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Wood Bison Habitat Assessment of Southern Minto Flats State Game Refuge

Clint Cooper, Ryan Adam, and C. Tom Seaton

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Cover Photo: Wood bison in the Southern Minto Flats State Game Refuge soft release pen, 2024. ©2024 ADF&G. Photo by Johane Janelle.

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Abstract

There is continued local, state, and international interest in restoring wood bison (*Bison bison athabascae*) to portions of their former range in Alaska. The Alaska Department of Fish and Game (ADF&G) has been working toward the restoration of wood bison since the early 1990s (ADF&G 1994). In 2015 and 2022, the department released wood bison into the lower Innoko/Yukon River area, establishing the first wild wood bison population to exist in the state in over a century.

In addition to the lower Innoko/Yukon River area, a 2013 Environmental Assessment identified the Minto Flats as another location where an experimental population of wood bison could be released (Rogers et al. 2013). The Minto Flats State Game Refuge (MFSGR) is located approximately 30 mi west of Fairbanks along the lower Tanana River in Interior Alaska. A 2006 habitat study had already assessed potential wood bison habitat in the portion of the MFSGR north of the Tanana River (northern MFSGR) and found that high-quality habitat was available for wood bison (Gardner et al. 2007). After public input during the 2023 and 2024 public planning team meetings, the release site for the experimental population was changed to the southern portion of MFSGR.

In June 2024, we conducted a study to evaluate wood bison habitat conditions in the portion of the MFSGR south of the Tanana River (southern MFSGR) using methods similar to those employed in previous studies (Berger et al. 1995, Gardner et al. 2007, Jamison et al. 2023). We utilized remote sensing vegetation models (Nawrocki et al. 2021) and helicopter-supported ground vegetation sampling to identify and quantify the prevalence of wetland sedge vegetation, a key component of wood bison diets. We estimated, using remote sensing, that the proportion of the study area consisting of wetland sedge habitat was greater in the southern MFSGR than in the northern MFSGR. The results of our on-the-ground vegetation assessment showed that the percent cover of major sedge species was almost identical to that found by Gardner et al. (2007) in the northern MFSGR and lower Innoko/Yukon areas; however, species composition varied somewhat. We concluded that a substantial amount of forage would be available to bison, occurring in a mosaic of large meadows, small meadows, and forest habitat; this should provide diverse opportunities for bison to forage.

In winter months, snow conditions likely influence bison’s ability to access forage. We assessed snow depth and characteristics as an additional factor influencing habitat suitability for wood bison. Snow depth data were compiled from historical ADF&G winter browse survey data, National Weather Service historical data, and National Resource Conservation Service Snow Telemetry Network (SNOTEL) automated snow depth stations. These data were compared to weather records from other areas of the state with established bison populations and used to consider the relative seasonal snow depth in relation to suitability for wood bison habitat (U.S. Department of Agriculture 2022, Pan et al. 2018). Based on these comparisons with other bison ranges, we conclude that snow depth on the Minto Flats in typical years should not adversely impact a wood bison population.

Key words: *Bison bison athabascae*, sedge, sedge meadow, *Carex*, snow, restoration, suitability.

Introduction

Modern bison have been present on Alaska's landscape for much of the last 10,000 years (Stephenson et al. 2001, Gates et al. 2010). During this period, bison were present over a large portion of Alaska and northern Canada; these northern bison were the wood bison subspecies (*Bison bison athabascae*). Over the past 400 years, the range of wood bison in Alaska and northern Canada shrank incrementally; subpopulations became fragmented and isolated, likely due to changes in climate, habitat availability, and hunting by humans (Stephenson et al. 2001, Government of Yukon 2012). By the early 20th century, bison were absent from Alaska, and the wood bison was thought to be extinct (Stephenson et al. 2001, Gates et al. 2010).

The Alaska Department of Fish and Game (ADF&G), with the help of numerous partners and donors,[1] has worked to restore wood bison to their native range within Alaska since the early 1990s (ADF&G 1994). Reintroducing bison to high latitudes of the North American continent has unique potential to restore them to their historic ecological niche, a task that is difficult to achieve in areas further south on the continent (Gates et al. 2010). Reintroduction efforts are valuable to bison conservation, as they expand the range and number of wild bison on the landscape (Gates et al. 2010, Aune et al. 2017, Rogers 2021). After years of planning, wood bison were reintroduced to the lower Innoko River in Alaska in 2015 (Seaton 2016, ADF&G 2018).

Bison are generally considered to be grazers, but their dietary composition is diverse and varies greatly across their range (Craine et al. 2015, Jorns et al. 2020). In Alaska, bison consume a diverse selection of forage plants. Nongraminoid plants, such as willows (*Salix* spp.) and forbs, are highly used during summer months (Waggoner and Hinkes 1986). Northern bison switch to a diet of primarily graminoids in winter months, with sedge (*Carex* spp.) making up a major component of the winter diet in most northern herds (Reynolds et al. 1978, Campbell and Hinkes 1983, Larter and Gates 1991, Jung 2015). Wetland sedge meadows produce high forage biomass and are utilized by many northern bison herds (Reynolds et al. 1978, Larter and Gates 1991, Belanger et al. 2020). High-quality bison forage exists in the form of sedge meadows distributed throughout the boreal forest zone (Stephenson et al. 2001, Gardner et al. 2007). There is potential that wetland sedge meadows in Alaska may be too wet for summer foraging but could become accessible during the long winters when the water is frozen and footing becomes firmer (Belanger et al. 2020).

Extreme snow conditions have been shown to influence overwinter bison survival in Alaska, as the authors have observed in Delta Junction during 2022 and the Lower Innoko/Yukon area during 2023, and elsewhere in North America (Meagher 1973). Snow depth and characteristics likely affect the ability of bison to move and access forage during winter. Starvation has been documented in winters with deep or hard, icy snow, which prevents bison from accessing available forage and increases energetic demands (Meagher 1973, Reynolds and Peden 1987, DelGiudice et al. 1994).

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[1] A list of partners and donors is available on the ADF&G website: https://www.adfg.alaska.gov/index.cfm?adfg=woodbisonrestoration.supporters.

High-quality bison habitat in Alaska, with the potential to support ≥400 wood bison, has been previously identified in the Yukon Flats, Minto Flats, and lower Innoko River areas (Berger et al. 1995, Gardner et al. 2007). Surveys of a portion of the Tetlin National Wildlife Refuge in eastern Interior Alaska revealed a similar species composition of sedge meadows as those found in the lower Innoko River area (Jamison et al. 2023); therefore, suitable habitat likely exists in other parts of the state outside the areas previously identified.

Two publications that guide wood bison restoration efforts in Alaska are *Environmental Assessment: Designation of Nonessential Experimental Population Status for Wood Bison in Interior Alaska* (Rogers et al. 2013) and *Establishment of a Nonessential Experimental Population of Wood Bison in Alaska* (U.S. Fish and Wildlife Service 2014). Part of the restoration process outlined in both publications involves obtaining input from interest groups on implementation and management efforts in all regions where experimental wood bison populations are attempted. Public planning teams that focused on the Minto Flats State Game Refuge (MFSGR) preferred a release site in a portion of the refuge south of the Tanana River (southern MFSGR) over one in a portion of the refuge north of the river (northern MFSGR). However, only habitat in northern MFSGR has been evaluated (Gardner et al. 2007). The purpose of this study was to evaluate bison habitat in southern MFSGR. To accomplish this evaluation, we 1) conducted a spatial analysis to quantitatively compare wetland sedge habitat in northern and southern MFSGR using remote sensing, 2) conducted helicopter-supported on-the-ground vegetation surveys of potential bison habitat, and 3) compiled snow data from previous surveys and datasets.

