SR-26-01

Moose Survey

South Canol Moose Management Unit
Early-winter 2022

March 2026

Moose Survey
South Canol Moose Management Unit, Early-winter 2022

Government of Yukon
Fish and Wildlife Branch
SR-26-01

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Summary

- We conducted an early-winter survey of moose in the South Canol Moose Management Unit (MMU) from November 10 to 15, 2022. This was the second survey in this MMU. The first survey was completed in November 2013. The purpose of this survey was to estimate the abundance, distribution, composition and trend of the moose population in the MMU.

- We surveyed 100 of 293 survey blocks, or about 34% of the total area. We observed a total of 416 moose, including: 133 mature bulls; 221 mature and yearling cows; 26 yearling bulls; 34 calves; and 2 unclassified adults.

- We estimated 681 (90% confident that the population is between 585 and 802) total moose in the South Canol MMU. This number is equal to a density of 142 moose per 1,000 km^2 over the entire area or 175 moose per 1,000 km^2 of suitable habitat, which is within the typical range of moose densities in the Yukon (100- to 250 per 1,000 km^2 of suitable moose habitat).

- We estimated 23 calves and 21 yearlings per 100 adult cows, which is within the range typically observed in surveyed areas with stable moose populations.

- We estimated 66 adult bulls per 100 adult cows, which is well above the minimum threshold of 30 adult bulls per 100 adult cows identified in our moose management guidelines.

- We did not detect a significant change in the total moose population since the previous survey of the MMU in 2013. However, there was a significant increase in the number of adult bulls.

- Licensed harvest in the South Canol MMU has been on a permit hunt authorization (PHA) since 2022.

- Because we detected no significant change in the total number of moose estimated since the 2013 survey, our data indicate that the total harvest (reported licensed plus estimated First Nation) between 2013 and 2022 (prior to licensed harvest restrictions) was sustainable.

- Results from this survey will inform management decisions for this MMU. First Nation harvest information is required to accurately assess the total harvest in this population and ensure it remains sustainable.

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Introduction

This report summarizes the results of the early-winter aerial survey of moose in the South Canol Moose Management Unit (MMU; Figure 1), conducted from November 10 to 15, 2022. This is the second early-winter survey of moose completed in this MMU. The purpose of this survey was to estimate the abundance, distribution, composition and trend of the moose population in the South Canol MMU. We use this information to assess the sustainability of moose harvest and to inform management decisions in the MMU.

Previous surveys

The first moose population survey of the entire South Canol MMU was conducted in November 2013 (Fontaine et al., 2016; Figure 2). The sampling effort for this survey was very high and moose were counted in 51% of the survey blocks. This survey utilized a 'stratified random block' methodology (Gasaway et al., 1986, Kellie and Delong, 2006), where survey blocks are selected randomly within predefined high and low strata.

Two moose surveys were flown in 2007, partially overlapping the South Canol MMU: the Little Salmon and Magundy rivers late-winter intensive stratification survey and the South Canol West early-winter moose population survey (O'Donoghue, 2013 and Westover et al., 2008, respectively). However, the overlap between study areas was minimal, making the results not directly comparable to the 2013 and 2022 South Canol early-winter moose population surveys.

Community involvement

Moose have been a key part of First Nation peoples' subsistence lifestyle for generations and remain the most widely hunted game species by both Yukon First Nation and non-First Nation hunters. The South Canol MMU overlaps the Traditional Territories of the Kaska Dena Council (Ross River Dena Council and Liard First Nation) and Teslin Tlingit Council.

Local experts from Watson Lake, Faro and the Teslin Renewable Resource Council provided knowledge about moose distribution in the South Canol MMU during early-winter. This knowledge contributed to the "expert opinion" layer that was used to inform the study design, specifically selection of survey blocks where observers count and classify moose.

