Yukon

SR-22-08

Moose Survey

Beaver River Watershed, early winter 2019

October 2022

Moose survey:
Beaver River watershed, early winter 2019

Government of Yukon
Fish and Wildlife Branch
SR-22-08

Authors
Mark O'Donoghue and Sophie Czetwertynski

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Copies available from:
Environment Yukon
Fish and Wildlife Branch, V-5
Box 2703, Whitehorse, Yukon Y1A 2C6
Phone 867-667-5721
Email: environmentyukon@yukon.ca
Online: open.yukon.ca and Yukon.ca

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Summary

- We conducted an early-winter survey of moose in the Beaver River watershed north-east of Mayo from October 31 through November 8, 2019 using helicopters. The main purposes of this survey were to estimate the abundance, distribution, and composition of the moose population in the watershed before a proposed 65-km all-season access road is built into this remote area.
- We counted all moose in survey blocks that covered about 40% of the survey area. We found a total of 631 moose: 184 adult bulls, 334 adult and yearling cows, 29 yearling bulls, and 84 calves.
- We estimated a population of 989 moose (90% confident that the population was between 883 and 1,103) for the survey area. This number is equal to a density of about 177 moose per 1,000 km^2 over the whole area, or 205 per 1,000 km^2 in suitable moose habitat. This is on the upper end of the range of typical Yukon moose densities of 100-250 moose per 1,000 km^2 of moose habitat.
- We estimated that there were about 30 calves and 19 yearlings for every 100 adult cows in the survey area. These ratios indicate that survival of calves born in 2019 and 2018 was about average compared to other Yukon areas surveyed.
- We estimated that there were about 61 adult bulls for every 100 adult cows in the survey area. This adult sex ratio is approximately equal to the Yukon average from surveyed populations, and well above the minimum threshold of 30 bulls per 100 cows identified in our moose management guidelines.
- This was the first population census for moose in the remote Beaver River watershed. These data can be used as a baseline for assessing the effects of any future developments or changes in harvest pressure.

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Introduction

This report summarises the results of the early-winter survey of moose in the Beaver River watershed north-east of Mayo and Keno City (Fig. 1), conducted October 31 to November 8, 2019. The purpose of the survey was to estimate numbers, distribution, and composition by age and sex of the moose population in the watershed before a proposed 65-km all-season access road is built into the area. We will use these data as a baseline for assessing the effects of any future developments.

Previous surveys

The Yukon Fish and Wildlife Branch has previously conducted only one other survey of moose that overlapped with the Beaver River watershed (Fig. 2). This was a late-winter distribution survey in March 2013 that covered the Beaver and lower Nadaleen River watersheds (O'Donoghue et al. 2013). There have been no surveys to estimate abundance or population composition in this area, as is the case for most other more remote parts of the territory.

There have been numerous surveys of moose in the more accessible Mayo Moose Management Unit to the south-west (Fig. 2), in early and late winter, and in several different areas going back to 1988. The most recent surveys were an early-winter census in November 2017 (O'Donoghue et al. 2019) and a late-winter distribution survey in February-March 2014 (O'Donoghue et al. 2016).

Early winter is the best time of year to estimate abundance of moose because of their concentration in high-altitude open habitats. Bull moose still have antlers at this time of year, so early-winter surveys also allow us to estimate the proportion of bulls in the population more accurately.

Community involvement

Residents of the Mayo area have consistently placed a high priority on monitoring the abundance, distribution, and health of the local moose populations. Concerns about the effects of industrial activities and new access roads have been consistently expressed at Northern Tutchone May Gatherings. Surveys of wildlife in areas with development pressures were also recommended in the *Community-based Fish and Wildlife Management Work Plan for the Na-Cho Nyäk Dun Traditional Territory for 2014-2019*, which was developed cooperatively by the Mayo District Renewable Resources Council, the First Nation of Na-Cho Nyäk Dun, and the Yukon Fish and Wildlife Branch. The Mayo District Renewable Resources Council provided some of the funding for this survey and staff of the First Nation of Na-Cho Nyäk Dun participated as crew leaders and observers.

