RONALD LAKE BISON (*BISON BISON*)

PROJECT UPDATE

DECEMBER 2015

[Photo: S. Nielsen]

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Background

In 2013, GPS radio-collars were deployed on a sample of female wood bison (*Bison bison; n* = 12) in the Ronald Lake herd of northeastern Alberta to inform regulatory and management decisions on the herd. In March 2014, 16 additional collars were deployed on both male (*n* = 6) and female bison (*n* = 12) to better understand individual variation within the herd to natural and anthropogenic landscape features. In the previous project update (November 2015), we described procedures used to screen the accumulated telemetry data to date (August 21, 2015) and presented preliminary analyses of bison movement rates and home ranges. In this update, we present preliminary analyses of seasonal habitat selection by Ronald Lake bison. Our main objectives for this reporting period were to: *i*) develop the analytical framework for evaluating habitat selection; *ii*) delineate biologically relevant seasons; and, *iii*) evaluate bison selection of land cover (or dominant vegetation type). These initial steps provide the foundation for subsequently assessing bison response to fire and anthropogenic disturbance and for developing final comprehensive models that describe seasonal habitat selection patterns of Ronald Lake bison.

Evaluating Resource Selection by Bison: General Framework

We evaluated seasonal selection of land cover by bison using a framework similar to the one outlined in the project's Preliminary Summary Report (Tan *et al*. 2015). Briefly, we evaluated land cover selection by estimating resource selection functions (RSFs), a modelling approach that compares environmental attributes (or resources) associated with "used" locations (e.g. GPS locations) to environmental attributes of unused or available locations generated within the spatial scale of interest (Manly *et al.* 2002). Here, we compared bison GPS locations to random locations (i.e. available locations) sampled within individual annual home ranges (i.e. 3rd order selection; Fig.1; Johnson 1980).

We characterized annual home ranges of bison using utilization distributions (UDs), which estimate a probability density function to describe an individual's space use (Worton 1989). To delineate home range boundaries, we used the 95% probability contour of the UD. Because land cover data used to assess resource selection does not extend into Wood Buffalo National Park (WBNP), we clipped UDs to the park boundary and excluded all GPS location locations within WBNP from further analyses (Fig. 1). We further clipped the eastern extent of UDs to the Athabasca River as no bison GPS locations are located east of the river, indicating that the river may form a geographic barrier to movement.

We calculated individual UDs on an annual basis with the starting point of each year based on an animal's first GPS location. Because all animals were captured during the end of March or early April and data screening procedures removed the first 2 weeks of GPS locations post-capture (see November 2015 Update), our sampling year for estimating annual UDs therefore started in mid-April and extended for 365 days. Animals with data spanning multiple years had multiple UDs and GPS (or used) locations within a given sampling year were compared to random points sampled within the annual UD calculated over that same time frame. This sample-year framework resulted in many animals having data fragments consisting of < 1 year of monitoring. Because estimates of home range size are sensitive to monitoring time (Börger *et al.* 2006), we conducted a sensitivity analysis to determine the amount of time (in months) required for estimates of annual home range size to stabilize. To identify this asymptote, we used piece-wise (or break point) linear regression on a subset of animals (n = 16) having a full year of data. This type of analysis evaluates for a break in the linear relationship between monitoring time and home range size and we specified a model where the slope is equal to zero after the break point (i.e. an asymptote). We pooled the data across animals and sampling years. Model output suggested that home range size reached an asymptote after 3.5 months of monitoring (break point = 3.5, SE = 0.2, p <0.001, Fig.2). Therefore, for a given sampling year, we excluded from further analyses those animals with < 3.5 months of data (2014: n = 3; 2015: n = 5).

Within each UD, we generated random points to sample resources available to individual bison. Because insufficient sampling of availability can lead to biased estimates of resource selection (Northrup *et al.* 2013; Benson 2013), we conducted a sensitivity analysis to determine the number of random points needed to adequately characterize availability within annual UDs (Appendix A1). Using data from the summer / fall season (see below), we performed repeated RSF analyses, plotting parameter estimates of land cover covariates against the number of random points used (range: 200 – 20,000 per UD). Based on this analysis, parameter estimates stabilized at 5000 random points per UD and we used this number in all subsequent analyses.

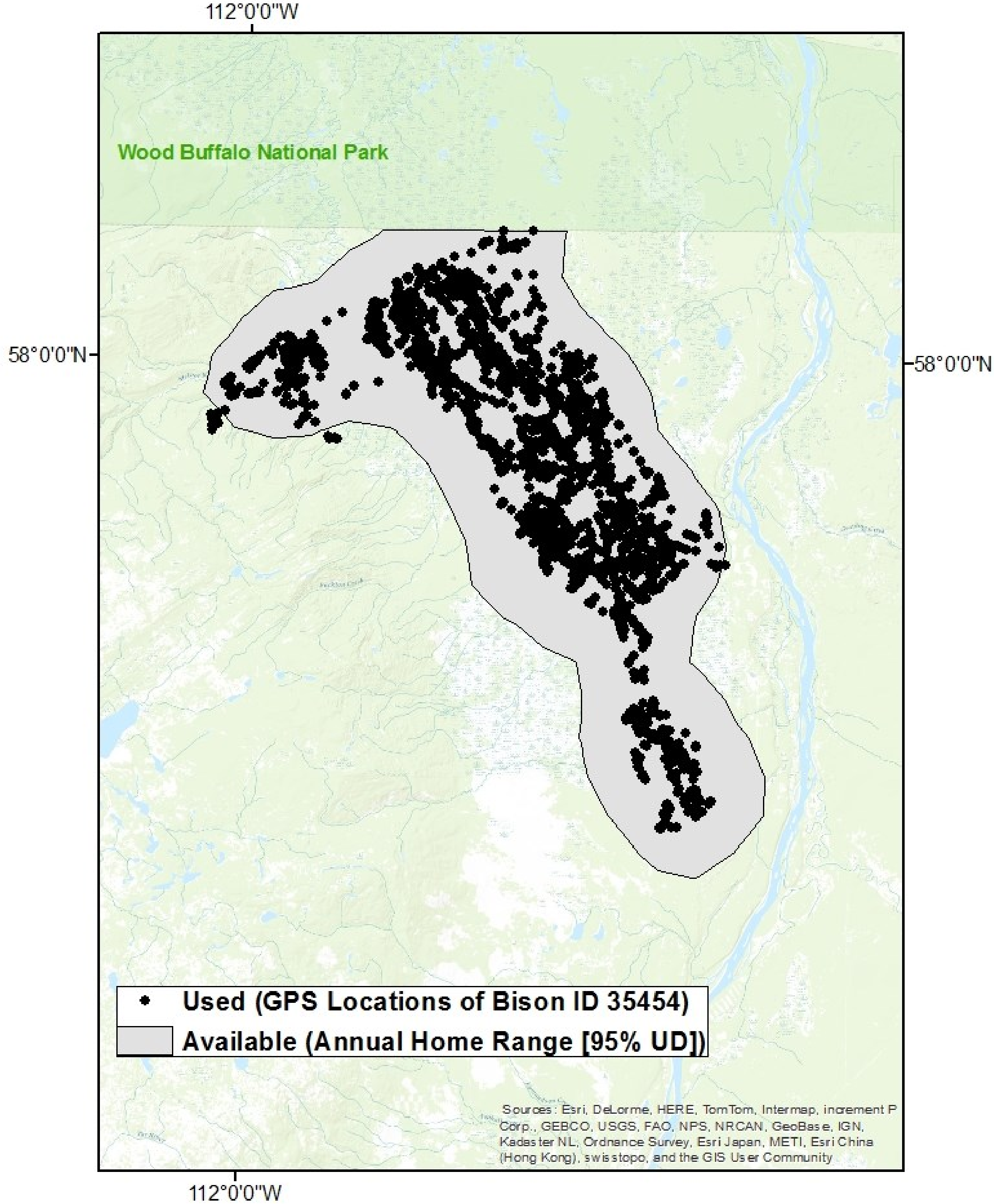

Figure 1: Scale of resource selection analyzed for wood bison in the Ronald Lake herd of northeastern Alberta. Analyses were conducted at a third-order scale, which compares bison GPS locations (here, bison collar ID 35454) to random locations sampled within an individual's annual home range. Home ranges were delineated using 95% utilization distributions, which were clipped to exclude areas within Wood Buffalo National Park (see main text).