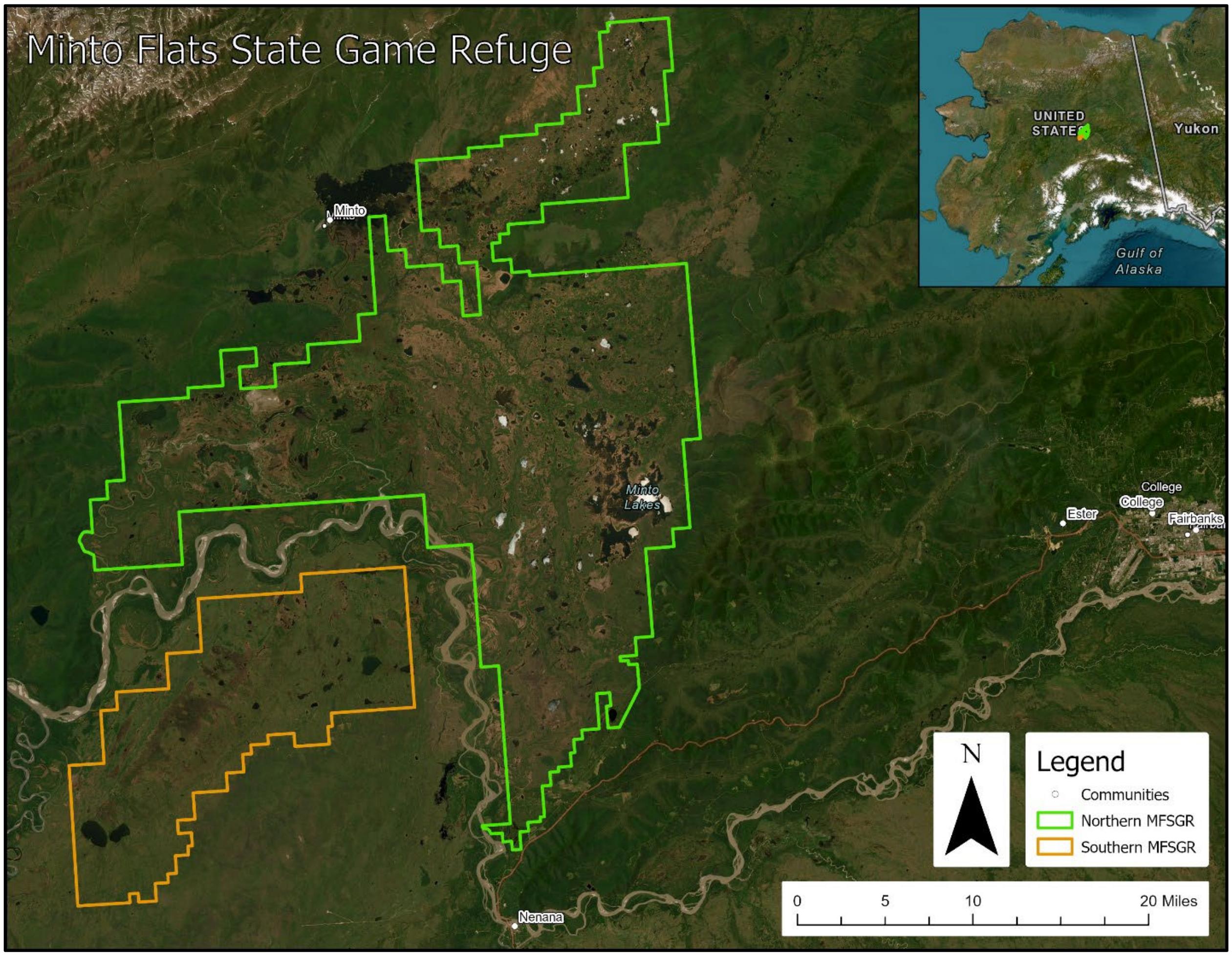
Study Area

This survey encompassed southern MFSGR, the portion of the refuge south of the Tanana River. The eastern boundary of the study area was approximately 43 mi (69.2 km) west of Fairbanks and 14 mi (22.5 km) northwest of Nenana. The study area encompassed 181 mi^2 (468.8 km^2) and ranged 27 mi (43.5 km) from the southwestern border of the MFSGR (lat 64.60360, long −149.92178) to the northeastern border of the southern MFSGR (lat 64.86344, long −149.25140). Minto Flats is a large area of interconnected lakes, rivers, sloughs, and marshes within the lower Tanana River drainage (Fig. 1). Vegetation in the refuge consists of a mosaic of riparian and aquatic vegetation, wet herbaceous meadows, and shrubs interspersed with deciduous, coniferous, and mixed forests that are ringed by forested hills (Clausen et al. 1992).

Methods

Spatial Analysis

Using a remote sensing vegetation model (Nawrocki et al. 2021), we identified portions of the southern MFSGR predicted to contain wetland sedge habitat and those predicted to consist predominantly of wetland sedge (>25% foliar cover of wetland sedge). We quantified the estimated sedge habitat in both the southern MFSGR and northern MFSGR and compared the results between the two areas. Afterward, we followed previous methodologies (Berger et al. 1995, Gardner et al. 2007, Jamison et al. 2023) to conduct a stratified random sample, selecting sampling locations within the wetland sedge polygons of the southern MFSGR.



Source: Map produced by ADF&G using ArcGIS Pro 3.2.0 software. Map layers © Esri, Earthstar Geographics, State of Alaska, TomTom, Garmin, FAO, NOAA, USGS, EPA, NPS, and USFWS.

Figure 1. Map of the Minto Flats State Game Refuge (MFSGR), Interior Alaska, 2024.

To conduct the site selection, raster data from the wetland sedge layer described in *Continuous Foliar Cover of Plant Species and Aggregates in North American Beringia* (Nawrocki et al. 2021) were uploaded to ArcMap 10.8.2 and converted into merged polygons representing continuous areas with predicted wetland sedge foliar coverage greater than 25% (Fig. 2). This polygon layer was stratified by polygon size to identify small sedge meadows (1–200 acres of extent) and large sedge meadows (>200 acres of extent; Fig. 3). From these strata, 30 polygons and 5 alternates were randomly selected from the small meadows, and 30 polygons and 3 alternates were randomly selected from the large meadows. Plot points for the small meadows were placed at the centroid of each polygon to facilitate easier helicopter access and to prevent duplicate sampling, while plot points for the large meadows were randomly assigned within the polygon (Fig. 3).

