Government of Northwest Territories
Gouvernement des Territoires du Nord-Ouest

Catherine Fairbairn
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DELIVERED VIA EMAIL

April 19, 2024

Dear Ms. Fairbairn:

Submission of the Aerial Moose Survey Report for the Mackenzie Valley Highway Project (EA1213-02)

The Government of the Northwest Territories Department of Infrastructure is pleased to submit the attached Mackenzie Valley Highway Project: Aerial Moose Survey Report. The report provides an updated estimate of moose density and abundance within the Regional Study Area to support the assessment of potential impacts of the Mackenzie Valley Highway (MVH) on wildlife harvesting.

Should you have any questions or if you would like further information, please contact me at (867) 767-9082 ext. 31035, or by email at Seth_Bohnet@gov.nt.ca. Alternatively, you can reach out to Patricia Coyne, Manager MVH Environmental Affairs at (867) 767-9082 ext. 31033, or by email at Patricia_Coyne@gov.nt.ca.

Sincerely,

Seth Bohnet
Director, Strategic Infrastructure
Infrastructure

Attachment

c.	Distribution List

Distribution List:

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Executive Director
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Government of Northwest Territories
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Mackenzie Valley Highway Project

Aerial Moose Survey Report

Wildlife Research Permit # WL501031

Hamsha Pathmanathan & Kevin Chan

February 29, 2024

Department of Environment and Climate Change, Wildlife Division

Government of the Northwest Territories

Introduction

The Mackenzie Valley Review Board's Terms of Reference for the Mackenzie Valley Highway Project (EA1213-02) mandates that "the potential impacts of the proposed highway on valued components related to wildlife and wildlife habitat, include a consideration of: 1) direct and indirect alteration of habitat including highway footprint impact, 2) wildlife movement patterns, home ranges, distribution and abundance, and 3) sensitive or important areas or habitat".

Moose were specifically included in the Terms of Reference as a "key line of inquiry" with respect to the assessment of potential impacts of the project on wildlife harvesting, given their importance as a harvested species by communities along the Mackenzie Valley Highway corridor. Among other impacts, the Terms of Reference requires that the Developer's Assessment Report for the project consider:

- "wildlife movement patterns, home ranges, distribution and <u>abundance</u>;"
- "changes in the <u>abundance</u> and distribution of harvested resources, including caribou, moose and other wildlife (e.g. furbearers, waterfowl) that would adversely affect harvesting;"

In March 2021, the Government of the Northwest Territories (GNWT) Department of Environment and Climate Change (ECC) undertook an aerial moose survey within the Regional Study Area for the Mackenzie Valley Highway (defined as a 15 km buffer on either side of the proposed highway alignment) to provide an estimate of moose density and abundance within the RSA to support the environmental assessment,

Methods

Study area

A map of the survey area was developed using the proposed Mackenzie Valley Highway alignment, borrow sites and associated access roads. Originally, the survey was designed using the Local Study Area (LSA), a 2 km buffer on either side of the road alignment, but the area was insufficient for the proposed survey method. Consequently, a 15 km buffer was placed on either side of the road alignment (hereafter referred to as the RSA), which encompassed an area of approximately 10,110 km^2 (Figure 1). Once the boundaries were finalized, a rectangular grid based on 2° latitude and 5° longitude (approx. 4 km by 4 km or 16 km^2) was overlaid on the survey area. Due to grid cells being included if they intersected with the perimeter of the RSA, the total final study area used in the analysis to estimate moose density and abundance was 11,898 km^2. Grid cells were classified as either high or low moose density based on the Important Wildlife Areas for Moose, which were identified through discussions with communities held from 2006 to 2009, co-management boards, departmental staff, and review of available reports (Wilson and Haas 2012; Figure 1). In addition, local knowledge from recent community engagement (2022) with six members of the Tulita Renewable Resources Council (TRRC) was incorporated to further refine the stratification. Participants were shown a gridded map encompassing the entire RSA and the participants classified cells as suitable or not suitable for moose occupation, or as areas where moose have been known to congregate. Positive responses were assigned as high density and negative responses were assigned as low density. Members of the Norman Wells Renewable Resources Council (NWRRC) were unavailable for engagement at the time survey planning took place.

Field Methods

Sixty (60) sample cells were randomly selected between the Sahtú and Dehcho region from the stratified grid cells in the RSA. Fourty (40) cells were selected from the high-density strata (20 blocks per region), and 20 cells were selected from the low-density strata (10 blocks per region) (Figure 2). Flightlines were flown at 500m spacing resulting in approximately 8 lines per grid cell.