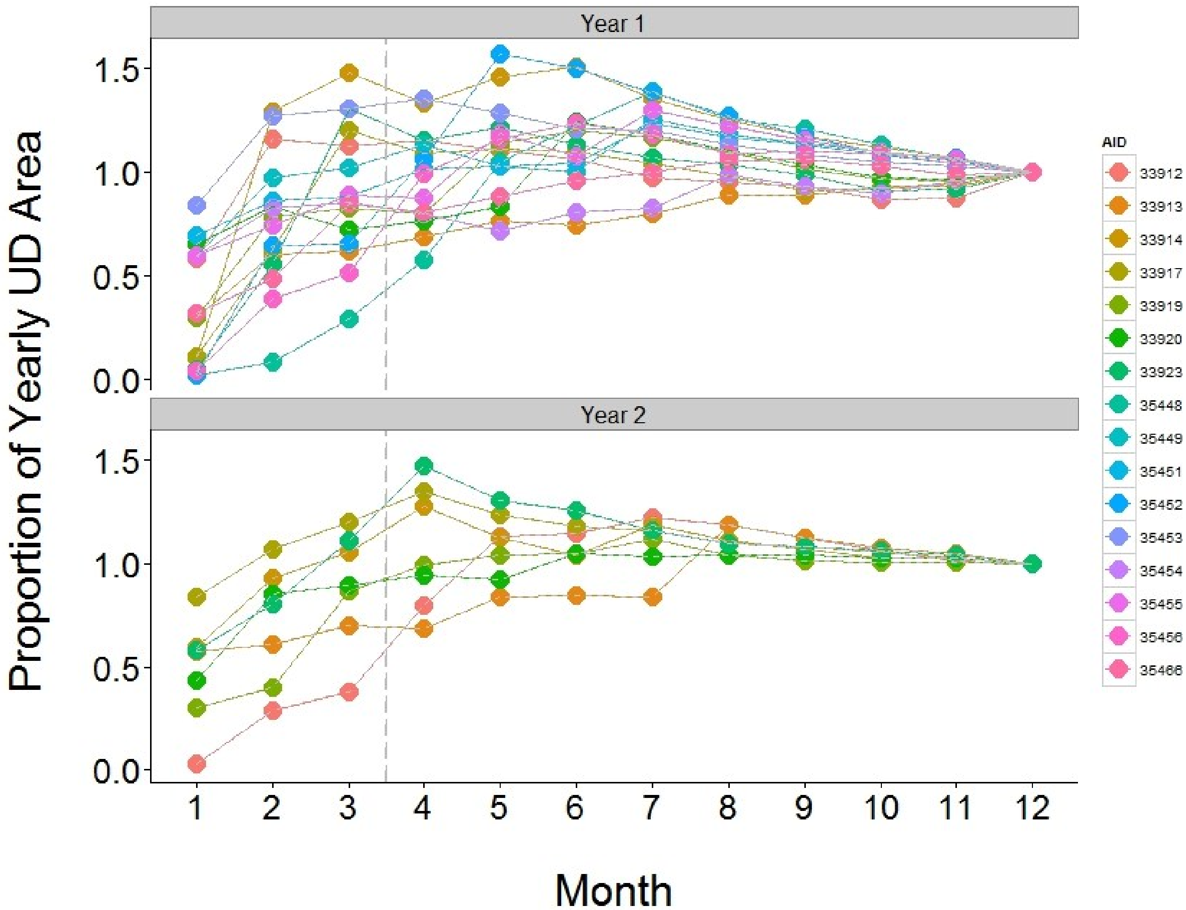

Figure 2: Sensitivity analysis to determine the minimum number of months required for estimating annual home range size of wood bison in the Ronald Lake herd of northeastern Alberta. From break point regression analysis, the grey dotted line indicates the point where home range size reaches an asymptote (break point = 3.5, SE = 0.2, $p < 0.001$).

Defining Seasons

A primary objective of our study is to evaluate seasonal changes in habitat selection by bison. To establish biologically relevant seasons for bison, we followed a similar approach as outlined in the Preliminary Summary Report (Tan *et al.* 2015). To determine the calving season, we assessed the movement behaviour of female bison during May and June (Appendix B). As previously reported (Tan *et al*. 2015), female bison appear to congregate in a defined calving area. We estimated the extent of this area using data from June 10, 2014 when females appeared to be maximally aggregated. We defined the start of the calving season as the date that the first female "settled" in this area (2013: May 21; 2014: May 28; 2015: May 20) and the end of calving when the last female left this area (2013: June 28; 2014: June 25; 2015: June 23). The summer / fall season extended from after calving to the first day of continuous snow on the ground as determined by data from Weather Canada's meteorological office in Fort McMurray. Because this data was missing for 2013, we used November 1 (2014: November 6; 2015: NA as existing bison GPS data does not extend past August 2015). Winter encompassed the period with contiguous snow cover (November 1, 2013 – April 18, 2014; November 7, 2014 – April 7, 2015). Spring extended from the last day with contiguous snow cover to calving (2013: April 25 – May 20; 2014: April 19 – May 27; 2015: April 8 – May 19).

Land Cover Data

For this preliminary report, we restricted our analyses to evaluating bison response to land cover (or dominant vegetation class). We used Enhanced Wetlands Classification (EWC) data from Ducks Unlimited Canada to characterize land cover (30-m pixel resolution; DUC 2011). The EWC data consists of 29 land cover classes, which for our analyses were reduced to 24 as we combined classes with small extents (e.g. Mudflats [<0.02%]) with other biologically similar classes and one class (Agriculture) did not occur in any bison UD (Table 1). Note that Alberta Vegetation Inventory data, which covers < 50% of our study area (Tan *et al*. 2015), was unavailable for this analysis.

Table 1: Classification of land cover types used to model resource selection by wood bison in the Ronald Lake herd of northeastern Alberta. Land cover classification was based on Ducks Unlimited Canada's Enhanced Wetlands Classification data (DU 2012).

Land cover	EWC Class	Description
Open Water	Open Water	Includes lakes, ponds, rivers and other water bodies. Aquatic and above surface vegetation each < 25%. Areal coverage: ~1%
Aquatic Bed	Aquatic Bed, Mudflats	Transitional between open water and emergent marsh. Aquatic vegetation > 25% (except Mudflats <25%). Above surface vegetation <25%. Areal coverage: <1%
Emergent Marsh	Emergent Marsh	Aquatic vegetation <25%. Above surface vegetation >25%. Saturated to permanently flooded. Common plant species: *Typha* spp., *Scirpus* spp, and *Juncus* spp. Areal coverage: <1%
Meadow Marsh	Meadow Marsh	Above surface vegetation >25%. Saturated to mesic-dry. Seasonally flooded. Common plant species: broadleaf sedges, bluejoint grass. Areal coverage: ~ 1%
Graminoid Rich Fen	Graminoid Rich Fen	Rich fen indicators: buckbean and wire sedge. Sphagnum <20%. Tree / shrub cover < 25%. Areal coverage: ~ 1%
Graminoid Poor Fen	Graminoid Poor Fen	Some fen indicators but Sphagnum > 20%. Tree cover < 25%. Areal coverage: ~ 1%
Shrubby Rich Fen	Shrubby Rich Fen	Fen indicators. Shrubs < 2m and shrub cover >25%. Tree cover <25%. Areal coverage: ~2%
Shrubby Poor Fen	Shrubby Poor Fen	Sphagnum > 20%. Shrubs < 2m and shrub cover >25%. Tree cover <25%. Areal coverage: ~ 1%
Treed Rich Fen	Treed Rich Fen	Fen indicators. Tree cover >25% but <60%. Sphagnum <20%. Areal coverage:~ 7%
Treed Poor Fen	Treed Poor Fen	Tree cover >25% but <60%. Dominant tree species: tamarack and black spruce. Sphagnum >20%.Areal coverage: ~ 7%
Open Bog	Open Bog	Sphagnum >20%. Tree and shrub cover <25%. Water table at or near surface. Areal coverage: < 1%
Shrubby Bog	Shrubby Bog	Ericaceous shrubs >25%. Tree cover <25%/ Sphagnum >20%. Areal coverage: < 1%
Treed bog	Treed Bog	Black spruce and Spaghnum moss dominated bogs with no hydrodynamic flow. Tree cover >20% but <60%. Areal coverage: ~1%
Shrub Swamp	Shrub Swamp	Mineral soils. Saturated to seasonally flooded. Tree cover <25%. Common shrubs: speckled alder and tall willow. Areal coverage: ~ 5%

