, and thus habitat use and predation avoidance patterns by the bison.

Below, I consider each of these groups of factors in more detail, with particular reference to source populations on the Great Plains.

2.3.1 Bison Adaption to Great Plains Terrain, Forage and Weather

Bison are North America's largest herbivore, historically persisting in large numbers in some of the most extreme areas for summer drought and winter cold on the continent. Thus there are many key linkages between bison, grassland conditions, and weather patterns (research reviewed by Binnema 2001, Peck 2001, Lott 2002, Gates et al. 2010). Bison's movement pattern out on the Great Plains in the spring coincides with the early emergence and most productive period for warm season grasses in the mixed and short grass prairie (Morgan 1979). In spring and early summer, potholes and other water sources remain most common allowing relatively expansive use of the habitat. Lactating cows and rutting bulls require ample water. Although a spring blizzard could be detrimental to the health of human hunters if bison cannot be found, these rapidly melting snowfalls only allow for a wider range of habitat use to avoid humans. As the summer proceeds, plant phenology and drought begin to drive bison closer to streams and to higher elevation areas where cool season grasses such as fescue are more abundant. During periods of extreme drought, the convergence of bison and other species on limited water sources on the plains is significant. Morgan (1979, 1991: 155-157) and Daschuk (2009) describe how the importance of ponds used by bison during droughts may account for First Nation's reverence of the beaver. Seager and Herweiger (2011) describe how a drought in the 1850s and 60s helped accelerate the demise of bison on the Great Plains:

This severe drought could not have come at a worse time for the Plains bison. Normally during droughts, of which they had seen many in their thousands of years on the Plains, they would have moved to the valleys but this time those ecological niches were occupied by Indians and emigrants and by their grazing animals. With the best grasses unavailable to them the bisons died in vast numbers. This was just one of the many factors (including more hunting) that led to their near extinction a few decades later.

For the Texas Panhandle specifically, Charles Goodnight told Haley (1936) that the summer of 1867 was so dry that bison herds gathered on the Little Colorado River in such numbers that "They had remained until the grass was gone, and had died from starvation by thousands and thousands. The dead buffaloes, which extended for a hundred miles or more, were so thick they resembled a pumpkin field."

After mating, bulls may lead movements out of the core areas on the plains. Late season drought or prairie fires may accelerate this movement to the edges of the plains. If forage is adequate however, bison may remain in this area throughout the winter, but drought, fire, cold weather or blizzards can force bison herds into parklands, riparian valleys or foothills. Under these conditions it is likely in early winter that a large dispersal event westward into the mountains, or northwards into the parklands and boreal mixed-wood would occur. Perhaps some combination of weather (drought followed by early season blizzards), fire burning off the plains grasses, and predation patterns would drive these movements. Cows, now relatively mobile calves, would follow bulls into new terrain beyond their normal migration patterns.

Also important was interaction between weather and human ignitions that resulted in large fires, both planned and unplanned, across the plains. These burns altered forage availability for bison. Wet spring and early summers create high grass biomass, and this creates a high potential for wide-ranging fires once grasses cure in the later summer or the following spring. In winters with low snowfall, fires can burn on the plains even in mid-winter, and there is often another period of high flammability after spring snow-melt, but before new grass growth occurs. Human mastery of fire, and the ability to skillfully use it to drive bison herds, or constrain where they could forage, would thus be closely linked to annual weather patterns. References of human use of fire to manage bison on the plains are numerous, for example see reviews of historical references by Oetelaar (2014), Binnema (2016), and Cunfer (2016). As Hind described, after his visits to the plains near the South Fork of the Saskatchewan (1860):

The ranges of the buffalo in the north-western prairies are still maintained with great exactness, and old hunters, if the plains have not been burnt, can generally tell the direction in which herds will be found at certain seasons of the year. If the plains have been extensively burnt in the autumn, the search for the main herds during the following spring must depend on the course the fires have taken

2.3.2 Bison Response to Predation on the Plains

Bison's adaption to living on expansive grasslands provides one of its defenses against predators such as humans, grizzly bears and wolves. On the plains bison can aggregate in large groups, and if challenged by predators, to move in almost unpredictable directions. Early in spring, the general pattern was for bison to move out of the woodlands and towards the center of their summer range. In this way, bison distance themselves from humans who, in March and April still need wood for heat and shelter (Binnema 2001, 2016; Peck 2001). Moreover, in April and May, wolves are tied to their den sites and cannot follow a herd for more than a few dozen kilometers. And if predators do venture out on the plains in the spring, due to lack of alternate food sources, they are often totally dependent on finding bison herds, and this could difficult in the expansive landscape. As bison herd sizes begin to grow in early summer at the center of their range (Figure 2.3.2-1), their immunity to high rates of predation decreases due to their sheer numbers versus the number of predators they might encounter. The figure below provides a simplified view of how herd size can improve survivorship rates in terms of responding to human group size. In the core calving and rutting areas used in spring and summer, groups of human predators are generally at their smallest, and bison herd size is at its largest, thus predation events result in the lowest rates of mortality. Moreover, at this time, bison have mixed herds where the large males can help protect calves from humans, wolves, or bears.

Finally, if bison do encounter a serious predation threat on the plains, they can respond by moving in a wide range of directions, and as the calves rapidly grow, moving long distances at rates of travel their predators cannot sustain (Epp, 1988; Binnema 2001). In 1834, naturalist John Kirk Townsend (1978) was ascending the North Platte River in today's Wyoming, and observed that:

"*buffalo still continue immensely numerous in every direction, and our men kill great numbers...*". A day later he recorded, "*When we rose this morning, not a single buffalo, of the many thousands that yesterday strewed the plain, was to be seen. It seemed like magic. Where could they have gone? I asked myself this question again and again, but in vain*."

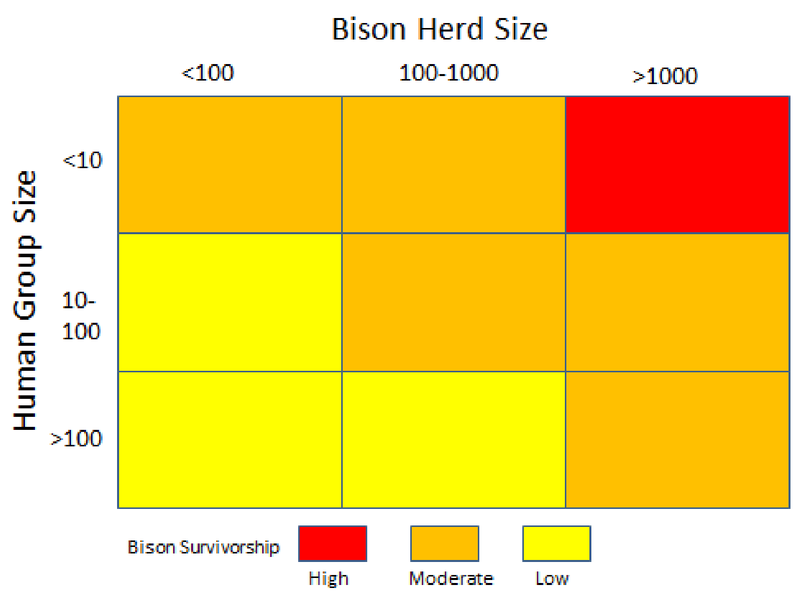

Figure 2.3.2-1: A conceptual model of bison mortality rates on open grasslands as a function of herd and human group size. Large herds have highest survivorship during encounters with human hunters.

2.3.3 Human Cultural Patterns on the Plains

The third group of factors arises from the first two—the significant effects of human cultural patterns. Because humans recognized that bison were in essence immense packages of important resources such as fat, protein, robes, hides, and leather, they attracted great attention. Bison could be often be most easily be obtained by organized human social groups, therefore they stimulated human behavior to form bands of communal hunters. Further, often more importantly, large accompanying camps of women, children and elders could be required to properly process the wide-range bison resources (Arthur 1975, Frison 1978; Reeves 1990, Colpitts 2015).

The historical and traditional knowledge literature provides numerous descriptions of communal bison hunting techniques (e.g., Kane 1859, Hind 1860, Spry 1968, Wood and Thiessen 1985). A range of human effects on bison density are possible—from displacing bison and reducing numbers to actually creating conditions favoring high densities of bison. Fawcett (1987) and Bamforth (1988) describe a range of motivations for humans to hunt in large groups. Possibly the most significant motivations for large hunting groups were to successfully herd and kill groups of bison, and also to have adequate hands available, particularly those of women and children to process the kills, but there were many other reasons such as visiting potential areas with predictable bison harvesting for annual sundances and other rituals that supported tribal and First Nation organization (Fawcett 1987). Large human groups killed many bison, and there are numerous accounts of how the hunt had to be carefully managed, or bison would rapidly flee from First Nation groups (Wood and Theissen 1985). Obviously, routine human hunting of an area could, over time result in lower bison densities.

However, other social factors could actually increase bison densities. As described above, human burning likely maintained vast areas of grassland on the Great Plains (Cunfer 2016), and attracted bison to predictable locations. But possibly most importantly were inter-tribal buffer zones. These zones usually arise in an area relatively unfavorable to human occupation—a high mountain range, or the wide windy wastes of the open Great Plains. Human groups, living in more hospitable habitats on either side of these barriers may share these boundary buffers as a common hunting or foraging area, but commonly the buffer zone is a “no-mans-land”, often between tribes at war. Here, only small groups of hunters or raiders venture, prepared for battle with their neighbors. Families, elders and children dwell in safer areas in the core of a tribes territorial areas. Many early European travellers observed the abundance of wildlife in intertribal buffer zones. For example, when Captain John Palliser traversed Canada’s shortgrass prairie in the 1850s, he observed that:

“The abundance of game here [and not anywhere else] is accounted for by its being the neutral ground of the Crees, Assineboines, and Blackfeet; none of these tribes are in the habit of re-sorting to its neighborhood except in war parties…. We are now in the heart of the buffalo country. This region may be called a buffalo preserve, being the battle-ground between the Crees and the Blackfeet…”
(Spry, 1968: p. 146)

Kay (2007) enumerated observations of wildlife and human abundance made in the journals of several observers in the Lewis and Clark expedition across western North America from 1804 to 1806. This large dataset clearly shows a pattern of high wildlife abundance in areas not heavily used by people, and in war zones wildlife is most abundant. Moreover, on the Great Plains, bison was only usually abundant in the center of these buffers zones, and their numbers rapidly dropped in areas frequented by humans. White-tailed deer appeared to be the most predation resistant of the larger game species. Other researchers that also describe high bison numbers in intertribal buffer zones on the Central Plains include West (1995), Flores (1999, 2003), and Hart (2001). It is interesting to consider that cultural developments such as improved weaponry (e.g., bow and arrow), introduction of the horse, and ultimately the expansion horse-mounted, Native American cultures such as the Blackfoot, Comanche, and Sioux (Binnema 2001; Hämäläinen 2008a,b) may have in some cases actually increased the areas of inter-tribal buffer zones, and thus favoured some increase in bison numbers on the Great Plains. Bamforth (1987:9) remarks the use of the horse in hunting bison “probably increased herd size and almost certainly made the animals far more mobile than in pre-horse times.” These cultural changes were of course further influenced as pandemics swept through the human populations across the plains (Calloway 2005, Daschuk 2013, Section 2.3 above).

2.4 Bison in Woodlands and Forests

Although this study and the above review focusses on bison on the movements of bison between prairie and mountains, historic bison range extends thousands of kilometers northwards (see Figure 2.1) into the foothill and boreal forests of North America (Allen 1876, Hornaday 1889, Roe 1972, Gates et al. 2011). Several of the northern bison movement routes evaluated here have areas of forest cover along their corridors between the northern plains and the Cordillera (Figure 1.1-1). These corridors lie through the zone where bison transition from plains to a woods ecotype. Bison are typically in smaller herds in this habitat, and their behavior may provide some information of characteristics of bison during Phase 2, or dispersal events phase of the conceptual model (Figure 2.2).

The difference between bison behavior the prairie versus woodlands has long been recognized. Henry Kelsey, who in 1690 was the first European to describe bison, travelled with Cree and Assiniboine hunting from large herds on the plains. However, he also commented on the rarity of bison in woodlands during the summer while camped at the edge of hills in southern Saskatchewan or Manitoba (location uncertain, Kelsey 1993):

August 28, 1691- *This day we lay still* y^e *Indians being willing for to go hunt Buffillo because there is none of these Beast in* y^e *woods…*

William Pink, a Hudson's Bay Company trader wintering with the Cree, likely northeast of Edmonton near Lac La Biche, made some of the first written observations of "wood bison":

November 13, 1766—*"... Heare I find Beaver very plenty the contrey here being fool of small rivers or cricks and standing waters, the land coavered with woods. Boffalous likewise plenty but very wilde to what the are in the oapen contrey* " (from William Pink's Journal, Maccago, 2009).

Based on studies of other migratory ungulates by Fryxell et al. (1988) and other studies, Epp (1988) and Epp and Dyck (2002) described bison movement behaviors on a spectrum from migratory in large groups on to the prairies, to non-migratory in smaller groups in woodlands. This range of movement behavior has been described for the African wildebeest by Estes (1974:188):

The wildebeest's variable social system enables it to alter its distribution pattern to fit a wide range of environmental conditions. Populations can follow any pattern from completely sedentary to migratory and more or less continually nomadic… Sedentary and migratory patterns often coexist within the same populations, and even at the same time and place.

Today, bison (woods and plains variants) still utilize large areas of boreal forest (e.g., Wood Buffalo National Park), and in some cases experience habitat and predation conditions similar to the historical patterns. Here are some salient characteristics of bison in these habitats derived from historical observations and current studies are be relevant to bison dispersion into the Cordillera in wooded valleys or northern areas:

- Bison in forests and woodlands were usually at lower densities, and generally did not form large herds such as found on the Great Plains (Epp 1988);
- In woodland areas, alternate prey to bison included moose, elk, mule deer and white-tailed deer. Thus predators such as humans, wolves, or bears could persist here even when bison densities were low. If bison were a preferred prey species, these predators could theoretically eliminate bison from some areas;
- Bison in forests required different human hunting techniques that bison on the plains. For example, in 1791 Hudson's Bay Company trader Peter Fidler hunted bison with the Chipewyan's in the forests south of Great Slave Lake, and the next winter he was with the Piegan hunting on the plains west of Calgary. With this knowledge, he remarked:

  December 28, 1792: … *the Buffalo in the Plains will not run half so far when frightened as those that are found amongst the woods. They will sometimes run & gallop several miles before they even stop the least. Those in the Plains generally stand several shots, particularly if first shot kills, before they run away, Those in the woods seldom more than 1 shot.* (Haig 1991:41)

  James Hector made a similar journal observation near Pipestone Pass in today's Banff National Park:

  August 26, 1859: *William told us at night that two years ago he killed a buffalo cow at this place, and that he saw at the time a band of seven,—two bulls, four cows, and a calf. They were of the thick-wood variety, which are larger and blacker, and with more spreading horns, than those of the prairies. They run swiftly through the woods, and, are quite as wary and difficult to hunt as the moose deer* (Spry 1968: p. 441).

2.5 Summary of Model for Bison Dispersal into Mountains and Forests

In summary, the evolution of the plains bison over the last 10 millennia, and the development of large productive herds in the centre of the Great Plains and their dispersals westwards was a complex interaction of abiotic and biotic factors with basic human nature itself. We can view this as a three-phase process (Figure 2.5-1). Phase 1 was a great annual "heartbeat" of bison movements between the center of the plains and their periphery. In spring and early summer large herds of bison would aggregate towards the center of the plains, and in late summer, fall and winter bison would move to surrounding woodland and foothill areas (Binnema 2016). This was the core process of an ecosystem that sustained a large core bison population that could not only sustainably feed its dependent predators such as humans, wolves and bears, but also create surpluses that could disperse further into adjacent areas.

Phase 2 and 3 of the movement model is less poorly understood. During these phases, smaller, spatially separated herds move into the mountains. Conceptually, Phase 2 can be viewed as a process where some combination terrain, vegetation, climatic and risk factors stimulate bison movements, possibly as periodic dispersal events, deep into the foothills, mountains and forests surrounding the plains. Once here, whether these herds persist or disappear (Phase 3), depends on biophysical factors (terrain, vegetation, snow depth) all interacting with communal hunting patterns.

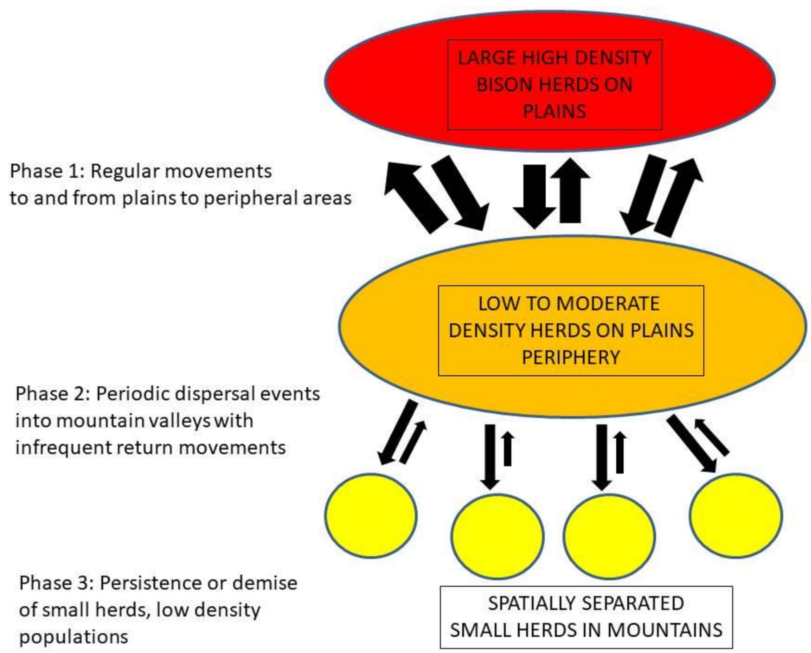

Figure 2.5-1: A three-phase conceptual model breaking down the process of periodic bison movements into the Western Cordillera.

3. METHODS

3.1 Landscape Ecology Approach

The converging research approaches of movement ecology (Aune et al. 2011, Zeller et al. 2012, Wade et al. 2015) and landscape genetics (Manel 2003, Keller 2015) provide a conceptual framework to evaluate the landscape-scale patterns of animal movements and incorporate movements into biodiversity research and conservation. A common product of these studies is a mathematical landscape resistance model, which represents the cost of movement, reduction in survival, or willingness of an animal to move through the environment as a function of landscape characteristics such as cover type, topography, predation risk, or degree of anthropogenic disturbance (Chetkiewicz 2006, Hilty 2006). Moreover, as increased knowledge of traditional human occupation patterns, movements, and hunting patterns becomes available through archaeological, historical, and traditional knowledge studies, this can also be integrated within spatial modelling frameworks (Osicki 2012). Thus, the historical long-distance movements of bison into the western Cordillera provide an opportunity to apply these research frameworks using a range of interdisciplinary knowledge sources for bison, once one of the widest ranging terrestrial mammals in North America. Moreover, for the western edge of bison range, numerous potential corridors exist for bison to move westwards into the mountains (Figure 1.1-1). Through comparison of patterns of movement within and between these corridors, we can obtain greater understanding of the bison's historical travel patterns, and large vertebrate ecology in general.

For this preliminary investigation, I hypothesize that bison generally followed an "abundant center distribution" (Figure 2.1-1) with movement corridors to the west being relatively direct from core population areas on the plains. These corridors would usually follow terrain lines of least resistance, and streams that were dependable sources of water. Bison certainly had more complex historical movements, either southwards or northwards, and often driven by fire or climate (see ecological review above), but for this initial investigation, the most direct route westwards from potential population core areas were evaluated. Further, I hypothesized that a three-phase movement model (Figures 2.2-1 and 2.5-1) would be a likely scenario that would lead to western dispersal. Routine, annual movements of bison from the center of the plains to peripheral areas could result in relatively large numbers of bison being in a position to use individual corridors depending on a range of biophysical characteristics for each individual corridor, and other factors such as time of year, weather, human use patterns etc.

Thus, for a set of likely potential bison movement corridors into the Western Cordillera, I evaluated:

- The potential bison source population area for the corridor- where was it, during what historical periods it was used, during what time of year was it used, where were known movement corridors westward, what were the human use patterns of the source area?

- Peripheral areas routinely occupied by bison to the west of the source- where were they, when were they occupied both by historic period and by time of year, what were their terrain and vegetation cover characteristics, and what were the human use patterns of the peripheral area?
- Travel corridors into the mountains- again, where were they, when were they occupied both historical period, and by time of year, what were their terrain and vegetation cover characteristics, and what were the humans use patterns over time in these corridors? What climatic or biological factors might favor dispersals into the corridors? What evidence is there that the corridor was occupied for long-term periods of time by self-sustaining bison populations independent of dispersals from the source or peripheral areas?

Several sources of information provided information to answer or partially answer these questions.

3.2 Archaeology

Archaeologists Kornfeld, Frison and Larson (2010) observe that: "*No other place in North America or possibly even the world offers a better opportunity to study prehistoric large mammal hunting strategies than the Northwestern Plains and the adjoining Rocky Mountains."* Moreover, understanding these cultural patterns can in turn then inform ecological conservation. Langemann (2011) in her discussion on the importance of archaeological studies for bison restoration in Banff and Waterton national parks observes:

Archaeological finds of bison, like a 3,700-year-old skull site at high elevation in Blakiston valley, can speak to the presence of bison in particular places at particular times. In addition, isotopic studies of their bone and teeth have shown patterns of seasonal migration between the fescue grasslands of the montane and the drier grasslands of the high prairies. It would make a difference to a bison recovery strategy if you knew the proportion of a herd that spent all their days in the park as compared to that which spent their time in seasonal migrations, or whether bison had been completely absent from an area for long periods.

Cooper's (2008) meta-analysis of archaeological data provides an indication of late prehistoric bison density patterns broken-down by three multi-hundred-year periods based upon communal kill site data (Figure 2.3-2). This provided a general idea of potential source population areas. Then, for each corridor I consulted published or website available reports for individual sites for information on the sex and age class of bison in the sample, and isotopic analyses of areas where these bison may have foraged or obtained water over time (see Cannon et al. 2015 for other examples of this technique).

3.3 Historical First Person Journal Accounts

Numerous researchers have analysed historical data evaluate bison seasonal movement patterns (summarized by Binnema 2001, 2016; Peck 2001) on the plains and periphery. More detailed spatial and temporal analysis of first-person journal accounts can provide useful data on wildlife abundance and distribution for specific areas or regions (Kay 1994). Most recently, Hart (2001), Kay (2007) and Bailey (2016) have provided examples of regional analyses of journal accounts that can be used to evaluate bison use within source, peripheral areas to the source, and corridors of the potential "three-phase" movement model.

For potential bison movement corridors, I continue to expand on their work by creating a database of historical journal accounts slightly modified from Kay's (2007) methodology. The database includes data on wildlife seen, wildlife killed, and herd size for wildlife species including: bison (*Bison bison*), elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus hemionus*), blacktailed Deer (*O. h. columbianus*), moose (*Alces alces*), pronghorn antelope (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*), grizzly bears (*Ursus arctos*), black bears (*U. americanus*), and grey wolves (*Canis lupus*).

- Quality of Location Observation- High for < 2 km resolution for overnight camp, moderate for 2-20 km resolution for location, low for >20 km resolution;
- Quality of Wildlife Observation: High for relatively complete wildlife observations for the day (e.g. Lewis and Clark journals), moderate for moderately complete, often just for game hunted, or references to food availability for the journalist's group, or low for a low quality observation or no data when there is no reference to wildlife (possibly due to either abundant game, or good food stores).
- Wildlife Seen Index- For each wildlife species for each day, "wildlife seen" is assigned a value of 1 for old sign, 2 for fresh sign, and 3 if the journalist actually saw the animal.
- Wildlife Killed- The actual number of wildlife killed is recorded per day per species if available. Where this is recorded as "some", this assigned a 3, "several" is assigned a 7, and "many" or "plenty" is a 20.
- Herd Size- For "herd size", if large groups of animals were seen or killed, this was assigned a "10" for that species-day.
- Native American presence- Also similar to Kay (2007), Native American occurrence was recorded as follows: old sign "1", fresh sign "2", or if a few native people were actually seen "3", or more than 10 people, a "10".