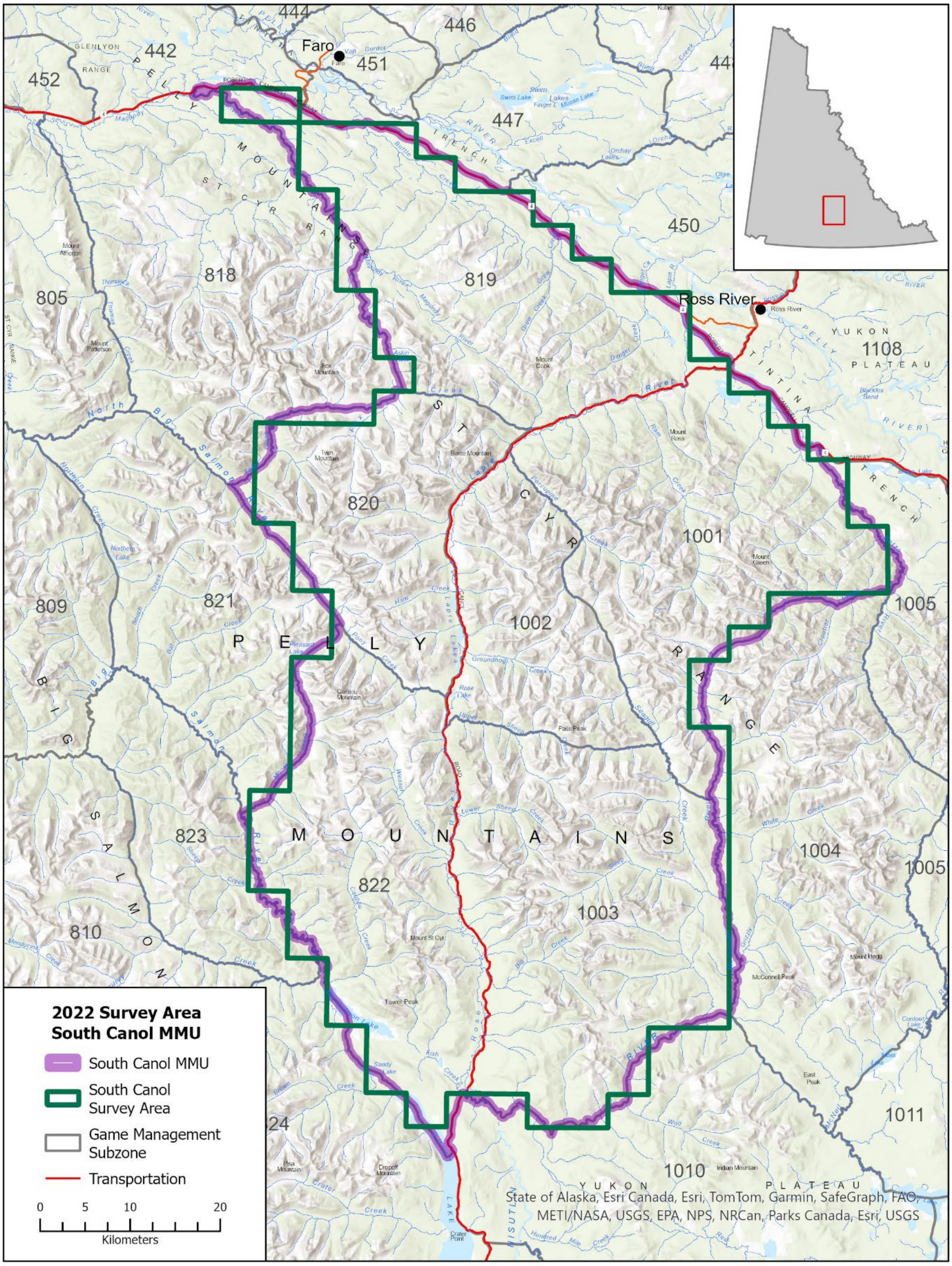

Figure 1. South Canol Moose Management Unit (MMU) and November 2022 early-winter survey area.

