Ecological Legacies of Stoney Nakoda Stewardship in a Montane Grassland: A Century of Vegetation Change in Egnuck Wida and the Kootenay Plains Ecological Reserve

by

Gabriel Schepens
B.Sc., University of Alberta, 2019

A Thesis Submitted in Partial Fulfillment of the
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We acknowledge and respect the lək̓ʷəŋən peoples on whose traditional territory the university stands and the Songhees, Esquimalt and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

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Abstract

In the Canadian Rocky Mountains, landscape patterns have changed dramatically in the last 150 years. Management transitions shift landscape vegetation patterns, and areas previously stewarded by Indigenous inhabitants are undergoing successional change. On the traditional territory of the Stoney Nakoda Nations, I document vegetation change on both the landscape and plot level. Using oblique photographs taken in 1924 paired with 2021 satellite imagery, I compared past and present vegetation types. Nearly half (47%) of the landscape surveyed showed seral progression in vegetation class, which was not explained by topography, geology, or climate warming. Grassland area decreased four-fold between 1924 and 2021. Grassland retention was strongly related to management zoning with greater losses in the Kootenay Plains Ecological Reserve than on lands under Stoney Nakoda management. Vegetation plots surveyed in 1981, 1996, and 2020 in the Kootenay Plains Ecological Reserve reveal changes to vegetation class, plant community composition and culturally important forbs. In plots previously composed largely of forbs and graminoids (mean cover of 35 and 32 % respectively), shrubs have become the dominant groundcover (increase from 0.4% cover in 1981 to 32% cover in 2020). Changes in community composition are evident between sample periods, indicating a shift in seral state. Culturally important forbs decreased in cover by 4 times since 1981. The most likely explanation for these results is the removal of Indigenous people and stewardship, which shaped these landscapes over millennia of seasonal camps, traditional fire stewardship, plant harvesting, and hunting. Future work led by Indigenous land stewards is necessary to re-establish and maintain the integrity of longstanding ecological processes in Rocky Mountain landscapes.

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Chapter 1: Introduction

Overview and Objectives

For my thesis, I endeavoured to better understand the changing landscape of the Rocky Mountain eastern slopes and contextualize the region's plant ecology through the lens of multiple land management practices, including Indigenous stewardship. Time I have spent in the Bighorn Area (west-central Alberta, Canada) over the past 25 years led me to ponder the structure and history of this unique landscape. After learning of changes to the area's montane grasslands through conversations, Indigenous knowledge, photo archives, and historic vegetation surveys, I set out to understand these ecological shifts. The scale of my study is two-fold: measuring the changes to vegetation at the plot level (plant species and community structure), and at the landscape level (dominant vegetation landcover). Pairing landscape analyses with plot-level details provide important insight to the breadth of ecological shifts occurring in Rocky Mountain grasslands.

I conducted my work with the knowledge that traditional Indigenous fire stewardship contributed to the establishment and maintenance of montane grasslands and other open areas (Lewis, 1982; Miller & Davidson-Hunt, 2010; Turner, 1999). Furthermore, in this study I expected that with the colonial displacement of Indigenous peoples from much of their homeland, and the resulting absence of their stewardship practices for over 50 years, there would be observable ecological results. Specifically, I anticipated that the absence of traditional fire stewardship, coupled with intentional fire suppression, could result in succession and encroachment into previously managed montane grasslands. Here I explore the roles of various land management regimes, including Indigenous stewardship, and biotic and abiotic factors in grassland transitions.

Ecological Context

The Bighorn Area of the Rocky Mountains Eastern Slopes is characterized by wide glacier-carved valleys shaped during the withdrawal of the Laurentide ice sheet at the end of the Pleistocene glaciation (Alberta Environmental Protection (AEP), 1996; Clague, 1989). Gravel bed floodplains and the adjacent valley of the North Saskatchewan River offer unique habitats that support high species diversity (Weaver, 2017). The Kootenay Plains Ecological Reserve, established in 1987, lies on terraces, alluvial fans and active floodplains of the North Saskatchewan River, at a mean elevation of 1370 m (AEP, 1996). Glacial tills and outwash debris from the Wisconsin Glaciation shape much of the valley floor, exposed when the North Saskatchewan River valley became ice-free over 9,000 years ago (AEP, 1996). Soils in this valley are mainly regosols and brunisols, which are calcareous and well-drained (AEP, 1996). The climate of the Kootenay Plains is dry (summer precipitation: 150-200 mm, winter: 100-220 mm) and the region receives warm winds which maintain moderate winter temperatures (AEP, 1996). The hydrology of the valley is dependent on seasonal melting from both snow and glaciers in the North Saskatchewan watershed (AEP, 1996). Kootenay Plains recreation amenities include hiking trails, climbing areas, and two campgrounds (AEP, 1996).

In the Kootenay Plains Ecological Reserve, plant communities are adapted to frequent fires, and some of the grassland is becoming encroached by trees and shrubs (AEP, 1996). However, fire exclusion policies dominate the changing landscape, where fires are controlled on crown lands (Murphy, 1985) and “fire suppression” is stated explicitly as a management plan for the reserve (AEP, 1996). Historically, the North Saskatchewan River valley saw frequent fires (23 year mean fire return interval) compared to the 50-70 year intervals in neighbouring valleys (Rogeau, 2010). Due to the dry climate and accumulated flammable organic debris, the upper North Saskatchewan River Valley has the highest wildfire threat in the Bighorn Area (Alberta Forestry Division, 2005). This risk is compounded by the valley's susceptibility to mountain pine beetle (*Dendroctonus ponderosae*) (Alberta Forestry Division, 2005).

In the Northern Rocky Mountains, fire acts as a dynamic disturbance regime that shapes a landscape of shifting mosaic patches of forest, shrub, and grassland. High intensity fires act in maintaining the heterogeneous stand ages of fire-dependent forests, as well as resetting the seral state of plant communities (Habeck & Mutch, 1973). Lower intensity fires, often occurring in spring, burn ground cover which allows for increased productivity of some forbs, graminoids and shrubs (Baker, 2009). Fire can act as a driver of diversity at intermediate levels of disturbance (Beckage & Stout, 2000; He et al., 2019). For example, in communities of understory vegetation in boreal pine forests, species richness increased in the decade following a surface burn (Marozas et al., 2007). Plant responses to fire can also have a bottom-up effect on ecosystems. In mountain grasslands, low-intensity fires increase productivity and nutrients in graminoids, leading to higher forage availability and nutritional quality for herbivores (Tracy & McNaughton, 1997).

Over millennia, understandings of the beneficial ecological effects of fires led Indigenous Peoples to burn their landscapes (Kimmerer & Lake, 2001; Lewis, 1982; Pyne, 1997; Stewart, 2002). Traditional fire knowledge and practice is multifaceted. Beyond deep Indigenous understanding of effects on plants and animals, there is also extensive knowledge surrounding seasonality, fuel characteristics, weather, return interval and consequences of not burning (Huffman, 2013; Lewis, 1982; Miller & Davidson-Hunt, 2010). In the boreal forest, First Nations burned “fire yards” (small grasslands) and corridors to increase the abundance of plant and animal resources (Lewis & Ferguson, 1988), including fire stewardship of medicinal plants and berries (Berkes & Davidson-Hunt, 2006). Though the scale of burning practices on the mountain landscape is debated (Baker, 2002), fire history evidence indicates that Indigenous fires influence the present ecology of the Northern Rocky Mountains (Barrett & Arno, 1982).

Recent changes to vegetation cover have occurred throughout the Rocky Mountains (Fortin et al., 2019; Rhemtulla et al., 2002; Stockdale et al., 2019; Trant et al., 2020). Repeat photography shows that change in vegetation cover has occurred in the Bighorn-Kootenay Plains over the past century, with increases in shrub, aspen, and conifers (Figure 1). It is likely that shrinking grasslands are paired with the loss of culturally important plants, especially early-seral species such as sage (*Artemesia spp.)* which require frequent low-intensity fires to thrive (Anderson & Bailey, 1980). Many plants of eco-cultural importance, such as berries (e.g., *Shepherdia canadensis, Vaccinium spp.)* also act as an important food source to at-risk animals such as grizzly bear (*Ursus arctos horribilis*) (McClelland et al., 2020; Stoney Consultation Team, 2016), which rely on forage in recently-burned open areas (Hamer, 1996). While fire management is considered under most conservation frameworks, links between diversity and traditional land stewardship in the Rocky Mountains are not well defined (White et al., 2011). Understanding the role of historic Indigenous burning practices in maintaining the area’s biodiversity will be crucial to future co-management conservation objectives, as will equal and meaningful decision-making and participation by Indigenous knowledge holders and communities (e.g., Nikolakis et al., 2020; Petty et al., 2015).

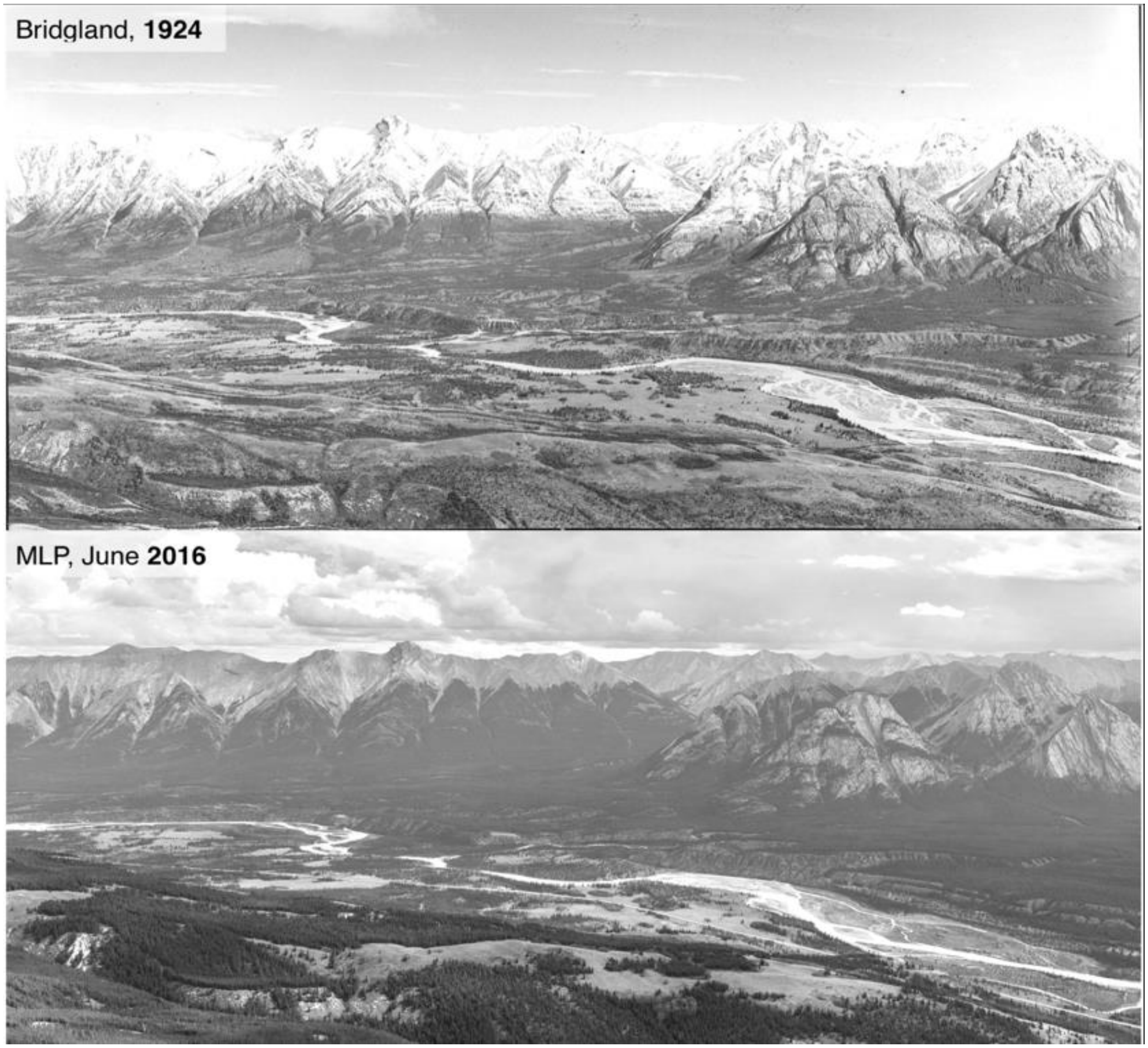

Figure 1: The Bighorn-Kootenay Plains in 1924, photographed by surveyor M. P. Bridgland, with repeat photo in 2016 courtesy of Mountain Legacy Project. Perhaps the most obvious change over 92 years is the increase in closed-canopy forest and the forest encroachment of open areas. Images publicly available at http://mountainlegacy.ca/

Colonial Context

The Wapta Mnû̲t̲h̲a (North Saskatchewan River) valley is the traditional territory of the Stoney Nakoda Nations (Snow, 1977). In 1877, the Stoney Nakoda signed Treaty 7 and set up cairns to delineate what they understood was promised reserve land in the valley's grasslands Egnuck Wida (sometimes called 'Kootenay Plains') (Larner, 1972). However, the grasslands lie in territory covered by Treaty 8 which the Stoney Nakoda did not sign: the grasslands remain unceded (Larner, 1972). After demands from the Stoney Nakoda, the Indian Affairs Branch outlined plans for a reserve in the headwaters of the North Saskatchewan River in 1910, which encompassed the Egnuck Wida grasslands and surrounding valleys from what was then known as Rocky Mountains National Park (now Banff National Park) to the Kiska Waptan (Bighorn River) (Larner, 1972). In the years following, a reserve had yet to be delineated, and colonial governments made numerous attempts to evict the Stoney Nakoda, including charging Chief Taotha Peter Wesley with trespass and violation of game laws (Larner, 1972). Decades of opposition from industry, forestry, and ranchers reduced the finalized reserve size to less than one tenth of the initial area, which was allocated in 1947 and did not satisfy the land claim (Larner, 1972).

In the time since the establishment of Bighorn Reserve, the Stoney Nakoda lands in question have been further fragmented and degraded. In the 1950s, seismographic surveys for coal exploration fragmented the landscape and drove out animals; at this time the Stoney Nakoda lost important hunting and trapping ability (Larner, 1972). In the 1970s, the Alberta Government began constructing a hydroelectric reservoir, which flooded over half of the valley where the 1910 reserve was promised (Larner, 1972). At that time, construction crews destroyed cultural sites, graves, and houses (Snow, 1977) and the Alberta Government sought to rescind Stoney Nakoda hunting and trapping rights (Larner, 1972).