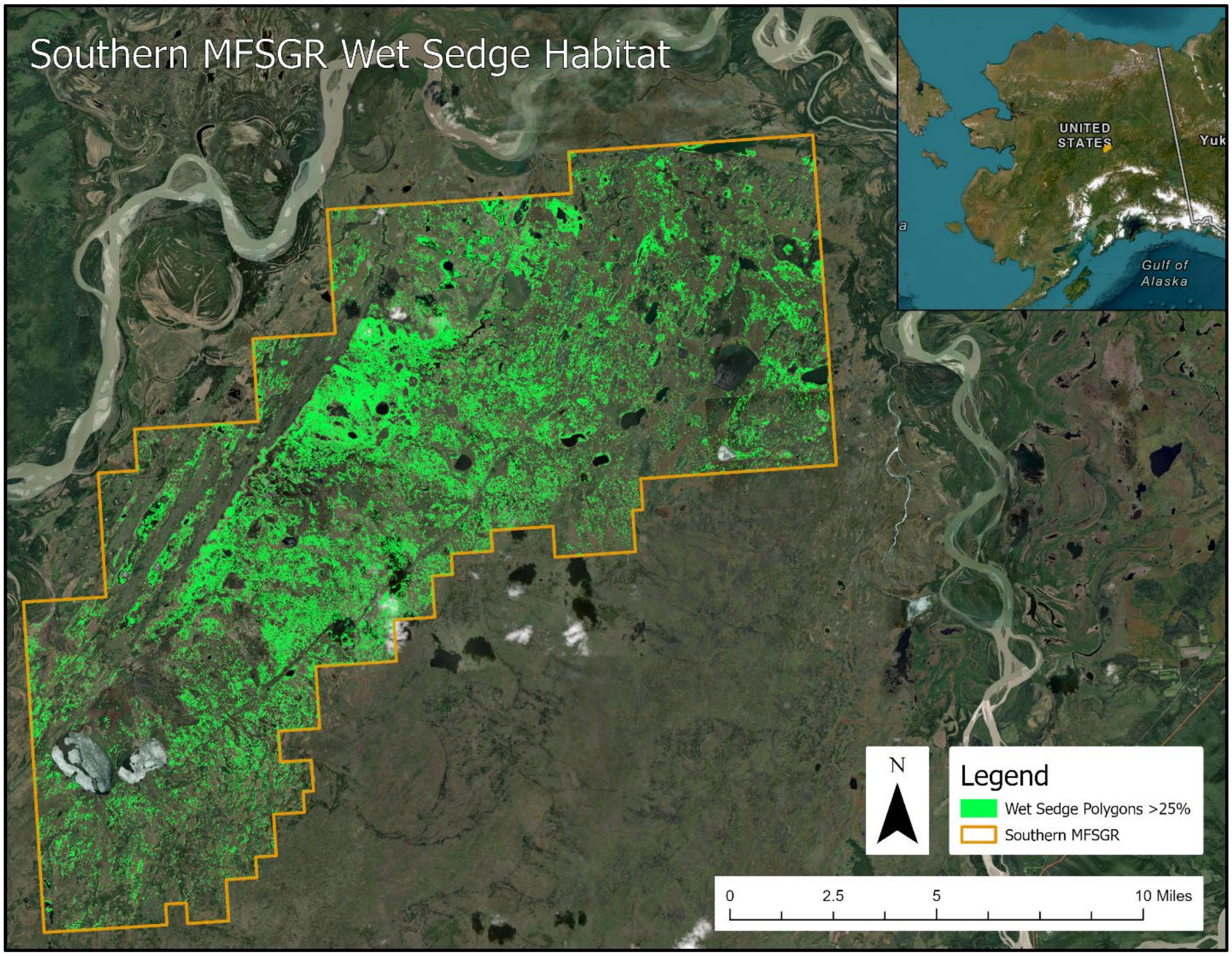


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Figure 2. Wetland (wet) sedge polygons with a predicted foliar coverage of >25% wet sedge within the southern Minto Flats State Game Refuge (MFSGR), Interior Alaska, 2024.

Vegetation Sampling

On 18–20 June 2024, we assessed vegetation in 59 plots (29 large meadows and 30 small meadows) within the southern MFSGR. To optimize helicopter time, we had 2 crews of 2 biologists each. Each crew included a lead botanist responsible for estimating cover and identifying primary species. Before field data collection, both lead botanists evaluated practice plots to calibrate cover estimates and ensure consistent methods were used.

Vegetation sampling points were assessed using a 10 m × 1 m (32.8 ft × 3.3 ft) sample plot, as described in Gardner et al. (2007) and Jamison et al. (2023). The specific plot locations and orientation were determined using a random distance between 0 and 100 m (0–328 ft) and azimuth between 0 and 359 degrees from the preselected point, rejecting distances and directions that would place sample plots outside the selected meadow. Species composition, foliar cover, canopy height, soil conditions (site wetness), and structural class were assessed at each plot. Photographs were taken in each plot.

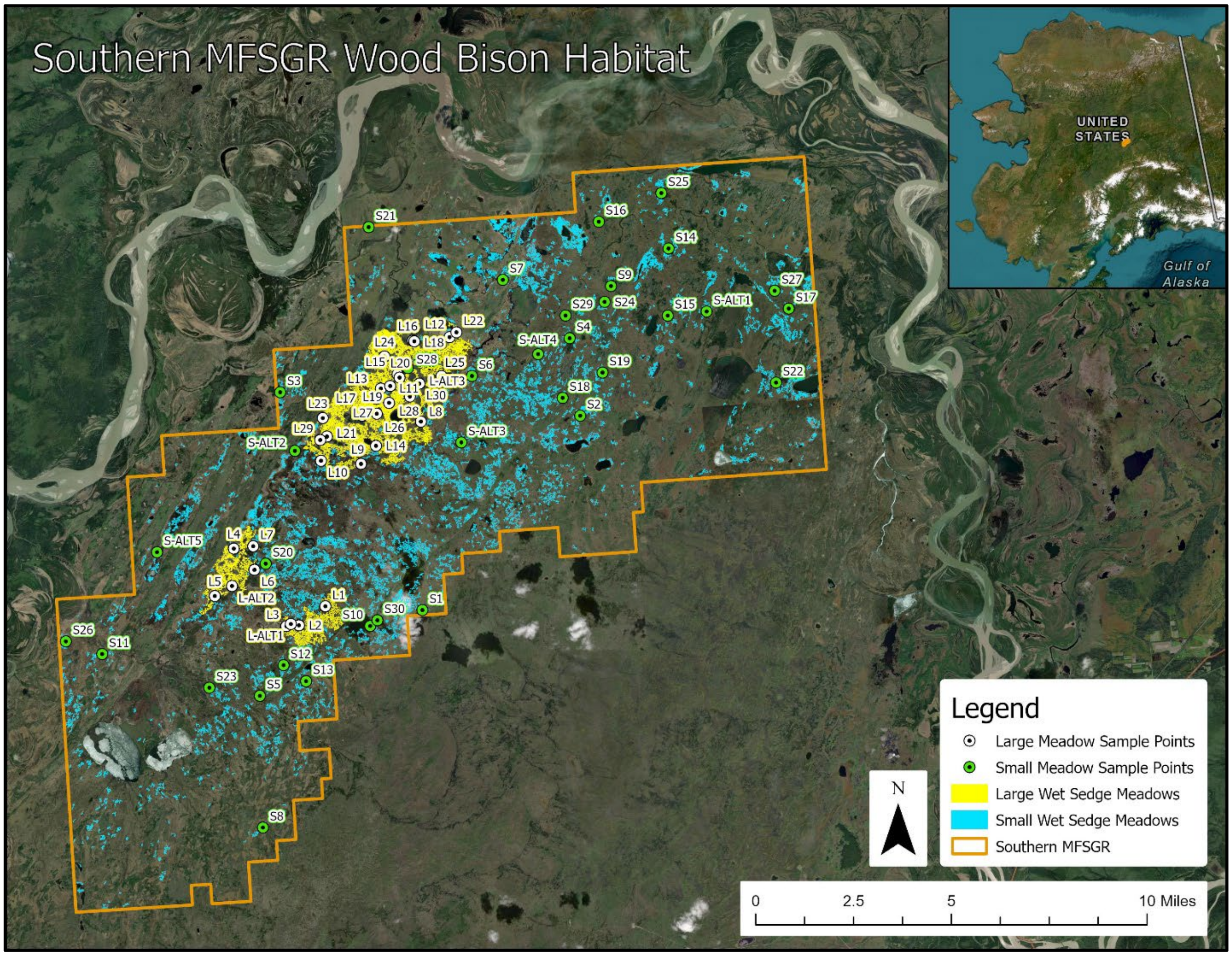

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Figure 3. Distribution of sampling points within the southern Minto Flats State Game Refuge (MFSGR), Interior Alaska, 2024.