The survey crew consisted of a pilot (F.Martin), a navigator/ data recorder (H. Pathmanathan) and 2 observers in the rear seats. Observers (K.Chan, C. Masse, J. Yakeleya, A. Austin, and M. Gast) from both the Sahtú and Dehcho regions were used during the survey. The aircraft was flown on north-south transects at an altitude of 200-400 ft and at 60-80 knots.

Observers sought to identify and follow tracks from the air and look for signs of moose (standing or bedded). Areas that were deemed to be suitable for moose habitat, such as clusters of willows around water bodies, were circled and intensely surveyed. All observed moose were circled at least twice to ensure that no other moose in the vicinity was missed. When more than 4 moose were observed in an area, multiple passes were made with the aircraft to ensure validity of count. The composition (age and sex) of observed moose was not classified due to the timing of the survey in March (bull moose have already dropped their antlers at this time of year, making identification of sex more challenging). All moose and incidental wildlife observations were recorded with GPS waypoints. Photos were taken where possible.

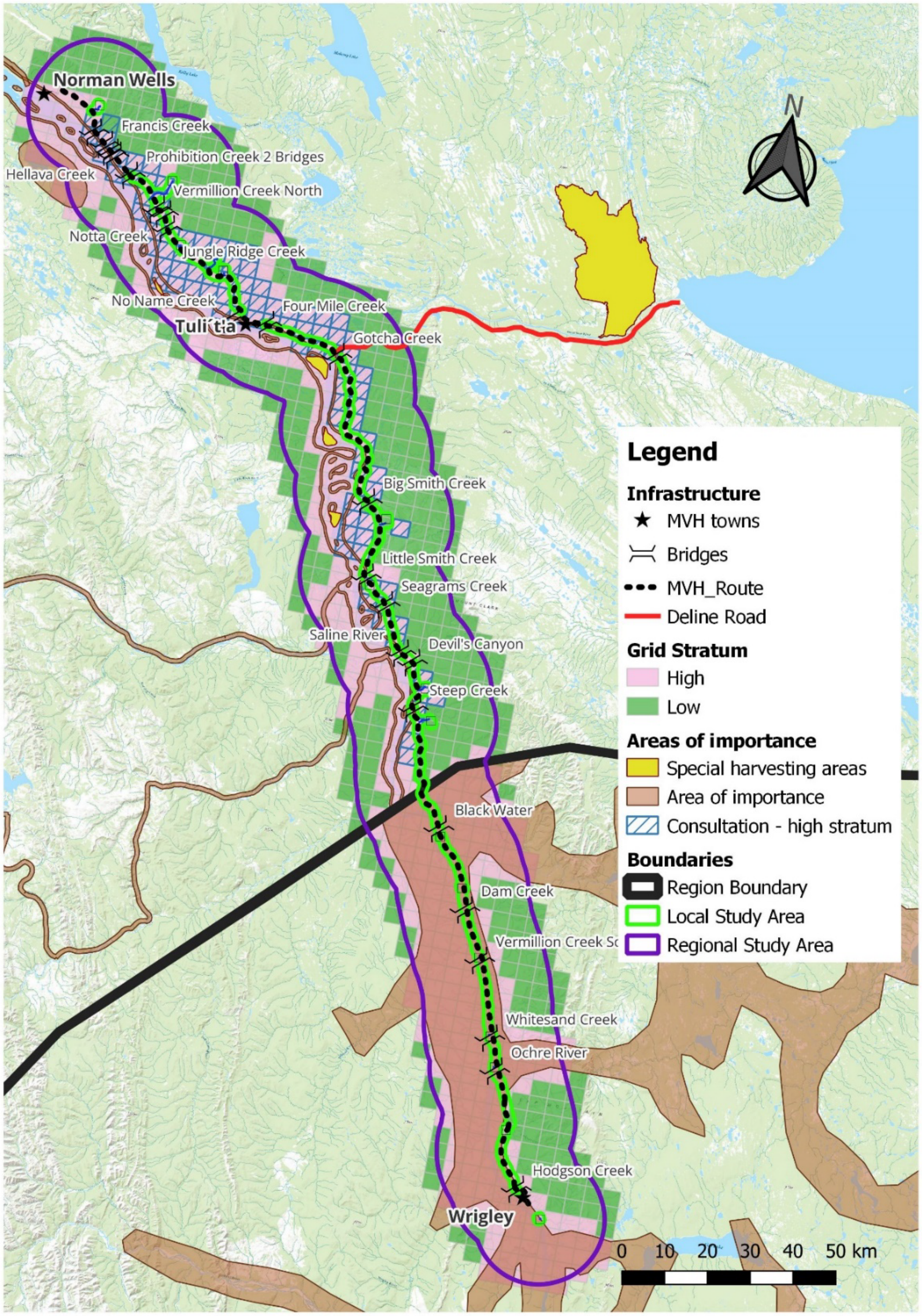

Figure 1.Map of the Regional Study Area (RSA; 15km buffer) and Local Study Area (LSA, 2km buffer). Grid cells were classified as high moose density (Pink) and low moose density stratum (Green). Consultation with the Tulita Renewable Resource Council provided input on key moose areas within the study area in the Sahtú region to designate as high (blue hatched grids)

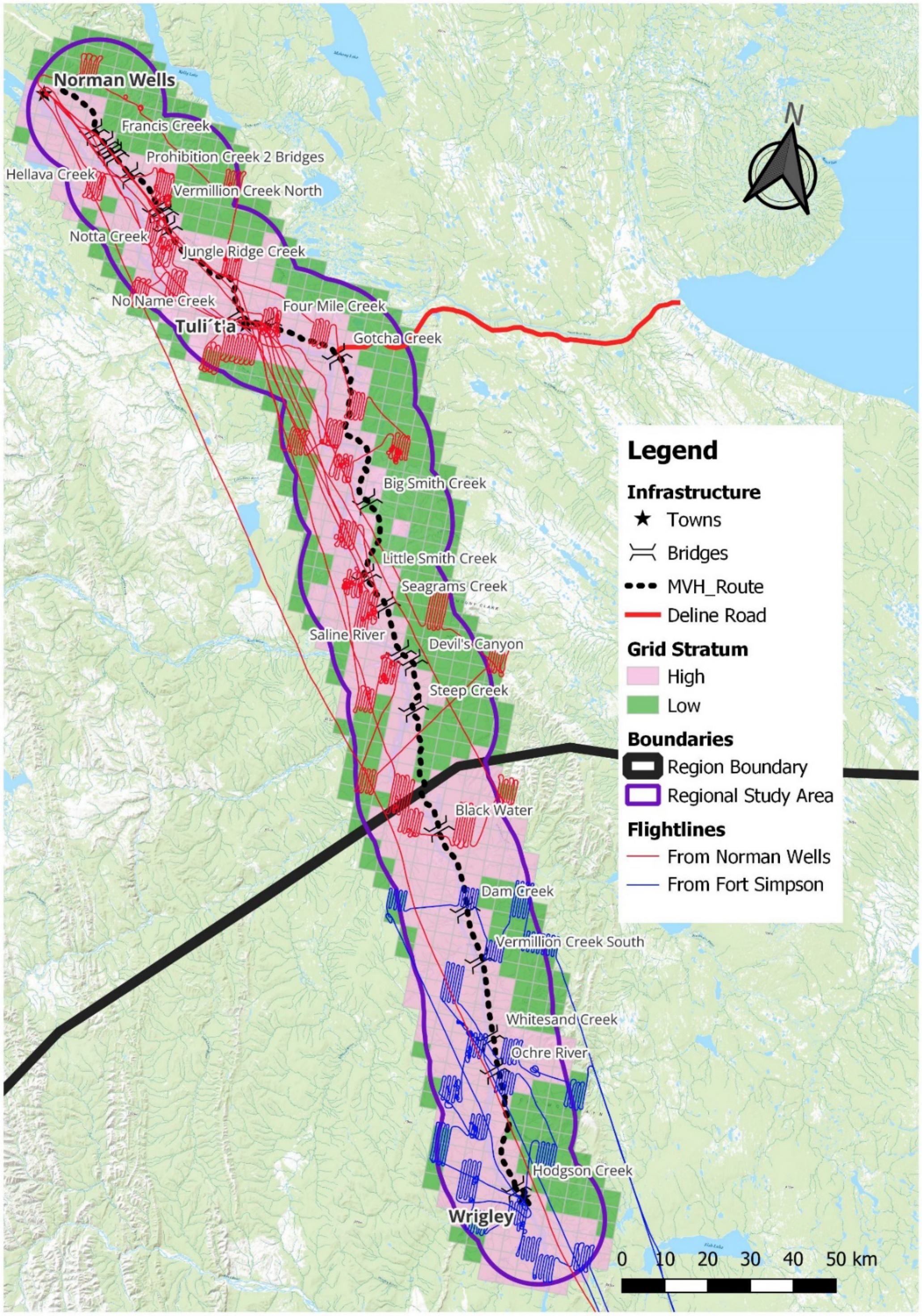

Figure 2. Survey stratification and selected blocks along the Mackenzie Valley Proposed Highway route. Actual flight lines are shown in red and blue.