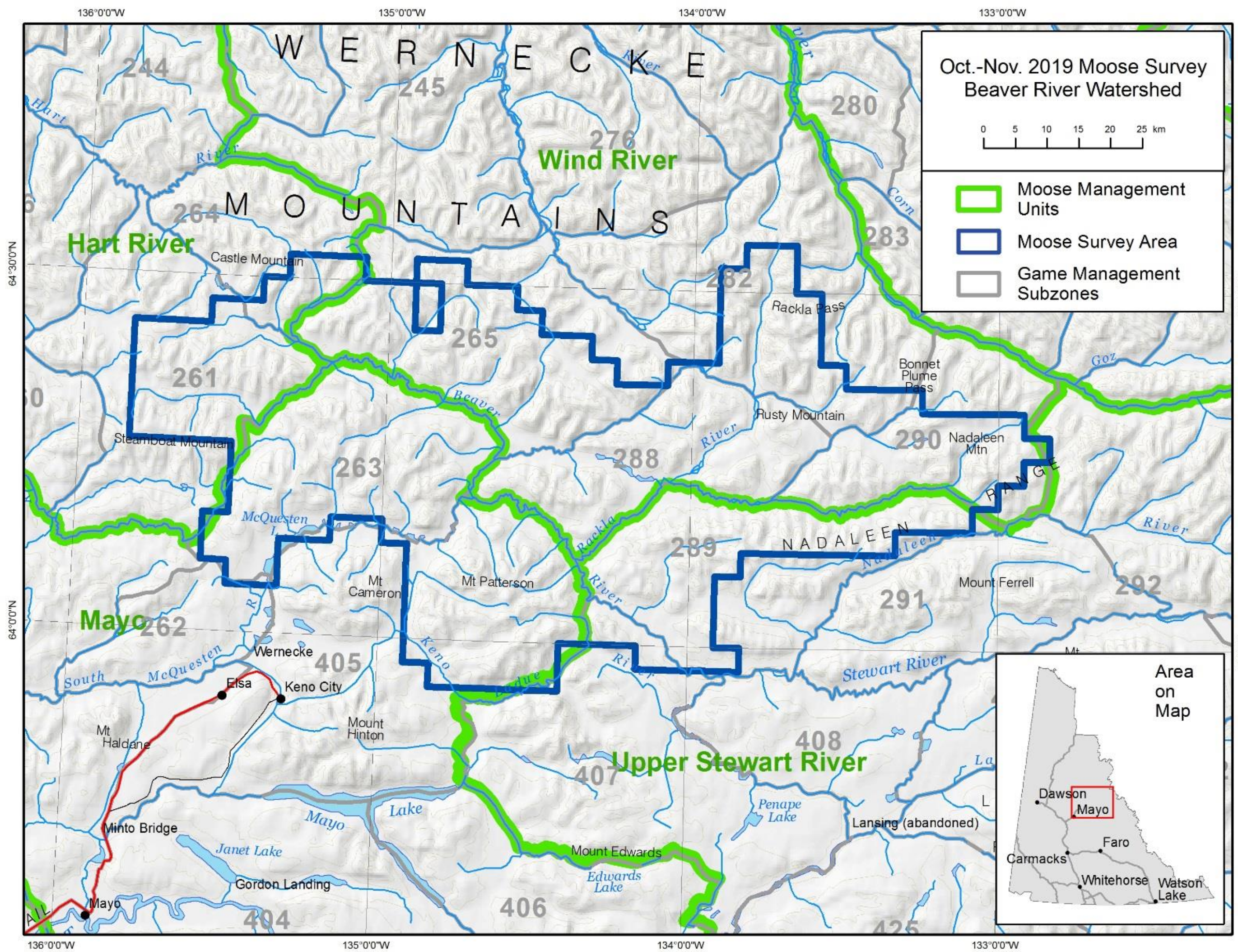

Figure 1. Moose survey area in the Beaver River watershed, October-November 2019.

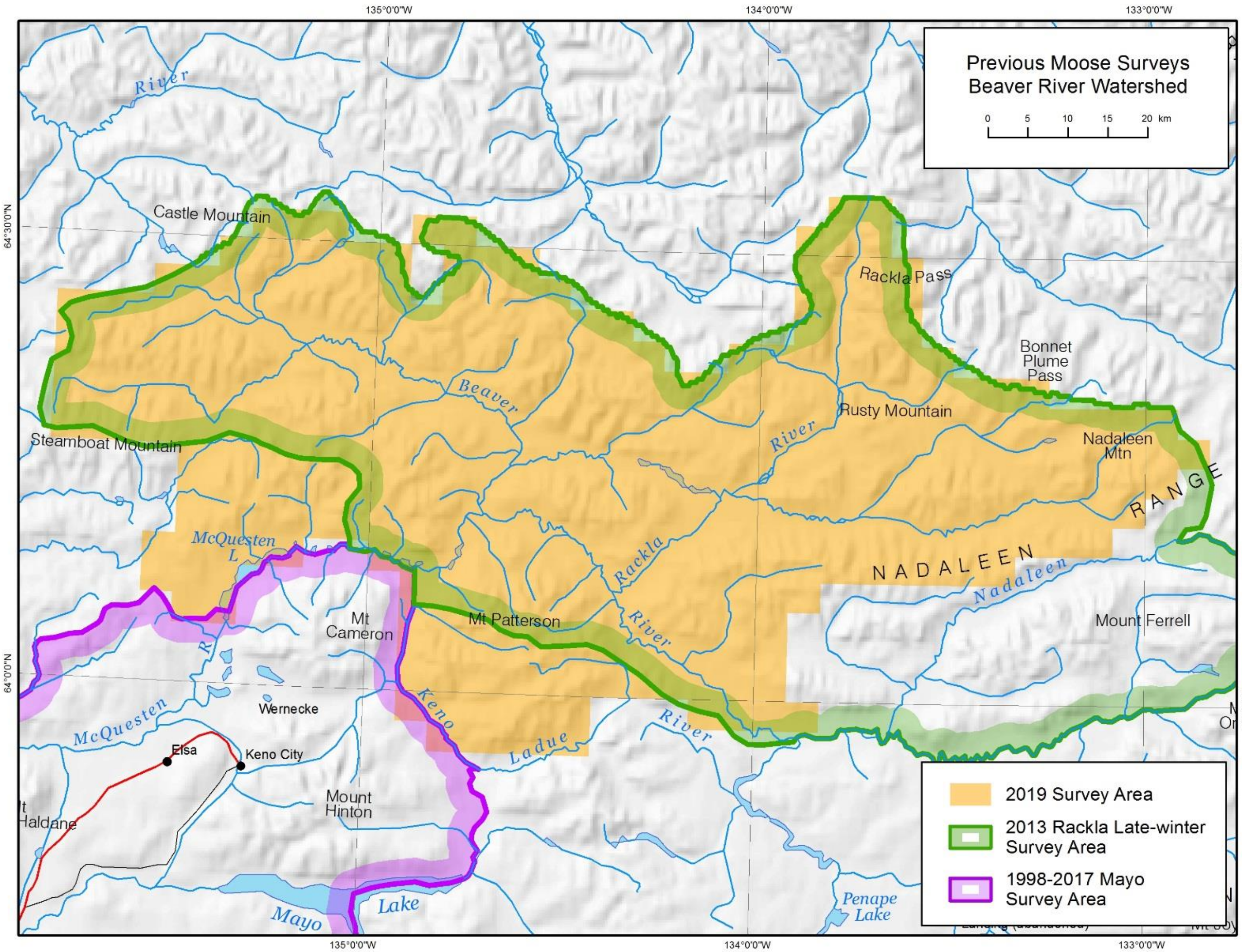

Figure 2 Previous moose surveys in and near the Beaver River watershed.

Study area

The survey area boundaries were defined mainly by the Beaver River watershed, except for the addition of two areas south-west of the watershed—north of McQuesten Lake and north of the Keno Ladue River—to fill in gaps between this survey area and the Mayo Moose Management Unit survey area (Fig. 2).

The Beaver River watershed survey area is about 5,600 km² and includes Game Management Sub-zones (GMSs) 263 and 288, and parts of GMSs 261, 264, 265, 282, 289, 290, 405, and 407 (Fig. 1). The survey area overlaps with parts of four Moose Management Units (MMUs)—the Hart River, Mayo, Upper Stewart River and Wind River MMUs. We manage moose harvest by MMU in the territory and typically establish survey area boundaries to correspond with those of MMUs and GMSs . However, this survey was aimed at gathering baseline data to evaluate the effects of proposed developments on the moose population, and so we used the more ecologically-based boundaries of a watershed.