Since the development of the reservoir, the Stoney Nations have been in the tribunal process of a Treaty land entitlement claim which has yet to be resolved (Bill Snow to Canada Energy Regulator, 2020). The reservoir and other industrial developments in Stoney Nakoda territory have led to the loss of traditional food plant resources and a rise of illness in the community (Barry Wesley to Canada Energy Regulator, 2020). A Stoney Nakoda Elder remarks that there are fewer berries and medicines and worries about being unable to teach her grandchildren traditional gathering practices (Elder Krista Hunter to Canada Energy Regulator, 2020). Another Stoney Elder has lost access to his family's Sun Dance area and is unable to find many spaces to conduct ceremony undisturbed (Elder Rod Hunter to Canada Energy Regulator, 2020).

Positionality

As a white settler from Treaty 6 territory, my relationship to the land, conservation and research is intrinsically tied to my identity, and thus limited by my own biases. While I value the Bighorn region as a place to spend time in nature with family and friends, I recognize that outdoor recreation is too often prioritized over the rights of First Nations. Further, I understand that my love for the Bighorn differs from an Indigenous connection to place. Specifically, Stoney Nakoda Nations describe a deep relationship to their homelands:

> These mountains are our temples, our sanctuaries, and our resting places. They are a place of hope, a place of vision, a place of refuge, a very special and holy place where

the Great Spirit speaks with us. Therefore, these mountains are our sacred places (Chief Snow, 1977). [p.13]

Academic research in ecology is overwhelmingly conducted by settlers who pay little regard to the First Nations whose lands they study. Though I intended to break from this norm, I fell short of what I envisioned as a truly collaborative project. At the outset of my research, I endeavoured to undertake a mutually beneficial project with the Bighorn Stoney community. I met with a Stoney Knowledge Holder while developing my project, which guided my research questions and methods. In attempts to counter the extractive legacy of academic work, I had funding to hire a field assistant from the Nation for both vegetation surveys and community engagement. I was invited for a ceremony in the grasslands before starting the field season, and planned to volunteer for a project developing Stoney signage in the Ecological Reserve.

Unfortunately, my field season in the summer of 2020 coincided with the first year of the COVID-19 pandemic. My university permits for conducting research with the Stoney Nation were suspended due to the public health emergency, and I was able only to survey vegetation. However, setbacks to my project paled in comparison to the immense burden of the pandemic on the Stoney Nation, and I shifted my project to avoid extra strain on the community.

One major shift involves the analysis of images. Without the opportunity to learn Stoney Nakoda ecological knowledge about the historic landscape, I instead reconstructed survey photos from the 1920s and compared them to present-day satellite imagery. While these data are valuable to ecology, it would be naïve to proceed without acknowledging the frameworks under which they were created. Early mountain imagery comes from the Dominion Land Survey, a colonial mapping process by which Canada asserted its status and transformed vast landscapes into squares of private property to be settled (MacGregor, 1981). The Dominion Land Survey led directly to violent dispossession of Indigenous lands, including armed conflict such as the Red River Resistance (MacGregor, 1981). A century later, satellite imagery represents an analogous tool: technology developed for military surveillance to maintain the global power of imperial states (Harris, 2006). Though these data are fraught with colonial issues, I hope the ways I have used them are of benefit to conservation and Indigenous stewardship objectives.

Chapter 2: Colonial management drives ecological change following exclusion of Indigenous stewardship in a Stoney Nakoda montane grassland, Canadian Rocky Mountains

Abstract

In the Canadian Rocky Mountains, landscape patterns have changed dramatically over the last century. Traditional Indigenous burning practices have kept Rocky Mountain landscapes open, diverse, and productive for millennia. Management transitions shift landscape vegetation patterns, and areas previously stewarded by Indigenous Peoples are undergoing successional change. On a traditional montane grassland of the Stoney Nakoda Nations, we documented vegetation change on both the landscape and plot level. Using oblique photographs taken in 1924 paired with 2021 satellite imagery, we assessed landscape vegetation changes and investigated abiotic and management factors. We also examined differences in vegetation class cover and plant community structure between surveys conducted in 1981, 1995, and 2020. Nearly half (47%) of the landscape surveyed showed seral progression in vegetation class, which was not explained by topography, geology, or climate warming. Grassland area decreased four-fold between 1924 and 2021. Grassland retention was strongly related to management zoning, with greater losses in the Kootenay Plains Ecological Reserve than on lands under Stoney Nakoda management. Vegetation plots surveyed reveal changes to plant community composition, and shifts in dominant vegetation class. In plots previously composed largely of forbs and graminoids, shrubs have become the dominant groundcover. Declines in historic vegetation include a loss of culturally important food and medicine plants to the Stoney Nakoda Nation. The most likely explanation for these results is a removal of Indigenous Peoples

and stewardship from the landscape. We demonstrate that the past century of colonial environmental management has altered ecological processes that were maintained on this landscape for millennia by Indigenous stewards.

Introduction

Indigenous Peoples are key actors in the ecology of the landscapes in which they live. For millennia, people have managed vegetation to increase the availability and productivity of culturally important plants, as well as to create habitat for animals, among other uses (Lake et al., 2017; Lewis, 1982; Miller & Davidson-Hunt, 2010; Stewart, 2002). Developed in relationship with local ecosystems, Indigenous fire knowledge is nuanced and multi-faceted (Huffman, 2013), and Indigenous fire stewardship increases biodiversity and landscape heterogeneity (Hoffman et al., 2021; Turner, 1999). Across North America, Indigenous Peoples shape the landscape with fire: intentional burning maintained open plains and productive mixed-age forests (Kimmerer & Lake, 2001; Miller & Davidson-Hunt, 2010; Stewart, 2002). In the Rocky Mountains, mosaics of grassland and forest exist as a result of millennia of landscape-level modification by First Nations (Barrett & Arno, 1982; Byrne, 1968; White et al., 2011). Over the past century, changes to mountain landscapes have occurred following suppressed fire regimes (Rhemtulla et al., 2002; Stockdale et al., 2019). In the context of Indigenous fire knowledge, where traditional burning practices are needed to keep grasslands open (Cree Knowledge Holder to Lewis, 1982), the succession of Rocky Mountain grasslands is expected. While the Rocky Mountains have a rich cultural history, legacies of Indigenous stewardship are often overlooked in ecological analyses of landscape structure, and require nuanced research methods (e.g., Lepofsky et al., 2017).

In the Rocky Mountains, frequent fire is the most important factor in maintaining grassland plant communities (Coop & Givnish, 2007). However, organized fire control and suppression efforts began in the Canadian Rocky Mountain Parks by 1909 (White, 1985) and in the Rocky Mountains Forest Reserve in 1930 (Murphy, 1985). Without fire, successional processes shift large areas of landscapes from early-seral vegetation to dominant woody competitors (Stockdale et al., 2019), a transition that is well underway in the Canadian Rocky Mountain Parks (Rhemtulla et al., 2002).

Landscape change across the Canadian Rocky Mountains is part of a colonial legacy, with Indigenous Peoples excluded from Rocky Mountain Park (now Banff National Park) at its inception (Binnema & Niemi, 2006). Indigenous Peoples face continued omission from management decisions in Banff and Jasper National Parks (Linnard, 2015; Youdelis, 2016), though new draft plans for Banff National Park include an Indigenous Advisory Circle (Parks Canada, 2021). Parks Canada ecologists have noted that the exclusion of Indigenous land-based activities such as fire and hunting threatens biodiversity and ecosystem integrity (Kay et al., 1999), for which landscape restoration should include Indigenous Knowledge Holders (White et al., 2011).

Grassland losses under colonial management are pronounced in the Wapta Mnûṯẖa (North Saskatchewan River) valley on the eastern slopes of the Rocky Mountains. When speaking with Stoney Nakoda community members, a Knowledge Holder told me of the many changes he has seen since he was a young boy (Wesley, 2019). For many generations, hundreds of members of the Stoney Nakoda Nation subsisted on this productive grassland ecosystem (Snow, 1977), where a warm climate supported cultivation of plants (Abraham, 1909 as cited in Larner, 1972). In the early 19th century, expedition journals document the site as a welcome rest stop—a savannah with abundant game for hungry travellers (Kay et al., 1999), where the forest had been cleared away by fire (Larner, 1972). A century ago, photographs of the valley obtained from the Mountain Legacy Project (MLP) show open grasslands and sparse trees (see Appendix, Figure 3). Presently, the region is controlled by the Alberta government, with most of the grasslands are under the management of Alberta Parks as the Kootenay Plains Ecological Reserve, wherein fires are suppressed (Alberta Environmental Protection, 1996). My study looks to historic imagery and past vegetation surveys to assess how ongoing landscape change impacts plant communities.

I hypothesize that the landscape of the Wapta Mnût̲h̲a valley is shaped by Indigenous stewardship practices which maintained open grasslands and an abundance of early-seral species, including culturally important forbs. Under current non-Indigenous management regimes, I predict a successional transition from grasslands to shrub-dominated and forested areas, with the decline of culturally important forbs. By analyzing historic imagery from 1924 and conducting repeat surveys of floristic plots (surveyed in 1981, 1995 and 2020), I have documented ecological changes to this cultural landscape. I then modelled these changes along climate, topographic and geological variables to test the alternative hypothesis of non-human drivers.

Methods

1. Site Description

The study area is a montane valley of the Wapta Mnûṯẖa (North Saskatchewan River) that is an important part of the traditional territories of *Iyarhe Nakoda,* the Stoney Nakoda First Nations (Snow, 1977). In the Wapta Mnûṯẖa valley, members of the Wesley Band led traditional lifestyles in the Egnuck Wida grasslands in defiance of colonial restrictions until the creation of the Bighorn Dam in 1972 (Snow, 1977). The hydroelectric reservoir was constructed in disregard of the Stoney Nations' unresolved treaty entitlement (Getty, 1975) and inundated areas that were part of the decades-long land claim (Larner, 1972). Although the Canadian Department of Indian Affairs recognized the validity of the Stoney Nations' land claim to the valley in 1910 (Larner, 1972), the industrial expansion continued in violation of the Stoney Nations' treaty rights, causing extensive damage to the Nations' land-based livelihoods (Getty, 1975; Snow, 1977). Most of the remaining grasslands upstream of the reservoir were zoned as the Kootenay Plains Ecological Reserve and a small portion leased to the Stoney Nations (AEP 1996).

Indigenous Peoples have lived on the grasslands of the Eastern Slopes of the Rocky Mountains for over 10,000 years (Ronaghan, 1993). The Wapta Mnûṯẖa study site lies in an important travel corridor and confluence of culture, where archeological sites of Ktunaxa camps exist alongside camps erected by Plains groups (Reeves, 1974) such as teepees made of hide or spruce bark by the Stoney Nation (Snow, 1977). Projectile points collected at 61 campsites show hunting in the valley in early through late archaeological periods (c. 10,000 years ago to present; Reeves, 1974). The most common ungulates processed were elk, sheep, deer, and bison (Reeves, 1974). These camps are often situated on south or west-facing exposures, which see less snow cover due to warm westerly adiabatic winds (Christensen, 1971), called *masta ganuṯẖa* in Nakoda (Stoney Education Authority, 2022). Movement models of pre-colonial mountain travel show high connectivity of the North Saskatchewan River valley and adjacent plains into the Rocky Mountains (Osicki, 2012). Archaeological sites occur in the upper North Saskatchewan River valley through the pass summit to the Howse River Valley (Christensen, 1971), documenting the importance of this low-elevation transmountain corridor. Pollen analysis of nearby Rocky Mountain lakes found *Artemisia spp.* dominant in early post-glacial plant assemblages (Beaudoin, 1984; Schweger, 1989), a sage genus characteristic of dry, open areas that has particular ceremonial and medicinal importance to many First Nations (Moerman, 1998).

The Wapta Mnûṯẖa valley is a montane subregion of the Rocky Mountains characterized by a grassland-forest mosaic, some of which is managed under the 3,439 hectare Kootenay Plains Ecological Reserve (Figure 2; Alberta Environmental Protection, 1996). The major grassland community is characterized by northern wheatgrass (*Elymus lanceolatus*), June grass (*Koeleria macrantha)*, pasture sagewort (*Artemisia frigida*), and pussytoes *(Antennaria parvifolia),* while forest stands are dominated by lodgepole pine (*Pinus contorta)*, white spruce (*Picea glauca),* and aspen (*Populus tremuloides)* (Alberta Environmental Protection, 1996). Rare plants include plantain goldenweed (*Pyrrocoma uniflora),* and a limber pine (*Pinus flexis*) tree over 1000 years old (Alberta Environmental Protection, 1997). Although the ecological reserve management plan acknowledged the grasslands were likely maintained by burning, fire has been suppressed in Kootenay Plains ER since its designation as a Natural Area in 1968 (Alberta

Environmental Protection, 1996). While the site is dry (mean annual precipitation of 400-500 mm) and windy (AEP, 1996), lightning fire risk is low (Rogeau, 1999). Where 4-10 fires were recorded each decade at the turn of the 20^{th} century, fires have become less frequent at the study site, with the last wildfire occurring in 1978 (see Appendix; Rogeau, 1999). Nearby fire scars in the upper North Saskatchewan River valley show a majority of fires prior to colonial development occurred in the spring (Rogeau, 2010), which is a common season for Indigenous burning (Lewis, 1982).

