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Recommended Citation

Leonard, Joshua L., "Evaluation of Bison (Bison Bison) Ecology at the Olson's Bison Conservation Ranches, Pine River Ranch, Manitoba, Canada" (2016). *Theses and Dissertations.* Paper 1084.

EVALUATION OF BISON (*BISON BISON*) ECOLOGY AT THE OLSON’S BISON CONSERVATION RANCHES, PINE RIVER RANCH, MANITOBA, CANADA.

BY

JOSHUA L LEONARD

A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Wildlife and Fisheries Sciences: Specialization in Wildlife Sciences

South Dakota State University

2016

EVALUATION OF BISON (*BISON BISON*) ECOLOGY AT THE OLSON'S BISON CONSERVATION RANCHES, PINE RIVER RANCH, MANITOBA, CANADA.

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGEMENTS

First, I would like to thank my major advisor, Dr. Jonathan A. Jenks, for providing me the opportunity to conduct this research. You have given me the freedom to develop this project and pursue my interests, but were always there to bring me back when I ventured too far from the objectives. I have grown both professionally and personally under your supervision and look forward to working as your colleague in the future. Thank you to my graduate committee members, Drs. Troy W. Grovenburg and Lora B. Perkins, for pushing me to be a better student and for providing assistance when it was needed.

A special thanks to Tom Olson and his family's business, Olson's Conservation Bison Ranches LTD, for their generosity to financially support me and this project through completion. Thanks also to Duane and Rose Lammers for their hospitality and logistical support while in Manitoba; the scar on my thumb from the late night hospital visit will never be forgotten. I will forever be indebted to you both.

Technical, lab, and analytical assistance was crucial for success of this project and I would like to thank all of those who helped. Thanks to Richard Metcalf for risking his life to capture bison neonates with us and bailing me out of hairy situations while on the ranch. Additionally, thanks to the remaining ranch hands at the Pine River Ranch for their comradery and technical assistance while in the field. Thanks also to Mae Elsinger and the Agriculture and Agri-Food Canada in Brandon, Manitoba, for the use of their ovens to dry forage samples. Last, but not least, I thank my mentee, Ryan Dufour, for analyzing thousands of hours of time-lapse videos. You have grown to be a great friend and I wish you, Aimee, and Raley the best of luck in your future endeavors.

I thank all the SDSU NRM graduate students for their willingness to help when a fellow colleague is in need. A special thanks to a few office mates: Neal Martorelli, Will Inselman, Albara Binothman, Stephen Jones, Lily Sweikert, Emily Mitchell, and Adam Janke. Thanks also to Terri, Kate, Di, and Dawn for all you have done for me and the department. Additionally, thanks to the comradery and long lasting friendships forged during intense broomball, dodgeball, and volleyball matches.

Thanks to my grandparents, Mike and Linda Leonard, for supporting me through both my undergraduate and graduate schooling. Our Sunday afternoon talks are something I look forward to all week. Thanks to my parents, Jayme and Martha Leonard, for always being there when I needed it. Dad, it’s always nice to have someone to share my hunting and fishing stories with, even if you thought that’s all I did while in South Dakota. Mom, I will have to settle up with you at a later date for all the Microsoft consulting throughout my career. Kayla (Hehe), thanks for being you and for setting the bar high by becoming a Physician’s Assistant; you have pushed me to become a better person and I thank you for that. I need to thank my wonderful girlfriend, Ashley Andersen. You have stuck with me all this time, editing my papers, listening to me rant, moving all around the country, and I thank you for always being by my side. Last, but not least, I thank Sage for being the ball of energy in my life who keeps me company and my toes warm at home writing my thesis. I would not be here fulfilling my dream if it weren’t for all your support, and for that, I will always be grateful for!

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ABSTRACT

EVALUATION OF BISON (*BISON BISON*) ECOLOGY AT THE OLSON'S BISON CONSERVATION RANCHES, PINE RIVER RANCH, MANITOBA, CANADA

JOSHUA L. LEONARD

2016

Bison (*Bison bison*), the largest mammalian species in North America, historically numbering in the tens of millions (Roe 1970, McHugh 1972, Dary 1989, Shaw 1995), was nearly extirpated at the turn of the 19th century (Knapp et al. 1999; Gates et al. 2010). At the time, estimates of less than 1,000 bison remaining in North America are widely accepted (Hornaday 1889; Seton 1927; Gates et al. 2010). The decline of bison includes factors such as disease (Flores 1991; Isenberg 2000), sport hunting (Danz 1997; Dary 1989; Hewitt 1919; Isenberg 2000; McHugh 1972), and unofficially funded commercial hunting by the U.S. government (Hornaday 1889; Mayer and Roth 1958; Isenberg 2000).

As bison populations started to decrease, private citizens were the catalysts in conserving bison in the early 1900's (Gates et al. 2010); since, at the time, laws protecting bison were minimal (Danz 1997). Protection for bison was first implemented in 1877 in Canada (Gates et al. 2001). The U.S. followed shortly thereafter, in 1894, when President Cleveland signed the National Park Protective Act (Lacey Act). The Lacey Act protected bison and imposed jail sentences or fines on anyone found guilty of killing bison in Yellowstone National Park, where the last free ranging bison were located (Boyd and Gates 2006). Furthermore, conservation efforts by state, federal, non-government organization (NGO), and private herdsmen have reestablished populations across North America. As a result, the United States Department of Agriculture's Census of Agriculture recently reported 162,110 bison on 2,584 farms (USDA 2012), whereas,

Canada reported 125,142 bison on 1,211 farms (Statistics Canada 2011). Of those, about 31,000 individuals (7.4%) are part of conservation herds, operated by state, federal, or an NGO agency (Gates et al. 2010).

Today, private stakeholders manage approximately 92% of the bison, with a common belief that management is primarily economically driven for profit, in contrast to the conservation focus of state, federal, and NGO managed herds (Hudson and Frank 1987). Therefore, private organizations are not considered conservation herds, even if the primary management goal is conservation oriented (Gates et al. 2010). Contrary to this misconception, the Olson's Conservation Bison Ranches manages for conservation by following the "*Bison Conservation Management: Guidelines for Herd Managers"* (Lammers et al. 2013). The basis of our research was to evaluate the efficacy of this manual for managing bison in private herds from a conservation standpoint. The projects main objectives were to 1) calculate forage availability and determine bison diet composition to understand forage selection (Chapter 1), 2) calculate biomass production and estimate carrying capacity of bison (Chapter 1), 3) calculate bison neonatal survival and determine cause-specific mortality (Chapter 2), and 4) examine corridor movements of bison in aspen-dominated forests (Chapter 3).

STUDY AREA

Our study was conducted on Olson’s Conservation Bison Ranches, Pine River Ranch (51°47’N, 100°30’W), within the Rural Municipality of Mountain (south), Manitoba, Canada (Figure 0.1). The Pine River Ranch is encompassed by the Swan Lake Ecodistrict (SLE), within the Interlake Plain Ecoregion (IPE) of the Boreal Plains Ecozone (Smith et al. 1998, Thorpe 2014). The privately operated ranch encompasses 12,500 ha of nine cross–fenced pastures (Figure 0.2) and manages approximately 1,800 bison (Table 0.1; Round-up, March 2016). The pastures are comprised of both deeded land and Crownland leases (Table 0.2).

Topography of the region is predominantly ridge and swale with an average elevation of 260 m above mean sea level (Thorpe 2014). The IPE mean annual temperature is 1.4° C, ranging from 18° C in July to -18.8° C in January. The area receives 50.0 cm of annual precipitation (Smith et al. 1998, Land Resource Unit 2000, Thorpe 2014). The SLE growing season is approximately 174 days with 1644 growing degree-days annually (Agronomic Interpretations Working Group 1995, Thorpe 2014).

Land cover in proximity to the ranch primarily consists of tree cover (65.6%), grasslands (16.5%), wetlands (8.5%), and cropland (6.6%; Thorpe 2014). Overstory tree cover is dominated by upland species including trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), spruce (*Picea* spp.), and willows (*Salix* spp.). Vegetation is primarily sedge (*Carex* spp.), meadowgrass (*Poa* spp.), and reed (*Phalaris* and *Calamagrotis* spp.; Smith et al. 1998). Soil classification for the Rural Municipality of Mountain was characterized as predominately eutric brunisol, dark gray chernozem, gray luvisol, organic, regosol, and gleysol soils (Ellis 1938, Soil Classification Working Group 1998, Land Resource Unit 2000).

Free-roaming populations of large ungulates co-inhabiting the ranch include moose (*Alces americanus*), elk (*Cervus elaphus*), and white–tailed deer (*Odocoileus virginianus*). Predators previously observed on the ranch included American black bears (*Ursus americanus*), mountain lions (*Puma concolor*), gray wolves (*Canis lupus*), coyotes (*C. latrans*), lynx (*Lynx lynx*), and bobcats (*L. rufus*).

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Table 0.1. Sex and age class distribution for Olson's Conservation Bison Ranches, Pine River Ranch herd, Manitoba, Canada (March 2016).

Age	Males	Females	Total
Calves	217	325	542
Yearlings	165	166	331
2 yr olds	168	147	315
Adults (3+)	55	591	646
Total	605	1229	1834

Table 0.2. Deeded and Crown land lease hectares for pastures on Olson's Bison Conservation Ranches, Pine River Ranch, Manitoba, Canada.

Pasture	Crown Land Lease	Deeded	Total
Aires	841.75	194.25	1036.00
Center-East	502.22	687.97	1190.18
Center-West	32.37	453.25	485.62
East	2733.65	582.75	3316.40
Home	97.12	194.25	291.37
Hunter	682.71	0.00	682.71
New Pasture[1]	863.60	0.00	863.60
South	453.25	452.44	905.69
South Sclater	1911.33	0.00	1911.33
Ranch Total	10001.41	2564.90	12566.31

[1] *Pasture currently under construction east of hunter pasture.*

Figure 0.1. Olson's Conservation Bison Ranches, Pine River Ranch, in relation to Winnipeg, Manitoba, Canada.

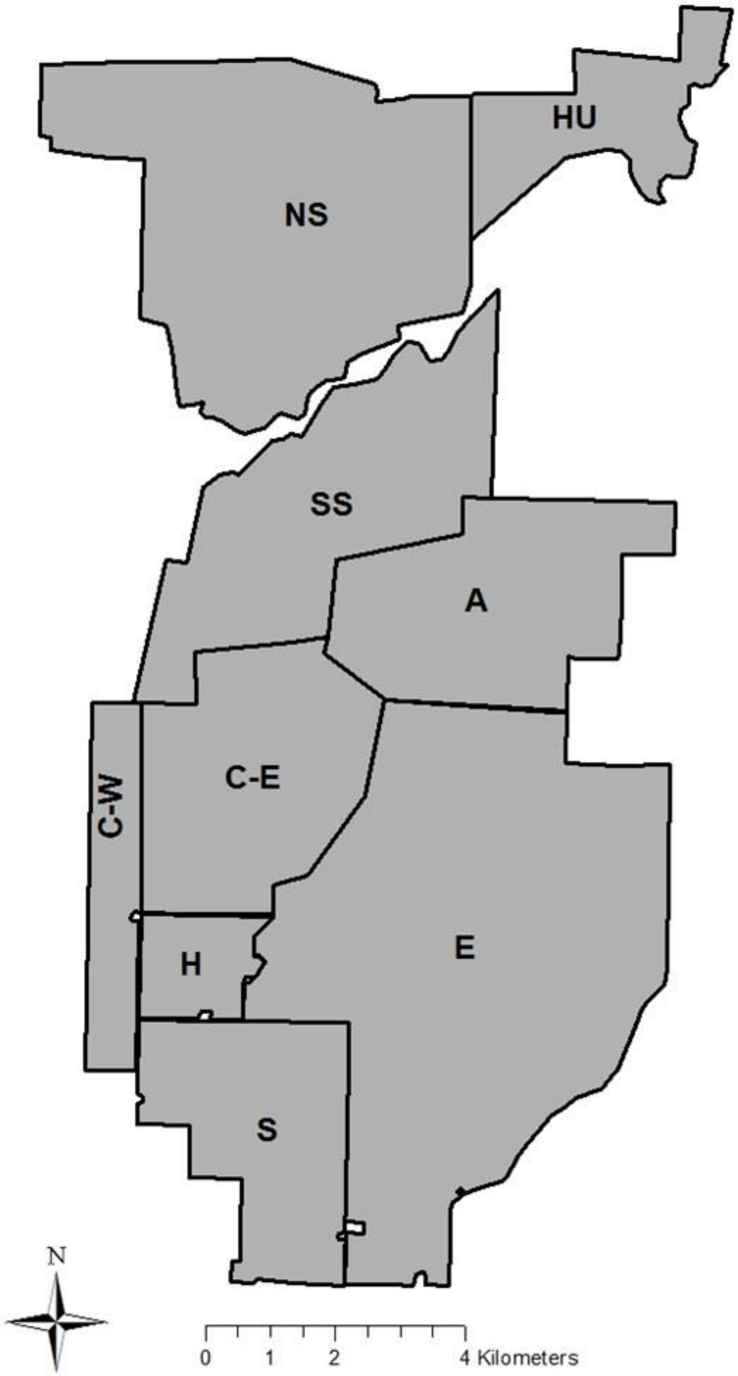

Figure 0.2. Olson's Bison Conservation Ranches, Pine River Ranch's Pastures: S (South), H (Home), C−W (Center−West), C−E (Center−East), SS (South Sclater), NS (North Sclater), HU (Hunter), A (Aires), and E (East), Manitoba, Canada.

CHAPTER 1: DNA BARCODING PLANT FRAGMENTS IN BISON FECES TO DETERMINE SUMMER DIET SELECTION ACCORDING TO FORAGE AVAILABILITY AND CALCULATING FORAGE BIOMASS PRODUCTION TO ESTIMATE CARRYING CAPACITY

This chapter is formatted for submission to Rangeland Ecology and Management and was coauthored by Lora B. Perkins and Jonathan A. Jenks

ABSTRACT

Bison were historically distributed throughout North America with the northern edge of the distribution occurring in North-central Manitoba and surrounding provinces. Despite bison occupying the boreal zone of North America, little is known of their forage selection patterns when occupying a densely forested aspen (*Populus* spp.) ecosystem. During June-August 2015, we initiated a study on Olson's Conservation Bison Ranch, Pine River, Manitoba, Canada, to examine forage selection patterns for bison (*Bison bison*) among and within summer months as well as calculate carrying capacity. We hypothesized that vegetative composition of bison diets would be consistent with availability, diets would shift along with forage availability, bison diets would predominately consist of grass and sedge species, and that the ranch is currently managing at, or below, carrying capacity. We opportunistically collected adult female fecal samples (N =100) and identified forage composition using the DNA barcoding method. We estimated availability of forage to the lowest taxonomical level possible using a modified Daubenmire frame and used the clip-plot method to estimate forage biomass production. Overall, bison diets were comprised of 44.3% grass, 37.7% forb, 16.3% browse, and < 2% sedge and rush. Forage availability was comprised of 51.2% grass, 28.3% forb, 1.7% browse, 11.0% sedge, and 7.6% rush. Total ranch biomass production equaled 11,662 animal unit months. All analyses indicated that use and availability differed ($P \leq 0.05$) for each taxonomical group throughout the summer. Grass and forbs were important dietary components for bison because combined, they comprised > 80% of bison diets. However, bison selected grass during June, but avoided grass during July and August, whereas bison selected forbs during July and August, but

avoided them in June. We recommend managing a maximum of ~2,200 total bison using rotational grazing during a 5–6 month period. Our results indicate that bison consumed more browse and other low cellulose, high cell soluble forages to meet their dietary needs. Thus, bison may act more like intermediate foragers similar to elk rather than grass-roughage feeders similar to cattle or sheep when inhabiting forested systems at the northern edge of their historical distribution.

