Ronald Lake Wood Bison Research Program: 2019 Annual Report

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Executive Summary

In this annual report, we discuss research activities in 2019 conducted by University of Alberta and Royal Alberta Museum researchers as it relates to the ecology of the Ronald Lake bison herd (RLBH). The research reported here addresses a number of knowledge gaps identified by the RLBH Technical Team. These knowledge gaps ask questions about the herd's range and distribution, mechanisms influencing seasonal migrations, use of landcover types by different species, and bottom-up (i.e., forage quantity and quality) and top-down (i.e., predation) influences on bison habitat selection. The overall objective of this research is to inform the management of the RLBH and its habitat, particularly as it relates to the potential development of the Frontier oil sands mine.

The knowledge gaps defined by the RLBH Technical Team's Work and Action Plan that were addressed in 2019 include:

- 1b – *What limits the northward movement of RLBH into Wood Buffalo National Park?*
- 1d & 3a – *How does spring green-up influence the RLBH's annual migration?*
- 2a, 2b, & 2c – *How are different habitats used by large mammals in the RLBH's range?*
- 3c & 3e – *What comprises the RLBH's diet? How does the quality and quantity of available forage change seasonally and how do these changes influence the RLBH's diet?*
- 4a, 4b, & 5a – *How do anthropogenic and natural disturbances affect the mechanisms driving habitat selection?*
- 4c – *How do snow dynamics influence movement and habitat selection by the RLBH?*
- 4c & 8e – *How does potential wolf predation influence the RLBH's habitat selection?*

We found that the southeastern corner of WBNP, which includes the northern extend of the RLBH's home range, is dominated by landcover types that are avoided by the both males and females throughout the year. We were able to identify migration corridors and stopover sites used by the RLBH and found a correlation between bison locations and higher quality vegetation during the migratory period. We established a series of long-term scat survey plots and report on seasonal use of landcover types by a number of different mammal species. We completed a review of American bison (*Bison bison*) diets, finding that there was a significant increase in browse, protein, and lipid consumption in bison herds further north. Our preliminary investigation into the mechanisms driving the RLBH's habitat selection shows a preference for open habitats not forage biomass. Analysis of our snow depth data showed that upland deciduous landcover types had the deepest snowpack and February was the month with the deepest snowpack. We collared wolves in two packs and generated home range estimates for each. Lastly, we collected scat samples that are being analyzed for dietary content.

Background

In 2011, a proposal was put forward to develop an oil sands surface mine, the Frontier project, which would be the most northern surface mine in Alberta's oil sands region. The mine would overlap partly with the range of the Ronald Lake wood bison (*Bison bison athabascae*) herd (RLBH). In Canada, wood bison are considered *Threatened* under the Species at Risk Act and the RLBH is listed as a *Subject Animal* under the Wildlife Act in Alberta (AEP & ACA, 2017). The RLBH is culturally important to local Indigenous communities, is considered disease (i.e., brucellosis and bovine tuberculosis) free (Shury et al., 2015), and has a unique genetic structure when compared to other bison herds in Alberta (Ball et al., 2016).

The RLBH Technical Team (RLBHTT) is comprised of representatives from local Indigenous communities, industry, and from provincial and federal government agencies, with the mandate to "identify the knowledge necessary for sound management of the [RLBH] and its habitat" (Terms of Reference, 2018). The RLBHTT identified a series of knowledge gaps (Table 1) related to the herd's ecology that needed to be addressed in order to meet their mandate. Since 2013, female bison in the RLBH have been fitted with GPS radio-collars to address some of these knowledge gaps. Since then, researchers at the University of Alberta and Royal Alberta Museum have been using these data to address a number of these knowledge gaps.

Research to date has explored bison movements, seasonal/annual ranges, mechanisms of habitat selection, responses to natural and anthropogenic disturbances, and factors limiting the use of the herd's northern range (Tan el at., 2015; DeMars et al., 2015; Belanger et al., 2017; Belanger et al., 2018; DeMars et al., 2019). Please note, throughout this report (except Knowledge Gap 1b) our results pertain only to female bison. Some noteworthy results previously reported include:

1) Consistent use of the same annual range and predictable seasonal changes in habitat selection;
2) Selection for graminoid- (i.e., grasses and sedges) rich habitats during winter;
3) Greater forage quantity, more biting insects, and less stable footing during summer;
4) Migration to a western part of their range during spring, likely when calving;
5) Marginally faster movements on linear disturbances;
6) Avoidance of disturbances when industrial activities were ongoing; and
7) The northern extent of the herd's range being dominated by landcover types typically avoided by the RLBH.

Here, we build upon this previous research, report on new results, and explore knowledge gaps that we have not reported on previously.

Table 1. The knowledge gaps identified by the Ronald Lake Bison Herd Technical Team that are reported on here, completed, or are ongoing as conducted by the University of Alberta and Royal Alberta Museum researchers.

Theme	Gap #	Project	Personnel	Status	Citation
Bison range	1A	Season & sex-specific ranges	Tan, DeMars & others	Complete (future updates)	DeMars et al. 2016
Bison range	1B	Northern extent (limits)	Belanger	Update in this report	Belanger et al. 2018
Bison range	1D	Migration routes	Tan, DeMars Hecker	Update in this report	DeMars et al. 2016
Habitat - Landcover	2A	Wetlands	DeMars, Belanger, Rawleigh	Update in this report	DeMars et al. 2016
Habitat - Landcover	2B	Human disturbances (energy)	DeMars, Belanger	Update in this report	DeMars et al. 2016
Habitat - Landcover	2C	Human disturbances (forestry)	DeMars, Belanger	Update in this report	DeMars et al. 2016
Habitat - Landcover	2D	Natural disturbances (fire)	DeMars	Complete (future updates)	DeMars et al. 2016
Forage (bottom-up)	3A	Greenup/phenology	Hecker	Update in this report	
Forage (bottom-up)	3C	Forage quantity/quality	Belanger, Hecker	Update in this report	Belanger et al. 2018
Forage (bottom-up)	3E	Anthropogenic changes	Hecker	Update in this report	Belanger et al. 2018
Habitat use	4A	Wallows & water	Hecker & others	Update in this report	Belanger et al. 2018
Habitat use	4B	Trade-offs (insects/ground)	Belanger	Complete	Belanger et al. 2017
Habitat use	4C	Winter snow	Belanger, Hecker	Update in this report	Belanger et al. 2018
Habitat use	5A	Anthropogenic disturbances	DeMars, Hecker	Update in this report	Belanger et al. 2018
Popln ecol (top-down)	4C/8E	Wolf predation	Dewart	Update in this report	Belanger et al. 2018
Popln ecol (top-down)	8C/G	Cow-calf & age structure	Belanger	Update in this report	Belanger et al. 2018
Future scenarios	6A/C	Habitat supply forecasts	Hecker, Nielsen	Ongoing	

Research progress

Knowledge Gap 1b - What limits the northward movement of RLBH into Wood Buffalo National Park?

Research objectives

The extent of interaction between the Wood Buffalo National Park (WBNP) and RLBH remains unclear (AEP, 2014). While there is speculation that the RLBH is a subpopulation of the WBNP herd, recent genetic and disease testing indicate that Ronald Lake bison have remained isolated from WBNP bison (Ball et al., 2016). Two main concerns regarding the interaction of these herds are the transmission of the diseases bovine tuberculosis and brucellosis present in the WBNP herds to the RLBH that have had no positive tests to date, and genetic mixing of Ronald Lake wood bison with WBNP bison, which is composed of both wood and plains bison, and (AEP, 2014). Though historical movements of bison from both herds suggest close proximity (AEP, 2014), there is a lack of evidence indicating physical interaction between these herds. The goal of this work is to determine if a physical barrier (e.g., landscape feature) exists north of the RLBH's range (DeMars et al., 2016) that may limit interaction between the two herds. Identifying a physical barrier that may limit bison movement can 1) help to support evidence that the herds have historically remained separated and 2) provide information for the management of continued separation of the herds, thus helping to alleviate concerns regarding their potential interactions.

Two prominent landscape features to the west and east of the RLBH's range are the Birch Mountains and the Athabasca River, respectively. With limited evidence to support bison movement outside their current range to the west and east, here we examine changes in the distribution of landcover types to the north as a factor potentially limiting the RLBH's movement north into WBNP. Specifically, we examine selection and avoidance along a north-south gradient. This analysis will help determine if changes in the distribution of landcover potentially limits northward movement of the RLBH into WBNP, and to a lesser extent, beyond the extent of their current range.

In our previous analysis investigating landcover type as a barrier to movement (e.g., Belanger et al., 2018), we grouped males and females in a single analysis and examined habitat selection on an annual basis. In our 2018 annual report, we concluded that the area north of the RLBH's range, which extends into the southern parts of WBNP, is very wet and is composed of large tracts of landcover types that are avoided by bison (e.g., shrub swamps). In this report, our objective is to again examine landcover type as a barrier to attracting bison to the north and thus movements that would interact more with bison from WBNP and to examine differences between males and females during four biologically relevant seasons.

Overview of research methods

Using Ronald Lake bison GPS radio-collar data (2013-2017) and Ducks Unlimited enhanced wetland classification (EWC), we modeled the distribution (habitat use) of Ronald Lake female and male bison in relation to landcover types during the calving, summer/fall, winter, and spring seasons. This analysis is similar to the resource selection function (RSF) analysis by DeMars et al. (2017), who also examined bison distribution in response to landcover type. Here we modeled each landcover type independent of all others. Specifically, we use univariate Poisson models to examine the effect of landcover type on the distribution (count of telemetry observations) of bison (Qian, 2016). As such, all landcover types are not in reference to a withheld category as they are in the DeMars et al. (2017) RSF analyses. Using univariate Poisson models allows for: 1) direct comparison of habitat use between models of the same type; and 2) estimation of habitat use coefficients for all landcover types, with no landcover type held as a reference category (Qian, 2016).

To model the distribution of bison in relation to landcover type, we followed the methods used by Belanger et al. (2018), whereby we constructed a 99% utilization distribution (UD) to define the range of the RLBH, and subsequently divided this UD into 30 east-west 'bands' of equal width along a north-south gradient. Within each band we calculated the number of female and male bison GPS locations for each season, and percent cover of each landcover type in each band. The seasons we used followed those described in DeMars et al. (2017; Table 2).

Progress / results

In total, we estimated selection coefficients for 216 univariate Poisson models (two sexes × four seasons × 27 landcover type; Table 3a & 3b). Our results demonstrate that use of habitats varies between sex and season, and that large tracts of avoided landcover types exist in the northern region of the RLBH's range and further north into WBNP (e.g., Figure 1). These results are consistent with analysis from Belanger et al. (2018), however, they more clearly demonstrate that large tracts of avoided landcover types for both male and females in all four seasons comprise much of the herd's northern range and areas further north into the southern parts of WBNP. Despite significance in nearly all models, due to the large difference in sample size between females (n = 44) and males (n = 5), we are more confident in our estimation of habitat use for females then for males, which is reflected by greatly reduced standard errors for females (Table 3a & 3b).

Though more unconventional than standard RSF analyses for large ungulates such as bison, the univariate Poisson models allows for the estimation of habitat use coefficients for all landcover types, including deciduous forest that was used as the reference category in DeMars et al. (2017). We point out, however, that these Poisson models are not 'true' selection estimates as we did not measure bison use of each landcover type compared to its availability, but instead examined how bison GPS location counts varied in response to landcover type availability. Further, we analyze landcover types independent of each other and do not account for interactions that may exist between them, and thus one should interpret these results with this in mind.

Similar to conclusions in Belanger et al. (2018), we detail three main inferences from this analysis. First, though not explicitly described in this report, the majority of the RLBH's range is composed of landcover types that are avoided by female bison across all seasons (e.g., Figure 1). Avoided landcover types by female bison include upland mixed-wood, pine, and conifer forests, shrub and tamarack swamps, and burned areas, which together makeup a large proportion of the area within their range. Second, relative to selected landcover types by female bison, the area north of the RLBH's range that is south and east of Lake Claire is composed of a greater amount of avoided landcover types across all seasons. Lastly, use of landcover types is much different for males compared to females. Though male bison show avoidance of many landcover types (Table 1b), a large proportion of the area within their home ranges is composed of selected landcover types. In conclusion, there are tracts of selected, forage dense landcover types, such as meadow and emergent marshes (Belanger et al., 2017), and deciduous forests dispersed throughout the RLBH's range and adjacent to Lake Claire that may act as a corridor for female and male bison movement north into WBNP by the Ronald Lake herd. However, if avoided landcover types are barriers to female bison movement, large tracts of avoided landcover types in the northern region of their range and the area southeast of Lake Claire may act as physical barrier to movement. For male bison, their selection of more landcover types may allow for more widespread movement, and thus landcover type may not be a factor limiting their movement.

Our investigation of whether landcover type potentially limits physical interaction between the WBNP herds and RLBH is another step in examining the mechanisms that may have influenced the historic and current separation of these herds. While the Birch Mountains and the Athabasca River are significant landscape features that may limit bison movement to the west and east, respectively, the degree to which landcover types act as a barrier to northward movement remains unclear. Continued investigation into landcover type and the myriad of other mechanisms acting as barriers to movement may provide further information on the potential interaction of the WBNP herds and RLBH. Direct observations of movement are needed to fully understand the proximity of bison from both herds, and thus potential for physical interactions. Ongoing radio-collaring of Ronald Lake bison and the recent collaring of WBNP bison will provide data that will help determine the proximity of these two herds. Though proximate analysis of mechanisms potentially limiting bison movement provides a basis for understanding the potential for interaction, radio-collar data from both herds will better assist management in addressing concerns related to their interaction.

Outstanding / upcoming work

While there may be a myriad of other factors, such as Canada Thistle (Pers. Comm. Technical Team meeting Nov 2019), limiting the interaction of the WBNP herds and RLBH herds, radio-collar data will provide a more clear understanding regarding recent interaction. Examination of the proximity of WBNP and Ronald Lake bison and the extent of their range overlap, combined with this analysis of use and avoidance of landcover types will help us better understand the potential for interaction between these two herds.

Table 2: The specific dates of the four seasons (i.e., winter, spring, calving, and summer/fall) as defined by DeMars et al (2015).