For first person journal databases for early travellers traversing bison range, I begin the database several days before bison or bison sign was actually encountered and continue until several days after the last bison was sighted. In addition, under "comments" I recorded journalist's observations on bison movement direction or causes.

3.4 Water Availability and Terrain

Several studies of wildlife movement through the western Cordillera and other areas show the importance of the width and length of valley bottom wildlife movement corridors (<25 degrees valley slope), particularly when species such as wary carnivores or ungulates are trying to avoid human disturbance or hunting (BCEAG 1998, Duke et al. 2001, Hilty et al. 2006).

I used "Google Earth" and automobile field trips to evaluate terrain conditions along potential movement corridors from the potential bison source population area to the western limits of bison range as indicated by archaeological or historical observations (see above). For preliminary evaluation, I visualized corridors as segments of linked 10 km by 10 km polygons running along potential bison movement routes from high density core areas on the plains westward into the cordillera. For terrain conditions, using Google Earth or on-the-ground observations it is possible to evaluate the following conditions along corridors:

- Length (km) of segments of corridors where valley bottom slopes are <100m in width,
- Length (km) of corridor segments 100m to 500m in width,
- Length (km) of corridor segments 500m to 1000m in width.
- Other terrain constraints to wildlife movement including cliff bands, canyons, lakes etc.

3.5 Vegetation

Historical vegetation cover, particularly when cover interacts with terrain, can influence wildlife movement through a variety of ways (BCEAG 1998, Zeller et al. 2012, Wade et al. 2015). For bison, large areas of open grassland allowed bison to form large groups and, when disturbed, move in unpredictable directions ways (see Section 2.5 above). In more constrained terrain, open vegetation cover might favor bison hunters trying to move bison towards terrain traps (Frison 2004, Brink 2008, Kornfeld 2010). Alternatively, low densities of bison in dense forest cover would be difficult to detect, and difficult to drive towards pounds or other communal hunting locations (Epp 1988). Hudson's Bay Company trader Peter Fidler travelled with Native Americans during bison hunts both in open prairie and forested environments. The extended passage below from Fidler's journal for December 28, 1792, while on the edge of the prairies near today's Calgary Alberta contrasts bison behavior in these habitats:

The Young Men sleep out all night in general, when they bring the Buffalo to the Pound, & sometimes they will bring whole herds above 40 miles off & sleep 2 or 3 nights according as they can drive them in a direct manner or not towards the Pound. The Old Men & Boys attend to the Dead Men, the Buffalo is pretty nigh, one or 2 men alternately keep a constant look out to notice when the Young men have brought the herd near, when the holler is made & every Oldman & boy immediately runs to the Dead men & lays flat on the ground, before the Buffalo is very nigh that they might see nothing stirring. The tent s are always pitched in a hollow that the Buffalo cannot see them until they are just on the point of getting into the Pound. Bringing the Buffalo to the Pound, particularly when at a great distance, is a very *hard job for the Young men, as they are obliged to run so very much to keep the Buffalo in the proper direction for the Pound. The is a deal of art in this driving the then the way they wish, as it is such a wild Animal, & the sight of a single person will frighten a whole herd. They will smell a person at an amazing distance when they are to the leeward of him, & if one runs, should there be thousands in the herd, they will all run; the Buffalo in the Plains will not run half so far when frightened as those that are found amongst the woods. They will sometimes run & gallop several miles before they even stop the least. Those in the Plains generally stand several shots, particularly if first shot kills, before they run away, Those in the woods seldom more than 1 shot.* (Haig, 1991:p. 42).

Similar to terrain conditions above, Google Earth and road travel was used to generally characterize current vegetation cover along 10 km by 10 km polygons linked along potential corridors from the plains into the mountains. For an initial scoping, this was simply characterized as dry grassland/shrubland, grassland, and forest. For future analysis, this could be better evaluated using digital maps of potential natural vegetation such as from the US National Vegetation Classification (USNVC 2016) and

In areas with current forest cover, I used historical photographs to evaluate past vegetation. These conditions in these views was further evaluated with long-term fire history information from regional mapping models of long-term fire frequency and reference vegetation conditions (such as LANDFIRE http://www.landfire.gov/) and individual fire history studies for specific areas. Further, I made repeat photographs of many historic views to assess vegetation cover change under modern conditions (see http://lensoftimenorthwest.com/). The repeat photographs provided opportunities for two additional interpretations:

- How do vegetation conditions change with less frequent fire? In some areas wildlife movement corridors may have been maintained by Native Americans burning (Arno and Barrett 1999: White et al. 2001). Large increases in current forest cover along wildlife corridors could indicate that Native Americans has historically maintained open vegetation conditions along corridors for attracting or driving bison.
- How do vegetation conditions change with changes in herbivore intensity? Historically, in areas with high bison density, trampling or browsing may have reduced the cover of woody species such as aspen or willow (Campbell et al. 1994). In contrast, in some modern landscapes, high densities of ungulates such as bison or elk may influence woody vegetation cover (White et al. 1998), and comparing modern to historic views can allow interpretations of possible past bison use.

3.6 Bison Wallows

Wallows are circular depressions formed by bison repeatedly rolling in soft soil (Figure 3.1-1). Both male and female bison may wallow during warmer season for a variety reasons including protection from flies and mating displays (Roe 1972: p.100-105; Coppedge and Shaw 2000). After use, wallows may become grass covered, and can be persistent on the landscape. The location and number of historic bison wallows can provide a source of information for the general region and specific areas utilized by plains bison during the late spring, summer and fall season. Wallows made during the warm season could indicate birthing and breeding behavior in the area, and thus a self-sustaining population that may not be necessarily dependent on dispersals from other core areas.

I used three techniques (described in detail in Appendix A) to determine wallow abundance:

- Google Earth- Recently active wallows with bare soil are visible in Google Earth, whereas historic grass covered wallows usually are not. For current-day existing herds I utilized Google Earth to locate and build a database of wallows locations. This provides a coarse level of understanding about on what terrain or vegetation types might be favored for historic wallowing for a given region or landscape;
- Road Plots- While driving potential bison movement corridors, I looked for historic wallows at likely locations (see above) from the plains source population area through to peripheral ranges around the plains, to the actual potential routes through the mountains. At likely locations I did a "road plot" or a rough tally of bison wallows per 1 kilometer x 100m of undisturbed range lands adjacent to the road.
- Hiking Transects- For smaller meadows or backcountry areas, particularly in the mountains, I tallied wallows while hiking transects of series of approximately 100m by 20m (Appendix A). Characteristics recorded for wallow locations included vegetation, soils, distance to water and cover, wallow dimensions, and wallow shape rating (where A= obvious wallow, B= likely wallow, and C= possible wallow). Hiking transects were also done on lands adjacent to current day bison herds in parks or on ranches to evaluate if historic wallows densities have similar densities and locations to modern wallows (see Google Earth above).

Figure 3.6-1: A Google Earth satellite image of current day bison wallows and trails leading to water on the National Bison Refuge, near Ravalli Montana. Wallows are approximately 2-4 m in diameter.

Preliminary results of transects of historic wallow abundance suggest that the technique likely has best application in the northern regions, or higher elevations of historic bison range. In southern areas, especially at lower elevations, few historic wallows are observed, even in locations where bison occurrence is common in the historic or archaeological record. This included plots and transects done in the Platte, lower Yellowstone, Snake watersheds. Potential reasons for the low number of wallows observed in southern versus northern regions include:

- Burrowing animals- Species such as prairie dogs, ground squirrels, pocket gophers and moles can greatly change soil profiles (Haussmann 2017). These species are generally more common at southern latitudes. For example there are 4 species of pocket gophers in Colorado occupying a range of elevations (Miller 1964), versus only 1 species in Alberta.
- Livestock grazing and drought history- In contrast to Canada, more locations in United States may have had extreme levels of grazing by sheep, cattle and horses in the late 1800s and early 1900s. This, in combination with droughts may have created bare soils and erosion that removed historic bison wallows.
- Irrigation and cultivation- Again, the area of land altered by these activities is greater further south.
- Clay content- Due to recent deglaciation, Canadian soils are younger, shallower, and may have higher clay content than more southern latitudes. This may influence soil stability after wallow creation, and small burrowing mammal abundance.

3.7 Traditional Human Use Patterns

As described in Section 1.1, human movement from the west towards concentrations of bison, and their hunting patterns once bison were encountered were "clearly a long-established process" (Roe 1972: 259) that may have strongly limited the expansion of bison's range westward. Unfortunately, there is as of yet no meta-analysis for this trans-mountain bison hunting pattern along the length of the Rocky Mountains. Osicki (2012:123) provides a preliminary quantitative comparison for 15 potential human travel routes across the Canadian Rockies.

However a wealth of general information exists for long-term human trans-Cordilleran movement by individual regions. For the South Pass, greater Yellowstone, and Bozeman Pass areas, long-term human use is described by several researchers including Nabokov and Leondorf (2004) and Hodge (2013). Further north, Anastasio (1985) describes the general cultural organizational system for southern plateau peoples along the Columbia River to move eastwards to hunt bison. Several authors describe the historical and archaeological evidence for human use of the well-known "Buffalo Road" along the Blackfoot River in Montana, and other routes over the continental divide to the Missouri River basin (Anatasio 1985, Reeves 2003, Farr 2003, Scott 2015). Along today's Alberta-British Columbia boundary, K'tunaxa (Kootenai) movement routes are described by researchers including Schaffer (1940), Binnema (2001), Reeves (2003), and Heitzmann (2009). Blackfoot foothill and mountain use is described by Reeves (2003), Brink (2008), and Zedeño et al. (2014). Secwempemc (Salish) travel across the mountains from the Columbia and Fraser rivers to the Saskatchewan watershed is described by Pickard (1989), Langemann (2002, 2018), Langemann and Perry (2002), and Osicki (2012). Further north, Burley et al. (1996) summarize traditional aboriginal use of the Peace River break through the Rocky Mountains.

In addition to these qualitative descriptions of human travel routes, human use patterns for the historic period are also available from human encounters tallied in the first person journal databases (see Section 3.3 above) where evidence of human presence is tallied by journal day as 0 (no evidence or observation), 1 (old sign), 2 (recent sign), 3 (1-9 people seen during day), 10 (10 or more people seen), following the method of Kay (2007).

3.8 Comparative Corridor Analysis

For this preliminary evaluation in this report, I did simple graphic comparison of general bison use, combined with vegetation and terrain characteristics for 9 corridors, from east to west and south to north:

- Platte-Salmon- potential travel routes from bison over South Pass and adjacent passes such as Togwatee, Hoback, Teton, and Lima to the headwaters of the tributaries to the Snake and Missouri rivers including Birch , Little Lost, Big Lost, and Beaverhead, and Bighole, and from here to the Salmon River ;

- Yellowstone-Missouri- from the headwaters of the Yellowstone River over Bozeman Pass to the Missouri River headwaters including the Jefferson, Beaverhead, and Big Hole, and from here to the Salmon and Clark Fork;
- Missouri-Blackfoot- from the Sun and Teton river tributaries of the Missouri, over Lewis and Clark Pass and adjacent routes over the Rockies (the Road to the Bison) to the Blackfoot River;
- Kootenay- from South Saskatchewan watershed to the upper Flathead and Kootenai/Kootenay rivers including South and North Kootenay and Crowsnest passes;
- Bow- from the Bow River watershed to the Kootenay and Columbia rivers including Kananaskis, Whitemans, Simpson, Vermilion, and Kickinghorse passes.
- Red Deer – from the Red Deer to the upper Bow River and hence Vermilion and Kickinghorse passes;
- North Saskatchewan- over Howse Pass to the Blaeberry and Columbia rivers;
- Athabasca- over Athabasca and Yellowhead passes to the upper Columbia and Fraser watersheds;
- Peace- the upper Peace River gap through the Rocky Mountains.

For each of these corridors, the most direct cross country and upriver route was plotted from the eastern edge of the high density bison observations on the plains (from journal wildlife observations, Section 3.3 above) westwards to the mountain valley pass. Terrain, vegetation, and bison density conditions (as described above) were approximated for approximately 10 km segments along each corridor. Human use patterns were not plotted, but were evaluated qualitatively from existing literature and the daily journal observations (Section 3.7 above).

4. RESULTS AND DISCUSSION

A literature review, Google Earth mapping, and preliminary wallow survey work began in June, 2015 with emphasis on the area from the Bow to the upper Missouri near Great Falls. In 2016 the focus was on the upper Red Deer and Bow watersheds (Alberta), and South Pass (Wyoming and south-eastern Idaho area). Wallow sampling was also done in several areas along the western slopes adjacent to these areas. In 2016 and 2017 first person journal entries concentrated on the upper Yellowstone, Platte, Sweetwater, and upper Snake watersheds. In 2018 this expanded westwards and northwards. This broad north-south approach allowed testing of the wallow sampling technique, and preliminary examination of a range of terrain vegetation type combinations.

Further plotting and analysis of the first person journal observations will help clarify the spatial-temporal variations of high bison density and corridor use. The datasets are currently available at this webpage:

https://lensoftimenorthwest.com/themes/lens-northwest-files/google-earth-map-journal-wildlife-observations/

I urge readers of this report to download these datasets, especially the Google Earth ".kmz" file for fine scale referencing of these results. Below, I will provide a preliminary corridor and general regional overview from the data available to date, and then provide qualitative descriptions by watershed.

4.1 Corridor Overview

Figure 4.1-1 shows the approximate areas of high bison density and selected potential movement corridors towards the mountains and foothills as indicated from a subjective evaluation of the historical journal analyses and wallow counts. The combination of historic journal observations, archaeological data, literature review, and bison wallow densities indicate that the highest spring-early summer bison densities occurred towards the center of the Great Plains. As a simple indication of this, one can observe hundreds of wallows within line of sight on suitable terrain near water 100 to 500 km out from the foothills (e.g., the elbow of the South Saskatchewan River) whereas there are very few wallows on most areas near the mountains (e.g., Head-Smashed-In Buffalo Jump area on the upper Oldman River). Or on the Platte River, travellers' journals routinely indicate high bison densities near the confluence of the north and south forks, whereas observations become more sporadic towards South Pass. Historic photographs and wallow tallies indicate few historic wallows at higher elevations here (CW wallow database), possibly indicating that early summer rutting activity and wallowing associated with mating occurred further east at lower elevations where pocket gophers and land uses at this latitude have eliminated this evidence (see Section 3.6).

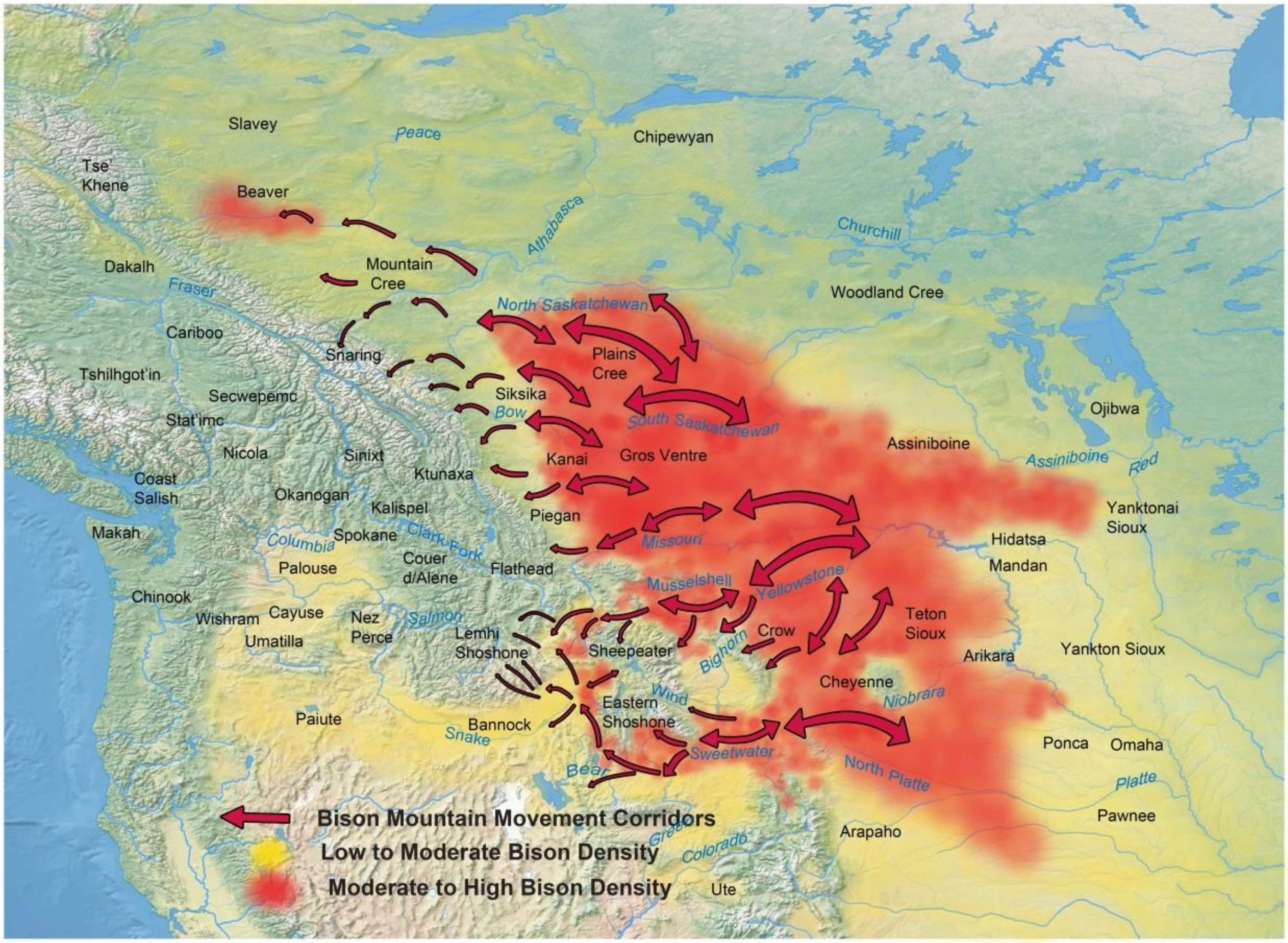

Figure 4.1-1: Select potential bison movement corridors from the Great Plains into the western Cordillera along major watersheds and valleys, showing the location c. 1800 of select Native American groups. Two way arrows indicate areas two way annual migrations may have occurred (Phase 1 movements, see Section 2.2.1). One way arrows indicate corridors where movements were likely generally westward dispersal events (Phase 2 movements, see Section 2.2.2) with lower return rates due to herding practices of Native Americans into more constrictive terrain, predation risk, and mortality.

Figure 4.1-2 illustrates a first approximation of relative bison density (c. 1820), vegetation, and terrain conditions along nine selected movement corridors into the Cordillera. All corridors historically connected core areas of 200 to 400 km wide of relatively high summer bison density on the Great Plains to the western edge of bison range through areas of at least moderate seasonal bison use. Based upon preliminary wallow and journal data, spring and early summer bison densities often decline approaching the Cordillera, often at distances of over 50 km from actual terrain constrictions.

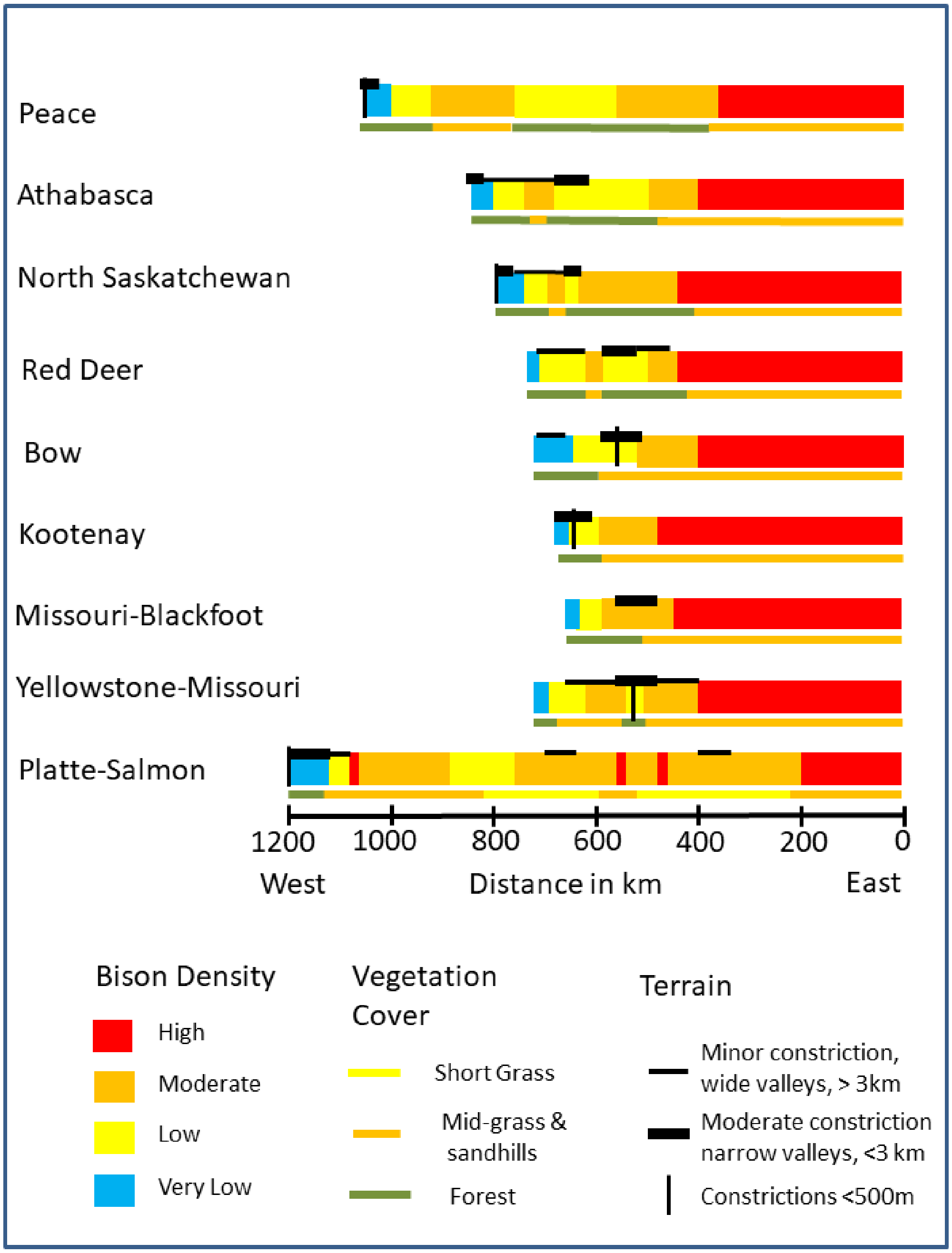

Figure 4.1-2: First approximation of relative bison density (c. 1820), vegetation cover and terrain conditions along selected, potential movement corridors into the western Cordillera. Distances are derived straight-line segments, standardized by starting from the eastern edge of high bison density range on the plains and moving westwards into the Cordillera to edge of occupied bison range. In corridors further north such as the Missouri-Blackfoot, Kootenay Pass and Bow River, the entry points to the mountains often have major terrain restrictions blocking large herd movements. For example, the Bow River valley is constrained to several sections of <200m wide of valley bottom travel route immediately upon entering the mountains.

Once inside the mountains, terrain constrictions become very important. Narrow valleys, or features such as bedrock outcroppings or lakes that cross valleys seem to have historically strongly limited bison movements westward. For example contrast, the distance bison traversed in the broad Platte-Salmon corridor over South Pass (the eventual route of the Oregon Trail) to bison movements up the Yellowstone valley. This corridor becomes increasingly constricted, and narrows to under 500m near Bozeman Pass. This limited “large herd” dispersal events westward into the upper Missouri River basin.

In contrast, although forest cover may limit large, unified herd movements, bison density can still be low to moderate across wide areas with forest cover. Kay et al. (2001) record moderate densities of bison in the forested Alberta foothills, and wallow transects to-date (this study) show moderately frequent wallows in valley bottom meadows across this area. “Plains” and “wood bison” variants had wide area of interconnectivity across southern boundary of the boreal forest and foothills in the broad corridor linking the prairies to the Peace River valley (see Figure 3.1; Roe 1956, Gates et al. 2010).