Most of the study area (about 4,825 km²) is considered suitable moose habitat, except for approximately 14% of the area, which includes large water bodies (0.5 km² or more in size) and land at or over 1,524 m (5,000 feet) in elevation. The Beaver River watershed is in the Mackenzie Mountains ecoregion in the southern Wernecke Mountains (Smith et al. 2004). The study area consists mostly of bare mountain ridges (peaks mostly 1,500-2,000 m) and broad U-shaped valleys of the Beaver and Rackla rivers and their tributaries, in the drainage of the upper Stewart River. About half of the area, in valley bottoms and on lower hills, is forest-covered with black and white spruce, aspen, paper birch, and balsam poplar, interspersed with wetland habitats in poorly drained sites. Willow and dwarf birch shrub habitats, alpine tundra, and lichen-dominated and unvegetated rocky areas typify the higher plateaus and upper valley slopes.

Forest fires are less frequent on the landscape than in the Tintina Trench to the south, but old and recent forest fires have occurred throughout the study area (Fig. 3). The most recent large fires were a 321 km² burn north-east of Mayo Lake that included part of the Keno Ladue River valley on the southern edge of the survey area in 2019, a 54 km² burn in the upper Beaver River valley in 2019, a 24 km² burn east of McQuesten Lake in 2015, a 47 km² burn near Rusty Mountain in 2004, a 51 km² burn along the lower Beaver River in 1994, and a 22 km² burn around McQuesten Lake in 1994.

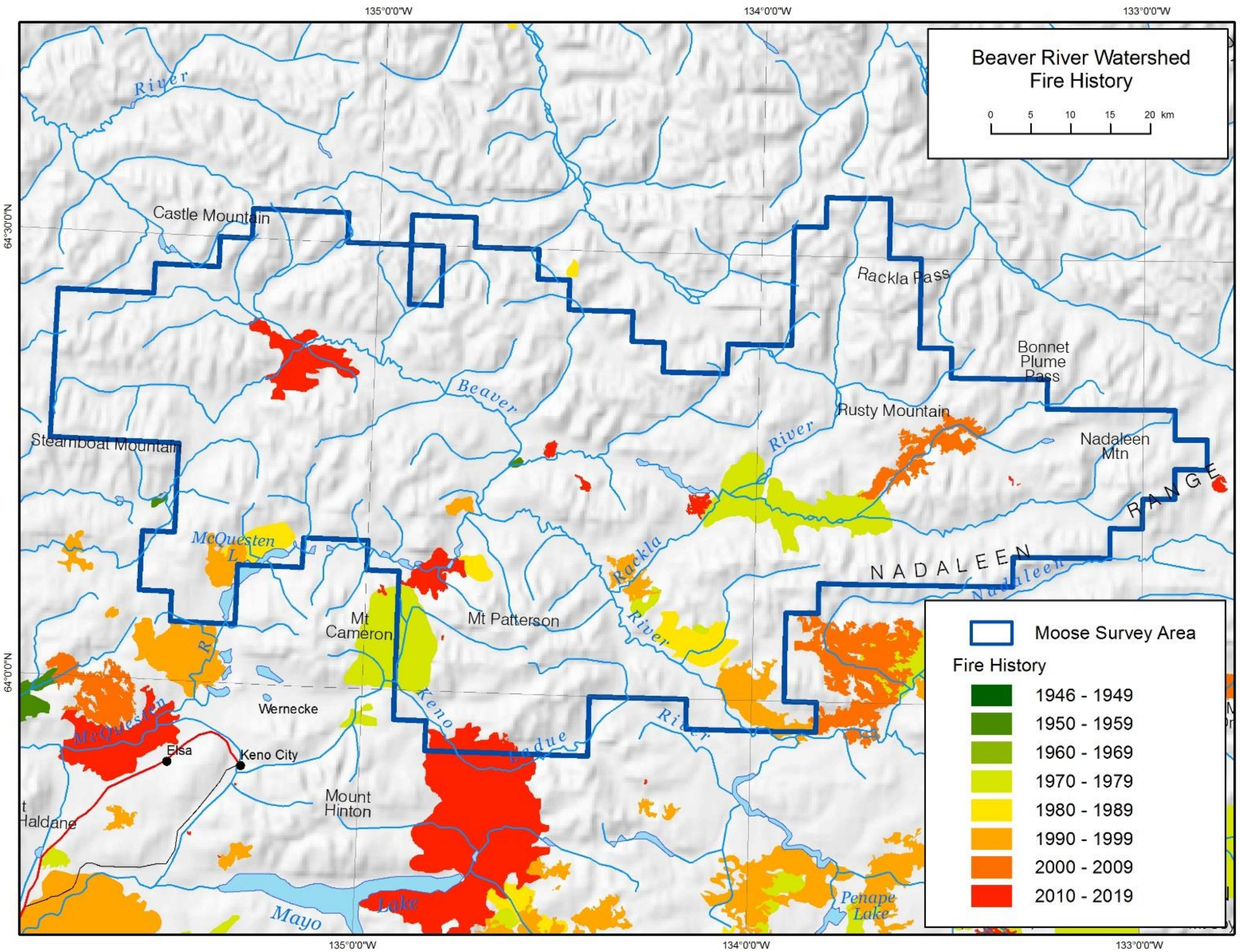

Figure 3 Beaver River watershed fire history.

Methods

We use a model-based technique to survey and estimate moose populations and composition in the territory (Czetwertynski et al., *in prep*; Appendix 1). Specifically, we develop models that relate moose abundance to information in individual survey blocks flown during the survey. This information is a combination of available local knowledge and landscape and habitat characteristics. These models are then used to estimate moose abundance over the areas where we did not count moose. We use any observed relationships between the composition of the moose population (by age and sex) and the habitat or landscape to correct for any bias in our sample. This analysis allows us to incorporate factors that affect the distribution of different age and sex classes across the landscape and predict the moose population composition for the entire area. Advantages of this survey method are that we can utilise local knowledge, estimate abundance in subsets of the survey area, account for differences in composition throughout the area, and target our sampling to areas where uncertainty is greatest.

The survey area is divided into rectangular blocks 14.9-15.2 km² (2' latitude x 5' longitude) in size. We select specific blocks and use helicopters to fly transects that are about 350 to 400 m wide (search intensity of about 2 minutes per km²) and count and classify every moose observed. Generally, we survey approximately 30% of the blocks within a survey area. During ferries, all survey staff record observations about moose habitat quality and moose abundance in as many different survey blocks as possible.