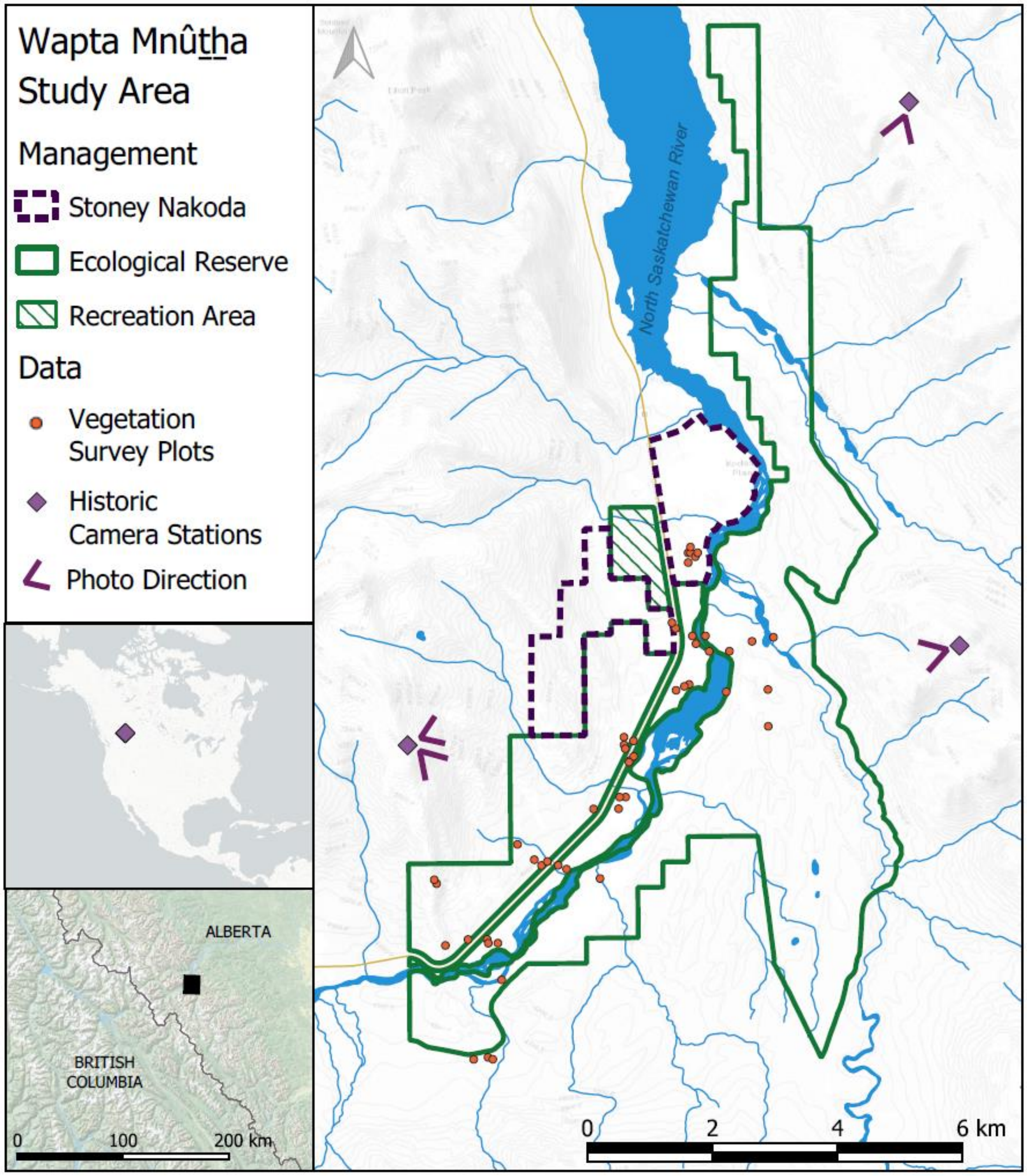

Figure 2: Map of the Wapta Mnûṯẖa study area, a montane valley on the Eastern slopes of the Rocky Mountains

2. Historic Imagery

To reconstruct the historic landscape, I used oblique photographs taken in 1924 by M. P. Bridgland as part of the Dominion Land Survey (MacLaren, 2005), freely available as part of the Mountain Legacy Project (Trant et al., 2015). The high resolution of glass-plate photographs (scanned to 4300 x 3000 pixels) allows for a landscape-level analysis of vegetation change (Rhemtulla et al., 2002). I selected four photographs taken at camera stations on three ridgelines overlooking the valley, which together provide coverage of what remains of the Kootenay Plains (Figure 2). The mean elevation of camera stations is 2381 m, compared to the valley bottom elevation of 1332 m.

2.1 Imagery Data

Image Classification and Transformation

I chose landcover classes that were easily identifiable in historic imagery: barren, herbaceous, shrub, broadleaf, and conifer. These classes are discerned in black and white photographs by differences in shade and texture, following methods used by the Mountain Legacy Project (Jean et al., 2015; Trant et al., 2015). Survey photographs were coarsely classified into the 5 categories above using a PYLC landscape classification tool developed for this photo archive (Rose, 2020). I then made fine-scale adjustments to classes by visual discernment (e.g., I manually drew outlines of 'herbaceous' class in open vegetated areas which lacked shrub-like texture). Areas covered with snow, ice, or water were not considered so as not to confound vegetation changes with snowmelt or riverbed movement.

For compatibility with modern GIS software, I converted the classified 1924 survey imagery using a monoplot transformation on each of the historic survey photos. This is a method which georeferences pixels in oblique photographs to their location on an orthogonal view of the landscape (Stockdale et al., 2015). I completed this transformation using the Image Analysis Tool developed for MLP (Sanseverino et al., 2016) by creating a virtual image to match the original photo with a 2 m resolution LiDAR-derived digital elevation model (DEM) and its corresponding hillshade. The classified landcover is then cast into the viewshed resulting in a GIS-ready landcover raster (Figure 3).

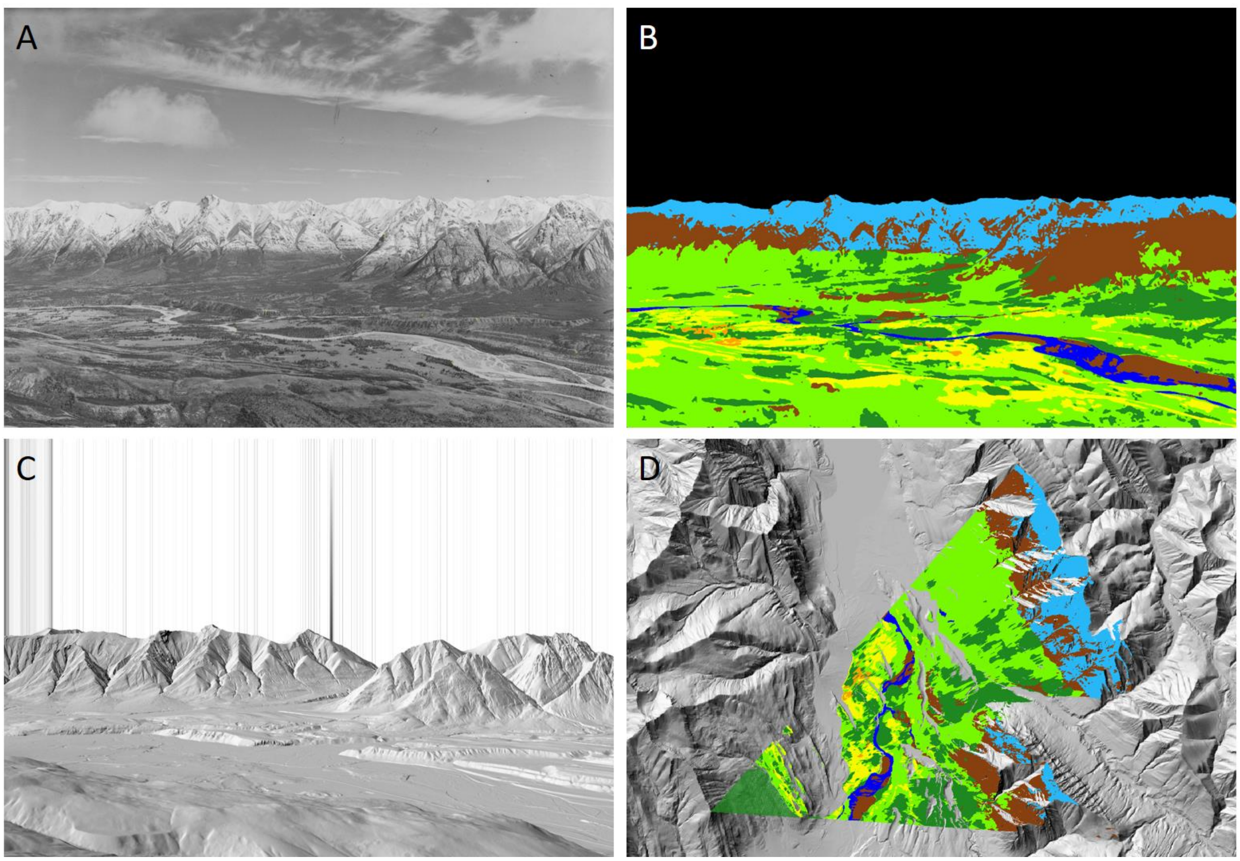

Figure 3: An oblique photograph taken in 1924 (A) first undergoes vegetation classification (B) and is then georeferenced using a monoplot transformation over an identical virtual image (C). The result is an orthogonal raster of vegetation class that covers the camera's original viewshed (D).

Since viewsheds do not cover the complete landscape (e.g., in some places there can be shading caused by topography), I used multiple overlapping viewsheds from three camera stations that survey the valley at different angles. To select the best pixel from the four viewsheds, I first merged the data by the most common vegetation class. For pixels which lacked a modal value, I selected the best pixel based on a rank-based system in the following order: foreground, midground, and background, on the assumption that vegetation classification was more accurate closer to the camera.

Error is present in the data extracted from historic imagery due to lens distortion, glass plate distortion, and user inaccuracies (Stockdale et al., 2015). To quantify error, I created a comparison method between ground control points and their respective points in the image. I marked 28 ground control points in the original images that could be visually identified on the LiDAR-derived digital terrain model (e.g., a large rock feature). I chose points that fell within the viewshed and among vegetation of interest so as to measure the most relevant transformation error. I then performed a monoplot transformation on the control points using the identical parameters used on the vegetation classification mask. Finally, I calculated the Euclidian distance between the ground control points on the digital terrain model and those from the monoplot transformation. The mean distance of displacement of ground control points was 13.3 m (SD = 11.2), which is approximately 7 pixels. As the historic vegetation is rectified onto a high-resolution digital terrain model, the total area of the valley is fixed which reduces the risk of overestimating historic total vegetation area.

I derived modern landcover data by visually classifying satellite imagery from Planet Imagery (2021) into the same landcover classes as above. I used satellite images from August 2021 at 3 m resolution, which I edited to grayscale before classifying to maintain classification consistency with historic black and white photographs. Landcover estimations of oblique and orthogonal imagery are comparable (Fortin et al., 2019), though closed-canopy forests tend to be slightly over-estimated in oblique imagery by about 13% (Stockdale et al., 2019). I do not expect this bias to negatively impact the results, as forest densification and encroachment has occurred since the oblique 1924 photograph. Due to differences in the area covered by the two surveys, I extracted 2021 satellite data from the 1924 viewshed for use and discarded areas not surveyed in 1924.

2.2 Imagery Analysis

Grassland change

I extracted herbaceous vegetation class from the 1924 and 2021 rasters for an analysis of grassland change between the two surveys. I performed all data analyses in R (R Core Team, 2021). Using the `raster` package (Hijmans, 2020), I counted the number of patches and measured each patch size in hectares. To explore how present management regimes affect grasslands, I calculated the above metrics in three management zones: Kootenay Plains Ecological Reserve, Kootenay Plains Recreation Area (which contains two campgrounds and a rock-climbing area), and Stoney Nakoda managed land, which is used exclusively by the Stoney Nations for land-based activities. To test whether grassland areas were relatively equal across management types, I compared grassland size to management zone size using a chi-squared test. To measure the influence of present management on grassland change, I calculated a grassland retention rate, which is the ratio between 1924 and 2021 grassland area, in each zone.

Modelling environmental predictors of succession

To analyze the role of environmental variables related to succession, I first created a binomial 'succession' raster based on seral progression of vegetation class, which I ordered barren, herb, shrub, broadleaf, conifer (Stockdale et al., 2019). Pixels in which the vegetation class had advanced along this continuum are represented with 1, while 0 represented no advance (stable or reverse). Transition to an earlier seral state was present in less than 4% of the data, so it is unlikely that the resolution lost by grouping 'stable' and 'reverse' will largely impact the results. I modelled this succession under a binomial generalized linear model as a function of environmental variables grouped under hypotheses of four potential drivers of change: climate, terrain, stand age, and vegetation class. I compared these four models to a combined model (all variables) and a null model using Akaike's Information Criterion (AIC).

Climate variables of mean annual temperature (°C) and growing degree days (number of days above 5°C) were obtained from tri-decadal normals derived from ClimateNA (Wang et al., 2016) at 1 km resolution. To determine local climate change, I subtracted the 1901-1930 climate normals from 1991-2020 climate normal, as in Trant et al. (2020). I then extracted data from these difference rasters for modelling. Terrain variables include slope (degrees), elevation (metres), and aspect (cardinal directions), which I created from a 2 m resolution LiDAR-derived digital terrain model. Because some rocky areas are not prone to vegetation establishment or succession, I also included surficial geology (Bayrock & Reimchen, 2007) as a categorical variable together with the terrain variables. Finally, I included the vegetation class of the 1924 survey and the stand origin year (Rogeau, 1999) to account for the different likelihoods of certain vegetation types to change seral stage.

3. Vegetation Resurvey

Our vegetation surveys followed the standardized provincial methods used in the previous surveys (Alberta Environmental Protection, 1994). Between July and August 2020, we resurveyed 42 plots out of the total 50 plots (plots #4-11 were not surveyed due to Stoney Nakoda COVID-19 community safety restrictions). To locate and map sites, we used a *Garmin inReach Mini* GPS device, with a reported accuracy of 3 meters. While past site coordinates had a lower accuracy (e.g., up to 30 m error in 1995; AEP, 1996), I selected the nearest appropriate location following the previous detailed site description and the site selection guidelines in Alberta's *Ecological Land Survey Site Description Manual* (Alberta Environmental Protection, 1994). At each 10 x 10 m plot, we measured percent cover and height (m) of each vegetation layer: graminoids, moss, forbs, shrubs, and trees (canopy and understory). We documented each plant species present and visually estimated percent cover, where 1 m^2 is equal to 1%. Species present at less than one percent were marked as 0.1 for a single individual and 0.5 for multiple individuals. Species names follow nomenclature retrieved from the Database of Vascular Plants of Canada (Canadensys, 2020). Voucher photos of 116 plant species from the study site are accessioned to the online open biodiversity database iNaturalist (*Kootenay Plains Survey 2020 · INaturalist*, n.d. [https://inaturalist.ca/projects/kootenay-plains-survey-2020]).

3.1 Vegetation Data

To look at vegetation change through time, I compiled data from 1981 (n = 25 plots; Wallis & Wershler) and 1995 (n = 50 plots; AEP 1996). The 1995 report resurveyed the 25 original sites from 1981 and added another 25 nearby. As no permanent plots were established in previous surveys and GPS locations reported in 1995 have an approximately 30 m error margin, I consider the resampling unit a node (plots in a spatial cluster < 1 km radius that sample similar habitat). The node is used in further modelling as a random effect to avoid biases associated with pseudoreplication. Across three surveys, I have grouped plots into 9 nodes based on visual assessment of grouping and similarity in microhabitat.