INTRODUCTION

Historically, bison (*Bison bison*) inhabited most of North America, ranging as far north as Alaska and the Northwest Territories, to Mexico in the south, and spanning coast to coast, from New Jersey to California (Truett, 1996; Lammers et al., 2013). Bison currently occupy most of these same regions in North America, but information on bison forage selection in the Boreal Plains Ecozone is lacking. Bison were typically classified as grass-roughage feeders (Hofmann, 1989); almost exclusively foraging on graminoids, such as grasses (Poaceae) and sedges (Cyperaceae). However, recent research in mixed-grass prairies of the Midwest contradicts this classification, with bison diets comprising high concentrations of eudicots, primarily forbs (Bergmann et al., 2015; Craine et al, 2015).

Diet selection of herbivores is typically determined through vegetative composition comparison of use to forage cover-abundance (hereafter; availability; Larter and Gates, 1991). Selection of a food item can be assumed if use is greater than forage availability (Johnson, 1980). In contrast, avoidance of a food item can be assumed if use is less than availability (Klein, 1970; Johnson, 1980). Typically, herbivore diets are quantified using the microhistological analysis method, first described by Baumgartner and Martin (1939), and later verified in numerous studies (eg., Denham, 1965; Sparks and Malechek, 1968). Microhistological analysis is popular and has been used to quantify ungulate diets worldwide (Jenks et al., 1996; Schuette et al., 1998; Gibbs et al., 2004; Beck and Peek, 2005; Forsyth and Davis, 2011). DNA barcoding is a relatively new technique currently in use for analysis of herbivore diets (Valentini et al., 2009), and is gaining popularity (Czernik et al., 2013; Bergmann et al., 2015; Craine et al., 2015;

Kartzinel et al., 2015). The technique has proven more accurate for quantifying composition of complex plant mixtures; 75% of the plant DNA extracted from fecal samples was identifiable to the genus level, versus 20% using microhistological analysis (Soininen et al., 2009).

Knowledge on forage selection by bison allows managers to accurately calculate carrying capacity in animal unit months (AUM's) for individual pastures and the ranch as a whole. An AUM is the amount of forage that a 454 kg bison consumes in one month (360 kg dry weight; Heitschmidt and Taylor, 1991). AUM's are often determined by the clip-plot method to calculate the amount of forage produced (hereafter; biomass) within a closed system (Larter et al., 2000; Strong and Gates, 2009). Accurate estimates for carrying capacity ensures that sufficient forage is available for bison to grow and successfully reproduce. Moreover, grazing at or below carrying capacity maximizes forage species diversity and increases overall production of the rangeland (Sanderson et al., 2004). However, information regarding biomass production and carrying capacity estimates for the Pine River Ranch is lacking.

Plains bison (*B. bison bison)* and wood bison (*B. bison athabascae*) diets have been analyzed across North America using microhistological analysis and observational forage bouts (Tables 1.1 and 1.2; Penden, 1976; Reynolds et al., 1978; Larter and Gates, 1991; Plumb and Dodd, 1993; Knapp et al., 1999). To our knowledge, only two studies have analyzed bison feces using DNA barcoding (Bergmann et al., 2015; Craine et al., 2015); however, neither study included analysis of forage availability to assess diet selection. Therefore, the objectives of our study were to 1) determine forage selection patterns for bison among and within summer months and to 2) estimate carrying capacity for bison on the Pine River Ranch in central Manitoba. We hypothesized that vegetative composition of bison diets would be equal to availability and that bison diets would shift along with the availability of forage within pastures. Moreover, we hypothesized that bison would select for grass and sedge species in line with their classification as grass-roughage feeders (Hofmann, 1989). Additionally, we hypothesized the Pine River Ranch was currently at, or below, carrying capacity.

METHODS

Forage Availability

Prior to sampling, we identified fields within pastures by searching them on a utility terrain vehicle or using satellite imagery; polygons for pastures were later delineated using ArcGIS 10.3 (ESRI, Redlands, CA, USA). We generated random sample points in ArcGIS within fields available to bison to estimate forage availability using a modified Daubenmire (1959) frame. At each sample point (N = 198), we placed a 25-cm^2 frame, 1 m from plot center, in each cardinal direction (Figure 1.1). We identified grass, forb, browse, sedge, and rush to the lowest taxonomical level and estimated aerial cover. We estimated cover score (0-20) for each species within 5% intervals ranging from 0-100% cover within each frame. Unknowns were classified as either “unknown grass”, “unknown sedge”, “unknown forb”, “unknown rush”, or “unknown browse”.

Fecal Collection

We collected fresh adult female bison fecal samples (N = 100) from June−August 2015. Fecal samples were collected opportunistically to ensure freshness and stored in test tubes with dry silica beads. We mixed a 4:1 ratio of dry silica beads to feces, respectively, to ensure complete desiccation (Murphy et al., 2002). Samples were stored at room temperature (~ 21–24°C) until DNA extraction.

DNA Extraction

Desiccated fecal samples were submitted to Jonah Ventures (Boulder, CO) for DNA analysis. Genomic DNA from samples was extracted using the MoBio PowerSoil htp-96 well Isolation Kit (MoBio, Carlsbad, CA) according to the manufacturer's protocol. A portion of the chloroplast trnL intron was PCR amplified from each genomic DNA sample using the c and h trnL primers (Taberlet et al., 2007). Both primers also contained a 5' adaptor sequence to allow for subsequent indexing and Illumina sequencing. Each 40 µL PCR reaction was mixed according to the Promega PCR Master Mix specifications (Promega catalog # M5133, Madison, WI), which included 0.4uM of each primer and 3.2 µl of gDNA. DNA was PCR amplified using the following conditions: initial denaturation at 94°C for 1 minute, followed by 36 cycles of 1 minute at 94°C, 30 seconds at 55°C, 30 seconds at 72°C, and a final elongation at 72 C for 1 minute. Amplicons were then cleaned using the UltraClean-htp 96 well PCR Clean-up kit (Mo Bio) according to the manufacturer's specifications and stored at 4 °C. A second round of PCR was performed to give each sample a unique 12-nucleotide index sequence. The indexing PCR included Promega Master mix, 0.5uM of each primer, and 4 ul of template DNA (cleaned amplicon from the first PCR reaction) and consisted of an initial denaturation of 95 °C for 3 minutes followed by 8 cycles of 95°C for 30 sec, 55°C for 30 seconds, and 72°C for 30 seconds. After the trnl-specific and indexing PCR reactions, 5µl of PCR products of each sample were visualized on a 2% agarose gel. Final indexed amplicons from each sample were cleaned and normalized using SequalPrep

Normalization Plates (Life Technologies, Carlsbad, CA) prior to being pooled for sequencing on an Illumina MiSeq (San Diego, CA) in the Colorado University Boulder BioFrontiers Sequencing Center using the v2 300-cycle kit (cat# MS-102-2002).

DNA Sequencing

TrnL amplicons were processed via the UPARSE pipeline (Edgar, 2013) and assigned taxonomy via the UTAX protocol (http://www.drive5.com/usearch/manual/utax_user_train.html) available in usearch (v8.1.1861) (Edgar, 2013). Sequences were de-multiplexed using a python script available from: https://github.com/leffj/helper-code-for-uparse/blob/master/prep_fastq_for_uparse_paired.py). Paired end reads were then merged using the -*fastq_mergepairs* option of usearch (Edgar 2010). Because merged reads often extended beyond the amplicon region of the sequencing construct (staggered merges; http://drive5.com/usearch/manual/cmd_fastq_mergepairs.html), usearch automatically trims overhangs, essentially removing the majority of primer and adapter regions. Further filtering of any primers and adapter regions that may remain were removed using cutadapt (Martin, 2011). Sequences were quality trimmed to have a maximum expected number of errors per read of less than 0.5.

To assign taxonomy to each operational taxonomic unit (OTU), an “in-house” UTAX trnL reference database was constructed by downloading annotated GenBank (Benson et al., 2005) records that contained the trnL gene. The amplicon region bounded by the trnL c & h primers (Taberlet et al., 2007) was extracted from the GenBank records using the UTAX protocol. All extracted amplicon regions were de-replicated to 100% sequence identity and any identical sequences across lineages were collapsed to the lowest-common-ancestor. Closed-reference OTUs were generated by searching against the trnL reference database at 99% sequence similarity. To ensure increased specificity of trnL OTU assignment against the reference database the -*maxaccepts* and -m*axrejects* usearch options were increased to 64 and 256, respectively.

Biomass Production

We calculated forage biomass using the clip plot method along with the aforementioned sample schematic (Figure 1.1); however, only the eastern subplot was clipped. We clipped and collected all forage 2-3 cm above the ground covering the 25-cm^2 subplot up to 2 m high (Larter et al., 2000; Strong and Gates, 2009). All samples were dried at 35 °C in a conventional oven for approximately 48 hours. We compiled subplot weights and averaged biomass production for each field. We then calculated bison animal unit months (AUM) for each pasture using our clipped plot results for deeded land and compiled them with AUM estimates available through Crown-land lease agreements. We estimated that roughly 454 kg of dry matter was required for one mature cow (~ 454 kg)-calf pair to graze for one month (1.0 AUM; Heitschmidt and Taylor, 1991), allocating ~ 20% for waste.

Dietary Statistical Analysis

We used ANOVA (JMP 12; SAS Institute 2013) to calculate compositional differences of taxonomical groups: grass, forb, browse, sedge, and rush, for assessing bison use and availability of forage throughout the summer. We had two type variables, bison use and availability, and three time intervals, June, July, and August. Additionally, we sampled two separate pastures during August to evaluate within month variation of diet selection. The among month ANOVAs investigated the difference of type, month, and the interaction of type and month. Data from both August samples were pooled for among month analyses. The within month ANOVA investigated the difference of forage type between the two pastures to determine their similarity.

We calculated selection indices for taxonomical groups for each month to understand how bison foraging shifted throughout the summer. Additionally, we calculated selection indices for both pastures sampled in August. Selection indices were the percentage of plant composition in diets compared to the percent composition of vegetation available (Krueger, 1973; Rosiere et al., 1975; Ramírez et al., 1993). Typically, an index of 1.0 indicates that percentage of forage in diets was equal to availability, however, we subtracted 1 from all indices so 0 would indicate equal diets and availability:

$$\text{Selection Index} = \frac{\%\ \text{plant composition in diet}}{\%\ \text{plant composition available}} - 1$$

Thus, indices > 0 indicated selection by bison, while indices < 0 indicated avoidance (Beck, 1975; Beck and Peek, 2005).

RESULTS

Diet Selection

Overall, bison diets were comprised (mean ± SEM) of 44.3 ± 3.5% grass, 37.7 ± 2.6% forb, 16.3 ± 2.3% browse, 1.1 ± 2.4% sedge, and 0.6 ± 1.3% rush, while forage availability was 51.2 ± 1.9% grass, 28.3 ± 1.5% forb, 1.7 ± 1.3% browse, 11.0 ± 1.3% sedge, and 7.6 ± 0.7% rush. Bison selection differed ($P \leq 0.05$) for each taxonomical group between months throughout the summer (Figure 1.2). Grass and forbs comprised > 80% of bison diets. However, bison selected grass during June (0.19), but avoided grass during July (–0.45) and August (–0.18), whereas bison selected forbs during July (0.92) and August (0.74), but avoided them in June (–0.06; Table 1.3; Figure 1.3). Bison avoided rush and sedge, while browse was highly selected throughout all summer months (Table 1.3).

Bison diets in August were comprised of 46.0 ±3.2% grass, 34.0 ± 2.0% forb, 17.4 ± 2.3% browse, 1.9 ± 2.2 sedge, and 0.6 ± 0.7% rush (Figure 1.2). Forage availability was comprised of 56.1 ±3.2% grass, 19.6 ± 2.0% forb, 1.4 ± 2.3% browse, 18.2 ± 2.2% sedge, and 4.6 ± 0.7% rush (Figure 1.2). Moreover, bison use and availability differed ($P \leq 0.05$) for grass, forbs, browse, sedge, and rush within the month of August (Figure 1.4). Selection indices were similar for browse, forbs, sedge and rush for both North and South Sclater pastures. However, bison use of grass differed ($P < 0.01$) in August; bison selected grass in North Sclater (0.08) and avoided grass in South Sclater (–0.45; Figure 1.5).

Grass was exclusively comprised of species from the family Poaceae predominantly consisting of *Poa palustris, Agrostis stolonifera, Bromus inermis, Phleum pratense, Phalaris arundinacea, Agropyron* spp., *Festuca* spp., *Elymus* spp., *Glyceria* spp., and *Calamagrotis* spp. Forbs were primarily comprised by the following (sub)-families in descending order of average composition (17.9%–1.3%): Asteraceae, Rosaceae, Fabaceae, Primulaceae, Chenopodioideae, Equisetaceae, and Plantaginaceae. Browse was comprised of Salicaceae, Betulaceae, Cornaceae, Aceraceae, Pinaceae, and Apocynaceae, with species predominately including *Acer negundo*, *Populus tremuloides, P. balamifera*, *Larix laricina, Salix* spp., *Betula* spp., *Alnus* spp., and *Pinus* spp. Sedge species included: *Carex bebbii*, *C. utriculata*, *C. aenea*, *C. aurea*, *C. sartwelli*, *C. disperma*, *C.* spp., *Schoenoplectus* spp., and *Eleocharis* spp. Rushes included *Juncus balticus*, and *J. dudleyi*.

Biomass Production

The Pine River Ranch produced approximately 5,294,548 kg of forage, sustaining 11,662 AUM's across nine cross-fenced pastures, annually (Table 1.4).

DISCUSSION

Diet Selection

Browse comprised 16.3% of all bison summer diets, which is unusually high considering bison do not typically utilize woody vegetation, unlike cattle (Figures 1.2 & 1.4; Plumb and Dodd, 1993). Moreover, browse selection indices were extraordinarily high in comparison to previously reported indices of 0.25 and 0.10 (Table 1.3; Plumb and Dodd, 1993). These high indices may be a result from a lack of sampling forest vegetation. Forests in our study were not sampled as research has shown that bison spend 80% of their time in or within 25 m of meadows (Fortin et al.; 2003).