4.2 Preliminary Model for the Interaction of Terrain and Forest Cover

Figure 4.2-1 is the first cut on a conceptual model of the interaction between terrain and forest cover on bison movement from high or moderate density areas on the plains (on the right), moving west to the narrow and often wooded valleys of the Cordillera (right hand side of figure to the left). The tree cover gradient can also be visualized as moving from south (bottom of figure) to the north.

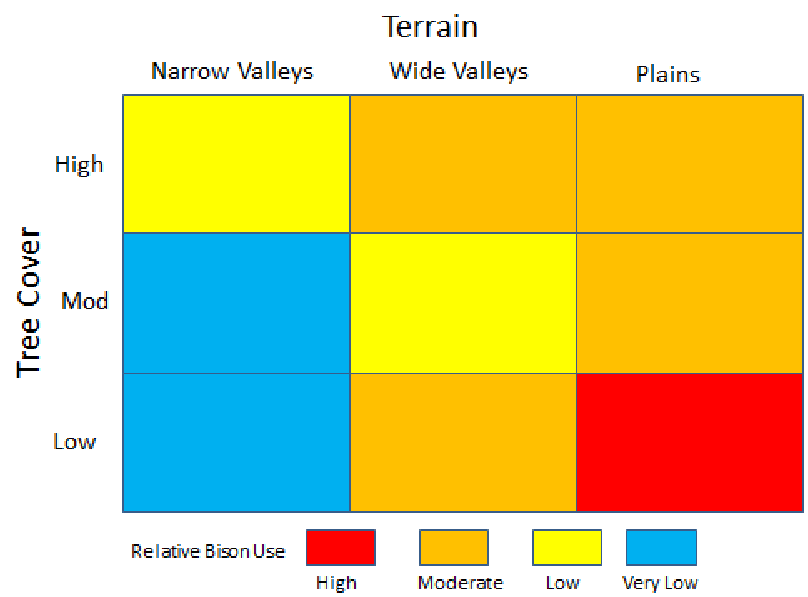

Figure 4.2-1: A preliminary conceptual model of the effect of terrain and vegetation cover on bison density in Western Cordillera, and adjacent plains and foothills to the east.

This model accentuates the effects of two of the dynamic processes shown in Figure 2.3-1: bottom up effects of terrain and forage versus the top-down effect of predator avoidance. Greater variability would occur if human cultural factors (e.g., intertribal warfare zones) were included. This model assumes that in all scenarios of terrain versus cover bison are at least periodically connected to a high density core population on the plains (e.g., central area distribution). Areas with low bison use may be self-sustaining for longer periods of time, but very low density areas are likely ephemeral populations that require periodic dispersal pulses from adjacent areas. More analysis is required to quantify and evaluate the effects of tree cover and terrain on historic bison use in the western plains and cordillera study area. Almost all current-day studies recognize these variables as important predictors of wildlife movement through corridors including, for example multiple species in the Bow Valley near Canmore and Banff, Alberta (BCEAG 1998) and lynx in northern Montana and Idaho (Squires et al 2013). However, the bison relationships with terrain and vegetation are more complex because bison herd size interacts with cover type. Large herds in broad open terrain will successfully use corridors, but as terrain constricts, increased forest cover is required for bison survivorship (Figure 4.2-1).

4.3. Bison Movement Corridor Regions

From a geographic perspective, application of this model for the Cordillera from South Pass north to the Peace River break, and including Native American cultural patterns (as of c. 1820) suggests that for bison movement corridors, the interaction of terrain, vegetation, and social conditions results in three broad bison movement regions for this time period: wide montane valleys, the mountain wall, and the forested foothills and boreal plains (Figure 4.3-1).

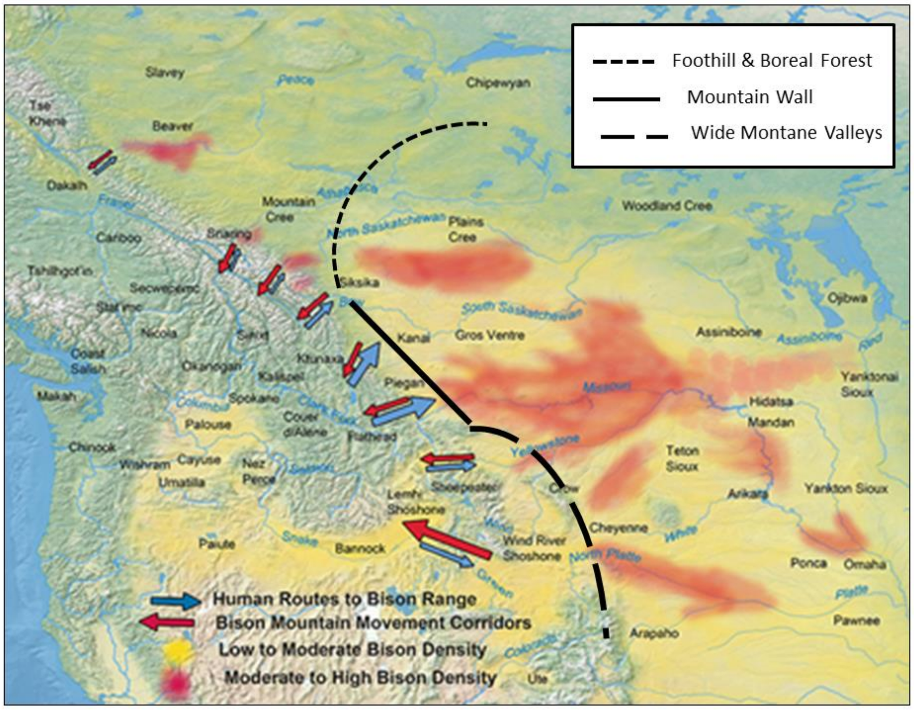

Figure 4.3-1: Three broad regions for differential bison movement corridor characteristics into the western Cordillera.

The following sections describe each of these regions, from south to north, and include reference to specific corridors, and relevant descriptions from early travellers and the traditional knowledge of the Native Americans they met or travelled with. I generally proceed by describing the most direct travel up river valleys from areas of high bison concentration to mountain valleys, and then describe important adjacent areas. For each region I provide an overview, and describe biophysical characteristic, cultural influences, spatial variation in the source population zone, temporal variation of bison use of the movement corridor, and spatial variation in the sink population zone. The montane valleys zone and South Pass is by far the spatially and temporally most complex bison movement route and receives extra attention.

In latter 2018, and 2019 I will post links to historic with current repeat photographs and more detailed descriptions of select corridors at the following webpage:
https://lensoftimenorthwest.com/themes/salmon-and-bison/

4.3.1 Wide Montane Valleys Region

Overview- Much of the eastern slopes of the Western Cordillera from South Pass near Casper north to the Gates of Mountains near Helena consists of isolated mountain ranges (Bighorn, Pryors, Crazy Mountains etc.) interspaced with large valleys (Platte, Bighorn, Yellowstone), often with low to moderate forest cover. Likely due to the width of the valleys, open vegetation cover and width of the valleys, moderate densities of bison appear to have periodically used the Cordillera, and particularly for South Pass, crossed the mountains and reached several hundred kilometers onto the western slopes (Bailey 2016). In the historic record there is some evidence of a bison dispersal event over South Pass. Bison observations were uncommon on the upper Snake, Missouri, and Salmon rivers prior to 1812, but are frequent after 1820. These historical accounts provide some background to evaluate causal processes for bison movements into the Cordillera (see more detailed discussion in Section 4.4). These accentuate the importance for wide montane valleys for bison persistence, and that terrain constrictions can limit bison movements into the mountains.

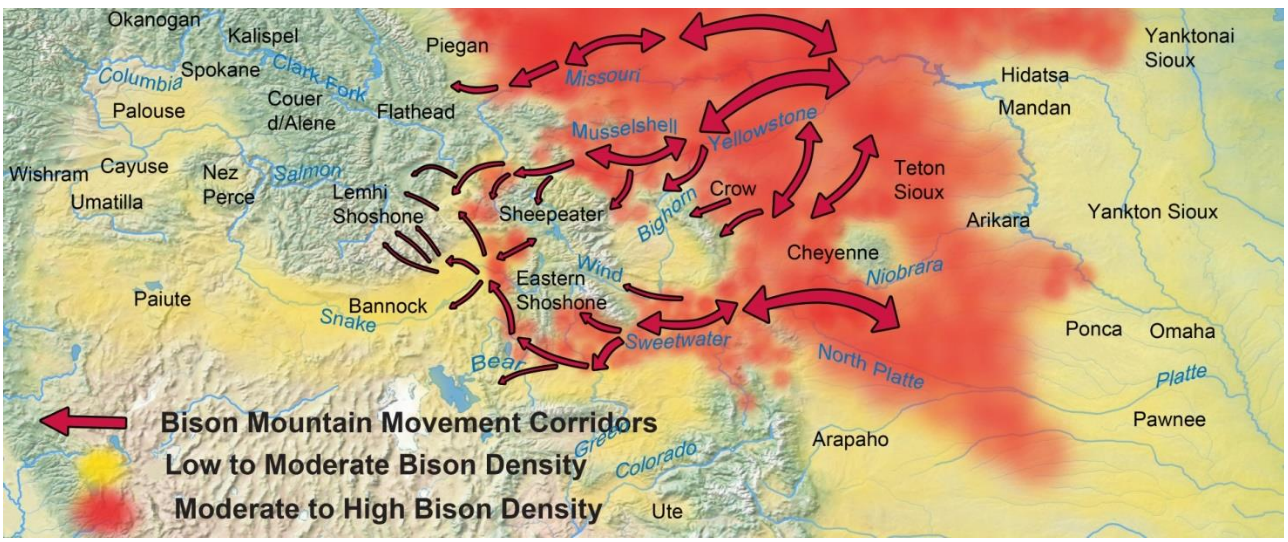

Figure 4.3.1-1: Some potential bison movement corridors in the montane valleys region of the Western Cordillera showing the location of selected Native American groups c. 1800. In the south is the South Pass corridor along the North Platte and Sweetwater rivers to the headwaters of the Snake, Salmon and Missouri rivers. To the center is the Yellowstone corridor over Bozeman Pass to the headwaters of the Missouri, and in the north is the Missouri River where mountains upstream of Great Falls blocked bison movement.

Biophysical Characteristics- South Pass corridor connects an area of consistently high bison density along the Platte River in Colorado and Nebraska (Figures 4.3.1-1) over 1000 km to the headwaters of the Salmon River in Idaho, and Big Hole River in Montana. This corridor’s broad width, along with the Yellowstone corridor over Bozeman Pass appears to have created a unique situation of periodically abundant bison in the wide montane valleys of the western slope of the Rocky Mountains from Colorado north to Montana—a situation that does not occur on the continent north of the Great Falls of the Missouri River (Figure 4.1-1). One of the most important spatial characteristics of the South Pass corridor is its width (>50km) on its and gentle slopes on its approach to continental divide, including vast areas of grass and shrubland terrain that would allow large bison herds to move westwards, using a consistent source of water along the Sweetwater River in summer, and snow in winter. The presence of water, riparian zone grasses, and gentle grades that favored bison movements also facilitated the establishment of the Oregon Trail, and European settlement of American's western coast (Bagley 2014). In contrast, the terrain at Bozeman Pass narrows to under 100m in width (Figure 4.1-2), decreasing the possibility large herds moving though the pass. Furthermore, due to low bison numbers, low forest cover, and restricted terrain, the mortality risk for any bison that enter this area is high, decreasing the probability that Bozeman Pass was routinely used as two-way seasonal movement route. Although the canyons of the Missouri River through Big Belt Mountains blocked bison movement near the river, it is possible that small herds of bison moved southwards from the Great Falls area southwards through the foothills along Old North Trail route used by the Blackfeet (McClintlock 1910, Reeves 1990b).

Cultural Influences- The montane valleys bison movement zone is the homeland to numerous Native American groups (Figure 4.3.1-1). To the east were the classic bison hunting cultures such as the Sioux, Crow, Cheyenne and Arapaho (DeMallie 2001). Further westwards, the Snake River plains and foothills and mountains around the Yellowstone caldera were occupied by peoples including three groups of Shoshone (Lemhi, Eastern, and Sheepeater) and the Bannock (Nabokov and Loendorf 2004). The area was also regularly visited from the west (Figure 4.3.1-1) by groups including the Nez Perce, Cayuse and Flatheads (Anatasio 1985, Josephy 1997), and from the north by members of the Blackfoot confederacy (Binnema 2001). Each of these peoples had sophisticated hunting, gathering, and burning skills. For example, trapper Osborne Russell in his journal entry for July 30, 1835 provides a classic description of Shoshone people occupying the Lamar River valley in the upper Yellowstone River watershed:

… at length came to beautiful valley about 8 Mls. Long and 3 or 4 wide surrounded by dark and lofty mountains…the banks of the stream in the valley were low and skirted in many places by beautiful Cotton wood groves. Here we found a few Snake (Shoshone) Indians, comprising 6 men, 7 women and 8 or 10 children who were the only inhabitants of this lonely and secluded spot. They were all neatly clothed in dressed deer and Sheep skins of the best quality and seemed to be perfectly contented and happy…Their personal property consisted of one old butcher knife nearly worn to the back two old shattered fusees which had long since become useless for want of ammunition, a Small Stone pot and about 30 dogs on which they carried their skins, clothing, provisions etc on their hunting excursions. They were well armed with bows and arrows pointed with obsidian the bows were beautifully wrought from Sheep, Buffaloe and Elk horns secured with Deer and Elk sinews and ornamented with porcupine quills and generally about 3 feet long…They said there had been a great many beaver on the branches of this stream but they had killed nearly all of them and being ignorant of the value of fur and singed it off with fire in order to drip the meat more conveniently…. (Haines 1966: 27-28)

On the plains and foothills, large groups of native peoples of 500-1000 men, women and children would travel for several months hunting gathering plant resources and hunting bison and other game. During the 1820s and 30s fur traders and trappers periodically travelled with these groups and document large-group communal bison hunting and meat/hide processing practices (Ferris 1940, Johnson 1984, Bailey 2016). Several intertribal buffer areas existed (Figure 4.3.1-1) where this intensive resource use did not occur due to the risks from enemy raiders. During the early 1800's these included the upper Platte and Wind rivers between the Crow, Sioux and Shoshone peoples (Hodge 2013), the headwaters streams of the Missouri between the Blackfoot confederation, Shoshone, and Nez Perce (Binnema 2001), and a large area along the Missouri and Yellowstone rivers between the Flathead, Blackfoot confederacy, Assiniboine, and Crow (Kay 1994, 2007; Farr 2003).

Spatial Variability in Bison "Source Population" Area- For movements towards South Pass, first person journal entries show a persistent area of high bison numbers from about 30 km east of the forks of the Platte River, west to the Green River headwaters (Figure 4.3.1-1). Possibly one core of this population was the Nebraska Sand Hills between the Platte and the Black Hills (Figure 4.3.1-2).

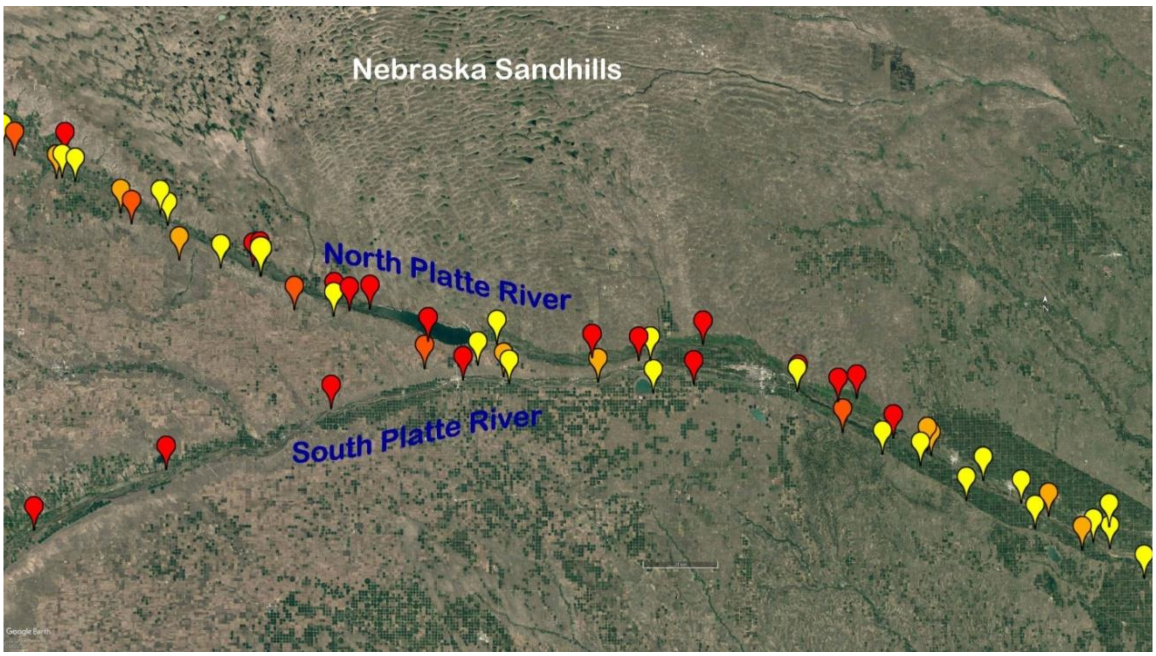

Figure 4.3.1-2: Journal observations of bison along the Platte River for the period c. 1811 to 1850 (from Northwest Plains & Cordillera first person journal database). Although we have very few historical observations of bison in the sand hills, the continual abundance of bison on the Platte River adjacent to the area suggests this may have been important habitat, and perhaps difficult to hunt.

This Nebraska Sand Hills area was seldom traversed by fur trappers, likely due to risks from Native Americans. However, traditional knowledge (e.g., Hassrick 1964, DeMallie 2001) and summaries of military expedition reports (e.g., Warren 1875) indicate relatively abundant bison. Moreover, the sand hills rolling terrain, and the high water tables (see lakes in Figure 4.3.1-2) interspersed grasslands might make this particularly good habitat (Loope and Swinehart 2000, Kornfeld et al. 2010, Fox et al. 2012). The Platte River area adjacent to the sand hills remained a persistent location for observing bison well into the 1850's, even after over two decades of heavy use by European travellers of the Oregon Trail corridor, and the location of trading posts such as Fort Laramie in the area.

In the Yellowstone watershed, high bison numbers were not encountered by William Clark in July, 1806 until his group was out on the plains beyond today's Big Timber (Moulton 1993, Vol. 8). However, later in the summer and in the fall, numerous expeditions record bison moving further westwards into foothill areas, possibly due to drought conditions on the plains (Northwest Plains Cordillera database 2018), and better quality forage at higher elevations.

Variation in Bison Corridor Use over Time- The montane valleys region can be used to evaluate variable use of the South Pass corridor use (North Platte River to Columbia watershed) over the Holocene period (Table 4.3.1-1). Archaeologists are particularly interested in the causes of this temporal variability to determine what factors contributed to periods of time when bison range extended westwards to the Palouse Prairies near the Columbia River in Washington state.

Table 4.3.1-1: Relative abundance (within individual study) of bison in archaeological studies organized from the Wyoming basin (top row) northwest to the Columbia River and plateau (bottom row). Consistent high abundance across a time period may indicate movement corridor connectivity across the region.

Bison Abundance by Time Period (k years BP)

Location and Reference	10		9		8		7		6		5		4		3		2		1		0
Wyoming Basin (Lubinski 2000)	H	H	H	H	H	VL	VL	VL	VL	VL	L	L	M	H	H	L	L	H	H	H	VL
Great Basin (Janetski 1997)																		H	M		
NE Great Basin (Lupo and Schmidt 1997)																	VL	L	H	H	M
Northern Utah (Lupo 1996)																				M	L
Salt Lake (Lupo and Schmidt 1997)																	VL	L	M	H	L
E Great Basin (Grayson 2000, 2006)																L	L	L	M	M	
W Great Basin (Grayson 2000, 2006)																VL	VL	VL	L	L	
Snake R. Plain (Plew and Sundell 2000)	VL	VL	VL	L	L	L	L	M	M	M	M	L	L	L	L	H	H	H	H	H	
Oregon Basin and Range (Stutte 2004)	VL	VL	VL	M	M	M	M	VL	VL	VL	VL	VL	VL	VL	VL	L	L	L	L	H	H
Oregon Blue Mtns (Stutte 2004)	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	L	L
Oregon Columbia Plateau (Stutte 2004)	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	M	M	M	M	M	VL	VL
Columbia Plateau (Chatters et al 1995)	L	L	L	L	L	L	L	VL	VL	VL	VL	VL	M	M	M	H	H	H	H	H	VL
Columbia Platea (Schroedl 1973)																	H	H	M	M	M
Eastern Washington (Lyman 2004)	M	M	M	M	M	VL	VL	VL	L	L	L	L	L	L	L	M	M	M	M	L	VL

This compilation of these studies does not show long periods of bison abundance across the region that would indicate consistent long-distance corridor connectivity and movement with possible exception of the period 500-1000 years BP. This corresponds to the period that Cooper (2008) mapped as relatively abundant bison on the upper Platte River south of the Nebraska Sand Hills in eastern Colorado. Moving west across the continental divide, for much of the prehistoric period bison were likely to infrequently encountered for regular communal hunts (Butler 1978; Plew and Sundell 2000), although they were probably a preferred resource when present (Henrikson 2003, 2004; Breslawski 2014).

Bison use of these corridors can be evaluated for the historical period with first person journal wildlife observations (Figure 4.3.1-3). These data show few bison in the period 1805-23 on the upper Missouri, Salmon, and Snake Rivers west of the mountains of the Yellowstone region. Three expeditions passed through this region during this period: Lewis and Clark in 1805-06 (Moulton 1994), westward bound Astorian William Price Hunt's party in 1811-12 (Appendix A in Rollins 1995), and eastward bound Astorian Robert Stuart in 1812-13 (Rollins 1995). All these groups reported little bison sign in this area, although a Shoshone interviewed by Lewis and Clark observed that bison had been more abundant in the upper Salmon-Missouri river watersheds in previous years (Moulton 1994).

