



# Ronald Lake Wood Bison Research Program: 2020 Annual Report

December 1, 2020

Lindsey T. Dewart<sup>1,2</sup>, Lee J. Hecker<sup>1,2</sup>, Darren M. Epperson<sup>1,2</sup>,  
Garrett Rawleigh<sup>1,2</sup>, Aidan H.C. Sheppard<sup>1</sup>, Scott E. Nielsen<sup>1</sup>,  
and Mark A. Edwards<sup>1,2</sup>

<sup>1</sup>University of Alberta, Department of Renewable Resources

<sup>2</sup>Royal Alberta Museum, Department of Mammalogy



ROYAL ALBERTA  
MUSEUM



UNIVERSITY OF  
ALBERTA



APPLIED  
CONSERVATION  
ECOLOGY LAB

## Table of Contents

<b>Executive summary</b> .....	<b>2</b>
<b>Background</b> .....	<b>4</b>
<b>Research progress</b> .....	<b>7</b>
Knowledge Gap 2a – What is the relationship between wetland characteristics and bison forage? .....	7
Knowledge Gap 2a & 4c – How are wetlands used by bison in the winter? .....	9
Knowledge Gaps 2a, 2b, & 2c - How are different habitats used by bison within their range? .....	12
Knowledge Gaps 3c & 3e – What is the herd’s diet and how does it change seasonally? .....	15
Knowledge Gaps 4a, 4b, & 5a – How do anthropogenic and natural disturbances affect habitat selection? .....	22
Knowledge gap 4c - Monitoring snow dynamics within the RLBH.....	26
Knowledge gap 4c - How do winter conditions influence bison movement and habitat selection? .....	29
Knowledge Gap 4c & 8e – Where and when are the RLBH at risk of predation by wolves? ..	33
<b>Conclusions</b> .....	<b>38</b>
<b>Acknowledgements</b> .....	<b>39</b>
<b>Literature cited</b> .....	<b>40</b>

### *Suggested citation:*

Dewart, L.T., Hecker, L.J. Epperson, D.M., Rawleigh, G., Sheppard, A.H.C., Nielsen, S.E. & Edwards, M.A. 2020. Ronald Lake Wood Bison Research Program: 2020 Annual Report. Report to the Ronald Lake Bison Herd Science Technical Team, December 1, 2020. University of Alberta, Edmonton, Alberta, Canada T6G 2H1, 43 pp.

For any questions, please contact the Principal Investigators of Dr. Scott Nielsen ([scottn@ualberta.ca](mailto:scottn@ualberta.ca)) and Dr. Mark Edwards ([Mark.Edwards@gov.ab.ca](mailto:Mark.Edwards@gov.ab.ca)).

*Cover photo credits to Lindsey Dewart (top) and Darren Epperson (bottom)*

## Executive summary

The Ronald Lake wood bison (*Bison bison athabasca*) herd (RLBH) is located at the northern extent of the Alberta oilsands region in the northeastern corner of the province. This herd holds cultural and ecological significance and has been of management concern for the past decade, with proposals to expand the Alberta oilsands northward to the bison herd's home range. The RLBH Technical Team was formed to ensure long-term herd sustainability by identifying ecological research needs to make informed management decisions. The team consists of appointed representatives from industrial companies, local First Nations and Métis communities, as well as provincial and federal government agencies. To fulfill their mandate, the team identified a series of knowledge gaps (Table 1) associated with the herd that are crucial to understanding their ecology, and partnered with the University of Alberta and the Royal Alberta Museum to fill those knowledge gaps. This report provides updates on research activities that have occurred since April 2020 and upcoming research plans for the winter season of 2021 on a subset of the identified knowledge gaps provided below:

- 2a – *How are wetlands used by bison in the winter?*
- 2a, 2b, & 2c – *How are different habitats used by bison within their range?*
- 3c & 3e – *What is the herd's diet and how does it change seasonally?*
- 4a, 4b, & 5a – *How do anthropogenic and natural disturbances affect habitat selection?*
- 4c – *How do winter conditions influence bison movement and habitat selection?*
- 4c & 8e – *Where and when are the RLBH at risk of predation by wolves?*

Our investigations into these knowledge gaps have and will continue to provide important insights regarding the RLBH. Our assessment of winter wetland forage sites revealed that bison foraged more intensively on sedges (e.g., *Carex atherodes*, *C. utriculata*, *C. aquatilis*) than grasses or woody plants, further clarifying their winter food preferences. The examination into seasonal changes in diet revealed a significantly more diverse and higher quality diet in spring and summer compared to winter. During preliminary investigations into the herd's habitat selection, we found that bison preferred open habitats with significantly less coarse woody debris (>2-cm diameter), shrubs and saplings in the spring and summer. We also assessed temperature and snow-depth as possible mechanisms for changes in bison movement rates during winter. This assessment showed that increases in snow depth caused decreases in bison movement rates while warmer temperatures corresponded with an increase in movement rates. Our analysis of wolf (*Canis lupus*) diets revealed bison presence in the diet of two out of three monitored wolf packs during late winter (i.e., March and April). However, winter diets across all wolf packs

consisted mostly of white-tailed deer (*Odocoileus virginianus*) and moose (*Alces alces*), while summer wolf diets were dominated by beaver (*Castor canadensis*).

We were able to accomplish data collection in the field during the spring and summer season of 2020 by adhering to University of Alberta COVID-19 restrictions drawn from Alberta Health Services and through communication with representatives of the Fort McKay community. Field work is planned to continue into the 2021 winter season to collect additional data to assess how different wetlands are selected by bison (knowledge gap 2a) and differential habitat used by bison relative to other large mammal species within the RLBH's range (knowledge gaps 2b and 4c). Field data collection for the other knowledge gaps addressed above (3c, 3e, 4a, 4b, 4c, 5a and 8e) have been completed, but analysis of bison and wolf diets and the effects of anthropogenic disturbances on habitat selection continues. The proposed field work for the upcoming winter 2021 season is conditional on the COVID-19 safety regulations put forth by the University of Alberta in accordance with the Alberta Health Services protocols.

## Background

The Ronald Lake bison herd (RLBH) is a small (< 200 individuals) population of wood bison (*Bison bison athabasca*) located in northeastern Alberta, Canada (Ball et al. 2016). The herd's range lies on the southeast border of Wood Buffalo National Park (WBNP), extends southward into the northern portion of the oilsands region, and is bounded by the Athabasca River to the east and the Birch Mountains to the west (DeMars et al. 2016). Wood bison hold a *Threatened* status in Canada, largely due to plains bison genetic introgression posing a threat to their genetic differentiation, and potential exposure to diseases such as brucellosis and bovine-tuberculosis (Shury et al. 2015; Ball et al. 2016; AEP and ACA 2017). The RLBH holds an additional status of *Subject Animal* under Alberta's Wildlife Act. This status was assigned to the herd due to its small size, disease free status, and genetic differentiation among other herds in the region. The RLBH started to gain more attention following proposals for oil and gas development within the southern portion of the herd's range.

The RLBH Technical Team was formed in 2011, in response to these development proposals. The Technical Team seeks to identify research needed in order to make informed management decisions on the long-term sustainability of the herd. The team is comprised of representatives from local industry, First Nations and Métis communities, and provincial and federal government agencies who all work together to identify important knowledge gaps regarding the herd's ecology (Table 1). In 2013, University of Alberta and Royal Alberta Museum researchers were invited to investigate some of those knowledge gaps with data provided by Alberta Environment and Parks and funding largely provided through a Natural Sciences and Engineering Research Council Collaborative Research and Development (NSERC CRD) grant with matched support from Teck Resources Limited.

Between 2013 and 2019, Alberta Environment and Parks fit 63 bison (5 male, 58 female) with GPS radio-collars. The research team has used these location data to investigate seasonal/annual ranges, seasonal changes in habitat quality, bison movements, elements regulating the herd's range, mechanisms influencing habitat selection, and reactions to anthropogenic disturbances (see Tan et al. 2015; DeMars et al. 2015; DeMars et al. 2016; Belanger et al. 2017; Belanger et al. 2018; DeMars et al. 2019; Hecker et al. 2019a; Hecker et al. 2019b; Belanger et al. 2020; Hecker et al. 2020a). Notable conclusions from this work include:

1. The same annual range is used regularly with predictable, seasonal changes;
2. The use of habitats in the spring (western range) around the time of calving coincide with areas of higher quality forage when compared to the rest of their range;
3. A spring migration by females to their western range is through the use of two distinct corridors;
4. The region separating WBNP herds and the RLBH is dominated by avoided landcover (e.g., wet shrublands & tamarack swamps);
5. Habitats rich in graminoids (i.e., grasses, sedges) are strongly selected during winter;

6. Summer habitats with high forage biomass have less stable footing and more biting insects, creating possible trade-offs between forage and predation during this time;
7. Females avoided disturbances with industrial activity during winter (i.e., oil sands exploration and forestry), but not footprints lacking human activity, while males were unaffected by anthropogenic activity although few were collared; and
8. Movement rates are marginally faster on linear disturbances compared to other habitats suggesting use of these features for movements and thus possibly less value as forage.

This annual report summarizes the research conducted since April 2020, building upon what was reported in the 2020 semi-annual report (Hecker et al. 2020a). This report also discusses future research. Although further field data collection is planned for 2021, this is conditional on COVID-19 safety restrictions.

**Table 1:** Knowledge gaps identified by the Ronald Lake Bison Herd Technical Team that are updated from the last report, completed, or are ongoing as conducted by the University of Alberta and Royal Alberta Museum researchers. Timelines for each project associated with a knowledge gap are provided.

Theme	Gap #	Project	Status
Bison range	1A	Season & sex-specific ranges	Complete (future updates)
Bison range	1B	Northern extent (limits)	Complete
Bison range	1D	Migration routes	Complete (future updates)
Habitat - Landcover	2A	Wetlands	Update in this report
Habitat - Landcover	2B	Human disturbances (energy)	Update in this report
Habitat - Landcover	2C	Human disturbances (forestry)	Update in this report
Habitat - Landcover	2D	Natural disturbances (fire)	Complete (future updates)
Forage (bottom-up)	3A	Greenup/phenology	Ongoing
Forage (bottom-up)	3C	Forage quantity/quality	Update in this report
Forage (bottom-up)	3E	Anthropogenic changes	Update in this report
Habitat use	4A	Wallows & water	Update in this report
Habitat use	4B	Trade-offs (insects/ground)	Complete
Habitat use	4C	Winter snow	Update in this report
Habitat use	5A	Anthropogenic disturbances	Update in this report
Future Scenarios	6A/C	Habitat supply forecasts	Ongoing / future work
Popln ecol (top-down)	8E/4C	Wolf predation	Update in this report
Popln ecol (top-down)	8C/G	Cow-calf & age structure	Complete (future updates)

## Research progress

### Knowledge Gap 2a – What is the relationship between wetland characteristics and bison forage

**Lead investigator:** Garrett Rawleigh

#### *Research objectives*

The objective of this research is to understand the relationship between groundwater level, substrate type, and dominant graminoid species in wetlands given their importance to winter diets in bison. This research will lead to a better understanding of what environmental characteristics of wetlands lead to preferred forage for bison.

#### *Overview of research methods*

Hydrological monitoring stations were distributed across 24 wetlands of four wetland types, each with different dominant graminoid species. These included six *Carex atherodes*-dominated wetlands, six *C. aquatillis*-dominated wetlands, six *C. utriculata*-dominated wetlands, and six grass-dominated wetlands (Figure 1). Wetland strata were selected based on wood bison selection, seasonal access, and dominant vegetation identified from prior surveys. Bison diet preferences in the region have been previously studied, with *C. atherodes* being the most selected forage type (Larter and Gates 1991; Fortin et al. 2002; Jung 2015). Other sedges common to the RLBH range, including *C. aquatillis* and *C. utriculate*, are also preferred over grasses (Jung 2015). One hydrology monitoring station was established in each selected wetland by boring a hole (i.e., well) and inserting a 1.5-inch diameter, 20-inch long PVC pipe (Driver 2010). Within each of these wells, a data logger (HOBO U201; Onset 2018) was secured to measure water level. Each groundwater well was capped to stop precipitation and debris from entering the well. One additional data logger was deployed at ground level in the center of the RLBH's range to provide a constant measure of barometric pressure required for calculating changes in water depths. All data loggers took measurements every 4 hours to provide not only seasonal trends, but also measures of how water levels fluctuate throughout the day and how they are affected by rainfall events. To record rainfall, a single automated rainfall gauge was deployed centrally to the wetland gauges. Rainfall data will be related to wetland water level data to understand how rainfall affects wetlands (Driver 2010). The rainfall gauge is calibrated to record the date and time of rainfall events, along with the volume of rain experienced in the study area.

Characteristics of each wetland were collected at each data logger location. A substrate core was collected and used to measure pH and classify the substrate as either organic or mineral (Kenkel 1987; Timoney 2008). A 12-m transect running parallel to wetland edge and centered on the data

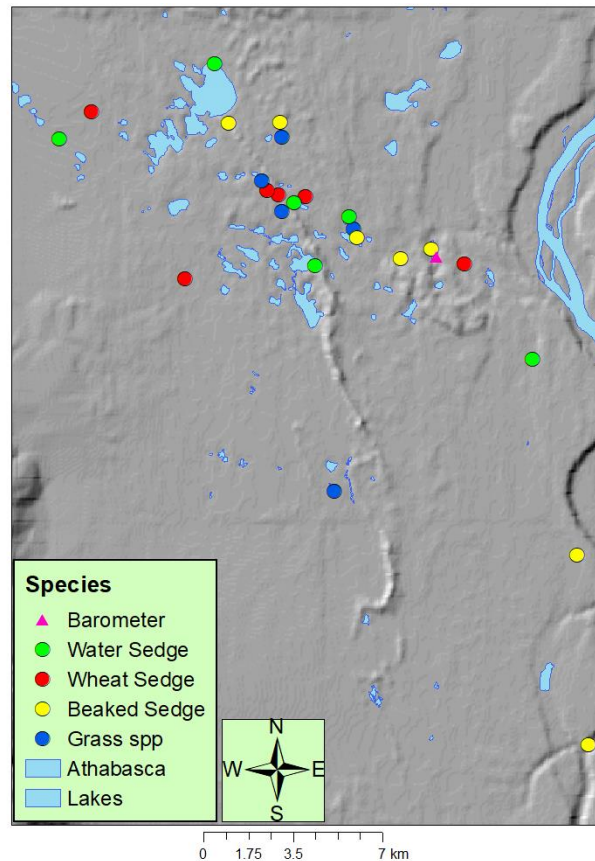
logger was used to collect data on vegetation. Specifically, we clipped vegetation, to the water surface level, within four 0.25 m<sup>2</sup> quadrats placed at the 0-m, 4-m, 8-m, 12-m marks on the transect and measured sward height. We separated vegetation samples by species, dried them for 24 hours at 60 °C, and weighed each to obtain a measure of dry biomass (University of Idaho 2009).