Year	**Season**	**Start Date**	**End Date**
2013	Winter	Jan 1	Apr 24
	Spring	Apr 25	May 20
	Calving	May 21	Jun 28
	Summer/Fall	Jun 29	Nov 1
2014	Winter	Nov 2, 2013	Ap 18
	Spring	Apr 19	May 31
	Calving	Jun 1	Jun 26
	Summer/Fall	Jun 27	Nov 7
2015	Winter	Nov 8, 2014	Apr 7
	Spring	Apr 8	May 13
	Calving	May 14	Jun 15
	Summer/Fall	Jun 16	Nov 14
2016	Winter	Nov 15, 2015	Mar 31
	Spring	Apr 1	May 2
	Calving	May 3	Jun 6
	Summer/Fall	Jun 7	Oct 20
2017	Winter	Oct 21, 2016	Apr 29
	Spring	Apr 30	May 17
	Calving	May 18	Jun 17
	Summer/Fall	Jun 18	Oct 28
2018	Winter	Oct 29, 2017	Apr 28
	Spring	Apr 29	May 12
	Calving	May 13	Jun 13
	Summer/Fall	Jun 14	Nov 2

Table 3a: Coefficients of univariate Poisson models examining the distribution of female Ronald Lake wood bison (*Bison bison athabascae*) GPS radio-collar locations (2013 – 2017) (n = 44 individuals) in response to the distribution of 27 landcover types for spring, calving, summer/fall, and winter seasons. All models fit better than null models based on AIC.

	Spring			Calving			Summer/fall			Winter		
Landcover type	β	S.E.	*p*	β	S.E.	*p*	β	S.E.	*p*	β	S.E.	*p*
Anthropogenic	-1375.01	20.86	< 0.001	-1780.01	16.90	< 0.001	161.85	7.43	< 0.001	-688.60	8.78	< 0.001
Aquatic bed	-100.10	8.58	< 0.001	25.42	5.82	< 0.001	-124.40	4.55	< 0.001	-281.10	4.77	< 0.001
Burn	-21.28	9.28	0.022	-68.10	7.10	< 0.001	369.90	3.08	< 0.001	-39.46	4.83	< 0.001
Conifer swamp	52.09	0.35	< 0.001	71.80	0.25	< 0.001	37.22	0.19	< 0.001	56.51	0.18	< 0.001
Cutblock	30.70	2.37	< 0.001	34.51	1.68	< 0.001	150.80	0.80	< 0.001	93.41	0.95	< 0.001
Emergent marsh	324.19	2.12	< 0.001	352.40	1.51	< 0.001	300.20	1.12	< 0.001	394.30	1.05	< 0.001
Graminoid poor fen	85.53	0.67	< 0.001	101.70	0.47	< 0.001	63.88	0.38	< 0.001	69.35	0.36	< 0.001
Graminoid rich fen	-63.53	1.49	< 0.001	-53.58	1.01	< 0.001	-60.49	0.77	< 0.001	-99.05	0.92	< 0.001
Hardwood swamp	17.37	0.67	< 0.001	30.58	0.46	< 0.001	37.29	0.33	< 0.001	8.69	0.35	< 0.001
Meadow marsh	53.42	1.03	< 0.001	75.19	0.70	< 0.001	41.74	0.56	< 0.001	75.89	0.49	< 0.001
Mixedwood swamp	-43.74	0.61	< 0.001	-54.57	0.51	< 0.001	-33.64	0.27	< 0.001	-40.87	0.30	< 0.001
Mudflats	-258700	972500	0.790	-253800	600500	0.673	-70920	2268	< 0.001	258000	484500	0.549
Open bog	2171.01	17.14	< 0.001	2327.01	12.04	< 0.001	1462.03	10.32	< 0.001	2187.02	8.70	< 0.001
Open water	72.23	0.79	< 0.001	68.45	0.57	< 0.001	25.08	0.44	< 0.001	69.03	0.40	< 0.001
Shrub swamp	-16.18	0.28	< 0.001	-13.07	0.19	< 0.001	-14.78	0.15	< 0.001	-18.05	0.15	< 0.001
Shrubby bog	380.80	2.87	< 0.001	400.11	2.04	< 0.001	219.80	1.73	< 0.001	402.90	1.44	< 0.001
Shrubby poor fen	92.35	0.60	< 0.001	111.40	0.43	< 0.001	70.68	0.33	< 0.001	80.74	0.31	< 0.001
Shrubby rich fen	13.12	0.61	< 0.001	0.96	0.47	0.040	-26.61	0.39	< 0.001	-7.57	0.34	< 0.001
Tamarck swamp	-51.40	0.96	< 0.001	-146.70	1.30	< 0.001	-39.50	0.46	< 0.001	-120.30	0.77	< 0.001
Treed bog	-2.33	0.97	0.016	-4.02	0.71	< 0.001	60.66	0.38	< 0.001	47.16	0.39	< 0.001
Treed poor fen	1.19	0.33	< 0.001	-15.41	0.28	< 0.001	-20.79	0.22	< 0.001	-25.53	0.22	< 0.001
Treed rich fen	14.16	0.31	< 0.001	5.29	0.24	< 0.001	-7.13	0.19	< 0.001	-10.55	0.19	< 0.001
Upland conifer	-9.61	0.19	< 0.001	-10.87	0.14	< 0.001	1.46	0.07	< 0.001	-2.04	0.08	< 0.001
Upland deciduous	7.97	0.13	< 0.001	13.02	0.10	< 0.001	14.06	0.07	< 0.001	13.89	0.07	< 0.001
Upland mixedwood	-85.65	1.64	< 0.001	-289.40	4.55	< 0.001	-137.80	1.26	< 0.001	-73.33	0.76	< 0.001
Upland other	-134.90	5.88	< 0.001	-372.20	12.79	< 0.001	6.49	0.62	< 0.001	-142.90	3.25	< 0.001
Upland pine	-10.69	0.17	< 0.001	-19.68	0.16	< 0.001	-24.61	0.13	< 0.001	-18.59	0.11	< 0.001

Table 3b: Coefficients of univariate Poisson models examining the distribution of male Ronald Lake wood bison (*Bison bison athabascae*) GPS radio-collar locations (2014 - 2015) (n = 5 individuals) in response to the distribution of 27 landcover types for spring, calving, summer/fall, and winter seasons. Asterisk indicates poor model fit compared to null model based on AIC.

	Spring			Calving			Summer/fall			Winter		
Landcover type	β	S.E.	*p*	β	S.E.	*p*	β	S.E.	*p*	β	S.E.	*p*
Anthropogenic	67.46	53.34	0.206 *	753.31	34.67	< 0.001	755.67	32.08	< 0.001	-224.09	39.01	< 0.001
Aquatic bed	-127.52	32.09	< 0.001	282.69	19.24	< 0.001	253.65	18.03	< 0.001	-247.70	23.36	< 0.001
Burn	-216.25	43.64	< 0.001	-599.12	50.79	< 0.001	196.08	17.72	< 0.001	-2867.06	441.20	< 0.001
Conifer swamp	-9.73	1.76	< 0.001	-9.13	1.27	< 0.001	14.93	1.00	< 0.001	-33.16	1.45	< 0.001
Cutblock	-134.91	16.57	< 0.001	-117.80	11.30	< 0.001	64.88	5.16	< 0.001	-1269.03	153.87	< 0.001
Emergent marsh	-48.45	12.15	< 0.001	150.55	6.63	< 0.001	237.01	5.59	< 0.001	-56.49	8.45	< 0.001
Graminoid poor fen	14.52	3.45	< 0.001	-47.54	3.66	< 0.001	32.39	2.10	< 0.001	41.92	2.04	< 0.001
Graminoid rich fen	-38.89	4.71	< 0.001	-263.98	7.91	< 0.001	-74.80	3.95	< 0.001	-90.29	4.38	< 0.001
Hardwood swamp	-23.63	2.91	< 0.001	7.21	1.86	< 0.001	25.58	1.62	< 0.001	-26.02	2.02	< 0.001
Meadow marsh	-194.13	8.24	< 0.001	-68.51	4.10	< 0.001	-34.71	3.40	< 0.001	-123.85	4.62	< 0.001
Mixedwood swamp	-19.97	1.43	< 0.001	-68.17	-2.24	< 0.001	-26.17	1.10	< 0.001	-75.19	2.29	< 0.001
Mudflats	2528.12	78.47	< 0.001	-1198.00	174.90	< 0.001	-3914.11	3.96	< 0.001	584.19	92.66	< 0.001
Open bog	738.14	86.72	< 0.001	-1382.00	113.20	< 0.001	524.51	61.66	< 0.001	1492.00	49.65	< 0.001
Open water	-66.74	4.12	< 0.001	3.45	2.39	0.150	-9.37	2.29	< 0.001	13.72	2.20	< 0.001
Shrub swamp	-11.81	0.98	< 0.001	-18.95	0.79	< 0.001	-11.65	0.65	< 0.001	-17.05	0.73	< 0.001
Shrubby bog	277.28	11.55	< 0.001	48.10	10.56	< 0.001	123.67	9.04	< 0.001	253.28	8.11	< 0.001
Shrubby poor fen	-6.28	3.36	0.061	-27.39	2.77	< 0.001	31.42	1.84	< 0.001	23.95	1.95	< 0.001
Shrubby rich fen	-10.21	2.52	< 0.001	-123.18	3.09	< 0.001	-68.77	2.27	< 0.001	18.13	1.51	< 0.001
Tamarck swamp	20.89	2.36	< 0.001	-19.01	2.09	< 0.001	-0.02	1.75	0.993 *	-36.89	2.21	< 0.001
Treed bog	-4.05	1.31	0.002	42.96	2.09	< 0.001	27.58	2.07	< 0.001	-44.66	3.14	< 0.001
Treed poor fen	-10.14	1.37	< 0.001	-21.47	1.13	< 0.001	-30.33	1.14	< 0.001	24.53	0.69	< 0.001
Treed rich fen	-4.05	1.31	< 0.001	-39.91	1.26	< 0.001	-22.50	1.02	< 0.001	11.38	0.81	< 0.001
Upland conifer	6.36	0.44	< 0.001	12.64	0.27	< 0.001	6.70	0.29	< 0.001	-1.75	0.38	< 0.001
Upland deciduous	13.50	0.51	< 0.001	15.06	0.38	< 0.001	15.21	0.35	< 0.001	0.21	0.29	0.473 *
Upland mixedwood	-97.11	6.59	< 0.001	-146.25	6.85	< 0.001	-4875.41	6738.56	0.942	23.68	1.95	< 0.001
Upland other	-10.55	5.31	0.047	19.07	2.78	< 0.001	-23.91	4.16	< 0.001	-110.39	11.41	< 0.001
Upland pine	-12.45	0.66	< 0.001	-14.95	0.51	< 0.001	-16.32	0.49	< 0.001	8.96	0.31	< 0.001

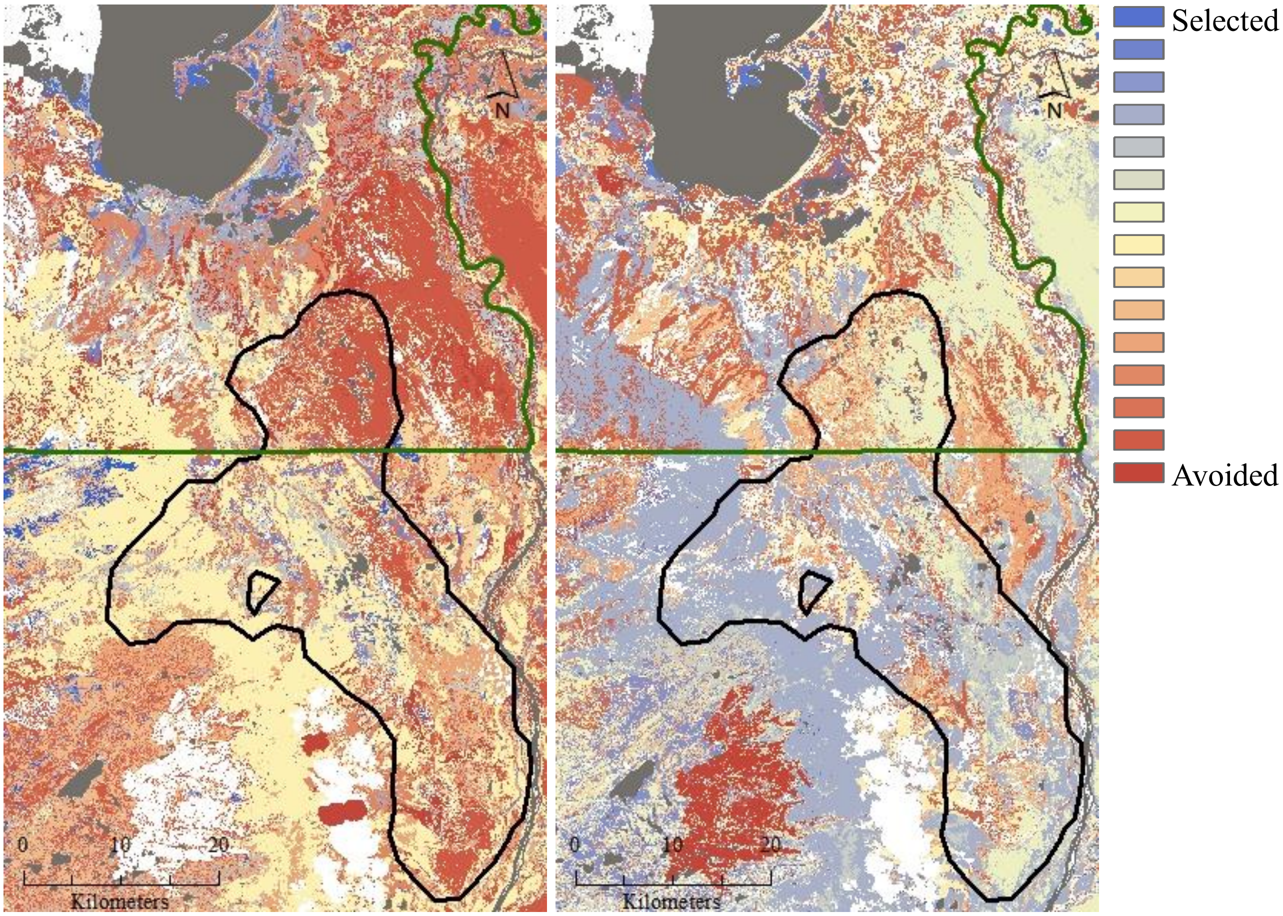

Figure 1. Maps of female (left) and male (right) Ronald Lake wood bison (*Bison bison athabascae*) habitat use of landcover types during the calving season derived from univariate Poisson models using GPS radio-collar locations (female 2013 – 2017; male 2014 – 2015). The scale bar represents the direction of selection based on the beta coefficients of the models with higher values (blue) representing selected landcover types and lower values (red) representing avoided landcover types. This map of habitat use for the calving season is an example and visual representation of the areas dominated by selected/avoided landcover types (spring, summer/fall, and winter seasons not shown in this report). White area are cloud cover, no data, or coefficients for non-significant models or models that fit poorly compared to null models; gray area is water; green boundary is Wood Buffalo National Park; black boundary is merged annual 99% utilization distributions of Ronald Lake bison GPS radio-collar locations (2013 – 2017).