For each plot, a single value was determined for canopy height and soil conditions. Canopy height was rounded to the nearest 5 cm (2 in) and measured as the natural standing height of the leaf coverage (excluding seed stalks and inflorescences) of the dominant plant species within the plot. Soil conditions for each plot were subjectively categorized as dry, damp, saturated, or flooded. Structural class was determined by selecting the best-fit category of dominant vegetation from the list provided in *Minimum Standards for Field Observation of Vegetation and Related Properties Version 1.1* (Vegetation Technical Working Group 2022).

Each plot was divided into ten 1 m^2 subplots. Species composition, ground cover, and absolute foliar cover were assessed for each subplot. Within each subplot, vascular plants were categorized to the lowest possible taxon, usually the species level. Absolute foliar cover for each plant taxon was estimated and defined as the portion of the plot covered (reported as percent cover) across all vertical strata by live plant parts (Vegetation Technical Working Group 2022). Ground cover was estimated as a proportion, with the total equal to 100%; categories included leaf litter, water, moss, lichen, wood, mineral soil, and organic soil. Taxa and ground cover that constituted ≥5% coverage within the subplot were estimated to the nearest 5%, while those that represented <5% of the total subplot area were estimated to the nearest 1%. Species that represented <1% were given a 1% estimate. To determine a final value for each plot, cover values from the 10 subplots were averaged to produce the plot average.

Sample sites were accessed using a Robinson R44 helicopter. A few sampling sites were skipped due to biological factors (i.e., a brood of ducklings, a nesting swan, and a cow moose with a calf) near the plot. We substituted the skipped sites with preselected alternatives when possible.

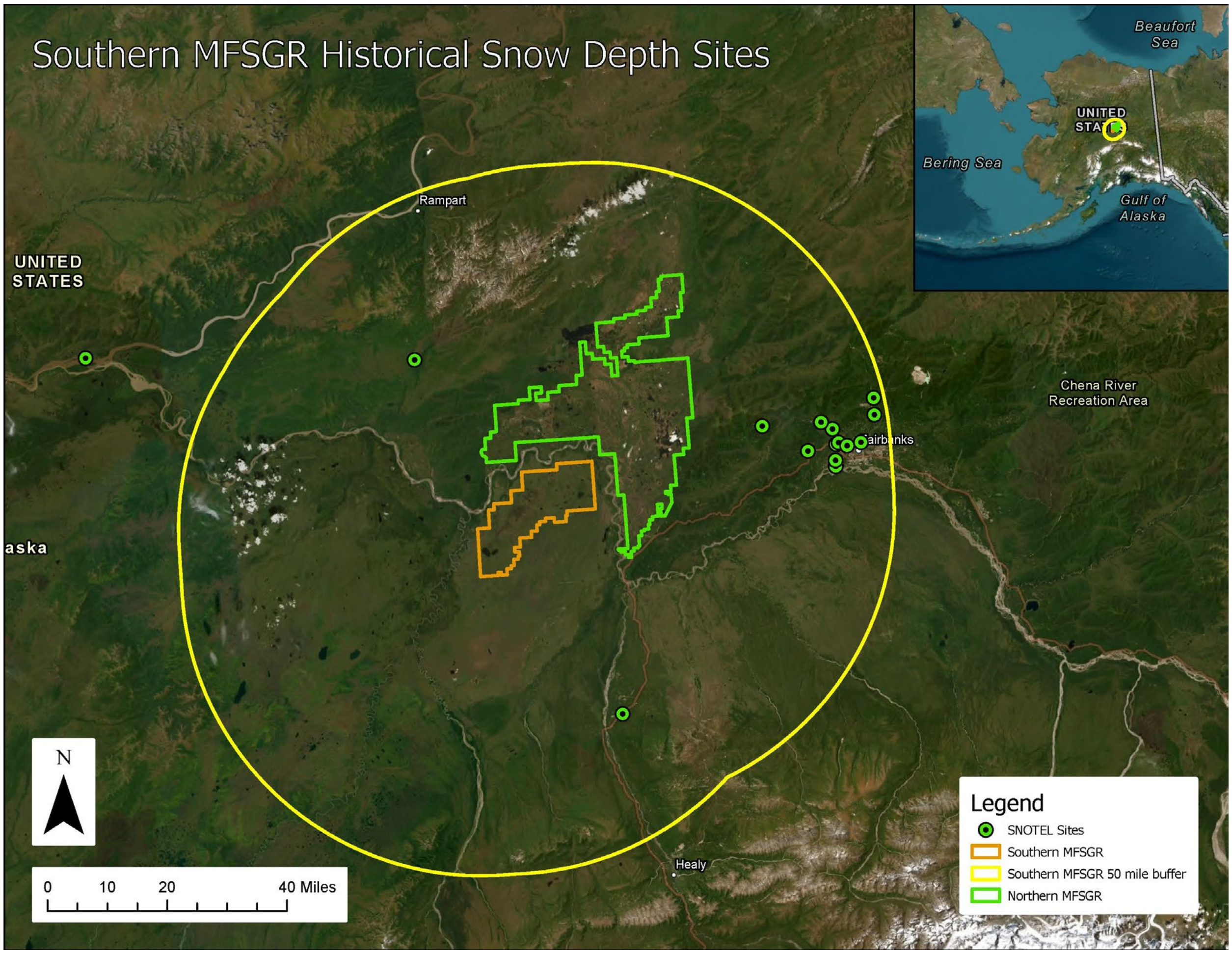
During data processing, each plant was assigned to one of the following functional groups: sedge, grass, forb, *Equisetum*, and woody. Sedges were separated from grasses due to their higher nutritional value, palatability, and usefulness to bison in this study area compared to available grasses. Cottongrass (*Eriophorum* spp.) belongs to the sedge family (*Cyperaceae*) and was therefore grouped with sedges.

We averaged percent cover for major species across the study area and for both large and small meadows. Standard deviation (SD) was calculated for the estimated percent cover averages. The area covered by each bison forage species was calculated by multiplying the percent cover by the area (in square miles) of meadow habitat. All data analysis and statistical calculations were performed in Microsoft Excel, Microsoft 365 MSO (Version 2405).