### ***Progress / preliminary results***

Data collected from this summer is still being inputted and analyzed in the laboratory.

### ***Outstanding / upcoming work***

In the summer and fall of 2021 we will retrieve the groundwater level loggers and take additional biomass and substrate samples. These data will be used to relate the environmental characteristics of wetlands to abundance/biomass of preferred forage.



**Figure 1:** Map of groundwater monitoring wells in wetlands stratified by dominant plant species, within the Ronald Lake bison herd's range. Dominant species of specifically interested included water sedge (*Carex aquatilis*), wheat sedge (*C. utriculate*), beaked sedge (*C. atherodes*), and grasses.

## **Knowledge Gap 2a & 4c – How are wetlands used by bison in the winter?**

**Lead investigator:** Garrett Rawleigh

### ***Research objectives***

The objective of this work was to understand what environmental factors in winter influence bison use of wetlands and the selection of forage within those wetlands. Winter in northern ecosystems is a period when wood bison rely almost exclusively on graminoid-dominated wetlands for sustenance due to a shortage of alternative forage (Jung 2015). Of the different cover types in the area, frozen wetlands have the highest available biomass and become more accessible to bison during winter resulting in their selection (Strong and Gates 2009). We aim to understand bison winter foraging by examining how snow conditions and vegetation type influence their foraging behaviour.

### ***Overview of research methods***

We visited winter clusters of bison locations provided by GPS-collars and searched for recent craters, which are areas where bison have pushed snow aside to access the forage beneath. These cluster sites were selected for their accessibility, and elapsed time since bison were present (i.e., less than seven day old). After locating craters, we measured a suite of environmental factors to examine how they influence foraging site selection by bison. These factors include snow characteristics (i.e., depth, density, crust hardness), crater size, distance to cover, area, dominant vegetation type, estimated percent cover, and foraging intensity. We measured snow depth to the nearest 0.5-cm beyond the crater edge in undisturbed snow. For large craters, we took the average of up to three snow depth measurements (Fortin 2005). Crater area was measured by walking the perimeter of the bison activity with a handheld GPS unit. We used a snow-metrics snowboard sampler to record the density of snow at each site at the same locations as depth measures. Snow crust characteristics were recorded as the presence or absence of a crust, and when present, hardness was measured using the hand-hardness test (Höller and Fromm 2010). Foraging intensity of each species present was assigned a numeric class on a scale of zero to four, with zero representing no foraging and four representing complete foraging to the ground level. Daily changes in snow depth are being measured using trail-cameras that take two pictures per day, of two to three snow gauges per camera (Figure 2). As a comparison, the same variables were measured at non-use sites located near each distinct crater.

### ***Progress / preliminary results***

In the winter of 2019-20, we collected data from 86 forage (used) sites and 86 non-used wetland sites between January and March of 2020. We are in the preliminary stages of analysis, but early

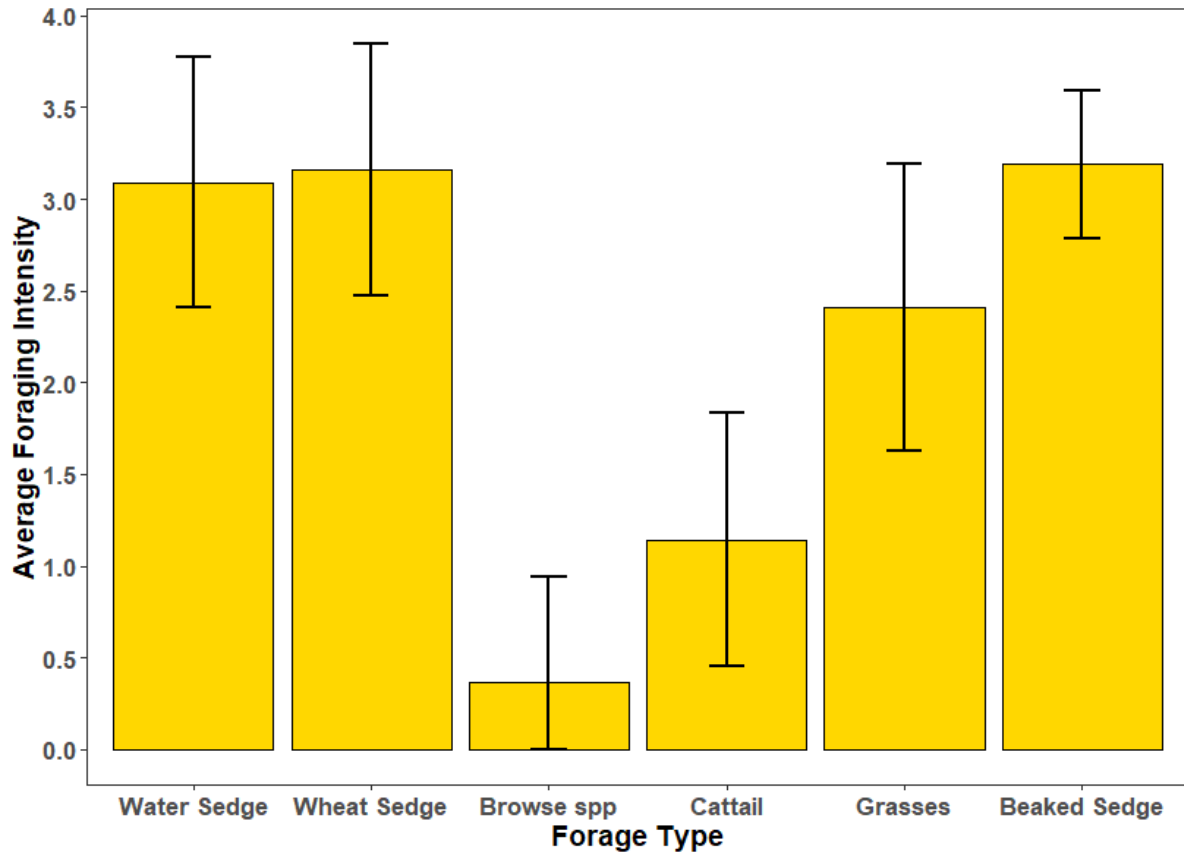
results support the general expectation that bison forage more intensely on sedges than other available graminoids (Figure 3). More specific relationships are forthcoming.

### ***Outstanding / upcoming work***

In the winter of 2020/2021, we will visit additional bison forage sites to increase sample sizes, increase the differences in winter conditions (e.g., snow depths), and further our understanding of bison winter foraging behaviour.



**Figure 2:** An example of a snow depth monitoring station in a meadow marsh. The yellow and white boards are our snow gauges, measuring snow depth to the nearest 5-centimeters.



**Figure 3:** Average winter foraging intensity of bison by species within wetlands. Species were assigned a numeric class to represent foraging intensity on a scale of zero to four, with zero representing no foraging and four representing complete foraging to the ground level. (Water sedge = *Carex aquatilis*, Wheat Sedge = *C. utriculata*, Beaked Sedge = *C. atherodes*).

## **Knowledge Gaps 2a, 2b, & 2c - How are different habitats used by bison within their range?**

**Lead investigator:** Darren Epperson

### ***Research objectives***

Our objective was to understand wildlife use of landcover types in the RLBH's range and in particular bison, but also how it relates to other large mammals. Wildlife use was monitored using animal scat surveys in permanent plots, a low-cost method for long-term monitoring changes in habitat use and relative abundance. These plot selections were independent of GPS collar locations and are non-biased regarding animals' herding behaviour (Alves et al. 2013).

### ***Overview of research methods***

In 2018, we established 17 permanent plots located in four different land cover types (i.e., marshes, upland deciduous, upland pine, and bogs) and two anthropogenic disturbance types (i.e., cutblock and seismic line) to monitor trends in bison and other large mammals (Hecker et al. 2019a). Two observers surveyed each plot, and counted and identified scat to species. Once the scat was recorded it was removed from the plot. Since detectability rates of scat differ between landcover types and seasons (Alves et al. 2013), we resurveyed each plot twice, with the second pass perpendicular to the first. Surveys were conducted in early October before full leaf fall to count summer use (May- October) and in early May to obtain winter counts (October – May). The counts were used to calculate relative habitat use of bison and overlapping use by other species.

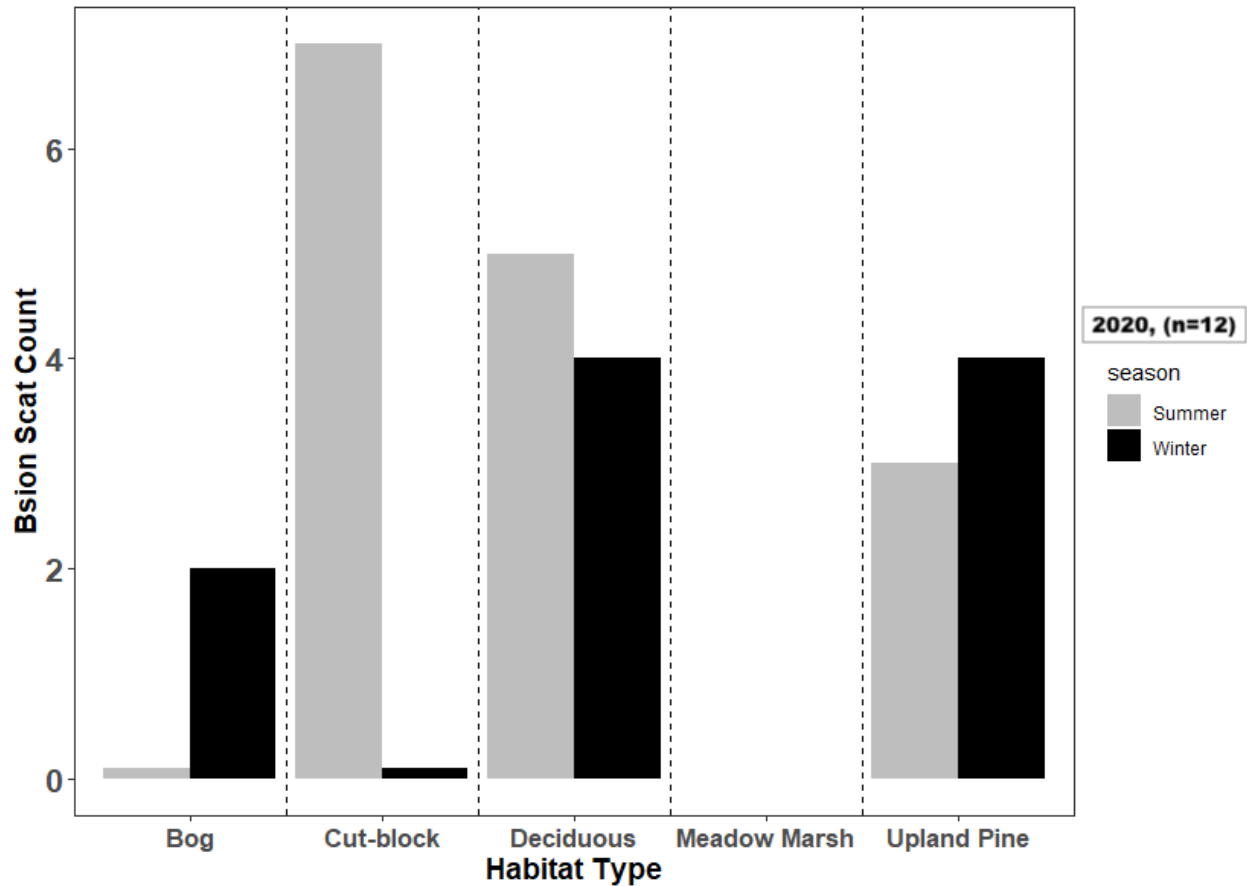
### ***Progress / preliminary results***

The 2019 – 2020 scat counts were disrupted by seasonal flooding. Consequently, plots established in marsh meadow habitats and on seismic lines were inaccessible and summer scat counts there were not completed. For the 12 available remaining plots, pine habitat was used most in winter and cut-blocks ( $n \leq 7$ ) in summer, with a null count for marsh meadows (Figure 4). Unfortunately, the 2019–2020 scat count data does not accurately represent habitat use, due to the inability to visit plots within all habitat types. Past surveys of the 17 plots demonstrated the dominant habitat use of marsh meadows by the RLBH ( $n \geq 30$ ) for winter and summer (Hecker et al 2019b).