We select blocks to survey using different criteria in each of three phases of the census survey:

1. In phase 1, we use any available local knowledge and information from previous or nearby surveys to classify blocks as having either high, medium, low, or very low expected moose numbers. We use this information to select survey blocks to be flown during the first 2 to 3 days of the survey (approximately 30% of the total number of blocks we expect to survey). We select blocks so that they are distributed across the survey area and cover the range of available habitat types and areas of different expected numbers of moose. For this survey, we had no previous early-winter surveys and little local knowledge on moose distribution at that time of year, so we used the model of the moose-habitat relationship from the 2017 moose survey in the adjacent Mayo MMU to initially stratify the area (Fig. 4).

2. In phase 2, we use a combination of landscape characteristics (land cover, slope, elevation) and local information from phase 1 to fit the best model describing moose abundance in surveyed blocks. We then use this model to predict the number of moose in un-sampled blocks. Survey blocks to fly the following day are selected based primarily on where the level of uncertainty in the predictions is greatest, and to ensure we collect appropriate data to evaluate predictor-moose abundance relationships. This process (model selection, fitting, prediction, identification of blocks to sample) is repeated nightly with additional data from each day of flying. This phase of the survey is complete when sampling 1) provides a total population estimate with adequate precision to make management decisions for the area, 2) meets all assumptions for the final model, 3) has enough blocks counted in each subarea for which estimates are desired, and 4) is appropriate to estimate population composition by age and sex. We sample approximately 60% of the total number of blocks we expect to survey in this phase.

3. In phase 3, we generate a map showing the predicted number of moose in un-sampled blocks based on the best model and have the field crew select blocks where they believe the predictions are the least accurate. We use local knowledge plus incidental observations made during the census to select additional blocks to count. This phase represents the last 1 or 2 days of the survey, depending on survey-specific conditions. Lastly, the final model is re-evaluated with all available data to determine if further sampling is required.

We classify all moose by age (adult, yearling, calf) and sex within blocks selected for sampling. We can reliably distinguish yearling bulls from adults in early-winter surveys based on antler size. However, yearling cows are often difficult to distinguish from adults. Therefore, we use the yearling bull estimate to account for yearling cows (the total number of yearlings is assumed to equal twice the estimated number of yearling bulls). The adult cow estimate is then accordingly reduced.

Finally, we use a Yukon average “sightability correction factor” of 9%, based on data from previous moose surveys, to estimate the number of moose we missed during our searches of each survey block and to correct our final population estimates accordingly. When comparing moose population data between years, we consider there to be a significant change when confidence intervals or prediction intervals do not overlap.

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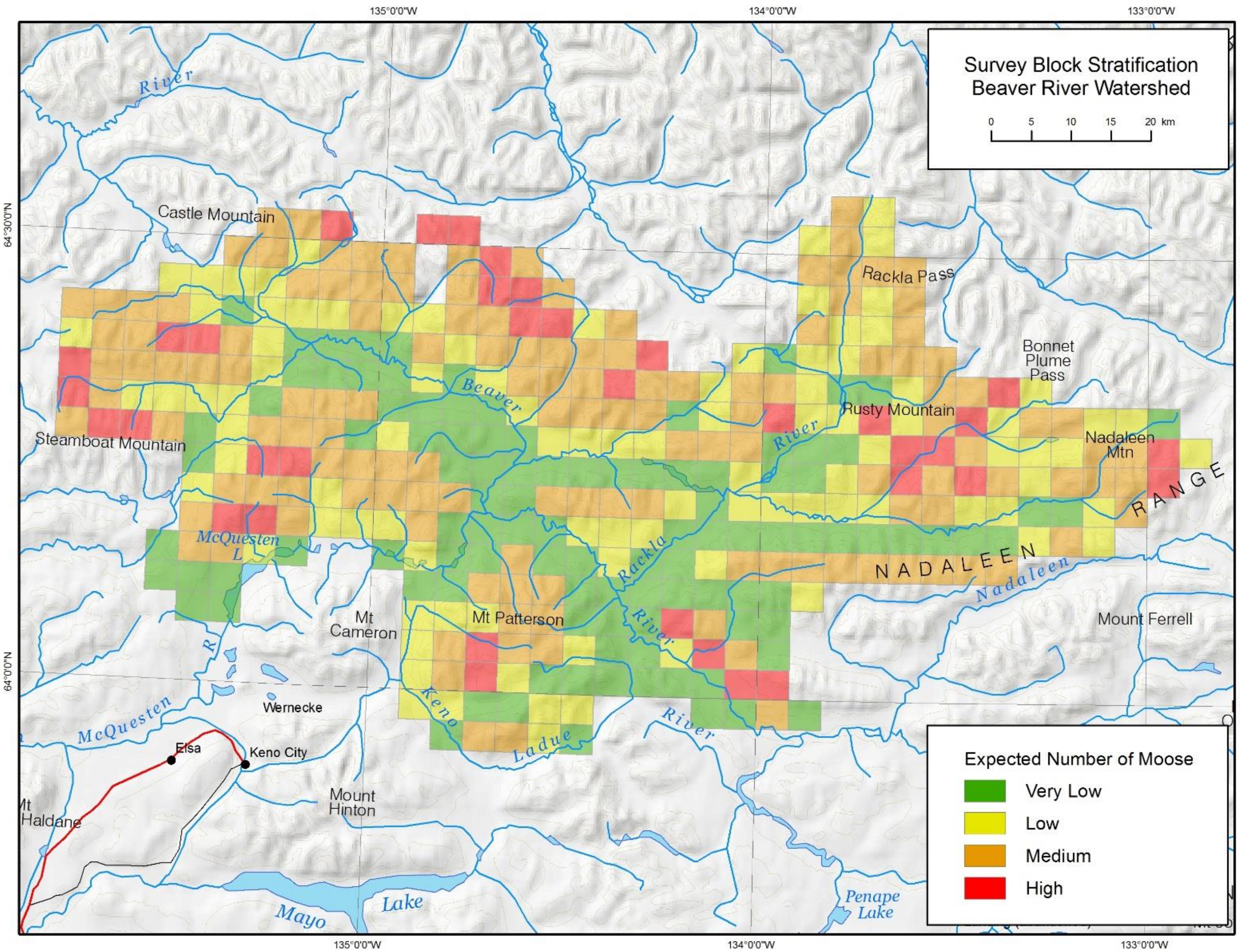

Figure 4 Survey block stratification in the 2019 Beaver River watershed moose survey area, based on moose–habitat relationships observed in the adjacent Mayo Moose Management Unit in 2017. These data, along with geographical locations, informed the selection of initial blocks to survey.