Land cover	EWC Class	Description
Hardwood Swamp	Hardwood Swamp	Mineral soils. Saturated to seasonally flooded. Tree cover >25%. Dominant tree species: paper birch and balsam poplar. Areal coverage: ~ 2%
Mixedwood Swamp	Mixedwood Swamp	Mineral soils. Saturated to seasonally flooded. Tree cover >25%. Mix of tree species: tamarack, paper birch and black spruce. Areal coverage: ~ 2%
Tamarack Swamp	Tamarack Swamp	Mineral soils. Saturated to seasonally flooded. Tree cover >25%. Tamarack >75% of tree species. Areal coverage: ~ 1%
Conifer Swamp	Conifer Swamp	Transitional between peatlands and upland. Black spruce dominant with tree heights > 10m. Areal coverage: ~ 5%
Upland Conifer	Upland Conifer	Tree cover >25% and ≥ 80% are conifer. Common tree species: white spruce, black spruce, balsam fir, jack pine. Areal coverage: ~ 14%
Upland Deciduous	Upland deciduous	Mineral soils with tree cover >25% and >25% deciduous trees Dominant tree species: aspen, balsam poplar, and paper birch. Areal coverage: ~40%
Upland Mixedwood	Upland Mixedwood, Upland Other	Mineral soils with tree cover >25% and >25% deciduous trees. Mix of conifer and deciduous trees with no dominant species. Areal coverage: ~ 4%
Cutblock		Cutblocks of varying seral stage. Classified as cutblock if boundary was still distinct at classification. Areal coverage: < 1%
Anthropogenic		Areas of >50% urban development. Areal coverage: < 1%
Cloud	Cloud, Cloud Shadow	Cloud and cloud shadow prevent land cover classification. Areal coverage: ~ 6%

Resource Selection: Statistical Analyses

We estimated RSFs using generalized linear mixed effect models (GLMMs; Zuur *et al.* 2009), which account for the hierarchical structure inherent in GPS location data and unequal sample sizes among individual bison. In all GLMMs, we assigned individual bison as a random grouping effect (i.e. a random intercept). These models took the form

$$ln\left[\frac{\pi(y_i=1)}{1-\pi(y_i=1)}\right] = \beta_0 + \beta_1 x_{1ij} + \ldots + \beta_n x_{nij} + \gamma_{0j} \qquad \text{(Gillies } et\ al. \text{ 2006)}$$

where the left-hand side of the equation is the logit transformation for location y_i, β_0 is the fixed-effect intercept, β_n is the fixed-effect coefficient for each land cover covariate x_n, and γ_{0j} is the random intercept for bison *j*. The fixed-effect coefficients yield inferences on how a typical bison selects resources and can be interpreted within the classic use-availability design of

$$\omega(x_i) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots \beta_n x_n) \qquad \text{(Manly \textit{et al.} 2002)}$$

where $\omega(x_i)$ is the relative selection value of a resource unit (or pixel) in category *i* as a function of the explanatory covariates (x_n) and their estimated coefficients (β_n).

Land cover was specified as a categorical (or factor) variable and we set Upland Deciduous as the reference category. Note that this model specification results in a ranking of land cover types and that inferences on selection of a given land cover type are relative to Upland Deciduous. We evaluated resource selection separately for males and females because, similar to other ungulate species, the two sexes are spatially separated outside of the rutting season (Mooring *et al.* 2005).

All statistical analyses were performed in R except for piece-wise linear regression which was estimated in STATA. We used the R package 'adehabitatHR' (Calenge 2006) to estimate UDs and the 'lme4' package (Bates *et al*. 2013) to estimate RSFs. Because these analyses are preliminary and restricted to land cover data only, we do not present evaluations of model fit or prediction at this time.

RESULTS

We focus on seasonal selection of land cover by bison. Summaries of home range size and movement rates are contained in the November 2015 Update.

Spring

During spring, both females and males demonstrated relatively high selection of graminoid rich fens (Table 2). For females, this land cover type was ranked second behind meadow marsh. Emergent marsh was also highly selected by females. For males, graminoid rich fen was ranked second behind upland conifer. Males also showed relatively high selection for conifer swamps and treed poor fens. Both sexes avoided open bogs and tamarack swamps. The sexes differed in their relative selection of mixedwood uplands and cutblocks. Females relatively avoided mixedwoods and selected cutblocks while males showed the reverse pattern.

Table 2: Selection coefficients (β; with standard errors [SE] and *p*-values) for land cover type during spring for wood bison of the Ronald Lake herd of northeast Alberta. Positive coefficients (> 0) indicate relative selection compared to Upland Deciduous forests while negative coefficients indicate relative avoidance.

	Females (n = 21)			Males (n = 3)		
Land Cover Type	β	SE	*p*	β	SE	*p*
(Intercept)	-2.79	0.12	< 0.001	-3.38	0.44	< 0.001
Open Water	-0.22	0.07	< 0.001	-1.76	1.01	0.08
Aquatic Bed	-1.97	0.26	< 0.001		*perfect avoidance*	
Emergent Marsh	0.91	0.06	< 0.001	-0.82	1.01	0.42
Meadow Marsh	1.96	0.03	< 0.001	0.32	0.47	0.49
Graminoid Rich Fen	1.54	0.05	< 0.001	1.51	0.30	< 0.001
Graminoid Poor Fen	-0.26	0.07	< 0.001	-1.04	0.72	0.15
Shrubby Rich Fen	0.59	0.04	< 0.001	0.13	0.29	0.66
Shrubby Poor Fen	0.62	0.05	< 0.001	-0.11	0.52	0.82
Treed Rich Fen	0.20	0.03	< 0.001	-0.24	0.19	0.21
Treed Poor Fen	-0.09	0.04	0.02	1.47	0.11	< 0.001
Open Bog	-1.76	0.25	< 0.001		*perfect avoidance*	
Shrubby Bog	0.02	0.11	0.83		*perfect avoidance*	
Treed Bog	0.68	0.06	< 0.001	-0.12	0.39	0.77
Shrub Swamp	0.23	0.04	< 0.001	-0.80	0.27	0.00
Hardwood Swamp	-0.37	0.07	< 0.001	-0.36	0.31	0.25
Mixedwood Swamp	-0.63	0.09	< 0.001	-1.85	0.71	0.01
Tamarack Swamp	-1.82	0.18	< 0.001	-2.17	1.01	0.03
Conifer Swamp	0.35	0.03	< 0.001	1.27	0.13	< 0.001
Upland Conifer	0.73	0.02	< 0.001	1.87	0.08	< 0.001
Upland Mixedwood	-1.86	0.17	< 0.001	0.79	0.15	< 0.001
Cutblock	0.65	0.12	< 0.001		*perfect avoidance*	
Anthropogenic	-0.47	0.24	0.05		*perfect avoidance*	
Cloud		*perfect avoidance*		-0.97	0.24	< 0.001

Calving

During calving, females showed high selection for meadow marsh and, to a lesser extent hardwood swamp, relative to upland deciduous forests (Table 3). All other land cover types were relatively avoided. Bogs, tamarack swamp, upland mixedwoods and cutblocks were the lowest rank land covers. For males, upland deciduous forest was the highest ranked land cover during this time although two of the three males had a few locations within anthropogenic areas. Similar to females, males also strongly avoided bogs and cutblocks and further showed strong avoidance of shrubby poor fens.

Table 3: Selection coefficients (β; with standard errors [SE] and *p*-values) for land cover type during calving for wood bison of the Ronald Lake herd of northeast Alberta. Positive coefficients (> 0) indicate relative selection compared to Upland Deciduous forests while negative coefficients indicate relative avoidance.