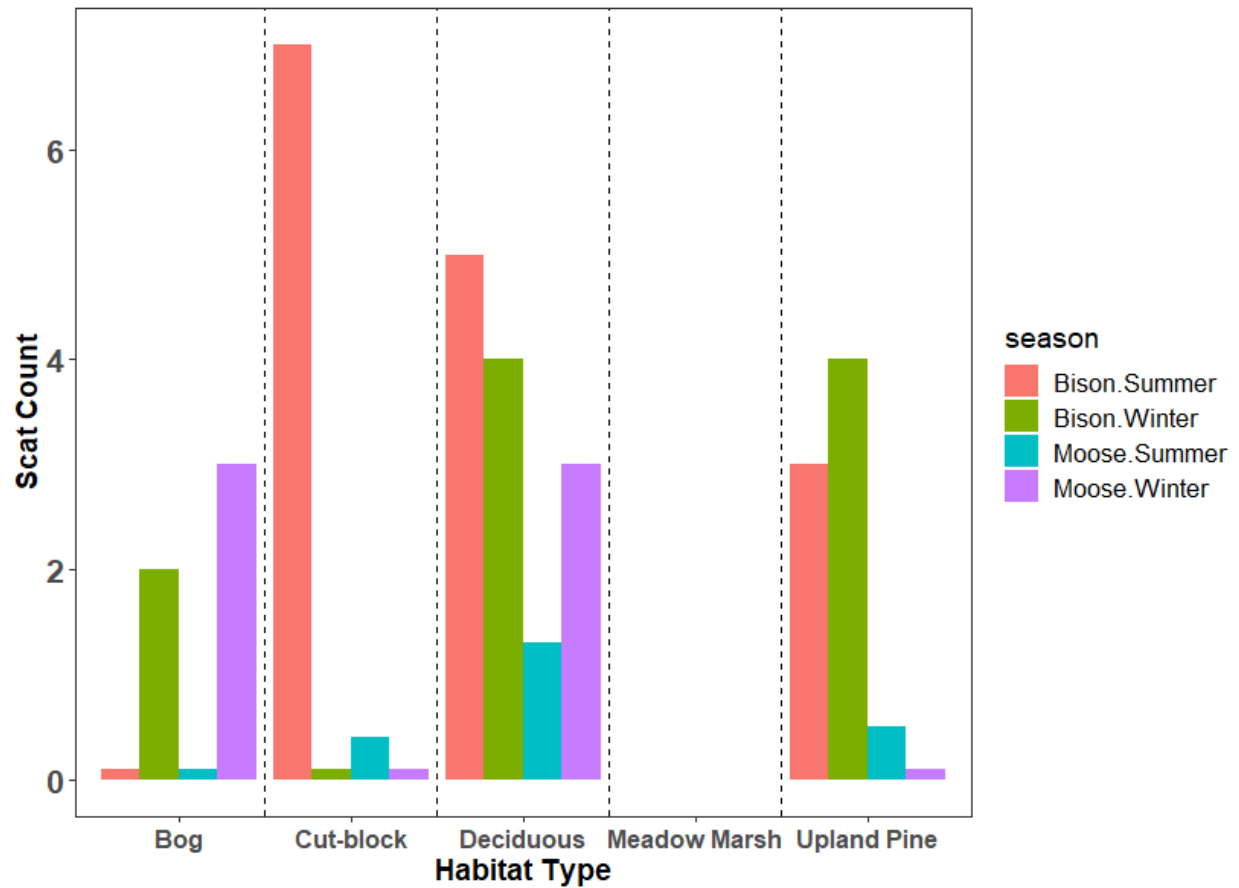
In addition to using GPS locations and scat surveys, our plot-based scat monitoring record use of habitats relative to other species. Using bison GPS locations and recent scat surveys, we found that bison and moose (*Alces alces*) substantially overlapped in their use of pine forest, deciduous forest, marsh meadow, cutblock, and bog habitats (Figure 5).

### *Outstanding / upcoming work*

Our plot-based scat surveys are designed to be a long-term study on changes in relative abundance of bison and co-occurring mammals and their interannual changes in habitat use. We plan to conduct our annual spring and fall surveys for the 17 long-term plots in May and October of 2021, respectively. Results will be reported in the 2021 annual report.



**Figure 4:** Winter and summer bison scat counts within 500-m<sup>2</sup> (50 × 10-m) plots for four landcover/disturbance types. Note that plots located in meadow marshes (2020) are null due to access issues resulting from excessive flooding during the summer of 2020.



**Figure 5:** Winter and summer 2018-2019 scat counts reveal species overlap in habitat use. Note that the 2019-2020 results do not display the use of marshes due to access issues as a result of excessive flooding in the summer of 2020.

## **Knowledge Gaps 3c & 3e – What is the herd’s diet and how does it change seasonally?**

**Lead investigator:** Lee Hecker

### ***Research objectives***

Our objective was to determine the composition of the RLBH’s diet and determine how it changes seasonally. We will also assess whether or not seasonal changes in diet composition result in corresponding changes in diet quality. We previously completed a review of the literature on American bison (*Bison bison*) diets that showed a significant positive correlation between latitude and amount of browse items, lipids, and proteins in bison diets (Hecker et al. 2020b). Therefore, we hypothesize the RLBH’s diet will contain large amounts of forbs and browse items which are high in proteins and lipids to meet the high metabolic requirements associated with living in the boreal forest.

### ***Overview of research methods***

During our field studies in 2018 and 2019 we collected 129 fecal samples from known bison locations (GPS) to quantify diet content during three seasons, as defined by DeMars et al. (2015): winter (January – March; n = 46 samples), spring (May – June; n = 38 samples), and summer (July – August; n = 45). Within each season, we randomly selected and combined three to five scat samples to create 10 composite samples for each season. Composite samples were analyzed using DNA barcoding (eDNA) techniques for diet composition (Craine et al. 2015). This method of diet analysis reports the results as a count of the number of times a unique DNA sequence was found within a sample. Each unique DNA sequence identifies a plant species, or assemblage of plant species in a genus or family. In the latter case, we used data from our field observations of foraged plants at bison locations to select the plant species most likely consumed by bison to represent that DNA sequence (King and Schoenecker 2019). The eDNA method of diet analysis is interpreted as the plants that the animal is acquiring protein from, rather than dry matter intake, and are therefore potentially biased towards plants with a higher protein content (Jorns et al. 2019; Hecker et al. 2020b). However, studies that have compared eDNA techniques to classic diet analysis methods, like micro-histology which describes the percentage of microscopic plant fragments in the scat samples, reported consistent results between methods (King and Schoenecker 2019).

We have made some minor adjustments to our assessment of the RLBH’s diet composition since Hecker et al. (2020a). First, we removed coniferous plants (e.g., jack pine; *Pinus banksiana*) and lycopods (e.g., stiff clubmoss; *Spinulum annotinum*) from consideration of the bison’s diet. These plants were never observed as foraged in the field, are not reported in the literature, and can be toxic to bison (Müller-Schwarze 1991; Belanger et al. 2018, Hecker et al. 2020b). Therefore, we do not consider these plants as contributors to bison diet, and rather consider their

presence in scat samples to represent either sample contamination (i.e., scat samples resting on that material) or incidental ingestion. We also combined all sedge, grass, and moss species into family groups due to a lack of confidence in their identification to the species level. Lastly, we expanded our definition of graminoids from strictly plants in the Poaceae, Cyperaceae or Juncaceae families, to include graminoid-like plants such as giant bur-reed (*Sparganium eurycarpum*), which are ecologically more similar to wetland graminoids than upland forbs.

In the field, we also collected samples of the plants found in the RLBH's diet during the season they were eaten. In addition, we collected plants (e.g., wheat sedge, *Carex atherodes*) that were frequently observed to be foraged at bison locations (Belanger et al. 2018), but that did not appear in eDNA analyses, to account for the biases associated with using this method of diet analysis. We clipped plants in a fashion that mimics the ways bison were observed foraging on the same species to ensure we collected the same plants parts (Shrestha et al. 2020). The collected plant samples were then analyzed to quantify the nutritional components (e.g., protein, lipids, carbohydrates, etc.). We assessed seasonal changes in diet quality by applying a multidimensional approach, known as nutritional geometry (Machovski-Capuska et al. 2016), to characterize the RLBH's realized macronutrient niche during the seasons of winter, spring, and summer.

### ***Progress / preliminary results***

We found a total of 134 unique DNA sequences in the fecal samples from the RLBH. In winter, 49.5% of the protein in the RLBH's diet was acquired from browse items and 44.4% came from graminoids. Forbs and other forage items (e.g., mosses and horsetails; *Equisetum* spp.) contributed 3.9% and 1.9% of the protein, respectively (Figure 6). Giant bur-reed, sedges (*Carex* spp.), low-bush cranberry (*Viburnum edule*), and red-osier dogwood (*Cornus sericea*) all contributed at least 10% of the protein in winter diets. During spring, 32.4% of the protein was obtained from browse items, 25.0% from graminoids, 12.6% from forbs, and 17.9% from other forage items (Figure 7). Sedges and bogmoss (*Sphagnum* spp.) contributed 19.0% and 11.4% of the protein to the spring diet, respectively. The RLBH's summer diet had 51.6% of its protein come from browse items, 0.5% from graminoids, 44.7% from forbs, and 1.5% from other forage items (Figure 8). Prickly rose (*Rosa acicularis*) and common fireweed (*Chamaenerion angustifolium*) were the primary single-species contributors of protein to the summer diet at 37.1% and 20.7%, respectively.

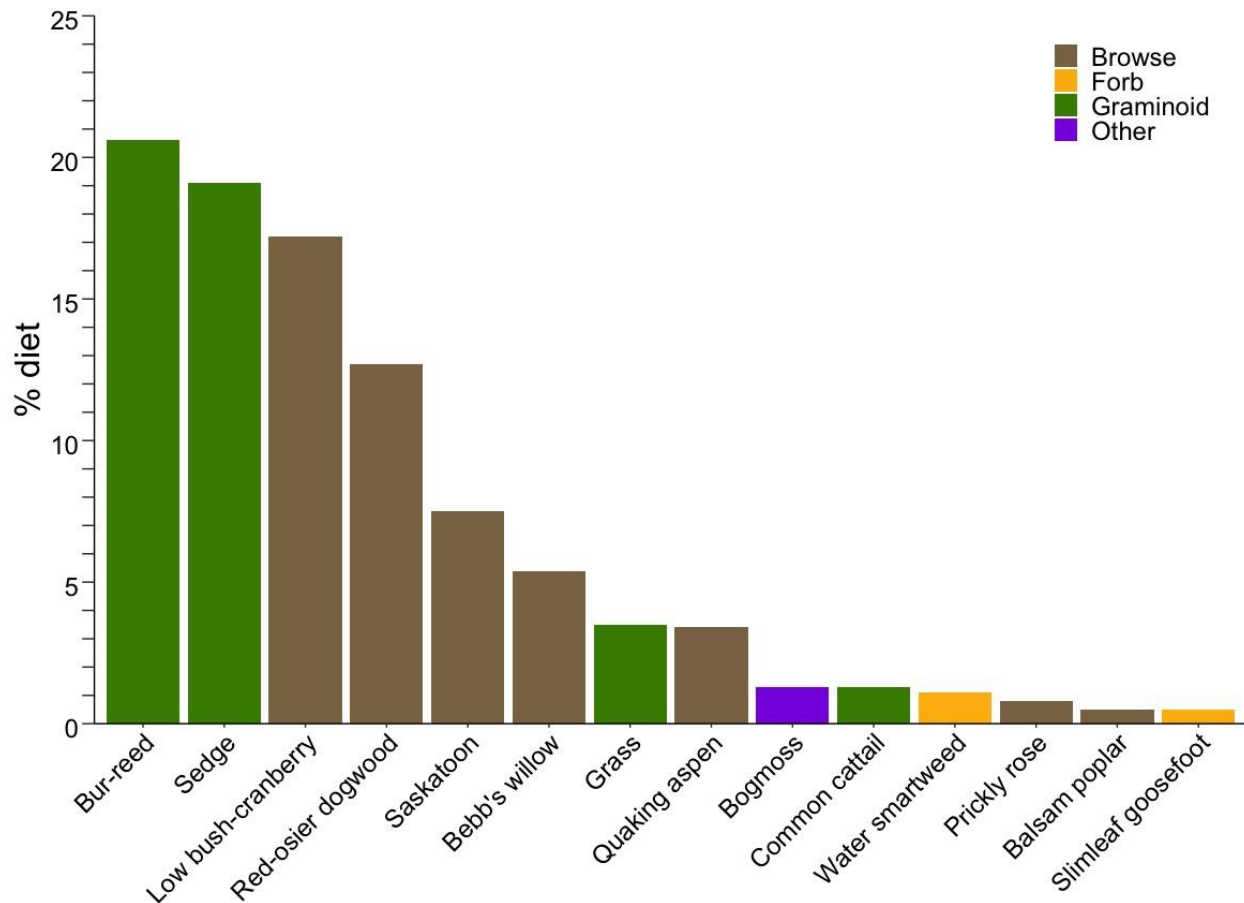
We analyzed the quality of 26 species of plants that accounted for at least 1% of the DNA sequence read counts, or were frequently observed to be foraged in the field. We were able to determine that the mean winter diet of the RLBH is composed of 82.5% (SD = 5.6) carbohydrates, 9.0% (SD = 5.2) lipids, and 8.4% (SD = 3.0) proteins. The digestible energy from macronutrients in mean spring diets were derived from 70.3% (SD = 6.8) carbohydrates, 11.4% (SD = 4.9%) lipids, and 18.3% (SD = 4.1) proteins. Mean digestible energy in macronutrients in

the summer diets was 71.6% (SD = 5.7) carbohydrates, 12.7% (SD = 5.0) lipids, and 15.7% (SD = 2.6) proteins. The higher quantities of lipids and proteins found in the spring and summer diets, compared to the winter diet, is an indication the diet of the RLBH is a higher quality during spring and summer compared to winter.