Knowledge Gaps 1d & 3a – How does spring green-up influence the RLBH's annual migration?

Research objectives

Our objective is to determine what factors influence the spring migration of the RLBH. In early May, the RLBH leaves the eastern parts of their range, where they spend the majority of summer, fall, and winter, to a distinct region (hereafter referred to as the western range) at the base of the Birch Mountains near the McIvor River (Tan et al., 2014). The RLBH then returns to the eastern parts of their range in June. The migratory behaviour has been observed every year and corresponds to the calving season (DeMars et al., 2016). Here, we explore the hypothesis that the spring migration is related to the improvement of forage quality during spring green-up.

Overview of research methods

We used telemetry locations from each individual bison 14-days prior to entering the western range and 14-days after leaving the western range to describe migratory behaviour during ingress (i.e., migration into the western range in May) and egress (i.e., migration out of the western range in June), respectively. Our observations of bison locations indicate that these 14-day window encapsulate the entire migration for each individual. We then generated Brownian Bridge Movement Models (BBMMs) to identify migration corridors and stopover sites during the migration periods (Horne et al., 2007).

To investigate the influence of spring green-up, we used normalized difference vegetation index (NDVI) to quantify forage phenology (Pettorelli et al., 2005). NDVI is thought to be an accurate assessment of forage quality as high NDVI values are correlated with high levels of crude protein in ungulate feces and fat gain (Hamel et al., 2009; Middleton et al., 2018). We related bison locations with NDVI values to determine if bison are selecting locations with higher quality vegetation during this time.

In 2015, we established a camera trapping program in and around an upland meadow located in the northeastern corner of the western range. These cameras have been monitoring the use of the meadow by different species, including bison.

Progress / preliminary results

We generated BBMMs for every individual collared bison, and then averaged the results for each year and across years to assess the RLBH's migratory behaviour. To date, we have created BBMMs for each year from 2013 – 2019 (Figure 2; Appendix I). Our BBMMs revealed the use of two migration corridors: one along a legacy seismic line entering the western range from the south, and one entering the western range from the north. The southern corridor is primarily used during ingress whereas the northern corridor is used during both ingress and egress in 2013 - 2016. From 2017 – 2019 the southern corridor was used during both ingress and egress. Prior to ingress, bison were scattered across the eastern range and migrated in small groups arriving in the western range within a few days of each other. During egress all collared bison migrated in one or two large groups.

Preliminary investigations of vegetation quality revealed that bison locations in the western range are associated with higher NDVI values when compared to the rest of their range during the same time period (Figure 3).

Camera traps have revealed that there is a positive correlation between bison and black bear (*Ursus americanus*) presence in the upland meadow during the spring. However, there is little wolf (*Canis lupus*) activity in and around the meadow during this time. Wolves tend to occupy the meadow in the late fall and winter, which is associated with a higher moose (*Alces alces*) activity (Belanger et al., 2017).

Outstanding / upcoming work

We plan to increase camera trap density along the migration corridors and reduce the number of cameras within the meadow. Specifically, we plan to establish at least three monitoring stations along the north and south migration corridors. These cameras will allow us to explore the timing of calving in relation to the migratory behavior, estimate of cow:calf ratios, and establish use of stopover sites during migration. A smaller number of cameras in the meadow will continue to be used for general behaviour of bison and presence and timing of potential predators.

We will calculate instantaneous rate of green-up (IRG) from NDVI values (Bischof, et al., 2012) to assess relationships between migration and phenology. Specifically, IRG values will allow us to explore the temporal correlation between bison migration and green-up of vegetation.

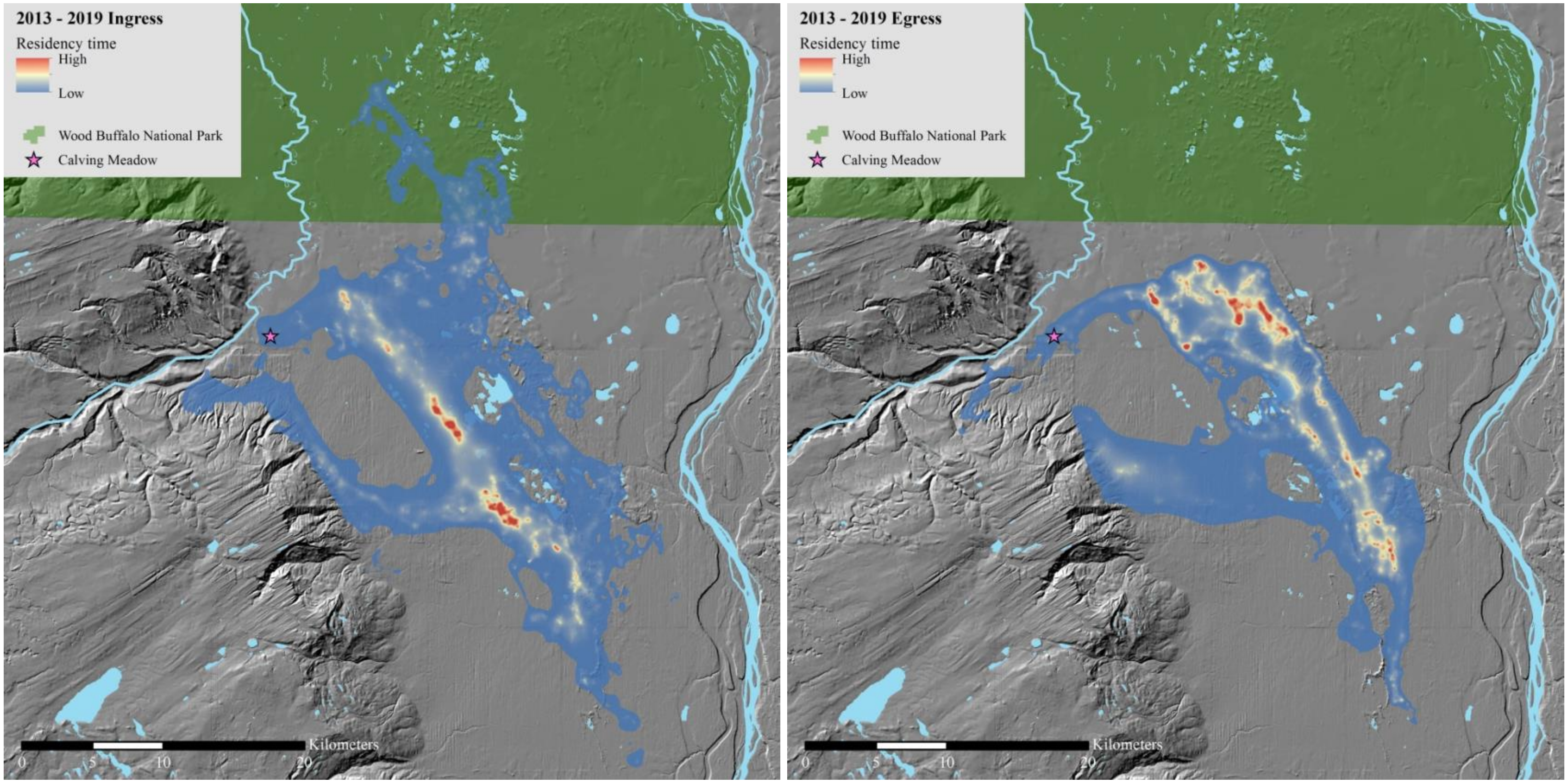

Figure 2: Mean Browning bridge movement models from 2013 - 2019 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The "calving meadow" is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.

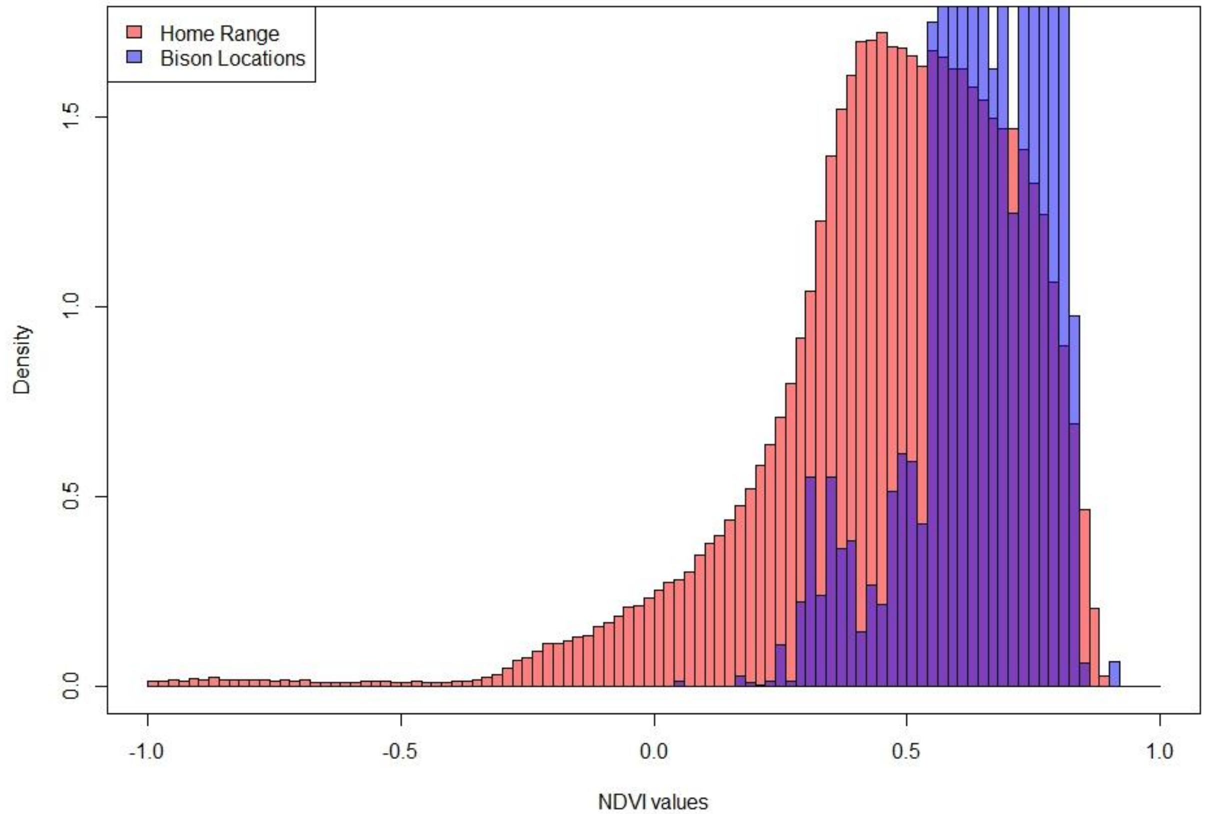

Figure 3: Normalized Difference Vegetation Index (NDVI) values at bison locations (blue) compared to random available locations (red) within the Ronald Lake bison herd's range (as defined by a 99% utilization distribution for female bison) from 2013 through 2016 spring (i.e., calving) seasons while they are within and migrating into the western range.

Knowledge Gaps 2a, 2b, & 2c - How are different habitats used by large mammals in the RLBH's range?

Research objectives

Our objective was to estimate and monitor seasonal habitat use by bison and other wildlife for different landcover types and disturbances. Specifically, we are interested in using long-term, non-invasive monitoring techniques that are not dependent on GPS radio-collar data, nor biased to herding behaviour. We address this by using plot-based animal scat surveys in different landcover types to monitor seasonal and annual differences in habitat use (Alves et al., 2013).

Overview of research methods

In the summer of 2018, we established 17 permanent plots located in four different landcover types (i.e., marshes, upland deciduous, upland pine, and bogs), and one disturbance type (i.e., cutblock). We constructed these plots by arranging six T-posts in a rectangular pattern encompassing a 500-m_2 area that are open to use by wildlife. Then, we counted, recorded, and removed all scat deposits within the plots. Two surveys are conducted during snow-free periods: one survey in spring after snowmelt and one survey in fall before snowfall. Sites are re-visited in late April to obtain winter counts, and again in late October to obtain summer counts (intervals of 6 months). Two observers survey the total area of each plot, counting individual scat deposits and identifying the species. After the scat is recorded, the observer removes the scat from the plot. Detectability rates of scat can differ between landcover types and seasons (Alves et al., 2013). To increase scat detectability, the two observers survey each plot twice, with the second pass being perpendicular to the first. These counts will be used to calculate relative habitat use of different landcover types by bison and other species.

Progress / preliminary results

The 2018-2019 scat counts exhibited a small seasonal shift in the use of landcover types by bison. While the dominant winter habitat use was marshes, we observed winter use of bogs, cublocks, and upland pine habitats. We observed an increase of summer bison activity within the upland deciduous habitats and no occurrences in pine, cutblocks, and bogs (Figure 4). We observed use of habitat in the five landcover types by multiple species (e.g., bison, moose and bear). Bison, moose, and bear overlapped their use in pine, deciduous, marsh, cut block, and bog, with marshes predominantly used by bison (Figure 5).