	Females (n = 21)			Males (n = 3)		
Land Cover Type	β	SE	p	β	SE	p
(Intercept)	-1.87	0.03	< 0.001	-2.11	0.06	< 0.001
Open Water	-2.14	0.11	< 0.001	*perfect avoidance*		
Aquatic Bed	-3.16	0.71	< 0.001	-1.15	1.02	0.26
Emergent Marsh	-1.4	0.12	< 0.001	-0.73	0.52	0.16
Meadow Marsh	1.39	0.03	< 0.001	-0.54	0.37	0.15
Graminoid Rich Fen	-2.12	0.16	< 0.001	-1.76	0.72	0.01
Graminoid Poor Fen	-1.96	0.12	< 0.001	-1.16	0.42	0.01
Shrubby Rich Fen	-2.73	0.13	< 0.001	-1.15	0.31	< 0.001
Shrubby Poor Fen	-2.01	0.11	< 0.001	*perfect avoidance*		
Treed Rich Fen	-1.56	0.05	< 0.001	-1.13	0.17	< 0.001
Treed Poor Fen	-1.25	0.04	< 0.001	-1.58	0.21	< 0.001
Open Bog	*perfect avoidance*			*perfect avoidance*		
Shrubby Bog	-5.05	1	< 0.001	-0.67	0.52	0.19
Treed Bog	-3.11	0.26	< 0.001	-1.98	0.58	< 0.001
Shrub Swamp	-1.2	0.05	< 0.001	-0.51	0.14	< 0.001
Hardwood Swamp	0.49	0.03	< 0.001	-0.71	0.22	0.00
Mixedwood Swamp	-0.1	0.05	0.06	-2.51	0.58	< 0.001
Tamarack Swamp	-3.7	0.38	< 0.001	-2.12	0.58	< 0.001
Conifer Swamp	-0.76	0.03	< 0.001	-2.00	0.31	< 0.001
Upland Conifer	-2.37	0.05	< 0.001	-0.90	0.11	< 0.001
Upland Mixedwood	*perfect avoidance*			-0.27	0.14	0.05
Cutblock	*perfect avoidance*			*perfect avoidance*		
Anthropogenic	*perfect avoidance*			1.50	0.44	< 0.001
Cloud	*perfect avoidance*			0.90	0.08	< 0.001

Summer / Fall

Females continued to show relatively high selection for meadow marshes after calving and extending into the fall (Table 4). In contrast to calving, females appeared to make more use of upland conifer forests, mixedwood forests and conifer swamps. The lowest ranked land covers for females were mixedwood swamp, cutblock and treed bog. For males, the highest ranked land covers for summer and fall were meadow marsh, upland conifer forest and conifer swamp. Males highly avoided shrubby bogs, mixedwood swamps and graminoid poor fens. Note that during this season, both male and female bison showed the highest variation in land cover use as no one land cover type was completed avoided.

Table 4: Selection coefficients (β; with standard errors [SE] and *p*-values) for land cover type during summer and fall for wood bison of the Ronald Lake herd of northeast Alberta. Positive coefficients (> 0) indicate relative selection compared to Upland Deciduous forests while negative coefficients indicate relative avoidance.

	Females (*n* = 21)			Males (*n* = 3)		
Land Cover Type	β	SE	*p*	β	SE	*p*
(Intercept)	-1.31	0.06	< 0.001	-1.03	0.17	< 0.001
Open Water	-0.48	0.04	< 0.001	-1.15	0.24	< 0.001
Aquatic Bed	-0.52	0.12	< 0.001	-1.24	0.62	0.05
Emergent Marsh	0.05	0.05	0.26	-0.81	0.32	0.01
Meadow Marsh	0.68	0.03	< 0.001	0.69	0.16	< 0.001
Graminoid Rich Fen	-0.02	0.05	0.70	-0.17	0.22	0.44
Graminoid Poor Fen	-0.74	0.05	< 0.001	-1.57	0.30	< 0.001
Shrubby Rich Fen	-0.31	0.03	< 0.001	-1.13	0.19	< 0.001
Shrubby Poor Fen	-0.68	0.04	< 0.001	-1.51	0.33	< 0.001
Treed Rich Fen	-0.19	0.02	< 0.001	-0.22	0.07	0.00
Treed Poor Fen	-0.47	0.02	< 0.001	-0.58	0.08	< 0.001
Open Bog	-0.39	0.17	0.02	0.53	0.74	0.47
Shrubby Bog	-0.63	0.08	< 0.001	-3.20	0.91	< 0.001
Treed Bog	-0.91	0.06	< 0.001	-1.22	0.24	< 0.001
Shrub Swamp	-0.61	0.03	< 0.001	-1.38	0.12	< 0.001
Hardwood Swamp	-0.54	0.04	< 0.001	-0.39	0.12	< 0.001
Mixedwood Swamp	-1.41	0.07	< 0.001	-2.57	0.33	< 0.001
Tamarack Swamp	-0.53	0.06	< 0.001	-1.04	0.20	< 0.001
Conifer Swamp	0.30	0.02	< 0.001	0.28	0.07	< 0.001
Upland Conifer	0.74	0.01	< 0.001	0.58	0.04	< 0.001
Upland Mixedwood	0.67	0.04	< 0.001	-0.33	0.09	< 0.001
Cutblock	-1.04	0.12	< 0.001	-1.16	0.33	< 0.001
Anthropogenic	-0.20	0.15	0.19	0.29	0.41	0.49
Cloud	-2.95	0.16	< 0.001	-0.06	0.07	0.32

Winter

During winter, both sexes had relatively high selection for fens and marshes (Table 5). Meadow marsh continued to be the top ranked land cover for females while graminoid rich fens was ranked highest for males. The sexes contrasted in their response to swamps with females relatively selecting shrubby and hardwood swamps and avoiding conifer and tamarack swamps while males showed relatively high selection for tamarack swamps and avoided mixedwood swamps. In general, both sexes avoided bogs although males did select shrubby bogs at a rate similar to upland deciduous forest. Both sexes also highly avoided cutblocks.

Table 5: Selection coefficients (β; with standard errors [SE] and *p*-values) for land cover type during winter for wood bison of the Ronald Lake herd of northeast Alberta. Positive coefficients (> 0) indicate relative selection compared to Upland Deciduous forests while negative coefficients indicate relative avoidance.

	Females (*n* = 19)			Males (*n* = 2)		
Land Cover Type	β	SE	p	β	SE	p
(Intercept)	-1.58	0.04	< 0.001	-2.18	0.19	< 0.001
Open Water	1.02	0.03	< 0.001	0.45	0.27	0.09
Aquatic Bed	-2.04	0.19	< 0.001	2.38	0.29	< 0.001
Emergent Marsh	2.48	0.03	< 0.001	0.59	0.38	0.12
Meadow Marsh	3.32	0.03	< 0.001	-0.29	0.45	0.51
Graminoid Rich Fen	2.10	0.04	< 0.001	2.39	0.18	< 0.001
Graminoid Poor Fen	1.05	0.03	< 0.001	1.50	0.20	< 0.001
Shrubby Rich Fen	1.51	0.03	< 0.001	1.29	0.15	< 0.001
Shrubby Poor Fen	1.41	0.03	< 0.001	1.94	0.20	< 0.001
Treed Rich Fen	0.64	0.02	< 0.001	0.97	0.10	< 0.001
Treed Poor Fen	0.08	0.03	0.004	0.85	0.10	< 0.001
Open Bog	-2.61	0.20	< 0.001	*perfect avoidance*		
Shrubby Bog	-0.30	0.10	0.001	0.14	0.43	0.75
Treed Bog	-0.09	0.07	0.16	-1.06	0.45	0.02
Shrub Swamp	2.04	0.02	< 0.001	0.23	0.13	0.07
Hardwood Swamp	0.80	0.03	< 0.001	-0.23	0.21	0.26
Mixedwood Swamp	0.17	0.05	< 0.001	-1.49	0.41	< 0.001
Tamarack Swamp	-1.56	0.13	< 0.001	1.01	0.17	< 0.001
Conifer Swamp	-0.37	0.03	< 0.001	0.12	0.16	0.45
Upland Conifer	-1.15	0.03	< 0.001	0.70	0.08	< 0.001
Upland Mixedwood	-1.30	0.10	< 0.001	-0.42	0.17	0.01
Cutblock	-1.62	0.23	< 0.001	*perfect avoidance*		
Anthropogenic	0.28	0.22	0.20	2.21	0.40	< 0.001
Cloud	*perfect avoidance*			1.05	0.09	< 0.001

Project Outlook

The above analytical framework provides the foundation for the next phases of modelling seasonal habitat selection by Ronald Lake bison. Our next objectives are to continue habitat selection modelling, specifically incorporating fire and anthropogenic disturbance variables to quantify how these variable influence seasonal space use of bison. We will also incorporate additional indices of forest structure using LiDAR data where available. Final seasonal models of habitat selection will be evaluated for both relative fit and predictive power.