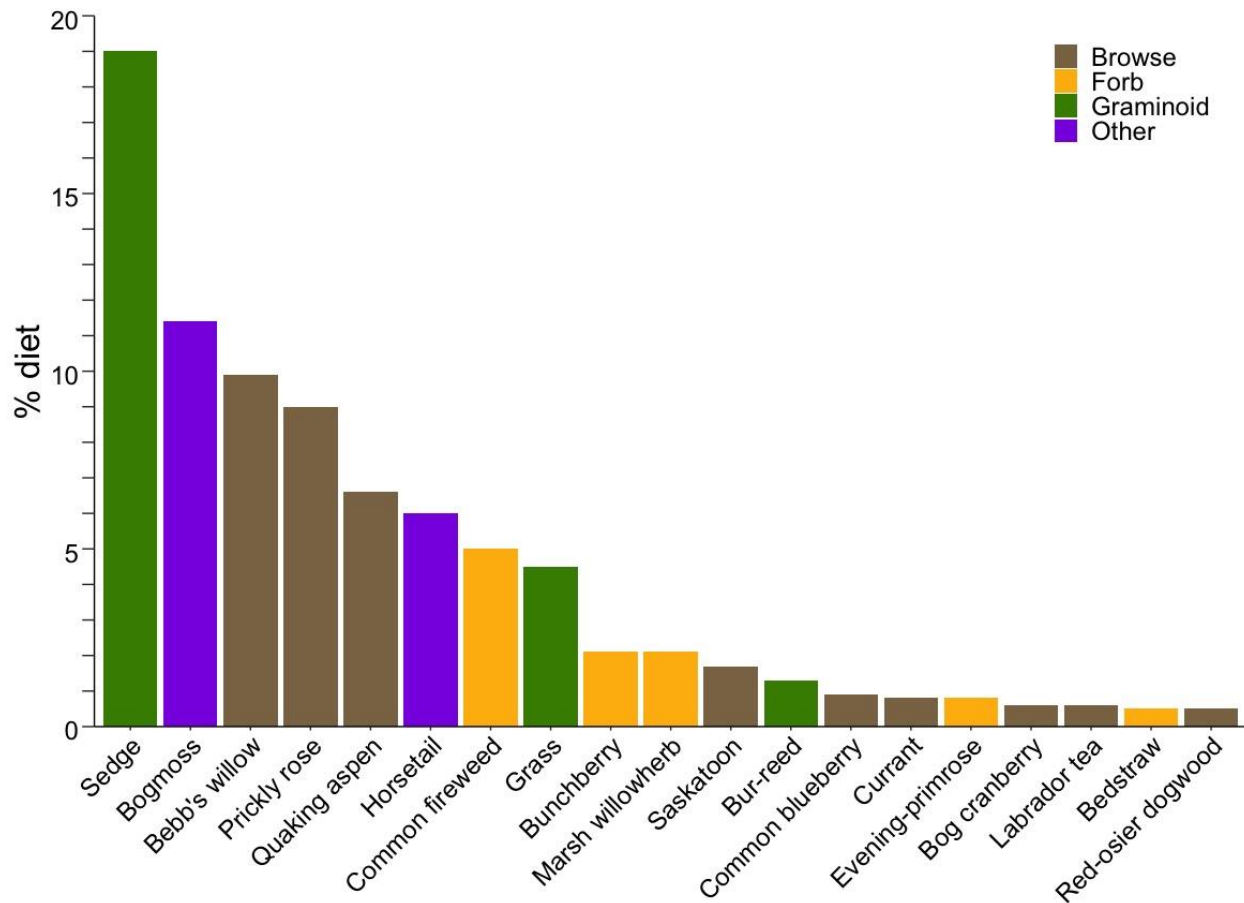
The RLBH had the greatest diversity of foods in their diet during the spring season with 19 unique DNA sequence accounting for at least 1% of the DNA sequences read. Summer and winter seasons had similar numbers of unique DNA sequences with 15 and 14, respectively. The diversity of unique plants in the seasonal diets corresponded with a greater diversity in the macronutrients acquired during the spring season. The breadth of the spring realized macronutrient niche for the RLBH was 1.5 times greater than winter and 2.5 times greater than summer (Figure 9).

### ***Outstanding / upcoming work***

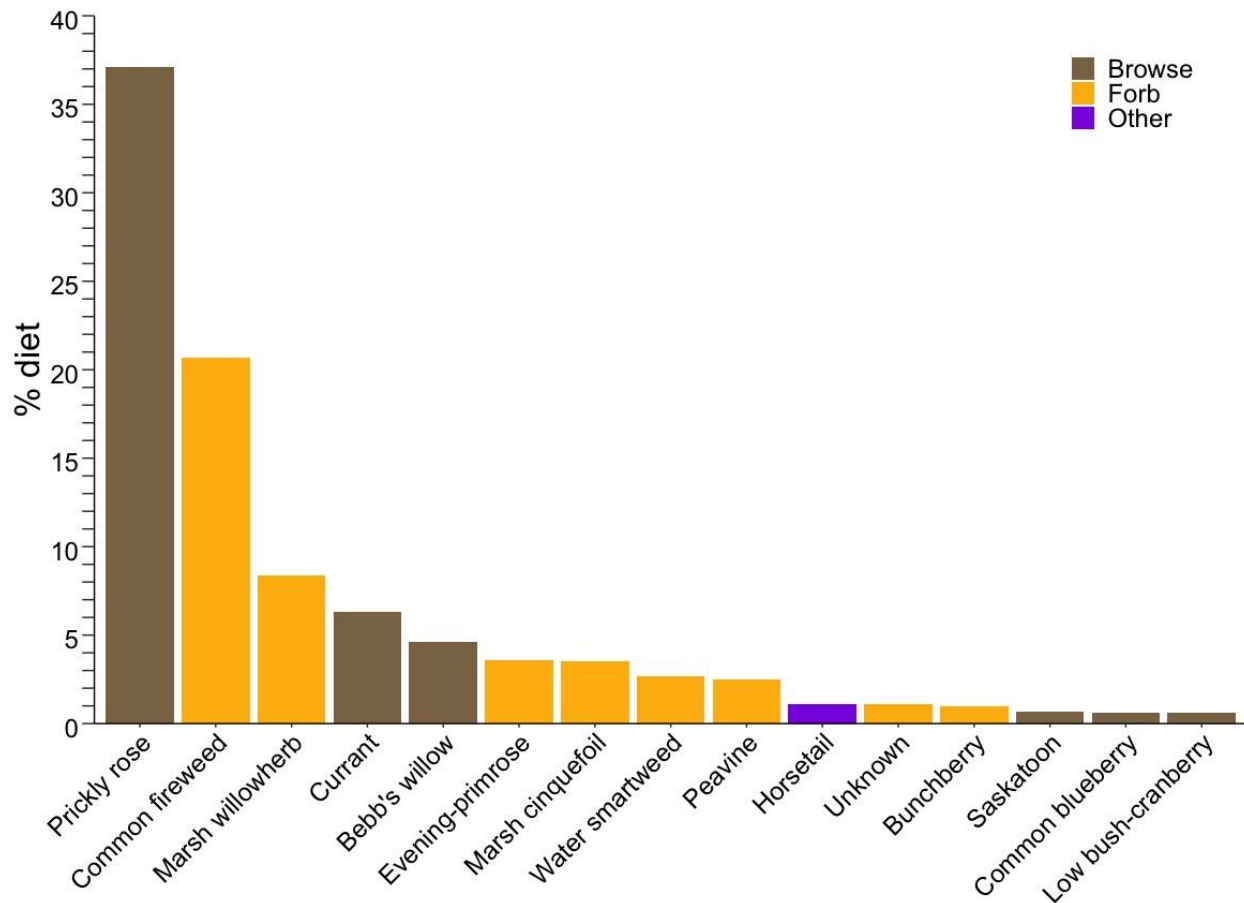
We consider this the conclusion of our investigation into the RLBH's diet content and quality and note that a complementary analysis of macronutrients in the diets of bison in North America was completed by us prior to this work (Hecker et al. 2020b) to provide context of where the diets of RLBH belongs relative to other populations. Future researchers should consider quantifying the fall (i.e., September - October) and early winter (i.e., November - December) diets for the herd as we did not explore these seasons and the literature is sparse on American bison diets in general for these times (Hecker et al. 2020b). Further, future researchers should consider exploring the potential regulatory effects of tannins in the RLBH's diet given the large quantities of browse items we found.



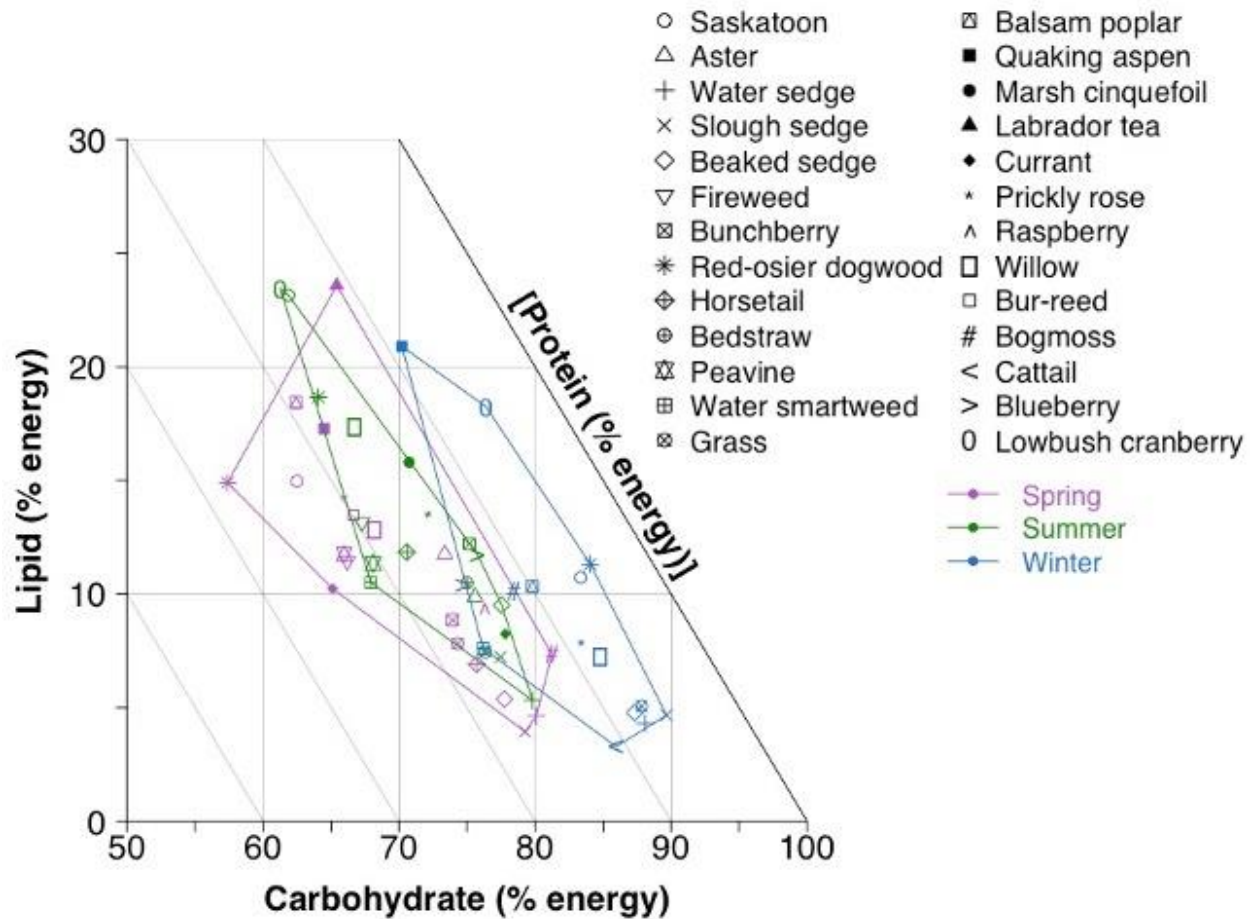
**Figure 6:** Winter diets of the Ronald Lake wood bison herd as analyzed using DNA barcoding (eDNA) techniques. The percent (%) diet is a measure of the number of times each DNA sequence is read divided by the total number of DNA sequences. Only plants that had DNA sequences contributing at least 1% of the diet are included in this figure. Browse items are woody plants, forbs are herbaceous plants, graminoids are grasses and sedges, and other is a category of miscellaneous plants including mosses, and horsetails.



**Figure 7:** Spring diets of the Ronald Lake wood bison herd as analyzed using DNA barcoding (eDNA) techniques. The percent (%) diet is a measure of the number of times each DNA sequence is read divided by the total number of DNA sequences. Only plants that had DNA sequences contributing at least 1% of the diet are included in this figure. Browse items are woody plants, forbs are herbaceous plants, graminoids are grasses and sedges, and other is a category of miscellaneous plants including mosses, and horsetails.



**Figure 8:** Summer diets of the Ronald Lake wood bison herd as analyzed using DNA barcoding (eDNA) techniques. The percent (%) diet is a measure of the number of times each DNA sequence is read divided by the total number of DNA sequences. Only plants that had DNA sequences contributing at least 1% of the diet are included in this figure. Browse items are woody plants, forbs are herbaceous plants, graminoids are grasses and sedges, and other is a category of miscellaneous plants including mosses, and horsetails.



**Figure 9:** Right-angled mixture triangle of the macronutrient (carbohydrates, lipids, and proteins) that account for the metabolizable energy in the Ronald Lake wood bison herd's diet. Convex hull polygons were generated around the plants species found in each season to represent the seasonal realized macronutrient niche for the herd; an estimate of the nutrient space the herd occupies each season.

## **Knowledge Gaps 4a, 4b, & 5a – How do anthropogenic and natural disturbances affect habitat selection?**

**Lead investigator:** Lee Hecker

### ***Research objectives***

Our objective was to understand the influence of forage quality and quantity and physical features on RLBH habitat selection and behavioural use of habitats, to address the knowledge gaps related to ecological drivers of habitat use. In particular, we were interested in assessing how disturbances from activities related to resource extraction (i.e., seismic lines, well-pads, and cutblocks) and wildfires change these aspects of habitat, and how the RLBH use them. Bison have been shown to select habitats that contain relatively high amounts of their favoured forages (Fortin 2002). We therefore hypothesize that bison will select disturbed habitats when there is an associated increase in the biomass of their preferred forages.

### ***Overview of research methods***

We used third-order resource selection functions (RSFs) to assess habitat selection by the RLBH within their home range (Johnson 1980). In the field, we surveyed bison (i.e., use) locations within 14 days of bison use and randomly generated, available locations. During these surveys, we recorded signs of bison behaviour (e.g., foraging, wallowing), time since most recent burn, burn intensity, distance to water (lentic and lotic), distance to graminoid rich landcover, canopy cover, ground firmness (substrate type + soil moisture), slope, aspect, tree density, shrub/sapling density, coarse woody debris (CWD; >2.5-cm) density, dominant graminoid species (where applicable), and percent cover of sedges, grasses, forbs, browse, bare soil, rock, moss, lichen, CWD, fine litter (<2.5-cm), and open water. By comparing these habitat characteristics between bison use and available locations we can ascertain their habitat preferences.