Outstanding / upcoming work

We will conduct winter and summer scat surveys for all 17 existing plots in April and October, of 2020 and will establish additional plots in areas of anthropogenic disturbance (e.g., wellpads, seismic lines) to ensure similar sample sizes among all key landcover and disturbance types. Our goal is to establish five or more replicate sites per landcover/disturbance type. Five or more plots are needed to contrast GPS locations and will be used in conjunction with GPS location data to quantify and verify patterns of habitat use and their changes through time. We are surveying five replicates per habitat based on tradeoffs between time and accessibility. We will use linear regression to investigate the relationship between bison scat counts and selection coefficients for the RLBH to validate the use of scat counts as an effective long-term method of estimating and monitoring seasonal habitat use (Belanger et al., 2018).

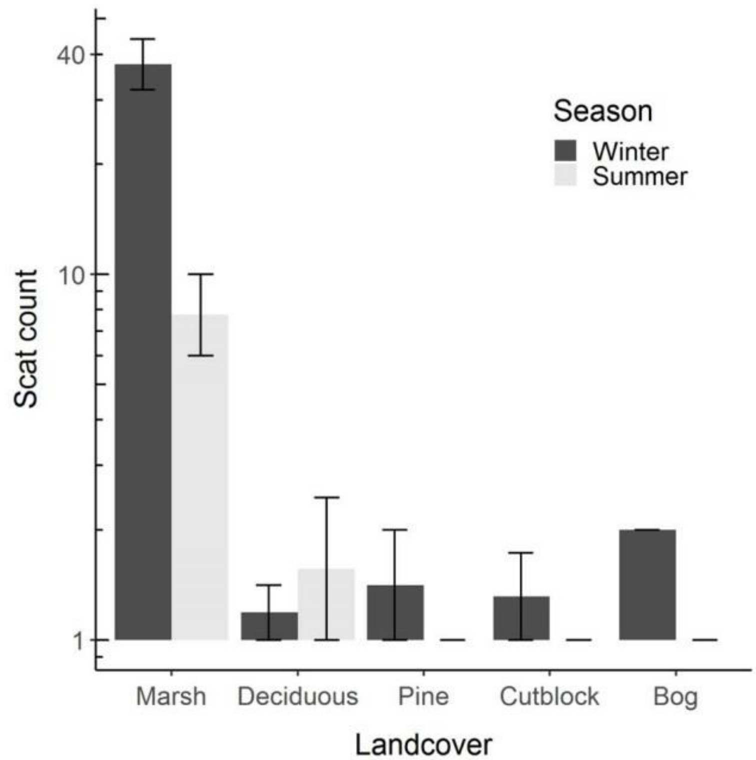

Figure 4: Winter and summer bison scat counts conducted in 500-m^2 (50 × 10-m) plots in five landcover/disturbance types. Note that the y-axis (scat count) is log (i.e., log_{10}) scale (i.e., the value starts at one).

Results 2018/2019 (n = 15):

- No deer or wolf scat

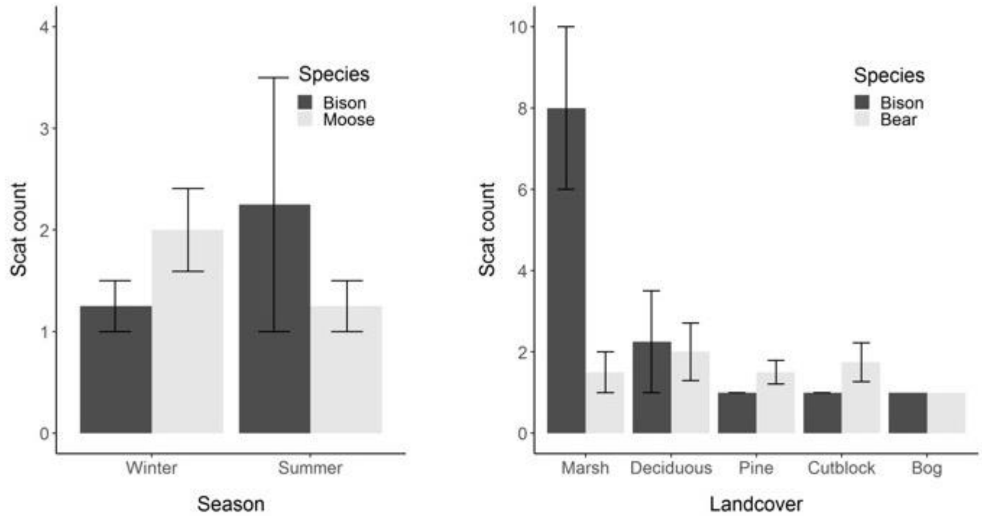

Figure 5: Winter and summer 2018-2019 scat counts reveal species overlap in habitat use. The use of marsh is predominantly bison. Note that the use of landcover types by bear is limited to summer months given their denning period over the winter.

Knowledge Gaps 3c & 3e - What comprises the RLBH's diet? How does the quality and quantity of available forage change seasonally and how do these changes influence the RLBH's diet?

Research objectives

Our objective is to define the diet of the RLBH, assess how it changes throughout the year, and determine the mechanisms that influence changes in diet. First, we will conduct a review of North American bison (*Bison bison*) diets which will allow us to generate a hypothesis about the composition of the RLBH's diets. Then, we will test this hypothesis through an analysis of the RLBH's diet during different seasons.

Overview of research methods

We reviewed and compiled the results of 28 analyses of American bison diets representing 16 herds (Figure 5). We applied the concept of nutritional geometry (Machovsky-Capuska et al., 2016) to determine the RLBH's dietary niche at two levels: the foods consumed (i.e., browse, forbs, graminoids) and the macronutrients acquired (i.e., lipids, proteins, carbohydrates). We used this concept to determine annual dietary niche breadth and seasonal changes in niche breadth. Additionally, we used linear models on compositional data (Atchison, 1982) to assess geographic changes in the bison herd's diet. Specifically, we selected three uncorrelated covariates as predictors of bison diet: latitude, elevation, and precipitation. We generated four sets of models for annual and seasonal diets with forbs and browse as the numerators for consumed foods and lipids and proteins for macronutrients.

In the field, we collected fresh (<14 days old) scat samples from the RLBH with the goal of collecting at least 40 samples for each season of spring, summer, and winter (Table 2). Samples are required to be <14 days old to reduce degradation of vegetative material in the sample.

At locations recently (<14 days) visited by bison we search for signs of foraging behaviour. Locations are only considered to be foraged by bison if we observe vegetation has been cropped and there are additional signs of bison presence (e.g., tracks or fur sheds). When a location meets these criteria we clip the same species and plant components that were consumed by the bison. Then, we dry and store vegetation samples for future analysis of digestibility and macronutrient content. Additionally, at these bison locations we estimate the area of each plant species consumed along a 30 × 2-m belt transect centered on the bison location. We use this measurement as an estimate for foraging intensity (Harvey and Fortin, 2013).

Progress / preliminary results

In previous annual reports, we estimated biomass for four functional forage groups (i.e., browse, forbs, grasses, sedges) known to dominate wood bison diets (e.g., Larter and Gates, 1991) within 23 different landcover types described by the Duck's Unlimited Enhanced Wetland Classification dataset (Belanger et al., 2018). These estimates revealed that meadow marshes contained the greatest amount of sedges, the preferred forage of wood bison (Jung et al., 2015).

Our review demonstrated that bison diets were dominated by graminoids and carbohydrates throughout the year. However, we describe an expansion of the dietary niche to include more forbs and browse during the growing season resulting in a nutritional niche that is 2.8 times larger in the growing season compared to winter (Figure 6). Our analysis of regional changes in bison diets indicated a significant positive relationship between latitude and the amount of browse, lipids, and proteins in bison diets (Table 4). Based on the results of this literature review, we anticipate the RLBH's diet to have more browse items, and higher lipid and protein levels compared to other American bison herds at lower latitudes. Mechanisms leading to this dietary composition include the greater availability of browse in RLBH's home range when compared to plains bison and the greater energy expenditure of bison in cool, wet climates (Jorns et al., 2019).

We completed our collection of bison scat samples in 2019. In total, we collected 46 winter samples, 38 spring samples, and 45 summer samples. Ten composite samples were created from these samples for each season and are currently being analyzed for dietary composition using eDNA methods (e.g., Craine et al., 2015).

Outstanding / upcoming work

Results of the eDNA analysis of the RLBH's diet will provide insight into seasonal selection of forage. The results of our dietary analyses will be used to inform the selection of vegetation species to be analyzed for dietary quality with the most frequently-foraged species analyzed for digestibility, and macronutrient and fiber content.

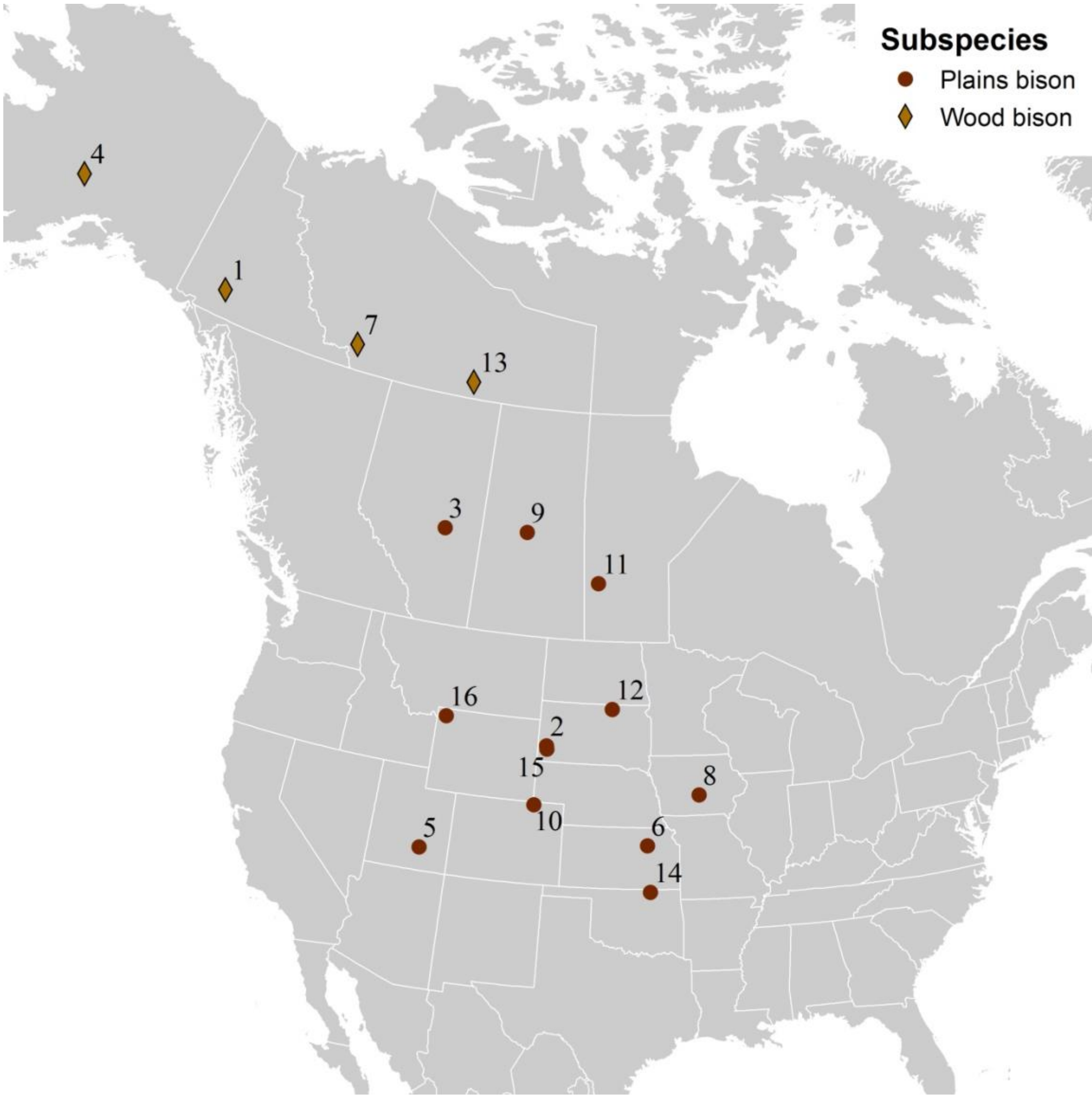

Figure 5: The distribution of the 16 American bison *(Bison bison*) herds that were used in this review of American bison diets. Point symbols indicate which herds are located in the historic range of plains bison (*B. b. bison*) and wood bison (*B. b. athabascae*). The 16 bison herds represented in our literature review of bison diets across North American: 1) Aishihik Lake, Yukon; 2) Custer Sate Park, South Dakota; 3) Elk Island National Park; 4) Farewell Lake, Alaska; 5) Henry Mountains, Utah; 6) Konza Prairie Preserve, Kansas; 7) Nahanni Butte, Northwest Territories; 8) Neal Smith National Wildlife Refuge; 9) Prince Albert National Park, Saskatchewan; 10) Pawnee National Grassland, Colorado; 11) Pine River Ranch, Manitoba; 12) Samuel H. Ordway Jr. Memorial Prairie, South Dakota; 13) Slave River Lowland, Northwest Territories; 14) Tallgrass Prairie Preserve, Oklahoma; 15) Wind Cave National Park, South Dakota; 16) Yellowstone National Park.