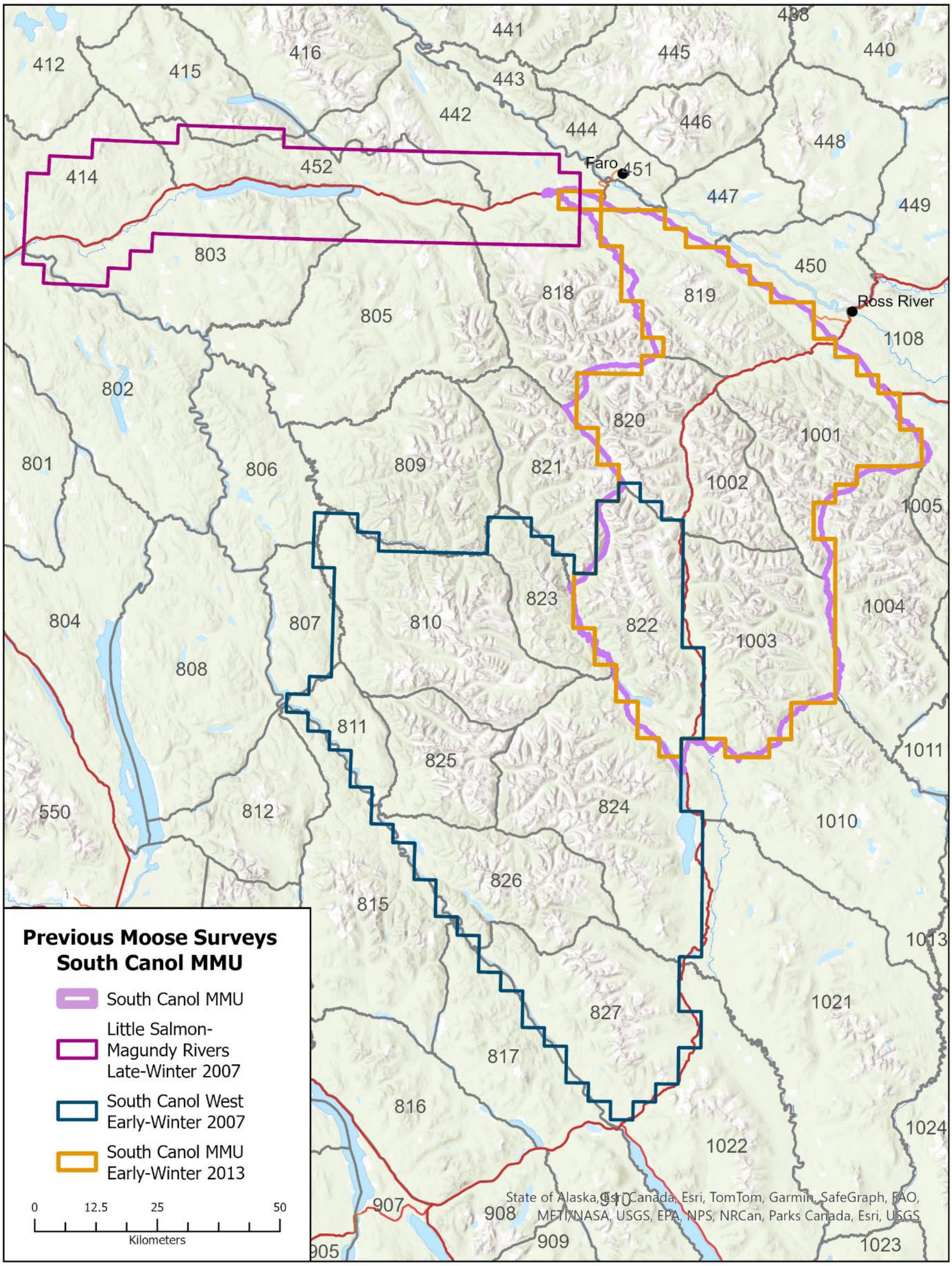

Figure 2. Previous moose surveys in the South Canol Moose Management Unit (MMU).