Logistic regression was used to analyze potential differences between bison use and available locations. Preliminary analyses reported here focus on habitat selection across all landcover groups and disturbance types (Hecker et al. 2019b) and for the three following seasons defined by DeMars et al (2015): spring (i.e., date of snow-melt to date first female enters calving area), summer (i.e., date first female leaves calving area until vegetation has senesced), and growing season (spring and summer). We compared models using Akaike Information Criteria (AIC) to select the model that was most parsimonious (i.e., lowest AIC) for each season. Models within two AIC values of each other were considered to be equally parsimonious (Burnham and Anderson 2002).

### ***Progress / preliminary results***

During the growing seasons (i.e., spring and summer) of 2018 – 2020 we surveyed a total of 480 bison and available locations (Table 2; Figure 10). This included 229 surveys during the spring season (107 bison and 122 available) and 251 surveys during the summer season (122 bison and 129 available).

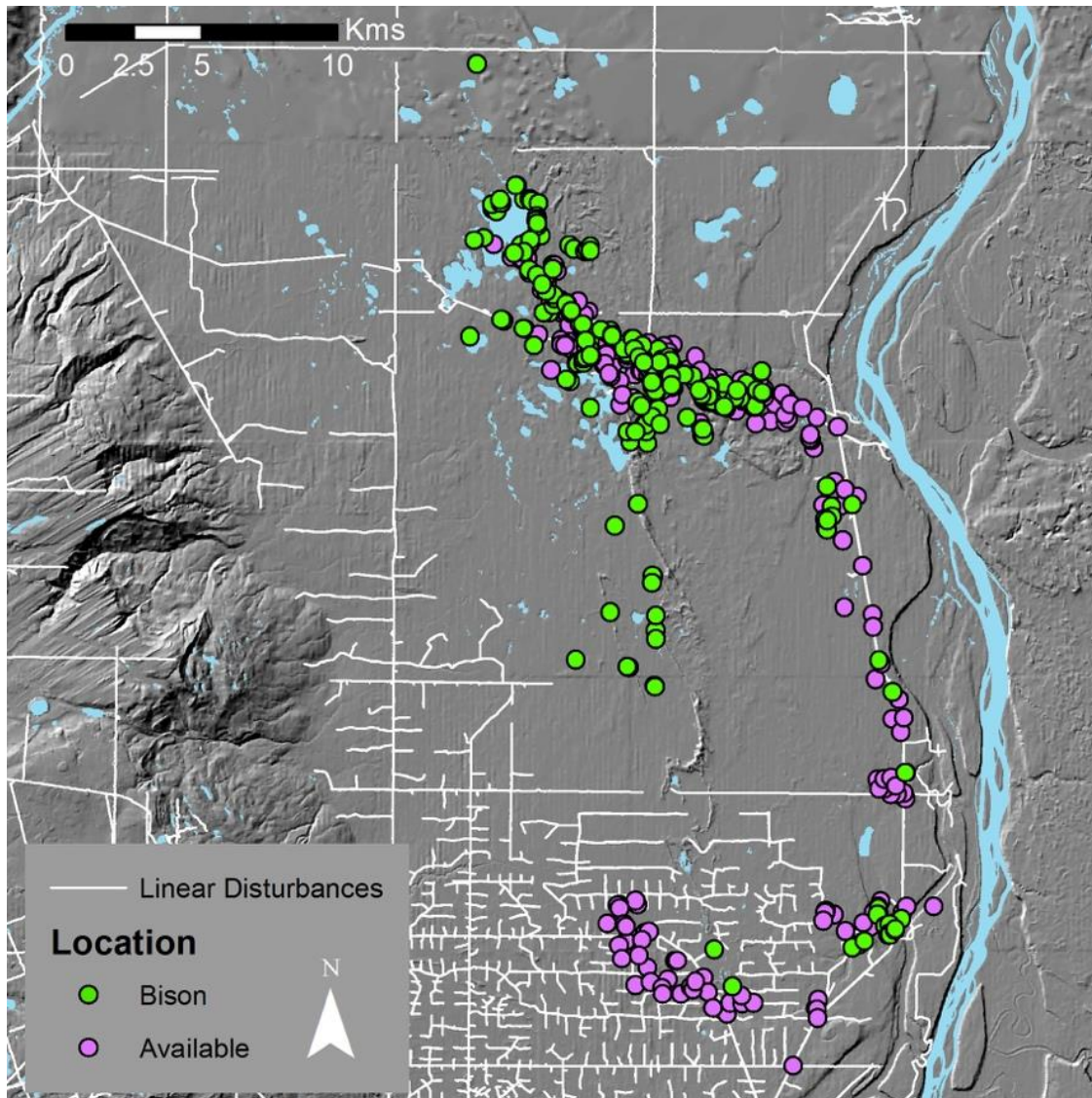
The two most parsimonious models for the entire growing season indicated significant avoidance of CWD density ( $p < 0.001$ ) and shrub/sapling density ( $p < 0.001$ ) by the RLBH (Table 3). These two models were equally supported ( $\Delta AIC < 2$ ) and together accounted for 97.2% of AIC weight (Table 3). Tree density was also included in these models, but did not have a significant effect ( $p = 0.601$ ) on habitat selection. Spring habitat selection models had similar results with the three most parsimonious models having AIC differences less than two and accounted for 90.8% of the weight in their AIC table. However, these models only indicated significant avoidance of shrub/sapling density ( $p < 0.001$ ; Table 3). Coarse woody debris density was avoided by bison ( $p < 0.010$ ), while tree density did not have a significant effect ( $p = 0.625$ ). In the summer, we found the two most parsimonious models for habitat selection were within two AIC values of each other and accounted for 63.5% of the weight in their AIC table (Table 3). These models showed a significant avoidance of areas with high CWD density ( $p < 0.001$ ), but no significant relationship with shrub/sapling density ( $p = 0.181$ ) and bison use.

### ***Outstanding / upcoming work***

Fieldwork related to addressing these knowledge gaps is complete. We now shift our focus to determining the influences on habitat selection to within landcover groups and disturbances. For this we will use mixed-effects RSF models to control for differences in landcover groups and assess the influence of disturbances within these groups. We reduced the 30 Duck's Unlimited Enhanced Wetland Classification landcover classes into six landcover groups, based on bison habitat preference and available biomass of functional forage groups within each landcover type (Table 2; Hecker et al. 2019b). These forthcoming mixed-effects models will conclude our analysis of the RLBH's habitat selection. Given the clustering of random locations in the southern portion of the study area, Moran's I statistics will be calculated to quantify spatial autocorrelation in the data (Plant 2012). Some random locations may be removed if spatial autocorrelation is deemed to be an issue.

**Table 2:** Summary of sites surveyed in spring ( $n = 229$ ; top) and summer ( $n = 251$ ; bottom) from 2018 – 2020. Sites are broken down by the season, location type (i.e., bison/use or random/available), landcover group, and disturbance type (Hecker et al. 2019b).

<b>Spring</b>	<b>Bison locations</b>			<b>Available location</b>		
	Natural	Linear	Cutblock	Natural	Linear	Cutblock
Upland conifer	7	0	0	9	1	0
Upland deciduous	29	4	0	23	7	2
Upland pine	34	1	2	21	9	9
Graminoid rich	22	0	0	17	1	0
Shrubby	4	2	0	8	5	0
Avoided	2	0	0	9	1	0
<b>Summer</b>	<b>Bison locations</b>			<b>Available locations</b>		
	Natural	Linear	Cutblock	Natural	Linear	Cutblock
Upland conifer	5	0	0	6	1	0
Upland deciduous	28	9	0	26	9	0
Upland pine	39	5	5	35	5	6
Graminoid rich	22	0	0	21	0	0
Shrubby	9	0	0	8	1	0
Avoided	0	0	0	9	2	0



**Figure 10:** Distribution of the 480 sites surveyed during the spring and summer of 2018 – 2020. Bison (i.e., use) locations are in green and available (i.e., random) locations are in purple.

**Table 3:** Akaike Information Criteria (AIC) tables of resource selection function models for three seasons: spring (i.e., date of snow-melt to date first female enters calving area), summer (i.e., date first female leaves calving area until vegetation has senesced), and growing season (spring and summer). The delta-AIC ( $\Delta$ AIC) values are the difference in AIC between the model and the most parsimonious model (i.e., lowest AIC) and the weight describes the weight of the AIC value compared to all the other models in the table. For brevity, we only report the three most parsimonious models and the null model for each season.

Season	Model	AIC	$\Delta$ AIC	Weight
Growing	~ coarse woody debris density + shrub/sapling density	626.46	0	0.683
	~ coarse woody debris density + shrub/sapling density + tree density	628.18	1.17	0.289
	~ shrub/sapling density	639.31	12.85	0.001
	~ [null]	665.28	38.82	<0.001
Spring	~ coarse woody debris density + shrub/sapling density	293.20	0	0.502
	~ coarse woody debris density + shrub/sapling density + tree density	294.95	1.75	0.209
	~ shrub/sapling density	295.07	1.87	0.197
	~ [null]	317.21	23.02	<0.001
Summer	~ coarse woody debris density	335.28	0	0.332
	~ coarse woody debris density + shrub/sapling density	335.46	0.18	0.303
	~ coarse woody debris density + tree density	337.37	2.09	0.117
	~ [null]	349.86	14.58	<0.001

## **Knowledge gap 4c - Monitoring snow dynamics within the RLBH**

**Lead investigator:** Darren Epperson

### ***Research objectives***

Our objective is to monitor daily snow cover dynamics throughout the RLBH home range. It is essential to understand snow dynamics in colder climates between different landcover types and features, moreover, how these dynamics change throughout the winter and how this affects bison foraging and movement (Larter & Gates, 1991). We measured daily maximum snow depths using ten permanent snow measurement sites located in upland pine, marsh meadow, upland deciduous, cutblock, and esker to represent different landcover types, disturbances, and features within the RLBH's range.

### ***Overview of research methods***

Two measurement boards placed three meters apart capture variations in snow depth. The measurement boards are scaled with graduated markings at 5-cm increments and are placed in three landcover types (i.e., marsh meadows, upland deciduous, upland pine), on one landscape feature (i.e., esker), and in one disturbance (i.e., cut-blocks) to monitor daily snow conditions. Specifically, we used time-lapse cameras mounted to T-posts, positioned in front of measurement boards. The cameras are set to capture two pictures daily, both at mid-day, to monitor the daily and seasonal snow depths (Johnson et al. 2000). Long-term data from the cameras will be related to bison GPS location data to quantify how snow depth influences winter habitat selection by the RLBH and their vulnerability to predation by wolves. The methods used here are designed for obtaining both daily resolution and long-term seasonal dynamics of snow depth by landcover type, allowing for analyses at different temporal scales.

### ***Progress / preliminary results***

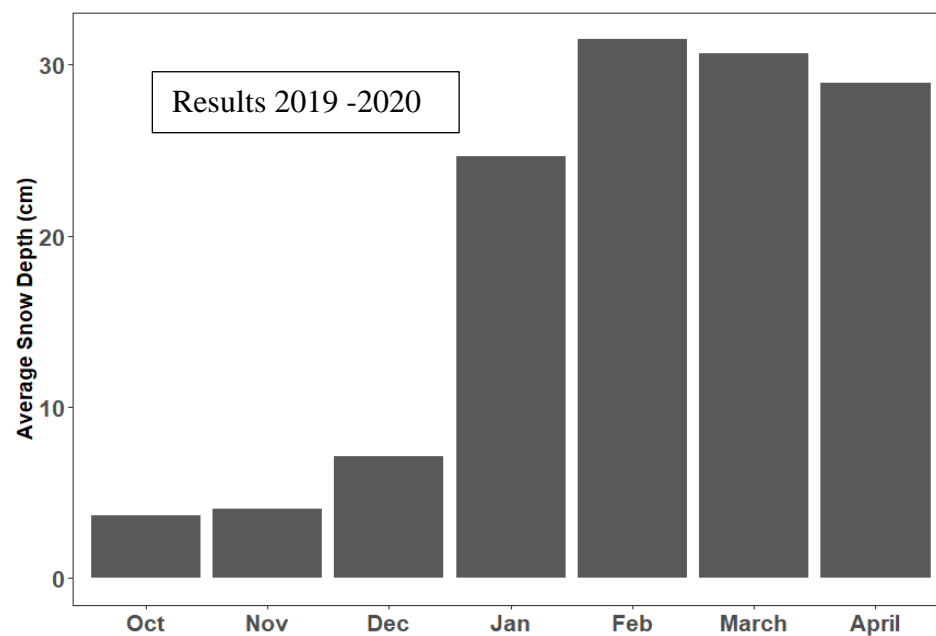
Five snow monitoring sites were added in 2019, bringing the total to ten monitoring stations within RLBH's home range. Preliminary results reveal that the deciduous landcover site had the deepest snow depth during winter 2019-20 (Figure 11). Additionally, the accumulated snow depth distribution per month, pooled across all ten monitoring sites, showed that February and March had the deepest snowpack, at approximately 33 cm during winter 2019-20 (Figure 12).

### ***Outstanding / upcoming work***

We will use the snow monitoring data in conjunction with other habitat analyses to better describe the ecological drivers of winter habitat selection by the RLBH. Results will be included in the 2021 annual report.



**Figure 11:** Maximum annual snow depth for each landcover during the 2019-20 winter period (October 2019 - May 2020).



**Figure 12:** Distribution of monthly maximum snow depth for 10 monitoring stations from the 2019-2020 winter (October 2019 – May 2020).

## **Knowledge gap 4c - How do winter conditions influence bison movement and habitat selection?**

**Lead investigator:** Aidan Sheppard

### ***Research objectives***

Our objective is to examine wood bison movements as influenced by snow and temperature. Within-season variation in winter precipitation and temperature and long-term alteration as a result of climate change have the capacity to influence bottom-up and top-down processes affecting bison movement, such as forage availability and predation (Bruggeman et al. 2008; Jung 2015; Boelman et al. 2019). Despite these wide-ranging implications, there lacks an explicit understanding of both the direction and magnitude of the response of bison movement to changes in snow and temperature. Because snow is understood to influence bison behaviour and bison are a cold-adapted species known for enduring temperatures with little change in behaviour as low as -30 °C, we hypothesized that movement rates would be inversely related to snow depth, and that bison would be limited by snow rather than cold temperatures. We identify the effects of snow and temperature and the strength of those effects on daily bison movement rates to improve our understanding of the winter movement ecology of wood bison.