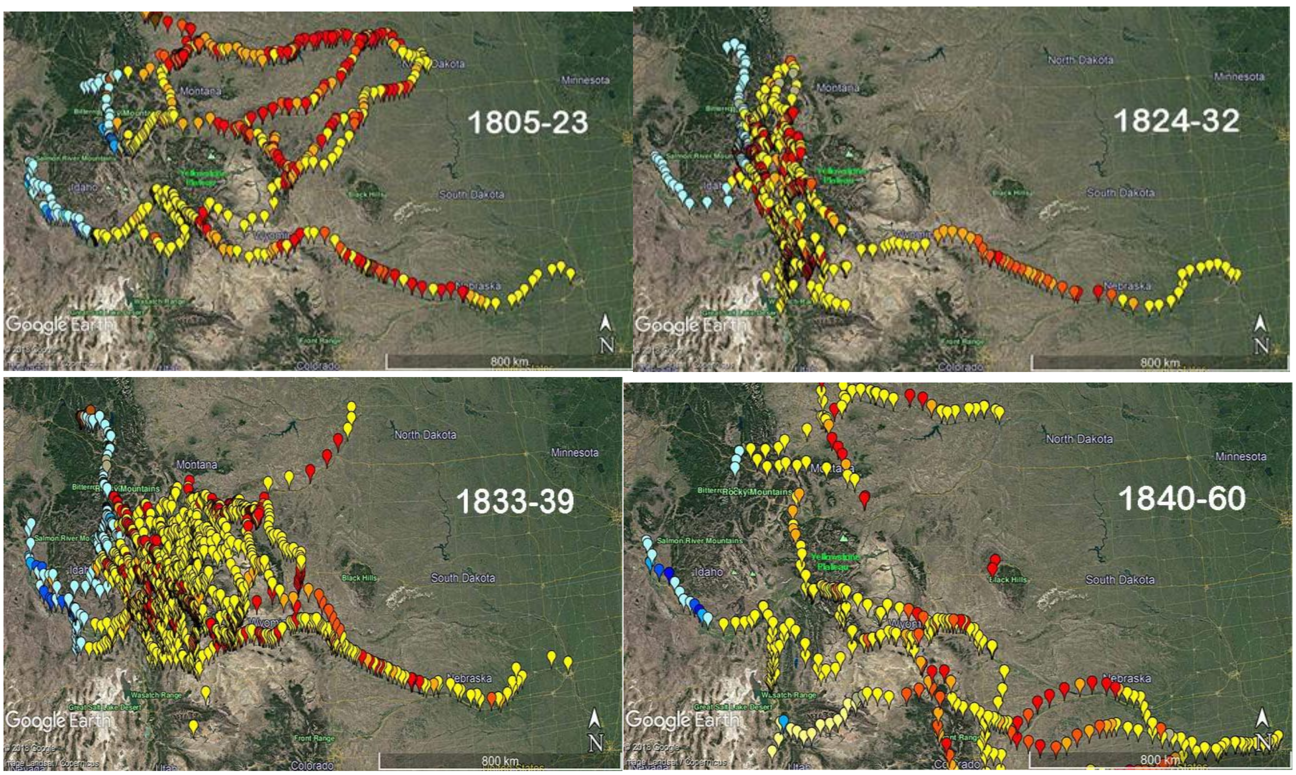

Figure 4.3.1-3: Bison observations (orange is small groups, red are large groups) in the montane valleys zone of the western Cordillera for four time periods (Northwest Plains Cordillera database, 2018-03-01). Yellow and pale blue indicate no wildlife observed, or no observation for day. Dark blue are salmon fisheries. For a more detailed view, download Google Earth journal wildlife observation file at:
https://lensoftimenorthwest.com/themes/lens-northwest-files/google-earth-map-journal-wildlife-observations/

However, traveller journals for the period 1824 to 1832 report abundant bison on the Snake River plains, upper Missouri streams (Big Hole, Jefferson, Beaverhead, and Ruby), and of particular interest, on the upper Salmon and Lemhi rivers and the narrow constrained valleys north of the Snake River (Birch Creek, Little Lost, and Big Lost rivers). When the snowpack was deep in midwinter, bison were particularly easy to hunt, and bison that had reached the headwaters of the Salmon were essentially trapped by snow in the passes to the south. Fur traders such as Peter Ogden and Warren Ferris in winter-camps in the Salmon watershed, with, or adjacent to large groups Native Americans were well-provisioned during this period. After 1832, bison distribution and abundance begins to decline west of the mountains, starting first with remote ends of the narrow Salmon River valleys (Figure 4.3.1-3). However, through the 1830s bison still remained relatively abundant along most the movement corridor from the Platte River northwest over South Pass, to the Snake River plains, then over Monida Pass and down the Beaverhead River and west to the Big Hole River basin— a distance still over 1000 km (Figure 4.3.1-3). After 1840 bison abundance westward the Platte River declines even further, to the point that in 1860 when Captain William Raynold's expedition rode from the Wind River across Jackson Hole, then over Teton Pass to Pierre's Hole then Madison rivers, they sighted less than 10 bison (Merrill and Merrill 2012).

The historical data thus indicates that west of the mountains their was a period of relatively abundant bison prior to 1800, low bison until about 1820, then possibly a major bison dispersal westwards, followed by another 20 year period of high bison until the 1840s, followed by another population decline. Bailey (2016) also describes this potential variation in bison numbers over time in the montane valley region of Idaho and Montana. There are many factors that could have caused this temporal oscillation pattern in bison numbers west of South and Bozeman passes. One scenario is this:

- Several archaeological studies (summarized by Cooper 2008, see Figure 2.3-1 and Table 4.3.1-1 above) conclude that about 500 years ago bison abundance in the source bison population area on the upper plains began to increase. Some studies conclude that this was due to cooler moister conditions. This might create more forage increasing bison birth productivity, and possibly more snow cover and other water sources which would reduce predation rates by reducing predicable bison concentrations near water sources;
- The Eastern Shoshone expansion across South Pass about 1600 AD (Hodge 2009) could have reduced bison abundance near the continental divide, but could have also created an intertribal buffer area on the upper Platte River and Nebraska Sand Hills areas between warring Shoshone, Crow, Cheyenne, and Arapaho peoples. This would maintained or created high bison numbers in a source population area to the east of South Pass but Shoshone use of the pass itself would have limited bison movements westward;
- The frontier of the Shoshone homelands moved westwards in the 1780s due to smallpox mortality, and warfare setbacks as their neighbors obtained guns and horses (Hodge 2009, 2013). These changing tribal buffer zones could have created a refuge for bison on the upper Platte River, and near South Pass and in the upper Green River Basin (Bamforth 1987, . Indeed, both Astorian expeditions in the early 1800s encountered numerous bison here (Rollins 1995, see journal observation databases).

- Abundant bison routinely utilizing the upper Platte and Green rivers could have moved easily moved westwards, likely along the "least resistance" route that eventually became the Oregon Trail. The stimulus for a westward dispersal event or series of events could have included weather events such as blizzards or droughts, and increasing pressure during the early 1800s from longer forays by the horse-mounted Crow, Sioux and Ponca hunters coming from the east (Wishart 1994, DeMallie 2001). This would tend to move bison westwards.
- Once on Snake River headwaters, in the "sink population" zone, bison would be herded and hunted in any number of directions (Figure 4.3.1-1) by large, well-organized groups of Shoshone and Bannock communal hunters (Nabokov and Loendorf 2004; Hodge 2009), and smaller groups of fur trappers (see following section).

Spatial Variability in Bison "Sink Population" Area- The montane valleys bison movement zone is complex terrain with numerous potential high mortality areas for bison. Moving west from South Pass on the headwaters of the Platte, or the Clark Fork of the Yellowstone in the Yellowstone watershed, the mountain valleys progressively narrow down into literally hundreds of terrain traps (indicated in general locations with one-way arrows in Figure 4.3.1-1). At this latitude of the Rocky Mountains, lower mountain valleys are generally lightly forested and this would facilitate communal bison hunting, using features such as arroyos, canyons, and cliffs (Frison 2004, Kornfeld et al. 2010). For example, Figure 4.3.1-4 shows the historical and current vegetation conditions along the Yellowstone River in the Paradise Valley south of Livingston, Montana. Here, archaeologists have located abundant evidence of native campsites, bison driveways, and other evidence of intensive bison hunting. Any bison driven up valley during the spring and summer would be contained and mired in winter snows where they could be easily hunted by specialized mountain peoples (such as the Sheepeater Shoshones described above). Alternately, bison might move down valleys during winter to avoid deep snow, but in many locations this would concentrate them in terrain traps such as the canyons along the Yellowstone or most other rivers. Again, this would facilitate communal hunting.

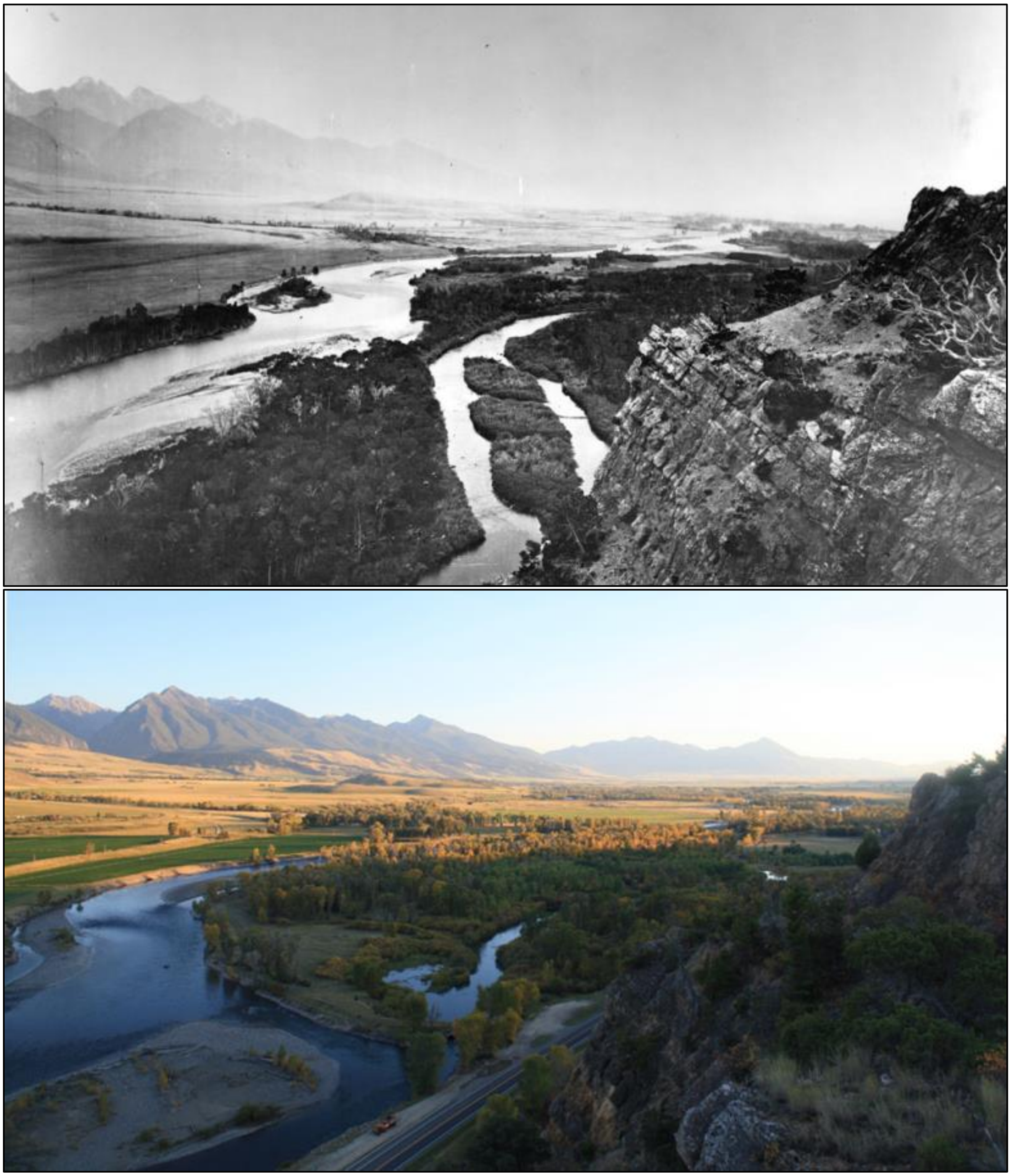

Figure 4.3.1-4: View south up the Yellowstone River from the First Canyon into Paradise Valley in 1871 (William Henry Jackson, USGS-jwh-00068) and in 2010 (CW-2010-10-01-0071). Arthur (1962, 1966) and Lahren (2006) describe abundant evidence of prehistoric human use and numerous communal bison-kill archaeological sites in this valley. Note that in this print of William Henry Jackson's negative, an extra ridge of mountains has been inserted on the east (left) side of the Yellowstone valley. Observe the dense riparian zones, both then and now, along the river, and compare this to then and now conditions within Yellowstone National Park (Figures 1.3-1 and 5.1-1).

The complexity of bison use of the montane valleys zone is also illustrated by the map of abundance of bison observed in daily journals for the period 1800 to 1860 (Figure 4.3.1-5). On the west side of the area, most bison observations occurred after the dispersal event of c. 1820 (see above). In general, bison were most abundant is large grasslands in the lower elevation valleys, and generally rare at higher elevations in narrower, more wooded valleys.

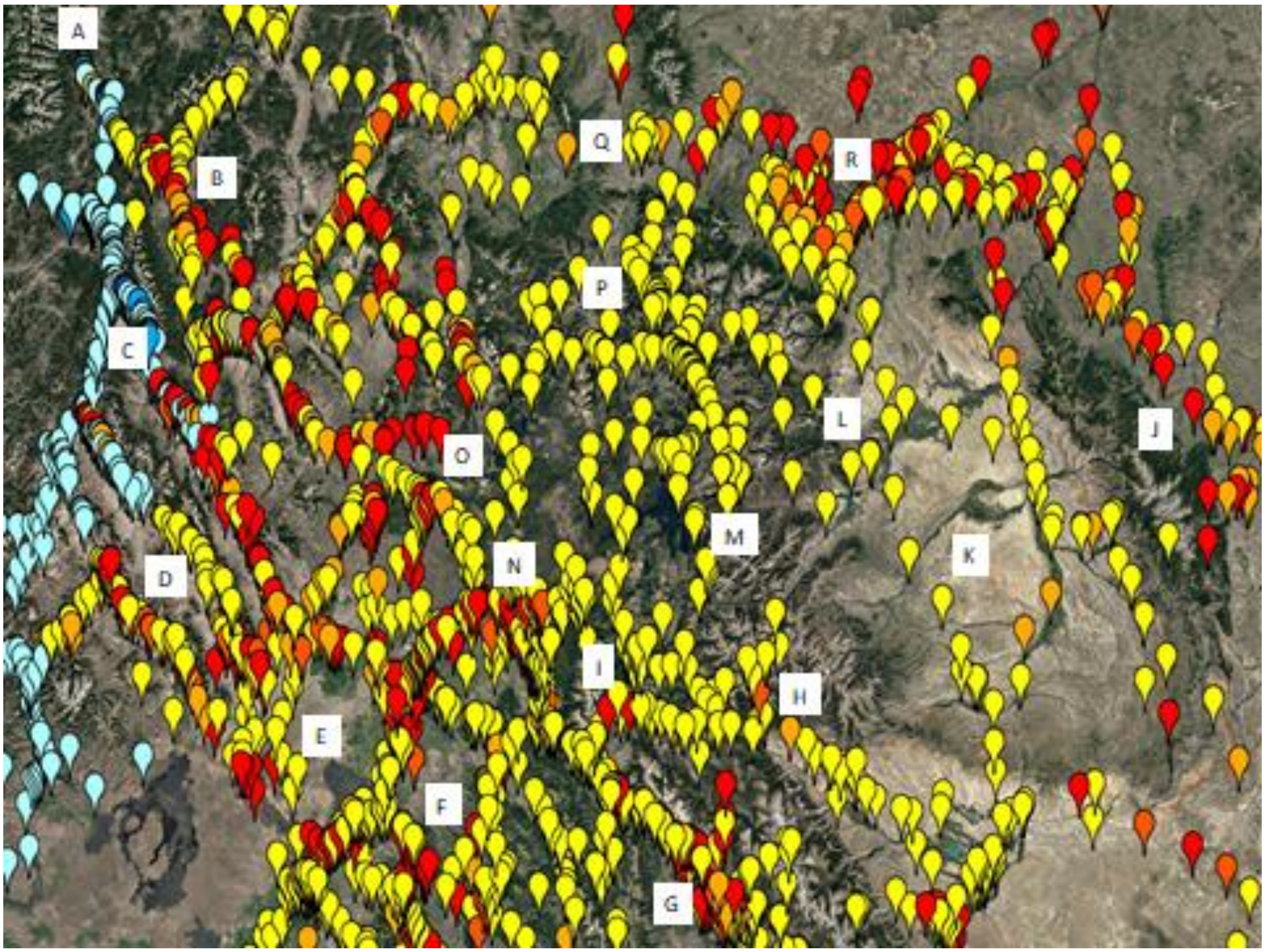

Figure 4.3.1-5: Relative numbers bison observed in first person daily journals (1800 to 1860) on the western side of the montane valleys bison movement zone, centered on the Greater Yellowstone ecosystem, but also showing lower elevation areas along main rivers such as the Snake, Green, Wind, Bighorn, Yellowstone, Madison, Big Hole, and Salmon rivers. Red indicates abundant bison, orange moderate number of bison, and yellow is no bison seen or no wildlife observations for day. Blue colours are associated with observed fish abundance on Pacific watershed streams. See text for details for areas keyed to letters. For a more detailed view, download Google Earth journal wildlife observation file at: https://lensoftimenorthwest.com/themes/lens-northwest-files/google-earth-map-journal-wildlife-observations/

Some observations based upon archaeology and first-person daily journalist observations, and keyed to locations on the map are as follows:

- **A: Bitterroot Valley**- Bison may have sporadically reached the lower Bitterroot Valley, either from passing down the Clark Fork, or over passes from the Big Hole. Wyeth, while visiting with a large camp of Flatheads, Nez Percé and other groups saw bison bones, and recorded that "*buffaloe have come here and even further but they are killed at once and do not get wonted*" (Johnson 1984, "wonted" means habitual in the area).
- **B: Big Hole**- Bison were routinely observed in this area during the 1820s to 40s period. From topography, and the pattern of bison observations connecting eastwards, the most likely route for bison to reach the Big Hole was from the south-east, from the Snake River plains and over Monida Pass.
- **C: Lemhi, Pahsimaroi, and Salmon river valleys**- Archaeological studies show that bison were at least periodically, relatively abundant in these watersheds (Butler 1971, Chatters 1982, Cannon 1997). Native Americans described to Lewis and Clark in 1805 that at that time bison were generally absent in these valleys (Moulton 1993). For a few years in the 1820's, Northwest Company and Hudson's Bay Company brigades journals report hunting bison herds occurring in these narrow valleys, and also relatively high numbers of Shoshone and other native groups predominantly fishing for salmon (Figure 4.3.1-5.) In some years it appears that bison may have come over from the Snake River plains were trapped on the valleys by deep snow on their northern edges (Ross 1956). By 1832, when Captain Bonneville wintered on the Salmon River (Irving 2004), bison were scarce in the watershed although they remained common to the south and east. It's likely that these valleys were a classic "sink population" area at the edge bison range where narrow open terrain, and abundant hunters sustained by alternate prey (e.g., salmon) could routinely hunt bison to very low numbers.
- **D: Big Lost, Little Lost, and Birch Creek valleys**- These valleys provided long corridors northwards from the Snake River plains where bison were either herded by hunters, or followed strips of riparian zones leading to passes to the Salmon River watersheds described above. Perhaps in dry summers, bison on the Snake River plains were drawn to the streams as a source of water, or the upper reaches of the valleys where grasses occurred on moist sites.
- **E: Snake River Plains**- During the period of high bison use (1820s to 30s) bison appear to have been driven down from higher elevations by deep snows, and provided large Native American camps and smaller groups of trappers with meat (Henrikson 2004).
- **F: Gray's Valley and Other Uplands**- During the snow-free seasons or when winter snowpack's were low, bison could roam over vast uplands in western Wyoming and Idaho. Historic wallows are found on the north end of Gray's Marsh, and likely occur elsewhere where bison herds grouped during the mating season.
- **G: Wind River Range and Upper Green River Valley**- This area appears to have routinely attracted bison, likely due to abundant forage along the river, and relatively moist grasslands conditions at upper elevations of the Wind River Range on the east and the Absoraka Range on the west. These bison could be contained and hunted by communal hunters in numerous mountain valleys ringing the Green's headwaters (Figure 4.3.1-6). Due its accessibility from

the east and west, and the abundance of bison and horse forage, the mountain fur trade's rendezvous was routinely held along the headwaters of the Green River from 1833 to 1840 (Bagley 2014).

- **H: Upper Wind River**- In 1860 the Raynold's expedition described a communal kill site upstream of Dubois where the Crow contained and killed a herd of bison the previous winter (Merrill and Merrill, 2012). Perhaps these bison had been herded up the narrow Wind River canyon from further downstream.
- **I: Jackson Hole**- Small herds of bison reached this area in summer by a few high passes over the mountains, leading to narrow valleys such as the Hoback or the Gros Ventre (Cannon et al. 2015). In some cases, they may have been driven into Jackson Hole by hunters through adjacent valleys similar to the Wind River event described above. In winter, bison within Jackson Hole would be trapped by deep snows surrounding the area, and forced to lower elevations where they could be easily found, then killed by hunters. After reviewing the archaeological (Wright 1975) and historical data for bison in the area, Wright (1984) concluded that "since populations were small, one successful kill of adults would have reduced the reproductive potential of the herd to a level where it would no longer have been a significant part of the ecosystem."
- **J: Eastern Slope of Bighorn Mountains**- The east side of the range receives abundant moisture from winter snowfall and spring rains from storms from the southeast that create productive grasslands. During the latter part of summer, bison were abundant here— in early summer of 1806, fur trader Larocque travelled with a large band of Crow that hunted bison here (Wood and Theissen 1985), and in 1811 William Price Hunt also met Crow in the area (Irving 2004).
- **K: Bighorn Basin**- Evidence of past bison use in the area is scant both in the archaeological record (Frison 2004, Kornfeld et al. 2010), and historical journals (Figure 4.3.1-5). The basin has very low forage availability because it is in a rain shadow between two high mountain ranges (Absoraka and Bighorn). Further, low elevation approaches to the basin run though constrained terrain that would facilitate bison hunting.

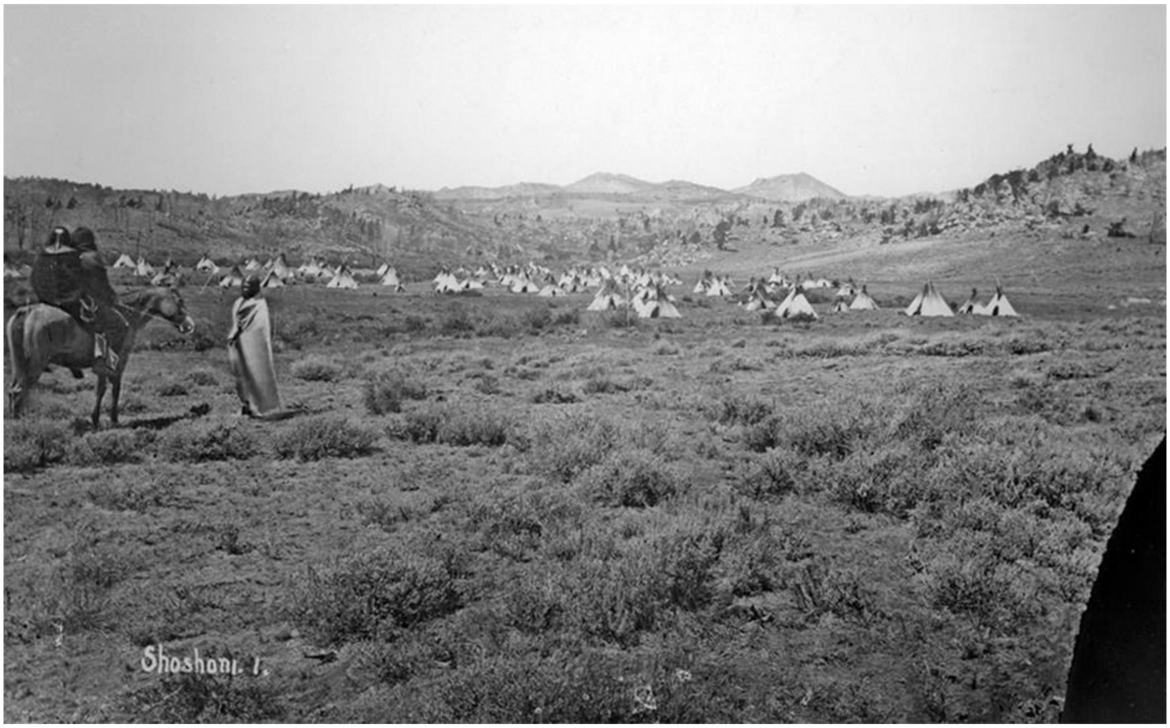

Figure 4.3.1-6. Chief Washakie's Shoshone camp in the foothills of the Wind River Range on September 3, 1870 (William Henry Jackson, Utah State Historical Society USHS-970.8-14638) and in 2010 (CW-2010-09-26-454). Since at least the 1600s, large groups of Shoshone travelled through headwaters of the Snake and Green river watersheds to hunt and process bison (Nabokov and Loendorf 2004; Hodge 2009). Native sagebrush and willow cover is now altered by hayfield irrigation and stock grazing.