Study area

The survey area encompasses the South Canol MMU, which includes Game Management Subzones 8-19, 8-20, 8-22, 10-01, 10-02, and 10-03 (Figure 1). The northern border of the study area is bounded by the Robert Campbell Highway from Faro to the Ketza River. It extends south on either side of the South Canol Road to Big Salmon Lake, Quiet Lake and the Nisutlin River. The eastern border is loosely bounded by the Ketza and McConnell rivers. The Magundy River, North Big Salmon River and Big Salmon River form the western boundary (Figure 1).

The total survey area is 4,807 km^2. Most of the area is considered suitable moose habitat (3,892 km^2), with 19% of the study area considered unsuitable, including large water bodies 0.5 km^2 or greater in size and land above 1,676 m (5,500 ft) in elevation.

Most of the survey area lies within the Pelly Mountains ecoregion (Yukon Ecoregions Working Group, 2004). There is a small portion of the Yukon Plateau North ecoregion found along the northern boundary, and the Yukon Southern Lakes ecoregion along the southern boundary in the vicinity of Quiet and Big Salmon lakes (Yukon Ecoregions Working Group, 2004). This area is predominantly the mountainous terrain of the Pelly Mountains and its subrange of the St Cyr Mountain Range. There are numerous rivers and creeks within the survey area, such as the Magundy, Lapie, North Big Salmon, McConnell, Big Salmon and Nisutlin rivers. The study area includes Big Salmon and Quiet lakes on the southwestern boundary, the Lapie Lakes along the South Canol Road near the center of the study area, as well as numerous small lakes throughout. Mean annual temperatures are near -3°C, but vary widely by season and elevation. Mean temperatures are near -20°C in January and near 10°C in July. Precipitation is relatively heavy in the ecoregion, with annual accumulation ranging from 500 to 650 mm. Winds are usually light and can become moderate in the fall and winter with passing weather systems (Yukon Ecoregions Working Group, 2004). Vegetation found in alpine environments is characterized by mountain avens (*Dryas sp.*), lichens, grasses (e.g., *Hierochloe alpina*, *Poa sp.*), and ground shrubs like willows (*Salix sp.*), shrub birch (*Betula glandulosa*), and ericaceous shrubs. Shrub birch and willows with scattered subalpine fir (*Abies lasiocarpa*) dominate subalpine environments. White spruce (*Picea glauca*) is the dominate tree species. Black spruce (*P. mariana*) occupies valley floors and north-facing slopes. Lodgepole pine (*Pinus contorta*) stands are common only along the northern and southern boundaries of the study area (Yukon Ecoregions Working Group, 2004).

Forest fires have not occurred throughout most of the South Canol MMU (Figure 3). The largest burns occurred in 1958, and are located south of Faro, south of Ross River, and in the southern part of the study area, near the Nisutlin River. Other fires occurred between 1951 and 2011, but all were small, isolated and intermittent (Figure 3). This area lacks productive burns that create high quality moose habitat (usually occurring about 11 to 30 years post-fire; Maier et al., 2005).