### ***Overview of research methods***

We acquired location data from eight collared female bison from the winter of 2018/2019. We removed records with no coordinate information or low fix accuracy with a dilution of precision value greater than 10-m (Bjørneraas et al. 2010). We defined winter as occurring from the first day of continuous snow cover (10 November 2018) to the last day of continuous snow cover (26 March 2019; DeMars et al. 2015). For each individual, we calculated mean daily movement rate in meters per minute ( $\text{m min}^{-1}$ ) to match the temporal scale of our predictor variables, incorporating a random effect for individual bison in our models to account for potential variation between bison.

We used mean snow depth data from four of our winter snow camera stations dispersed across the study area and calculated the average daily maximum and minimum temperature using recordings from the two nearest available weather stations to the study area (Aurora and Mildred Lake; Alberta Agriculture and Forestry 2020; Hecker et al. 2019; Fig. 13). We then used Linear Mixed Models (LMMs) to assess the influence of snow depth, minimum temperature, and maximum temperature on movement rates. We fit LMMs using the lme4 package (Bates et al. 2014) in R (R Core Team 2019), with individual as a random effect to account for variations in movement rates between individual bison. We modelled interactions between fixed effects to test the hypothesis that it is the multiplicative effect of snow and temperature that is the important determinant of bison daily differences in movement rates.

To enable behavioural inferences beyond changes in daily movement rates, we delineated scales of bison behaviour. Johnson et al. (2002) applied a non-linear curve fitting procedure first proposed by Sibly et al. (1990) to differentiate scales of movement in woodland caribou (*Rangifer tarandus caribou*). We applied the method adapted by Johnson et al. (2002) in our study to characterize scale-specific movements of wood bison in the Ronald Lake study area. Next, we calculated the daily proportion of small-scale (i.e., local) and large-scale (i.e., landscape) movements for each bison to characterize typical behaviour activity during the study period, summarizing the daily proportion of each scale of movement across all bison (Fig. 15).

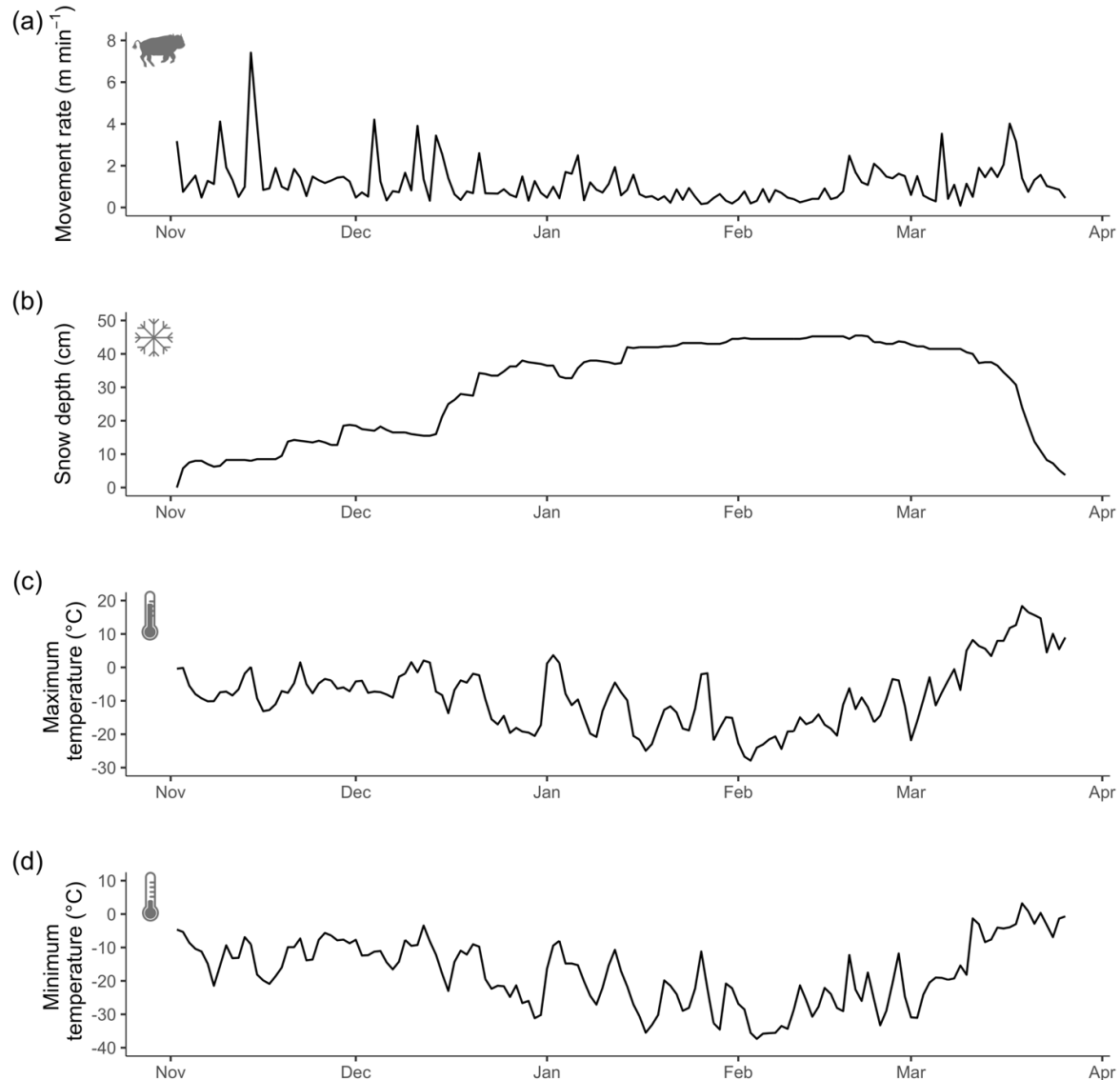
### ***Progress / preliminary results***

The most supported model included snow depth, maximum temperature, and the interaction of snow depth and maximum temperature and accounted for 98% of model weights. Our most supported model confirmed the expected, significant negative effect of daily snow depth on mean daily wood bison movement rates, predicting that for every 10 cm increase in snow depth at a constant daily maximum temperature of 0 °C, movement rates decreased by 9.86 m min<sup>-1</sup> (Figure 14a). In contrast, a 10 °C increase in maximum daily temperature at a 0 cm snow depth significantly increased daily movement rates by 10.32 m min<sup>-1</sup>, and this effect appears to be non-linear with a notable limitation in movements below -15 °C (Figure 14b). However, a significant interactive effect between daily snow depth and daily maximum temperature predicted that the effect of snow depth on bison movement rates changed depending on temperature (Figure 14c). At low temperatures, daily movement rates remained relatively low at levels of 0.07 m min<sup>-1</sup> regardless of snow depth, but increased to as high as 2.79 m min<sup>-1</sup> when snow depth was lower as daily maximum temperature increased (Figure 14c). Standardized coefficients demonstrated that the effect of maximum temperature on bison movement rates was about 25% larger than that of snow depth per one-standard deviation change in the variable.

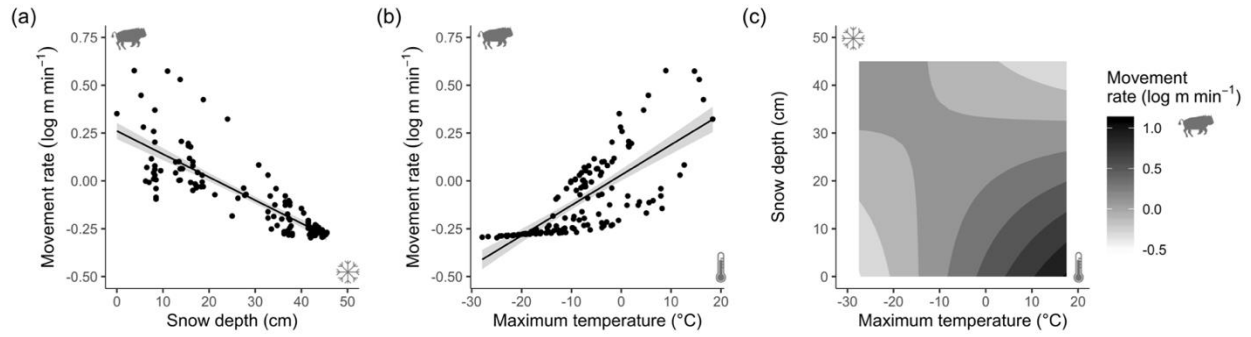
The average daily proportion of small-scale (i.e., local) movements for all bison ranged from 0.53 to 1.00 ( $\bar{x}$  = 0.95, SD = 0.06), and large-scale (i.e., landscape) movements ranged from 0.00 to 0.47 ( $\bar{x}$  = 0.05, SD = 0.06; Figure 15). Small-scale movements were the dominant behaviour for the winter study period as would be expected with the average daily proportion of large-scale movements not exceeding 0.47 (Figure 15). The average daily proportion of small-scale movements was significantly higher than large-scale movements ( $T(288) = -123.69, p < 0.01$ ).

### ***Outstanding / upcoming work***

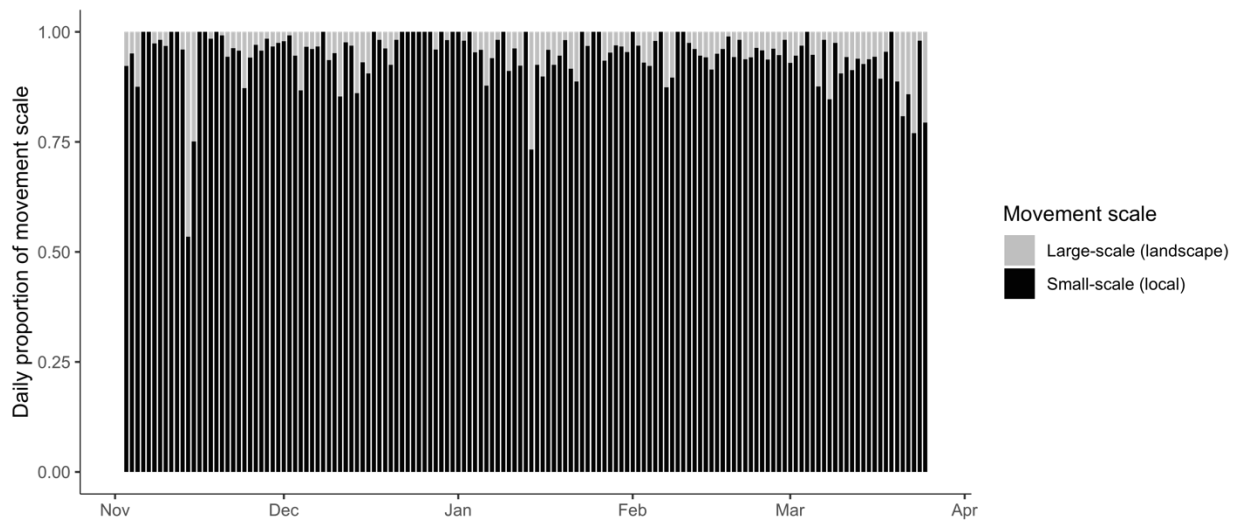
This work which is currently under review in the Canadian Journal of Zoology concludes our investigation of the influence of winter conditions on the RLBH's movement. Future researchers investigating bison movement rates could improve the understanding of the relationship between bison movement and the winter environment, especially that of male bison, which may respond differently than females to snow and temperatures and overall may have different average activity (i.e., movement rates).



**Figure 13:** Summary graphs showing a) example daily movement rate ( $\text{m min}^{-1}$ ) for wood bison (*Bison bison athabasca*) individual 23277, b) daily snow depth (cm), c) daily maximum temperature ( $^{\circ}\text{C}$ ), and d) daily minimum temperature ( $^{\circ}\text{C}$ ) in the Ronald Lake study area, Alberta, Canada, during the winter of 2018/19.



**Figure 14:** Predicted movement rate (log m min<sup>-1</sup>) for a) snow depth (cm), b) maximum temperature (°C), and c) the interaction between snow depth and maximum temperature for wood bison (*Bison bison athabasca*) individual 23277 from the Ronald Lake herd during the winter of 2018 - 2019. Shaded region surrounding lines indicate 95% confidence interval.



**Figure 15:** Average daily proportion of small-scale (local) and large-scale (landscape) movements for 8 female wood bison (*Bison bison athabasca*) from the Ronald Lake herd during the winter of 2018/19.

## **Knowledge Gap 4c & 8e – Where and when are the RLBH at risk of predation by wolves?**

**Lead investigator:** Lindsey Dewart

### ***Research objectives***

The objective was to better understand predation pressure on wood bison in the Ronald Lake area. By studying wolves, a predator of bison in other systems, we can better understand the ecology of both species. When wolves have multiple abundant prey items available to them, their selection of prey type involves considerations of risk of injury to pack members, catchability of prey, and whether the prey will offer sufficient biomass/nutrition to feed the pack (Becker et al. 2008; Mattioli et al. 2011). These selection choices can change at different times of year due to changes in prey abundance, accessibility, and vulnerability (Carbyn et al. 1993; Huggard 2011; Smith et al. 2000). In systems that include bison, wolves often choose to hunt alternative prey species to reduce risk of injury, but may capitalize on vulnerable bison individuals when an opportunity arises (Jaffe 2001; Shave et al. 2020; Smith et al. 2000). Little is known about the predator-prey relationship between wolves and the RLBH, so we examined wolf diets to determine if bison are a component, and investigated potential temporal and spatial patterns related to wolf predatory activity.

### ***Overview of research methods***

We programmed GPS radio-collars at a four-hour fix interval (Webb et al. 2008) and deployed them on wolves whose pack territories overlap the bison range, by use of aerial net-gunning in the winter and foothold-trapping in late summer. Movements of wolves and bison were monitored throughout the year to determine the ranges and range overlap of each species using 95% utilization distributions (UDs) for the same time period (Worton 1989). Cluster analysis was used to identify potential kill sites that were prioritized by handling time (i.e., continuous time spent within a 300-m radius), and were visited on the ground. Site investigations consisted of systematically searching for wolf scat samples, prey remains to identify species, and finding evidence to confirm a wolf kill occurred (i.e., broken branches, blood). Winter (1 Nov. 2019 – 30 Apr. 2020) wolf diets were quantified by the number of each prey species found at kill sites.