Snow Depth and Conditions

Snow depth data were compiled from historical records available from the National Weather Service (NWS) and the U.S. Department of Agriculture's National Resource Conservation Service (NRCS; NWS 2024, NRCS 2024). This data includes records from NRCS automated snow telemetry (SNOTEL) snow monitoring systems, which archive historical snow data across Alaska. We used data from 15 stations (Fig. 4) located around Interior Alaska, including all locations within 50 mi (80 km) of the study area that had at least 5 years of snow depth data. At 26 miles (41.8 km), Manley Hot Springs was the closest site to the study area. In addition, data from Tanana Airport was included because it was the nearest station (71 mi; 114 km) west of the study area with long-term snow depth records. The period of record for the stations ranged from 7 to 122 years, with the longest-running station located at Tanana Airport (Table 1).

Snow records were collected from 15 snow depth stations across 4 communities: 12 from the Fairbanks area and 1 each from Clear, Manley Hot Springs, and Tanana. Due to the uneven distribution of available records, data were analyzed both by individual station and by the respective community (Table 1). The average annual maximum snow depth, the maximum recorded snow depth, and the average date of maximum annual snow depth were calculated for each station. These results were pooled to provide the average annual maximum and maximum recorded snow depths for each community. This was then averaged to provide a geographically adjusted average annual maximum snow depth. Given the varied sources of data, accuracy, and collection methods, there are significant constraints on the ability to extrapolate and draw conclusions from the existing data; however, we may gain insight into general trends and reported extremes of snow conditions.



Source: Map produced by ADF&G using ArcGIS Pro 3.2.0 software. Map layers © Esri, Earthstar Geographics, State of Alaska, TomTom, Garmin, FAO, NOAA, USGS, EPA, NPS, and USFWS.

Figure 4. Distribution of historical snow depth sites surrounding the southern Minto Flats State Game Refuge (MFSGR), Interior Alaska, 2024.

Additionally, ADF&G biologists measured snow depth to the nearest 0.1 m (3.9 in) during browse surveys of the northern MFSGR in March 2010 and March 2024. We calculated the average snow depth from those surveys and compared it to NWS and NRCS data.

Results

Spatial Analysis

The GIS (Global Information System) analysis of the southern MFSGR (116,491 acres) resulted in an estimated 68,612 acres containing wetland sedge habitat. Of this area, 17,055 acres had a predicted foliar coverage of >25% wetland sedge (Fig. 2). This indicates that a predicted 58.9% of the study area contains wetland sedge habitat, and 14.6% of the study area contains high densities of wood bison winter forage. Using the same methods to assess the northern MFSGR (385,184 acres) resulted in 138,069 acres of wetland sedge habitat (35.9% of the total area), with 21,537 acres (5.6% of the total area) having a wetland sedge foliar coverage of >25% wetland sedge.

Table 1. National Weather Service snow data, Interior Alaska, accessed 27 June 2024.

Site name	Community	Period of record (years)	Max depth (in)	Max date	Average max (in)	Average annual max date
Clear Sky	Clear	12	43	4/03/2021	23	3 Mar
Ester 5NE	Fairbanks	27	42	4/04/2021	22	3 Mar
Ester	Fairbanks	18	42	4/04/2021	23	6 Mar
Fox 2 SE	Fairbanks	26	42	3/29/2020	22	28 Mar
Keystone Ridge	Fairbanks	20	48	1/22/2000	27	23 Mar
Goldstream Creek	Fairbanks	15	39	2/23/2022	24	8 Apr
College Observatory	Fairbanks	76	52	3/28/1991	22	20 Mar
University Experimental Station	Fairbanks	120	58	4/09/1918	21	20 Mar
Fairbanks INTL AP	Fairbanks	95	57	2/11/1937	21	15 Feb
Fairbanks Airport #2	Fairbanks	21	34	2/25/2017	21	7 Mar
Fairbanks F.O.	Fairbanks	10	31	2/26/2017	21	8 Apr
Aurora	Fairbanks	22	36	4/04/2021	22	7 Mar
Fairbanks 5.7 N	Fairbanks	9	39	3/26/2020	30	1 Mar
Manley Hot Springs 15NE	Manley Hot Springs	7	36	4/04/2021	25	3 Mar
Tanana Airport	Tanana	122	59	3/07/1952	26	9 Mar

Source: National Weather Service (2024).

VEGETATION SAMPLING

We identified 43 unique species during the vegetation survey. Percent occurrence, foliar cover values, and estimated area covered by major wood bison forage species (those with an average foliar cover >1%) are presented in Table 2. Collectively, sedges (*Carex* spp.) occurred in 98% of plots (all but 1) and had an average foliar cover of 26.4%. The most frequently encountered wood bison forage species was creeping sedge (*C. chordorrhiza*), which occurred in 86% of plots. Woolly fruit sedge (*C. lasiocarpa*) had the highest average canopy cover of any species, at 10.7% ± 18.0 (SD). Buckbean (*Menyanthes trifoliata*) and marsh cinquefoil (*Potentilla palustris*) are common forbs in wet meadow habitat and were included because they have been found in the diet of the Innoko bison herd. A complete list of species, including scientific and common names, is provided in Appendix A.

Table 2. Percent cover, frequency of occurrence, and total area covered by major bison forage species encountered during meadow vegetation sampling, southern Minto Flats State Game Refuge, Interior Alaska, June 2024.

Species	Percent cover ± SD[a]	Occurrence (%)	Area covered (mi^2)[b]
Carex lasiocarpa	10.7 ± 18.0	45.8	3.3
Carex chordorrhiza	6.1 ± 7.5	86.4	1.9
Carex aquatilis	4.8 ± 8.2	61.0	1.5
Carex rostrata and *C. utriculata*	2.6 ± 4.7	42.4	0.8
Carex limosa	1.5 ± 3.2	40.7	0.4
Calamagrostis canadensis	3.5 ± 8.3	39.0	1.1
Menyanthes trifoliata	3.2 ± 7.7	40.7	1.0
Equisetum fluviatile	2.7 ± 6.5	44.1	0.8
Eriophorum vaginatum	2.4 ± 8.6	13.6	0.7
Potentilla palustris	1.9 ± 3.3	59.3	0.6

[a] SD is an abbreviation for standard deviation.
[b] Area covered was calculated based on a total meadow habitat area of 30.75 mi^2.

Sedge was the most dominant functional group (*Carex* spp. and *Eriophorum* spp.), accounting for 29.8% of foliar cover. Woody species were the next most abundant functional group, with an average foliar cover of 16.7%. Among these woody species, leatherleaf (*Chamadaphne caliculata*) was the most abundant at 9.0%, which is likely not a useful forage species for bison. Willows (*Salix* spp.) collectively accounted for 1.2% foliar cover. When the functional group foliar cover values were scaled to equal 100%, excluding ground cover, sedge accounted for over half of the vegetative cover, followed by woody, forbs, grasses, and horsetails (Fig. 5).

Vegetative community composition varied between large and small meadows, with small meadows being more diverse (41 species in small meadows, 28 in large meadows). The major bison forage species and average foliar cover in large meadows are presented in Table 3; the major species and average foliar cover in small meadows are presented in Table 4. Large meadows were wetter than small meadows, with 93% of large meadows flooded compared to 53% of small meadows. Structural class also varied by meadow size. Large meadows primarily consisted of sedge emergent (83%), while small meadows supported a more diverse mix of plant communities, including sedge emergent (30%), low shrub (37%), and others (Table 5).