Research indicates that aspen stands in central Canada have been expanding in the last 100 years (Strong, 1977; Looman, 1979; Archibold and Wilson, 1980; Hildebrand, 1987), occupying grassland prairies, thus, increasing the probability of bison, and other large ungulates with large bite sizes (Hudson and Frank, 1987), incidentally consume young growth of encroaching woody vegetation. Additionally, high-protein plants, such as eudicots, may be over-represented in the trnL libraries relative to biomass density as protein concentration among plants is likely to be associated with differences in chloroplast density (Bergmann et al., 2015). Therefore, future research is necessary to determine if proportions of trnL sequences in fecal samples are similar to those consumed. Moreover, information is lacking on whether DNA degradation of consumed forages from different taxonomical groups is equal or disproportionate. This, along with the lack of management to limit forest encroachment into fields on this ranch and the surrounding area, may explain the high browse consumption. Nevertheless, our results suggest that future sampling of forest vegetation may be advantageous to determine if browse is an essential forage class for bison or if it is being incidentally consumed.

Our sampling was restricted to the summer as bison were supplementally fed throughout remaining seasons (Fall–Spring). Sampling year-round would contribute significantly to understanding how bison diets shift on a seasonal time scale as research has shown when foraging in a similar habitat, bison almost exclusively forage on sedge during the winter (Larter and Gates, 1991). If free-roaming bison in the Boreal Plains Ecozone exhibit the same behavior, then management for a more heterogeneous vegetation schematic would be favored to meet dietary requirements for bison year-round. Moreover, the sedge bison avoided during the summer might prove beneficial for bison during the winter months.

Change in dietary composition throughout the summer was not surprising as North American bison are temperate ruminants that take advantage of available vegetation during this season (Schuler et al., 2006; Fortin and Fortin, 2009). However, bison diets did not shift according to availability as predicted. Grass became more abundant as summer progressed, but use declined, whereas, use of forbs increased as availability decreased (Figure 1.2). This result may be explained by plant phenology (Bergmann et al., 2015); herbivores tend to forage on new growth that is higher in moisture and protein content, while lower in fiber and secondary metabolites, which yields forages with higher digestibility and palatability (Craine, 2009). Moreover, as the cell walls of grass develop, phenolic acids and lignin are deposited, lowering digestibility and palatability over time (Jung and Allen, 1995). However, grass-roughage feeders like bison and cattle have evolved to exploit forage with low digestibility, thus, suggesting bison may not actually be a predominately grass-roughage feeder (Hofmann, 1989). Nevertheless, bison diet selection was likely influenced by an interaction between forage availability, palatability, and timing of when plants are most nutritious as bison select for high-protein plant species (Coppock et al., 1983; Larter and Gates, 1991; Fortin et al., 2003). Thus, it would be advantageous to calculate diet selection of free–roaming bison in a landscape similar to central Manitoba to determine what may be driving bison forage selection.

Historically, bison have been considered to be strict grazers (Penden, 1976; Reynolds et al., 1978; Plumb and Dodd, 1993; Coppedge and Shaw, 1998; Knapp et al., 1999) and are currently classified as grass-roughage feeders (Hofmann, 1989), similar to that of cattle and sheep. However, our data, along with others (Bergmann et al. 2015; Craine et al. 2015), has indicated that eudicots, such as forbs and browse, comprised a large proportion of bison diets (Figures 1.2 & 1.4). Not only were forbs and browse a large proportion of bison diets (> 50%), they were selected when grasses were abundant, suggesting that bison may actually be intermediate feeders (Hofmann, 1989). A common example of an intermediate feeder is an elk (*Cervus elaphus*). Elk diets in both the forested ecosystem of the Pacific Northwest and the mixed conifer-prairie ecosystem of the mid-west predominately consume grass and forb classes during the summer months (Leslie et al., 1984; Gibbs et al., 2004). Summer dietary shifts of elk were similar to that of bison in our study in that grasses dominated diets in June and shifted to forbs during July and August, again, suggesting a change in the forage characterization of bison.

Although suggestions have been made that bison diets may be changing as a result of climate change (Craine et al., 2015), we believe that an alternative hypothesis for this diet shift may be due to the spatial limitations enforced on bison. It is plausible to believe that bison diets may be more similar to those of their nomadic ancestors given the ability to migrate across North America. Most ruminants occupying the Afrotropic and Holarctic ecozones shift their diets seasonally (Hjeljord et al., 1990; Watson and Smith, 2002; Tshabalala et al., 2010), and those that do not change diets respond via migration (Wilmshurst et al., 1999; Sawyer and Kauffman, 2011). Large ruminants, including bison, are sometimes migratory (Berger, 2004). Migration is a strategy in which animals maximize fitness during seasonal and variation in spatial resources (Boyce, 1979; Swingland and Greenwood, 1983). Moreover, migration allows individuals to maximize intake rates of high quality forage by following spatiotemporal patterns (i.e; pheonological gradients; Fryxell et al., 2004; Hebblewhite et al., 2008). However, now spatially limited, bison may have adapted to shift their diets seasonally and consume more browse and other low cellulose, high cell soluble forages to meet their dietary needs. Thus, suggesting that domestication of bison may have resulted in foraging behaviors more similar to elk and other intermediate feeders than that of cattle or sheep, especially at the northern edge of the historical distribution of the species.

Biomass Production

Bison on the Pine River Ranch rotationally graze approximately six months of the year (May–October) without being supplementally fed. They are supplementally fed alfalfa-grass hay mixture and grain, primarily oats and barley, during the harsh winter and into early spring as forage is minimal and covered in deep snow. We recommend a maximum population of 2,200 bison to ensure adequate forage is available throughout the grazing period given the annual biomass production of the Pine River Ranch. However, our estimate for carrying capacity is likely low since precipitation was below average in central Manitoba during spring and summer of 2015 (R. Metcalfe, personal communication). Biomass production was likely lower in 2015 than average as research has shown that biomass production is directly related to precipitation during spring and summer (Coe et al., 1976). Additionally, our estimates may be low as we did not account for the high browse consumption revealed by dietary analysis (Figures 1.2 & 1.4). If bison are purposefully consuming browse, then carrying capacity would be greater given the high prevalence of woody vegetation on the ranch. However, we still recommend managing ≤ 2,200 bison as annual precipitation can fluctuate annually and the use of browse by bison is not yet fully understood.

IMPLICATIONS

Bison reintroductions across North America are becoming more widely implemented (ADF&G, 2015; Banff National Park, 2015; Steenweg et al., 2016), thus increasing the need for information regarding bison diet selection across their historical range. To date, management plans and estimates of stocking rates for bison have focused primarily on providing sufficient forage availability of monocots (eg., grasses, sedges, and rushes). However, the diet results from the DNA barcoding provides insight that managing for a diverse vegetation schematic may be advantageous to meet bison dietary needs year–round. If browse is an essential component in bison diets, than carrying capacity estimates may be higher than previously expected in densely forested areas inhabited by bison. Moreover, use of this relatively new, but highly accurate technique to understand bison dietary selection shifts in potential reintroduction sites will be crucial for future success. Thus, we hope public and private herd managers will continue to use the DNA barcoding technique to analyze bison diets across multiple ecoregions to expand on the knowledge of bison diet selection to maximize likelihood for successful reintroductions.

ACKNOWLEDGEMENTS

Research was funded in part by Olson's Conservation Bison Ranches and the Department of Natural Resource Management at South Dakota State University. We thank D. J. Lammers and R. Metcalfe for field and logistical support. Thanks also to J. M. Craine and A. J. Beckley, Jonah Ventures, Boulder, Colorado, for analysis of bison fecal samples. We thank M. Elsinger and Agriculture and Agri-Food Canada, Brandon, Manitoba, for technical assistance and use of their ovens for drying forage samples. N. Martorelli provided statistical assistance.

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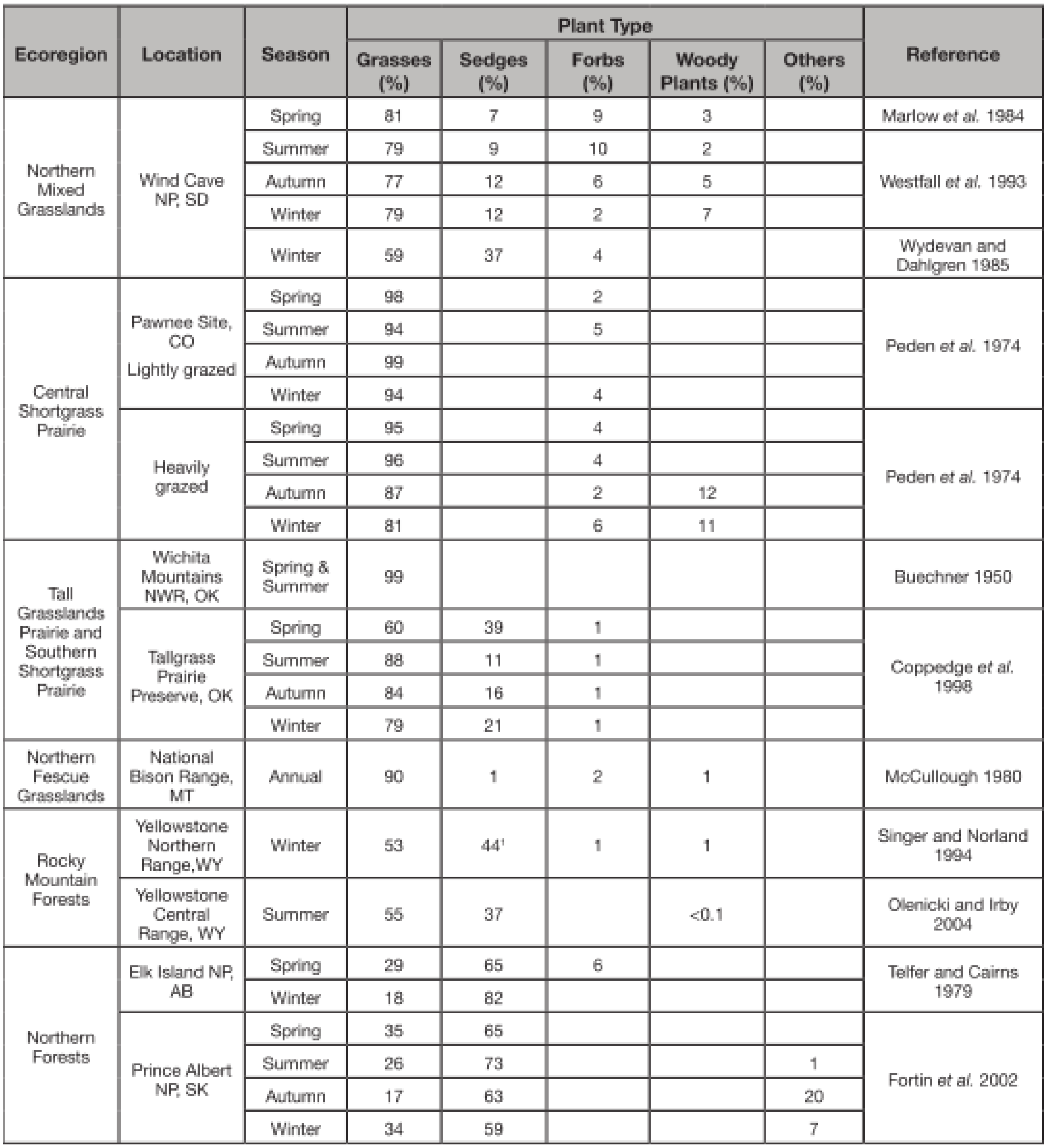
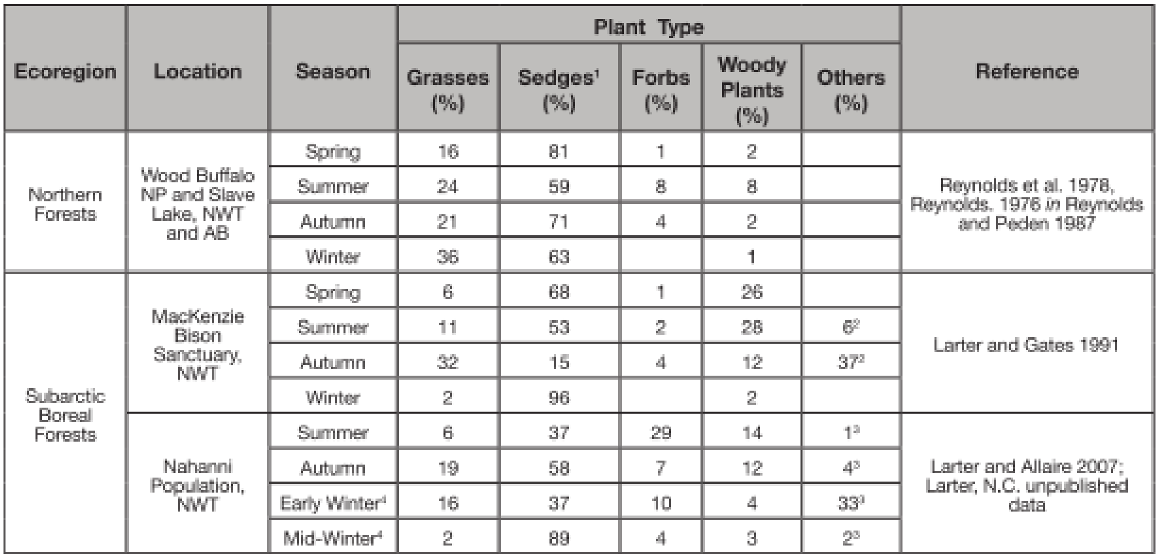
Table 1.1. Plains bison (*Bison bison bison*) diet composition within North American ecoregions (Gates et al. 2010).



Ecoregion	Location	Season	Plant Type					Reference
			Grasses (%)	Sedges (%)	Forbs (%)	Woody Plants (%)	Others (%)	
Northern Mixed Grasslands	Wind Cave NP, SD	Spring	81	7	9	3		Marlow *et al.* 1984
		Summer	79	9	10	2		Westfall *et al.* 1993
		Autumn	77	12	6	5		
		Winter	79	12	2	7		
		Winter	59	37	4			Wydevan and Dahlgren 1985
Central Shortgrass Prairie	Pawnee Site, CO Lightly grazed	Spring	98		2			Peden *et al.* 1974
		Summer	94		5			
		Autumn	99					
		Winter	94		4			
	Heavily grazed	Spring	95		4			Peden *et al.* 1974
		Summer	96		4			
		Autumn	87		2	12		
		Winter	81		6	11		
Tall Grasslands Prairie and Southern Shortgrass Prairie	Wichita Mountains NWR, OK	Spring & Summer	99					Buechner 1950
	Tallgrass Prairie Preserve, OK	Spring	60	39	1			Coppedge *et al.* 1998
		Summer	88	11	1			
		Autumn	84	16	1			
		Winter	79	21	1			
Northern Fescue Grasslands	National Bison Range, MT	Annual	90	1	2	1		McCullough 1980
Rocky Mountain Forests	Yellowstone Northern Range,WY	Winter	53	44[1]	1	1		Singer and Norland 1994
	Yellowstone Central Range, WY	Summer	55	37		<0.1		Olenicki and Irby 2004
Northern Forests	Elk Island NP, AB	Spring	29	65	6			Telfer and Cairns 1979
		Winter	18	82				
	Prince Albert NP, SK	Spring	35	65				Fortin *et al.* 2002
		Summer	26	73			1	
		Autumn	17	63			20	
		Winter	34	59			7	

Table 1.2. Wood bison (*Bison bison athabascae*) diet composition within North American ecoregions (Gates et al. 2010).