- **L: Absoraka Range** – The valleys into the range are steep-walled and narrow, and in winter are blocked at upper elevations by snow. Bison could thus be herded into these valleys for "storage-on-the-hoof" (a technique described by Frison 2004, Kornfeld et al. 2010). For example, Howard (1941) documented a story told by the Crow Plenty Coups to Horace La Bree, an early settler. When Plenty Coups was about 12-years old (about 1860), his father took him on a bison hunting trip up the Yellowstone River. He recounted that they spotted a "*herd of 200 or 300—going up— toward these mountains*." The hunting party pursued the bison across the Yellowstone River, and up Buffalo Creek where animals were reported trapped against a cliff and killed.
- **M: Yellowstone Lake and Plateau**- Due to conditions along travel routes described above, few bison could routinely reach this area from the large herds to the east (Gates et al. 2005, Gates and Bromberg 2011), and there no visual observations of bison here prior to the 1860s (Figure 4.3.1-5). However, similar to densely forested areas to the north (see Section 4.3.3), it is likely that a low densities of spaced-out bison could persist on the plateau for extended periods (Meagher 1973) if they avoided open valleys or large meadows where they could be easily killed by communal hunters. The geologist Arnold Hague (1893, quoted in Meagher 1973) described this type of behaviour in an early account Yellowstone's bison, likely a remnant population from the 1820-30 herds: *"Even in this elevated region they live for the greater part of the year in the timber….most unusual save in md-winter to find them in an open valley or on a treeless mountain slope. They haunt the most inaccessible and out-of-the-way places… living in open glades and pastures, the oases of the dense forest…. The rapidity of their disappearance on being alarmed. It is surprizing how few bison have been seen in the summer, even by those most familiar with their haunts and habits. The wander around in small bands.*" This description closely matches behaviour of low density bison herds observed by early journalists in boreal forests further north (Section 2.4) that "spaced- out" to reduce human predation risk.
- **N: Bechler Meadows and Southwest Yellowstone Plateau Approach**- During the 1820s and 30s several journalists recorded numerous bison in grasslands along the lower Teton, Warm Fork, and Henry's Fork rivers. From here, bison could, if hunted, "space-out" into dense forests to the northeast near Bechler Meadows. In fact, in June 1825, Peter Ogden's brigade traded with Shoshone hunting bison near here (Rich 1950), and it is quite possible that some of these bison dispersed into today's Yellowstone National Park.
- **O: Red Rocks and Henry Lake Meadows**- Several first-person journals record hunts of abundant bison on the upper Beaverhead and Ruby rivers (Figure 4.3.1-5). Meagher (1973) observes that for the Red Rock Lakes area: "*numbers of bison once lived close to the park. Many skulls have been found in the Red Rock Lakes area, approximately 35 miles west of Yellowstone (Owen Vivian 1968 pers. comm.) Frank Childs, former Yellowstone ranger who worked on Red Rocks land acquisition matters during the mid-1930s, heard that 300 bison died there during a bad winter many years earlier (1965 pers. comm*.). Today, numerous historical wallows are visible near Red Rock Lakes, and it is likely that some bison did cross over the pass into the Henry's Lake area, or reached here via the upper Beaverhead or

Henry's Fork rivers. Bison moving further eastward would be at high predation risk along the Madison River canyon into Yellowstone National Park.

- **P: Paradise Valley along Yellowstone River**- Once bison travelling up the Yellowstone River passed through the gap along the river south of Livingston, they were effectively contained in Paradise valley, walled-in on the east by the Absoraka Range, and the west by the Gallatin Mountains. Due to open vegetation conditions and containment (Figure 4.3.1-4), communal hunters could easily work these herds. Arthur (1966) describes numerous archaeological features related to bison hunting including small jumps and drive lanes. Moreover, during deep-snow winters bison would be forced down valley to the narrow gap near Livingston. Lahren (2006) describes relatively abundant bison occurrence in archaeological sites here. Given this high risk of predation, bison would be unlikely to persist here, and historical journals record no bison observations upstream on the Yellowstone above Livingston, although numerous bison occurred further downstream (Figure 4.3.1-5).
- **Q: Bozeman Pass and Three Forks**: In his journal observations for July 14, 1806 William Clark described recently used bison trails connecting the Three Forks area to Bozeman Pass (Moulton 1993). However, this travel corridor narrows to less than 50m wide at Bridger Canyon (Figure 4.1-2), so the number of bison that could travel from the Yellowstone watershed over the pass to Three Forks was greatly constrained by terrain that risk sensitive bison would avoid.
- **R: Lower Yellowstone River**- During the 1800s, early travellers frequently observed bison along the Yellowstone River today's Big Timber down to the confluence with the Missouri. For this period, Hodge (2013:195) described this as an intertribal buffer zone between the Crow and the Shoshone: "*Crows struggled with the Lakota, but they continued their westward push along the Yellowstone River, depriving Shoshones of prime hunting grounds. Indeed, many traders who visited that area between 1802 and 1806 noted that the Yellowstone valley teemed with game. Larocque, for one, observed that "the country abounds so much in Buffaloes and Deer that they [Crows] find no difficulty in finding provision for a noumerous [sic] family." But this was not Shoshone country, for by 1800 Crows claimed lands as far west as the Absaroka and Wind River Ranges. Crows and Shoshones sometimes fought as a result, but they had common enemies in the Blackfeet, Sioux, and Gros Ventre and occasional truces resulted.*

Montane Valleys Region: Summary of Preliminary Evaluation of Bison Movement Corridors- Researchers propose alternate hypotheses for bison movements in this region of the Rocky Mountains. Gates et al. (2005), quoting long-time Yellowstone bison researcher Mary Meagher state:

Prehistorically, YNP bison ranges were probably the "tips of the fingers" of seasonal migration from large source populations associated with expansive grasslands (Figure 4.1) lying to the north, west and southwest around the Yellowstone Plateau (Interview with Mary Meagher, July 15, 2004). The high mountains on the east side of YNP and discontinuous habitat would likely not have supported bison *migration. Historical accounts indicate that interior ranges also supported resident bison populations (Meagher 1973: Appendix II).* (Gates et al. 2005, pg. 79, also see Gates and Broberg, 2011, p. 66)

In contrast, more recently United States national park researchers Schullery and Whittelsey (2006) reviewed selected temporal and spatial scale analysis of bison abundance in the mountains and plains of the Greater Yellowstone area, and concluded that:

What the historical record does tell us is that bison were here, they were all over the place, they were abundant, and, if we may add a new and sadder meaning to Warren Ferris's words, "nothing remains visible of the long black lines but dark clouds slowly sweeping over the distant plains (Schullery and Whittelsey 2006).

Detailed eco-cultural data, and preliminary quantification of a process-based wildlife corridor movement model (Figure 4.1-2) supports the Meagher's "tips of the fingers" analogy for bison movements into the uplands and mountains of this area of the Rocky Mountains (Gates et al. 2005:79). Long-term spatial and temporal variability in bison use of the montane valleys region of the western Cordillera was variable and complex, but still relatively predictable (Bailey 2016). This variation is related to interactions between biophysical and cultural factors relatively unique to this region, and that created different bison movement patterns than regions further north. Bison were most common on the plains and grasslands in large montane valleys, and infrequently observed in mountainous or forested terrain.

More specifically, historic bison occurrence in the Yellowstone region of the Rocky Mountains did not, as Schullery and Whittlesey (2006) state, follow a pattern where "they were all over the place, they were abundant…" Similar to their controversial conclusions on the abundance of Yellowstone elk in the early historic period (Schullery and Whittlesey 1992, disputed by Keigley and Wagner 1999, Wagner 2006), this statement is highly questionable based upon historical data. Within the high country and mountains of the Yellowstone plateau, the weight of evidence is that bison were at relatively low densities. This was the result of a complex corridor movement processes interacting with terrain, habitat, and predation conditions that need to be more accurately described and understood.

4.3.2 Mountain Wall Region

Overview- From Lewis and Clark Pass near the Great Falls on the Missouri in Montana northward to where the Bow River enters mountains (near current-day Calgary Alberta), relatively level prairie with low vegetation cover reaches right to the wall of the Rocky Mountains (Figure 4.3.2-1). Due to chinooks, bison use was periodically high on these plains and low foothills during the winter. Valleys entering the mountains are narrow, and at least at their entry points to the mountains historically had very low forest cover (Figure 4.3.2-2) due to historical burning patterns (Barrett 1993, Rogeau et al. 2016). Ironically, these conditions appear to have greatly limited bison movements into the mountains. Possibly relatively high Native American numbers, including hunting parties crossing from the Cordillera from the west (Schaeffer 1940, Anatasio 1985, Scott 2015), and communal hunting techniques used in open vegetation near the mountains (Reeves 1990, 2003; Brink 2008) made bison killing relatively easy, limiting bison numbers that actually reached or entered the mountains, and thus limiting movements westward.

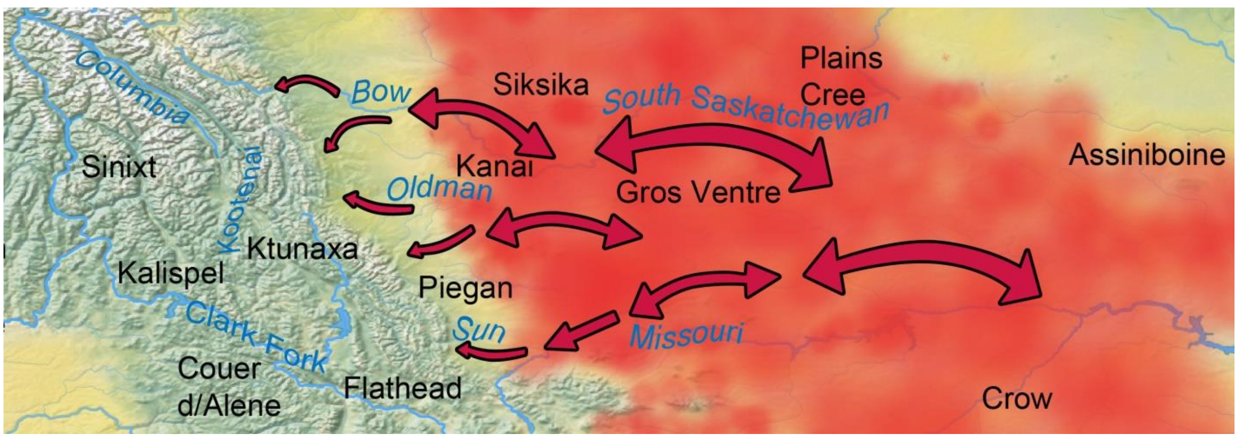

Figure 4.3.2-1: Some potential bison movement corridors in the “mountain wall” region of the Western Cordillera showing the location of selected Native Americans c.1800. Red indicates relatively high bison source population areas, grading through yellow to low bison density, and green (no bison). Two-way arrows indicate annual bison movements, one-way arrows indicate potential dispersal into sink population areas.

Biophysical Factors- The 1500m high wall of rock rising out of the foothill grasslands along the Rocky Mountains between the Missouri and the Bow rivers (Figure 4.3.2-2) is visually stunning for today’s tourists, and historically provided unique terrain for prehistoric bison and their hunters. In winter, the chinook winds that pass over the Rockies from the southwest, frequently blast the grasslands free of snow. Here, bison in many years could escape deep snowpack and colder conditions further out on the plains. In fact, in many winters, bison might not encounter snow until within the mountain valleys. The strong warm winds and snow free condition keeps the country tree-free. Firstly, large wind-driven fires can occur here virtually any month of the year, and some of largest fires are human-ignited blasts that sweep for many kilometers eastward, consuming the long-dried, dormant grasses through the late summer, fall, winter, and green-up in later spring. Fire frequency is less than 30 years at edge of forests, and may have occurred almost annually in portions of the adjacent grasslands (Barrett 1993, Rogeau et al. 2016, Stockdale 2018). Secondly drought conditions limit where forests can grow, and the rate of regeneration, thus the landscape stays tree-free. However, the fescue grasslands at the edge of the mountains are better watered than the short and mixed grass prairies to the east, thus in most years bison might move here later in summer to obtain higher quality forage. Then, beyond the climatic and vegetation conditions there is the terrain itself. Almost all valleys in this section of the Rockies narrow, usually within a few kilometers of entering the mountains into corridors, walled by rock, streams, or lakes less than 200m wide. These mountain valley corridors, coupled with presence of savvy human hunters, could have been lethal terrain traps for bison (Reeves 1990, Frison 2004, Kornfeld et al. 2010).

Figure 4.3.2-2: Vegetation conditions below the Livingston Range in southern Alberta in 1884 (George Dawson, Geological Survey of Canada, PA-037973), c. 1915 (Dominion Forest Collection-6844) and in 1999 (CW-1999-09E-08). Historically, high fire frequency, largely caused by native burning (Rogeau et al. 2016, Stockdale 2017) removed trees between the prairies and mountain slopes to the west. Open vegetation conditions may have facilitated communal hunting practices where bison were driven towards the mountains then killed in terrain traps such as narrow valleys, snowfields, pounds, or jumps.

Cultural Influences-The biophysical factors that favoured bison's movement towards the mountains in late summer and winter, and potentially easy entrapment within its valleys, appear to have favoured unique communal hunting cultures centered on the foothills and adjacent plains such as the Piegan, Kainai, and Siksika peoples (Reeves 1990, 2003; Brink 2008; Zedeño et al. 2014).

Spatial Variability in Bison "Source Population" Area- Several studies describe the abundance of bison by season for this region (e.g, Binnema 2001, Peck 2001, see Section 2.2.1). In general, during the spring and summer bison herds amalgamated in the centre of the plains along the South Saskatchewan, Milk, and Missouri rivers, and in the fall and early winter, depending on drought, snow or other conditions would move westwards towards the foothills where the Sun, Belly, Oldman, Highwood, Bow, and other headwater streams left the mountains. Bison observations made in historical journals are shown Figure 4.3.2-3.

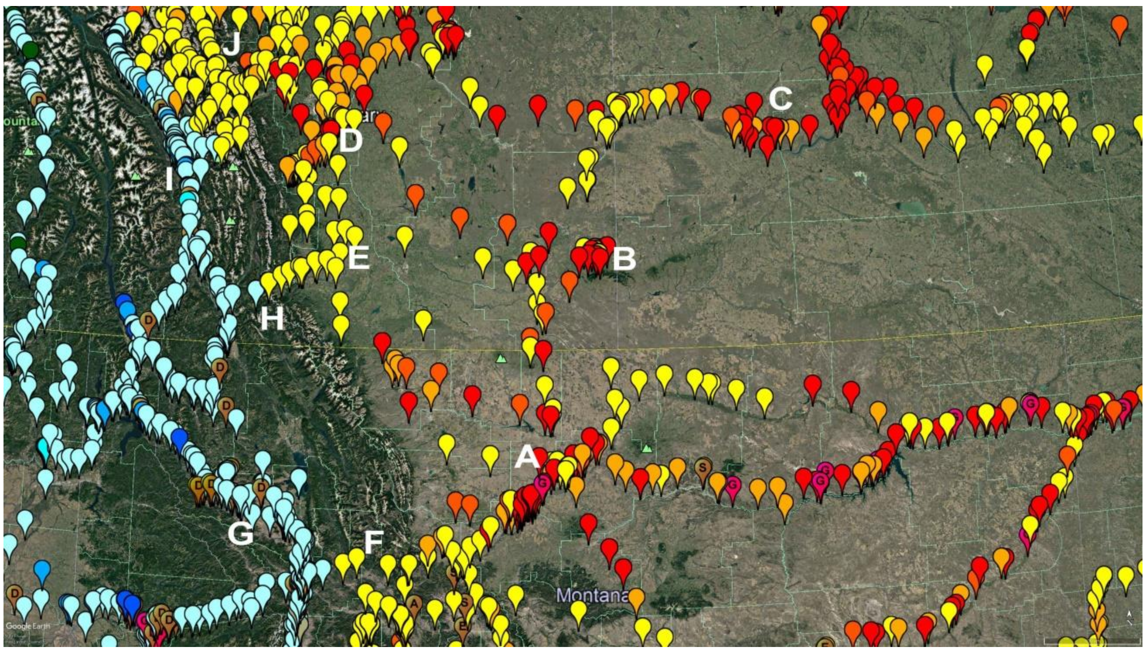

Figure 4.3.2-3: Relative numbers bison observed in first person daily journals (1790 to 1860) in the "mountain wall" region at the headwaters of the Sun (Missouri), Belly, Oldman, Highwood and Bow rivers flowing east, and Clark Fork, Kootenai, and Columbia rivers flowing west. Red indicates abundant bison, orange moderate number of bison, and yellow is no bison seen or no wildlife observations for day. Blue colours are associated with observed fish abundance on Pacific watershed streams. Other wildlife observed (subjective observations) is indicated by D (deer), S (bighorn sheep). See text for details for areas keyed to letters in white bold text. For a more detailed view, download Google Earth journal wildlife observation file at: https://lensoftimenorthwest.com/themes/lens-northwest-files/google-earth-map-journal-wildlife-observations/

Some potential patterns in the source zone based upon this research, first-person daily journalist observations and wallow surveys, and keyed to locations to Figure 4.3.2-2 are as follows:

- **A: Great Falls on the Missouri**- This area had high bison densities during the period of the Lewis and Clark expedition (Moulton 1993), and based upon archeological site bone assemblages, may have had relatively consistent high bison numbers for the last 1500 years (Figure 2.3-1, from Cooper 2008). High bison densities in summer this close to the mountains could be somewhat unique. During the 1700s and 1800s this likely occurred because the area was in a war buffer zone between the Blackfoot confederacy (Piegan, Kainai, Siksika, Gros

Ventre), the Crow to the southeast, and several groups to the southwest such as the Kootenai, Flathead, and Nez Percé (Anastasio 1985, Binnema 2001, Kay 2007).

- **B: Cypress Hills-** These wooded uplands area a relative "oasis" in the dry prairies along the 49th parallel, and lie in the center of the large bison populations that likely lay along the Missouri and Milk rivers to the south, and South Saskatchewan valley to the north. Although herds of bison might avoid these hills when occupied by humans, the historical journal observations by Harriot for late November, 1822 (Binnema and Ens 2016) and Palliser for August, 1859 (Spry 1968) show that bison were attracted to the grasslands surrounding the hills by good forage in summer droughts, and cover during the winter. However, to-date few wallows have been located in the hills (CW bison wallow database in progress), indicating that at least in early-mid summer, bison likely moved elsewhere.
- **C: The Elbow on the South Saskatchewan River**- For the northern portion of the mountain wall region, in summer, and perhaps winter in many years, the closest routine sources of abundant bison appear to have been along the South Saskatchewan and lower Red Deer rivers, eastwards to where the river bends to the north. Several journals report encountering abundant bison in this area including Peter Fidler in 1793 (Johnson 1967), the Saskatchewan River Expedition of 1821-26 (Binnema and Ens 2016) and the Palliser Expedition of 1857-59 (Spry 1968). Moreover, there are superabundant wallows visible on hillslopes along many sections of this valley (CW bison wallow database in progress), and likely in the past there were even higher densities near the river before being altered by flooding or agriculture.

Variation in Bison Corridor Use over Time- Over the time of the historical period (1790s to 1860s) there seems to be a consistent pattern of abundant bison to the east on the plains, and very few bison in the mountains (Figure 4.3.2-2). Likewise, the archaeological record does not show a great deal of variability of bison use in the source population area for the period 500 AD to 1700 AD (Cooper 2008, see Figure 2.3-2). Bison wallow surveys to-date have found few wallows in or near the mountains indicating no or few periods of past dispersal events into mountain valleys where bison persisted into the summer wallowing period. The consistency of this temporal pattern may best indicated by wallow survey results to-date. These find no bison wallows in the grasslands along the Blackfoot River in Montana, whereas less than 70km to the east, over relatively moderate terrain, Lewis and Clark observed vast herds of bison in 1805-06, and Cooper's (2008) archaeological meta-data research indicates this pattern of low permeability into the mountains west of Great Falls may have been consistent into the past. However, given that wallow surveys may not be applicable to this area (see Section 3.6), additional archaeological work will be required here (Scott 2014) to interpret the long-term temporal pattern.

Spatial Variability in the Bison "Sink Population" Area- As discussed above, there is scant historical data for bison use within the cordillera itself for the "mountain wall" region. Reeves (2003) describes that:

"Small herds of mountain bison seasonally frequented the eastern slope valley floors. They moved from winter ranges in the lower grasslands, and valley sides at the mountain front where calving would occur in mid-late May, upvalley and upslope into summer-early fall ranges in the higher tributary valleys,

mountain slopes and along the Continental Divide where the summer rut occurred. They returned down valley and downslope in the fall. The local herds consisted of small cow/calf groups, small bull groups, and isolated animals moving on this general round. No doubt some animals stayed in the lower valleys and slopes year round. Herds may not have only seasonally dispersed upvalley and upslope, but probably seasonally migrated between the Eastern Slope valleys as do elk herds in Waterton-Glacier today."

Reeve's (2003) "small herds" bison use model can to some degree be evaluated with archaeological research, historical journals, and wallow surveys that provide descriptions of ecosystem states and processes, particularly along the edge of the "sink population" area on the Rocky Mountain front. Select areas are described below, keyed to the letters in Figure 4.3.2-2:

- **D: Upper Highwood Valley**- It is from this watershed that we have one of the earliest, and clearly described historical passages how some herds of wary bison entered the mountains. For December 28, 1792, while camped with a large camp of Piegan, Peter Fidler recorded how young men would go out onto the prairie, and drive bison westwards: *The Young Men sleep out all night in general, when they bring the Buffalo to the Pound, & sometimes they will bring whole herds above 40 miles off & sleep 2 or 3 nights according as they can drive them in a direct manner or not towards the Pound. The Old Men & Boys attend to the Dead Men, the Buffalo is pretty nigh, one or 2 men alternately keep a constant look out to notice when the Young men have brought the herd near, when the holler is made & every Oldman & boy immediately runs to the Dead men & lays flat on the ground, before the Buffalo is very nigh that they might see nothing stirring. The tents are always pitched in a hollow that the Buffalo cannot see them until they are just on the point of getting into the Pound. Bringing the Buffalo to the Pound, particularly when at a great distance, is a very hard job for the Young men, as they are obliged to run so very much to keep the Buffalo in the proper direction for the Pound. The is a deal of art in this driving the then the way they wish, as it is such a wild Animal, & the sight of a single person will frighten a whole herd. They will smell a person at an amazing distance when they are to the leeward of him, & if one runs, should there be thousands in the herd, they will all run* (Haig, ed. 1991:p. 42). Moreover, in several journal entries, Fidler describes how the Piegan were routinely burning snow-free areas of the prairies during the winter (Haig, ed. 1991), and these burns may have partially influenced bison movement patterns.
- **E: Upper Oldman and Head-smashed-In**- Brink (2008) uses this bison jump in this area as a focal point to describe research on bison movements and human hunting patterns in the mountain wall region. Archaeological evidence indicates the jump was mainly used in the late fall or early winter to kill mixed herds of females accompanied by calves and young of the previous year. These animals may have sought forage or have been hazed by humans westwards from the plains (see above) towards the Livingstone Range (Figure 4.3.2-2), then were driven by hunters back to the east and over rock cliffs such as Head-Smashed-In, or into other traps such pounds or narrow draws (Reeves 1990, 2003). Only a few wallows occur in surveys to-date in this area suggesting only light summer use of this area (CW bison wallow

database in progress). Further, the grasslands here are dominated by rough fescue which is most persistent in areas where it is not heavily grazed in spring or early summer, indicating a long-term grazing regime where bison were further out on the plains during the spring and early summer, but may have had moderate grazing impacts in fall or winter (Wikeem 1985, Willms 1991, Adams et al. 2005).