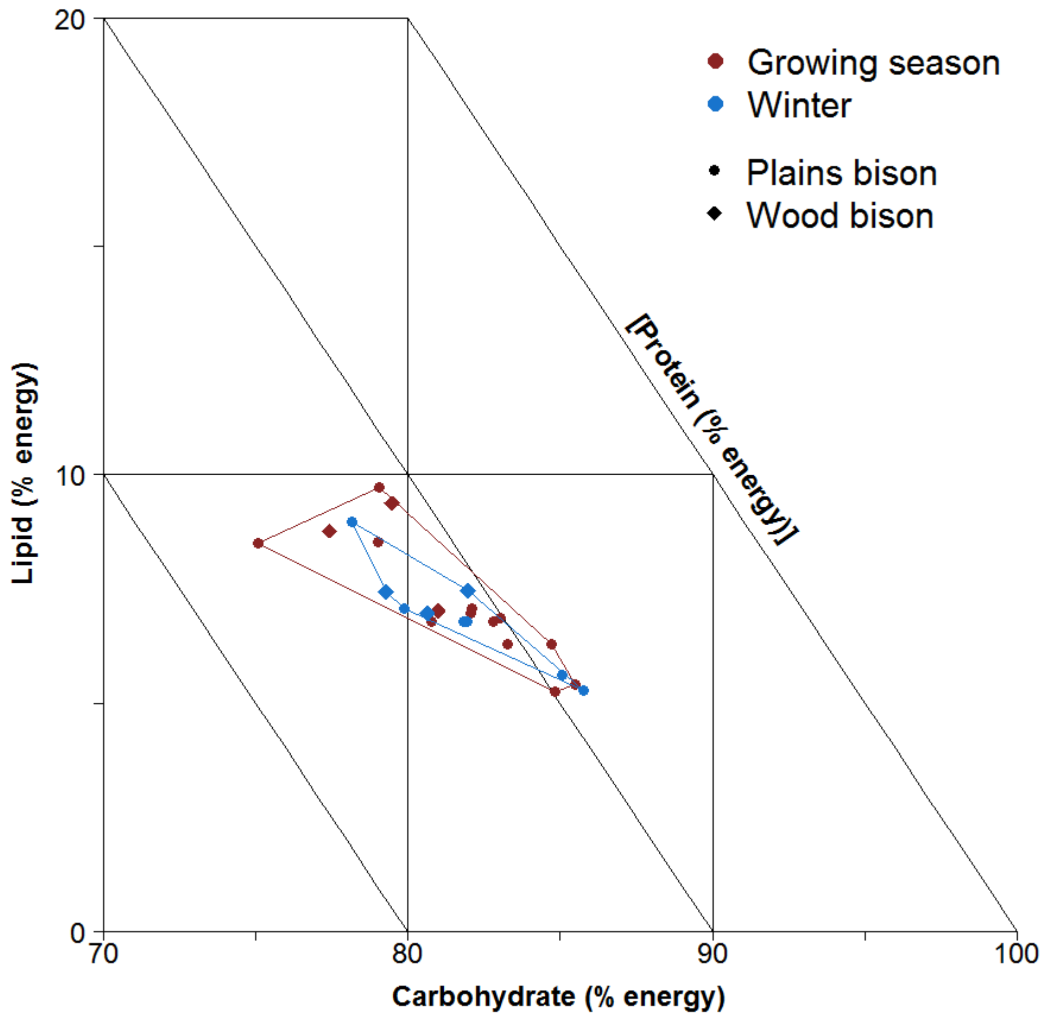

Figure 6: Right-angle mixture triangle showing the seasonal proportions of dietary macronutrients (realized macronutrient niches) for North American bison herds for the growing season (red) and winter (blue). The diagonal lines represent 10% increments from the implicit axis (protein), which starts at 0% energy on the far right. The numbers refer to the same herd codes described in Figure 5.

Table 4: Summary of compositional linear models used to investigate the environmental and climactic factors influencing North America bison's (*Bison bison*) food exploitation and realized macronutrient niches. Compositional linear models were run for annual and seasonal (i.e., growing and winter seasons) diets. For brevity, we abbreviated graminoids (G), browse (B), forbs (F), carbohydrates (C), proteins (P), and lipids (L).

Annual				***Growing***				***Winter***		
ln(B/G)	Estimate	*p*		ln(B/G)	Estimate	*p*		ln(B/G)	Estimate	*p*
Latitude	0.222	**0.029**		Latitude	0.244	0.153		Latitude	0.159	0.216
Elevation	0.001	0.341		Elevation	0.002	0.270		Elevation	0.002	0.164
Precipitation	0.030	0.433		Precipitation	0.032	0.585		Precipitation	-0.034	0.640
ln(F/G)	Estimate	*p*		ln(F/G)	Estimate	*p*		ln(F/G)	Estimate	*p*
Latitude	-0.037	0.652		Latitude	-0.054	0.674		Latitude	-0.206	0.136
Elevation	0.001	0.602		Elevation	0.000	0.966		Elevation	0.000	0.819
Precipitation	0.040	0.311		Precipitation	-0.008	0.863		Precipitation	-0.120	0.178
ln(P/C)	Estimate	*p*		ln(P/C)	Estimate	*p*		ln(P/C)	Estimate	*p*
Latitude	0.017	**0.013**		Latitude	0.019	**0.034**		Latitude	0.015	0.080
Elevation	0.000	0.720		Elevation	0.000	0.937		Elevation	0.000	0.895
Precipitation	-0.001	0.556		Precipitation	0.001	0.789		Precipitation	0.001	0.883
ln(L/C)	Estimate	*p*		ln(L/C)	Estimate	*p*		ln(L/C)	Estimate	*p*
Latitude	0.014	**0.011**		Latitude	0.026	**0.003**		Latitude	0.015	0.087
Elevation	0.000	0.320		Elevation	0.000	**0.042**		Elevation	0.000	0.705
Precipitation	0.002	0.342		Precipitation	0.006	**0.029**		Precipitation	0.000	0.942

Knowledge Gaps 4a, 4b, & 5a – How do anthropogenic and natural disturbances affect the mechanisms driving habitat selection?

Research objectives

Here, our objective was to determine the influence of forage quality, forage quantity, and physical characteristics on the RLBH's habitat selection. Specifically, we explore how these factors influence habitat selection seasonally and how natural (e.g., burns) and anthropogenic (i.e., well pads, seismic lines, and cutblocks) disturbances alter these relationships.

Overview of research methods

We are implementing second-order resource selection functions (RSFs) to explore bottom-up influences on habitat selection within the RLBH range (Johnson, 1980). In the field, we surveyed locations recently (<14 days) used by bison and randomly selected available locations to be compared in our RSFs. We selected the 14-day window to ensure the vegetation is in a similar phenophase as when the bison was present. All bison and available locations were stratified by landcover group and disturbance type. We consolidated the 30 landcover types provided by the Dcuk's Unlimited EWC dataset into seven landcover groups (i.e., graminoid rich wetlands, shrubby wetlands, treed wetlands, upland conifer, upland pine, upland deciduous, and water/insignificant) based on biomass estimates of different functional forage groups (i.e., forbs, browse, sedges, grasses; Belanger et al., 2018; Hecker et al., 2019). Then, we survey bison and available locations in three disturbance types (i.e., natural/undisturbed, seismic lines/well pads, and cutblocks) within each landcover group. We aimed to have an equal number of bison and available locations within each disturbance type and landcover group (e.g., cutblocks in upland deciduous stands). No locations were surveyed within the water/insignificant landcover group as these landcover types (e.g., mudflats) lack forage (Hecker et al., 2019).

At bison and available locations, we quantify habitat characteristics that may influence habitat selection. These habitat characteristics include: biomass of functional forage groups, time since most recent burn, intensity of most recent burn, slope, aspect, ground firmness (substrate type + soil moisture), distance to nearest water source (i.e., lentic and lotic), distance to nearest graminoid-rich landcover group, canopy cover, tree density, shrub/sapling density, and coarse woody debris (CWD) density (Hecker et al., 2019). Additionally, we quantified the intensity of five different bison behaviours (i.e., grazing, browsing, bedding, traveling, and wallowing) by measuring the area within a 15-m radius of the location that contain signs of each behaviour.

Progress / preliminary results

To date, we have surveyed a total of 214 locations (102 bison, 112 available; Figure 7). Preliminary RSFs demonstrate that bison are selecting habitats with lower CWD, shrub/sapling, and tree densities. None of the top models included biomass (Table 5). We interpret these results as bison selecting for more open habitats and that biomass of forage itself is not limiting. However, we suggest that these results be interpreted cautiously as the models do not yet incorporate stratification of landcover groups or disturbance types, nor assessments of forage quality.

Outstanding / upcoming work

Surveys of bison and available (random) locations will continue through August 2020. When data collection is completed, we will incorporate landcover group and disturbance type stratifications into our RSFs. Additionally, we will investigate seasonal changes in habitat selection by separating data by seasons (Table 2). We will use a helicopter to survey locations that are not accessible via ground surveys to avoid biasing site selection.

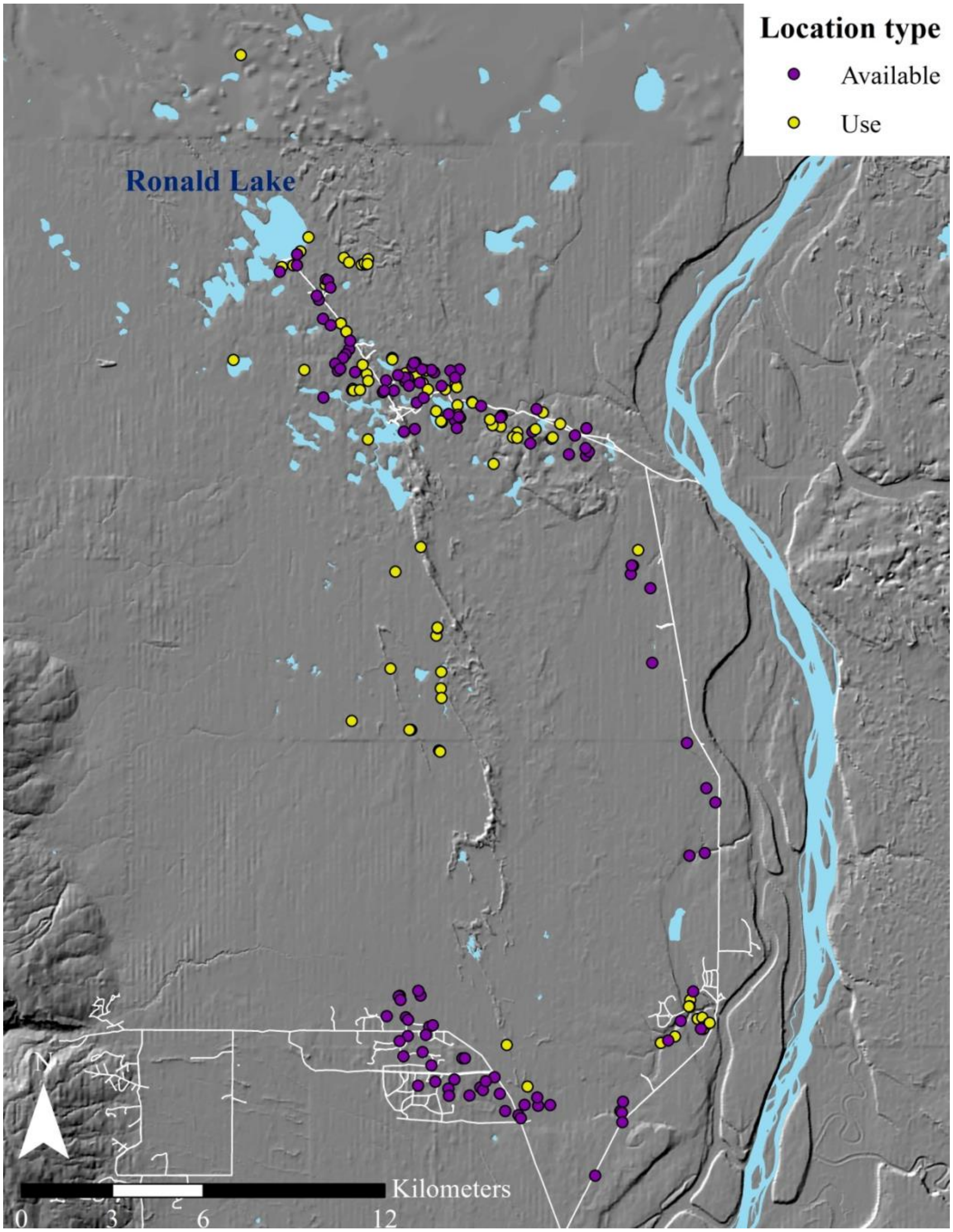

Figure 7: The 214 locations surveyed to date. The white lines represent the extent of our ground access.

Table 5: Preliminary results from logistic regression models comparing local habitat measures at bison use to random locations. For brevity, only the 10 most parsimonious models and the null model (intercept) are displayed. Note that due to small sample sizes we did not attempt to differentiate habitat preferences between seasons.

Covariates	**Coef.**	**AIC**	**ΔAICc**	**Weight**
~CWD density + tree density + shrub density	-0.007 -0.048 -0.184	204.1	0	0.997
~CWD density + shrub density	-0.006 -0.053	215.8	11.7	0.003
~CWD density	-0.061	221.8	17.7	<0.001
~CWD density*CWD height	-0.117	222.3	18.2	<0.001
~CWD density*CWD decay	-0.104	222.9	18.7	<0.001
~shrub density	-0.009	226.5	22.4	<0.001
~tree density	-0.161	229.4	25.3	<0.001
~CWD*CWD height*CWD decay	-0.012	230.5	26.4	<0.001
~Canopy cover	-0.012	236.4	32.3	<0.001
~	-0.457	239.7	35.6	<0.001
~distance to marsh	-0.003	240.3	36.2	<0.001

Knowledge gap 4c - How do snow dynamics influence movement and habitat selection by the RLBH?

Research objectives

Our objective here is to describe how bison respond to ecological drivers and how these drivers influence habitat selection during winter. In colder climates, it is essential to understand how the variations of snow (dynamics) differ among landcover types and disturbances, how this changes over the course of the winter, and how this affects bison foraging and movement (Larter & Gates, 1991). We measure on a daily basis, maximum snow depths for different landcover types, disturbances, and features within the RLBH. In conjunction with measuring snow density and crust thickness during random site visits, we are using five permanent snow measurement sites located in upland pine, marsh, upland deciduous, cutblock, and the esker. Using the temporal resolution of snow depth for each landcover type, disturbance type, and landscape feature, we will relate shifts in habitat use by exposing site-specific characteristics that bison are exposed to.