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APPENDIX A1: RANDOM POINT SENSITIVITY ANALYSIS

We conducted sensitivity analyses to determine the number of random points to adequately characterize availability within bison home ranges. We used the 95% probability contour of utilization distributions to delineate bison home ranges. To identify the number of random points where parameter estimates for land cover stabilized, we conducted repeated RSFs using the summer / fall data, varying the number of random points used each time (range: 200 – 20,000). This analysis suggested that parameter estimates stabilized at ~ 5000 random points (Fig. A1).

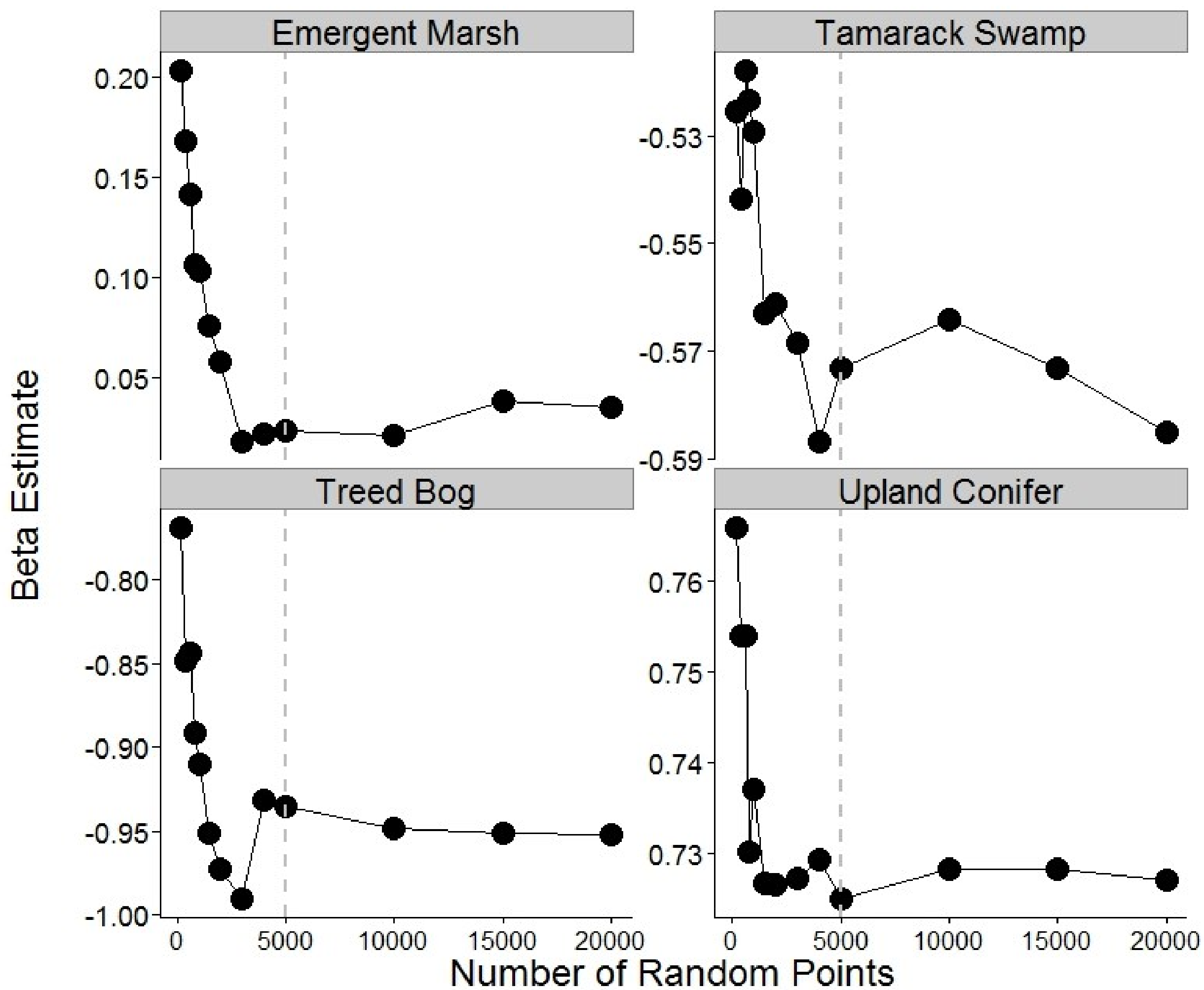

Figure A 1: Sensitivity analysis to determine the number of random points required to adequately characterize availability within bison home ranges. Parameter (Beta) estimates for land cover types stabilized at ~ 5000 points (grey dashed line).

APPENDIX B: MOVEMENT BEHAVIOUR OF FEMALE WOOD BISON DURING MAY AND JUNE, 2013 - 2015

We assessed female movement during May and June to identify the calving season for Ronald Lake wood bison. The Preliminary Summary Report (Tan *et al*. 2015) demonstrated that female bison congregate in a discrete area during June to calve. To identify this area, we created a minimum convex polygon around bison GPS locations on June 10, 2014 when females were maximally aggregated (Fig. B1). We defined the start of calving as the date when the first female migrated to and settled in the calving area (Figs. B2 – B4) and the end of calving when the last female departed the calving area (Figs. B5 – B7).

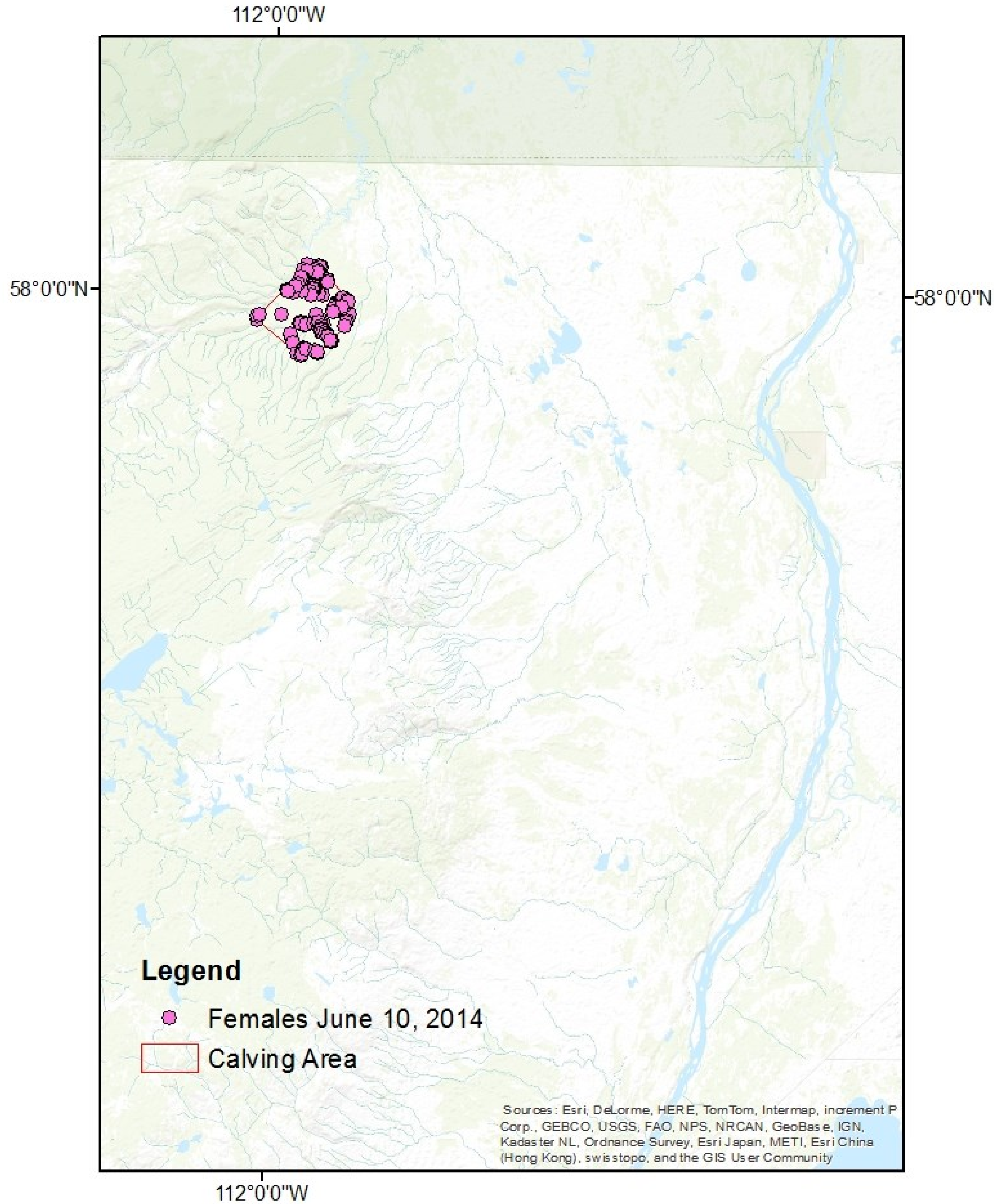

Figure B 1: The calving area of female bison of the Ronald Lake herd of northeast Alberta. The calving area was delineated using a minimum convex polygon around GPS locations of all radio-collared females on June 10, 2014.