Ecoregion	Location	Season	Plant Type					Reference
			Grasses (%)	Sedges[1] (%)	Forbs (%)	Woody Plants (%)	Others (%)	
Northern Forests	Wood Buffalo NP and Slave Lake, NWT and AB	Spring	16	81	1	2		Reynolds et al. 1978, Reynolds, 1976 *in* Reynolds and Peden 1987
		Summer	24	59	8	8		
		Autumn	21	71	4	2		
		Winter	36	63		1		
Subarctic Boreal Forests	MacKenzie Bison Sanctuary, NWT	Spring	6	68	1	26		Larter and Gates 1991
		Summer	11	53	2	28	6[2]	
		Autumn	32	15	4	12	37[2]	
		Winter	2	96		2		
	Nahanni Population, NWT	Summer	6	37	29	14	1[3]	Larter and Allaire 2007; Larter, N.C. unpublished data
		Autumn	19	58	7	12	4[3]	
		Early Winter[4]	16	37	10	4	33[3]	
		Mid-Winter[4]	2	89	4	3	2[3]	

Table 1.3. Bison diet selection indices (mean ± standard error) for functional groups throughout the summer on Olson's Conservation Bison Ranch's, Pine River Ranch, Manitoba, Canada.

Taxonomical Group	Month		
	June	July	August
Browse	6.76 ± 2.97	7.45 ± 1.44	10.98 ± 2.20
Forb	–0.06 ± 0.10	0.92 ± 0.13	0.74 ± 0.13
Grass	0.19 ± 0.09	–0.45 ± 0.05	–0.18 ± 0.06
Rush	–0.92 ± 0.06	–0.95 ± 0.02	–0.85 ± 0.04
Sedge	–0.98 ± 0.01	–0.94 ± 0.01	–0.90 ± 0.03

Table 1.4. Deeded land and Crown land lease AUM pasture estimates for Olson's Bison Conservation Ranches, Pine River Ranch, Manitoba, Canada.

	Crown Land		Deeded Land		Pasture Total	
Pasture	Hectares	AUMs	Hectares	AUMs	Hectares	AUMs
Aires	841	327	194	390	1035	717
Center-East Side	502	344	687	1045	1189	1389
Center-West Side	32	32	453	930	485	962
East	2733	2136	583	895	3316	3031
Home	97	209	194	575	291	784
Hunter	683	1055	0	0	683	1055
New Pasture[1]	864	587	0	0	864	587
North Sclater	2747	1629	0	0	2747	1629
South	453	313	452	965	905	1278
South Sclater	1911	817	0	0	1911	817
Pasture Total	10863	7449	6338	2563	13426	12249

[1] *Pasture currently under construction east of hunter pasture.*

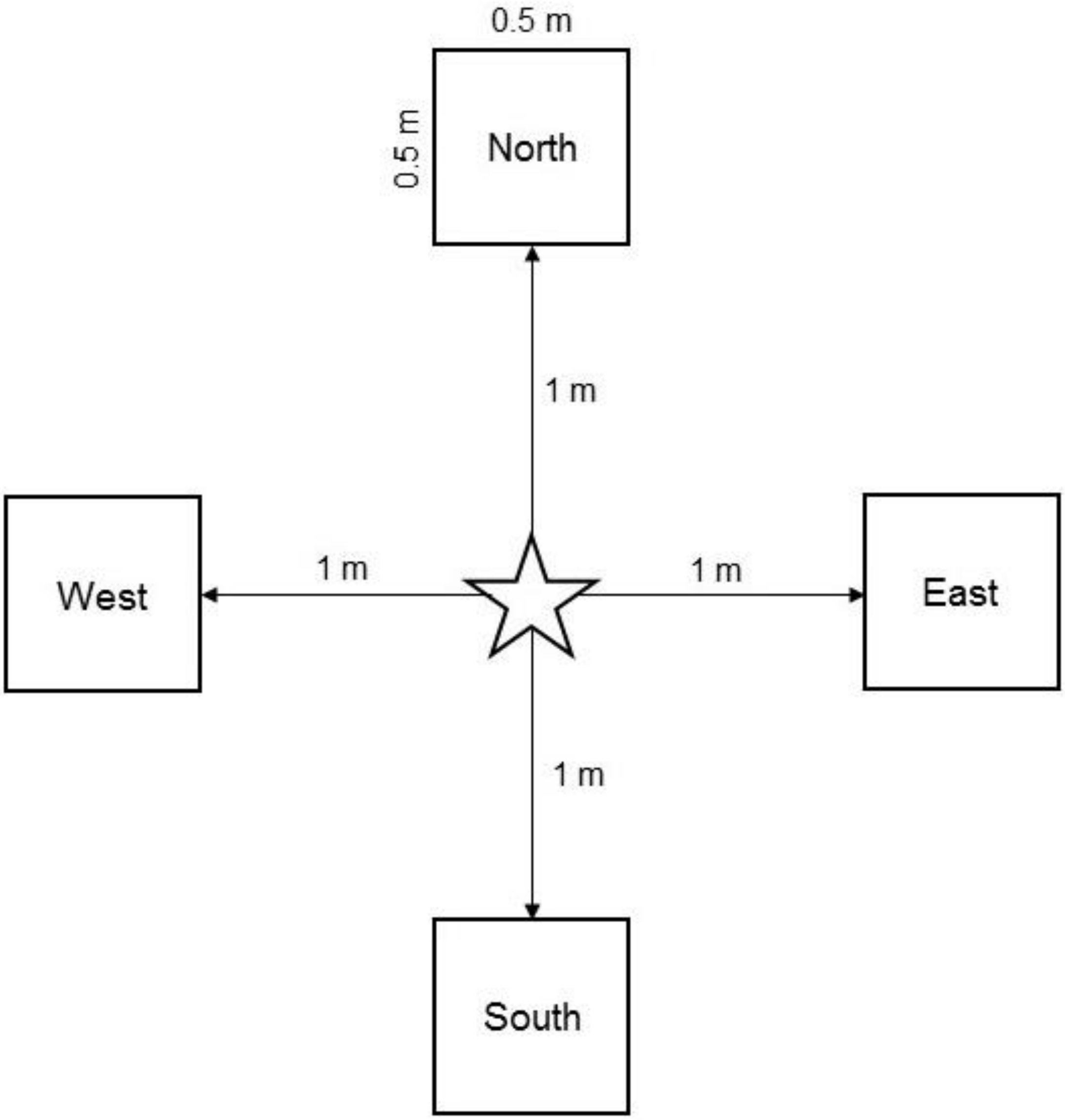


Figure 1.1. Daubenmire sampling schematic for estimating forage availability on the Olson's Bison Conservation Ranch's, Pine River Ranch, Manitoba, Canada. Star = sampling point.

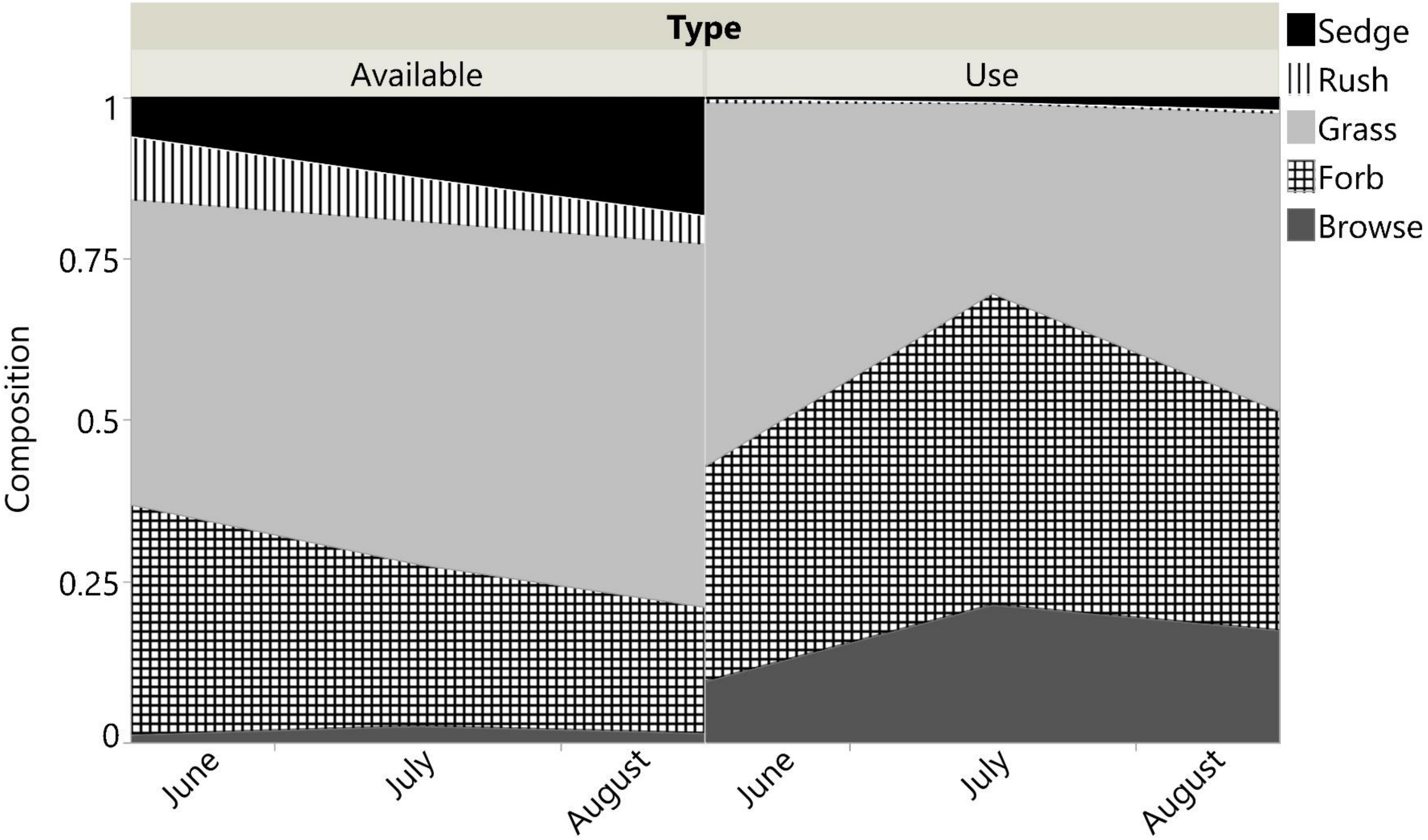


Figure 1.2. Compositional comparison of bison use and forage availability between months for browse, forb, grass, rush, and sedge on Olson's Conservation Bison Ranch's, Pine River Ranch, Manitoba, Canada.

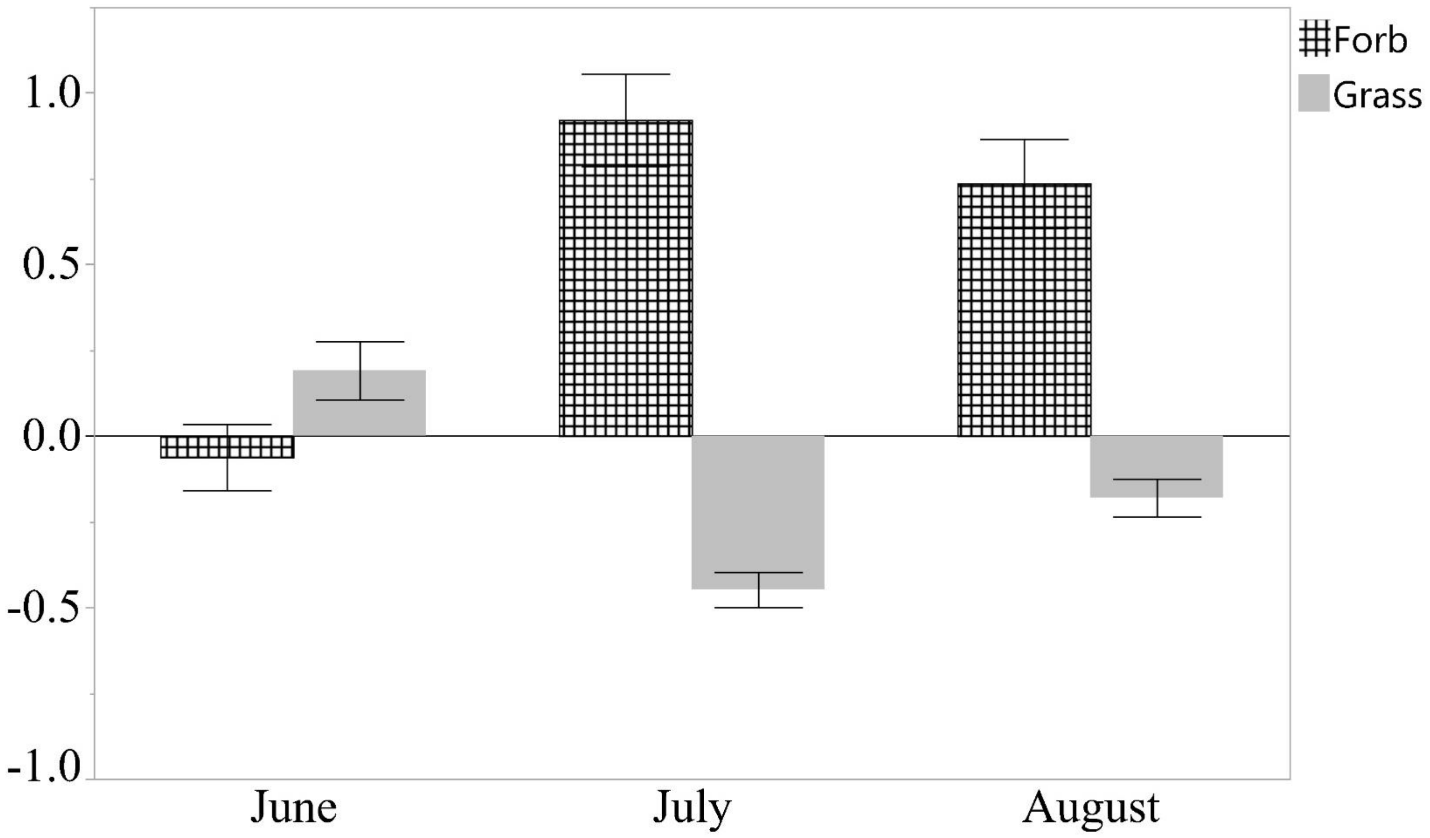


Figure 1.3. Forb and grass selection indices for summer bison diets on Olson’s Conservation Bison Ranch’s, Pine River Ranch, Manitoba, Canada. Each error bar is constructed using 1 standard error from the mean.