Overview of research methods

Two measurement boards with graduated markings set at 5 cm increments are placed in three landcover types (i.e., marshes, upland deciduous, upland pine), on one landscape feature (i.e., esker), and in one disturbance (i.e., cutblocks) to monitor daily snow conditions. Here, we are using a time-lapse camera mounted to T-posts and positioned in front of measurement boards. The cameras are set to capture two pictures daily at mid-day to monitor the daily and seasonal snow depths (Johnson et al., 2000). Our observations of snow characteristics also allow us to obtain an estimate of snow characteristics within the RLBH's range. Long-term data from these cameras will be related to bison GPS location data to quantify how snow depth influences winter habitat selection by the RLBH. The methods used are designed for obtaining both daily resolution and long-term seasonal dynamics of snow depth per landcover type allowing for analysis at different temporal scales.

Progress / preliminary results

Five snow monitoring stations were established in the summer of 2018. Preliminary results reveal that the deciduous landcover site had the deepest snow depth during winter 2018-19 (Figure 8). Additionally, the accumulated distribution of snow depth per month pooled across all five monitoring sites showed that January and February had the deepest snowpack at approximately 50 cm during the winter 2018/2019 (Figure 9).

Outstanding/upcoming work

We will use the snow monitoring data in conjunction with other habitat analyses to better describe the ecological drivers of winter habitat selection by the RLBH. We will establish two more monitoring stations within each of the three landcover groups, features, and disturbance types already identified. Snow density and crust measurements from the random sites will be included in the 2020 annual report.

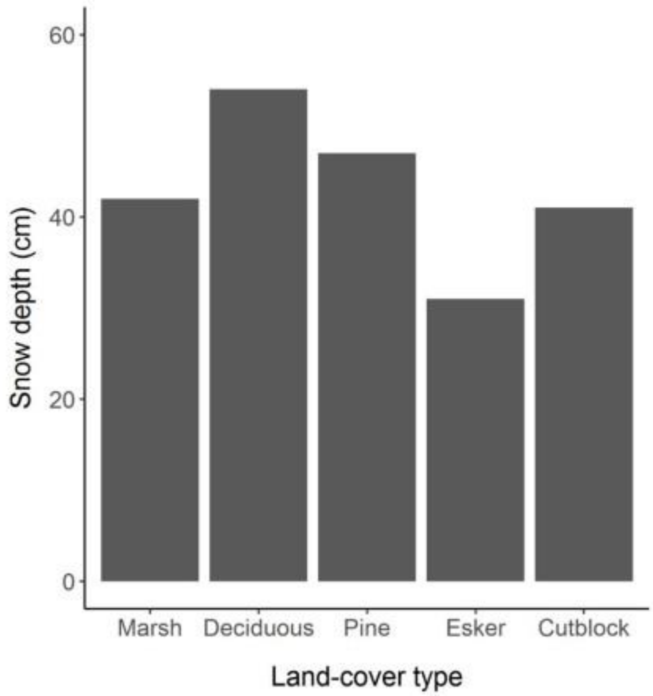

Figure 8: Maximum annual snow depth for each of the five stations during the 2018-19 winter period (September 2018 - May 2019).

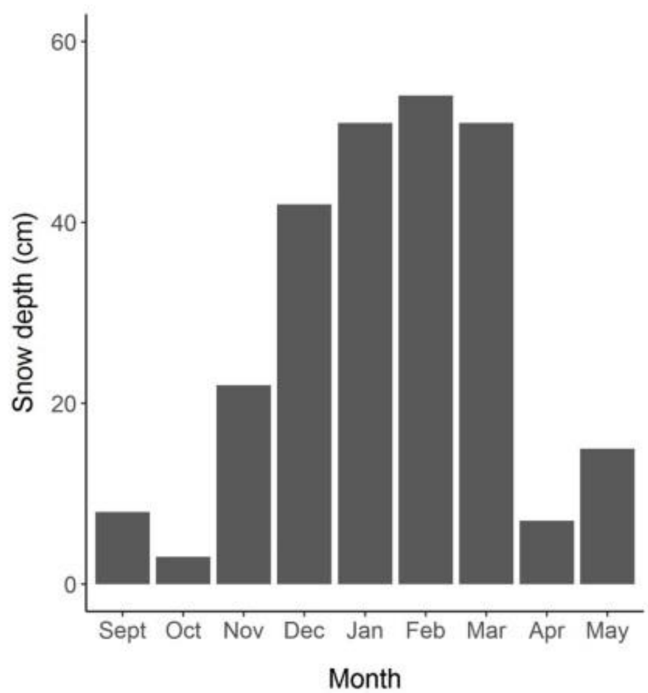

Figure 9: The distribution of monthly maximum snow depth for the five stations during the 2018-2019 winter.

Knowledge Gap 4c & 8e – How does potential wolf predation influence the RLBH's habitat selection?

Research objectives

Here we are investigating the effects of wolf predation on bison by examining the following 3 objectives: 1) to estimate seasonal wolf diet content; 2) to examine spatial and temporal wolf-bison encounter risk within the RLBH home range; and 3) to explore the influence of site characteristics and environmental conditions on predation risk. The study of predator-prey dynamics can be complex, involving both direct and indirect effects on their prey. The lethal effects of predation can have clear limiting influences on prey abundance, but the non-lethal inherent risk of predation can also limit prey populations through stresses associated with vigilance behaviour and reduced reproductive rates (Creel & Christianson, 2008; Laundre et al., 2001, Eberhardt et al., 2003; Fortin et al., 2004; Pressier et al., 2005). These non-lethal effects can be greater in habitats where predation is more likely (Brown, 1999), and may be influential in shaping prey behaviour by increasing vigilance and decreasing forage intake (Harvey & Fortin, 2013).

Overview of research methods

We used aerial net-gunning to deploy three GPS radio-collars on wolves from two packs in late winter 2019, programmed to acquire locations every 2 hours. In fall 2019, we continued capture efforts to collar additional wolves using padded leg-hold traps as per best practices capture procedure. Of the three wolves collared, two are part of what we refer to as the west-pack and the third is part of the east-pack. Wolf location data are being used for GPS cluster analyses (Webb et al., 2008) to identify potential kill, den, and rendezvous sites, as well as to describe their diet. We search these sites to find and identify prey species, age, sex, and health, as well as to collect wolf scat samples for diet content analysis of snow-free and winter seasons. In the lab, we separate and identify undigested prey remains in wolf scat and use the point-frame method (Ciucci *et al.* 2003), for creating wolf scat content samples to assess seasonal wolf diet. This method involves a form of random sub-sampling that drastically reduces analysis time but results in the same level of accuracy as hand sorting the entirety of each sample (Ciucci *et al.* 2003). We are also measuring cluster site characteristics (Table 6) to better understand factors that influence wolf habitat selection and the effect of habitat characteristics and environmental conditions on predation risk, prey selection, and wolf behaviours and habitat use.

We are continuing to examine and compare the movement and habitat use of wolves and bison through the winter to develop seasonal resource selection models (Johnson, 1980) to estimate encounter risk. These models will use animal locations to generate habitat characteristics (Boyce et al., 1999) that are important to both wolves and bison. By comparing important habitat characteristics for both species, we can estimate the spatial and seasonal pattern of encounter risk (Hebblewhite et al., 2005; DeCesare et al., 2014) between bison and wolves within the study area. We will develop seasonal spatial encounter risk models using landcover type, distance to water, distance to cover, distance to disturbance, and distance to marsh as predictors of encounter risk. By not only investigating the direct effects of wolf predation on the RLBH, but also incorporating a seasonal encounter risk model, we will be able to inform how often bison are exposed to indirect effects of predation activity.

Progress / preliminary results

A total of 2,651 locations have been recorded for the three collared wolves from 1 April – 25 October, 2019. (mean = 884, range = 720 - 1104). The snow-free season home range size of the west pack is an estimated 4294 km^2 and the east pack 998 km^2. The total area occupied by the two packs covers 81% of the annual distribution for collared bison (Figure 10). We monitored location data from these GPS collars to identify cluster sites, prioritized field visits to these GPS locations using cluster analysis following methods from Webb *et al*. (2008). Thus far, we have visited 58 wolf cluster sites from the west-pack and 38 from the east-pack. We visited more sites in the west-pack because these two wolves roamed independently within their territory.

Thus far, we collected 35 scat samples from 15 west-pack site visits and 65 scat samples from 12 east-pack sites for a total of 100 scat samples from 27 sites. The larger number of east-pack scat samples is due to the pack operating on the same trail system that our field crews use, while the west-pack operates in a more inaccessible portion of the RLBH's range. An additional 72 scat samples were collected on trails from the east-pack and 10 from a pack operating in the south portion of the study area with no collared individuals. We have processed all snow-free season scat samples and are currently preparing these samples for diet analysis.

Outstanding / upcoming work

Additional wolf collaring will occur in winter 2020 by use of helicopter net-gunning. We plan to deploy four to six more GPS-collars, with the goal of deploying two collars per pack, to account for mortalities or collar malfunctions. We will continue to monitor wolf locations for potential kill sites (i.e., clusters) that will be prioritized through cluster analysis using a stratified random design (Table 7). Site visits will continue by ground or air in three-week increments until May 2020. Snow-free season analysis and resource selection model development will commence in winter 2020.

In winter 2019/2020, we will identify prey remains extracted from scat samples through the use of a reference collection created with assistance from the Royal Alberta Museum and Adorjan and Kolenosky (1969). We will collect additional scat in the winter season to address seasonal differences in wolf diets.

Table 7: The environmental characteristics and conditions measured at cluster sites in 2019.

Site Measures	**Method**
Tree and CWD Density	30 × 2 m Transect: DBH and Count
Shrub and Sapling Density	30 × 1 m Transect: Stem Counts
Access and Site Use	Game Trail Count and Use Score
Available Prey	50 × 2 m Transect – Scat Counts
Snow Depth (cm) and Density	Snow Tube and Scale
Crust Hardness	Hardness Test
Temperature (℃)	Weather Stations
Elevation (m) and Slope (degrees)	GPS and Clinometer

Table 6: The prioritization strategy for selection of wolf cluster sites.

Class	**Cluster Time (hours)**	**Percent Visited**
A	>24	100%
B	20-22	100%
C	16-18	75%
D	12-14	50%
E	8-10	25%
F	4-6	15%
G	2	10%

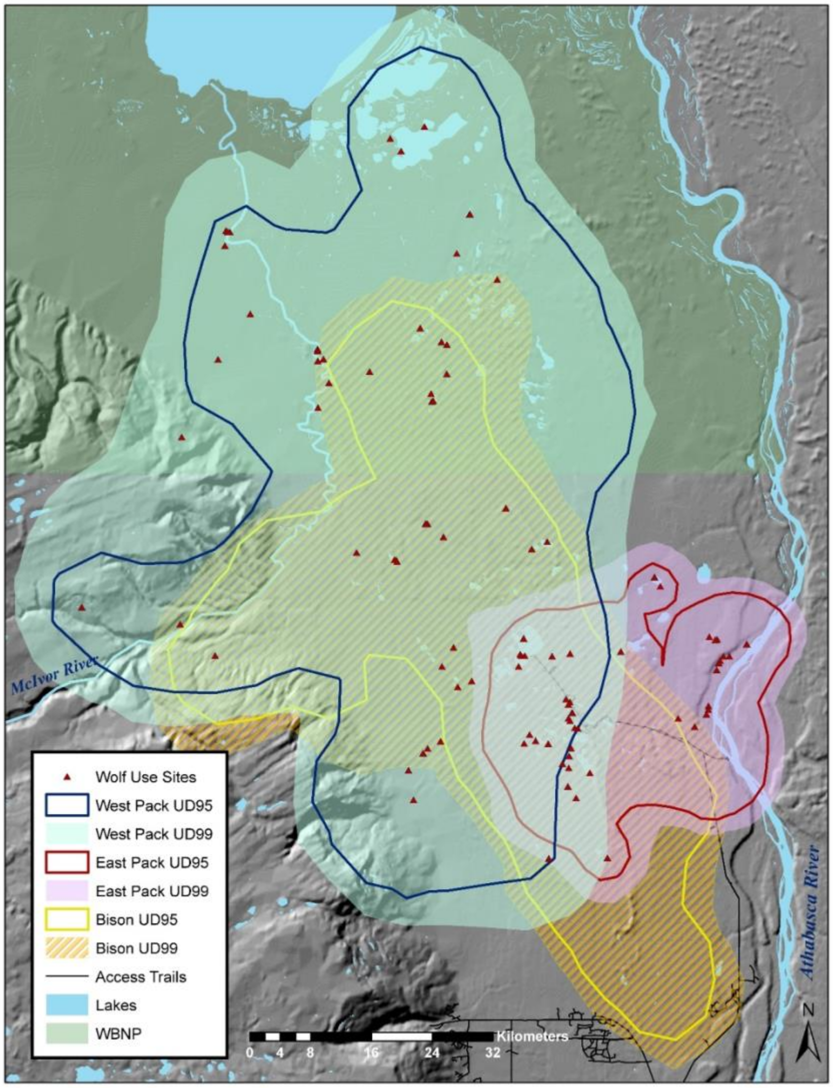

Figure 10: Displays 96 wolf use site visited (red triangles) within home ranges (utilization distributions) of the RLBH (yellow scored), the West wolf pack (blue) and the East wolf pack (red) based on locations from April 1 – October 25, 2019. Black lines (trails) show the extent of ground access.

Conclusions

In this annual report, we describe the research conducted in 2019 as it relates to knowledge gaps identified by the RLBH Technical Team. We mapped bison habitat preferences with a focus on their northern range in four seasons and compared differences between sexes finding that preferred bison habitats become less common at their northern limits. Our preliminary analysis of the RLBH's spring migration identified two migration corridors and revealed a positive correlation between bison locations and higher quality forage as measured by NDVI. Our long-term wildlife monitoring plots showed differential habitat selection by bison in winter and summer, particularly for marshes. We completed a literature review of American bison diets revealing selection for more browse item with greater amounts of lipids and protein at higher latitudes. We are using these results to predict the composition of the RLBH's diet, which is currently being analyzed. Our initial analyses of bottom-up effects on habitat selection did not show selection for greater biomass, rather it indicated selection for more open habitats. Our snow monitoring stations disclosed greater snow depth in upland deciduous habitats and maximum snowpack in January and February of 2019. We also collared three wolves from two packs. Potential kill site surveys, wolf dietary analyses, and predation risk modeling are ongoing. As we address knowledge gaps in the RLBH's ecology, we are considering how these results can be applied to guide responsible mitigation of mine development and reclamation. We will continue addressing these and other knowledge gaps in 2020.