Statistical analyses

Estimates of the moose population were calculated using a spatial interpolation method known as Finite Population Block Kriging (FPBK), sometimes referred to as a geospatial population estimator (Higham, Matt et al., 2022). Block kriging estimates averaged values over blocks (e.g. grid cells) within a fixed geographic area that may be spatially autocorrelated using a general linear model. FPBK also has an advantage over regular block kriging because FPBK incorporates a finite population correction factor to reduce the prediction variance. In this case, FPBK is used to estimate a mean or total number moose from census counts (i.e. perfect detection) of moose in a subset of sampled grid cells. FPBK has been used successfully for estimating moose abundance in Alaska, Yukon Territory and the Northwest Territories and has the advantage of 1) usually being more precise than stratified random sampling, 2) allowing for small area estimation, and 3) allowing for non-random sampling designs.

We incorporated habitat into the estimation model using the 2015 Landcover of Canada (Latifovic, 2019) classification raster with a 30 m resolution. The 12 available landcover classes were aggregated by pooling classes with like classifications (Appendix A: Table A1) resulting in the following classifications: Conifer, Taiga, Forage, Open, Wetland, and Water. The Conifer landcover class was removed from the analysis due to high correlation with the Open and Forage classifications which may have caused issues with collinearity. Proportions of each landcover class were then calculated for each grid cell and used as independent variables.

A global model was fit using the proportion of each landcover class (Taiga, Forage, Open, Wetland, and Water) in each grid cells and stratum as predictors and competing models were fit using single habitat classes in addition to stratum resulting in 7 competing models (Global, stratum only, and 5 habitat classes with stratum; see Appendix A: Table A1). The covariance between sample units was estimated using an exponential model and restricted maximum likelihood (REML) and each stratum was allowed to have a separate covariance parameter estimate. The most parsimonious model was identified from other candidate models using the lowest ΔAIC, with models ΔAIC <2 being considered as statistically indistinguishable (Burnham and Anderson 2002). Allowing each stratum to have separate covariance estimates resulted in each model having 2 AIC values (High density and Low density) to be evaluated. If the lowest AIC value for the High density and Low density were not the same model, both models would be reported. All analyses were performed using the *sptotal* package in R (Higham, Matt et al., 2022; R Development Core Team, 2020). Estimates of the mean (Dˆ) were reported with 90% confidence intervals (90% CI) and coefficient of variation (CV).

Results

Field Survey Summary

The aerial survey was conducted over an 8-day period from 16 March to 24 March 2021 using a Cessna 206 aircraft (North-Wright Airways). This was done to maximize contrast between the snow cover and the animals and increase detectability of individuals. Weather conditions were variable with temperatures ranging from -30°C to -14°C. Skies were clear on 3 days, overcast on 2 days, and broken clouds on 1 day. Low cloud ceiling on 2 days led to weather days where no or only a few blocks were surveyed. Light conditions ranged from flat to bright, and there was full snow coverage in all surveyed cells.

Observations

A total of 134 moose in 54 groups were seen on-transect during the survey and an additional 61 moose were incidentally seen in 33 groups off-transect (Figure 3). Off-transect individuals were recorded but not included in the analysis. Group sizes ranged from 1-16 animals. Average group size in the survey area was 2.3 individuals. Observations of all wildlife sightings are summarized in Table 1. Total moose counts within surveyed cells varied between 0 and 40, with most surveyed cells having <10 individuals (Figure 4, Appendix A: Table A1).

Table 1. Observations of all wildlife and associated number of groups seen on-transect (surveying in grid cell), and off-transect (ferrying/ outside of grid cell).