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Weather and snow conditions

Weather conditions were mixed for this survey. Between 31 October and 8 November, we could not fly on two full days because of low clouds and snow. On two other days, we worked under clouds and snow most of the time. The weather was clear on four of the seven days we flew, and we had high clouds on the remaining day. Temperatures were mostly mild and ranged from -27°C to -3°C. Winds were mostly gentle; strong winds were encountered only on the last day of flying.

Snow cover was complete and at depths greater than 15 cm throughout the survey area. We had fresh snow right before the survey started and during the survey, which aided in spotting fresh tracks. Light conditions ranged from flat to bright.

Results and discussion

Stratification

Based on the model from the 2017 Mayo MMU moose survey, we classified 36 (10%) of the 373 survey blocks as high, 136 (36%) as medium, 96 (26%) as low, and 105 (28%) as very low expected abundance of moose (Fig. 4).

The blocks with higher expected numbers of moose were those with subalpine shrubs and recent (5-35 years old) burns, which were well-distributed throughout the survey area. Lower numbers of moose were expected in the valleys of the Beaver and Rackla Rivers and their main tributaries.

Coverage

We counted moose in 150 of the 373 blocks, or about 40% of the total area, and concentrated our efforts in blocks where our models predicted high or uncertain numbers of moose (Fig. 5).

It took us about 57.2 hours to count moose in these blocks, for a search intensity of 1.53 minutes per km^2—this is lower than our target search intensity of 2 minutes per km^2, but only because we did not take time to search for moose in unvegetated alpine habitats. We used another 37.4 hours of helicopter time to ferry between survey blocks, our fuel caches in Keno City and at the Rau airstrip, and back and forth to Mayo.

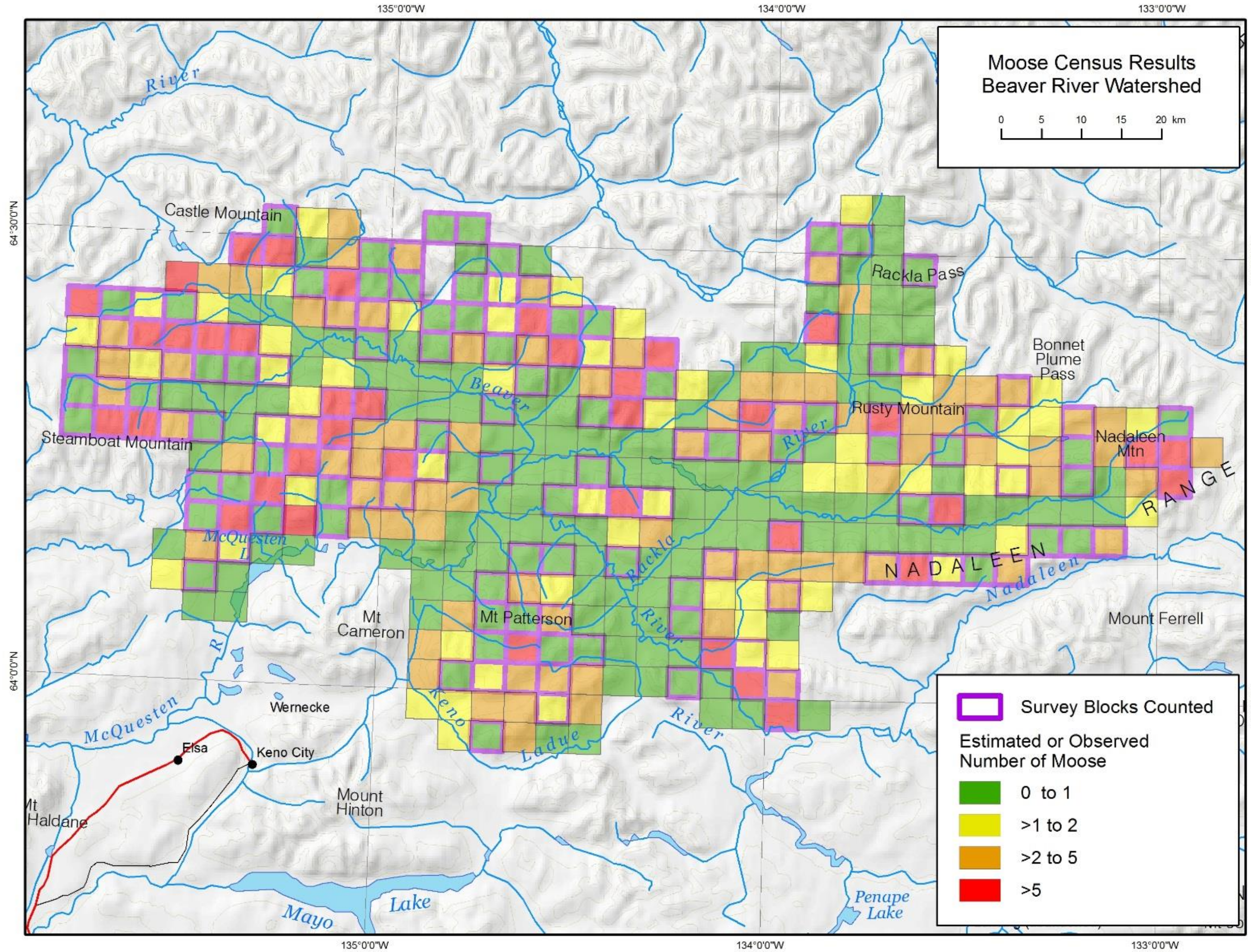

Figure 5 Census results in the 2019 Beaver River watershed moose survey area. Observed numbers of moose were counted by helicopter. Predicted numbers are based on models developed from the survey information collected.

Table 1. Observations of moose in survey blocks during the Beaver River watershed survey, October-November 2019.

	Total
Number of blocks counted	150
Number of adult bulls	184
Number of adult and yearling cows*	334
Number of yearling bulls	29
Number of calves	84

* Adults and yearling cows cannot be reliably distinguished from the air, so they are counted together.