- **F: "Buffalo Road Trail" and Blackfoot River Prairies -** The influence of native hunters on bison herds in the mountain wall region is best understood along the Blackfoot River on the route western from the Clark Fork to the Sun River and Great Falls area. As described by Scott (2015), "the Buffalo Road Trail was used for centuries by Columbia Plateau Indians to access buffalo hunting grounds east of the Continental Divide." Of interest here is to consider that not only would this trail provide an easily travelled access for hunters travelling east, but also theoretically for bison to travel west. Not surprisingly, while travelling on easy trails eastwards in July, 1806, Meriweather Lewis' group did see bison sign west of the divide along the Blackfoot River, and the next day he crossed to the eastern slopes to reach areas of abundant bison (Moulton 1994, Vol. 8:94-97). So given that bison were abundant only 2 days relatively easy travel to the east, why did Lewis not see abundant bison on the large prairies along the Blackfoot River? Why do wallow surveys to date not find wallows in this area of excellent habitat? A potential explanation is that this corridor was, for centuries, routinely used by hunters specifically going east to hunt bison (Farr 2003, Scott 2015), and given the constrained valley terrain, any bison encountered on these trips would be immediately killed. So regardless of the high bison density immediately to the east, any bison moving through the Blackfoot corridor or into other valleys such as the Sun River other could not withstand intense, ongoing human predation from the west. Blackfoot confederacy tribes from the prairies, or mountain native peoples such as the Flathead and the Kootenai had clearly mastered the use of the terrain on the eastern slopes of the Rocky Mountains to entrap and hunt bison. As an example , in 1941, Frank McCleod documented an account given by his mother, Mary Finley, about accompanying Flathead bison hunters to the Sun River area in 1836: *"We made our camp at the mouth of the north fork of the Sun River. Early the morning after our arrival, our men left camp for a hunt on the prairies. Empty handed they returned that night. They informed us that they had seen many large herds stampeding in a northerly direction, but they were unable to get within killing distance of the animals….The third morning the hunters rode away in hope, nor were they to be disappointed .They succeeded in sheering what we called a small herd up North Fork Canyon. Their intention was to kill just the amount that was needed. However, the herd swung up along our side of the canyon. The trail terminated in a narrow cliff. The buffalo could not turn around and make their way back to safety. Over the side they literally poured in a 300 foot drop to the jagged rocks below."* (Whealdon and others 2001:40-41).
- **G: Horse Plains on the Clark Fork River-** This area was a marshalling center for large groups of Columbia Plateau people (often >1000 people) to meet and organize logistics prior to going east to the prairies by the Buffalo Road Trail, Kootenay Passes, or other routes, and when they returned to process and trade bison products such as beat meat, pemmican, leather, or robes

(Anatasio 1985). Starting in 1811 the Northwest Company and the Astorians, and later the Hudson's Bay Company established posts here to send traders out with these groups, or trade with them upon their return (Ross 1956, Rich 1950).

- **H: Kootenay Passes**- Prior to the 1800s, the K'tunuxa, and possibly several other Columbia Plateau groups were using these passes to routinely reach the Great Plains on the headwaters of the Belly and Oldman rivers (Schaeffer 1940, Reeves 2003). Large groups would likely assemble on the Horse Plains, Tobacco Plains, or other secure areas west of the divide, and spend long periods of time on the prairies obtaining bison. Thus, the plains at the entrances to these passes, and the valleys approaching them from the east (e.g., Waterton and Castle rivers) would be heavily used by hunting groups coming and going. Similar to the Buffalo Road Trail environs described above, this human corridor use likely blocked most incursions of bison from the east. In the 1800s, although bison were often common on the prairies near the eastern approaches to these passes, they were not observed in the mountains (Figure 4.3.2-2, NWPC wildlife journal database). Surveys to-date have not located bison wallows on grasslands at the base of the western, Flathead valley approaches to either the south or north Kootenay passes, although given the archaeological evidence for prehistoric bison in the approach valleys from the east such as Blakiston Brook (Reeves pers. comm.; Reeves 2003) it is likely that bison did periodically reach the Flathead valley.
- **I: Columbia and Kootenay Valleys, Rocky Mountain Trench**- Stretching northwards from the Tobacco Plains on the Kootenay River, to north of Windermere Lake on the Columbia River is a large area of warm dry open woodlands, marshlands and small prairies along the bottom of the Rocky Mountain Trench. Today this important year-round range for a variety of large ungulates (moose, elk, white-tailed and mule deer), and historically if any bison did cross through the passes of the "mountain wall region" they would have eventually reach here. However, archaeological research (summarized by Heitzmann 2009), historic journal wildlife observations (Kay et al. 1999, 2000; Kay and White 2001), and bison wallow surveys (CW bison wallow database) show little or no past bison use in the area.
- **J: Upper Bow River Valley-** The headwaters of the Bow River including the Ghost and Kananaskis breach the eastern slope at the north end of the "mountain wall" region. All these watersheds have narrow gaps that constrict wildlife movements that even today result in high mortality risk or wildlife avoidance due to highways and urban development (BCEAG 1998, Duke et al. 2001). Dense vegetation now provides some cover for wildlife, but historically frequent fires maintained shrublands and meadows here (White et al. 2001, Rogeau et al. 2004, White and Hart 2007), favoring communal bison herding and hunting. Moreover, this region was also used at least periodically by K'tunaxa and Salish peoples coming from the west (Langemann 2001). Bison approaching the mountains along the Bow River, and particularly to bison in narrow gaps such near Wedge Mountain in the Kananaskis, Lac des Arcs in the Bow, and along Lake Minnewanka and Ghost Lakes on the Ghost River corridor (Landals 2008) would be at high hunting risk. As a result, over the long-term, bison numbers were likely low in the southern area of today's Banff National Park, and this prediction is supported to date by archaeological data (Kay et al. 1999), historical wildlife observations

(Figure 4.3.2-2 above), bison wallow surveys (CW database in progress). However, bison observations recorded by James Hector in 1859 (Spry 1968) indicate bison movement connectivity between the upper Bow and North Saskatchewan watersheds (see Section 4.3.3).

Mountain Wall Region: Summary of Preliminary Evaluation of Bison Movement Corridors- The consistent spatial and temporal lack of bison movements into the Rocky Mountains between the Missouri's "Gateway to the Mountains" near today's Great Falls north to the Bow River west of Calgary suggests that Reeves (2003) description of relatively low bison use of the mountains here may, if anything, be an overestimation. This area may provide a strong example of interaction between long-term biophysical and cultural processes strongly limiting bison use of the mountains. On the basis of Fidler's detailed description of Piegan bison hunting during the winter of 1792-93 (Haig 1991), and other descriptions of traditional knowledge and First Nation's sophisticated bison hunting techniques in this region, it is reasonable to propose that the Blackfoot peoples and others, over many centuries, maintained open vegetation conditions, and developed an intricate system of pounds, terrain traps, jumps, snow traps and other bison communal hunting techniques (Reeves 1990, 2003; Brink 2008, Zedeño et al. 2014). This social system effectively limited most bison incursions into the Rocky Mountain front. The few bison that did survive this intense hunting, and did get into the mountains then encountered numerous peoples such as the Ktunaxa and Flathead coming from the west, apparently stopping bison colonization of high quality grassland habitats in the Rocky Mountain Trench and adjacent valleys. Whatever processes caused this sharp edge of bison range along the mountain wall region, they may to have been consistent for most, if not all, of the Holocene period, for no bison herds appear to have become established on these high quality grasslands, lying less than 50 km to the west of the continental divide (Roe 1972, Kay et al. 1999, Kay and White 2001; Adams and Dood 2011).

4.3.3 Forested Foothills and Boreal Plains Region

Overview- Northwards from the Bow River, a widening wedge of conifer and mixed conifer forest covers the foothills and plains. During deep snow winters on the plains, high densities of bison would enter the aspen parklands adjacent to this forest (Binnema 2001,2016; Peck 2001). In sharp contrast to the "Mountain Wall" zone immediately to the south, these conditions appear to have favored bison entering the mountains, at least for a distance of 20 to 100 km westwards (Figure 4.3.3-1). In fact, the grasslands on the Ya Ha Tinda along the Red Deer River have the highest historic wallow densities of any area yet surveyed within the western Cordillera (see below), and historic bison observations (Kay et al. 2000) and bison wallows are moderately common on the North Saskatchewan's Kootenay Plains and in the Athabasca Valley of Jasper National Park. Further north, low densities of bison were common in the boreal forest and foothills, and at least into the 1790s, bison were common on the grasslands of the Peace River immediately east of the mountains (Ferguson 1993).

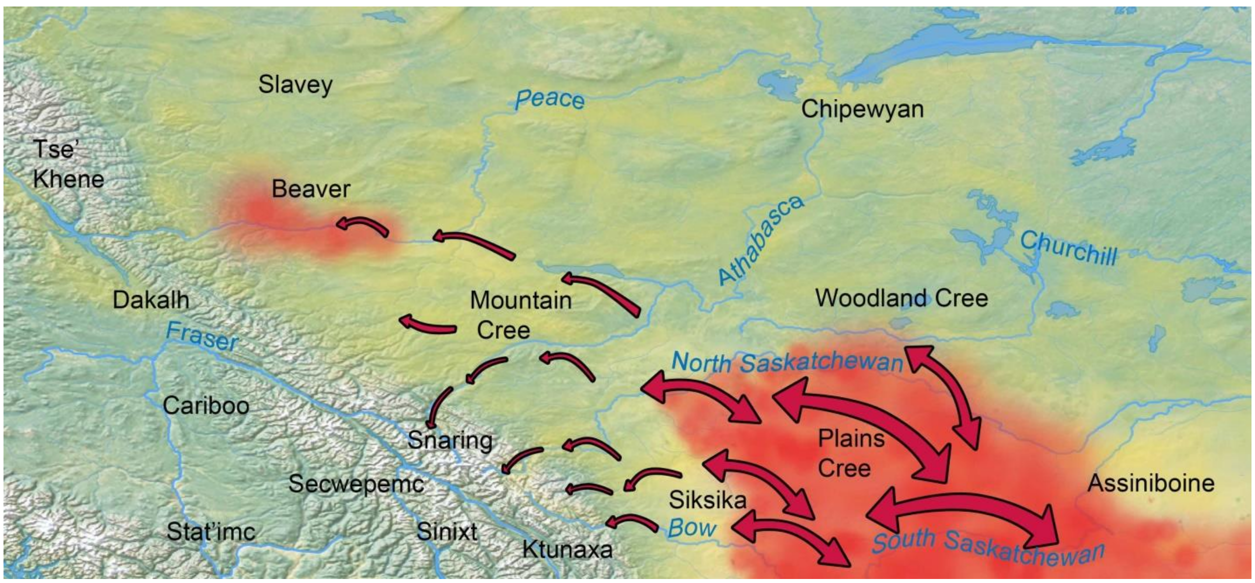

Figure 4.3.3-1: Potential bison movement corridors in the "forested foothills" region of the Western Cordillera showing the location of selected Native Americans c.1800. Red indicates relatively high bison source population areas, grading through yellow to low bison density. Two-way arrows indicate annual bison movements, one-way arrows indicate potential dispersal into sink population areas.

Biophysical Factors- The physiographic conditions of the forested foothills and boreal plains region is similar to the mountain wall region to the south—flat level terrain rising into ranges of foothills, and then the front ranges of the Rocky Mountains. What is different is the vegetation cover. Here, moister conditions increased the long-term wildland fire cycles >50 years compared to <30 years in areas further south (Rogeau et al. 2016). Thus, instead of fescue grasslands and aspen parklands abutting the mountains, the transition between the prairies and mountains to the north is covered with dense forest, widening from no forest cover along the Bow River, to 30 km along the Red Deer River (Figure 4.3.3-2), to 100 km on the North Saskatchewan, 200 km on the Athabasca, to over 300 km from the northern prairies to the Peace River (Figure 4.3.2-1). This is largely a conifer or boreal mixed wood forest dominated by uplands of lodgepole pine, white spruce and aspen, muskegs of black spruce and tamarack, and relatively small grasslands (Strong and Leggat 1992, Meidinger and Pojar 1991). Bison in these northern forests tend to "space-out", and become cryptic and wary (Section 2.4). Bison may also have historically utilized muskegs where travel and detection is difficult. Climatic and weather patterns are different on the northern plain than more southern areas, and this may also influence bison movements. The snowpack is typically deeper, long cold periods occur more often, and fewer chinooks occur that would melt away snow. This may tend to drive bison further into woodlands adjacent to the plains during cold, snowy winters.

Figure 4.3.3-2: View west of meadows along the Red Deer River and the Rocky Mountains from topographic survey station 148 west of Sundre, Alberta in 1917 and on June 18, 2008. Contrast historic forest cover conditions in this area to conditions further south shown in Figure 4.3.1-2.
(Source: M.P. Bridgland, Mountain Legacy, BRI1917-B17-190 and ML-B0001661, http://explore.mountainlegacy.ca/stations/243).

Cultural Influences-The "annual round" of boreal and woodland cultures occupying the region was different than those to the south. Unlike plains cultures that usually maintained moderate to large camps largely dedicated to communal bison hunting (Binnema 2001, Peck 2001), during several periods each year, northern woodland people often fragmented into small family groups to hunt and trap individual watersheds where game such as bighorn sheep, moose, deer or elk also occurred (McMillan 1995, Burley et al. 1996, Kay et al. 2000; Langemann 2001, 2011, 2017; Allen 2018). One potential influence of more dispersed humans on bison is that they would perhaps enter the foothills and mountains in an area of low human density, thus initially survivorship near the mountains would be much higher than in the open foothills to the south. Secondly, with good cover, bison could not be easily herded or communally hunted. However, over time, bison in woodlands and mountains, facing consistent predation from humans, often sustained by alternate prey such as bighorn sheep and moose, would tend towards low densities, and apparently bison became very secretive, and often use muskegs, bogs or other terrain that was difficult for humans to hunt (see Section 2.4).

Spatial Variability in the Forest Foothills and Plains Bison "Source Population" Area- The pattern of bison abundance and distribution remains poorly known across the vast curve from the Rocky Mountains to the Canadian Shield where the northern prairies grade into aspen parklands, mixed woods, and ultimately the boreal forest. However, what is apparent is that in past times, forest cover was clearly favourable bison habitat. Bison occupied, in nearly continuous distribution, a vast area of northern grasslands and forests north as far as at Great Slave Lake. Several area specific observations are keyed to the Figure 4.3.3-3.

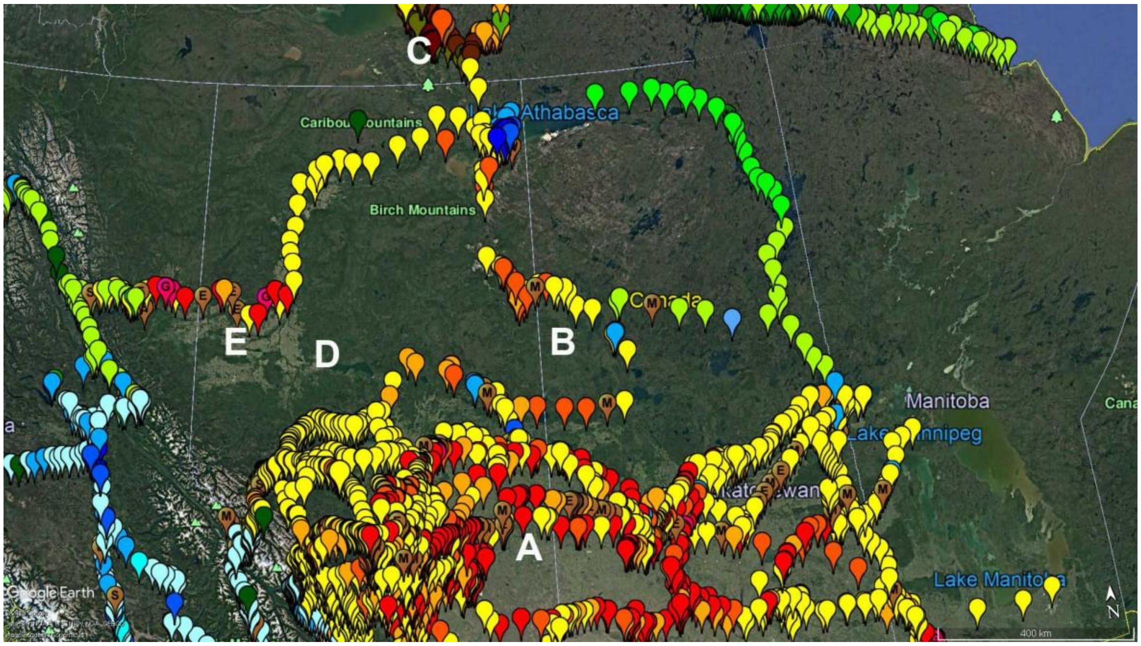

Figure 4.3.3-3: Relative numbers bison observed in first person daily journals (1790 to 1860) in source bison population area for the forested foothills and plains region. Red indicates abundant bison, orange moderate number of bison, and yellow is no bison seen or no wildlife observations for day. Blue colours are associated with observed fish abundance on Pacific watershed streams. Green colours are associated with observations in terrain primarily occupied by moose and caribou. Other wildlife observed (subjective observations) is indicated by D (deer), S (bighorn sheep), G (grizzly bear), M (moose) etc. See text for details for areas keyed to letters in white bold text. For a more detailed view and legend, download Google Earth journal wildlife observation file at: https://lensoftimenorthwest.com/themes/lens-northwest-files/google-earth-map-journal-wildlife-observations/

- **A: Northern Plains Grasslands and Parklands-** High densities of bison occurred, particularly in the summer, on the central northern plains in intertribal buffer zones between various factions of Cree, Assiniboine, Gros Ventre, Siksika and other groups, depending on tribal relations (Binnema 2001, 2016; Peck 2001; Colpitts 2015). During cold or deep-snow winters bison would move westward or northward into areas with denser forests but in other winters could remain well out on the grasslands, causing hardship for native peoples usually camped in more to the west or north in parkland aspen. There are numerous accounts of this bison movement pattern in this region, including from Anthony Henday in the winter of 1754-55 (Belyea 2000), Matthew Cocking in the winter of 1772-73 (Burpee 1909), for numerous native groups during the mild winters of 1830 to 1934 (Colpitts 2015), and by James Hector in 1858 (Spry 1968). Binnema (2016) describes the potential directions for future interdisciplinary research that can reveal the patterns of weather, fire, and human use that explain bison abundance by season across this region.

- **B: Southern Boreal Plains-** Early in the fur trade period, bison appear to have been relatively abundant in many forested areas north of the prairies. For example, Hudson's Bay Company mapper Philip Turnor describes how, by travelling the Christina River in 1791, his party had good bison hunting opportunities, compared to the more heavily used areas, but once his party descended to the Clearwater and Athabasca rivers, bison were not seen (Tyrrell 1934). Likewise, Mackenzie, during his trips from 1789 to 1793 reports few bison along heavily travelled areas of the lower Peace and Athabasca rivers (Lamb 1970).
- **C: Northern Boreal Plains-** Similar to intertribal buffer zones to the south, northern forested areas also appear to have maintained relatively high bison densities when they existed between tribes at war. In 1791-92, Peter Fidler hunted numerous bison while wintering with a group of Chipewyan in a disputed area along the Buffalo, Slave, and Talston rivers just south of Great Slave Lake (Tyrrell 1934).
- **D: Lesser Slave Lake to Peace River-** An obvious route from high density the northern prairies to the Peace River grasslands was along this corridor running northwest from Edmonton. Unfortunately, there are few, if any actual observations of living bison in this area. In 1899, Mair (1908:78) traversed this corridor and reported that for the area northwest of Lesser Slave Lake: "Though emphatically now a region of forest, there is reason to believe that vast areas at present under timber were once prairies, fed over by innumerable herds of buffalo, whose paths and wallows can still be traced in the woods."
- **E: Peace River Grasslands-** During the latter 1700s, this was an inter-tribal buffer zone between peoples to the west of the Peace River gap (Tse Khene, Sekani, Dakahl), and the Beaver, Chipewyan, and Cree to the east. Bison were relatively abundant here, as described by in 1793 by Alexander Mackenzie (1803), and early Northwest Company traders (Burley et al. 1996). By the 1820s bison numbers declined, likely due to heavy hunting to supply trading posts along the Peace, and Fort Chipewyan on Lake Athabasca (Ferguson 1993).

Variation in Bison Corridor Use over Time- During the historic period, there appears to have been little variability in the temporal pattern in bison corridor use into the mountains adjacent to this area. It was simply a pattern of general decline. As described by James Hector in 1858 when describing the area between the Athabasca and the Peace rivers (Spry 1968:126): "*Until a few years ago, these prairies* (along the Smokey River) *supported large bands of buffalo and elk. When we compare the description given by Sir Alexander McKenzie of the prairie country along Peace River, with its vast herds of buffalo and elks, when he passed in 1793, with the present northern limit of the large herds of these animals, at least three degrees of latitude further south, the change is very striking; and still more so if it is true, as the hunters say, that the disappearance of the large quantities of game has only taken place within the last 20 years*." Thus, although human densities were not high across much this region, routine hunting, and likely the introduction of firearms, reduced bison numbers. However, archaeological data (Kay et al. 1999, Kay and White 2000) and the abundance of wallows detected in several valleys (see below) indicate that there were at least brief periods in the prehistoric past where bison abundance was high in some locations within the mountains.

Spatial Variability in Bison "Sink Population" Areas- The movement of bison into the mountains along in the foothills forest region provides an interesting contrast in corridor biophysical and cultural characteristics and variable bison penetration distances (Figures 4.1-2 and 4.3.3-1). There is adequate information to describe 4 movement corridors into the mountains (Bow, Red Deer, North Saskatchewan, and Athabasca), but several other movement routes exist into the mountains (e.g. Clearwater, Brazeau, Smokey River etc.). Figure 4.3.3-4 shows historic journal observation of bison and other species along these corridors. Observations keyed to several locations along these corridors follow below.

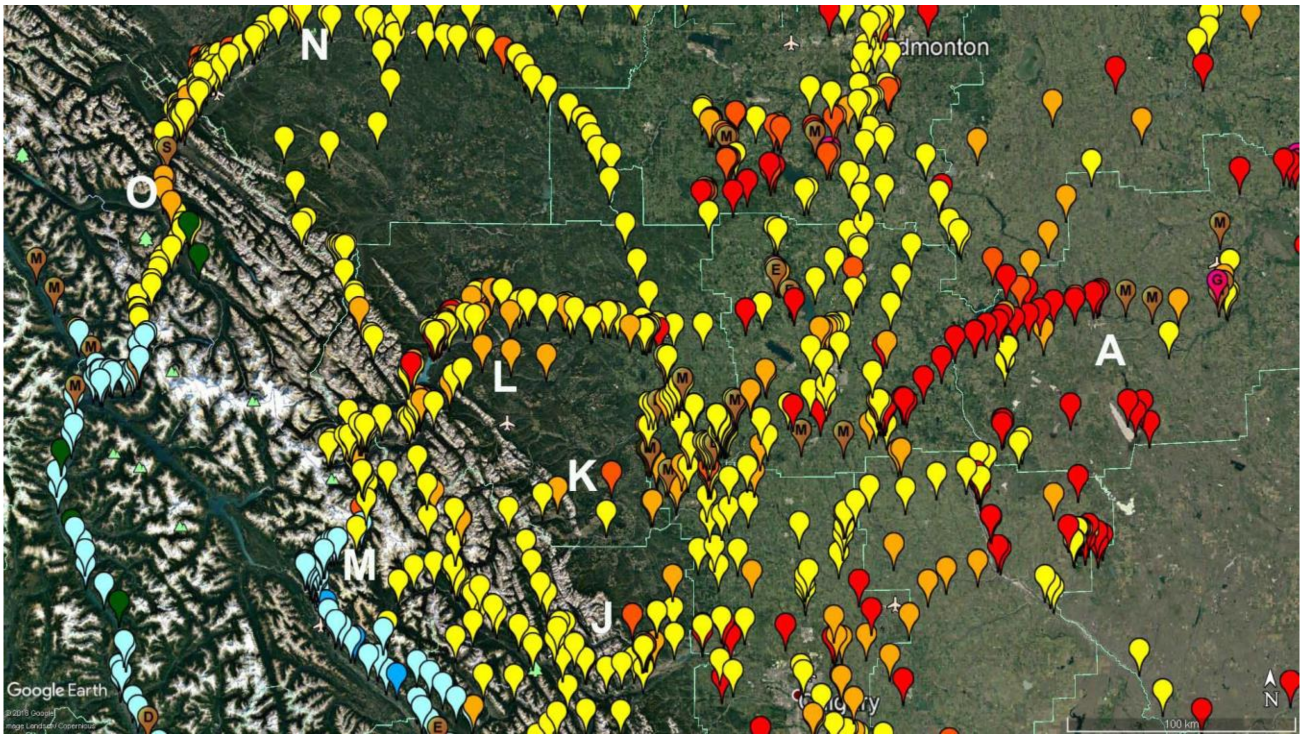

Figure 4.3.3-4: Relative numbers bison observed in first person daily journals (1790 to 1860) in the source population zone (A), and sink bison population areas (letters J to O) for the forested foothills and boreal plains region. Red indicates abundant bison, orange moderate number of bison, and yellow is no bison seen or no wildlife observations for day. Blue colours are associated with observed fish abundance on Pacific watershed streams. Green colours are associated with observations in terrain primarily occupied by moose and caribou. Other wildlife observed (subjective observations) is indicated by D (deer), S (bighorn sheep), G (grizzly bear), M (moose) etc. See text for details for areas keyed to letters in white bold text. For a more detailed view and legend, download Google Earth journal wildlife observation file at:
https://lensoftimenorthwest.com/themes/lens-northwest-files/google-earth-map-journal-wildlife-observations/

- **A: Source populations on the Northern Plains-** As described above, abundant bison existed here, and during cold or snowy winters they would move west towards the mountains or northwards into the aspen parkland and mixed-wood regions. The close proximity of this high number of bison, and the variability in weather conditions may have periodically created conditions where major dispersal events occurred into the forests occurred along the periphery of the plains.