Species	**On-transect Individuals (Groups)**	**Off-transect Individuals (Groups)**	**Total Individuals (Groups)**
Moose	134 (54)	61 (33)	195 (87)
Muskox	63 (4)	61 (5)	124 (9)
Caribou	0	1 (1)	1 (1)
Wolves	0	4 (1)	4 (1)
Wolverine	1 (1)	0	1 (1)
Fox	0	2 (2)	2 (2)

Population and Density Estimation

Model selection results for the FPBK are summarized in Table 2. The most parsimonious model identified through the model selection for both the high density and low-density strata was the global model with all predictor variables and parameter estimates are summarized in Table 3. The global model predicted an average estimate of 2,028 moose (SE = 407.94, CV = 0.20) with a 90% CI ranging from 1,357 – 2,699 for the RSA. The model predicted an estimate of 377 moose (SE = 25.31, 90% CI = 335 - 418) for the low-density strata areas within the RSA and an estimate of 1,652 (SE = 407.15, 90% CI = 982 - 2321) for the high-density strata areas within the RSA. Average density for the RSA is approximately 17 moose/100 km^2.

The model for the low-density strata had a better fit having higher generalized R^2 value (0.96) than the high-density strata (generalized $R^2 = 0.39$) and a much lower CV (0.07 vs 0.25). The strongest predictor of winter moose density in both models was the proportion of water in the grid cell, with proportion of wetland being a significant predictor in the low-density strata model.

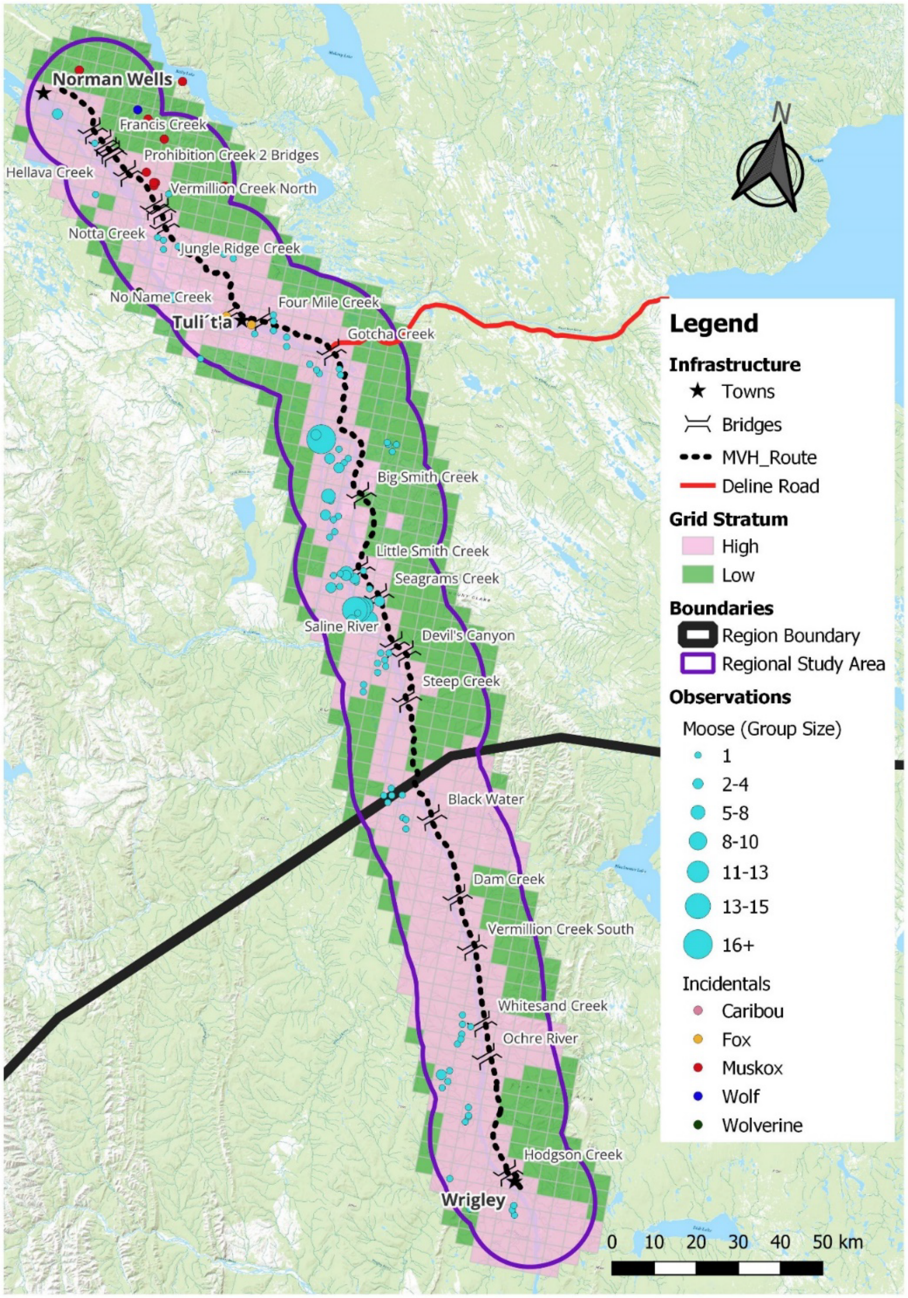

Figure 3. Moose and incidental observations within the Mackenzie Valley Highway project survey area. Moose observations are categorized by group size indicated by size of the point.