Observations of moose

We counted a total of 631 moose, 29% of them adult bulls, 53% adult and yearling cows, 5% yearling bulls, and 13% calves (Table 1). We observed an average of 280 moose for every 1,000 km² searched. These values (total number and composition by age and sex) cannot be directly used as estimates in un-surveyed blocks because our sampling was biased towards blocks with greater numbers of moose.

Distribution of moose

Moose were widely distributed in the survey area, with the highest numbers observed in subalpine shrubs and higher elevation open spruce forest with good willow cover in mountainous terrain (Fig. 5). There were also good numbers of moose in the 1994 burn along the lower Beaver River (Fig. 2, 5). We saw relatively few moose in the 2015 and 2019 burns, in closed mature white and black spruce and aspen forested areas, and in lowland habitats of any kind.

Abundance of moose

The model that best predicted moose abundance included several factors positively related to moose numbers: 1) moose selected for shrub habitats and old burns (5 to 35 years old; moose mostly observed in a 25-year-old burn) and shrub habitats, 2) hilly terrain at mid- to upper elevations (1,300-1,700 metres), and 3) slopes less than 15˚ (model details are in Appendix 1). This model is consistent with our observations that most moose move to higher elevation habitats with abundant willows during the early winter.

The estimated number of moose in the entire survey area, based on our census counts and model predictions, was 989, and we are 90% confident that the population was between 883 and 1,103 (Table 2).

The estimated density of moose in the entire survey area was 177 per 1,000 km², or 205 per 1,000 km² of suitable moose habitat (Table 2). This is on the upper end of the range of typical Yukon moose densities of 100-250 moose per 1,000 km² of suitable habitat (Environment Yukon 2016).

Table 2. Estimated abundance of moose, corrected for sightability (91%), in the Beaver River watershed moose survey area in October-November 2019.

	Best estimate*	90% prediction interval**
Estimated total number of moose	989	883-1103
Adult bulls	288	257-324
Adult cows	511	465-575
Yearlings	89	76-109
Calves	142	122-167
Density of moose (per 1,000 km^2)		
Entire area	177	158-197
Moose habitat only***	205	183-229

* The sum of the estimated numbers of adult bulls, adult cows, yearlings, and calves is slightly different than the estimated total number of moose in the study area because we rounded off estimates from individual survey blocks to estimate numbers in each age and sex category of moose.
** A "90% prediction interval" means that, based on our survey results, we are 90% sure that the true number lies within this range.
*** Suitable moose habitat is considered to be all areas at elevations lower than 1,524 m (5,000 ft.), excluding water bodies 0.5 km^2 or greater in size.

Table 3. Estimated composition of the moose population in the Beaver River watershed moose survey area in October-November 2019.

	Best Estimate	90% prediction interval*
% Adult bulls	29	28-31
% Adult cows	47	45-49
% Yearlings	9	8-10
% Calves	14	13-16
Adult bulls per 100 adult cows	61	57-67
Yearlings per 100 adult cows	19	17-23
Yearlings per 100 adults (recruitment rate)	11	9-12
Calves per 100 adult cows	30	28-34
% of cow-calf groups with twins	10	7-13

* A “90% prediction interval” means that, based on our survey results, we are 90% sure that the true number lies within this range.

Ages and sexes of moose

We found that habitat type influenced the distribution of different age and sex groups of moose in the survey area. Specifically, we saw a significantly greater proportion of adult bulls and lone adult cows in survey blocks with more of the most favoured land cover types (shrub habitats and burns) and topography. In contrast, cows with calves tended to space themselves more away from these habitats (details in Appendix 1). We used these relationships to estimate the composition of the moose population by age and sex in the entire survey area and account for this observed bias (Table 3).

Our survey results indicate that the survival of calves born in 2019 and 2018 was about average compared to other Yukon areas surveyed. We estimated there were 30 calves and 19 yearlings for every 100 adult cows in the population (Table 3), whereas Yukon averages are 29 calves and 18 yearlings per 100 adult cows (Environment Yukon 2016). Estimates of recruitment from one survey are snapshots in time, and survival varies from year to year.

We estimated that there were 61 adult bulls for every 100 adult cows in the survey area (Table 3). This is about equal to the Yukon average of 64 bulls per 100 adult cows, and well above the minimum level of 30 bulls per 100 cows recommended in the *Science-based Guidelines for Management of Moose in Yukon* (Environment Yukon 2016).

Harvest

This survey was conducted to gather baseline data on the moose population in a mostly remote area before a proposed 65-km all-season access road is built. For this reason, the survey area boundaries mostly followed those of the Beaver River watershed and not those of MMUs.

Harvest of moose is reported by Game Management Subzone and evaluated at the Moose Management Unit scale. This survey area covered two entire GMSs, parts of seven others, and parts of four MMUs (Figure 1). We therefore cannot reliably evaluate harvest pressure in this survey area (we usually can't tell where within a GMS harvest occurred) and compare it to the estimated sustainable level (10% of adult bulls, or 29 bulls per year; Environment Yukon 2016).

The total harvest of moose in the Mayo MMU has been above sustainable levels in recent years, and the population was declining between 2006 and 2017 (O'Donoghue et al. 2019). Most harvest in the three more remote MMUs (the Hart River, Upper Stewart River, and Wind River MMUs) is by non-resident licenced hunters and is estimated to be within sustainable limits at 1.0-1.4% of the populations (estimates of densities of moose in these areas are based on habitat and local knowledge rather than census data).

Other wildlife sightings

In addition to the 631 moose we counted during the 2019 census, we saw 215 moose in 87 groups outside the surveyed blocks or while travelling between blocks.

We also saw 144 caribou in 17 groups in three regions in the survey area: 24 were in 3 groups north of Steamboat Mountain (from the Hart River herd); 117 were in 12 groups in the north-central part of the survey area, just south of the Wind River headwaters (likely from the Bonnet Plume herd); and 3 were in 2 groups near Rusty Mountain (from an unknown herd).

We found one sow grizzly bear with 2 cubs at a den site in the north-central part of the survey area and observed 3 wolverines at 3 different sites in the western part of the survey area.

We also saw 2 adult bald eagles and a snowy owl.