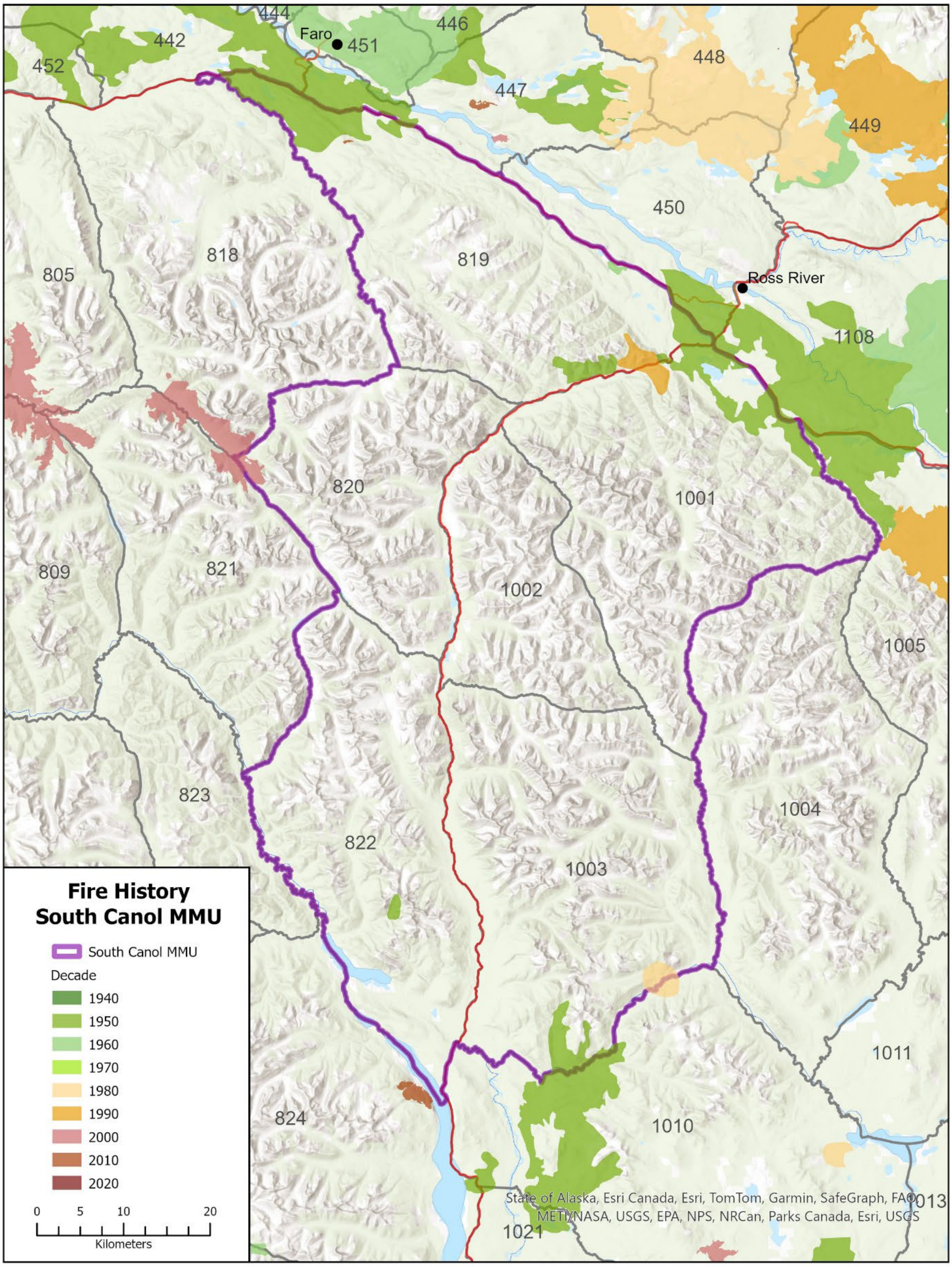

Figure 3. South Canol Moose Management Unit (MMU) fire history.

Methods

Overview

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, landscape information 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 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 found to 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 include the ability to 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- to 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, when possible, navigators guide helicopters such that ferry routes cover unsurveyed blocks, survey staff record observations about moose habitat quality and moose abundance in as many different survey blocks as possible. This information is used to evaluate the final model predictions.

Within blocks selected for sampling, we classify all moose by age class (adult, yearling, calf) and sex. In early-winter surveys, we can reliably distinguish yearling bulls from adults 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 “signtability 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 90% confidence intervals or prediction intervals do not overlap.

Survey block selection

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

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 such that they are distributed across the survey area and cover the range of available habitat types and areas of different expected numbers of moose.