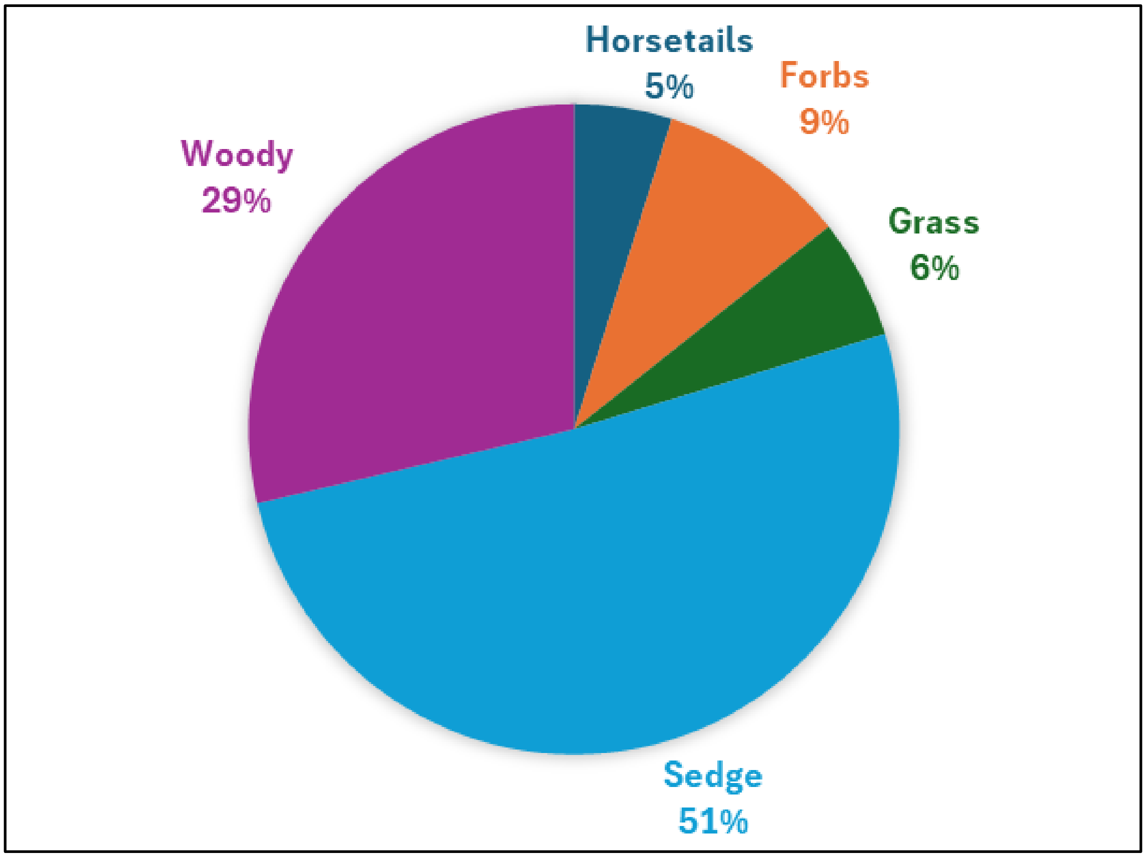


Figure 5. Relative foliar cover of vascular plant functional groups encountered during meadow vegetation sampling, southern Minto Flats State Game Refuge, Interior Alaska, June 2024.

Table 3. Percent cover and frequency of occurrence in large meadows (≥200 acres) of major bison forage species encountered during meadow vegetation sampling, southern Minto Flats State Game Refuge, Interior Alaska, June 2024.

Species	Percent Cover ± SD	Occurrence (%)
Carex lasiocarpa	19.3 ± 20.5	79.3
Carex cordorrhiza	7.3 ± 7.2	100.0
Carex rostrata and *C. utriculata*	2.8 ± 4.1	55.2
Carex aquatilis	2.5 ± 3.9	41.4
Carex limosa	1.8 ± 2.5	62.1
Equisetum fluviatile	4.2 ± 8.4	65.5
Calamagrostis canadensis	1.7 ± 6.8	20.7
Menyanthes trifoliata	1.7 ± 2.6	51.7
Potentilla palustris	1.2 ± 1.9	62.1
Eriophorum angustifolium	1.0 ± 4.6	31.0

Table 4. Percent cover and frequency of occurrence in small meadows (1–200 acres) of major bison forage species encountered during meadow vegetation sampling, southern Minto Flats State Game Refuge, Interior Alaska, June 2024.

Species	Percent cover ± SD	Occurrence (%)
Carex aquatilis	7.0 ± 10.4	80.0
Carex chordorrhiza	4.9 ± 7.6	73.3
Carex lasiocarpa	2.5 ± 9.9	13.3
Carex rostrata and *C. utriculata*	2.4 ± 5.4	30.0
Carex limosa	1.1 ± 3.7	20.0
Equisetum fluviatile	1.2 ± 3.5	23.3
Calamagrostis canadensis	5.2 ± 9.3	56.7
Menyanthes trifoliata	4.6 ± 10.4	30.0
Potentilla palustris	2.6 ± 4.1	56.7
Salix fuscescens	1.3 ± 2.9	46.7
Eriophorum vaginatum	4.8 ± 11.7	26.7

Canopy height averaged 59 cm overall (SD = 16.8), 56 cm in large meadows (SD = 11.0), and 62 cm in small meadows (SD = 20.6).[2] Ground cover consisted of water (56%), leaf litter (35%), moss (10%), and wood (0.2%). Soil conditions are presented in Table 6.

The average combined foliar cover of primary sedge species (*Carex* spp.) in our study area was 25.7%, compared to 25.8% in the northern MFSGR (calculated from Gardner et al. 2007), 25.1% in the lower Innoko/Yukon (calculated from Gardner et al. 2007), and 21.8% in the Tetlin National Wildlife Refuge (calculated from Jamison et al. 2023).

Snow Depth and Conditions

Among the 15 selected snow data stations (Fig. 4), when averaged across all sites, the average maximum annual snow depth was 23.3 in (58.7 cm) with a range of 21 to 30 in (53.3–76.2 cm) and an average date of annual maximum snow depth of 12 March with a range of 1 March to 9 April (NWS 2024). The maximum depth record for the sample sites during the period of record was 59 in (149.9 cm), occurring at Tanana Airport on 7 March 1952. When data were pooled by community (Fig. 6), the geographically adjusted average maximum annual snow depth was 24.3 in (61.7 cm).

Snow depth data collected by ADF&G in the northern MFSGR averaged 16.0 in (41.0 cm; n = 40) during 23–25 March 2010, and 22 in (56.0 cm; n = 36) during 23–25 March 2024.