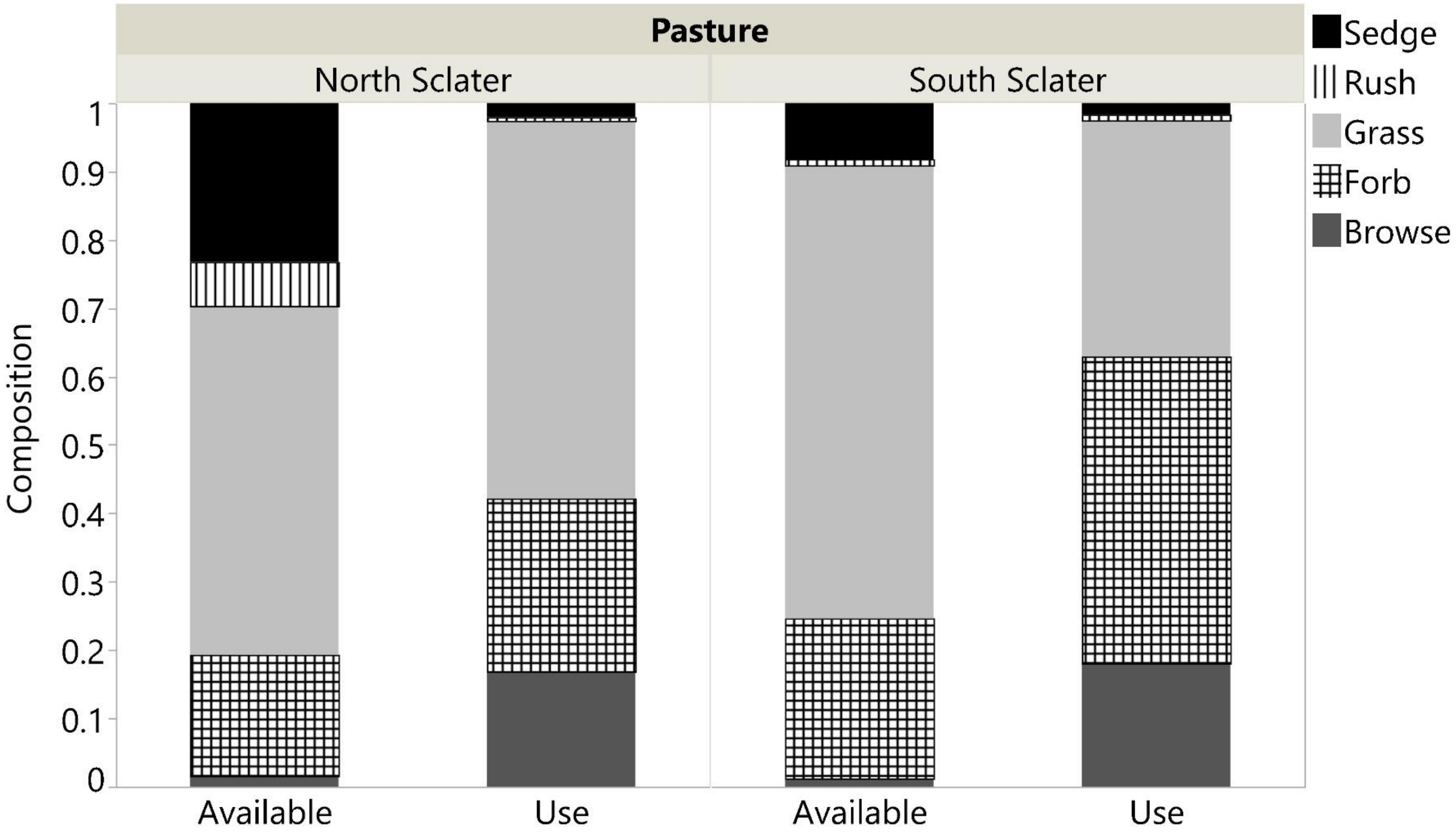


Figure 1.4. Compositional comparison of bison use and forage availability for North and South Sclater pastures within the month of August for browse, forb, grass, rush, and sedge on Olson's Conservation Bison Ranch's, Pine River Ranch, Manitoba, Canada.

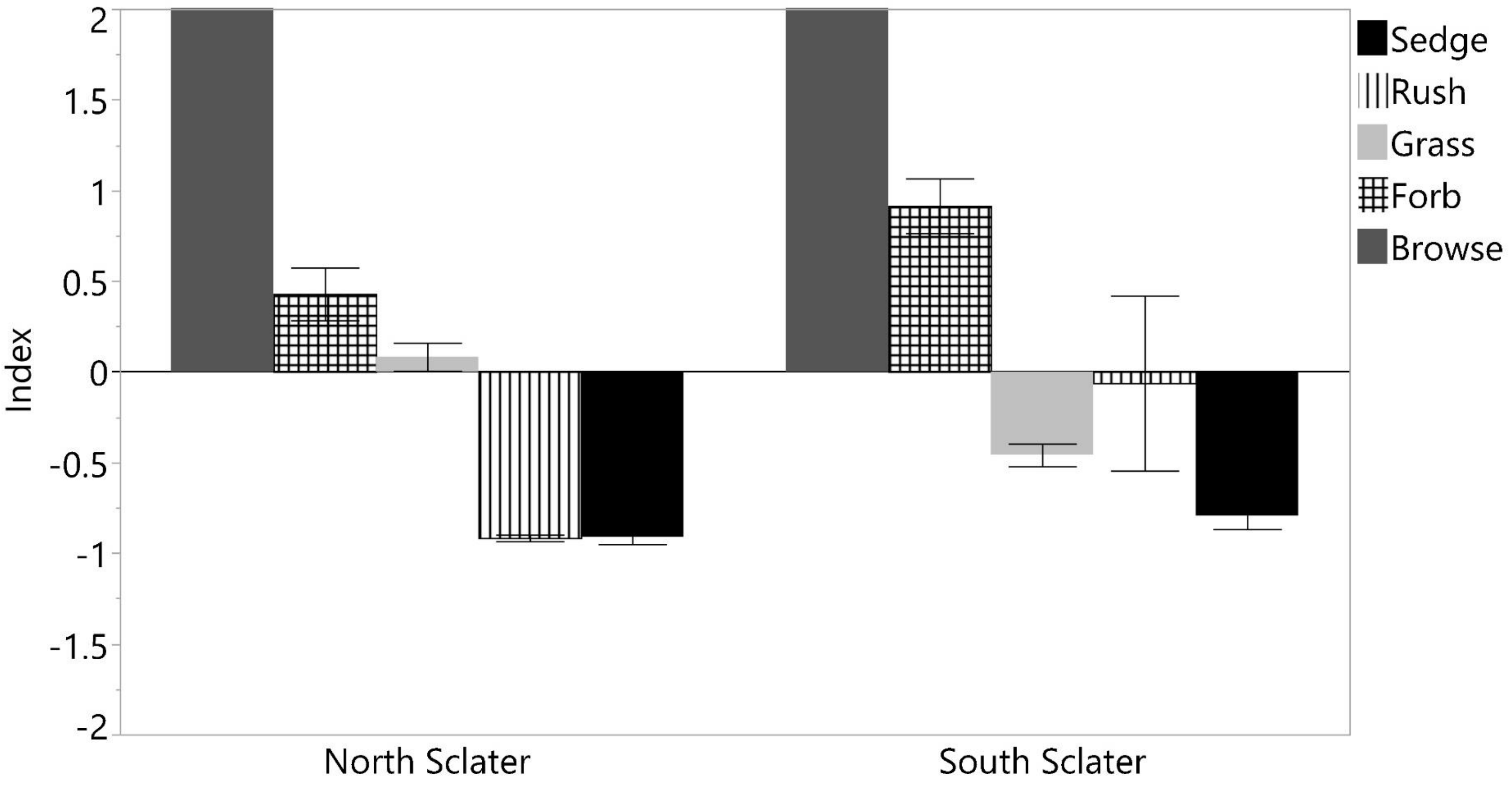


Figure 1.5. Bison diet selection indices for functional groups in North and South Sclater pastures for the month of August on Olson's Conservation Bison Ranch's, Pine River Ranch, Manitoba, Canada. North and South Sclater browse indices are 9.67 and 14.09, respectively. Each error bar is constructed using 1 standard error from the mean.

CHAPTER 2: A NEW APPROACH TO CAPTURE NEONATE BISON TO DETERMINE SURVIVAL, CAUSE-SPECIFIC MORTALITY AND MODEL FUTURE POPULATIONS

This chapter is formatted for American Midland Naturalist and is coauthored by Will M. Inselman, Lora B. Perkins, Troy W. Grovenburg, and Jonathan A. Jenks

ABSTRACT

Knowledge of ungulate neonate survival allows for estimation of recruitment; crucial information for management decisions allocating harvest or cull rates, depending if the population is to remain stable, increase, or decline. However, survival rates for neonatal bison are mostly observational and anecdotal, which can be attributed to the lack of information on techniques to effectively capture and safely handle neonates. In May–July 2015, we initiated a study on Olson's Bison Conservation Ranches, Pine River Ranch, Manitoba, Canada, to evaluate a new approach to effectively capture and handle neonate bison, monitor known-fate survival, and model future populations using both empirical and theoretical parameters. We captured bison neonates using a modified .308 caliber net–gun deployed from a utility terrain vehicle. We successfully captured and radio–tagged 10 male and 16 female neonate bison in 37 attempts (70.3% success). Over a period of four days, 16.0 man hours were spent pursuing and handling neonates, with an average capture rate of one bison neonate for every 0.6 man hours. Average handling time of bison neonates was 3.7±1.6 mins and ranged from 1.0−7.5 mins. Monitoring of neonate survival was limited to 77 days as all ear tags were dislodged to unknown circumstances. One mortality was observed resulting in an apparent survival of 96.7 % for neonates 0-2 months of age. Results of our study indicate that our approach was effective and efficient for capturing and handling bison neonates safely. No injuries or capture related mortalities were observed throughout the capture process and monitoring period. With the development of an effective transmitter for bison neonates, our capture approach will allow biologists to monitor neonate survival and collect cause–specific data on mortality of neonates in managed bison populations.

INTRODUCTION

Knowledge regarding neonate survival and cause−specific mortality rates are essential parameters to model populations (Lebreton *et al.*, 1992). Understanding neonate survival rates allows for estimation of recruitment; crucial information for management decisions allocating harvest or cull rates, depending if the population is to remain stable, increase, or decline (Williams *et al.*, 2002). Neonate ungulate survival rates can be low because of their vulnerability to predation (Barrett, 1984). Effective management decisions are difficult to make, if not impossible, lacking estimates of neonate survival for a given population. Although knowledge of survival rates for a population is essential, determining cause-specific mortality is equally important (Keller *et al.*, 2013). Previous research suggests that maintaining a stable population with high neonatal mortality is difficult (Cook *et al.*, 1971). Information regarding cause-specific mortality within a population allows for alterations in management practices to potentially increase survival and recruitment rates.

Survival rates for bison ≤ 1 year of age are mostly observational and anecdotal, which can be attributed to the lack of information on techniques to effectively capture and safely handle bison neonates (Fuller *et al.*, 2007; Gates *et al.*, 2010). To our knowledge, previous studies of bison neonate survival rates have been observational, primarily cow-calf pair counts, lacking information on known−fate mortality agents (Table 2.1). Additionally, most managers do not handle and tag bison neonates until ≥ 6 months of age because they are susceptible to injuries in corral systems (D. J. Lammers, personal communication).

Techniques to capture large ungulates and their offspring are similar for most species. Previous techniques employed to capture ungulates include: helicopter net–gunning (Barrett *et al.*, 1982; White and Bartmann 1994; Jacques *et al.*, 2009), chemical immobilization (Haigh and Gates, 1995; Fuller *et al.*, 2007), clover traps (Clover, 1956), rocket nets (Beringer *et al.*, 1996), drop–nets (White and Bartmann, 1994), drive nets (Kock *et al.*, 1987), and hand–captures (Grovenburg *et al.*, 2014; Smith *et al.*, 2014). Clover traps, rocket nets, drop nets, and drive nets are non–selective techniques that require significant effort to complete. Conversely, hand–captures, net–guns, and chemical immobilization are selective techniques to capture individuals being targeted by researchers.

Currently, a need exists for an approach to effectively capture neonate bison (Haigh and Gates, 1995). Methods for capturing adult bison are available (Haigh and Gates, 1995; Joly, 2001; Fuller *et al.*, 2007) and could potentially be employed to capture neonates. Contrary to methods employed by Haigh and Gates (1995), Joly (2001) recommended the use of a net–gun over chemical immobilization when capturing bison; reduced handling times decreased the chance of capture–related mortality. Lacking a chase vehicle for protection when handling neonates captured with a net–gun from a helicopter could predispose researchers to increased risk of injury from parturient female bison. Moreover, helicopter captures are expensive and may not be effective in a densely forested landscape. Therefore, an alternative approach to capturing neonates from a helicopter needs to be developed. The objectives of this study was to evaluate the effectiveness of capturing bison neonates with a net–gun from a utility terrain vehicle (UTV), calculate neonate survival and determine cause–specific mortality, and model future populations. A successful approach to capture neonatal bison will allow managers to monitor marked bison neonates, providing data for estimating survival, cause-specific mortality, and recruitment for managed bison populations across North America. Moreover, these empirical parameters will help managers accurately model future populations and aid in determining proper cull rates depending on specific management objectives.

METHODS

Neonate Capture

Neonatal bison captures were conducted 19–22 May 2015, within the South Pasture of the Olson's Conservation Bison Ranch (Figure 0.2). The South Pasture encompasses 976 ha, of which 264 ha (27.1%) was considered open/grassland, with the remaining 712 ha (72.9%) characterized as forest or wetlands. However, only four open/grasslands totaling 165 ha (17.0%) were considered suitable for captures due to limited accessibility and terrain conditions (Figure 2.1).

Prior to capture, we baited bison into open fields by dispensing 800 kg of oats from a Trip Hopper Range Feeder trailer (T&S MFG., INC., Jermyn, TX, USA). The hopper, towed by a pick–up truck (hereafter bait–truck), dropped 3 kg of grain in 3 m intervals. This method dispersed the herd over a large area, which allowed the capture crew to identify target neonates. Target neonates were individuals with exposed umbilical cords, wet or dry, and were estimated to be < 7 days old (R. L. Metcalfe, personal communication).