Conclusions and recommendations

- We estimated that there was a fairly high-density moose population in the Beaver River watershed compared to other areas surveyed in the territory.
- Survival of calves and yearlings was about average in 2019 and 2018 in the Beaver River watershed.
- The ratio of adult bulls to adult cows in the survey area was about the same as we observed in other regions surveyed in the territory.
- These data are the first estimates of abundance and composition by age and sex of the moose population in the Beaver River watershed.
- Results from this survey provide rare and valuable information about moose density and composition in remote areas with very low harvest pressure.
- This survey should be repeated if industrial activity and access into the Beaver River watershed increase significantly, to evaluate the effects of development on the moose population.

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Appendix 1 – Analyses and models used to estimate the abundance and composition of moose in the Beaver River watershed from 2019 early-winter survey data.

We estimated the abundance and composition of moose in the Beaver River watershed using a three-staged approach. We first used moose locations in surveyed blocks to generate Resource Selection Probability Functions (RSPFs). This information was then scaled up to the survey block and used with abundance information to generate count models and provide estimates of moose with prediction intervals for unsampled survey blocks. Lastly, we used predicted and observed moose abundance together with moose composition information from surveyed blocks to estimate the composition of moose over the entire survey area.

Potential covariates were screened/sampled for all analyses to ensure that they met model assumptions, were spatially representative, and were biologically relevant. We used screened covariates to generate potential models and selected the best model based on Akaike's Information Criterion (AIC; Burnham and Anderson 2002).

<u>1) Abundance estimation</u>

We generated a small-scale grid such that within each survey block (approximately 4 km x 4 km), there were 100 sub-blocks (approximately 400 m x 400 m). We selected this sub-block size because we believe it captures the approximate error in moose locations taken from the helicopter and represents the scale at which moose site selection occurs (Third Order Selection, Johnson 1980). We queried each sub-block for landscape and vegetation characteristics that could potentially influence moose occurrence/abundance. All covariates were screened for their relationship to occurrence/abundance, and those that had biologically and statistically significant relationships were considered in candidate models (Table 1).

Our initial dataset included 631 moose locations, and we generated 63,000 random locations (approximately 100 random points for each moose location). We restricted random locations to sub-blocks within sampled survey blocks and where we observed no moose (unused sub-blocks). We intersected the moose and random locations within sub-blocks to describe the landscape and vegetation characteristics for each point location at the 400 m scale.

To estimate the RSPF, we assumed that habitat selection is similar for all age/sex animals, excluding calves, so calf-cow groups were considered as 1 location. Therefore, the final dataset included 547 moose locations and 63,000 random locations. For simplicity, we used logistic regression to estimate coefficients for the RSPF model because of our used and unused sub-block design. The model that best described moose habitat selection at the 400m scale included 4 covariates (Table 2). Specifically, moose selected sub-blocks where the majority land cover was burns (5-35 years old) or shrubland. Moose further selected for mid- to upper elevations in the survey area (1300 to 1700 meters), average slopes of less than 15 degrees, and sub-blocks with a greater percentage of tall shrub cover (Table 3). We used this model to predict RSPF values for sub-blocks in unsampled survey blocks and then summed all RSPF values within each survey block. These summed block-level RSPF values then represented a general "habitat quality" covariate used in further analyses. For clarity, we use "Summed_RSPF" to describe this survey block-level covariate.

We used Zero-Inflated Negative Binomial regression Models (ZINB) to describe the distribution of the number of moose counted in sampled survey blocks. These models best describe low density and spatially aggregated moose distribution across survey blocks in Yukon because they account for overdispersion and excess zeros. We estimated models with the zeroinfl() function in the pscl package for R (Zeileis et al. 2008). The model that best described the data included 2 count model coefficients and 1 coefficient in the zero-inflation component (Table 4). The number of moose observed in a survey block was positively correlated to the proportion of the survey block with *TallShrub* and to the *Summed_RSPF*, the "habitat quality" of the survey block. In addition, there was a greater likelihood of observing 0 moose in a survey block at lower *RSPF* values. This model was used to predict the number of moose in unsurveyed units of the survey area (Table 5). The final population estimate and bootstrapped prediction intervals were obtained by combining the actual number of observed moose in sampled survey blocks with predictions from unsampled survey blocks (Czetwertynski et al., *in prep*).

2) Composition estimation

We used a compositional analysis to describe the composition of the moose population in the sampled dataset using the vglm() function in the VGAM package for R (Yee 2010). We found that the best model included the *Summed_RSPF* covariate that accounted for the greater proportion of lone adult cows and adult bulls in survey blocks with greater *Summed_RSPF* values (Table 6). This model (Table 7) was then applied to unsurveyed sample units, where the total number of moose was predicted by the ZINB model, to obtain the composition estimates and associated bootstrapped prediction intervals of the moose population in the survey area (Czetwertynski et al., *in prep*).

Table 1: Description of selected list of coefficients considered for Resource Selection Probability Functions (RSPFs) and models of abundance/composition of moose in the Beaver River watershed, October-November 2019.

Covariate Name	Description	Source
NALC_5	Categorical covariate of the majority land cover class within sub-blocks reduced to 5 classes (conifer, deciduous/mixed, shrubland, other, burns 5-35 years old).	2010 North American Land Cover 30 m x 30 m resolution, Canada Center for Remote Sensing (CCRS), Natural Resources Canada. Canadian National Fire Database.
NASA_1	Categorical covariate of the majority land cover class within sub-blocks reduced to 6 classes (conifer, deciduous/mixed, tall shrub, other vegetation, non-habitat, burns 5-35 years old).	2014 NASA ABoVE (Arctic-Boreal Vulnerability Experiment) Land Cover 30 m x 30 m resolution. https://doi.org/10.3334/ORNLDAAC/1691
NASA_2	Categorical covariate of the majority land cover class within sub-blocks reduced to 6 classes (conifer, deciduous/mixed, tall or low or open shrub, other vegetation, non-habitat, burns 5-35 years old).	2014 NASA ABoVE (Arctic-Boreal Vulnerability Experiment) Land Cover 30 m x 30 m resolution. https://doi.org/10.3334/ORNLDAAC/1691
NASA_3	Categorical covariate of the majority land cover class within sub-blocks reduced to 6 classes (conifer, deciduous/mixed, tall or low or open shrub or herbaceous, other vegetation, non-habitat, burns 5-35 years old).	2014 NASA ABoVE (Arctic-Boreal Vulnerability Experiment) Land Cover 30 m x 30 m resolution. https://doi.org/10.3334/ORNLDAAC/1691