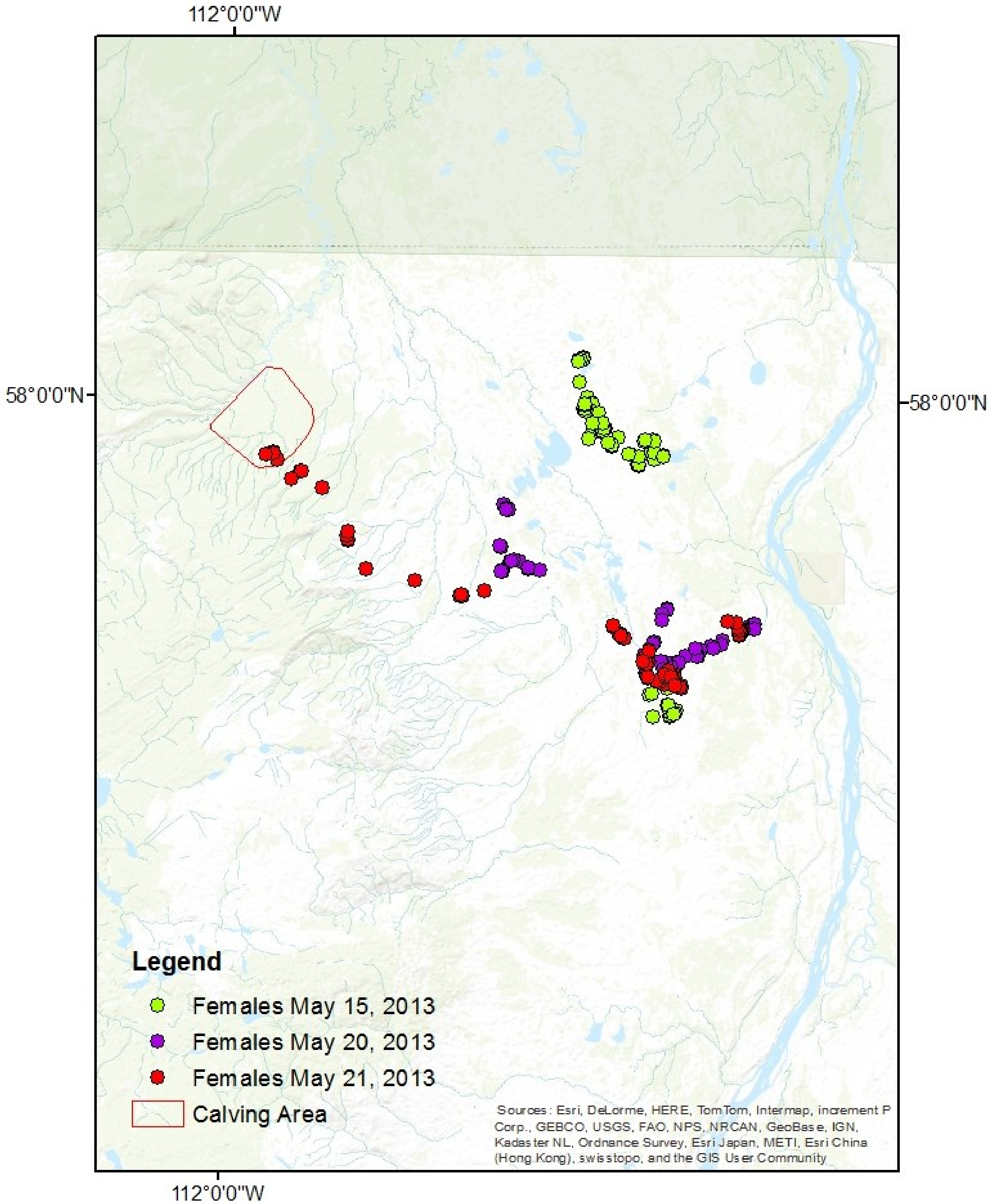

Figure B 2: Movements of Ronald Lake female bison during May 2013. Females first started migrating to and settling in the calving area on May 21.

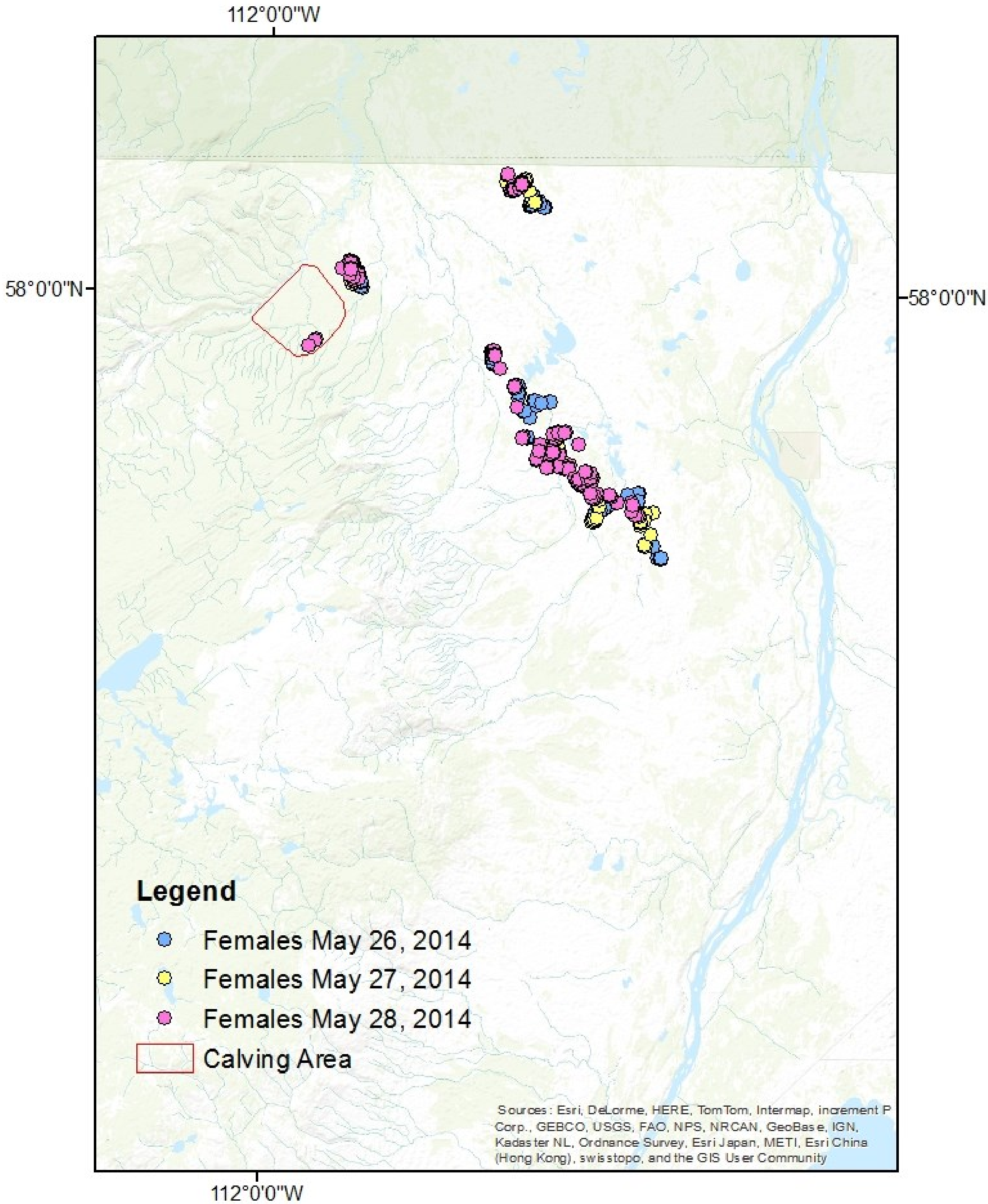

Figure B 3: Movements of Ronald Lake female bison during May 2014. Females first started migrating to and settling in the calving area on May 28.