- **J: Bow River Valley-** As described in Section 4.3.2 above, this valley is in included in the "mountain wall" region because it likely had relatively low bison abundance, evidenced by archaeological, wallow and historic journal observations (Kay et al. 1999, Figure 4.3.3-4). To contrast this with valleys further north, this was likely the result of four factors: 1) the Bow valley has open grassland terrain running from the plains right to its entrance into the mountains. This facilitated communal hunting that would reduce bison numbers; 2) immediately after its entrance into the mountains, the valley bottom corridor is reduced to less than 50m in width near Lac des Arcs and Gap Lake. Any bison that did reach the mountains would be easily trapped here by hunters; 3) for much of the historic and prehistoric period, the entrance to the valley was in the territory of the Blackfoot confederacy who were highly experienced in using this type of terrain to do communal bison hunting; and 4) once within the mountains, the Bow River watershed is easily accessible on the west from passes heavily used by several groups (Ktunaxa, Secwempec, possibly the Sin'ixt) all likely in this area with the intent of hunting bison (Langemann 2001, Kay and White 2001).
- **K: Red Deer River Valley-** The Ya Ha Tinda grasslands of the of the Red Deer valley (Figure 4.3.3-5) have the highest density of old bison wallows of any area yet surveyed within the Rocky Mountains (CW wallow database). Bison bones predominate in several archeological sites in the area (Ronaghan 1993, Langemann 2017). However, historic travellers such as David Thompson in 1801 (Belyea 1994) and De Smet in 1844 (Thwaites 1906) did not observe numerous bison in this area (Figure 4.3.3-4) suggesting that although very high bison use could occur here, these were episodic events. One complex hypothesis for this pattern is as follows: 1) Less than 100 km to the east of the mountains, the great plains adjacent to the Red Deer River area were routinely used by abundant bison during much of the year (Figure 4.3.3-4); 2) This large source population could result during a dispersal event in high numbers bison entering a relatively narrow band of forest (<30 km) that covers the foothills along valley as it enters the mountains (Figure 4.3.3-2). Wildland fires or winter blizzards on the prairies might stimulate significant bison movements in this area (Binnema 2016), and thus be the triggers for these dispersal events; 3) Once within the foothills, unlike grassland areas further south where bison would be rapidly killed by communal hunters, within the forests of the Red Deer watershed bison could space out to reduce predation (Section 2.4). However, native hunters occupying the lower foothills would tend to drive these animals up valley towards more constrained terrain; 4) In the summers following a dispersal event, bison spread through the forests, following their traditional pattern on the plains, would naively aggregate, mate and wallow on mountain grasslands near the river; 5) This herding would facilitate high predation by humans, possibly by driving bison further westward into the mountains, along human-burned, valley-bottom corridors (White et al. 2001b, 2011). This hunting would rapidly reduce bison numbers; 6) predation rates may have been further increased by K'tunaxa, Secwepemc, or Sin'ixt hunters from the west who would establish camps at locations such as Drummond Creek on the Red Deer headwaters, and drive bison westwards up to these camps to process them (White in Shury 1999, White et al. 2001, Langemann 2017); and 7) during time periods when a Native American group had exceptionally strong political control of the watershed, it would be possible to use the natural barriers surrounding the high

quality winter range on the Ya Ha Tinda and other grasslands to actually maintain bison herds by societal restrictions on the killing of breeding cows. This could further explain the abundance of wallows on the Ya Ha Tinda. However, during most time periods, like most regions used by bison, this area was likely a "hunting commons" (Langemann 2017) where this potential traditional use management strategy would not occur due to the generally high nutritional value of cows, and nomadic use by competing native groups (Kay 1994, Kay et al. 1999).

Figure 4.3.3-5. Looking east down the Red Deer River valley across the Ya Ha Tinda grassland from Wapiti Mountain in 1918 (M.P. Bridgland, Topographic Survey for Bow and Clearwater Forests, Station 208, Mountain Legacy Project BRI1918_B18-405) and in 2008 (Mountain Legacy Project B-0002520). By blocking narrow gaps in the mountain ridges in the background, First Nations could contain bison on high quality winter ranges within the mountains. In the background lie the foothill's forests and the Great Plains. For an enlarged, overlay view, see:
https://lensoftimenorthwest.com/galleries/alberta/south-saskatchewan/red-deer/ya-ha-tinda-mountain-prairie/

- **L: North Saskatchewan Valley-** This is a broad low elevation corridor that extends over 100 km into the mountains, and crosses the continental divide at Howse Pass. There are numerous historical journal observations of bison (Figure 4.3.3-4), as well as other wildlife, on the Kootenay Plains about 30 km within the mountains, including those by David Thompson in 1807 (Belyea 1994) and Alexander Henry in 1811 (Coues 1897). Some authors describe that abundant game here during the historical period may be the result of being in an inter-tribal war zone between Kootenai and Secwempec cultures from the west, and Cree and Blackfoot cultures to the east (Millar 1915, Kay et al. 1999, 2000). The Nakoda peoples describe traditional hunting and burning practices to maintain bison and elk habitat in the area (Allan 2018). Few archaeological studies of sites in the valley have been completed, but bison remains occur in those surveyed to-date (e.g., Allan 2018). Bison wallows are relatively abundant on transects done on the upper Kootenay Plains, and near Saskatchewan Crossing (CW bison wallow surveys). Processes influencing bison dispersing into the valley may be similar to those described above for the Red Deer watershed. The wide alluvial flats lying along the river may have been an ideal corridor for bison movements westwards nearly 100 km into the mountains.

- **M: Howse Pass and Blaeberry River-** Howse Pass, linking the North Saskatchewan watershed to the Pacific-flowing Blaeberry River is significant for bison ecology. About 8 km east of the pass is one of the few documented bison pounds within the Rocky Mountains. It was first noted by David Thompson in 1807 (Belyea 1994), and further described by Alexander Henry, who called it a "parc" during his visit in February, 1811: *"The Kootonases Parc stands upon the North side of the River and is nothing more than a narrow sloping stripe of soil covered with some small wood and grass running up along the declevity of the Mountain in an oblique direction for about one fourth of a mile when it terminates by a steep precipice down which it seems the Kootonaes formerly drove the animals after having enticed them to enter upon this narrow strip of soil. The place appears perfectly well adapted for the purpose, and every animal that would enter upon it could not possibly avoid being killed by the fall or at least so mamed as to prevent his escape…. On shovelling away the snow we found Bull Buffalo dung in abundance but it seems these animals come up thus far in the Summer Season only, as we had not seen a track since leaving the Forks, nor of any animal whatever.* (Gough 1988:511). On October 28, 1808, David Thompson's brigade followed a small herd of bison cows, likely driven by his hunters, over Howse Pass, and over 20 km down the narrow trail on the headwaters of the Blaeberry River where he recorded: "Cows still going before us—saw 2 of them" (Belyea 1994: 100). This may be the best documented of case of bison reaching the Pacific watershed slope in Canada.
- **N: Middle Athabasca River Valley-** In November and December 1810 David Thompson traversed the boreal forest between the North Saskatchewan and Athabasca rivers. At this time low densities of bison were still encountered in the uplands here. However, subsequent to that time bison were scarce, and numerous brigades travelling down the Middle Athabasca River from 1811 through the 1860s rarely reported any game, and no bison (Figure 4.3.3-4). This area appears to have been intensively used by independent Metis and Iroquois trappers (Murphy et al. 2007) who likely hunted out bison in the early 1800s.
- **O: Upper Athabasca Valley-** Early in the fur trade period, members of several brigades saw bison in the Athabasca valley near the current town of Jasper, including Thompson in 1810-11 (Belyea 1994), Franchere in 1814 (Franchere 1969), and Cox in 1817 (Cox 2004). Old bison wallows are visible along the Athabasca River (especially near the current air field), but they are not as common as along the Red Deer or North Saskatchewan rivers further south. Again, this relative abundance of bison in a relatively narrow valley this far into the mountains and distant from the plains is unusual. Possibly the processes of bison reaching the upper Athabasca River were similar to those described for the Red Deer River further south (see above), but due to a wider area of forest to cross, fewer bison arrived here from the plains. These bison may have been the primary goal of Salish hunters from the west, who were traditional hunters in the area (Pickard 1989, Osicki 2012, Dekker 2018). However, after bison were hunted out of the forests of the middle Athabasca River (see above), this connectivity with the plains was broken, and intense hunting associated with Jasper House and the fur trade eliminated bison in the upper watershed by the early 1820s.

Forested Foothills and Boreal Plains: Summary of Preliminary Evaluation of Bison Movement Corridors- The narrative above describes a unique situation where bison occurred routinely in the past as far as nearly 100 km into the Rocky Mountains. As described for the Red Deer valley above, this hypothetically could be an eco-cultural process driven by a unique combination of factors:

- High numbers of bison on the grasslands of the prairies 50 to 200 km west of the entrance to these mountain valleys (Binnema 2001, 2016);
- A general pattern of migration of these animals towards the foothills in the latter summer (during dry periods), or in the early winter (Reeve 1990, Binnema 2001, Peck 2001);
- Summer wildland fires, severe winter cold weather or a deep snow event that would trigger a large-group bison dispersal into the forests of the foothills. In these forests bison would start to space out, and could not been communally hunted as they would in more open grasslands (Binnema 2016);
- The relatively small groups of human hunters in this zone might generally push these now-dispersing bison towards the mountain valleys to the west, where they could be more predictably contained, not towards the plains to the east. Human burning would enhance habitat along these corridors, and help draw bison into the mountains (White et al. 2001b, 2011);
- In the immediate years following a dispersal event, following their experience on the plains, these bison might be drawn to grasslands along the rivers in the mountains. Here, they would wallow and breed, but again forced by hunters further into the mountains, eventually into blind valleys and pounds beyond which few bison survived;
- In the unique situation where a native band had strong political/military control of a valley, the mountain ridges, broken only by narrow gaps surrounding grassland winter range, could be used to contain bison herds, and these could be sustained by cultural restrictions on hunting to maintain a breeding herd of cows. This might explain the abundance of wallows in some grasslands such as the Ya Ha Tinda. This cultural situation would be unusual, but not unlike the First Nation's management of sustainable salmon fisheries on the Columbia and Fraser rivers to the west (Campbell and Butler 2010). It may not be coincidental that high density of bison wallows on the Red Deer and North Saskatchewan rivers occur in areas periodically occupied by western slopes people with salmon fishery management traditions experience.
- The hypothetical eco-cultural pattern described above will require substantial interdisciplinary research to evaluate and modify (Shury 1999). Some of the bison behaviour and human herding processes involved will be evaluated through the monitoring of bison recently re-introduced to Panther River in the Red Deer watershed in Banff National Park (Parks Canada 2017).

These patterns of bison use in the Rocky Mountain foothill and adjacent mountains will likely recognize that long-term, characteristic bison ecology in this area is clearly more complex than a model developed by Steenweg et al. (2016) based upon habitat relationships, forage availability, bison energetics and snowfall scenarios to estimate nutritional carrying capacity. In comparing an area of northeastern Banff National Park to other bison restoration projects, this research concluded:

The most realistic scenario that we evaluated resulted in an estimated maximum bison density of 0.48 bison/km^2. This corresponds to sufficient habitat to support at least 600 to 1000 plains bison, which could be one of the largest 10 plains bison populations in North America…The successful reintroduction of bison into Banff would represent a significant global step towards conserving this iconic species, and our approach provides a useful template for evaluating potential habitat for other endangered species reintroductions into their former range… (Steenweg et al. 2016:1/22).

Although there may be forage in the mountains to support this number of bison, these numbers are not supported by findings of movement corridor analysis approach described here. In fact, due to interacting effects of distance from the core population, human predation, bison behaviour patterns in wooded terrain, and narrowing gaps proceeding further into the mountains, the high density of bison proposed by Steenweg et al. 2016 are not at all characteristic of Canadian Rockies long-term ecosystems (Figure 4.1-2), especially more than 10 km within the mountains. Consider that even though first person journal observations begin here early in the historical times, less than 100 bison were observed in Banff and surrounding area (e.g. Kootenay Plains) for the whole period of 1800 to 1860 (Figure 4.3.3-4). Similarly, archaeological sites contain bison as an important component at the edge of the plains and into the foothills and front ranges, but this declines rapidly moving into the mountains (Kay et al. 1999, Kay and White 2001).

5. BISON'S WESTERN RANGE EDGE: SUMMARY, PRELIMINARY CONCLUSIONS AND FUTURE RESEARCH

5.1 Summary of Alternate Hypotheses for the Western Edge of Bison Range

Two general alternative hypotheses for historical bison movements and density in the Western Cordillera .

- **Hypothesis 1: "Abundant center distribution with episodic western dispersal" with numerous bison on the plains and periodic bison movements westward into the Cordilleran areas-** This is the traditional interpretation of traditional, historical, and archaeological knowledge. Bison within the cordillera were historically low density, ephemeral populations hunted by Native Americans, often coming from the east, but sometimes coming from the west, explicitly to hunt them (Kingston 1932, Roe 1972, Van Vuren 1987, Kay 1994, Bailey 2016). Low densities of bison in the mountains were connected by movement corridors to high density core bison populations on the plains, annual migratory movement patterns of bison to the western edge of the plains (Reeves 1990, Binnema 2001, 2016; Peck 2001), and dispersal events that periodically drove smaller groups further westward.

- **Hypothesis 2: "Natural regulation" or persistent areas of historically high bison density in the Cordillera-** This possibility is suggested by historical journal observations of some occurrences of abundant bison within the mountains, recent observations that bison can reach high densities within and west of the Cordillera, forage availability, and historical wallow densities showing localized area of abundant bison use in some mountain valleys. Since 1968, this hypothesis has been used to guide bison (and elk) conservation in Yellowstone National Park (Houston 1982, Despain 1986, Huff and Varley 1999, USDI 2000, Wagner 2006, Plumb et al. 2008, White et al. 2013), and more recently discussed as a potential option for Banff National Park (Steenweg et al. 2016).

Evaluating these alternate hypotheses for processes influencing long-term bison densities in the Cordillera is of significant importance for guiding current restoration efforts. Bovids (e.g., bison and domestic cows) can have significant herbivory and trampling effects, particularly in riparian zones (Figure 5.1-1). Understanding long-term bison abundance is thus important for restoration projects in such as in Yellowstone and Banff national parks, where there are legal requirements to maintain characteristic, long-term ecosystem states and processes to sustain not just bison, but a wide range of biodiversity (Woodley 2010, White et al. 2013).

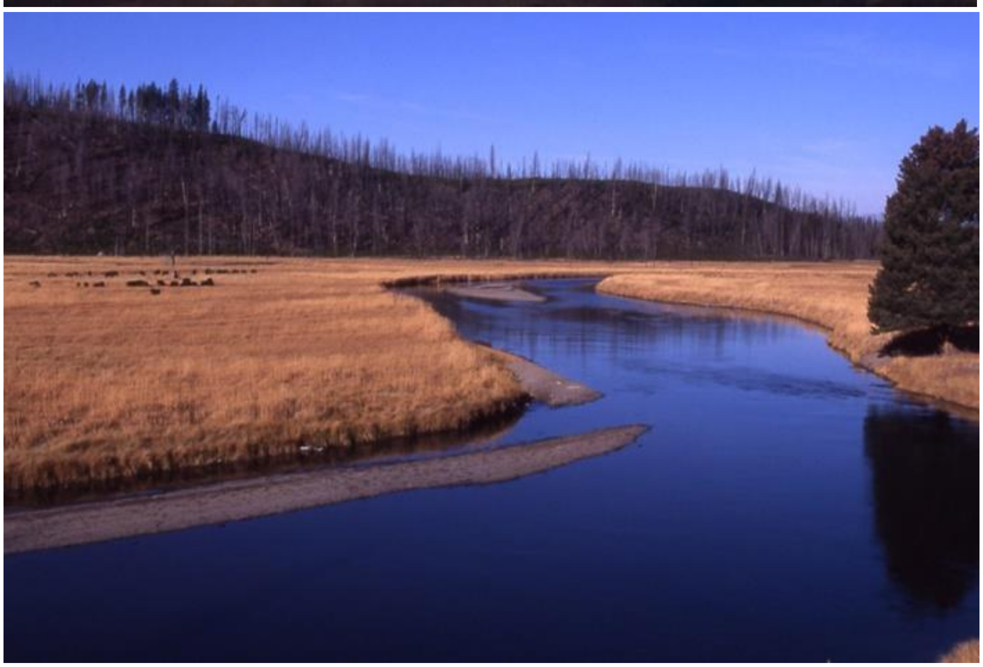

Figure 5.1-1. Seven Mile Bridge area along the Madison River in Yellowstone National Park on September 30, 1938 (from an early Kodachrome slide, Cushman Collection, Indiana University Archives P15797) and in 1999 (USNPS-YELL-16356). The early photograph shows a typical Cordilleran riparian zone of willow and cottonwoods. For the last several decades, high densities of elk, and more recently bison occur in this area (Garrott 2008). Bison herds are visible in the 1999 photograph. A longer series of repeat photographs for the location and more complete description of ecological change is available at: https://lensoftimenorthwest.com/galleries/montana-wyoming/yellowstone/yellowstone-national-park-madison-river/

5.2 Preliminary Results of a Landscape Ecology Approach

The converging research approaches of movement ecology (Chetkiewicz et al. 2006, Aune et al. 2011, Zeller et al. 2012, Wade et al. 2015) and landscape genetics (Manel 2003, Keller 2015) appears to offer a useful approach to conceptually model, and synthesize processes for a select set of potential movement corridors linking high density "source populations" on the Great Plains to "sink populations" within the Cordillera (Figure 4.1-2). Bison's historical movements westward can be generally explained by landscape connectivity, where landscape resistance factors include distance, habitat suitability, weather, predation risk, and the energetic cost of movement across a portion of the range a species. Similar results have been observed for a range of species including grizzly bear (Chetkiewicz et al. 2006), woodland caribou (Gubili et al. 2016), desert bighorn (Creech 2014) and elk (Hebblewhite and Merrill 2009, McClure et al. 2016). Unique to bison is our amazing understanding available from archaeological, traditional knowledge and historical studies on how long-term human communal hunting practices could influence bison movement patterns and mortality rates, and preliminary modelling for these long-term human movement processes is now becoming available for areas of the Cordillera (e.g., Osicki 2012).

Here, referencing the three-phase conceptual model (Figure 2.2-1), I will summarize some significant characteristics of bison movement corridors in the overall plains and cordilleran region keyed to letters shown Figure 5.2-1. More specific information is available for individual corridors in Section 4.3. Again, I recommend reading this section in combination with the Google Earth map of historical wildlife observations to obtain a detailed view of the landscape in the areas described: https://lensoftimenorthwest.com/themes/lens-northwest-files/google-earth-map-journal-wildlife-observations/

- **Phase 1: Annual Large Scale Bison Movements**: Logically, the primary process for bison dispersals westwards could be annual movement patterns from the formation of large herds in the centre of the prairies during the late spring and early summer, and movement to the foothills and woodlands surrounding the grasslands in the late summer fall and winter (Reeves 1990; Binnema 2001, 2016; Peck 2001), shown in Figure 2.2-1 and Figure 4.3-1 (e.g., movements from areas A to B). This process places large numbers of bison at the western edge plains in a position where a "dispersal event" of smaller herds moving further west could occur (Figure 2.5-1). The data gathered for this study to-date gives reasonable support this annual movement pattern for areas northward from the Milk to the North Saskatchewan River. The "rising of the bison" towards the mountains was a commonly observed late fall or winter phenomena, largely driven by winter snow and cold.

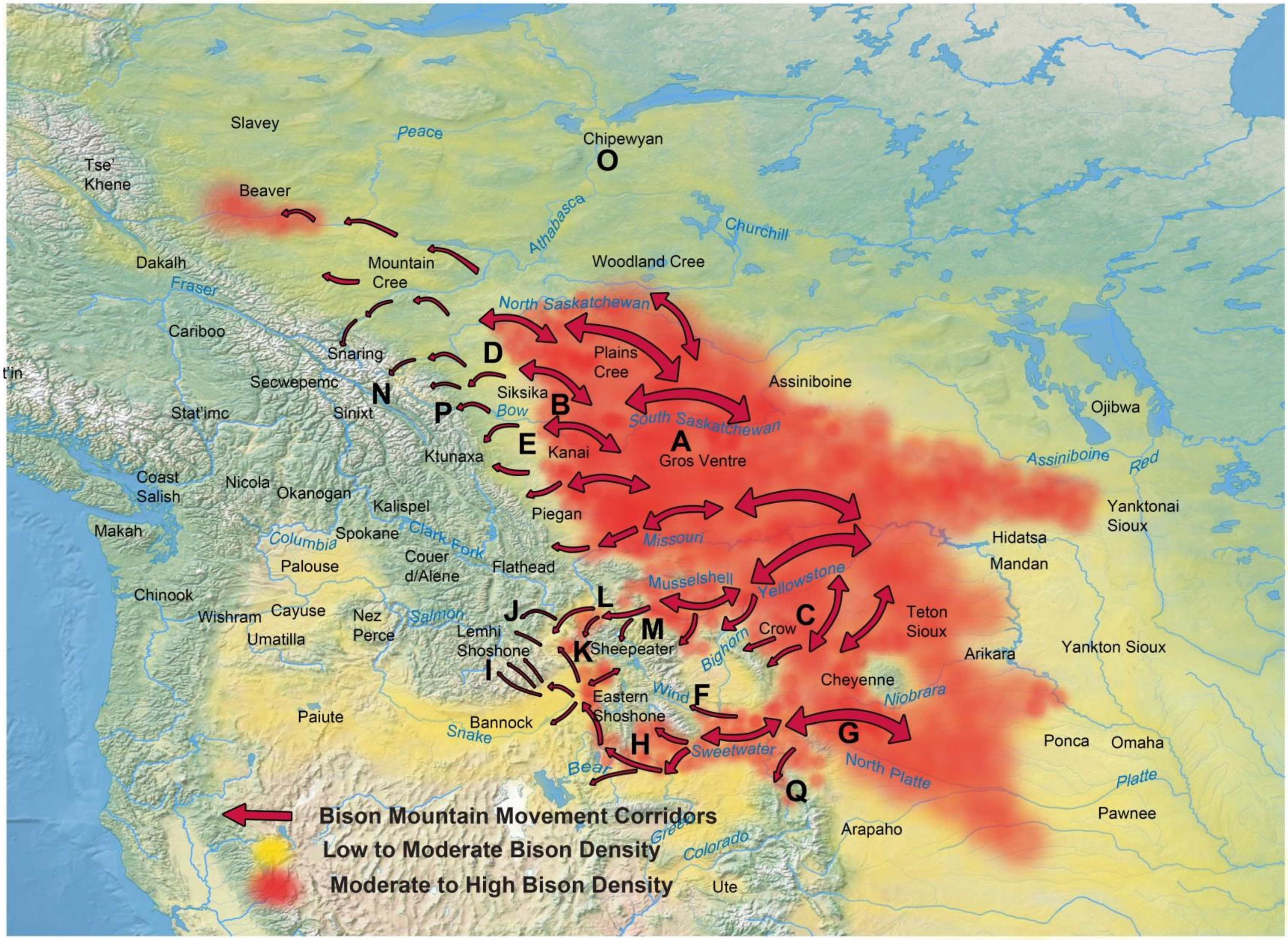

Figure 5.2-1: Potential bison movement corridors into the Western Cordillera from the Great Plains showing select Native American groups. Two way arrows indicate potential annual migration routes near rivers. One way arrows indicate periodic dispersal routes where annual migrations might not occur due to high predation risk and mortality. Large case letters are keyed to discussion in text.