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Appendix I: Annual Brownian bridge movement models

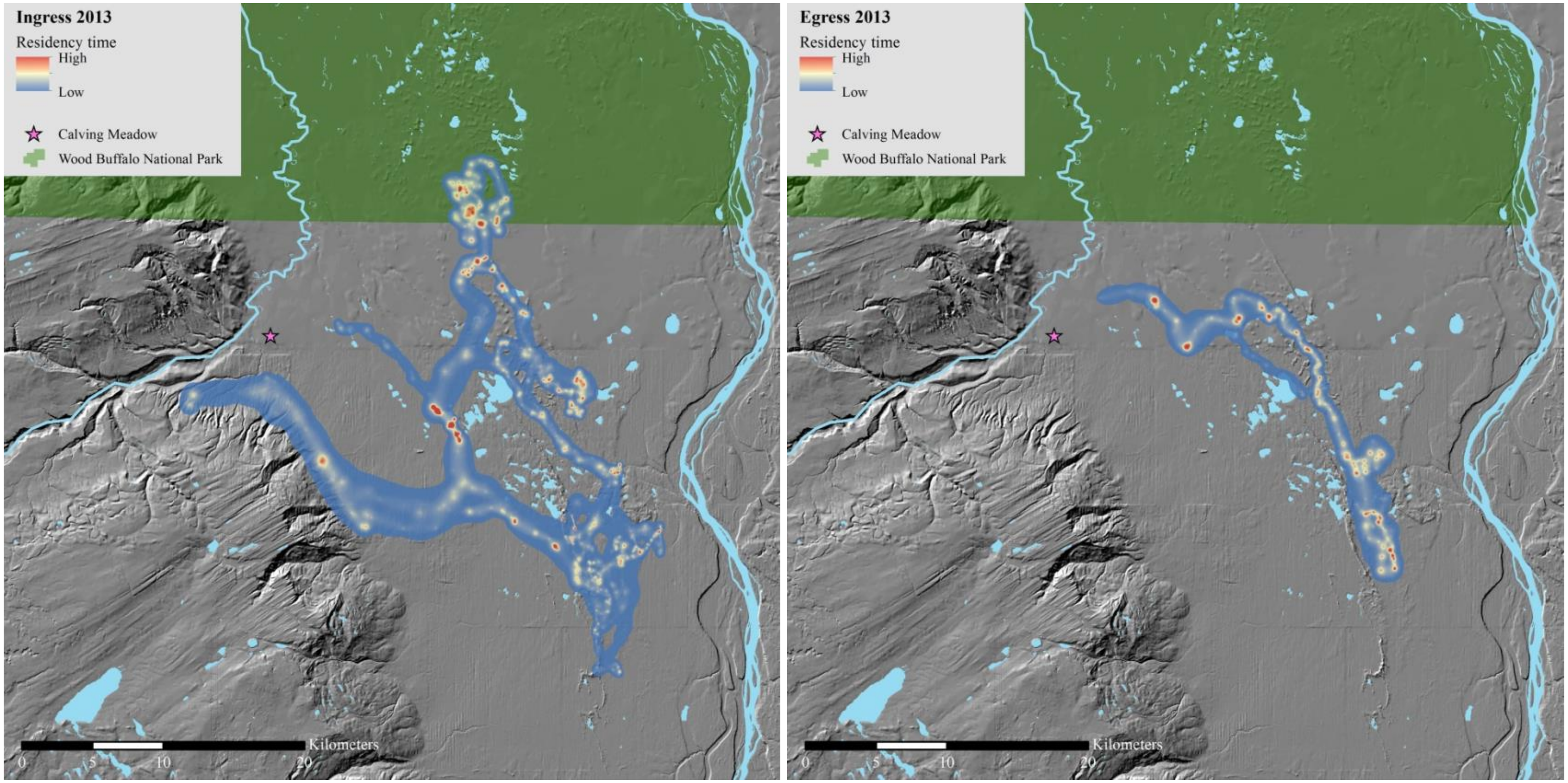

Figure 11: Browning bridge movement models during the 2013 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The “calving meadow” is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.

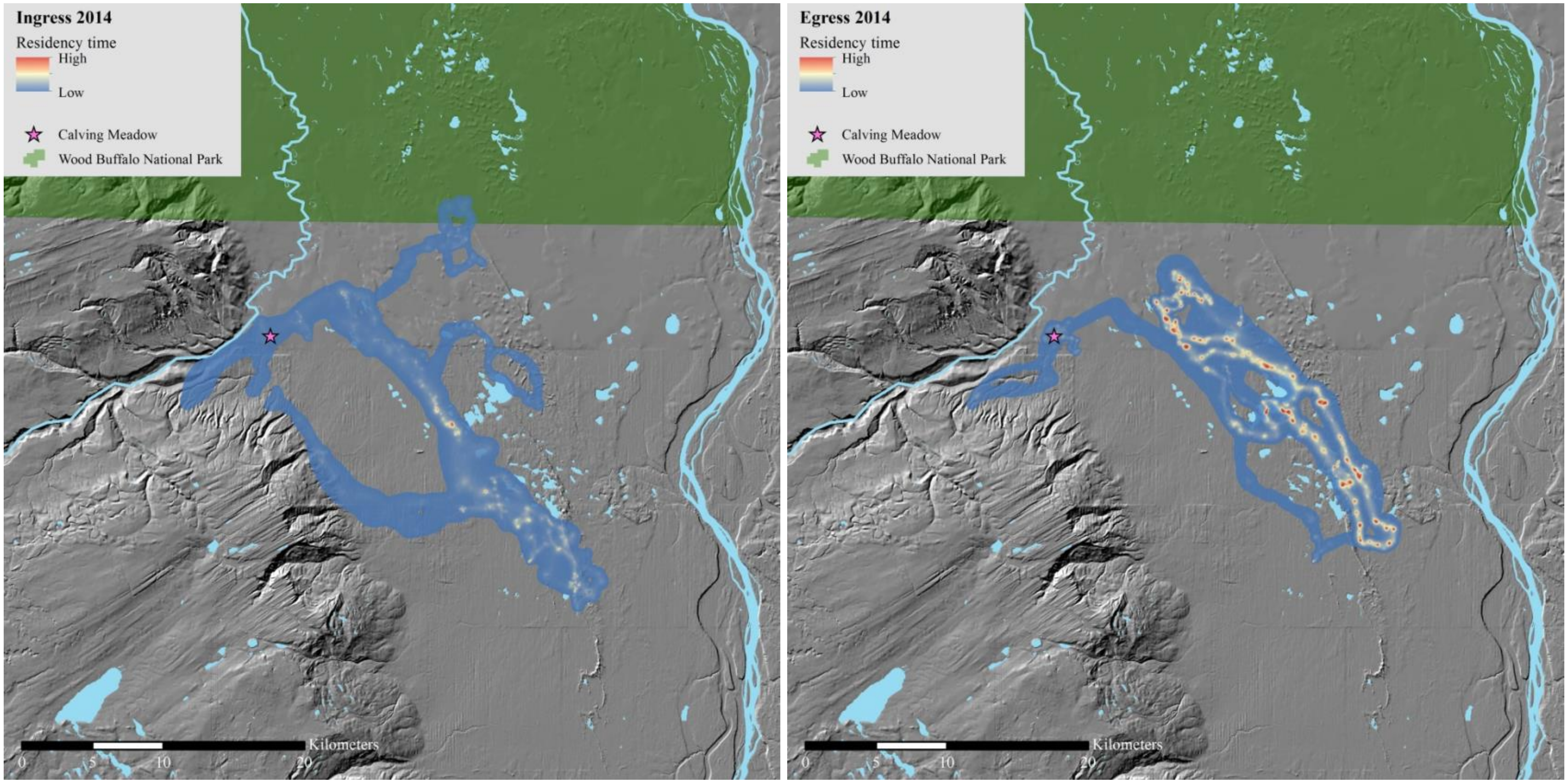

Figure 12: Browning bridge movement models during the 2014 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The "calving meadow" is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.

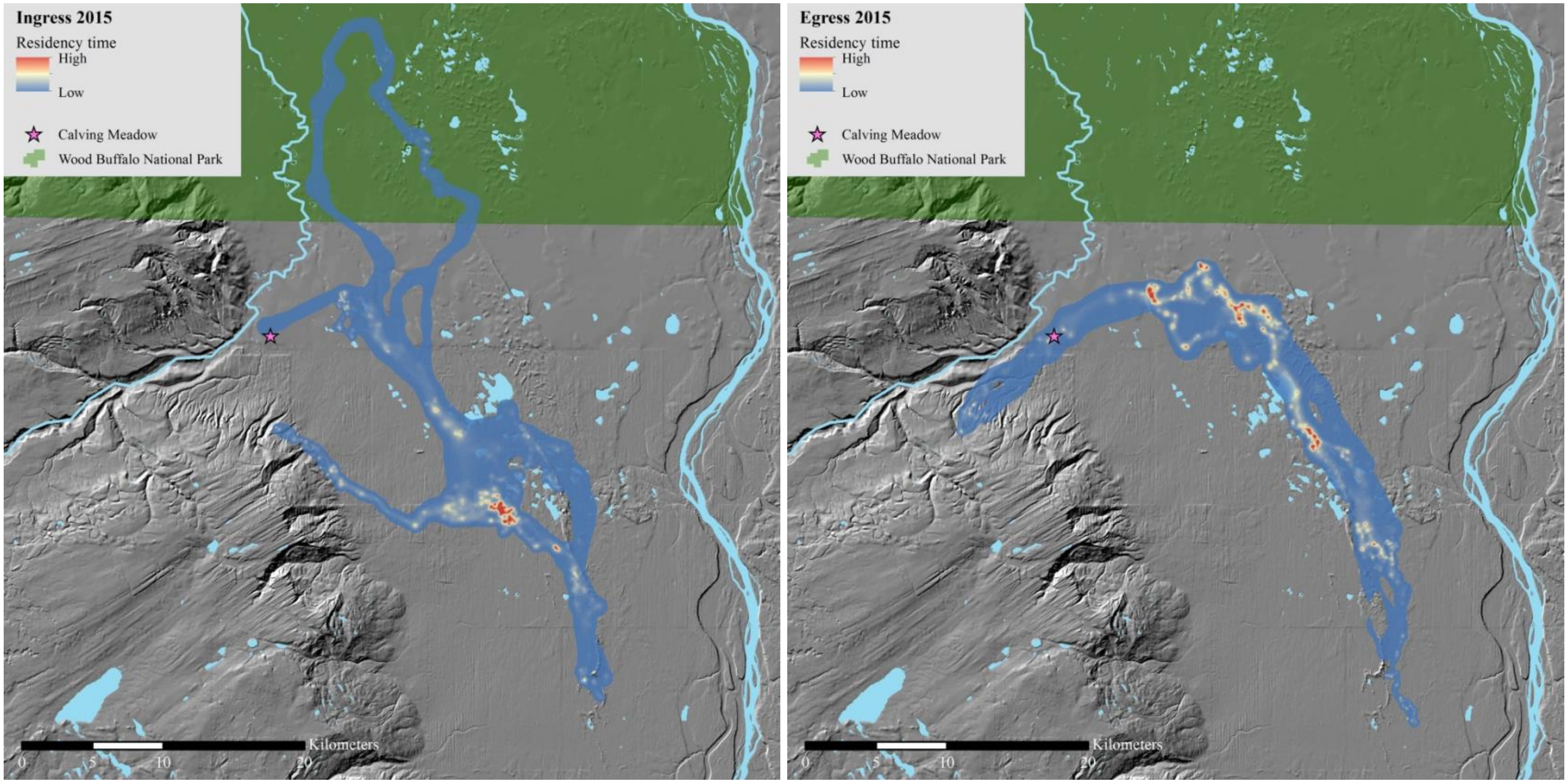

Figure 13: Browning bridge movement models during the 2015 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The "calving meadow" is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.