We mechanically restrained bison neonates using a modified .308 caliber net–gun (Wildlife Capture Equipment, Austin, TX, USA; Barrett, 1982) that deployed a 4.6 m2 net. The capture crew consisted of three individuals: a UTV driver, net–gunner/mugger, and bait–truck operator. Target neonate bison were singled out from the herd with the UTV until within range (< 15 m) for the net-gunner to deploy the net. After successfully restraining a neonate, the bait–truck operator would assist the mugger in retrieving the neonate while the UTV operator kept the mother from intercepting the crew. Neonates were placed into the bed of the bait–truck for safe handling. The UTV was parked parallel to the most exposed bumper of the bait–truck to deter protective female bison from injuring the capture crew during the handling process. Each calf was fitted with a model M3620 very high frequency (VHF) ear tag transmitter (Advanced Telemetry Systems (ATS), Isanti, MN, USA) to monitor for capture–related mortality. All three crew members remained vigilant for bison that posed a threat to the capture team.

Throughout the capture process, data for each bison neonate was collected; sex, maternal identification, and time spent pursuing and handling the calf. Any injuries to neonates occurring from capture were documented. Radio–tagged neonates were monitored for captured–related mortality at least once daily for 30 days (Beringer et al., 1996). The Institutional Animal Care and Use Committee at South Dakota State University (Approval No. 15–038A) approved all animal handling methods for bison neonates.

Calf Survival and Cause−Specific Mortality

We used a handled receiver (R–1000, Communication Specialists, INC., Orange, CA, USA) and an H-antenna (ATS) to monitor neonate bison for captured–related mortality at least once daily for 30 days (Beringer et al., 1996), and continued daily for an additional 47 days, or until individual ear–tags were recovered. A field necropsy was performed upon discovery of a deceased neonate to best determine cause of death.

Population Modeling

A complete census of the Pine River Ranch herd was conducted during the annual round–up in 2016 and partially in 2015. In 2016, we classified individuals as a brown calf (~ 8–10 months old), yearling heifer (2014 calf, 190-320 kg), two year old heifer (2013 calf, 320-410 kg), adult cow (3+ years old, 410+ kg), yearling bull (2014 calf, 180-340 kg), young bull (2−5 years old, 340-500 kg), and breeding bull (5+ years old, 500+ kg; Berger and Peacock, 1988). We estimated age by analyzing tooth replacement, horn development, pelage, weight and/or rib separation (G. Clapham, personal communication; Fuller, 1959). Referencing our 2015 capture data, we assumed calf and yearling sex ratios of 2:3, males to females, respectively. We conducted rectal palpation on all females ≥ 2.5 years old to test for pregnancy and estimate fetus development (Kirkpatrick et al., 1992). Additionally, we noted any 2015 calf with a ripped left ears with the assumption this resulted from an ear tag being dislodged during summer 2015.

We developed an interactive model using Microsoft Excel (Microsoft, Redmond, WA, USA) to predict a 15 year population growth using empirical and theoretical data on population dynamic parameters for bison (Van Vuren and Bray, 1986). Our exponential “no cull” model includes survival estimates for calves (0.915), yearlings (0.955), two year old heifers (0.960), young bulls (0.950), cows (0.960), and breeding bulls (0.950), pregnancy rates for two year old heifers (0.531) and cows (0.714), and no cull rates. Our stable model suggests cull rates for two year old heifers (0.180), young bulls (0.340), cows (0.250), and breeding bulls (0.970), while the survival and pregnancy rates remained the same as the no cull model. Our 15 year goal was to manage the bison population between the estimated carrying capacity of 2,000-2,200 individuals (Chapter 1) and to approximately manage for a cow:bull ratio of 8:1, to maximize reproductive success (D. J. Lammers, personal communication). Additionally, we estimated projected sales given our suggested cull rates for the stable population model. We estimated rail weight by taking 50% and 60% of the average live weights of female and male cull bison, respectively, from March 2016 roundup. Projected sales were calculated given current estimates of \$8.47 US dollars*kg−1 for cull cows, \$9.57 US dollars*kg−1 for 2 year old heifers, and \$9.79 US dollars*kg−1 for young and breeding bulls (D. J. Lammers, personal communication).

RESULTS

Neonate Capture

We successfully captured and radio–tagged 10 male and 16 female neonate bison in 37 attempts (70.3% success). Over a period of four days, 16.0 man hours were spent pursuing and handling neonates, with an average capture rate of one bison neonate for every 0.6 man hours. Average handling time of bison neonates was 3.9±1.6 mins and ranged from 1.0−7.5 mins. Unintentionally, two neonates were captured in one net. This capture was removed from our handling time analysis as we cut holes in the net to release the neonates. No injuries or mortalities were observed throughout the capture process. Moreover, no capture–related mortalities occurred during the 30 day monitoring period. All ear tag transmitters detached and were recovered by day 77. However, our 30 day post capture survival was 100% (N=21).

Calf Survival and Cause−Specific Mortality

Survival monitoring was limited to 77 days as all ear tags dislodged by 30 July 2015. We documented one mortality on day 44 (27 June 2015) with cause of death being starvation/drowning. This individual was mired in mud and was too weak to get out, resulting in death by drowning. She was weak and stunted when captured because her mother was unhealthy. Her mother died the same fate 2 days prior on 25 June 2015. It is likely the neonate received minimal nutrition, if any at all, in the form of milk from her mother throughout her life, which resulted in her weak state. Therefore our apparent survival for 0-2 months of age was 96.7 %.

Population Modeling

The March 2016 census produced a total population of 1,834 bison. The population distribution comprised of 542 calves, 331 yearlings, 147 two year old heifers, 168 young bulls, 591 mature cows, and 55 breeding bulls. Rectal palpation resulted in 78 pregnant two year old heifers and 422 pregnant cows. We observed 23 brown calves with ripped left ears of the 227 individuals checked. Therefore, our 10 month survival estimate is 76.7% (23/30).

The March 2015 annual round-up documented 263 pregnant female bison that should have given birth May−August 2015. These individuals would be documented as brown calves during the March 2016 round-up as their pelage transitions from orange to brown at approximately 3 months-of-age (R. Metcalfe, personal communication). However, only 227 brown calves were observed in March 2016, resulting in an 86.3% parturition/10 month survival rate.

Our theoretical “no cull” model produced a population of 21,211 bison by 2031 (Figure 2.2). Our “best model” yielded a population of 2,099 bison in 2031 while remaining a stable 7:1 cow:bull ratio throughout (Figure 2.3), satisfying both management goals. Moreover, the projected revenue given the suggested cull rates stabilizes at approximately $880,000, annually (Figure 2.4).

DISCUSSION

Neonate Capture

Results of our study indicated that our approach was effective for capturing and handling bison neonates safely. We captured 26 neonates with minimal effort, a small capture crew, and few man hours. Data collection was limited to reduce handling time and to limit potential capture myopathy and abandonment, which increases in ungulates as handling time increases (Firchow et al., 1986; Beringer et al., 1996). However, no previous research has been conducted handling bison < 7 days old and thus, potential for capture myopathy and abandonment was unknown. No mortalities were reported during handling in contrast to studies of neonate ungulates (Ballard et al., 1981; Bertram and Vivion, 2002), but we recommend maximum handling times < 7.5 mins to reduce chance of capture–related mortality.

Although our study was conducted on a private, captive herd, we believe this approach can be implemented across ecosystems where bison currently inhabit. Few populations of bison are considered “wild” and of those, most are confined to boundaries in which they roam, similar to our study. Our study site was heavily forested (65.6%), limiting our suitable capture areas to open/grassland totaling 165 ha (17.0%). Our approach will be most effective in habitats with a higher proportion of open/grasslands as bison spend up to 80% of their time inside or within 25 m of meadows (Fortin et al., 2003).

Manually restraining bison neonates via net–gun was chosen over alternative techniques because it has the lowest combined risk to ungulate health when compared to use of chemical immobilization, or drop–nets and drive nets (Kock et al., 1987). Additionally, drop–nets, drive–nets, and rocket nets are mass capture techniques and were not practical in our circumstance as we were selectively targeting neonates. Conversely, chemical immobilization has the highest combined risk as cow–calf pairs would need to be immobilized to safely handle neonates (Kock et al., 1987). Upon darting, the potential for bison to run is high and in heavily forested landscapes could increase risk of injury to bison and capture crew members. Moreover, drugs required for chemical immobilization add cost and require training and permitting.

Processing the herd through a corral system could be effective for neonate capture but it is likely handling time would be greater, consequently increasing the likelihood of capture–related mortality (Firchow et al., 1986; Beringer et al., 1996). Likewise, neonates may be more susceptible to injury and endure more stress over a longer period of time in corrals. Nevertheless, research should be conducted to evaluate the effectiveness of alternative techniques to capture bison neonates less than a week old.

Population Modeling

We potentially missed up to 3 calves as we forgot to check a few individuals early on in the process. If so, our survival estimate would be 86.7% (26/30 calves), which is similar to our predicted survival from the annual round-up data (86.3%). However, our 10 month survival of 76.7-86.7% is significantly lower than the 0-2 month survival of 97%, which is unusual as one would assume that survival would increase with age. The harsh winters endured by the older age class of calves could explain the decreased survival rates. Additionally, wolves tend to associate with the bison herd in the winter months more than any other time of the year (R. Metcalfe, personal communication), likely predating on vulnerable calves in deep snow. Moreover, calves unaccounted for can be explained by error from both pregnancy testing in March 2015 and identification of brown calves in March 2016. Some yearlings in the 180−230 kg range may actually be brown calves, but were mistakenly identified as yearlings due to their advanced horn development. We did observe at least two additional non-tagged neonate mortalities during June−July 2015 that were a result from infections of injuries incurred at a young age. Although our model is designed specifically for the Pine River Ranch, similar models for other ranches can be produced given management goals, empirical data, and/or life history tables.

CONCLUSIONS

Bison reintroductions across North America are becoming widely implemented (ADF&G, 2015; Banff National Park, 2015; Steenweg *et al.*, 2016), thus increasing the need for effective monitoring techniques. Our approach allows biologists to capture and safely handle bison neonates at a young age. However, development of a more reliable VHF transmitter to attach to bison neonates is necessary to monitor survival > 2 months of age. Knowledge on mortality agents affecting bison neonates allows for improvements in management practices to potentially increase survival of managed bison herds. Additionally, our technique provides bison ranchers a low-cost means to safely and efficiently capture and mark their bison earlier in the year.

ACKNOWLEDGMENTS

We thank R. Metcalfe for logistical and field support throughout our study. We also thank C. N. Jacques and J. B. Smith for providing comments on earlier drafts of our manuscript. Funding was provided in part by Olson's Conservation Bison Ranches, South Dakota State University's Department of Natural Resource Management, and South Dakota Agricultural Experiment Station.

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Table 2.1. Observational neonate (<1 year) survival rates (%) of plains and wood bison (modified from Gates et al. 2010).

Subspecies	**Location**	**Age**		**Comment**	**Reference**
		<6 months %	**<1 year %**		
Plains bison	Henry Mountains, UT	93			Van Vuren, 1986
	Wind Cave, SD	99		1 of 153 calves born died	Green and Rothstein, 1991
Wood bison	WB[1], NWT and AB		<10		Fuller 1962
	WB[1], NWT and AB		41	Calculated from life table	Carbyn *et al.*, 1993
	WB[1], NWT and AB	47	33		Bradley and Wilmhurst, 2005
	MBS[2], NWT		95	Increasing population[4]	Calef, 1984
	SRL[3], NWT	6			Calef, 1985
	SRL[3], NWT	30		Following wolf decline	Calef, 1986

[1] *WB= Wood Buffalo*
[2] *MBS= Mackenzie Bison Sanctuary*
[3] *SRL = Slave River Lowlands*
[4] *Few wolves present*

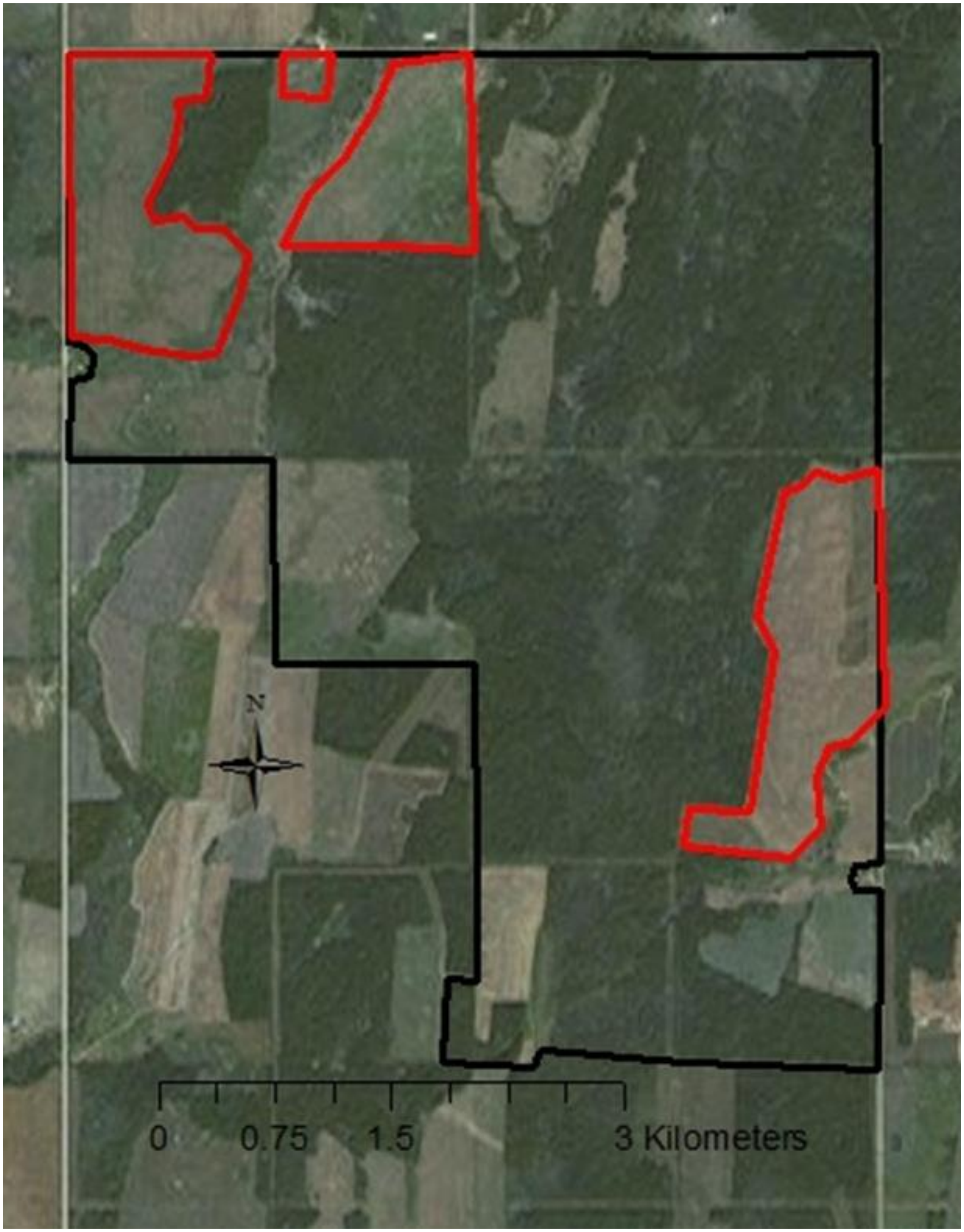

Figure 2.1. Fields suitable, outlined in red, for neonatal capture within the South Pasture of Olson's Conservation Bison Ranches, Pine River Ranch.