To compare data from three different surveys, I updated species codes from past data to match the present data format. I consulted the Database of Vascular Plants of Canada (Canadensys, 2020) for taxonomic history and present species nomenclature. As data from 1981 were recorded in binned cover estimates, I used the mean of each bin in analysis for compatibility with visual cover data from 1995 and 2020. This method of cover comparison is supported by Damgaard (2014), which shows that both visual (continuous) percent cover data and Braun-Blanquet (binned) cover data produce estimates of true cover with comparable accuracy.

3.2 Vegetation Analysis

I conducted an analysis of community data under a multivariate framework with the vegetation analysis package `vegan` (Oksanen et al., 2020). To down-weight the few species with large cover, I applied a log transformation (ln(cover + 1)). For the community analysis, I applied non-parametric multidimensional scaling (NMDS) with Bray-Curtis distances using the `metaMDS` function. To test differences in plant communities between survey years, I applied a Permutational Analysis of Variance (PERMANOVA) using Bray-Curtis distances with the `adonis` function. Though sample sizes differ between years, the PERMANOVA assumption of similar dispersion of points among groups is met (McArdle & Anderson, 2001), so I included all data points in multivariate analyses.

To compare univariate plot-level characteristics such as shrub cover, I used a mixed-effects modelling function with the `lme4` package (Bates et al., 2015). I created linear models of cover by year with node (group of sites) as a random intercept, weighted by survey year to account for differences in sample size and variance between groups. I used a log transformation as the response variable, which is appropriate to the approximately log-normal distribution of the data. Due to low timescale resolution with only three surveys, I modeled year as a factor instead of as a continuous variable to avoid interpolation between studies. Under this framework, I compared mean cover values between years for three plot-level vegetation classes: graminoids, forbs, and shrubs. Further, I selected a subset of 12 forb species (listed in Appendix 2) that are culturally important to the Stoney Nation (based on Scott-Brown, 1977) and ran the above models on the sum of their cover. Scott-Brown worked with Stoney Nakoda women in Morley (150 km south of the Bighorn Stoney community) to document medicinal and food plants (1977). From Scott-Brown's work, I selected plants at my study site that have are common enough to form reliable abundance comparisons. Examples of selected food plants are nodding onion *Sijamnâmnân (Allium cernuum)* and sweetvetch *Mâkuthkiya (Hedysarum spp.);* medicinal plant examples are fringed sagebrush *Pezi mnathkathka (Artemisia frigida)* and yarrow *Sijamnâmnân (Achillea millefolium).*

Results

1. Landscape Imagery Comparison

1.1 Grassland Change

Landscape composition differed between 1924 and 2021 imagery surveys. Both the number and size of grassland patches have changed between survey years (Figure 4), with 597 patches measured in 1924, and sizes ranging from 10 to 100,000 m^2. While the largest size classes in 2021 remain, few patches smaller than 1000 m^2 persist (Figure 5). The loss of small patches led to a threefold increase in mean patch size between the sample periods (**2021**: n = 57, μ = 28 596 m^2; **1924**: n = 597, μ = 8 690 m^2; Welch's t-test t = -3.26, df = 67.4, p = 0.002).

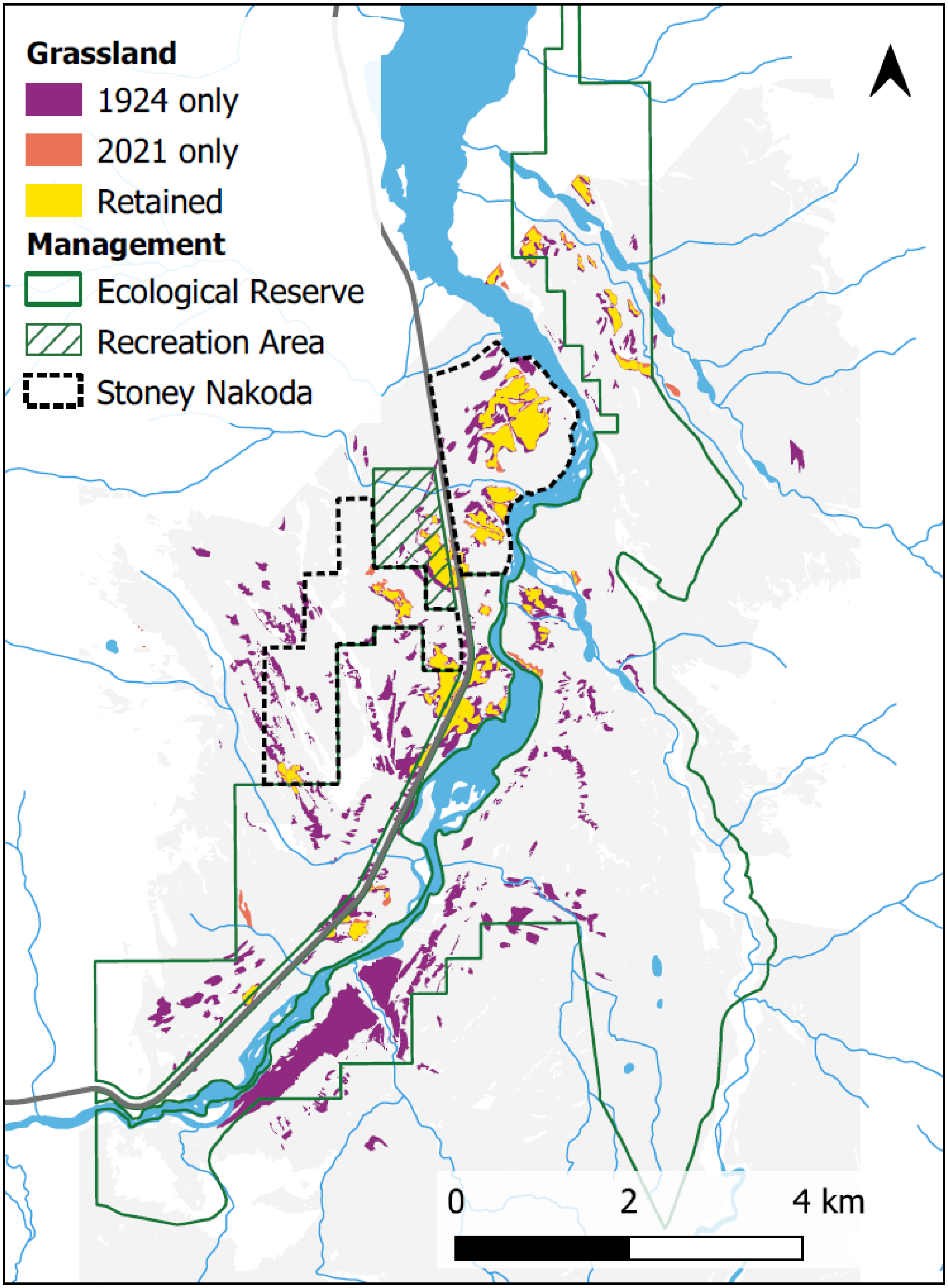

Figure 4: Egnuck Wida grassland change in the Wapta Mnûṯẖa valley between the survey years of 1924 and 2021.

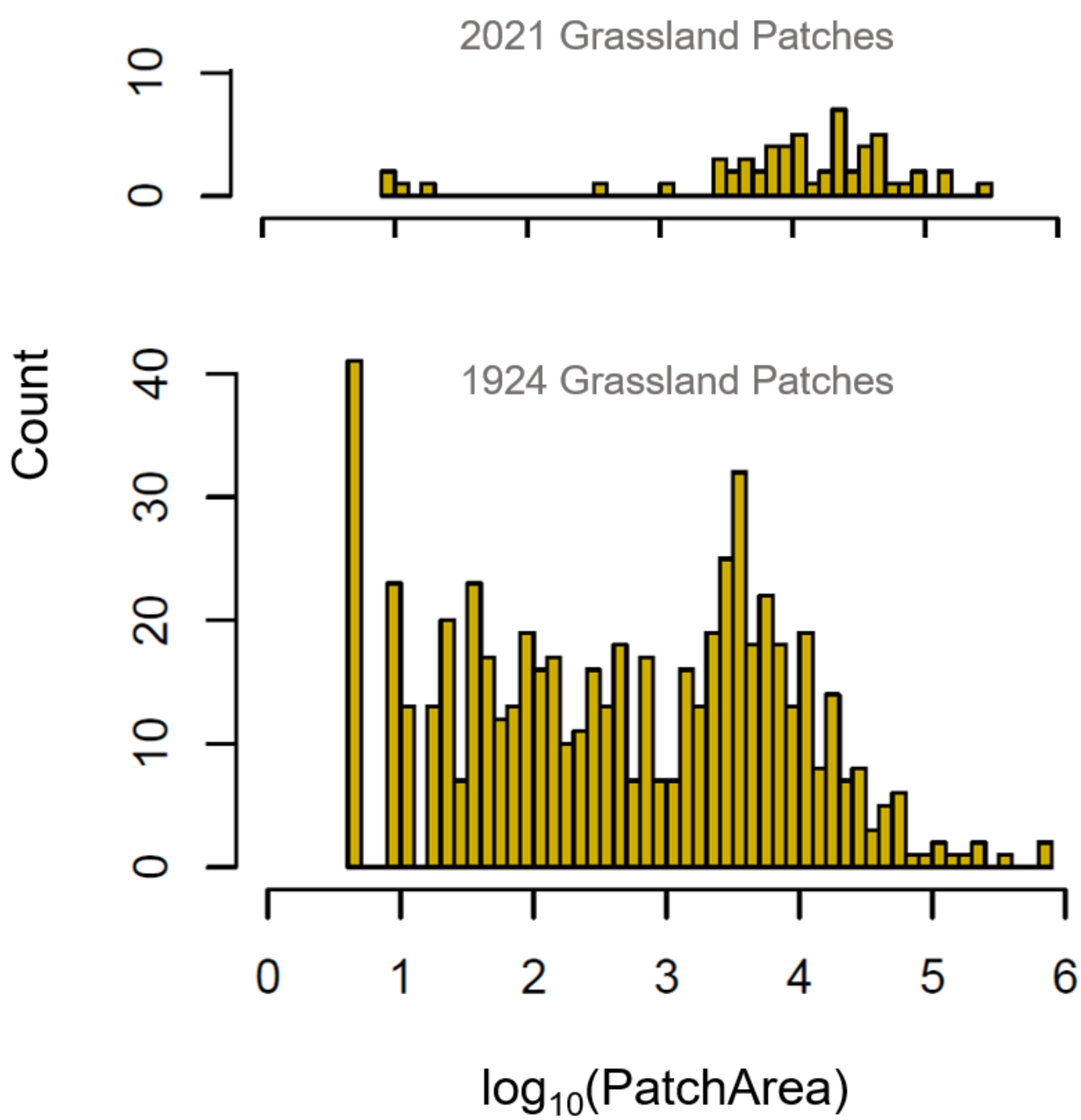

Figure 5: Histogram of grassland patch area in **2021** (n = 57, μ = 28 596 m^2) and in **1924** (n = 597, μ = 8 690 m^2).

Grassland area measured in 2021 is unequally distributed between management zones, with Stoney Nakoda leased lands and the Recreation Area having higher grassland area than expected as calculated with a Chi-squared goodness of fit test ($\chi^2 = 61.3$, df = 3, $p < 0.001$; Table

1). The retention rate of grassland between 1924 and 2021 was over three times higher on Stoney Nakoda leased lands compared that of the Ecological Reserve (Table 1). The recreation area, which hosts two maintained campsites of several hectares each, has the highest grassland retention (91%).

Table 1: Areas in each management zone (ha), with percent calculated from the sum of each previous column. Grassland area differs significantly from expected ($\chi^2 = 61.3$, df = 3, $p < 0.001$). Grassland retention is the ratio of 2021 area to 1924 area, by management zone.

Management zoning	Survey area		1924 grassland area		2021 grassland area		Grassland retention
	hectare	%	hectare	%	hectare	%	
Stoney Nakoda	585.0	6.4	110.7	21	70.61	43	0.64
Ecological Reserve	3206	35	311.7	60	62.65	38	0.20
Recreation Area	28.28	0.31	15.13	2.9	13.73	8	0.91
Other	5329	58	81.25	16	16.01	10	0.20

1.2 Succession

Of the landscape surveyed, 46.8% of pixels progressed to a later seral state. Herbaceous cover decreased to 25% of its original area, while conifer cover increased by 147%. A vegetation transition matrix shows conversion of the landscape to conifer following the loss of bare, herbaceous, shrub, and broadleaf cover (Table 2). Of the five binomial models tested to explain vegetation succession, the best model by AIC comparison includes only initial vegetation class as a predictor (Table 3). None of the abiotic variables tested (terrain and climate variables) explained succession and these models performed worse than the null model (Table 3).

Table 2: Vegetation transition matrix, in percentage of class total in 1924. Grey cells represent pixels that did not change between surveys, while white cells show the transition of 1924 vegetation class (row) to 2021 vegetation class (column).

		2021 Vegetation Class				
		Barren	Herb	Shrub	Broadleaf	Conifer
1924 Vegetation Class	Barren	39.9	0.2	12.9	0.1	46.9
	Herb	0.4	24.8	52.8	1.3	20.7
	Shrub	1.8	1.0	25.0	3.9	68.4
	Broadleaf	3.1	1.4	14.3	24.8	56.4
	Conifer	0.3	0.1	6.3	2.4	90.8

Table 3: Model selection of a binomial generalized linear model describing the succession of vegetation as a response to explanatory environmental variables.

Hypothesis	**Model Variables**	**ΔAIC**	**df**	**weight**
Vegetation	~ 1924VegClass	0.0	5	0.9956
Combined	~ 1924VegClass + StandAge + Elevation + Aspect + Slope + Geology + Temperature + DegreeGrowDay	10.8	22	0.0044
Stand age	~ StandAge	161.4	2	<0.001
Null	~ 1	161.7	1	<0.001
Terrain	~ Elevation + Aspect + Slope + Geology	164.2	15	<0.001
Climate	~ Temperature + DegreeGrowDay	164.6	3	<0.001

2. Vegetation Resurvey

In the summer of 2020, I recorded 123 species over 42 survey plots. Combined with data from the 1981 and 1995 surveys, 165 species have been observed in the study area. The median richness per plot was 19, with a range of 5 to 38. Across three surveys, I found changes to the dominant vegetation class cover, transitions in community composition, and the decline of culturally important species.