To quantify summer (1 May – 31 Oct 2019) wolf diets, prey hair was extracted from each scat sample and a subsample of these items were selected using the point-frame method (Ciucci et al. 2004). This method involves a systematic approach to ensure subsampled items are randomly selected to represent the overall contents of the sample. Impressions of the prey hair were made in a clear medium to easily view cuticle scale and medulla patterns, which were used to identify prey to taxonomic family by comparing to a reference collection and the use of “A Manual for the Identification of Hairs of Selected Ontario Mammals” (Adorjan and Kolenosky, 1969).

Snow depth, temperature, and stage of winter season (i.e., days since first snowfall) were variables considered in generalized linear models used to test for temporal patterns in successful wolf predatory events. For each day of the winter season, the number of collared packs was included as an additional variable to account for variation in the number of monitored packs through the winter season. Daily snow depths were measured by averaging the snow depth recorded from four snow stations placed in different habitat types within the study area (see section on Knowledge gap 4c above for more details on snow measures). Daily temperature measures were averaged between the two nearest weather stations to the study area (Aurora and Mildred Lake; Alberta Agriculture and Forestry 2020).

### ***Progress / preliminary results***

Collared wolves provided movement data for three packs in 2019/20. These were the McIvor, Dianne, and Southline packs, named for dominant landscape features within their ranges, and consisting of six, two, and nine adult pack members, respectively. The McIvor and Dianne packs were monitored from April 2019 – March 2020 with a range size of 1,759-km<sup>2</sup> and 1,901-km<sup>2</sup>, respectively, while the Southline pack was monitored from mid-January to mid-April 2020 with a range size of 2,500-km<sup>2</sup> moving extensively through other pack territories. Combined, the three packs territories overlapped with 98% of the RLBH's range.

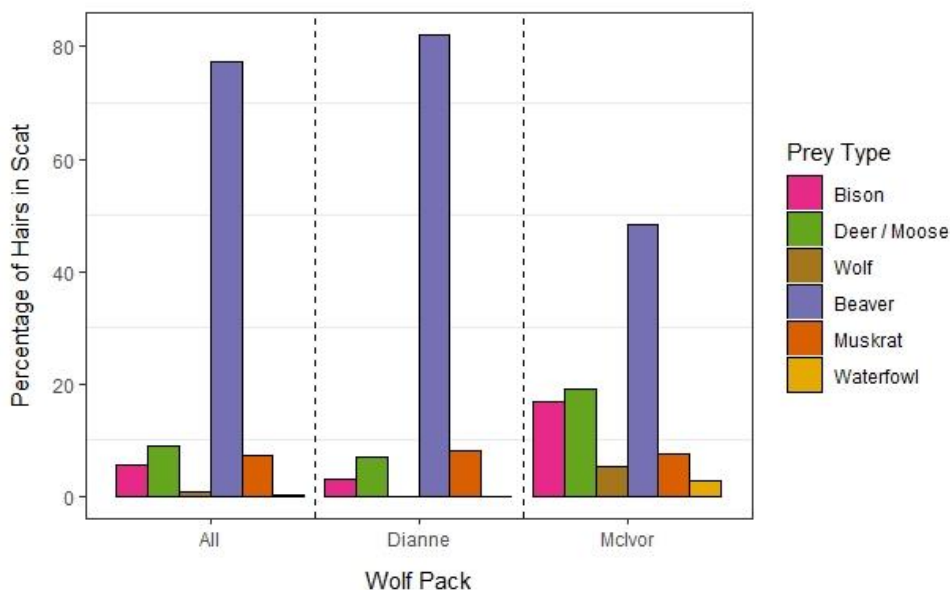
Wolf scat content identification from 172 samples collected in the summer season revealed that the collective wolf diet of the McIvor and Dianne packs consisted of 77% beaver (*Castor Canadensis*), 9% ungulate (white-tailed deer [*Odocoileus virginianus*] and moose), 7% muskrat (*Ondatra zibethicus*), 6% bison, and trace amounts of waterfowl (Figure 16). The Dianne pack diet consisted of 82% beaver, while the McIvor pack diet was more diverse with comparatively more large prey items, but still dominated by beaver at 48% (Figure 16). Notably, some large prey content within the scat may be partially explained by scat samples collected at re-visited moose and bison mortality sites that occurred before wolf collars were deployed in late winter 2019.

A total of 58 wolf cluster sites were visited in the winter season, 39 (67%) of which were confirmed large mammal kill sites that occurred, on average, every 8.6 days. Based on the 39 kill events, the combined winter diet of all packs consisted of 36% moose and 36% white-tailed deer, while bison consisted of 15%, wolf at 8%, and black bear at 5% of the kill sites (Figure 17). Remains of bison were discovered at both McIvor and Southline pack kill sites, which constituted 40% of the McIvor pack winter kills and 17% of the Southline pack winter kills (Figure 17). The McIvor pack winter diet consisted equally of bison and moose (36%), the Southline pack diet comprised mostly of moose (58%), and the Dianne pack winter diet was dominated by white-tailed deer at 69% (Figure 17).

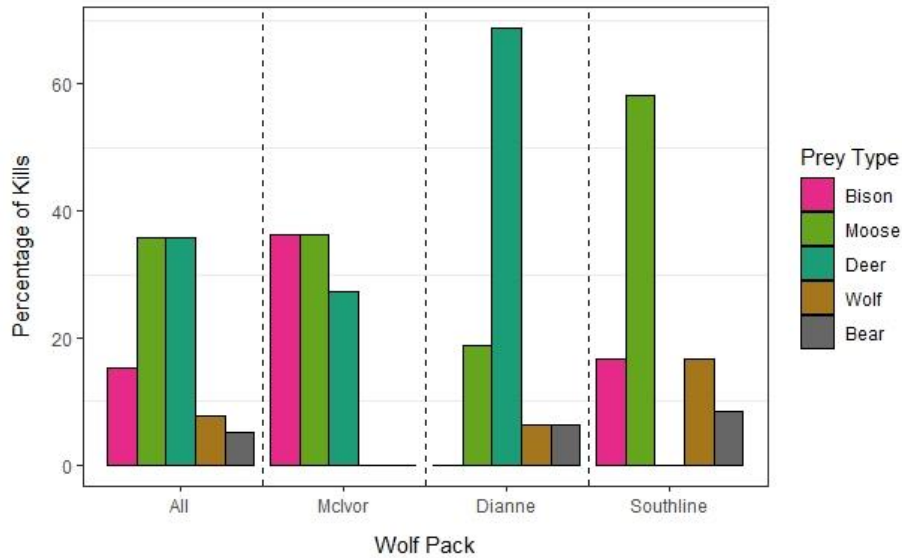
We found that bison kill events occurred later in the winter compared to moose or deer, which were killed by wolves throughout the winter season (Figure 18). To investigate this trend, winter conditions on days that bison kills occurred were compared to winter conditions over the rest of the winter to reveal possible temporal patterns associated with successful wolf predation events on bison. The most parsimonious model revealed that the stage of winter was the best predictor of bison kill events. Results showed that the probability of wolves killing a bison began to increase in early February and continued to grow until mid-April (Figure 19).

### *Outstanding / upcoming work*

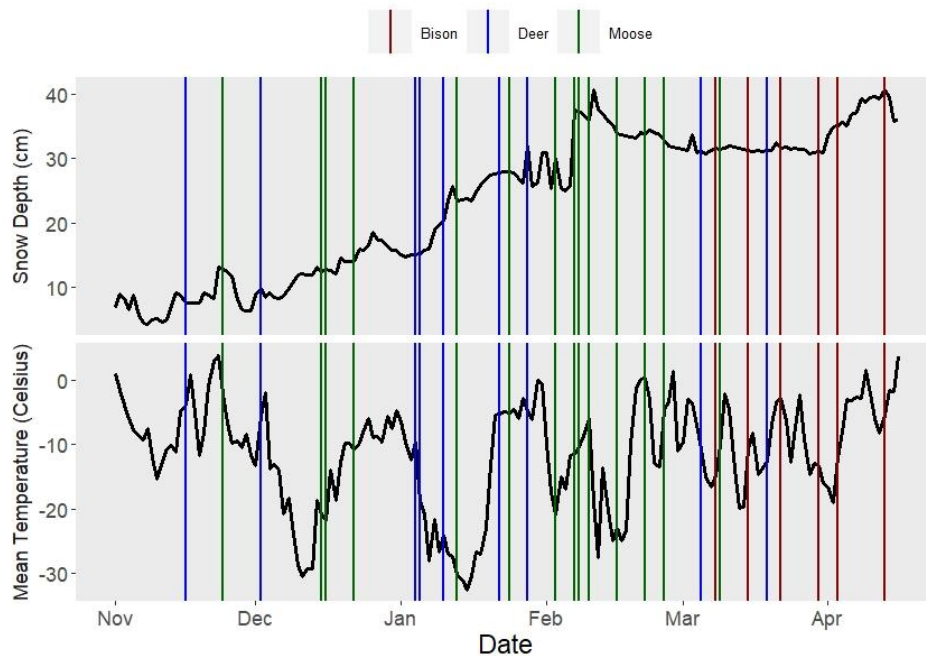
Third order resource selection function (RSF) models will be developed by comparing habitat and landscape characteristics at wolf use sites with random sites across the study area to reveal what is spatially important to wolves in this system (Manly et al. 1993; Boyce and MacDonald 1999). These models will account for habitat type, elevation, slope, and distances to anthropogenic disturbances, water, and habitat edge. A series of wolf RSF's will be developed and compared to examine wolf habitat use in relation to bison use for the winter season. Results will allow us to estimate spatial patterns of predation risk for bison by wolves within the study area.



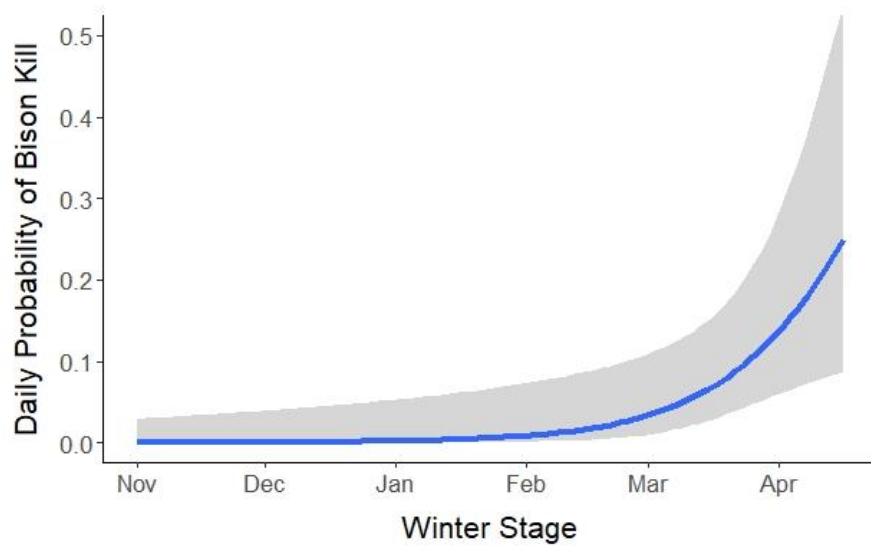
**Figure 16:** Summer (May 1 – Oct 31, 2019) wolf pack diet content in the Ronald Lake area analyzed through identification of prey hair extracted from wolf scat. This figure displays the percent occurrence of hair of each prey species found in all wolf scat samples collected. Wolf packs considered in the analysis were the Dianne and McIvor pack, while the, “All” column represents both pack diets combined.



**Figure 17:** Winter (Nov 1, 2019 – April 17, 2020) wolf pack diet content in the Ronald Lake area analyzed by number of prey species found at wolf kill sites throughout the study area. This figure displays the percentage of prey species found at all wolf kill sites visited. Wolf packs considered in this analysis were the McIvor, the Dianne, and Southline packs, while the, “All” column represents the three pack diets combined.



**Figure 18:** Timing of wolf kills grouped by prey type during the winter season (Nov 1, 2019 – April 17, 2020) within the Ronald Lake area. The top panel displays the timing of wolf kill events in relation to daily snow depth (cm) represented by the black line, while the bottom panel displays timing of wolf kills in relation to mean temperature (°C), also represented by the black line. Prey species include wood bison in red, white-tailed deer in blue, and moose in green.



**Figure 19:** Results of logistic regression, predicting the effect of the timing during the winter, labeled here as ‘winter stage’ (i.e. days since first snowfall; Nov 1, 2019 – April 17, 2020), on the probability of a bison being killed by wolves in the Ronald Lake area. The grey area represents the 95% confidence intervals.

## Conclusions

Our research team continues to build on the existing knowledge of the RLBH, guided by the knowledge gaps identified by the RLBH Technical Team. Since April 2020, we have conducted further research on a subset of these knowledge gaps. Recent research progress includes further investigation into the herd's seasonal bison diet, foraging behaviour, winter movement rates, predation pressure, and use of different habitat types within the study area.

Our analysis of bison scat samples revealed a seasonal change in bison diets with spring and summer diets being of a higher quality than winter. During winter, we found that bison forage more intensively on sites dominated by sedges rather than grasses or woody plants. Deep snow decreased rates of movement, while warmer temperatures facilitated an increase in movement rates. Analysis of wolf diets revealed that beaver dominated summer diets of wolves, while wolf winter diets predominantly consisted of white-tailed deer and moose. Bison kills were made by two different wolf packs and accounted for 15% of wolf kills in the latter half of the winter season. Upland site data were collected for our long-term study of habitat use by large mammals within the RLBH range, but marshes and seismic line sites were inaccessible due to excessive flooding in the study area.

Continued research for 2021 will include snow monitoring and the examination of characteristics of bison use of wetlands, bottom-up influences of bison habitat use, bison and other wildlife use of different landcover types, and spatial wolf-bison encounter risk reflecting top-down influences on bison. Field work data collection is now complete for projects related to wolf and bison diets, while data collection on bison use of different landcover types and characteristics of bison wetland use is planned to continue through 2021, contingent on COVID-19 restrictions.