Table 2. Model selection results for the FPBK models. Lowest ΔAIC was selected as the best model.

Model	Low			High		
	ΔAIC	**Rank**	**Weight**	**ΔAIC**	**Rank**	**Weight**
Global	0.00	1	1.00	0.00	1	1.00
Null	60.33	7	0.00	53.29	7	0.00
Forage	58.70	6	0.00	46.80	6	0.00
Open	57.62	5	0.00	46.72	5	0.00
Taiga	57.89	4	0.00	45.29	4	0.00
Water	14.21	2	0.00	31.15	2	0.00
Wetland	46.29	3	0.00	40.19	3	0.00

Table 3. Parameter estimates for the best FPBK model.

Parameter	Low				High			
	Estimate	**SE**	**t-value**	**p-value**	**Estimate**	**SE**	**t-value**	**p-value**
Intercept	-0.162	0.098	-1.652	0.121	-2.325	2.736	-0.85	0.402
Open	-1.135	0.372	-3.053	< 0.01	-0.022	8.806	-0.002	0.998
Taiga	0.391	0.348	1.124	0.280	0.646	8.129	0.079	0.937
Forage	0.509	0.296	1.717	0.108	6.156	6.519	0.944	0.352
Wet	5.828	3.891	1.498	0.156	6.489	238.45	0.027	0.978
Water	34.215	2.449	13.969	< 0.01	39.776	9.281	4.286	< 0.01
Covariance	**Low**				**High**			
Nugget	0.048				25.266			
Partial Sill	0.000				7.868			
Range	273571.9				19.623			
Generalized R^2	0.96				0.39			