2.1 Vegetation Classes

Between three survey years, forb and graminoid cover decreased while shrub cover increased (Table 4, Figure 6). For both graminoid and shrub cover, the largest change occurred between 1981 and 1995 whereas cover appears stable between 1995 and 2020. Forb cover shows steady decrease between all surveys. The variance of the random effect of node was small (ranging from 1.21 - 1.57), which indicates that changes to vegetation classes occur throughout the study area with little influence of microhabitat. Cover of culturally important forbs showed a decrease across sampling years (Table 4); the largest change occurred between 1995 and 2020, wherein cover decreased by 73%. The culturally important forb with the greatest change was fringed sage *Pezi mnthkathka (Artemisia frigida)* (mean cover in 1981: 8.1%; 2020: 0.3%).

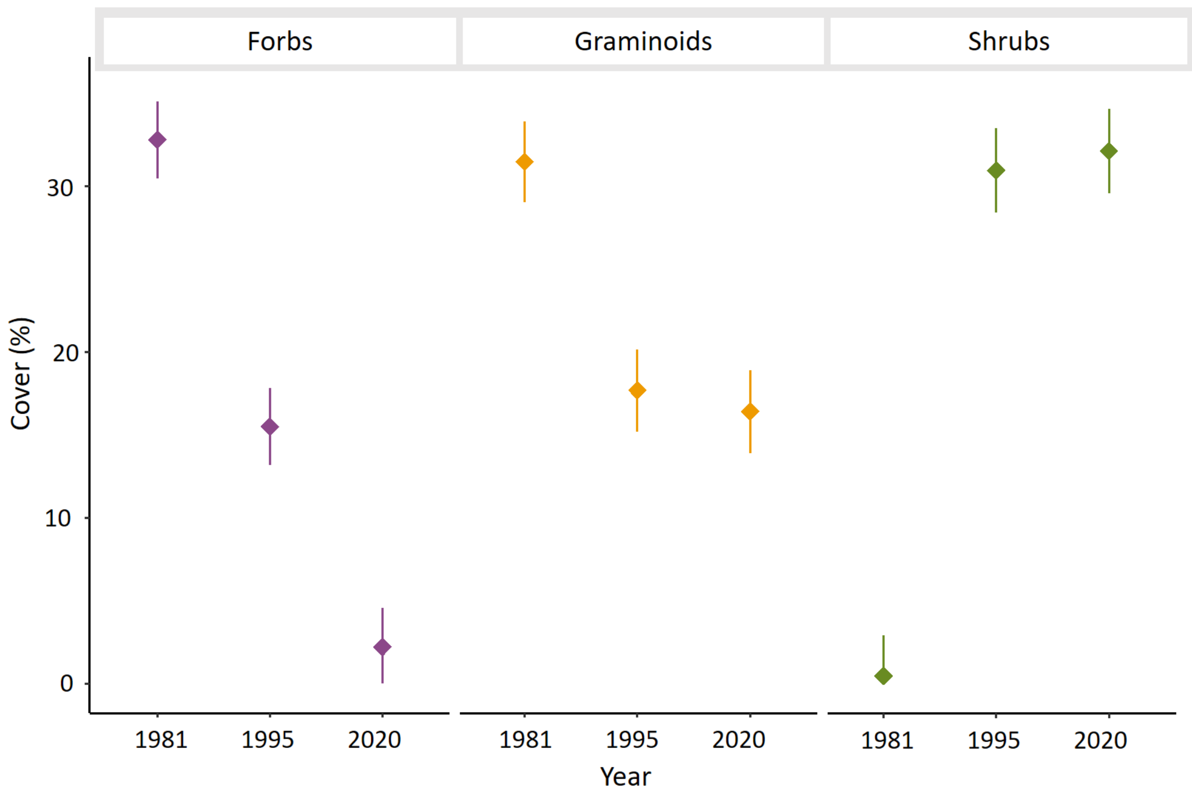

Figure 6: Model estimates with 95% confidence interval for cover of forbs, graminoids, and shrubs over three survey years

Table 4: Model summaries of logistic regression of vegetation cover by year, with a random effect of node, for each vegetation class: shrub, graminoid, forbs, and a subset of culturally important forbs.

	Predictor	***Estimate***	***SE***	***p***	**σ^2_{Node}**
Shrub Cover					1.36
	Intercept [1981]	0.458	1.24	**-**	
	Year [1995]	30.96	1.29	<**0.001**	
	Year [2020]	32.13	1.3	<**0.001**	
Graminoid Cover					1.52
	Intercept [1981]	31.49	1.23	-	
	Year [1995]	20.17	1.25	**0.0164**	
	Year [2020]	18.91	1.26	**0.0087**	
Forb Cover					1.57
	Intercept [1981]	35.14	1.17	-	
	Year [1995]	17.84	1.18	<**0.001**	
	Year [2020]	4.55	1.18	<**0.001**	
Culturally Important Forb Cover					1.21
	Intercept [1981]	7.83	1.16	-	
	Year [1995]	6.31	1.01	0.20	
	Year [2020]	1.71	1.01	<**0.001**	

2.2 Community Composition

Community composition was different in each survey year (Figure 7A; PERMANOVA, F statistic = 13.713, R^2 = 0.107, p < 0.001). There is no difference in group dispersion, analogous to variance, between years (PERMDISP, F statistic = 0.5785, p = 0.5624). All vegetation classes (graminoids, forbs, shrubs, and trees) contribute to site differences when overlaid on NMDS ordination (Figure 7B, Appendix 2).

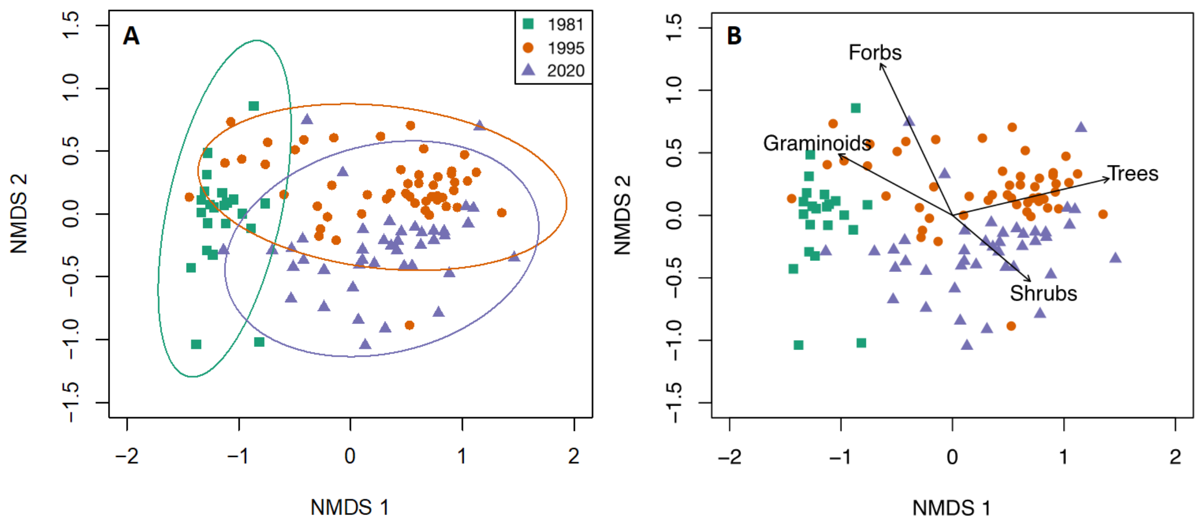

Figure 7: Non-metric multidimensional scaling of vegetation communities in 1981 (green squares), 1995 (orange circles), and 2020 (blue triangles) with A) 95% confidence ellipses, and B) association vectors of vegetation class. Stress = 0.17. R^2 = 0.97

Discussion

Since 1924, almost half the study area in the Wapta Mnût̲h̲a valley has experienced ecological succession. Succession of vegetation communities was not explained by abiotic variables including climate warming, topography, and geology. In a little less than a century, the grassland area has decreased by 75%, primarily driven by the disappearance of small sized patches. Present grassland area and retention rates are related to management zoning, with a higher proportion of retained grasslands on lands managed by the Stoney Nakoda Nation compared to the Ecological Reserve. Over the past 40 years, plant communities in the Kootenay Plains Ecological Reserve have shifted from forb- and graminoid-dominated plots to a domination by shrubs. These changes also occur at the species level: plant community composition shows only small overlap in similarity between 1981 and 2020. Culturally important species to the Stoney Nations were also affected with cover of culturally important forbs decreasing four-fold.

These patterns of succession are not unique in the Rocky Mountain landscape. Previous research with historic survey photographs has documented landscape homogenization as historically open areas infill with late-seral forests (Fortin et al., 2019; Rhemtulla et al., 2002). At a landscape level, Mitchell (2005) documented a 52% reduction in grassland area and an increase of 40% in shrub area in the Canadian Rocky Mountains between 1949 and 1997 using a remote sensing approach. In the context of this transitionary state, our observations of change in the Wapta Mnûṯẖa valley are consistent with our understanding of this landscape. Evident differences in community composition between 1981 and 2020 provide context for the seral shift in plots, where former grasslands have transitioned to later seral species.

1. Landscape Change

Due to the difficulty of acquiring high-resolution long-term data to study transitioning landscapes prior to modern satellite imagery, few quantitative analyses explore the role of environmental variables in the past century of Rocky Mountain landscape succession (or any landscape, for that matter; Verniest & Greulich, 2019). While climate change plays a large role in shrubification of some northern ecosystems (e.g., Jia et al., 2009), there is little evidence that warming temperatures are the primary driver of vegetation change in the Canadian Rocky Mountains (Stockdale et al., 2019; Trant et al., 2020). In fact, future climate conditions are expected to favour the expansion of grasslands on the eastern slopes of the Rocky Mountains

(Schneider, 2013). In this study, I have found no effect of abiotic environmental variables on vegetation change, but a weight of evidence approach suggests that human management has played a role, in particular through fire suppression. A removal of Indigenous Peoples and stewardship carries a suite of changes including supressed fire regimes, changes to grazer populations, and reduced traditional plant cultivation.

The Egnuck Wida grasslands have a deep history of Indigenous life, inhabitation, use, and stewardship over millennia (Reeves, 1974), which has left traces on the modern landscape. Grassland areas surveyed in this study have archaeological evidence of lithic (stone) tools, sundance lodges, burnt soil horizons, and flat terraces for habitation (Ronaghan & Beaudoin, 1987). Over a century ago, the Stoney Nakoda built log houses, horse corrals and other structures which have since been demolished (Larner, 1972). The largest remaining grassland patch in the Wapta Mnûṯẖa valley is presently used by the Stoney Nations for land-based cultural activities.

Changes to grassland patch structure can be understood in the context of Indigenous burning practices, which create patterns on the landscape. First Nations of the boreal forest burned 'fire yards' (small grasslands) and corridors (Lewis & Ferguson, 1988). First Nations in the Rocky Mountain foothills used air currents to guide fire when burning mountain meadows (Lewis, 1982). In montane areas, targeted burning of food resources produced a network of small open patches (Turner et al., 2011). These small grassland patches have been lost on the Egnuck Wida landscape.

Members of the Stoney Nation lived, hunted, and trapped in the Wapta Mnûṯẖa valley up until the creation of the Bighorn dam in the 1970s (Chief Snow 1977). Indigenous burning practices were often used to clear larger areas for camps and hunting areas (Lewis, 1982). Grasslands areas outlined in this study overlap with previously documented camp and house sites (Larner, 1972; Ronaghan & Beaudoin, 1987). Traditional Stoney Nakoda fire stewardship includes burning for hunting, such as at nearby *Wodeja odabi makoche* ("abundant of animal area") which was traditionally burned to create grazing for large game, especially elk and bison (Allan 2018). Elk (*Cervus canadensis*) populations have declined in Stoney Nakoda montane grasslands, in part due to habitat changes (Hebblewhite et al., 2006).

Burning grasslands continues to be an important stewardship practice for the Stoney Nations, who collaborate with the province to light spring fires on their lands in Morley (Roy-Denis, 2015), which lies in the foothills 150 km south of the Bighorn Stoney community. In Banff National Park, Indigenous fire regimes are crucial to ecological diversity and function, prompting fire managers to seek advice from Stoney Elders (White et al., 2011). Although Indigenous fires no longer occur in the Kootenay Plains Ecological Reserve, the grassland mosaic was likely maintained over centuries by Indigenous fire stewardship and the resulting frequent low severity fire regime (Alberta Environmental Protection, 1996).

2. Species Change

At a finer scale, fire may also be used to steward plants of cultural significance to Indigenous Peoples, plants that were/are traditionally used for ceremony, medicine, and food (Roy-Denis, 2015; Turner, 1999). In North America, Indigenous fire is used to increase the abundance of food plants such as camas (*Camassia spp.;* Turner, 1999*)*, huckleberry (*Vaccinium spp.;* Johnson, 1999), and blueberry (*Vaccinium spp.*; Miller & Davidson-Hunt, 2010). In montane areas, patches cleared by fire were important harvest sites for roots and bulbs such as nodding onion *(Allium cernum)* and lilies *(Lilium spp.)* (Turner et al., 2011). Lilies have overwintering buds protected from fire below the soil surface; wood lily *(Lilium philadelphicum)* has shown increases in cover in recently burned areas (Catling, 2009). In the Wapta Mnûṯẖa valley, wood lily *Warcha* and nodding onion *Sijamnâmnân* were found in open meadows that would likely have benefitted from spring burns.

With grassland succession, the cover of culturally important plants shifted from forbs to shrubs. By outcompeting resprouting herbs, evergreen shrubs such as juniper *(Juniperus spp.)* dominate mountain landscapes following the cessation of periodic fires (Burkhardt & Tisdale, 1976). In dry open areas, I found that places with previously high sage *Pezi mathkathka (Artemisia frigida)* cover shifted to woody groundcover, mainly bearberry *Siyota hatha (Arctostaphalos uva-ursi)* and creeping juniper *Pepeth'a (Juniperus horizontalis).* Annual spring burning of Alberta grasslands is shown to decrease the cover of woody shrubs while increasing the cover of fire-dependent forbs including *Artemisia frigida* (Anderson & Bailey, 1980). *Pezi* sages (*Artemisia* spp.) are important medicine plants to the Stoney Nations (Scott-Brown, 1977), and have been a prominent feature of the area's vegetation community for millennia (Schweger, 1989).