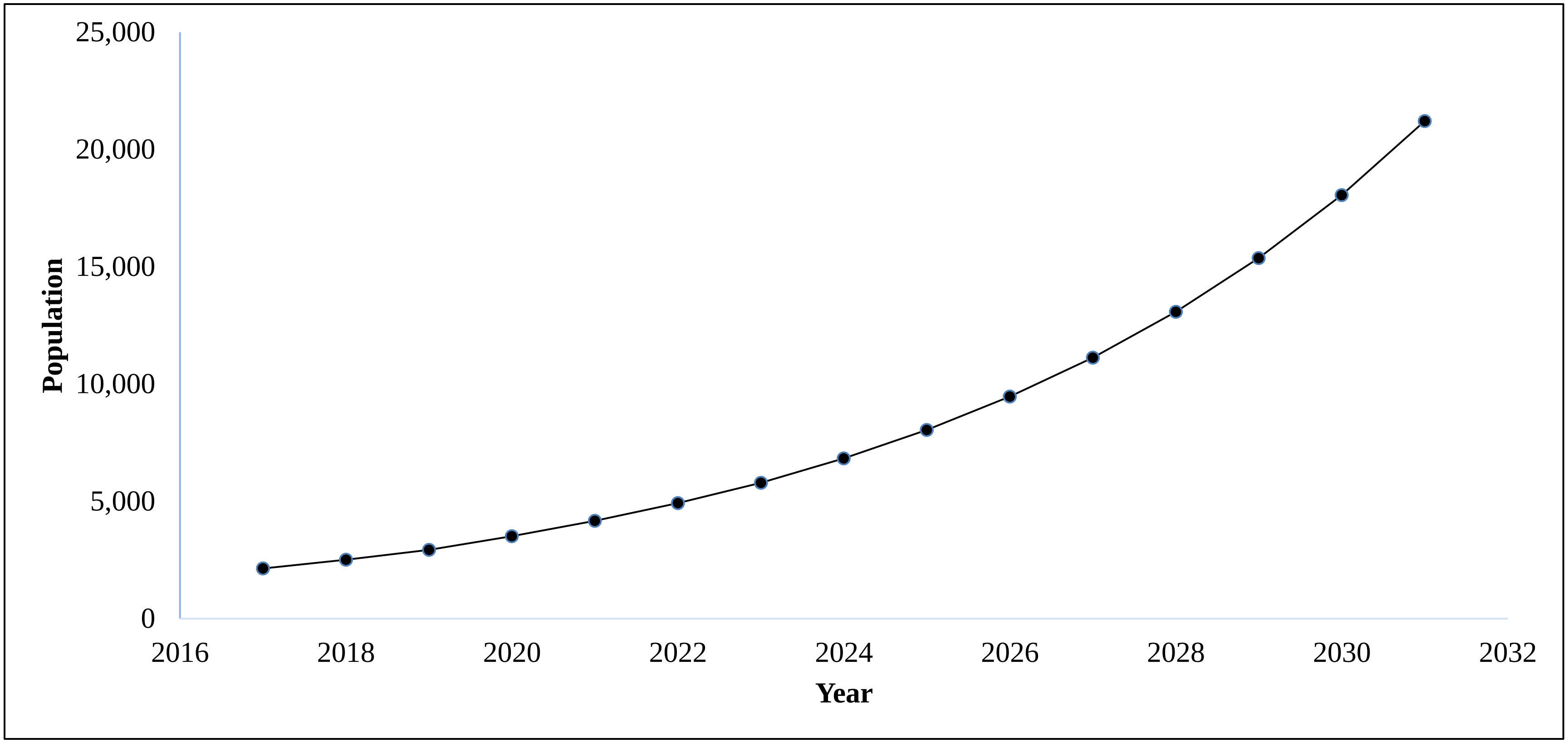

Figure 2.2. Theoretical 15 year (2016-2031) “no cull” population model for the Olson’s Bison Conservation Ranches, Pine River Ranch, Manitoba, Canada.

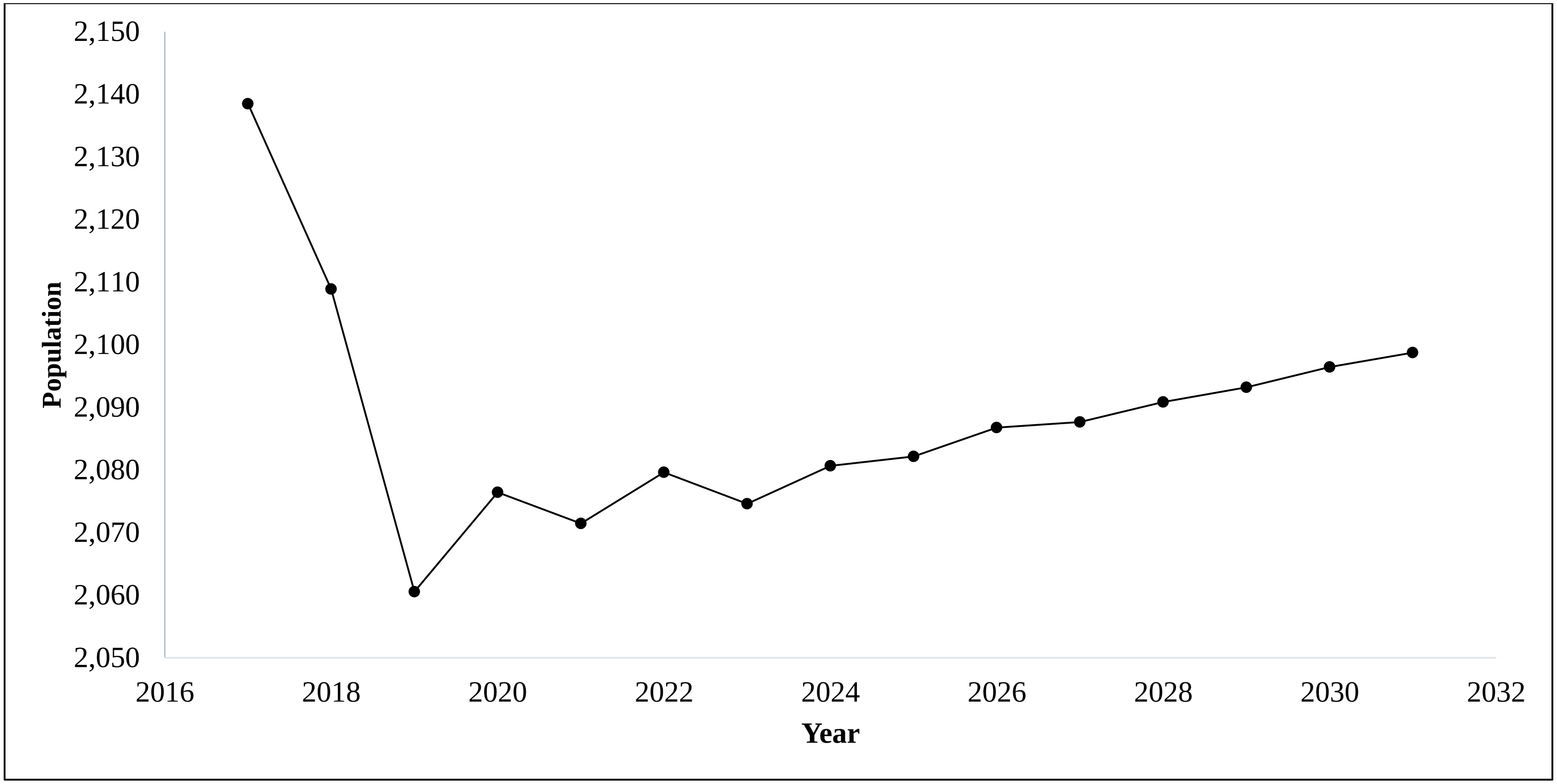

Figure 2.3. Projected population growth for our "best" model given suggested annual cull rates, based off 2016 annual round-up data, for Olson's Conservation Bison Ranches, Pine River Ranch, Manitoba, Canada.

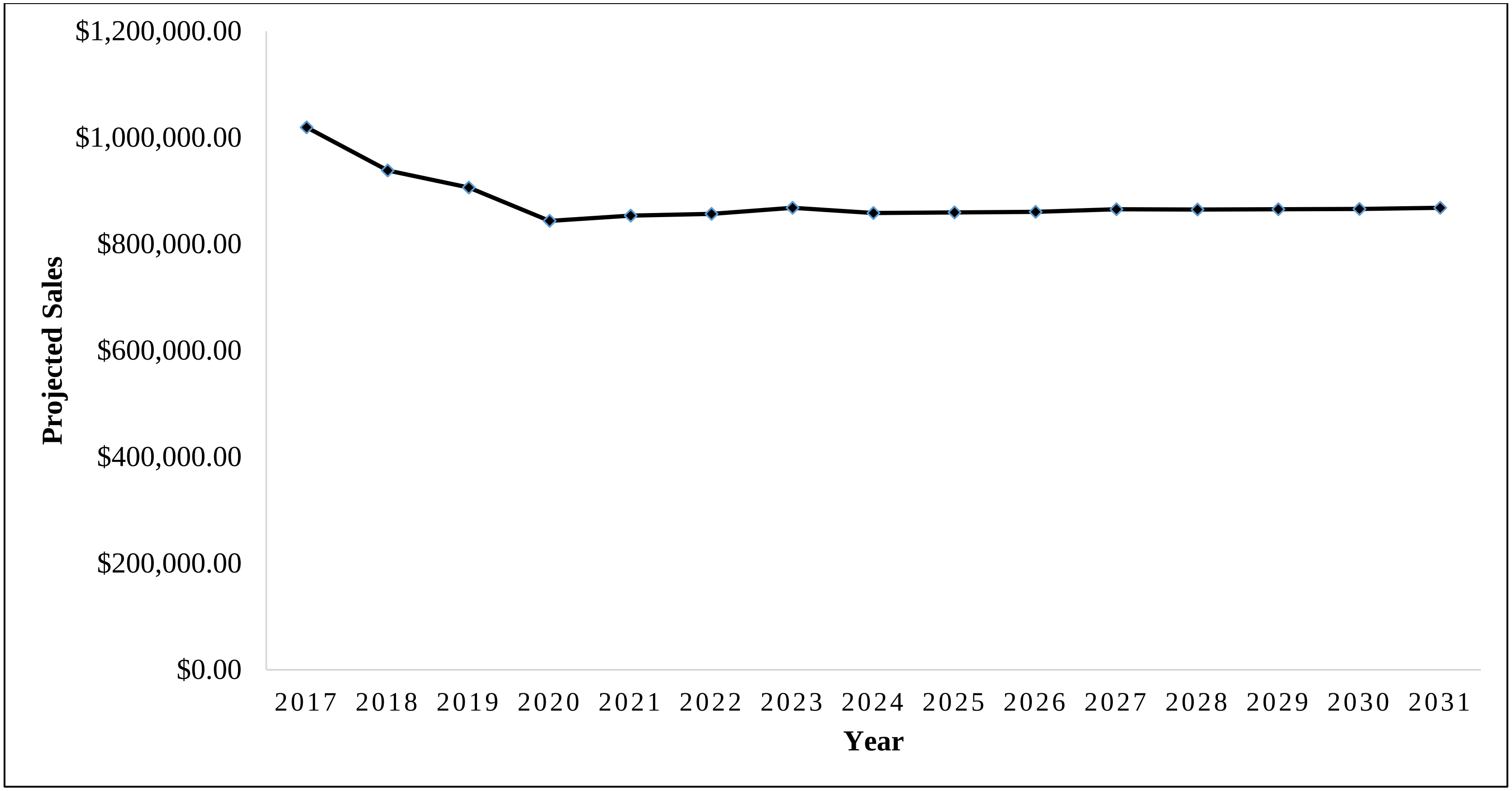

Figure 2.4. Projected annual revenue model for 15 years given suggested cull rates and current market prices for average bison rail weights on Olson's Bison Conservation Ranched, Pine River Ranch, Manitoba, Canada.

CHAPTER 3: BIOTIC FACTORS INFLUENCING CORRIDOR USE OF BISON IN AN ASPEN DOMINATED FOREST OF THE BOREAL PLAINS ECOREGION OF MANITOBA, CANADA.

This chapter is formatted for Prairie Naturalist and coauthored by Ryan N. Dufour, Troy W. Grovenburg, Lora B. Perkins, and Jonathan A. Jenks

ABSTRACT

Wildlife utilize corridors to facilitate movement between patches of habitat that have been naturally or unnaturally fragmented. Despite their functionality, prey, such as bison (*Bison bison*), that occupy forested systems are unable to detect predators where vegetation obstructs their vison, making them more vulnerable to predation. Our objective was to determine what biotic factors influence corridor selection by bison to improve understanding of how bison utilize a heavily forested landscape. During the summer of 2015, we deployed time lapse and passive infrared triggered game cameras for 9 consecutive days at the entrances and exits of 10 randomly selected corridors on Olson's Bison Conservation Ranches, Pine River Ranch, to capture day and night movement of wildlife. We measured corridor length, width, and vegetative characteristics including understory density, basal area, and canopy density. We analyzed approximately 2,676 hours of footage and documented 304 events including American black bears (*Ursus americanus*), gray wolves (*Canis lupus*), coyotes (*C. latrans*), and bison. Bison did not select for corridors according to vegetative characteristics ($P > 0.05$). Presence of bison in corridors was negatively correlated (Spearman Rho = –0.539) with presence of American black bears ($P = 0.021$). Our data indicated that bison were more prevalent in less dense, less stocked aspen corridors with higher visual detection distances, which were avoided by bears. Our results, along with recommended future research, will provide bison managers and biologists' recommendations to encourage use of these habitats by bison.

INTRODUCTION

Habitat loss, along with fragmentation, are two of the largest threats to preserving biodiversity and are a potential cause of extinction (Noss 1987, Henle et al. 2004). Research indicates that aspen stands have been expanding in the last 100 years (Strong 1977, Looman 1979; Archibold and Wilson 1980, Hildebrand 1987), occupying grassland prairies and naturally fragmenting the prairie landscape. As a result, the ability for grassland obligate species to access crucial resources in fragmented grassland patches is potentially obstructed (Petit et al. 1995, Buza et al. 2000). Grassland prairies are crucial habitat for bison (*Bison bison*) as they spend 80% of their time inside or within 25 m of meadows (Fortin et al. 2003). Many species of wildlife utilize habitat corridors (i.e., strips of habitat that connect two different areas) to travel between adjacent habitats (Soule 1999); facilitating movement between connected patches of habitat that have been naturally or unnaturally fragmented.