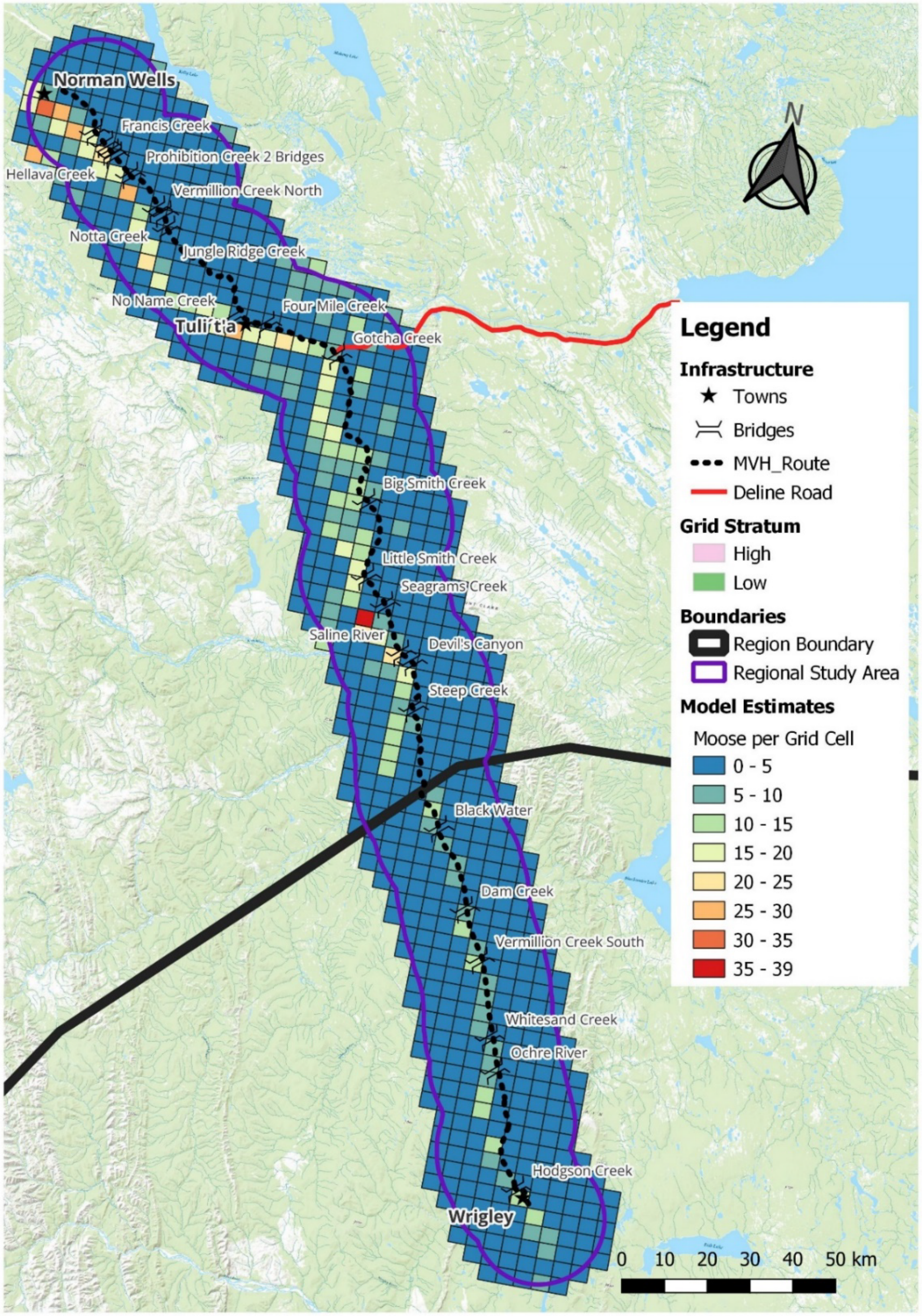

Figure 4. Estimated abundance and distribution of moose from the best FPBK model. Note that grid cells were categorized with negative values due to kriging weights (see conclusions for more details) and are categorized as zero on this map.

Conclusions

Our recent survey of Moose in the MVH RSA resulted in a population estimate of 2,028 moose (SE = 407.94, CV = 0.20) with a 90% CI ranging from 1,357 – 2,699. This equates to an average density of approximately 17 moose/100 km^2, ranging from 14.4 to 22.7 moose/100 km^2. The majority of moose were seen on or along the river (Figure 3) and this was seen in the estimated distribution as well (Figure 4).

The GNWT had previously monitored moose numbers in areas surrounding the Mackenzie river using Gasway aerial surveys (Gasway et al., 1981) with estimates from surveys in Sahtú ranging between 8 to 15 moose per 100 km^2, though at least one survey suffered from high estimates with poor confidence (see Table 4 for summary of previous surveys). In recent years, the GNWT has used the more widely adopted FPBK method (Higham et al., 2021; Kellie & DeLong, 2006) though this survey is the first instance of its use in the Sahtú. Most of these early surveys were limited to small study areas and focused either on important harvesting areas, where high numbers of moose were expected to be found, or areas with proposed industrial resource development. Only an extremely small area of the Sahtú region was covered and only a few areas were surveyed more than once. A larger scale distance sampling (Buckland et al., 2015) survey of the Sahtú was conducted and moose densities were estimated at approximately 1.4 and 3 moose/100 km^2 in the southern Sahtú in 2020 and northern Sahtú in 2021, respectively.

In the Dehcho region, following Larter's (2009) survey design, GNWT conducted 3 geospatial surveys (FPBK method) along the Mackenzie River, within an area extending from Jean Marie River to the Blackwater River north of Wrigley in winters 2003/04, 2011/12, and 2017/18 (Larter 2018). Surveys were completed in two phases with one survey in late-November and the other in mid-February of each winter. Total moose densities recorded in these surveys were lower (range 4.22 to 5.29 moose/100 km^2) than those estimated from previous surveys conducted along the Mackenzie River in the Sahtú (Table 4). Larter (2018) concluded that the best estimates of adult moose density in the Dehcho Mackenzie Valley study area showed little or no trend, appearing relatively stable from 2003-2018 (Table 4). Estimates of moose density from the 2021 survey of the MVH RSA are more similar to previous surveys in the Sahtú region, and roughly 3-4 times higher than those reported from the Dehcho surveys.

Table 4. Summary of previous moose surveys of the Mackenzie River Valley in the Sahtú and Dehcho regions (Area abbreviations: NW = Norman Wells, TUL = Tulita, MV = Mackenzie Valley).