Stoney Knowledge Holders describe how community health is impacted by landscape changes which make it difficult to harvest traditional medicines (Stoney Members to Canada Energy Regulator, 2020). With the loss of traditional food and medicine plants documented in this study, may come lower harvest availability for the Stoney Nations. Beyond ecological consequences, changes to the Egnuck Wida cultural landscape affect Indigenous resource access.

3. Limitations

The data used in this study was collected over a timeline in which methods and perspectives have evolved. Previous work does not necessarily reflect modern research practices, though is valuable given the scarcity of historic data. For example, ethnobotanical methods to document culturally important plants have advanced since Scott-Brown (1977) conducted her work with the Stoney Nations (e.g., Joseph et al., 2021; Stoffle et al., 1990). Therefore, the list of cultural plants referred to in this thesis should not be understood as comprehensive, exhaustive or authoritative. While it was beyond the scope of this study to revisit Stoney Nakoda ethnobotany work, future co-produced studies may provide better insight to plant stewardship and changes. Current best practices for coproduction of knowledge support Indigenous sovereignty through ownership, control, access and possession (OCAP) principles (First Nations Information Governance Centre, 2022).

Further, this study is restricted in its geographic area due to the nature of the available datasets. At a small study site, spatial autocorrelation may exist between vegetation plots near to each other, where proximity reduces statistical independence. While we were not able to include replicates across multiple montane landscapes, these results are nonetheless valuable as a case study of a valley with deep cultural history.

Conclusion

In this study, I have documented a profound change to the montane Egnuck Wida grasslands of the Wapta Mnûṯẖa valley, which has both ecological and cultural relevance. When management regimes based on millennia of Indigenous stewardship are altered, especially through the loss of fire in this region, there are fundamental shifts to plant communities, including declines of some culturally important species. Conservation efforts on Indigenous land must consider the ecological role of Indigenous stewardship (Bliege Bird & Nimmo, 2018), and engage Indigenous decision makers in fire co-management (Mistry et al., 2019). Globally, Indigenous fire stewardship practices are necessary to maintain biodiversity and landscape structure (Hoffman et al., 2021). Over the past decade, First Nations across Canada have begun to revitalize cultural burning practices, which work towards conservation and building resilience in the face of wildfire hazards (Christianson et al., 2021). Further work is needed to support First Nations in contemporary land stewardship and conservation, which is essential to achieving inter-governmental conservation goals such as Aichi Targets (Indigenous Circle of Experts, 2018).

Chapter 3: Conclusion

Academic Context

Understanding of large-scale landscape management by First Nations globally has been missing from the field of ecology for most of its academic history. Owing to racist assumptions that have been coined the 'Pristine Myth' (Denevan, 1992), colonizers failed to realize the extent of landscape modification in North America. Resistance to the idea that landscapes could be modified at a large scale without colonial technology has stifled research on Indigenous stewardship, for example Omer Stewart could not publish his ethnographic work on the importance of Indigenous fire in the 1950s (Stewart, 2002). Some prominent fire ecologists have clung tightly to the notion of untouched 'wilderness', employing unfounded arguments about the limitations of Indigenous Peoples' ability to influence their environment (e.g., Baker, 2002). However, by combining evidence from diverse disciplines ecologists are able to explore a nuanced narrative of Indigenous management (Lepofsky et al., 2017).

Colonial biases continue to dominate our field, with influences on learning, research, and conservation. At no point in any Ecology courses at the University of Alberta (BSc 2015-2019) did I learn about the countless ways Indigenous Peoples shaped the plains, boreal, and parkland forests; it appeared professors regarded these ecosystems as *terra nullius*. Though Indigenous management carries persistent and long term influences on vegetation dynamics, composition, and diversity, less than 10% of research papers published on these topics in North American ecosystems in the past decade acknowledge Indigenous Peoples or their legacies (Schang et al., 2020). While some academics are conducting ecological research in the context of Indigenous stewardship, this framework is not widely recognized as a crucial foundation to

Ecology but rather as the subordinate field of *Ethno-Ecology.* Considering evidence that societies around the globe have transformed their environments for millennia (Ellis et al., 2021), conducting ecological research with a *terra nullius* bias is a dangerous oversight that contributes to continued colonialism in Western Ecology.

We are poised in the midst of a resurgence of Indigenous land management in Canada, with powerful collaborative conservation planning led by Indigenous values (e.g., Council of the Haida Nation & Government of Canada, 2018). The Canadian government has recognized that Indigenous-led conservation areas are essential to meeting conservation goals (Indigenous Circle of Experts et al., 2018), and has committed funding (Government of Canada, 2021) to projects it has previously opposed. In the face of climate change and uncertainty, Indigenous knowledge, which encompasses millennia of active observation and adaptation, will be crucial to climate resilience planning (Makondo & Thomas, 2018). At the University level, decolonial approaches to ecological research in collaboration with First Nations are becoming more prominent (e.g., Joseph et al., 2021), and consent for ecological research is required under international law (Ban et al., 2018).

Overall, I hope to advance interdisciplinary and biocultural perspectives about changing landscapes. Documenting ecological aspects of Indigenous stewardship deepens our understanding of the role of long-term human interactions with the environment, and the effects of colonial land dispossession. Recently, conservation dialogue has begun to focus on restoration of Indigenous stewardship in rapidly changing landscapes (e.g., Bliege Bird & Nimmo 2018). Integrating this research into conservation planning in the Bighorn-Kootenay Plains area will require collaborative work with the Stoney Nakoda Nations under respectful frameworks (e.g., Indigenous Circle of Experts et al., 2018) which acknowledges the expertise of Stoney Nakoda ecological knowledge and longstanding stewardship.

Limitations and Future Directions

The conclusions drawn in my research are based on descriptive surveys rather than experimental research. Instead of an 'analytical' approach, which answers binary questions with simple frequentist tests, I have taken an 'integrative' approach which draws on converging lines of evidence to arrive at the most likely conclusion (Holling, 1998). For example, I did not compare surveys between burned and unburned sites, but rather modelled landscape change along a variety of co-occurring landscape attributes. In long-term ecological studies, there are a variety of statistical methods used to disentangle the effects of multiple variables (Verniest & Greulich, 2019). To address the issue of confounding variables, I included eight high-resolution landscape and climate variables in my analyses, and ensured adequate spacing between randomized sample points such that each data point was unique (no two data points fell within one raster cell). Ecological features on stewarded landscapes may also be auto-correlated; Indigenous burning practices are used to maintain trails, traplines, campsites, and food resources (Lewis, 1982), which are spatially explicit and related features on the landscape. This is addressed in my linear models, where inclusion of fine-scale environmental variables reduces biases related to spatial autocorrelation by explaining the data's spatial structure (Diniz-Filho et al., 2003). Future explorations on the structure of a cultural landscape (e.g., Johnson & Hunn, 2010) compared to a random model would lend insight to the degree and style of modification.

One major limitation of my study was the inability to include grazers and their effects on vegetation in analyses of landscape change. Shifts in management directly affect the population of grazers, particularly ungulates, which indirectly cascades to the plant community upon which they forage (Painter et al., 2018). In the Canadian Mountain Parks, changes to hunting, fire, and human use have altered elk-aspen herbivory, leading to changes in landscape vegetation structure (White, 2001). At a nearby montane grassland on Stoney Nakoda traditional territory, Ya Ha Tinda *('Mountain Prairie')*, elk populations have declined over 70% from estimated population carrying capacity (Hebblewhite et al., 2018). Ya Ha Tinda has been an important ungulate hunting ground for over 9,000 years (Ronaghan, 1993), and the front ranges of the Rocky Mountains have sustained both hunters and populations of bison, elk, sheep, and deer for over 10,000 years (Reeves, 1974). The Stoney Nations carry ecological knowledge surrounding sustainable hunting practices (Snow, 1977) and have stewarded productive grazing areas for elk and bison herds for generations (Allan, 2015).

As part of Canada's strategy to settle the prairie provinces, bison were extirpated from the plains in the late 1870s (Daschuk, 2013). Bighorn sheep were historically abundant in the North Saskatchewan River Valley, but were over-hunted to approximately one-quarter of their population by 1915, and then underwent demographic oscillations due to harvest and disease (Stelfox, 1971). Due to fire suppression efforts leading to grassland encroachment, bighorn sheep forage habitat has decreased in the Rocky Mountains (Schirokauer, 1996). The Stoney Nations also had horses in the valley for at least two centuries, most of which were exterminated by Alberta Government officials in the 1950s (Larner, 1972). Taken together, colonial wildlife management practices, paired with landscape alteration, have resulted in fundamental changes to the ecology of grazing in the Rocky Mountain Eastern slopes. At the landscape scale, future research could include ungulate grazing models in restoration, and monitor grazer responses to traditional burning practices.

A future direction for research on Indigenous burning practices could continue to document its effects on the landscape, though these are already well understood by Indigenous knowledge holders, and deepen collaborative work with First Nations on fire restoration. Western Science can work in support of Indigenous conservation goals by providing tools to assist in the restoration of Indigenous burning practices and the development of a sovereign fire management program (Nikolakis et al., 2020). For example, fire ecologists have worked with the Karuk and Yurok Peoples to assess cultural targets of fire restoration, such as enhancement of basket weaving resources (Marks-Block et al., 2021). Experimental Indigenous fire stewardship research and modelling can be valuable to inform the restoration of historically stewarded species such as beargrass (Hart-Fredeluces et al., 2021).

Fire restoration faces contemporary threats such as climate change, species invasion, and landscape change. In the Wapta Mnûṯẖa valley, mitigating the spread of invasive species is essential in future fire restoration planning. Specifically, invasive plants along the valley's roadside such as *Melilotus spp.* and *Bromus inermis* thrive in recently burned areas (Spellman et al., 2014), and new fire-cleared areas could provide an opportunity for these plants to invade the grasslands and the Ecological Reserve. Other barriers to the restoration of Indigenous burning practices in the Bighorn area include a high fuel load which increases fire severity risk (Alberta Forestry Division, 2005). Along with other changes such as a warmer climate, increased fuel loads and invasive species create a system that is fundamentally different from that which was originally maintained by Indigenous burning, which will require innovative solutions to restore traditional landscape stewardship. For example, modelling of 'Indigenous Cultural Ecosystem Services' (e.g., plant harvesting) under future climate conditions provides Indigenous managers with tools for climate adaptation tailored to Indigenous goals (Mucioki et al., 2021).

Contributions

At my initial meeting with Stoney Consultation Officer and Knowledge Holder Barry Wesley in the first semester of my MSc, we discussed shared goals of this project. Along with conservation, a priority was to increase recognition of the Stoney Nakoda's relationship to the land, as their stories and knowledge are often overshadowed by colonial narratives. In writing this thesis, I have attempted to include Stoney Nakoda history, knowledge and relationships to highlight their relevance to the ecological findings in this study. While I have 'documented' changes to the grasslands, this knowledge is not new: Stoney Knowledge Holders are intimately familiar with changes to their lands and understand the many interconnected drivers of change (e.g., Stoney Members to Canada Energy Regulator, 2020). Instead, I hope that this work, undertaken in the quantitative framework of Western Science, could serve as a useful tool to compliment Indigenous knowledge in service of future Stoney conservation goals.

Undoubtedly, the valley holds high conservation value. Of all the Bighorn Area, the North Saskatchewan River valley received the highest Riparian Climate-Corridor Index score (a measure of a riparian area's ability to provide cooler and more humid microclimate refugia), making it an important candidate for climate change adaptation planning (Weaver, 2017). In 2018, the surrounding slopes of the North Saskatchewan watershed were proposed to be protected as Bighorn Wildland Provincial Park (Alberta Environment and Parks, 2018), however the park designation lost government support due to political changes in 2019. The Bighorn provides key ecosystem services such as freshwater for the city of Edmonton, climate regulation, and nature-based recreation (Mitchell et al., 2021). The Bighorn remains a priority region for Central Rocky Mountain habitat protection by the Yellowstone to Yukon Conservation Initiative (y2y.net), and will likely be subject to new land use planning in the coming decade, to which I hope my research will be of use.

More importantly, the Wapta Mnûṯẖa valley is one of the last intact biocultural sites of the Stoney Nations. The Stoney Nations hold a sacred relationship with the montane grasslands (Snow, 1977), where community members hold ceremony on ancestral sites (Elder Rod Hunter to Canada Energy Regulator, 2020). Amidst threats of colonial dispossession, members of the Stoney Nation lived in the grasslands to honor the legacy of their families (John Abraham, as cited in Larner, 1972). Land-based cultural experiences provide opportunities for Stoney youth to learn from their Elders (Snow, 1977), and traditional harvest forms an essential part of Stoney livelihoods (Stoney Members to Canada Energy Regulator, 2020). To Chief John Snow, the shining mountains at dawn are a reassurance that future generations will walk the same paths as their ancestors (Snow, 1977).

Finally, I hope to bridge the distance between academia and community by creating accessible forms of my results. This spring, I will create products for community use, such as posters, plain-language synopsis, presentations, and potential interpretive panels in the valley. Barry Wesley and I have received a community conservation grant from Y2Y, with which we hope to create educational and artistic paneling throughout the valley. These panels will include Stoney history of the territory, ecological knowledge, and Stoney place names. With the grant, we hope to engage youth in learning, Stoney stewardship, and gaining experience with community-led conservation initiatives.

Conclusions

My thesis provides an example of ecological shifts that occur following colonial dispossession of Indigenous lands and the continued exclusion of Indigenous Peoples and their stewardship practices. In a Stoney Nakoda montane valley, thousands of years of management expertise has been replaced, and the once-stewarded grasslands have been encroached by shrub and forest. Grassland area now covers only one quarter of its previous extent, with losses of small grass patches throughout the valley. Land previously covered by a diversity of forbs and graminoids is now dominated by woody shrubs, and medicine plants such as *Pezi* sage are less abundant. Importantly, the ecological impacts of colonialism concern Stoney Nakoda members, as cultural land-based resources are becoming scarce. My work highlights an urgent need for collaborative management structures in the Kootenay Plains Ecological Reserve, wherein the Stoney Nakoda Nations hold decision-making roles over the restoration of their traditional lands.