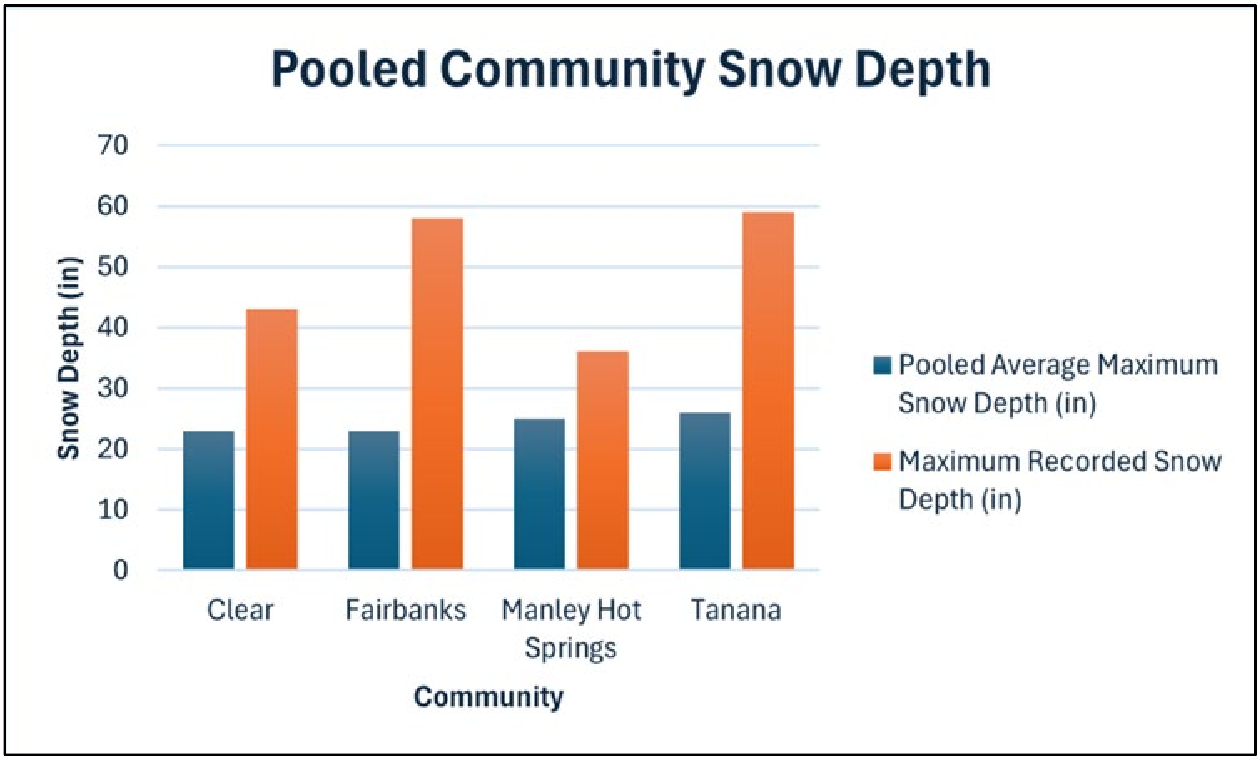
[2] One centimeter equals 0.394 inches.

Table 5. Structural class by meadow size, southern Minto Flats State Game Refuge, Interior Alaska, June 2024.

	Structural class % (*n*)								
Meadow size	Sedge emergent	Sedge meadow	Forb emergent	Graminoid emergent	Aquatic forb	Bog meadow	Tussock Meadow	Low shrub	Dwarf shrub
Large	83 (24)	7 (2)	0 (0)	3 (1)	0 (0)	0 (0)	0 (0)	7 (2)	0 (0)
Small	30 (9)	3 (1)	10 (3)	0 (0)	3 (1)	7 (2)	7 (2)	37 (11)	3 (1)
All	56 (33)	5 (3)	5 (3)	2 (1)	2 (1)	3 (2)	3 (2)	22 (13)	2 (1)

Table 6. Soil conditions by meadow size, southern Minto Flats State Game Refuge, Interior Alaska, June 2024.

	Soil Conditions % (*n*)			
Meadow size	Flooded	Saturated	Damp	Dry
Large (29)	93 (27)	7 (2)	0 (0)	0 (0)
Small (30)	53 (16)	27 (8)	20 (6)	0 (0)
All (59)	73 (43)	17 (10)	10 (6)	0 (0)



Source: Data collected from National Resource Conservation Service (NRCS) Snow Telemetry Network (SNOTEL) automated snow depth stations and National Weather Service (NWS) historical records (NRCS 2024, NWS 2024).

Figure 6. Plot of average maximum annual snow depth and maximum recorded snow depth by community, Interior Alaska, accessed 27 June and 2 July 2024.

Discussion and Conclusions

Our remote sensing comparison of the northern and southern MFSGR revealed that the southern MFSGR contained a higher density of habitat estimated to consist primarily of wetland sedges than the northern MFSGR (14.6% versus 5.6% of land area). Because our methods (remote sensing and spatial analysis) differed from those used by Gardner et al. (2007; aerial survey and visual estimation), estimates of sedge meadow habitat in northern MFSGR are not directly comparable between studies (5.6% versus 25.8%). Additionally, our spatial analysis found that the southern MFSGR contained a greater density of habitat estimated to contain at least 1% wetland sedge, compared to the northern MFSGR (58.9% versus 35.9% of land area). We compared the northern and southern MFSGR to place the southern MFSGR in context with what Gardner et al. (2007) identified as suitable wood bison habitat in the northern MFSGR. Our findings suggest that a higher proportion of suitable habitat exists in the southern MFSGR than in the northern MFSGR. Our spatial analysis also supports the hypothesis that the southern MFSGR contains a sufficient amount of sedge meadow habitat to be considered high-quality bison habitat.

We estimated the foliar cover of sedge species (*Carex* spp.) from vegetation plots in our study area to be almost exactly the same proportion as that found on the north side of the Tanana River by Gardner et al. (2007; 25.7% versus 25.8%) and similar to estimates from the lower

Innoko/Yukon River (Gardner et al. 2007) and the Tetlin National Wildlife Refuge (Jamison et al. 2023). Therefore, we establish in this survey that graminoid meadows in the southern MFSGR contain a similar amount of sedge vegetation as sites previously identified as high-quality bison habitat.

The species composition of sedges was similar between this survey and those of Gardner et al. (2007) and Jamison et al. (2023), although some variation occurred. Notably, the most commonly encountered sedge in this survey (and the most common plant), *Carex chordorrhiza*, was not a major species in either the Gardner et al. (2007) or Jamison et al. (2023) surveys. *C. chordorrhiza* is a small sedge (up to 35 cm, 13.8 in) that typically grows in standing water. This species is likely less useful to bison compared to larger, hardier sedges, which produce greater vegetative biomass. A couple of Canadian studies (Reynolds et al. 1978, Larter and Gates 1991) point to the importance of slough sedge (*C. atherodes*) in the diets of wood bison herds. However, Jung (2015) identified 9 different sedges in the diet of Aishihik bison, with water sedge (*C. aquatilis*) being the most abundant and slough sedge being absent. The Aishihik herd is located in the Yukon Territory, where elevations are higher and wetland sedge meadows are less extensive than in other wood bison herd ranges. Nevertheless, the Aishihik herd has thrived since its reintroduction (Miller et al. 2023), suggesting that slough sedge is not a requirement for wood bison. Reynolds et al. (1978) documented the use of *C. rostrata* by wood bison in the Slave River lowlands of the Northwest Territories. *C. utriculata*, *C. rostrata*, and *C. lasiocarpa* are all large wetland sedges found in our study area, which produce high biomass and may be used by bison similarly to *C. atherodes*. Additionally, *C. aquatilis* was common throughout our study area, especially in small meadows.