Survey Year	Source	Region	Area	Density (per 100 km^2)	Coefficient of Variation
1984	Jingfors et al., 1987	Sahtú	NW	15	0.11
1989	Latour, 1992	Sahtú	NW	15	0.19
1993	MacLean, 1994	Sahtú	TUL	8	0.12
1995	Veitch et al., 1996	Sahtú	NW	17	1.32
1999	Swallow et al., 2003	Sahtú	TUL	11	0.12
2001	GNWT unpublished	Sahtú	NW	7	0.35
2003	Larter 2018	Dehcho	MV	4.22	NA[1]
2011	Larter 2018	Dehcho	MV	5.29	NA[1]
2017/18	Larter 2018	Dehcho	MV	4.47	NA[1]

[1] Coefficients of Variation were not provided in Larter 2018.

Several issues arose from the statistical analysis of the data. Many of the grid cells had predictions of negative densities. This can occasionally be resolved by using a log transformation of moose count to force all estimates to be positive. However, the current implementation of the *sptotal* package does not allow for the estimation of the confidence interval and SE on an untransformed scale after performing a transformation (Matt Higham personal communications). These negative estimates for sites can occur with kriging even when data is positive due negative kriging weights being assigned to observed data points. This generally does not affect the predictions of the total abundance of the study area and would mainly affect predictions of individual sites so long as the sample size is large and there isn't extreme skewness in the observed counts (Matt Higham personal communications). With this survey, we did observe a large range of counts per cell and an inflated number of zero count cells even in the 'high' stratum areas (see Appendix: Figure A1). Although we did obtain a reasonable CV for our average estimate, given the small comparative area, limited number of cells surveyed, and the wide range of counts, it would be prudent to approach the estimates and the predicted distribution with caution.

Personal Communications

Dr. Matt Higham, Assistant professor, St. Lawrence University, Canton, NY, USA

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Appendix A

Table A1. Pooled classification of land cover types based on the Landcover of Canada 2015 base layer.

Variable	Landcover of Canada 2015	Description
Conifer	Temperate or Subpolar Needle Leaf	Forests generally taller than 3 m and accounting for more than 20% of total vegetation cover. The tree crown cover consists of at least 75% needle-leaved species.
Taiga	Subpolar Taiga	Forests and woodlands with trees generally taller than 3 m, accounting for more than 5% of total vegetation cover, with shrubs and lichens commonly present in the understory. The tree crown cover consists of at least 75% needle-leaved species. This type occurs across northern Canada and may consist of treed muskeg or wetlands. Forest canopies are variable and often sparse, with generally greater tree cover in the southern parts of the zone than in the north.
Forage	Temperate or Subpolar Broadleaf Deciduous	Forests generally taller than 3 m and accounting for more than 20% of total vegetation cover. These forests have more than 75% of tree crown cover represented by deciduous species.
	Temperate or Subpolar Shrub Land	Areas dominated by woody perennial plants with persistent woody stems, <3 m tall and typically accounting for more than 20% of total vegetation cover.
	Mixed Forest	Forests generally taller than 3 m and accounting for more than 20% of total vegetation cover. Neither needle leaf nor broadleaf tree species make up more than 75% of total tree cover, but they are co-dominant.
Open	Subpolar or Polar Shrub Land-lichen-moss	Areas dominated by dwarf shrubs with lichen and moss, typically accounting for at least 20% of total vegetation cover. This class occurs across northern Canada.
	Temperate or Subpolar Grassland	Areas dominated by graminoid or herbaceous vegetation, generally

		accounting for more than 80% of total vegetation cover. These areas are not subject to intensive management such as tilling, but can be used for grazing.
	Subpolar or Polar Grassland-lichen-moss	Areas dominated by grassland with lichen and moss, typically accounting for at least 20% of total vegetation cover. This class occurs across northern Canada.
	Subpolar or Polar barren-lichen-moss	Areas dominated by a mixture of bare areas with lichen and moss, typically accounting for at least 20% of total vegetation cover. This class occurs across northern Canada.
	Barrenland	Areas characterized by bare rock, gravel, sand, silt, clay, or other mineral material, with little or no "green" vegetation present regardless of its inherent ability to support life. Generally, vegetation accounts for <10% of total cover.
Wetland	Wetland	Areas dominated by perennial herbaceous and woody wetland vegetation which is influenced by the water table at or near surface over extensive periods of time. This includes marshes, swamps, bogs, etc., either coastal or inland, where water is present for a substantial period annually.
Urban	Urban	Areas that contain at least 30% urban constructed materials for human activities (cities, towns, transportation, etc.).
Water	Water	Areas of open water, generally with <25% of non-water cover types. This class refers to areas that are consistently covered by water.

Figure A1. Histogram of counts from survey of high and low stratum grid cells