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Appendix 1: The Kootenay Plains Landscape

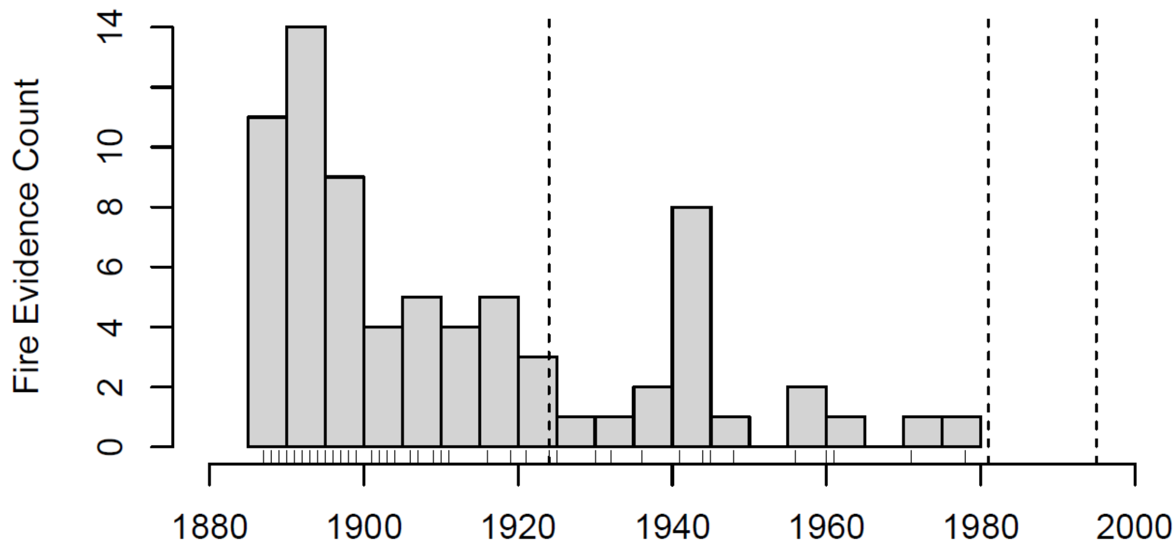

Figure 8: Histogram of fire evidence data (scars and rebound) in the upper North Saskatchewan River valley surrounding the study site. Data collected in 1997 by (M.-P. Rogeau, 1999), n= 255 trees. Dotted lines indicate historic data: 1924 photography, 1981 and 1995 vegetation surveys. Data show a decrease in fire frequency over the course of the 20th century.

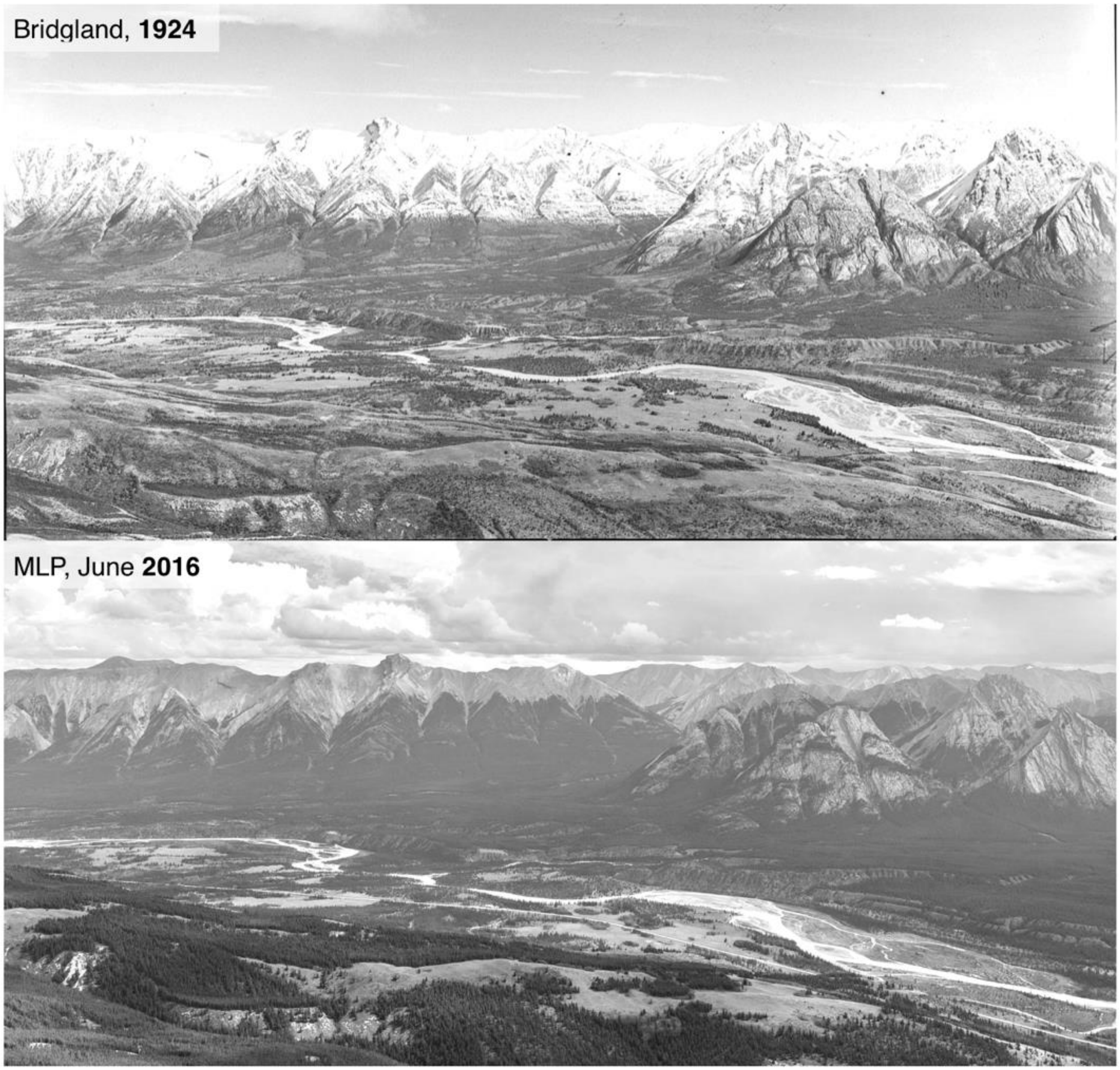

Figure 9: Mountain Legacy Project. [online] Photo pairings at station 355 overlooking the Wapta Mnûṯẖa valley accessed 03/11/2019 at explore.mountainlegacy.ca.

Figure 10: An example of shrubification of a montane grassland. Here, sparse trees begin to populate an open area and groundcover is dominated by woody shrubs such as bearberry, creeping juniper, and wolf willow. Photo taken at plot 19, August 2020.

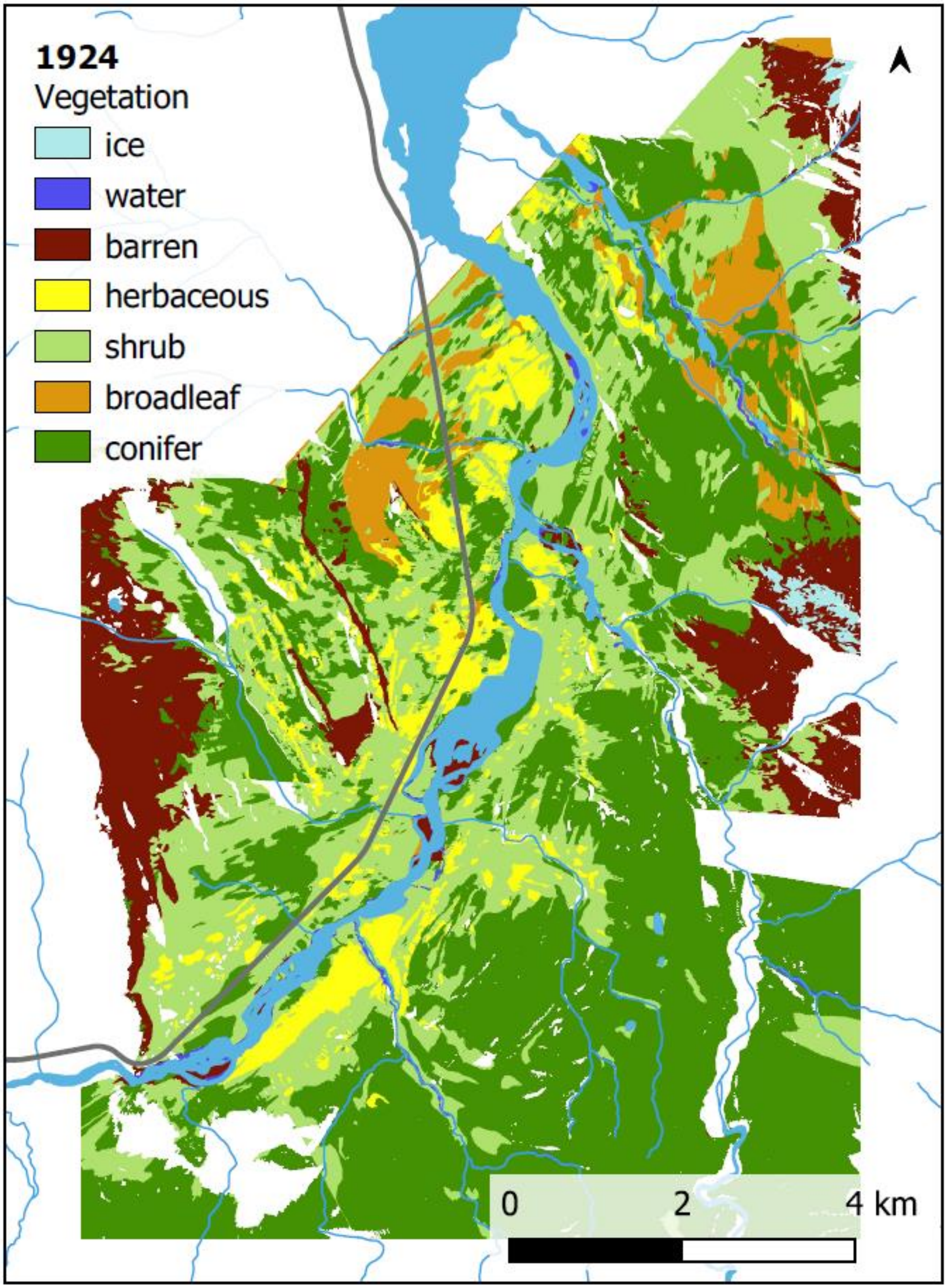

Figure 11: Vegetation cover in the study viewshed in 1924, as derived from historic imagery

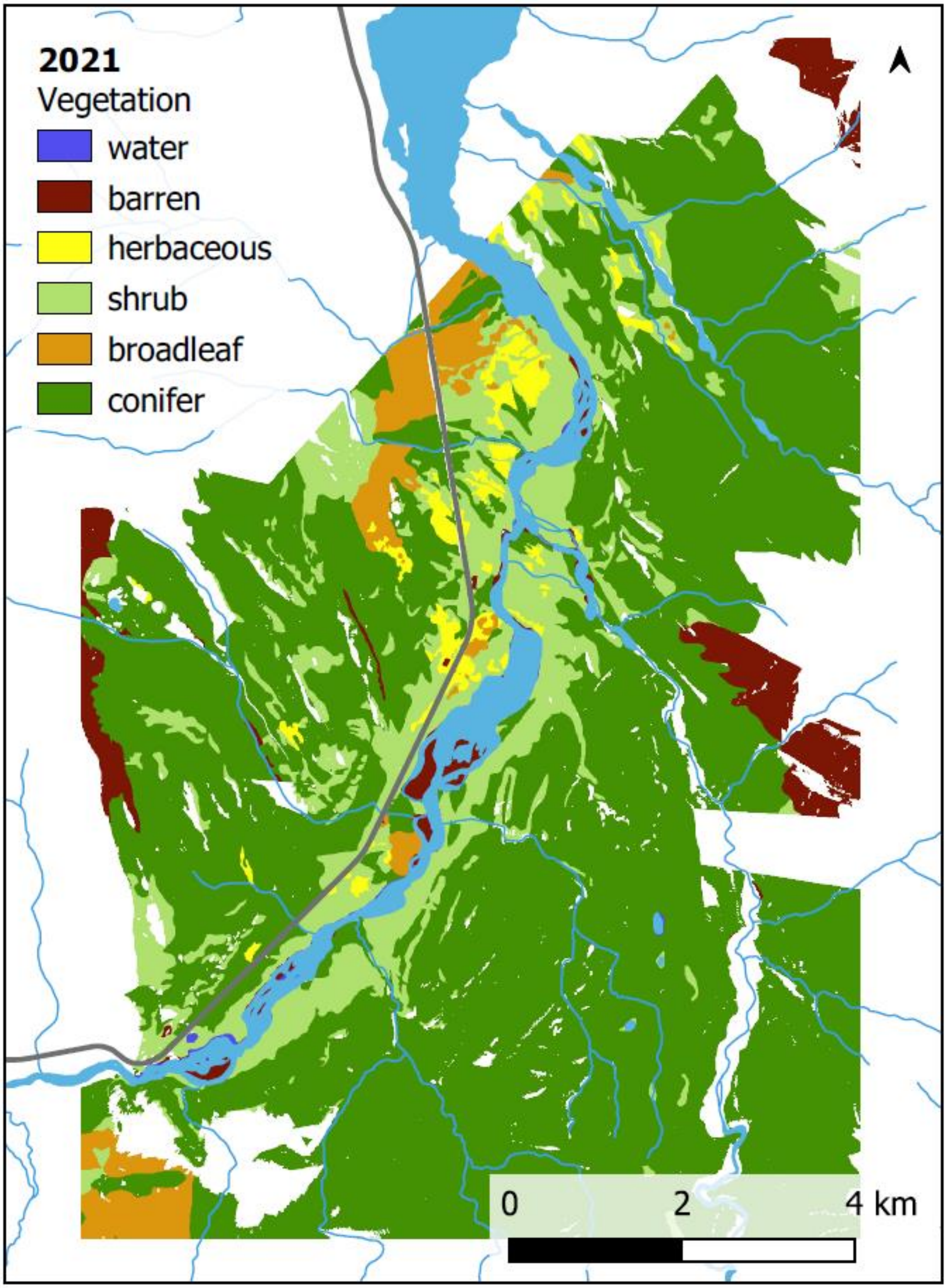

Figure 12: Vegetation cover in the study viewshed in 2021, as derived from satellite imagery

Appendix 2: Vegetation Plots

Table 5: Culturally important forbs to the Stoney Nations, as per Scott-Brown 1977

Latin	English	Stoney Nakoda
Campanula alaskana	Harebell	*Nâbeopostabin*
Chamaenerion angustifolium	Fireweed	*Charhnorhâ*
Achillea millefolium	Yarrow	*Pore okporhnibin*
Allium cernuum	Nodding onion	*Sijamnâmnân*
Anticlea elegans	Mountain deathcamas	*Sijamnâmnân tâga watawawan*
Artemisia frigida	Fringed sagebrush	*Pezi mnathkathka*
Fragaria virginiana	Virginia strawberry	*Châdeden*
Gaillardia aristata	Common gaillardia	*Wathithin*
Galium boreale	Northern bedstraw	
Geum triflorum	Prairie smoke	*Châkahu snaya îgen*
Hedysarum alpinum	Alpine sweet-vetch	*Mâkuthkiya*
Lilium philadelphicum	Wood lily	*Warchah*
Pyrola asarifolia	Bog wintergreen	*Chab nûrenen*

Table 6: Association vectors of site-level vegetation class in the non-metric multidimensional scaling ordination.