## **Acknowledgements**

There are a number of people and organizations we would like to thank for making this research possible. Rob Belanger, a former MSc student and Research Assistant, provided early field research and supported early monitoring projects (e.g., snow, scat surveys). We thank our partners Craig Dockrill, Joann Skilnick and Troy Hegel from Alberta Environment and Parks, and Karen Halwas, Neil Sandstrom and Lindsay Sutton with Teck Resources Ltd. We would like to acknowledge the following local community members and trappers for their assistance: Roy Ladouceur, Mike Berdinski, Chuck Shovelup and Mike Martin. We are also thankful for all the field technicians that have helped with data collection: Alex Coley, Melissa Dergousoff, Ashley Hillman, Neal Josephs, and Adam Scharnau. We are thankful for the support of the Ronald Lake Bison Herd Technical Team. Further, we are especially grateful to the Treaty 8 First Nations that sit on the Technical Team, including Athabasca Chipewyan First Nation, Mikisew Cree First Nation, Fort MacMurray First Nation #468, and Fort McKay First Nation, and for the Métis Indigenous groups that are involved with the Technical Team, including Fort Chipewyan Métis Local 125, Fort McMurray Métis Local 1935, Fort McKay Métis 63, and Lakeland Métis Local 1909. Finally, we would like to thank our funders Teck Resources, the Natural Sciences and Engineering Research Council (NSERC), the Alberta Conservation Association, the Northern Scientific Training Program, and the University of Alberta's Northern Research Awards, and for the in-kind support of the University of Alberta, Department of Renewable Resources, Applied Conservation Ecology Lab, and the Mammalogy program at the Royal Alberta Museum.

## Literature cited

- Adorjan, A.S., and G.B. Kolensosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Department of Lands and Forest Research Branch 90 pp.
- Alberta Agriculture and Forestry. 2020. Alberta Climate Information Service (ACIS). Alberta Government. <https://acis.alberta.ca>
- Alberta Environment and Parks and Alberta Conservation Association. 2017. Status of the American Bison (*Bison bison*) in Alberta: Update 2017. Alberta Environment and Parks. Alberta Wildlife Status Report No. 38 (Update 2017). Edmonton, AB. 134 pp.
- Alves, J., A.A. da Silva, A.M. Soares, and C. Fonseca. 2013. Pellet group count methods to estimate red deer densities: Precision, potential accuracy and efficiency. *Mammalian Biology*. 78(2):134-141.
- Ball, M.C., T.L. Fulton, and G.A. Wilson. 2016. Genetic analyses of wild bison in Alberta, Canada: implications for recovery and disease management. *Journal of Mammalogy*. 97(6): 1525-1534.
- Bates, D., M. Mächler, B. Bolker, and S. Walker. 2014. Fitting linear mixed-effects models using lme4. *ArXiv:1406.5823 [Stat]*. <http://arxiv.org/abs/1406.5823>.
- Becker, M.S., R.A. Garrott, P.J. White, C.N. Gower, E.J. Bergman, and R. Jaffe. 2008. Chapter 16 Wolf prey selection in an elk-bison system: choice or circumstance? *Terrestrial Ecology*. 3:305-337
- Belanger, R.B., C.A. DeMars, L.J. Hecker, M.A. Edwards, and S.E. Nielsen. 2017. Ronald Lake wood bison annual report: November 30, 2017. Ronald Lake Bison Report. University of Alberta, Edmonton, Alberta, Canada T6G 2H1. 76 pp.
- Belanger, R.J., L.J. Hecker, L.T. Dewart, S.E. Nielsen, and M.A. Edwards. 2018. Ronald Lake Wood Bison Research Program: Annual Report 21 December 2018. University of Alberta, Edmonton, Alberta, Canada T6G 2H1. 30 pp.
- Belanger, R.J., M.A. Edwards, L.N. Carbyn, and S.E. Nielsen. 2020. Evaluating trade-offs between forage, biting flies, and footing on habitat selection by wood bison (*Bison bison athabasca*). *Canadian Journal of Zoology*. 98(4):254-261.
- Bjørneraas, K., B. Van Moorter, C.M. Rolandsen, and I. Herfindal. 2010. Screening global positions system location data for errors using animal movement characteristics. *Journal of Wildlife Management*. 74(6):1361-1366.
- Boelman, N.T., G.E. Liston, E. Gurarie, A.J.H. Meddens, P.J. Mahoney, P.B. Kirchner, G. Bohrer, T.J. Brinkman, C.L. Cosgrove, J.U.H. Eitel, M. Hebblewhite, J.S. Kimball, S. LaPoint, A.W. Nolin, S.H. Pedersen, L.R. Prugh, A.K. Reinking, and L.A. Vierling. 2019. Integrating snow science and wildlife ecology in Arctic-boreal North America. *Environmental Resource Letters*. 14(1): 010401. doi:10.1088/1748-9326/aaec1.
- Boyce, M.S., and L.L. McDonald. 1999. Relating populations to habitats using resource selection functions. *Trends in Ecology and Evolutions*. 14(7):268-272.

- Bruggeman, J.E., R.A. Garrott, P.J. White, F.G.R. Watson, and R.W. Wallen. 2008. Chapter 28 effects of snow and landscape attributes on bison winter travel patterns and habitat use. *Terrestrial Ecology*. pp. 623–647. doi:10.1016/S1936-7961(08)00228-5.
- Burnham, K.P., and D.R. Anderson. 2002. Model selection and multi-model inference: a practical information-theoretic approach, 2nd ed. Springer, New York.
- Carbyn, L.N., S.M. Oosenbrug, and D.W. Anions. 1993. Wolves, bison, and the dynamics related to the Peace-Athabasca Delta in Canada's Wood Buffalo National Park. *Journal of Wildlife Management*. 59(1).
- Ciucci, P., E. Tosoni, and L. Boitani. 2004. Assessment of the point-frame method to quantify wolf *Canis lupus* diet by scat. *Wildlife Biology*. 10(1):149-153.
- Craine, J. M., E. G. Towne, M. Miller, and N. Fierer. 2015. Climatic warming and the future of bison as grazers. *Scientific Reports*. 5(2015): 16738.
- DeMars, C.A., S.E. Nielsen, and M.A. Edwards. 2015. Ronald Lake Bison (*Bison bison*): Project Update. University of Alberta, Edmonton, Alberta, Canada T6G 2H1. 26 pp.
- DeMars, C.A., S.E. Nielsen, and M.A. Edwards. 2016. Range use, habitat selection and the influence of natural and human disturbance on wood bison (*Bison bison athabasca*) in the Ronald Lake area of northeastern Alberta. University of Alberta, Edmonton, Alberta, Canada T6G 2H1. 80 pp.
- DeMars, C.A., S.E. Nielsen, and M.A. Edwards. 2019. Effects of linear features on resource selection and movement rates of wood bison (*Bison bison athabasca*). *Canadian Journal of Zoology*. 98(1):21-31.
- Driver, K.M. 2010. Distinguishing the hydrologic regimes and vegetation of fens and wet meadows in the Rocky Mountains. Colorado State University.
- Fortin, D. 2002. Optimal searching behaviour: the value of sampling information. *Ecological Modelling*. 153(2002):279-290.
- Fortin, D. 2005. Elk winter foraging at fine scale in Yellowstone National Park. *Oecologia*. 145(2):335- 343.
- Fortin, D., J.M. Fryxell, and R. Pilote. 2002. The temporal scale of foraging decisions in bison. *Ecology*. 83(4):970-82.
- Hecker, L.J., L.T. Dewart, R.J. Belanger, S.E. Nielsen, and M.A. Edwards. 2019a. Ronald Lake wood bison research program: Semi-annual progress report 2019. University of Alberta, Edmonton, Alberta, Canada, T6G 2H1. 19 pp.
- Hecker, L.J., L.T. Dewart, D. Epperson, M.A. Edwards, and S.E. Nielsen. 2019b. Ronald Lake wood bison research program: 2019 annual report. University of Alberta, Edmonton, Alberta, Canada, T6G 2H1. 46 pp.
- Hecker, L.J., L.T. Dewart, D.M. Epperson, G.J. Rawleigh, A.C. Sheppard, S.E. Nielsen, and M.A. Edwards. 2020a. Ronald Lake wood bison research program: 2020 semi-annual report. University of Alberta, Edmonton, Alberta, Canada, T6G 2H1. 37 pp.
- Hecker, L.J., S.C.P. Coogan, S.E. Nielsen, and M.A. Edwards. 2020b. Latitudinal and seasonal plasticity in American bison *Bison bison* diets. *Mammal Review*. DOI:mam.12229.

- Höller, P., and R. Fromm. 2010. Quantification of the hand hardness test. *Annals of Glaciology*. 51(54):39-44.
- Huggard, D. 2011. Prey selectivity of wolves in Banff National Park. I. Prey species. 2011. *Canadian Journal of Zoology*. 71(1):130-139.
- Jaffe, R. 2001. Winter wolf predation in an elk-bison system in Yellowstone National Park, Wyoming. Montana State University, Bozeman, Montana, U.S.A.
- Johnson, C. J., K. L. Parker, and D. C. Heard. 2000. Feeding site selection by woodland caribou in north-central British Columbia. *Rangifer*. 20(5):158-172.
- Johnson, C.J., K.L. Parker, D.C. Heard, and M.P. Gillingham. 2002. Movement parameters of ungulates and scale-specific responses to the environment. *Journal of Animal Ecology*. 71(2):225–235.
- Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology*. 61(1):65-71.
- Jorns, T., J. Craine, E.G. Towne, and M. Know. 2019. Climate structure bison dietary quality and composition at the continental scale. *Environmental DNA*. 2(1):77-90.
- Jung, T.S. 2015. Winter diets of reintroduced bison (*Bison bison*) in northwestern Canada. *Mammal Research*. 60(4):385–391.
- Kenkel, N.C. 1987. Trends and interrelationships in boreal wetland vegetation. *Canadian Journal of Botany*. 65(1):12-22.
- King, S.R.B., and K.A. Schoenecker. 2019. Comparison of methods to examine diet of feral horses from noninvasively collected fecal samples. *Rangeland Ecology & Management*. 72(4):661-666.
- Larter, N.C., and C.C. Gates. 1991. Diet and habitat selection of wood bison in relation to seasonal changes in forage quantity and quality. *Canadian Journal of Zoology*. 69(10):2677-85.
- Machovsky-Capuska, G., A.M. Senoir, S.J. Simpson, and D. Raubenheimer. (2016) The multidimensional nutritional niche. *Trends in Ecology and Evolution*. 31:355-365.
- Manly, B.J., L.L. McDonald, D.L. Thomas, T.L. McDonald, and W.P. Erickson. (1993) *Resource Selection by Animals*. Chapman & Hall, London, United Kingdom.
- Mattioli, L., C. Claudia, A. Gazzola, M. Scandura, and M. Apollonio. 2011. Prey selection and dietary response by wolves in a high-density multi-species ungulate community. *European Journal of Wildlife Research*. 57:909-922.
- Müller-Schwarze, D. 1991. The chemical ecology of ungulates. *Applied Animal Behaviour Science*. 29:389-402.
- Onset. 2018. HOBO U20L Water Level Logger (U20L-0x) Manual. [https://www.onsetcomp.com/files/manual\\_pdfs/17153-G%20U20L%20Manual.pdf](https://www.onsetcomp.com/files/manual_pdfs/17153-G%20U20L%20Manual.pdf)
- Plant, R.E. 2012. *Spatial data analysis in ecology and agriculture using R*. Taylor & Francis Group. Boca Raton, FL, United States of America
- R Core Team. 2019. R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria. <https://www.R-project.org/>

- Shave, J., S. Cherry, A. Derocher, and D. Fortin. 2020. Seasonal and inter-annual variation in diet for gray wolves *Canis lupus* in Prince Alberta National Park, Saskatchewan. *Wildlife Biology*. (3)
- Shrestha, T.K., L.J. Hecker, A. Aryal, and S.C.P. Coogan. 2020. Feeding preferences and nutritional niche of wild water buffalo (*Bubalus arnee*) in Koshi Tappu Wildlife Reserve, Nepal. *Ecology & Evolution*. 00:1-9.
- Shury, T. K., J. S. Nishi, B. T. Elkin, and G. A. Wobeser. 2015. Tuberculosis and brucellosis in wood bison (*Bison bison athabasca*) in northern Canada: a renewed need to develop options for future management. *Journal of Wildlife Disease*. 51(3):543-554.
- Sibly, R.M., H.M.R. Nott, and D.J. Fletcher. 1990. Splitting behaviour into bouts. *Animal Behaviour*. 39(1): 63–69. doi:10.1016/S0003-3472(05)80726-2.
- Smith, D., D. Mech, M. Meagher, W. Clark, R. Jaffe, M. Phillips, and J. Mack. 2000. Wolf-bison interactions in Yellowstone National Park. *Journal of Mammalogy*. 81(4):1128-1135.
- Strong, W.L., and C.C. Gates. 2009. Wood bison population recovery and forage availability in northwestern Canada. *Journal of Environmental Management*. 90(1):434-40.
- Tan, T., S.E. Nielsen, and M.A. Edwards. 2015. Ronald Lake bison (*Bison bison*) preliminary summary report: March 2013 – March 2014 telemetry data study. University of Alberta, Edmonton, Alberta, Canada T6G 2H1. 55pp.
- Timoney, K. 2008. Factors influencing wetland plant communities during a flood-drawdown cycle in the Peace-Athabasca Delta, northern Alberta, Canada. *Wetlands*. 28(2):450-63.
- University of Idaho. 2009. Direct Measures of Biomass: Basic Procedures for Directly Measuring Biomass. [accessed July 7, 2020].  
[https://www.webpages.uidaho.edu/veg\\_measure/Modules/Lessons/Module%207\(Biomass&Utilization\)/7\\_3\\_Direct%20Methods.htm](https://www.webpages.uidaho.edu/veg_measure/Modules/Lessons/Module%207(Biomass&Utilization)/7_3_Direct%20Methods.htm)
- Webb, N.F., M. Hebblewhite, and E.H. Merrill. 2008. Statistical methods for identifying wolf kill site using global positioning system locations. *Journal of Wildlife Management*. 72(3):798-807.
- Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology*. 70(1):164-168.