Observations of plains bison (*Bison bison bison*) behavior and mortality in Yellowstone National Park have found that prolonged winters with deep, crusted snow are the most important factors influencing bison mortality; however, in snow conditions without crusting or icing layers, bison have been observed moving and foraging in snow depths over 42 in (106.68 cm; Meagher 1973). The typical snow depths around Minto Flats (average maximum annual snow depth = 23.3 in, 58.7 cm) should be within a suitable range for bison habitat. Heavier snowfall occurs in areas with thriving bison populations, including Yellowstone National Park (West Yellowstone snow sensor – median annual maximum snow depth = 42.0 in, 106.7 cm; NRCS 2024). Maximum annual snow depths in Minto Flats are comparable to the 1991–2020 normal February snow depths in areas of Alaska with established plains bison populations: Farewell bison herd (McGrath = 22 in, 56 cm), Copper River bison herd (Dadina Lake = 26 in, 66 cm), and Delta Junction bison herd (Gerstle River = 15 in, 38 cm; U.S. Department of Agriculture 2022). Record snow depth at various snow stations surrounding the study area largely depended on the duration of the historical data. All stations used in this study with more than 75 years of snow depth records had maximum recorded snow depths of over 50 in (52 in, 57 in, 58 in, and 59 in). Comparisons to other bison ranges indicate that typical snow years should not unduly impact wood bison in the Minto Flats. However, this area has the potential to receive infrequent heavy snow accumulations that could result in occasional biologically significant impacts on a wood bison population.

The snow depth data collected within the northern MFSGR during March 2024 (average depth = 22 in, 56 cm), March 2010 (average depth = 16 in, 41 cm), and March 2004 (average depth = 15.9 in, 40.4 cm; Gardner et al. 2007) align with the corresponding data from the NWS and

NRCS snow depth sites in the surrounding area (NRCS 2024, NWS 20204). However, no direct measurements of snow have been taken in our study area. As described by Gardner et al. (2007), winds in MFSGR tend to reduce snow depth in meadow systems, often exposing low vegetation that would otherwise be covered in snow. The authors have made aerial observations of the study area in late winter and have observed many meadows blown clear of snow, with standing sedge visible above little to no snow cover. The study area may receive higher winds than surrounding areas where snow depth is measured and may often have substantially less snow cover than surrounding areas.

The presence of icing and hard snow layers has been found to impact winter movement, forage availability, and survival of bison (Meagher 1973, Reynolds and Peden 1987, Gardner et al. 2007). Reynolds and Peden (1987) found that snow hardness was a more significant factor influencing bison use than snow depth, in snow depths up to 60 cm (23 in). In December 2021, an extreme ice event (up to 2 in or 50.8 mm of rain on snow) paired with significant snowfall swept across Interior Alaska, having broad impacts on ungulate populations (T. Paragi, Wildlife Biologist, ADF&G, Fairbanks, 2021, unpublished report; T. Hollis, Area Biologist, ADF&G, 2024, Fairbanks, personal communication). While historical data on icing events are limited, recent work using remote sensing of rain-on-snow events has found large interannual variation of these events in Alaska. Between 1 November 2003 and 31 March 2016, 12 rain-on-snow events were documented in Fairbanks, ranging from 0.25 to 24.13 mm (0.0098–0.95 in) and averaging 7.22 mm (0.28 in; Pan et al. 2018). Further work is needed to understand the impact that snow characteristics and icing events have on bison populations.

Wet meadow habitats produce high biomass of graminoids compared to other habitat types and are especially important to northern bison during winter (Reynolds et al. 1978, Larter and Gates 1991, Belanger et al. 2020). Tradeoffs exist in bison habitat selection between forage availability and other factors such as footing and biting insects (Belanger et al. 2020). Bison across North America are known to vary their diets seasonally (Jorns et al. 2020, Craine 2021). Northern bison select a diverse mix of graminoids, forbs, shrubs, and horsetails in summer, while in winter, their diet primarily consists of graminoids (Reynolds et al. 1978, Campbell and Hinkes 1983, Larter and Gates 1991, Jung 2015). Due to the high proportion of standing water in large meadows of our study area, bison may select habitat types other than large meadows in summer, when the soil is saturated and footing is soft. Small meadows were drier than large meadows and may provide better footing during summer. Small meadows contained more *Carex aquatilis* than large ones, were more diverse, and may provide summer forage such as marsh cinquefoil and willow. The mosaic nature of meadow and forest habitat types in the area should provide diverse options for bison to choose from in summer. In winter, when bison are more dependent on graminoids, nutrition is most limiting for Alaska ungulates, and frozen ground provides firmer footing, the large wetland sedge meadows in the southern MFSGR should provide substantial bison forage.

In conclusion, the mosaic of habitat types present in the southern MFSGR should provide diverse opportunities for bison to forage. Habitat in the southern MFSGR is similar to that in the northern MFSGR, and the estimated proportion of wetland sedge habitat exceeds that in the northern portion of the refuge. Snow depths are unlikely to preclude bison from foraging in normal winters. Bison forage species are present in both large and small meadow habitats in sufficient quantity to support the establishment of a new herd of wood bison in the area.

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Appendix A. List of plant species found in a vegetation survey of southern Minto Flats State Game Refuge, Interior Alaska, June 2024.

Scientific name	Common name
Alnus crispa	mountain alder
Alnus spp.	alder species
Andromeda polifolia	bog rosemary
Betula glandulosa	resin birch
Betula nana	dwarf birch
Betula neoalaskana	Alaska paper birch
Betula papyrifera	western paper birch
Calamagrostis canadensis	bluejoint reedgrass
Carex aquatilis	water sedge
Carex capitata	capitate sedge
Carex chordorrhiza	creeping sedge
Carex diandra	lesser panicled/lesser tussock sedge
Carex lasiocarpa	wooly fruit sedge
Carex limosa	mud sedge
Carex loliacea	rye-grass sedge
Carex rostrata	beaked sedge
Carex rotundata	round sedge
Carex spp.	sedge species
Carex utriculata	Northwest Territory sedge
Chamadaphne caliculata	leatherleaf
Cicuta mackenzieana	Mackenzie's water hemlock
Drosera anglica	English sundew
Drosera rotundifolia	roundleaf sundew
Equisetum arvense	field horsetail
Equisetum fluviatile	water horsetail
Equisetum palustre	marsh horsetail
Eriophorum angustifolium	tall cottongrass
Eriophorum gracile	slender cottongrass
Eriophorum russeolum	red cottongrass
Eriophorum spp.	cottongrass species
Eriophorum vaginatum	tussock cottongrass
Larix laricina	tamarack

-continued-

Appendix A. List of plant species found in a vegetation survey of southern Minto Flats State Game Refuge, Interior Alaska, June 2024, continued.

Scientific name	Common name
Ledum groenlandicum	western Labrador tea
Ledum palustre	bog Labrador tea
Menyanthes trifoliata	buckbean
Myrica gale	sweetgale
Petasites frigidus	coltsfoot
Picea mariana	black spruce
Picea spp.	spruce species
Potentilla fruticosa	shrubby cinquefoil
Potentilla palustris	marsh cinquefoil
Rubus chamaemorus	cloudberry
Salix bebbiana	Bebb's willow
Salix candida	silvery willow
Salix fuscescens	Alaska bog willow
Salix pulchra	diamond-leaf willow
Salix spp.	willow species
Triglochin maritimum	seaside arrowgrass
Utricularia spp.	bladderwort species
Vaccinium uliginosum	bog blueberry
Vaccinium vitis-idaea	lingonberry