Elev	Mean elevation in km of the sub-block.	Canadian Digital Elevation Model 30 m x 30 m resolution, Natural Resources Canada.
Slope	Mean slope in degrees of the sub-block	Canadian Digital Elevation Model 30 m x 30 m resolution, Natural Resources Canada.
TallShrub	Percent of the survey sub-block (400 m x 400 m) or block (4 km x 4 km) with Tall Shrub cover type.	2014 NASA ABoVE (Arctic-Boreal Vulnerability Experiment) Land Cover 30 m x 30 m resolution. https://doi.org/10.3334/ORNLDAAC/1691
SinAspect	Mean eastness of the sub-block with values ranging from -1 (west-facing) to 1 (east-facing).	Aspect in radians calculated from Canadian Digital Elevation Model 30 m x 30 m resolution, Natural Resources Canada.
CosAspect	Mean northness of the sub-block with values ranging from -1 (south-facing) to 1 (north-facing)	Aspect in radians calculated from Canadian Digital Elevation Model 30 m x 30 m resolution, Natural Resources Canada.
Conifer	Percent of the survey block with Evergreen and Woodland cover type.	2014 NASA ABoVE (Arctic-Boreal Vulnerability Experiment) Land Cover 30 m x 30 m resolution. https://doi.org/10.3334/ORNLDAAC/1691

Table 2: List of models considered to describe the Resource Selection of moose at the sub-block (400 m) scale in the Beaver River watershed (November 2019) with associated AIC scores.

Model	df	AIC	ΔAIC
NALC_5	5	5869.5	310.7
NASA_1	4	5914.9	356.1
NASA_2	4	5954.0	395.2
NASA_3	4	5992.3	433.5
NALC + Elev + $Elev^2$	7	5728.4	169.6
NASA_1 + Elev + $Elev^2$	6	5789.6	230.8
NASA_2 + Elev + $Elev^2$	6	5820.3	261.5
NASA_3 + Elev + $Elev^2$	6	5882.9	324.1
NALC_5 + Elev + $Elev^2$ + Slope	8	5635.9	77.1
NALC_5 + Elev + $Elev^2$ + TallShrub	8	5613.5	54.7
NALC_5 + Elev + $Elev^2$ + SinAspect	8	5717.6	158.8
NALC_5 + Elev + $Elev^2$ + CosAspect	8	5662.2	103.4
NALC_5 + Elev + $Elev^2$ + TallShrub + Slope	**9**	**5558.8**	0.0

Table 3: Logistic regression estimates for the Resource Selection Probability Function (RSPF) used to describe locations of moose at the sub-block (400 m) scale (Log-likelihood=-2770.4) in the Beaver River watershed (November 2019). We used this model to generate RSPF values for unsurveyed sub-blocks.

	Estimate	Standard Error	*Z*	*P*
(Intercept)	-23.768	2.195	-10.83	<0.001
NALC_5				
Deciduous/Mixed	0.318	0.231	1.38	0.169
Shrubland	0.592	0.139	4.26	<0.001
Other	-0.846	0.179	-4.73	<0.000
Burns(5-35 years old)	1.974	0.192	10.28	<0.001
Elevation	26.923	3.382	7.96	<0.001
$Elevation^2$	-8.976	1.299	-6.91	<0.001
TallShrub	2.055	0.223	9.22	<0.001
Slope	-0.054	0.007	-7.54	<0.001

Table 4: List of best models describing the number of moose observed in survey blocks (4km scale) in the Beaver River Moose Management Unit (MMU) survey area (November 2019) with associated AIC scores.

Model		*df*	AIC	ΔAIC
Count Covariates	Zero Inflation Covariates			
Summed_RSPF	NA	3	710.9	26.1
Summed_RSPF + Conifer	NA	4	708.0	23.2
Summed_RSPF + TallShrub + Conifer	NA	5	699.4	14.6
Summed_RSPF + TallShrub	Conifer	6	699.1	14.3
Summed_RSPF	Summed_RSPF + Conifer	6	692.1	7.3
Summed_RSPF	Summed_RSPF	5	690.2	5.4
Summed_RSPF + TallShrub	**Summed_RSPF**	**6**	**684.8**	**0**

Table 5: Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed sample blocks (approximately 16 km^2) in the Beaver River Moose Management Unit (MMU) survey area (November 2019) (Log-likelihood=-336.4). We used this model to generate the population estimate and prediction intervals for the Beaver River MMU.

	Estimate	Standard Error	*Z*	*P*
Count model coefficients (negbin with log link):				
(Intercept)	0.480	0.289	1.66	0.098
Sum_RSPF	0.370	0.237	1.56	0.119
TallShrub	6.161	2.485	2.48	0.013
Log(theta)	-0.243	0.183	-1.33	0.184
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	4.276	1.839	2.33	0.020
SUM_RSPF	-12.267	5.670	-2.16	0.031

Table 6: List of best models describing the composition of moose observed in the Beaver River Moose Management Unit (MMU) survey area (November 2019) with associated AIC scores.

Model	AIC	ΔAIC
TallShrub	860.9	15.9
Conifer	858.7	13.7
Null	852.2	7.3
Sum_RSPF	**845.0**	**0.0**

Table 7: Compositional model regression estimates for moose in the Beaver River Moose Management Unit (MMU) survey area, November 2019 (Log-likelihood=-). This model was used to generate the composition and related prediction intervals for the Beaver River MMU.

	Estimate	Standard Error	*Z*	*P*
(Intercept):BULL_LARGE	0.291	0.280	1.039	0.299
(Intercept):BULL_SMALL	-1.522	0.454	-3.349	0.001
(Intercept):COW_1C	-0.278	0.343	-0.811	0.417
(Intercept):COW_2C	-1.941	0.860	-2.256	0.024
(Intercept):LONE_COW	0.327	0.269	1.212	0.225
Sum_RSPF:BULL_LARGE	0.428	0.221	1.941	0.052
Sum_RSPF:BULL_SMALL	0.400	0.339	1.180	0.238
Sum_RSPF:COW_1C	0.088	0.277	0.317	0.751
Sum_RSPF:COW_2C	-0.547	0.819	-0.668	0.504
Sum_RSPF:LONE_COW	0.659	0.211	3.118	0.002

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