Further south, the above winter-summer pattern may vary, and be more related to summer drought on the plains, and moister conditions at higher elevations. Bison movement westward might start might start much sooner each year. For example, in Wyoming and Colorado, Fremont (1851) appears to describe a pattern bison moving westward in the spring following the melting snowline to higher elevations. In July and August, 1805, Northwest Company trader Andrew Laroque accompanied a large camp of Crows as they ascended the Little Missouri and Powder rivers to the Bighorn Mountains (Wood and Theissen 1985). This group seemed to be following (or driving) bison towards the mountains as they ascended these streams (Area C). In 1811, Astorian William Price Hunt's group also encountered numerous bison (and bison hunters) on the eastern slopes of the Bighorn Range in mid-summer (Rollins 1995).

- **Phase 2: Dispersal Events-** The second part of the corridor movement process is some set of events on the plains (above) that brings a relatively large number of bison to the west edge of the plains, then triggers further movement westward, probably more unidirectional, of smaller herds led by males (Gates and Larter 1990), towards the foothills, forests, or mountain valleys (Figure 2.5-1, Figure 5.2-1). Probably because of sporadic occurrence, evidence of this process remains limited. When it was described, such as by Henday on the Clearwater River in January 13, 1755 (Area D, Belyea 2001), Fidler on the Highwood River in the winter of 1792-93 (E, Haig 1992), or Raynolds for the winter of 1859-60 on the upper Wind River (Area F, Merrill and Merrill 2012) human hunters appear to have further driven the animals westward towards or into the mountains. Perhaps this was the general process— localized weather or fire events push bison to the vicinity of humans camped at the edge of the plains. These people in turn drove them further westward into more ideal communal hunting terrain. However, for the suspected South Pass dispersal event of c. 1820 (Section 4.3.1), the large number of bison that appear to have moved westward suggests a large scale weather events, such as a series of blizzards, that drove bison to the west from the Platte at least to the Green River (G to H).

- **Phase 3: Bison Small Herd Demise or Persistence**- In this progress report I have not focussed on what factors may have allowed bison to persist over multiple years along, or near the end of movement corridors at the edge of their range. Figure 2.2.3-1 provides a preliminary model of how snow depth and terrain might interact in these areas. Likely deep snow depths in grass-shrub, open terrain, such as in the upper Salmon River watershed (I), Big Hole (K), Red Rocks Lakes areas could have greatly facilitated humans finding and hunting of bison, particularly in the narrower sections of valleys, or at upper elevations, such as along the eastern front of the Rocky Mountains south of the Bow River (B). In forested areas, trees provided cover for bison, and made communal hunting more difficult, even when snow depths increased, possibly explaining bison persistence in foothill forests and forested valleys (D), and the boreal forest (O).

- **Herd and Population Dynamics in Movement Corridors**- Bison movement in the corridors described in this report may have taken only a few hours from source to sink for short corridors (<100 km) such the Belly, Oldman, or Highwood River (E) to over a year for longer corridors

(>1000 km) such as the Platte River (G) to the Green River (H), and ultimately the Salmon (I) or Big Hole (J) rivers. For multi-year movements, likely small herds of bulls, separated from cows in fall and winter, dispersed more frequently and rapidly, then returned to cow herds that in turn followed this route the following year (Gates et al. 2005, 2010). Several observers describe bulls in the vanguard of a bison herd movements. Possibly lone bulls, through long survival by avoiding predation through spacing, maintained the key knowledge of dispersal routes. For long corridors where multi-year dispersals might be required, there should also be evidence of cows, birthing and breeding in the archaeological, wallow, and historical data. For example, wallows occur at Gray's Marsh and Red Rocks Lakes (K) along the Platte-Salmon river corridor.

- **Terrain along Corridors**- Analysis of bison movement corridors across the vast landscape of the western plains and cordillera certainly accentuates the adage of a "chain is only as strong as its weakest link." Clearly, bison movement rates would be greatly constricted through corridors into the Cordillera where the terrain narrows to <100m. Communal hunters could, under open vegetation conditions (Figure 4.2-1) possibly attain very high kill rates in these narrow gaps due to relatively low bison numbers and abundant terrain traps (Frison 1978, 2004; Kornfeld et al. 2010). Useful examples are: 1) Bozeman Pass (L) which likely choked bison connectivity between the Yellowstone and Missouri watersheds, 2) Paradise Valley with the First and Second Canyons of the Yellowstone (M, Figure 4.3.1-4) which, in combination with communal hunting likely filtered-out most all bison movement onto the Yellowstone plateau from the north; and 3) The canyons of the upper Madison River on the west edge of the Yellowstone plateau (Figure 5.1-1) which could have partially blocked bison movements.

- **Vegetation Cover along Corridors**- Probably one of the most counter-intuitive findings of this research is the effects of increasing forest cover. One traditional explanation for the failure of bison to cross the passes northern Rockies is that forest cover impeded movement of bison from the plains to large grasslands, sometimes only <100 km further west, along in the Columbia and Fraser watersheds (e.g. area N). For large herd movements, this idea is partially supportable. However, considering that bison populations extend >500 km northwards through the boreal forest (area O), it seems unlikely that forest cover alone blocked bison travel in the Rocky Mountains. In fact, in this study, comparing the distance travelled by bison in multiple corridors with similar terrain, shows increasing forest cover likely facilitated bison movements into the mountains (Figure 4.1-2). This observation is supported by traditional knowledge and historical observations of bison behavior in forests, and the difficulty of hunting them here (see Section 2.4).

- **Interactions between Terrain and Vegetation Cover**- These factors are clearly individually important for bison movement, but the potential interaction effects between them (Section 4.2, Figure 4.2-1) is an important preliminary finding of this study. This interaction appears tied to communal hunting effects, where if valleys become narrower, and have open cover, they become increasingly more lethal due to ease of hunting. Thus there may be behavioral aversion of risk-sensitive herds of bison entering narrow terrain. However, when forest cover is heavy, and bison are in smaller groups, they may utilize narrower corridors. This type of wildlife behaviour is recognized in modelling wildlife use and guidelines for establishing valley-bottom multi-species wildlife corridors in the Bow Valley (Area P) of the Canadian Rockies (Paquet et al. 1996, BCEAG 1998, Duke et al. 2001, Clevenger et al. 2002), and may help explain historic bison use of the forested foothills and several mountain valleys north of the Bow River. These types of interaction require further quantitative analysis for wider application (Chetkiewicz et al. 2006).

- **Dispersal Southwest in the Rocky Mountains and down the Colorado River-** This study has focussed on the area from South Pass north, but the North Platte River and tributaries near here may also be the source of bison movements further down Green and Colorado rivers, and potentially reaching the Grand Canyon (Plumb et al. 2016). Although there is bison habitat in this arid environment (e.g., Schoenecker et al. 2015), likely bison could not have directly dispersed westwards to lower Colorado from the southern plains due to high human densities and rugged terrain along the Rio Grande and Arkansas rivers. However, as described by Meaney and Van Vuren (1993), the valleys at the headwaters of the North Platte, Green, and Colorado rivers (Area Q) may have functioned similarly to other corridors further north. In June, 1844 Fremont's (1851) expedition proceeded southwards to the headwaters of the North Platte, then over the continental divide through North, Central, and South parks. Along the route he described bison, bison trails connecting the parks, and on June 20, 1844 he describes Arapahoe people driving bison through Rocky Mountain valleys linking South and North parks (see journal wildlife observations map and database). Could small herds of bison periodically reach the Grand Canyon by the hypothetical dispersal process described here that connected them to the headwaters of the Salmon and Big Hole rivers— broad-scale vegetation, climatic, and cultural patterns brought large herds of bison to the upper North Platte River where they fragmented into smaller groups, then were driven even further south-westwards through narrow mountain valleys by Native Americans?

5.3 Next Steps: Future Research and Analysis

The general hypothesis described here is that bison connectivity from the Great Plains into the Western Cordillera is an exercise in comprehending movement corridors, used by North America's largest terrestrial animal, reaching over 1000 kilometers westwards from large herds of bison on the plains to small herds and individuals in the distant narrow mountain valleys to the west. Biologist Mary Meagher aptly termed these incredible long-distance excursions as "the tips of the fingers" for bison range (Meagher in Gates et al. 2005:79). Moreover, use of movement corridors fluctuated from an age-old, intimate relationship with First Nations' communal hunting patterns on the plains and the mountains (Kingston 1932; Roe 1951, 1972). The long-lasting, continental-level phenomena ended in the 1800s with the demise of the great bison herds and many components of long-term native cultures. It can never be even partially restored under today's human's population and infrastructure development levels. However, high profile bison restoration projects are ongoing in several plains and mountain areas, often with important participation of Native Americans, so improved understanding of its eco-cultural processes is timely.

This progress report describes a "first-cut" on developing more detailed predictions and analysis procedures for how these historical corridors worked. Here is a list of where the research process could go next:

- **First Person Journals-** Much of the finer scale information available for historical bison abundance is provided by historic first-person journal accounts (Hart 2001, Kay 2007, Bailey 2016), recorded and spatially mapped at the daily level. In this study, I have expanded this work following the methodology of Kay 2007 to include a broader region and more journal sources. Additional work is required to link these observations to specific Native American groups, site specific types of communal hunting etc. at this fine scale.

- **Wallow Transects-** In northern areas and at higher elevations where there is high ground cover in grasslands, the density of historic bison wallows also provides a fine scale indicator of past bison densities. Unfortunately, bison wallows may not be persistent at lower elevation and south of the US-Canada border due to various reasons that require more investigation (see Section 3.6).

- **Repeat Photography**- Historic photographs generally show prolific burning across most landscapes, and dense riparian zones along most stream courses. Recent photographs show increasing forest cover, and although riparian zones remain intact in many areas, these ecologically rich habitats have disappeared where herbivores such as elk and bison are abundant (Figure 5.4-1; Kay 1990, White et al. 1997, White and Feller 2004, White and Hart 2007). More repeat photography will be useful to evaluate fire versus herbivory effects in areas such as along rivers in the prairies.

- **"Citizen Science"**- Plotting the location and observation data from historic journals, bison wallow transects and repeat photography are all excellent topics for "citizen science" research. I encourage interested folks to read up on their favorite historical travellers, plot routes on Google Earth, collect some historic photographs of these areas, and get out into the field with a camera and look for old bison trails and wallows. I'd be pleased to post this work on the "Lens of Time Northwest" website: https://lensoftimenorthwest.com/landscape-change-though-time/

- **Mathematical Wildlife Corridor and Connectivity Models**- This project is a first step quantifying bison movements westward, where the use of corridors is conceptually modelled upon the processes of habitat selection and movement, integrated with landscape features such as terrain, water availability and forest cover. Much more work can be done to quantitatively integrate these factors using a host of related techniques such as least-cost paths, graph theory, circuit models, and step selection functions (e.g., Chetkiewicz et al. 2006, Belote et al. 2016).

Bison movements have already been modelled for smaller regions than considered here (Gates et al. 2001, 2005; Gates and Broberg 2012). For further work with bison at its western range edge, there are literally dozens of potential corridors linking bison observations (from journals, archaeological sites, or wallows) from dense populations on the plains to low density herds at the edge of the range. Future quantitative comparative corridor analysis can refine the interactive effects of terrain, vegetation cover, and other factors. One of the best existing models may be the rationale and guidelines for wildlife corridors in the Bow Valley, Alberta. These are valley-bottom focussed corridor models, where wildlife movements are dependent on avoiding high human use and associated mortality factors (Paquet et al. 1996, BCEAG 1998, Clevenger et al.2002, White et al. 2007). Although the wildlife mortality causes are different today (e.g. highway traffic versus communal hunting), the general terrain and vegetation factors may applicable to historic bison use.

- **Integrate Human Use Patterns into Corridor and Connectivity Models**- Long-term human occupancy and terrain movements through the mountains, and particularly eastward from the Columbia and Snake watersheds can also be modelled with least cost techniques that integrate numbers of people, distance, favoured terrain and vegetation for campsites and trails (Langemann and Perry 2002), locations of potential prey available for human hunting (Osicki 2012), and other factors. These models can be informed by integrating regional integrations of archaeological research (e.g., Reeves 2003, Cooper 2012, Heitzmann 2009, Kornfeld et al. 2010), first person journal accounts (Kay 2007, Bailey 2016), and traditional knowledge (Snow 1977, Anatasio 1985, Zedeño et al. 2014).

- **Test Existing Wildlife Corridor and Connectivity Models**- Dozens of examples (reviewed by Aune et al. 2011, Zeller et al. 2012, Wade et al. 2015) exist of various quantitative exercises to mathematically model wildlife and fish dispersal and migration patterns. Unfortunately, many of these models focus on existing land use conditions, and from necessity, species that tend to use higher elevations, because lower elevation corridors are completely blocked by modern land use. Historical bison movements may be a case where we can use relatively good knowledge to compare predictions of current potential low elevation movement routes (e.g., McClure et al. 2016, Belote et al. 2016) with some knowledge of historical movements.

- **Model Small Herd Bison Persistence or Demise**- Using GIS models of terrain, vegetation cover, and snow depths (monthly or seasonal means) it should be possible to generate a preliminary model of areas where low densities of bison at the western edge of their range might persist or would likely disappear over time.

- **Integrate Archaeological and Historical Research**- There is clearly many topics and many areas that require more research across the vast region described here (e.g., see summary by Reeves 2001). However, if I could pick one single area that might be most interesting, I suggest the Ya Ha Tinda along the upper Red Deer River. From wallow densities (CW wallow surveys) and archaeological work (e.g., Ronaghan 1993), we know that bison have occupied this area almost since deglaciation, and periodically, possibly in high numbers. As described by Langemann (2017), further research here could tell much more about the origins of bison that came here, how frequently they came, and how long herds persisted. This information, when integrated with historical research, such as proposed for the Great Plains just to the east (Binnema 2016), and traditional knowledge (described above) might rapidly yield great understanding on bison corridor use. Further, Cannon (2000) describes several ways zoo-archaeology can contribute to our understanding of bison ecology in the mountains: 1) Extraction and analysis of phytoliths and plant macrofossils from bison teeth, to determine diet; 2) Stable isotopic analysis for reconstructing grazing patterns of past individual bison, and possible migration; 3) Metric analyses, for determining demographic profiles of populations, and 4) Comparison of genetic diversity in prehistoric populations with that of modern populations.

- **Bison, Humans, and Ecological Integrity**- Understanding the long-term interaction between bison at the edge of their range, and humans in the western Cordillera will greatly aid in using bison restoration projects to maintain ecological integrity, or ecological health to these lands. This is important not just for actual bison restoration projects (Figure 5.3-1), but also for managing other lands used for grazing, forestry and other activities. Simple models that presume high numbers of bison in the mountains will fail to integrate the complexities of the long-term human-bison relationship in the mountains, and how this influenced ecosystem development. Most significantly, if traditional knowledge from both First Nations and early European travellers on the human influences on bison's western range boundary hold true, bison management in the mountains is an important opportunity for exploring opportunities for using reconciliation with Native Americans to restore missing hunting, gathering, and burning processes to restore ecosystem health to public lands.

Figure 5.3-1. Bison in Windy Holding Pasture in the upper Red Deer River watershed in March, 2018 prior to being released as an experimental free roaming herd on the eastern slopes of Banff National Park (Parks Canada photo). Using an ecological integrity or health paradigm for restoring bison offers an excellent opportunity for conserving bison, maintaining long-term ecosystem states and processes (including riparian zone willow shown above), and reconciliation with First Nations whose traditional hunting, gathering and burning practices have long influenced bison ecology in the Western Cordillera.

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Appendix A
Survey of Historic Bison Wallows
Methodology as of August 24, 2015

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Introduction- Bison wallows are depressions formed by a large animal repeatedly rolling in soft soil. Both male and female bison may wallow during warmer season for a variety reasons including protection from flies and mating displays. The location of historic bison wallows can provide a source of information for the general region and specific areas utilized by plains bison during the late spring, summer and fall season prior to their near extinction in the latter 1800s. However, wallows may only persist where soils are lightly disturbed by pocket gophers, erosion etc. and this appears to be in northern regions, or upper elevations.

Pre-historic period bison wallows on the Ya Ha Tinda Ranch, upper Red Deer River, Alberta.

I recommend that anyone doing these surveys starts with a session in an area where bison and their wallows currently exist. Even a trip around a paddock in a car helps calibrate your eye, particularly for wallow shape. Better yet is to wait for a safe time period (not during the rut), and actually walk some transects through occupied bison habitat. Another option is to visit an area recently occupied bison (e.g., Banff's now closed bison paddock) and calibrate measurements there on a set of known past wallows.

General Location- Bison wallows from current bison herds are visible on Google Earth images, particularly those images made in late summer after the peak of the wallowing season. These images indicate that current wallowing may be concentrated on lower elevation grasslands near sources of water. Google Earth can also show you areas not disturbed by agriculture, good access routes etc. This is a good place to start for searching out potential locations to do wallow transects.

Transect Size- Transects are strings of sub-transects 20m wide by 100m long, generally in a polygon pattern to bring you back to your starting location. The length and shape of the transect string varies, depending on grassland and terrain conditions. An ideal shape is triangular, perhaps only 100m (1 sub-transect) on a side for a small meadow, but maybe up to 1 km on a side (10 sub-transects) for a prairie area. If you're in a meadow, run a few sub-transects into the neighboring forest to check these areas.

Transect Orientation- Wallows often lie along the edge of terraces paralleling streams or ponds. If possible, orientate 1 side (1/3) of your string transects to collect information on these hotspots if they exist in your area.

Data Recording- I use a field note book with about 15 columns, and orientate my observations by transect or unique sets of wallows across the page (see Figure 1 below). I will use at least one line per sub-transect, perhaps summarizing all observations along the sub-transect in that line. If there are unique wallows or sets of transects along the wallow I want to discuss, I will add a separate line for these, with a unique waypoint, or same waypoint, but under the same sub-transect number.

Waypoint- Unique waypoint number from your GPS for the start of a sub-transect or wallow/set of wallows. You'll need to learn how to download these into a database. Contact me for the system I use (borrowed from Parks Canada, Banff).

Transect-subtransect number and bearing- A sequential numbering system for chains of transects made by the recorder. Use a two part number system (eg. CW- 32-23) the first number is the group of transects, and the second number is the subtransect (100m long) in the chain. Sub-transect bearing is simply the general direction you are walking (eight cardinal directions: N, NE, E, SE, S, SW, W, NW) so the transect could be approximately repeated from a waypoint. If you are recording multiple locations of wallows along a sub-transect, keep the sub-transect number the same, but list the waypoints as necessary.

#wallows- number of wallows whose centre point is within 20m of the sub-transect, either along the whole transect (often 0), or perhaps a unique set of wallows along the transect, with a unique waypoint, but the same transect number. The number of wallows for the all the lines for a sub-transect should sum to the total number of wallows along the transect. A computer subroutine adds each observation line for the same transect to sum the total number of wallows for each transect if you use more than 1 line.

Aspect/slope- The general aspect direction of slope along the sub-transect or a unique set of wallows (8 cardinal directions, S, SE etc. facing), and the slope angle in degrees (just ballpark this if you want), or use a compass or other gadget.

Landform type and position- This is a work in progress. Here's some of my usual descriptors:
- alluvial terrace, low, mid or high (ATL, ATM, ATH), alluvial fan (AF), glacial till landforms on slopes low, mid or high (TSL, TSM, TSH), rolling general level till areas in swales (TRS), on gentle slopes (TRM), or on a humped ridge (TRR), regalsolic slopes (RH, RM, RL), riparian floodplains (FL). Position gives another descriptor for transect or wallow location, and I often use edge (E), lower, mid or upper (L, M, U). For example, for wallows I have tallied so far, the most common landform type and position is ATL with an E position.

Vegetation type- Grassland (G), Shrubland (S), Aspen/poplar (A), Closed Conifer (C), Open conifer (OC), or mixedwood of deciduous and conifer species (MW).

Distance and height to water- in meters, to the nearest meter if less than 10 meters, nearest 10 meters if 10 to 100 meters, or nearest 100 meters if greater than 200 meters. Often you have to go back to Google Earth after you've done some sub-transects to approximate this.

Distance to cover- How close could a human, grizzly bear, or wolf pack sneak up to the sub-transect/wallow in meters? Approximated as above.

Soil texture and material- Fine (F), moderate (M) or coarse {C) textures with materials including silt (Si), clay (CL), loess, (Ls), loam (Lm), sand (Sa), gravel (Gr) or cobbles (Co), or bedrock (Be). I usually just use visible soil profiles to approximate this, but if you have small shovel or trowel, and like digging, feel free to do this if you're outside a park, and not digging into a pit house archaeological site.

Wallow characteristics- length, width, and depth to .1m, and a shape qualifier. I recommend that people doing surveys go initially a location where bison wallows exist, and see what an actual wallow looks like to get a feel for what they are dealing with. Wallow shape goes like follows:
- A: obviously a wallow, clearly shows historic animal activity, often rounded, but possibly modified by wind or water, but no other cause possible, usually bigger than 2 by 2 meters;
- B: possibly a wallow- has some characteristics, but not as definitive as above;
- C: Depression that is probably not a wallow, or has some other cause such as tree well, wind or water erosion or whatever. You may not want to tally all of these you see, but include a few if they are common in the landscape, and A and B type wallows are not.

Remarks- put in as much as you want.

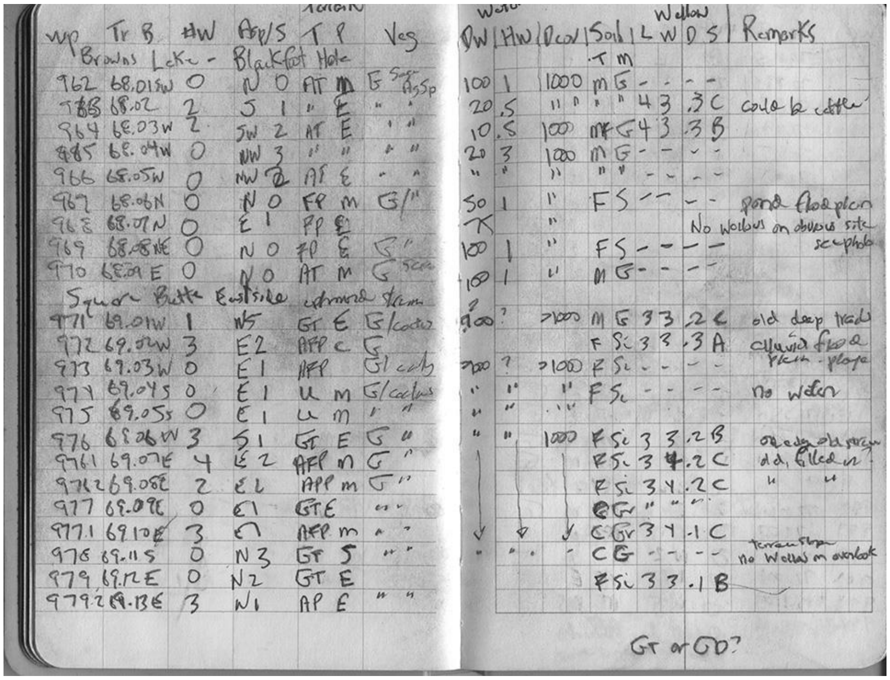

Figure A-1: CW notebook from a session of wallow tallying in Montana.

Appendix B:
Report Updates

- **2018-10-04**- Posted first version available for downloading
- **2018-10-25**- Expanded the acknowledgements, and added excellent traditional knowledge quote of a Flathead hunting expedition to hunt bison on the north fork of the Sun River (p. 65).