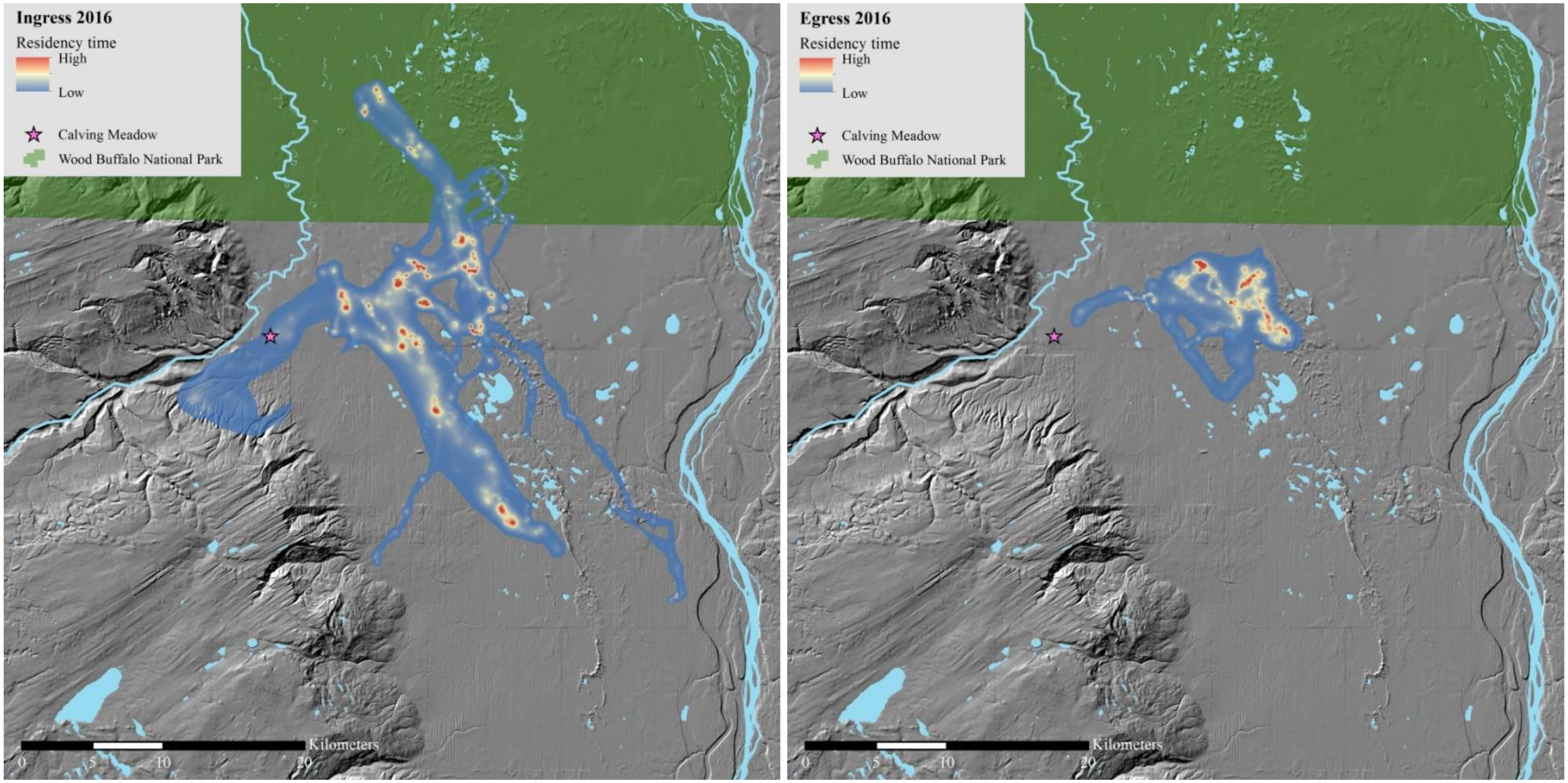

Figure 14: Browning bridge movement models during the 2016 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The "calving meadow" is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.

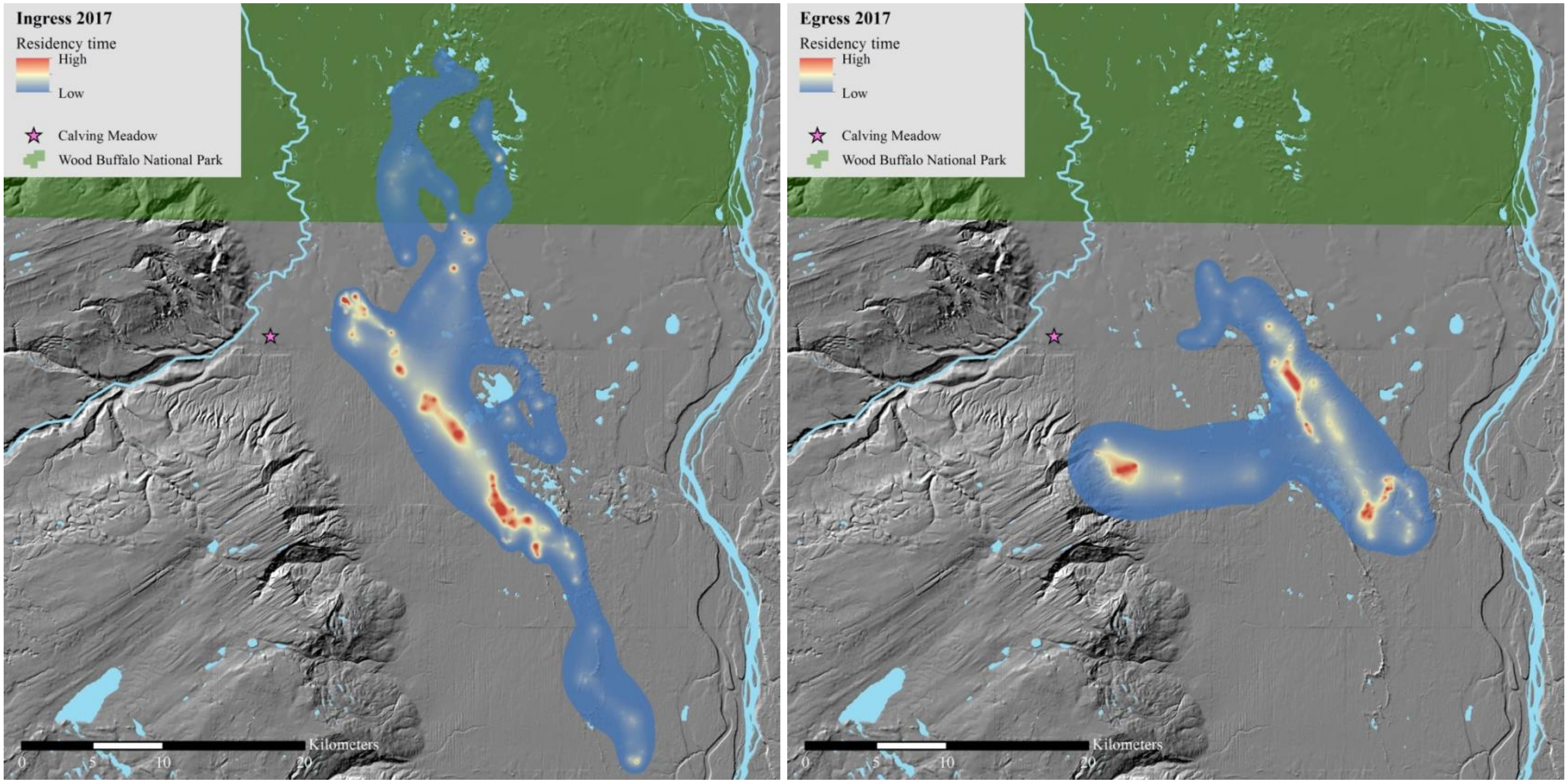

Figure 18: Browning bridge movement models during the 2017 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The "calving meadow" is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.

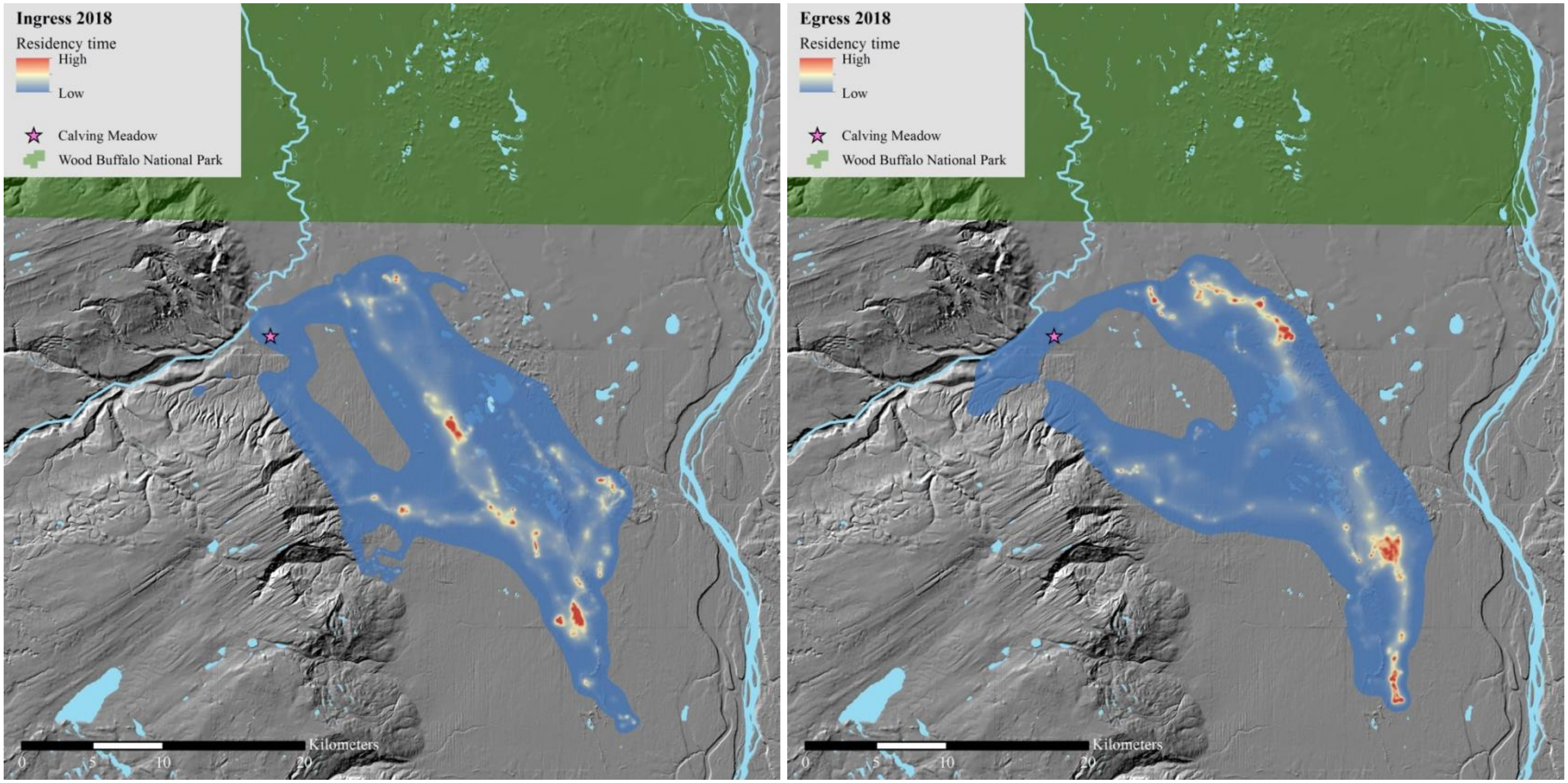

Figure 19: Browning bridge movement models during the 2018 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The "calving meadow" is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.

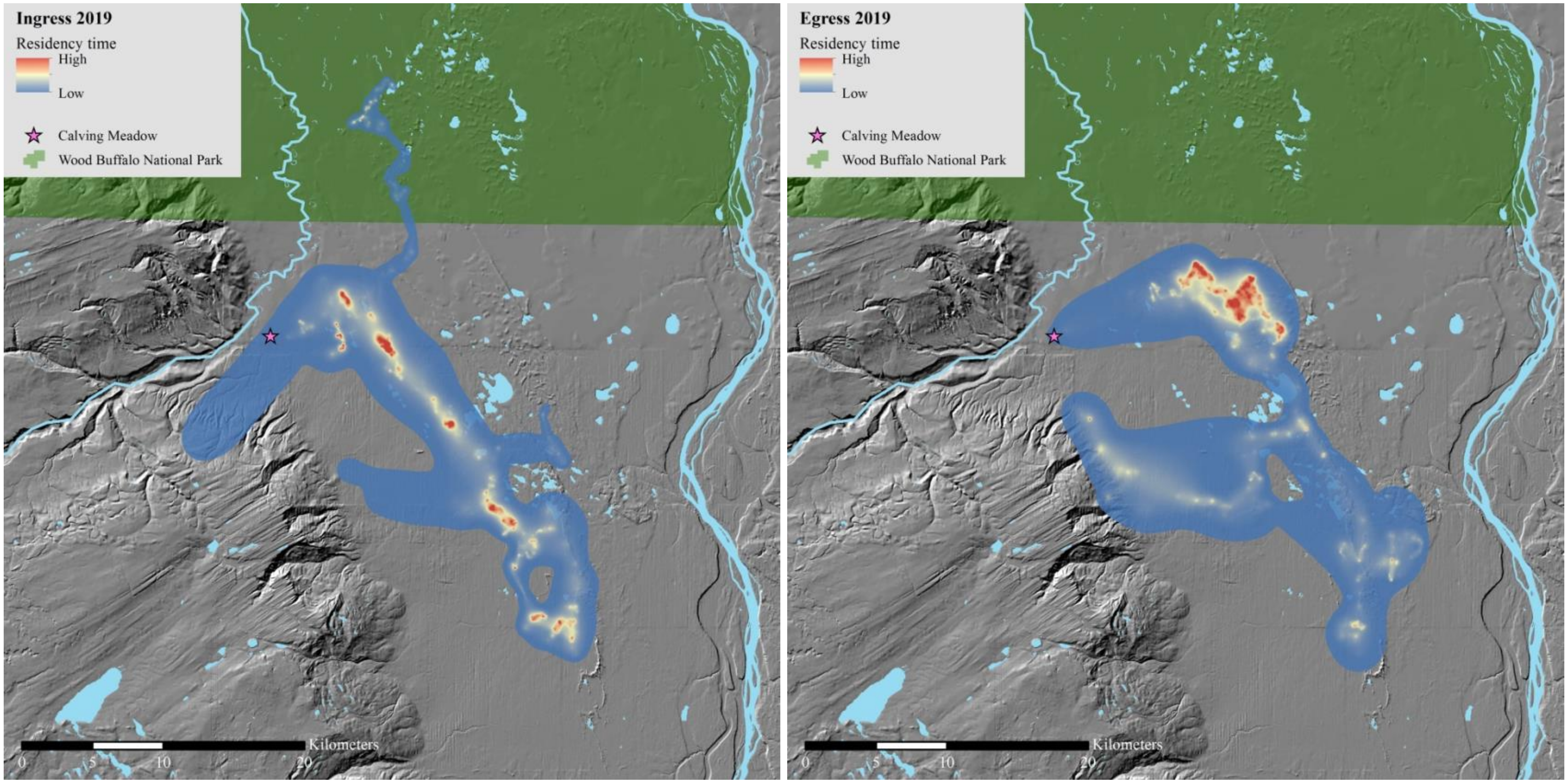

Figure 20: Browning bridge movement models during the 2018 migration into the western range (i.e., ingress; left) and migration out of the western range (i.e., egress; right). Regions with high residency times (red) are those where bison spent longer amounts of time, whereas regions with low residency times (blue) represent areas bison moved through quickly. The “calving meadow” is an upland meadow located in the center of the western range. Ronald Lake is the large body of water located roughly in the center of each map.