	NMDS1	**NMDS2**	R^2	p
Graminoids	-0.90159	0.43258	0.2979	< 0.001
Forbs	-0.46873	0.88334	0.4395	< 0.001
Shrubs	0.79710	-0.60384	0.1775	< 0.001
Trees	0.97869	0.20536	0.4774	< 0.001

Table 7: Species codes used in 2020 vegetation resurvey. Some species names or groupings have changed since 1996 and 1981 surveys; previous names are indicated in this table where applicable.

Species Code	Latin	Common Name	1996	1981
ABIELAS	*Abies lasiocarpa*	Subalpine fir		
ABUTTHE	*Abutilon theophrasti*	Velvetleaf		
ACHIMIL	*Achillea millefolium*	Yarrow		
AGOSGLA	*Agoseris glauca*	pale agroseris		
ALLICER	*Allium cernuum*	nodding onion		
AMELALM	*Amelanchier alnifolia*	saskatoon berry		
ANDRCHA	*Androsace chamaejasme*	rock jasmine		
ANDRSEP	*Androsace septentrionalis*	northern fairy candelabra		
ANEMCYL	*Anemone cylindrica*	Cylindrical thimbleweed		
ANEMMUL	*Anemone multifida*	cutleaf anemone		
ANEMPAR	*Anemone parviflora*	small-flowered anemone		
ANETGRA	*Anethum graveolens*	Dill		
ANTEALP	*Antennaria alpina*	Alpine pussytoes		
ANTELAN	*Antennaria lanata*	white margined pussytoes		
ANTEPAR	*Antennaria parvifolia*	Small-leaf pussytoes	*Antennaria aprica*	*Antennaria nitida*
ANTHODO	*Anthoxanthum odoratum*	sweet vernalgrass		*Hierochle odorata*
ANTIELE	*Anticlea elegans*	mountain deathcamas	*Zigadenus elegans*	*?*
AQUIBRE	*Aquilegia brevistyla*	Blue columbine		
ARABHIR	*Arabis hirsuta*	Hairy rockcress		
ARCEAME	*Arceuthobium americanum*	lodgepole pine dwarf misteltoe		
ARCTUVA	*Arctostaphylos uva-ursi*	Bearberry		
ARNICOR	*Arnica cordifolia*	Heart-leaf arnica		
ARTECAM	*Artemisia campestris*	Field wormwood		
ARTECAN	*Artemisia cana*	Silver sagebrush		
ARTEDRA	*Artemisia dracunculus*	Tarragon		
ARTEFRI	*Artemisia frigida*	Fringed sagebrush		
ASTEALP	*Aster alpinus*	Alpine Aster		
ASTRALP	*Astragalus alpinus*	Alpine milkvetch		
ASTRAUS	*Astragalus australis*	Indian milkvetch		*Astragalus aboriginum*
ASTRLAX	*Astragalus laxmannii var robustior*	Ascending milkvetch	*Astragalus striatus*	*Astragalus striatus*
ASTRMIS	*Astragalus missouriensis*	Missouri milkvetch	*Astragalus missouriensis*	*Astragalus agrestis (very similar sp)*
BETUOCC	*Betula occidentalis*	Western birch		
BOECDIV	*Boechera divaricarpa*	Spreading rockcress	*Arabis divaricapa*	*Arabis divaricapa*

BOTRLUN	*Botrychium lunaria*	common moonwort		*Botrychium lunaria*
BROMINE	*Bromus inermis*	Smooth brome		*Bromus inermis pumpellianus*
CALAPUR	*Calamagrostis purpurascens*	Purple reedgrass		
CALASTR	*Calamagrostis stricta*	slim-stem small reedgrass		
CALYBUL	*Calypso bulbosa*	fairy-slipper		
CAMPALA	*Campanula alaskana*	Harebell	*Campanula rotundifolia*	
CAREEBU	*Carex eburnea*	Ebony sedge		*Carex filifolia (very similar sp)*
CARERIC	*Carex richardsonii*	Richardson's sedge		
CARESCI	*Carex scirpoidea*	Bulrush sedge		
CARESIM	*Carex simpliciuscula*	Simple Kobresia	*Kobresia simpliciuscula*	
CARESTE	*Carex stenophylla*	Low sedge		*Carex eleocharis*
CASTLUT	*Castilleja lutescens*	Stiff yellow paintbrush		
CASTMIN	*Castilleja miniata*	Giant Red paintbrush		
CERAARV	*Cerastium arvense*	Field chickweed		
CHAMANG	*Chamaenerion angustifolium*	Fireweed	*Epilobium angustifolium*	
CHENALB	*Chenopodium album*	Common lamb's-quarters		
COELVIR	*Coeloglossum viride*	Bracted Green orchid		
COMAUMB	*Comandra umbellata*	Bastard Toadflax		*Comandra umbellata pallida*
CORATRI	*Corallorhiza trifida*	yellow coralroot		
CREPELE	*Crepis elegans*	elegant hawk's-beard		*Crepis runcinata (very similar sp)*
CYPRPAS	*Cypripedium passerinum*	Sparrow's-egg Ladyslipper		
DASIFRU	*Dasiphora fruticosa*	shrubby cinquefoil	*Potentilla fruticosa*	
DICRSCO	*Dicranum scoparium*	Broom moss		
DRYADRU	*Dryas drummondii*	Yellow mountain avens		
ELAECOM	*Elaeagnus commutata*	Wolf willow		
ELYMALA	*Elymus alaskanus*	broad-glumed wheatgrass	*Agropyron violaceum*	
ELYMINN	*Elymus innovatus*	Hairy wild rye		
ELYMLAN	*Elymus lanceolatus*	thickspike wildrye	*Agropyron dasystachyum*	*Agropyron dasystachyum*
ELYMSMI	*Elymus smithii*	western wheatgrass	*Agropyron smithii*	*Agropyron smithii*
ELYMTRA	*Elymus trachycaulus*	slender wheatgrass	*Agropyron trachycaulum*	*Agropyron subsecundus*
ELYMVIR	*Elymus virginicus*	Virginia wild rye		
EQUIARV	*Equisetum arvense*	field horsetail		
ERIGCAE	*Erigeron caespitosus*	Caespitose fleabane		
ERIGGLA	*Erigeron glabellus*	Smooth fleabane		
ERYSASP	*Erysimum asperum*	Prairie-rocket wallflower		*Erysimum inconspicuum (v similar species)*

EURYCON	*Eurybia conspicua*	Showy aster	*Aster conspicuus*	
EURYSIB	*Eurybia sibirica*	Siberian Aster	*Aster sibiricus*	*Aster sibiricus*
FESTSAX	*Festuca saximontana*	Mountain fescue		
FRAGVIR	*Fragaria virginiana*	Virginia strawberry		
GAILARI	*Gaillardia aristata*	Common gaillardia		
GALEROT	*Galearis rotundifolia*	round-leaved orchid	*Orchis rotundifolia*	
GALIAPA	*Galium aparine*	Catchweed bedstraw		
GALIBOR	*Galium boreale*	Northern bedstraw		
GALITRI	*Galium triflorum*	Fragrant bedstraw		
GENTAMA	*Gentinella amarella*	Autumn gentian		
GEOCLIV	*Geocaulon lividum*	Northern comandra		
GEUMTRI	*Geum triflorum*	Prairie smoke		
GOODREP	*Goodyera repens*	Lesser rattlesnake plantain		
HEDYALP	*Hedysarum alpinum*	Alpine sweet-vetch		
HEDYBOR	*Hedysarum boreale*	Boreal sweet-vetch		
HELIHOO	*Helictochloa hookeri*	Hooker's oatgrass		
HETEVIL	*Heterotheca villosa*	Hairy Goldenaster		
HYLOSPL	*Hylocomium splendens*	Stairstep moss		
JUNCBAL	*Juncus balticus*	Baltic rush		
JUNICOM	*Juniperus communis*	Common juniper		
JUNIHOR	*Juniperus horizontalis*	Creeping juniper		
JUNISCO	*Juniperus scopulorum*	Rocky mountain juniper		
KOELMAC	*Koeleria macrantha*	Prairie junegrass		*Koelaria cristata*
LILIPHI	*Lilium philadelphicum*	Wood lily		
LINNBOR	*Linnaea borealis*	Twinflower		
LINULEW	*Linum lewisii*	Lewis flax		
LONIDIO	*Lonicera diocia*	twinning honeysuckle		
MAIASTE	*Maianthemum stellatum*	Starry false solomon's-seal	*Smilacina stellata*	*Smilacina stellata*
MARCPOL	*Marchantia polymorpha*	common liverwort		
MEDISAT	*Medicago sativa*	Alfalfa		
MELIOFF	*Melilotus officinalis*	yellow sweetclover		
MERTPAN	*Mertensia paniculata*	Tall bluebell		
MONEUNI	*Moneses uniflora*	one-flowered wintergreen		
MUHLRIC	*Muhlenbergia richardsonis*	Mat muhly		
MULGPUL	*Mulgedium pulchellum*	Blue lettuce		*Lactua pulchella*
ORTHCHR	*Orthothecium chryseum*	Golden Erect-Capsule moss		
ORTHLUT	*Orthocarpus luteus*	yellow owl's clover		
ORTHSEC	*Orthilia secunda*	one-sided wintergreen		
OXYTCAM	*Oxytropis campestris*	Field locoweed		*Oxytropis campestris*

OXYTSER	*Oxytropis sericea*	silky locoweed		
OXYTSPL	*Oxytropis splendens*	showy locoweed		
PACKCAN	*Packera cana*	Woolly groundsel	*Senecio canus*	*Senecio canus*
PACKPAU	*Packera paupercula*	balsam ragwort	*Senecio pauperculus*	
PACKSTR	*Packera streptanthifolia*	rocky mountain goundsel	*Sececio streptanthifolius*	*Senecio cymbalarioides*
PARNPAL	*Parnassia palustris*	marsh grass-of-parnassus		
PHYSDID	*Physaria didymocarpa*	double bladderpod		
PICEGLA	*Picea glauca*	White spruce		
PICEMAR	*Picea mariana*	black spruce		
PILOTRI	*Pilosella tristis*	woolly hawkweed	*Hieracium (triste?)*	
PINGVUL	*Pingula vulgaris*	common butterwort		
PINUCON	*Pinus contorta*	Lodgepole pine		
PINUFLE	*Pinus flexis*	Limber Pine		
PLANERI	*Plantago eriopoda*	Saline plantain		
PLEUSCH	*Pleurozium schreberi*	Red-stemmed feather moss		
POACUSI	*Poa cusickii epilis*	Skyline bluegrass		
POAPRAT	*Poa pratensis*	Kentucky Bluegrass		
POLYJUN	*Polytrichum juniperinum*	Juniper haircap moss		
POPUBAL	*Populus balsamifera*	Balsam poplar		
POPUTRE	*Populus tremuloides*	Trembling aspen		
POTEGRA	*Potentilla gracilis*	Slender cinquefoil		*Potentilla gracilis*
POTEPEN	*Potentilla pensylvanica*	Prairie cinquefoil		
PROSTRA	*Prosartes trachycarpa*	Rough fruited fairy bells	*Disporum trachycarpum*	
PTILCRI	*Ptilium crista-castrensis*	ostrich-plume moss		
PUCCNUT	*Puccinellia nuttalliana*	Nuttall's alkaligrass		*Puccinellia nuttalliana*
PULSNUT	*Pulsatilla nuttalliana*	Prairie pasqueflower		*Anemone patens*
PYROASA	*Pyrola asarifolia*	bog wintergreen		
PYROCHL	*Pyrola chlorantha*	green-flowered wintergreen		
PYRRUNI	*Pyrrocoma uniflora*	one-flowered goldenweed		*Haplopappus uniflorus*
RANUCAR	*Ranunculus cardiophyllus*	Heart-leaved buttercup		
RHODGRO	*Rhododendron groenlandicum*	labrador tea	*Ledum groenlandicum*	
RHYTROB	*Rhytidiopsis robusta*	pipe cleaner moss		
RIBEOXY	*Ribes oxyacanthoides*	canadian gooseberry		
ROSAACI	*Rosa acicularis*	prickly wild rose		
ROSAWOO	*Rosa woodsii*	Wood's rose		
SALIBEB	*Salix bebbiana*	Bebb's willow		
SALIGLA	*Salix glauca*	Grey willow		
SALIMAC	*Salix maccalliana*	McCalla's willow		

SALIMYR	*Salix myrtillifolia*	Myrtle-leaf willow		
SALIPET	*Salix petrophila*	Rocky mountain willow		
SHEPCAN	*Shepherdia canadensis*	Buffaloberry		
SILEDRU	*Silene drummondii*	Drummond's catchfly		*Lychnis drummondii*
SISYMON	*Sisyrinchium montanum*	Strict blue-eyed grass		
SOLISPA	*Solidago spaulata*	coast goldenrod		*Solidago decumbens*
SPIRBET	*Spiraea betulifolia*	white spirea		
STELLON	*Stellaria longipes*	Long-stalked starwort		
STIPRIC	*Stipa richardsonii*	needlegrass		
SYMPCIL	*Symphyotrichum ciliolatum*	Lindley's Aster	*Aster ciliolatus*	
SYMPERI	*Symphyotrichum ericoides*	White heath aster	*Aster ericoides*	
SYNTRUR	*Syntrichia ruralis*	Star moss		
TARAOFF	*Taraxacum officinale*	common dandilion		
THALVEN	*Thalictrum venulosum*	Veiny meadow-rue		
TRIAGLU	*Triantha glutinosa*	sticky false asphodel	*Tofieldia glutinosa*	
TRIFHYB	*Trifolium hybridum*	Alsike clover		
VACCVIT	*Vaccinium vitis-idaea*	ligonberry		
VICIAME	*Vicia americana*	wild vetch		
VIOLADU	*Viola adunca*	Early blue violet		
ZIZIAPT	*Zizia aptera*	heart-leaved alexanders		