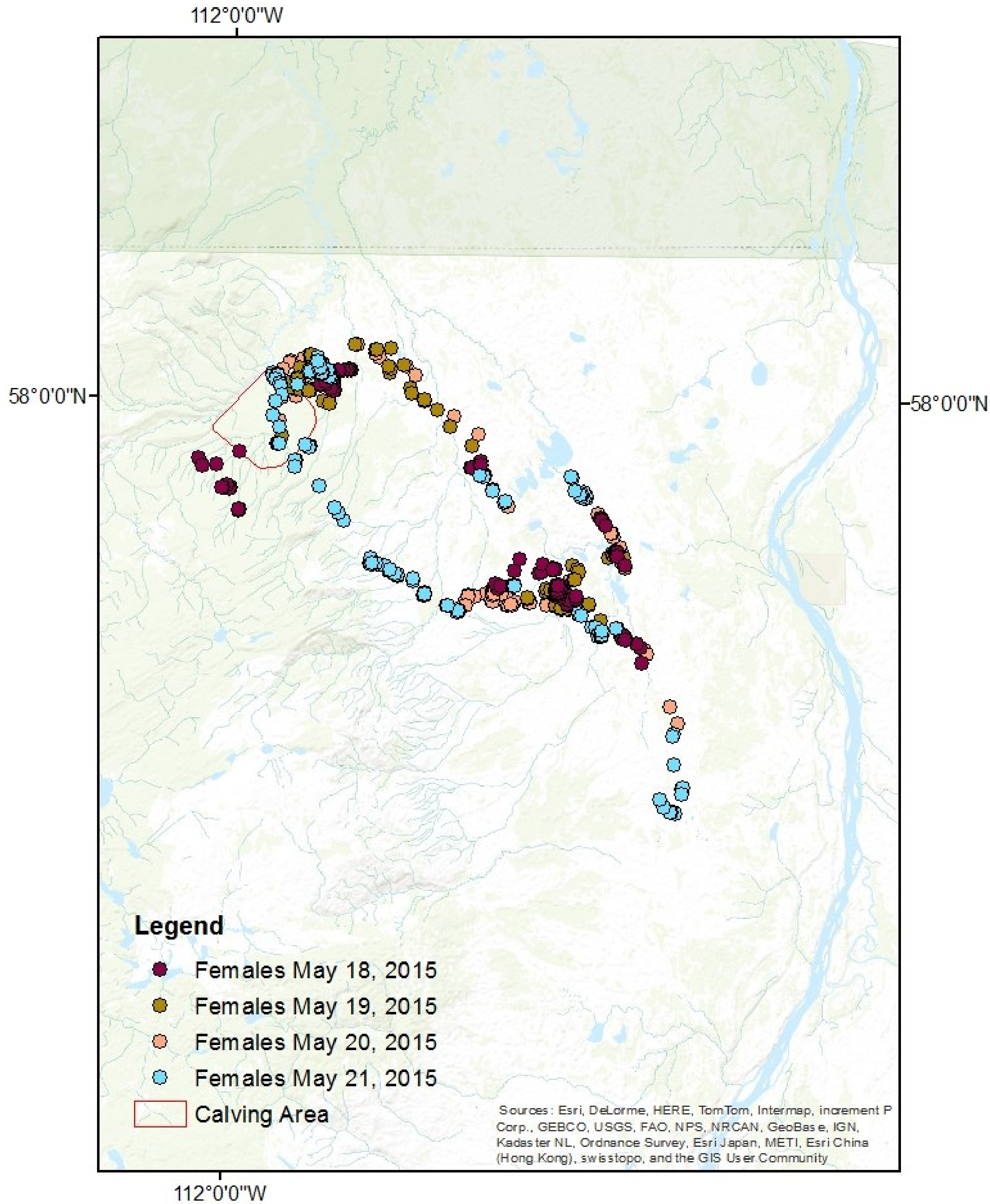

Figure B 4: Movements of Ronald Lake female bison during May 2015. Females first started migrating to and settling in the calving area on May 21.

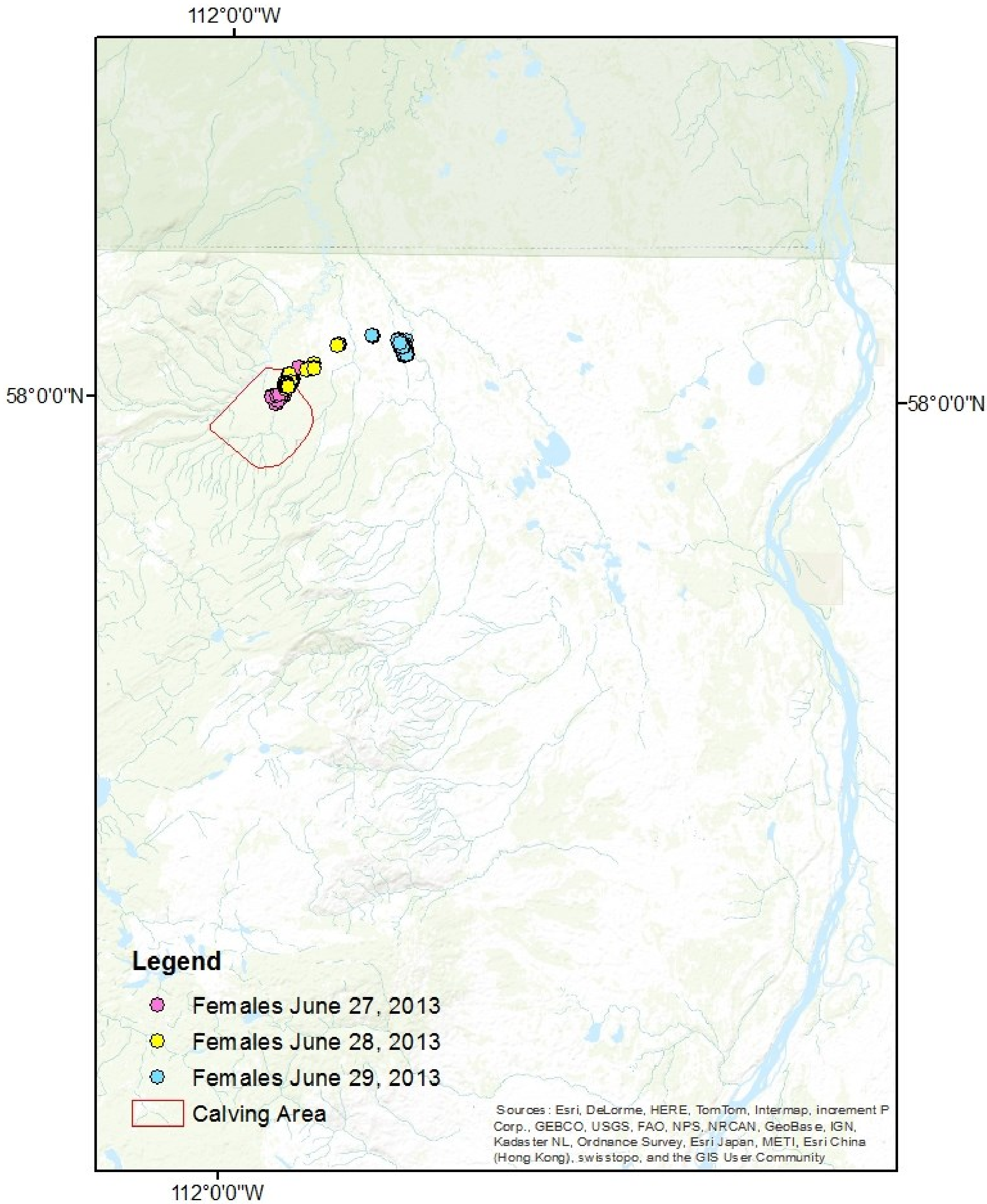

Figure B 5: Movements of Ronald Lake female bison during June 2013. The last female to leave the calving area departed on June 29.