Species, such as bison, that occupy forested systems are unable to detect predators where vegetation obstructs their vison, making them more vulnerable to predation (Carbyn and Trottier 1988). In central Manitoba, bison frequently encounter densely forested areas when traveling between grassland patches and use open corridors to avoid dense vegetation. Moreover, observations on bison movements indicated that corridors are traveled at different rates and frequencies (D. J. Lammers, Olson's Bison Conservation Ranches, personal communication). The objective of this study was to determine what biotic factors influence corridor use by bison to improve understanding of bison ecology within forested-prairie systems. We hypothesized that bison would use corridors that exhibit vegetative characteristics that increase visual detection of predators.

If the bison are avoiding corridors due to decreased visual detection of predators and the apparent risk of predation, then aspen regeneration patterns could affect how grassland prairies and forested meadows are utilized by the species. Given basic knowledge of corridor characteristics, travel corridors can be created to connect areas not being utilized by bison; maximizing the use of the landscape and helping maintain the natural grassland prairies from succumbing to forest succession.

METHODS

Corridor monitoring was conducted June–August 2015, within the East, East-Center, and North Sclater Pastures on Olson Bison Conservation Ranches, Pine River Ranch, (51°47’N, 100°30’W) northeast of Pine River, Manitoba, Canada (Figure 0.2; Table 3.1). We identified pre-existing corridors between grassland patches in pastures using aerial imagery or by searching the ranch with off-road vehicles prior to deploying cameras. We used ArcGIS 10.3 (Esri, Redlands, California, USA) to randomly select 10 corridors within the pastures. We monitored 4 corridors in both East (June) and East-Center (July), and 2 in North Sclater (August) pastures. We deployed time-lapse PlotWatcher Pro (Day 6 Outdoors, Columbus, GA, USA) and passive infrared triggered Moultrie M-880 (Moultrie, Birmingham, AL, USA) game cameras at the entrances and exits of corridors to capture diurnal and nocturnal movements of bison and predators (Figure 3.1). The cameras continually monitored corridor movement for 9 consecutive days during June, July, and August 2015. We analyzed both time-lapse videos and still images, and recorded unique events describing species, time entered/exited, number of individuals per group, and sex, if possible. A unique event was defined when a species either entered, exited, or completely passed through the corridor. Bison that passed through a corridor in ≤ 5 minutes were considered part of a herd and were compiled into a single event.

We used ArcGIS to measure corridor length and to randomly select 5 random sample points along each of the corridors. At each point, we measured corridor width from which we calculated average width of each corridor. Additionally, we recorded two bearings perpendicular to the corridor, which were used to establish vegetative sampling transects. We calculated understory density, basal area, and canopy cover at the sample point center and along each transect at 10 m intervals. We used a modified 1–m^2 "cover cloth" (Nudds 1977) divided into 10–cm^2 quadrants, alternately colored black and white, to determine understory density. We suspended the cover cloth in the center of the corridor to estimate percent obstruction of vegetation at each 10 m interval by kneeling to bison head level. We used a 10 factor JIM-GEM® Cruz All (Forestry Suppliers, Jackson, MS, USA) angle gauge to calculate basal area. We used a Forestry Suppliers Spherical Crown Densiometer® to estimate canopy cover. We collected understory density (%), basal area (m^2*ha^{-1}), and canopy cover (%) data along each transect every 10 m until either 100% understory density or 100 m was reached.

Statistical Analysis

We used Program R (Vienna, Austria) to run multiple analysis of variance (ANOVAs) tests with repeated measures to analyze vegetative influences on corridor selection by bison. We used Systat (San Jose, California, USA) to run descriptive statistics: Spearman Rank Correlation to test for correlations between bison and predator use, a Sign Test to determine whether the correlation was statistically significant, and a two-sample t-test to compare corridor vegetative characteristic means.

RESULTS

The average corridor length was 0.31 ± 0.11 km, ranging from 0.17 to 0.44 km and the average corridor width was 17.04 ± 14.94 m, ranging from 3.90 to 53.36 m. We analyzed 2,676 hours of footage and documented 304 events including American black bears (7), gray wolves (18), coyotes (39), and bison (240). Bison did not select for corridors according to vegetative characteristics ($P > 0.05$). Presence of coyotes or wolves did not significantly affect bison corridor use ($P > 0.05$). Presence of bison in corridors was negatively correlated (Spearman Rho = −0.54) with presence of American black bears. A sign test (two-sided probabilities, $P = 0.02$) indicated that the relationship between bison and American black bear observations was significant. Two-sample t-tests resulted in statistically significant vegetative parameters that differed between bear and bison corridor use (Table 3.2).

DISCUSSION

Our results indicated that bison and bears have an inverse relationship when selecting for corridors. A potential explanation for this relationship is that bison are avoiding corridors due to the limited visibility and the increased potential threat of bears. Our study occurred while bison neonates were most vulnerable (≤ 3 months of age) and large ungulates with neonates often avoid patches of thick vegetation (Bastille-Rousseau et al. 2011). Black bears are opportunistic predators and frequently move among patches of vegetation-rich habitats, resulting in a higher probability of encountering ungulate neonates (Bastille-Rousseau et al. 2011). Black bears have been documented predating on large ungulates capable of defending themselves like bison, including moose (*Alces* *americanus*), deer (*Odocoileus* spp.), elk (*Cervus elaphus*), and caribou (*Rangifer tarandus*; Wertz et al. 2001, Zager and Beecham 2006, Bastille-Rousseau et al. 2011). Moreover, black bears were responsible for 65% mortality of woodland caribou neonates (Lambert et al. 2006, Bastille-Rousseau et al. 2011). Although predation on bison by black bears has not yet been documented, to our knowledge, it is reasonable to hypothesize that predation may occur under ideal circumstances. Additionally, the "landscape of fear" (Laundré et al. 2010) is an innate behavior instilled within most prey species and could be driving this artificial risk of predation response by bison. If bison are avoiding corridors due to the potential risk of predation, then aspen regeneration patterns could affect how grassland prairies and forested meadows are utilized by bison.

Alternatively, bison may have been avoiding corridors due to limited forage availability in narrow, densely vegetated corridors, resulting in a negative correlation of use due to differences in habitat selection. Black bears tend to associate with densely forested habitats, whereas bison are most commonly found in open meadows (Fortin et al. 2003). Similar to Bastille-Rousseau et al. (2011), black bears in our study associated with woody vegetation-rich habitats, including corridors with relatively higher canopy cover and basal area, and lower detection distances. On the contrary, bison spent the majority of their time in open areas, foraging on graminoids produced in fields and meadows (Chapter 1, Larter and Gates 1991, Plumb and Dodd 1993). However, when using corridors, bison selected those that were generally wider, lower in canopy cover and basal area, and had increased detection distances. Therefore, the negative correlation in corridor use may be a direct result in differences in habitat preferences. Nonetheless, future space-use studies deploying VHF or GPS transmitters on bison and black bears in areas where they co-inhabit should be conducted to better understand this relationship.

Although coyotes and wolves were detected during our study, none of the analyses including either species were statistically significant in influencing bison corridor use. Wolves tend to hunt in packs of 6 to 12 individuals to acquire food resources (Thurber and Peterson 1993). We recorded individuals or pairs of wolves, not a pack, which may lower the likelihood of predation, ultimately, lowering the predation-risk influence of corridor selection by bison. Solitary wolves and pairs will readily hunt large mammal neonates (Thurber and Peterson 1993); however, we did not observe this behavior during our study. The Pine River Ranch has previously documented wolf predation on bison, typically in late fall and winter months (R. Metcalfe, personal communication), which leads us to believe there may be some influence by wolves on bison corridor use. However, our limited sample size was not sufficient to detect this effect. Moreover, the Moultrie passive infrared cameras malfunctioned frequently, contributing to numerous missed opportunities to detect nocturnal predators, such as wolves and coyotes. Coyote diets are primarily composed of small mammals, but they will feed on larger animals when a carcass is readily available (Gese et al. 1996). Therefore, predation by coyotes on healthy bison is unlikely. Additionally, the influence on bison corridor selection by coyotes is minimal, if at all, and limited to the "landscape of fear" (Laundré et al. 2010) theory as there is no previous documentation of coyotes predating on bison.

We document no significant differences in vegetation components related to bison corridor selection. Although not statistically significant, we did observe bison were more frequently using corridors that were generally wider, lower in canopy cover and basal area, and had higher detection distances. Additionally, a *posteriori* observations indicated that bison frequented corridors connecting two grasslands that comprised a large proportion of grasslands within each specific pasture. Bison are typically considered grass-roughage feeders and spend ≥ 80% of their time inside or within 25 m of grasslands, potentially explaining bison selection for corridors connecting larger contiguous open areas (Hofmann 1989, Fortin et al. 2003). Future research incorporating spatial analysis of corridor connectedness and distance from anthropogenic effects should be conducted to determine if these variables may be driving bison use of corridors.

MANAGEMENT IMPLICATIONS

Data from this project will aid public and private managers regarding how bison movements may be influenced by structural vegetative corridor characteristics and the presence of predators. Our results indicate that generally wider, lower canopy cover, and corridors with greater detection distances will likely increase bison use. Information from this study will benefit bison ranching operations in heavily forested landscapes by providing management recommendations to facilitate bison movement throughout their range and potentially reduce risk of mortality to bison.

ACKNOWLEDGEMENTS

Funding for this research was provided in part by: Olson’s Conservation Bison Ranches, South Dakota State University’s Department of Natural Resource Management, South Dakota Agricultural Experiment Station at SDSU, and Orville and Enolia Bentley - Food, Agricultural, and Biological Sciences Undergraduate Research Award. We thank

D. J. Lammers and R. Metcalfe for logistical support. Thanks also to A. E. Andersen for field assistance.

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Table 3.1. Pasture cover types percentages (%) in the three pastures analyzed for corridor use by bison and predators on Olson’s Bison Conservation Ranches, Pine River Ranch, Manitoba, Canada.

Pasture	Open/Grassland (ha)	Open/Grassland (%)	Forest/Wetland (ha)	Forest/Wetland (%)	Total (ha)
East	333	9.20	3,287	90.80	3,620
East-Center	267	21.80	958	78.20	1,225
North Sclater	189	7.46	2,343	92.54	2,532

Table 3.2: Separate variance analysis results to determine if the difference of means was statistically significant.

Variable	Mean Difference	95% Confidence Interval		t	df	*P*-value
		Lower Limit	Upper Limit			
Length	−0.10	−0.28	0.08	−1.52	4.55	0.20
Width	13.92	−1.33	29.17	2.14	7.26	0.07
CC	−24.95	−41.12	−8.79	−3.56	7.98	0.01
BA	−148.16	−191.61	−104.70	−7.92	7.68	0.01
Distance	8.67	0.36	16.98	2.42	7.80	0.04

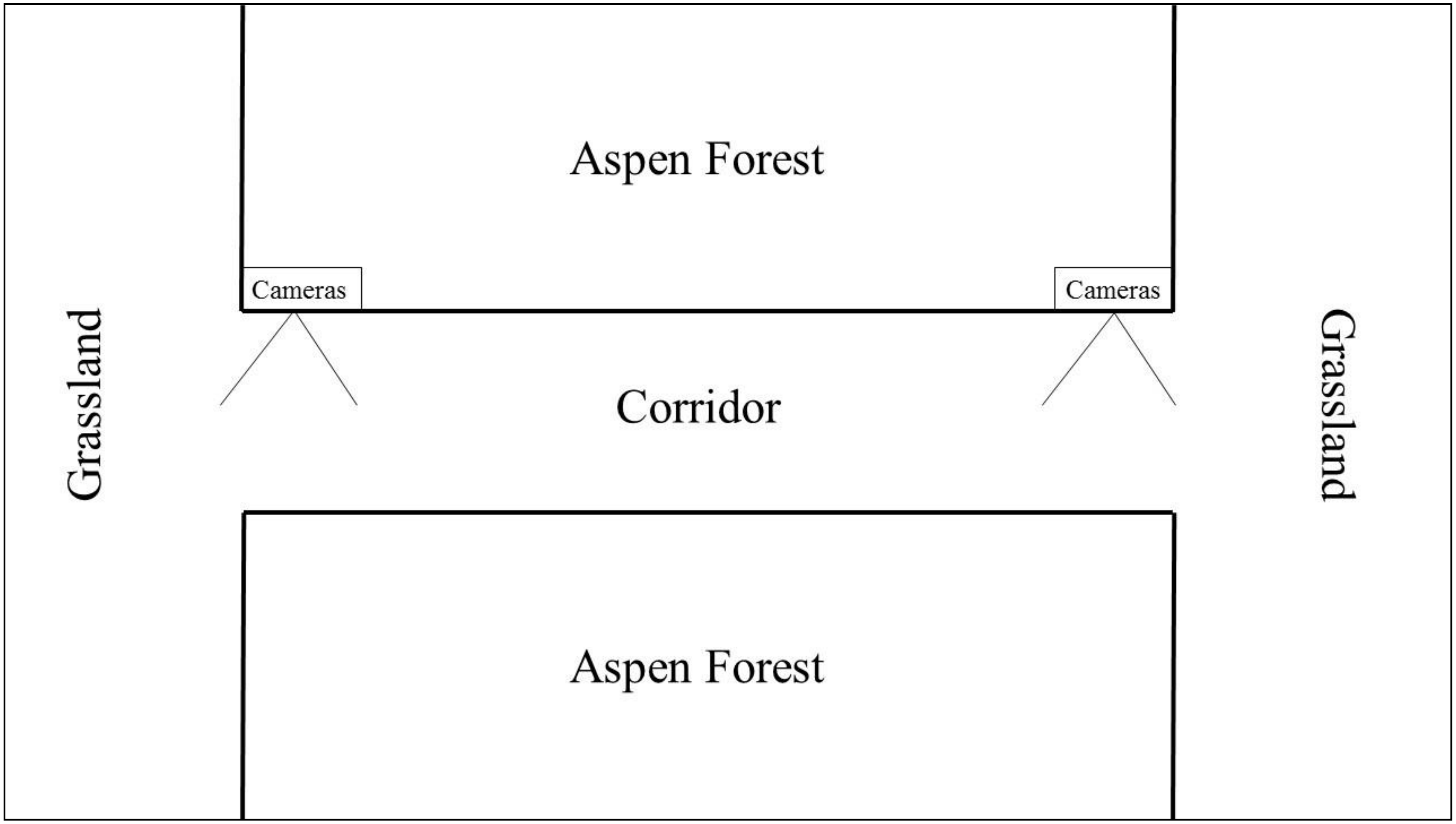

Figure 3.1. Corridor camera trap sampling schematic on the Olson's Bison Conservation Ranches, Pine River Ranch, Manitoba, Canada.