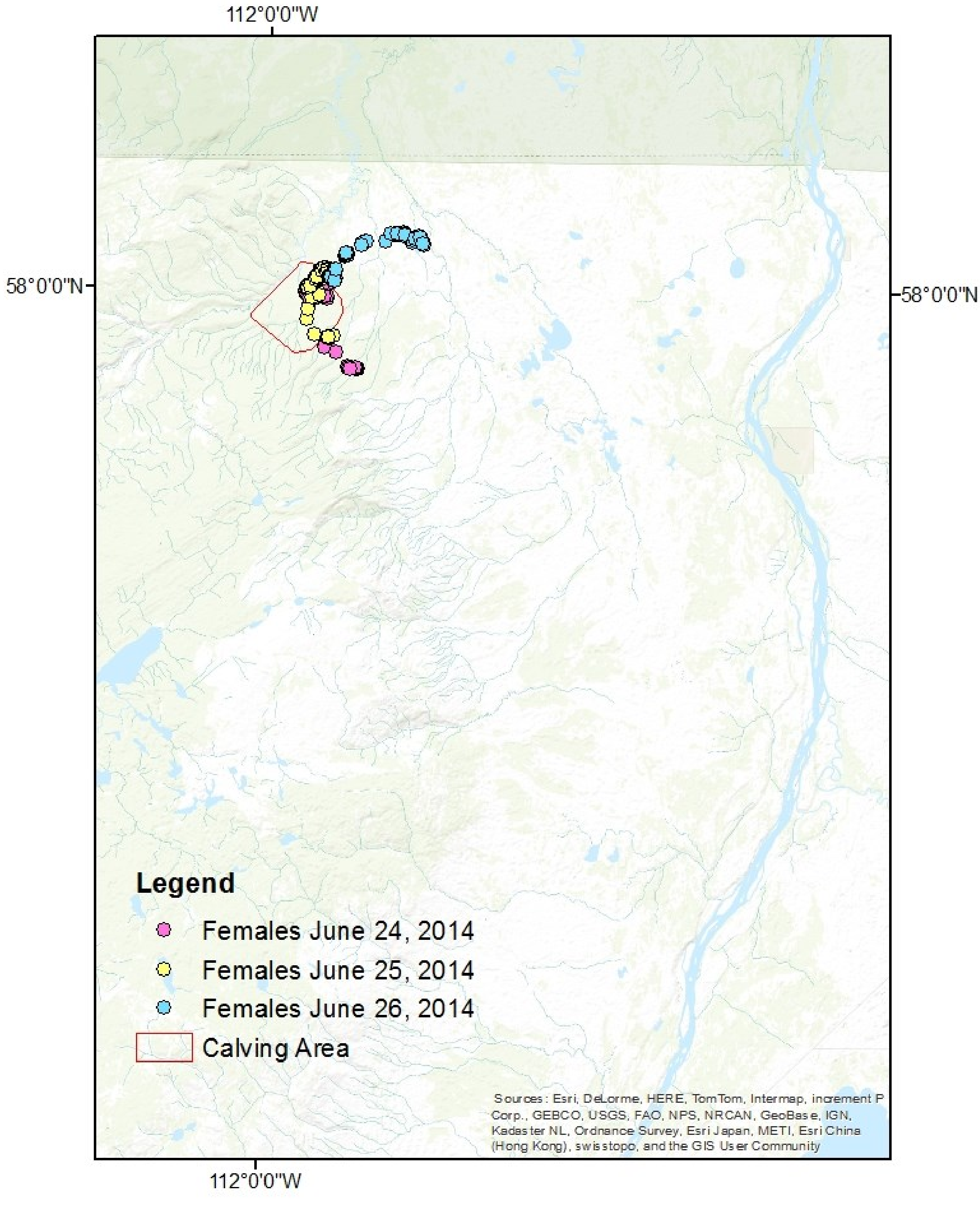

Figure B 6: Movements of Ronald Lake female bison during June 2014. The last female to leave the calving area departed on June 26.

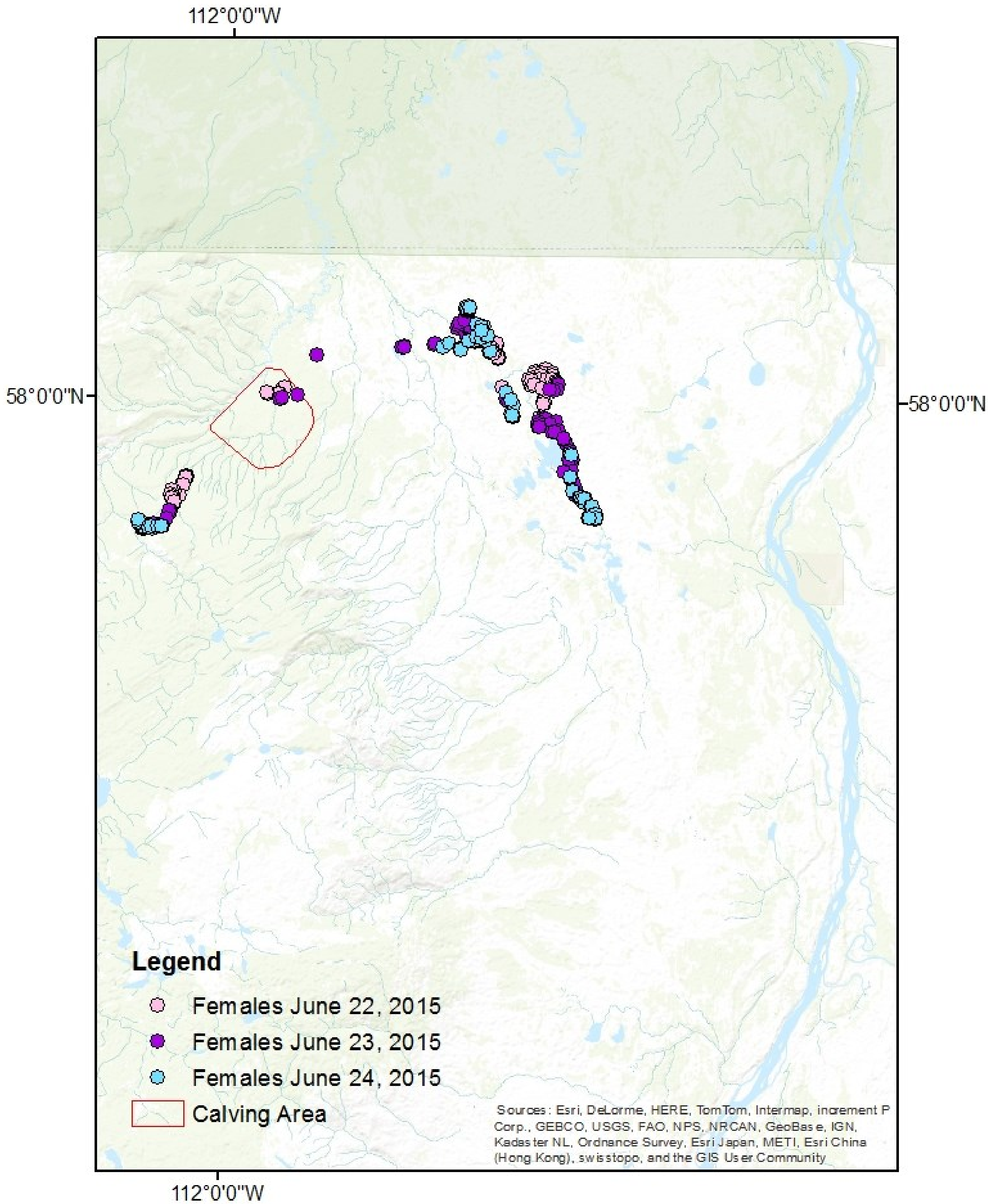

Figure B 7: Movements of Ronald Lake female bison during June 2015. The last female to leave the calving area departed on June 24.