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. We select survey blocks to be flown the following day 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 four criteria are met. They are: 1) sampling provides a total population estimate with adequate precision to make management decisions for the area, 2) sampling meets all assumptions for the final model, 3) enough blocks have been counted in each subarea for which estimates are desired, and 4) sampling is appropriate to estimate population composition by age and sex. In this phase we sample approximately 60% of the total number of blocks we expect to survey.

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 survey 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.

Results and discussion

Weather and snow conditions

The weather was a mix of overcast to clear during the survey, with temperatures ranging between -14°C and +1°C. Visibility was predominantly high during the survey with some medium visibility conditions. Light conditions ranged from flat to bright; wind varied from light to very strong.

Snow cover was complete at low to intermediate depths. Snow age was predominantly moderate (4 to 7 days since last snowfall); however, air temperatures rose near the end of the survey, bringing fresh snow in portions of the survey area which aided in spotting new tracks on the final two survey days.

Coverage

We surveyed 100 of 293 survey blocks, or about 34% of the total area (Figure 4). We exceeded the 30% coverage because many of the surveyed blocks contained alpine habitat (≥ 1,676 m) not suitable for moose and required less flight time. We surveyed many subalpine blocks where we had the highest expectation of finding moose in early-winter and the greatest uncertainty in predicting the number of moose. We spent less time surveying low elevation forested areas where we expect low moose abundance,

We flew a total of 68.1 hours using two helicopters. We spent 47.7 hours counting moose in survey blocks and had an average search intensity of 1.75 minutes per km^2 (Figure 4). This lower-than-average search intensity (2 minutes per km^2) was the result of flying a large proportion of subalpine blocks with a high proportion of alpine habitat considered unsuitable for moose and therefore not surveyed. We used 20.4 hours of helicopter time to ferry between survey blocks, fuel caches, and between Faro and the survey area.

Observations of moose

Moose were observed in 56 of the 100 blocks surveyed. We observed a total of 416 moose, including 133 (32%) mature bulls, 221 (53%) mature and yearling cows, 26 (6%) yearling bulls, 34 (8%) calves, and 2 (<1%) unclassified adults (Table 1). However, these values (total number and composition by age and sex) cannot be directly applied as estimates in unsurveyed blocks because our sampling was biased towards blocks with greater numbers of moose.

Table 1. Observations of moose in surveyed blocks during the South Canol Moose Management Unit (MMU) early-winter survey, November 2022.

	Total
Number of blocks counted	100
Number of adult bulls	133
Number of adult and yearling cows[1]	221
Number of yearling bulls	26
Number of calves	34
Number of unclassified adults	2
Total number of moose observed	**416**

[1]Adult and yearling cows cannot be reliably distinguished from the air, so they are counted together.

Distribution of moose

As expected in early-winter, moose were concentrated in the subalpine, higher elevation creek draws and willow flats, where available. We observed the highest numbers of moose in the subalpine areas of the St Cyr range, including in the vicinity of Askin Lake; in the vicinity of Mount Cook; between Twin Mountain and Barite Mountain; in the vicinity of Pass Peak; in the Caribou Creek and Mount St. Cyr area; and north and south of Big Creek (Figure 5). We counted few moose in lowland and forested areas. In general, the distribution of moose remained consistent with the previous early-winter survey in this area (Fontaine et al., 2016).

Abundance of moose

The model that best predicted moose abundance included several factors positively related to moose numbers in surveyed blocks: moose selected for shrub habitats, mid-elevations (1,300 to 1,700 m) and slopes less than 20 degrees (Appendix 1). This model is consistent with our observations and previous analyses (Clarke, 2017) that most moose move to higher elevation habitats with abundant willows during early winter.

The estimated number of moose in the entire survey area, based on our counts and model predictions, was 681, and we are 90% confident that the population was between 585 and 802 moose (Table 2).

The estimated density of moose in the entire survey area was 142 moose per 1,000 km^2, or 175 moose per 1,000 km^2 of suitable moose habitat (Table 2). This is within the range of typical Yukon moose densities of 100 to 250 moose per 1,000 km^2 of suitable habitat (Environment Yukon, 2016).

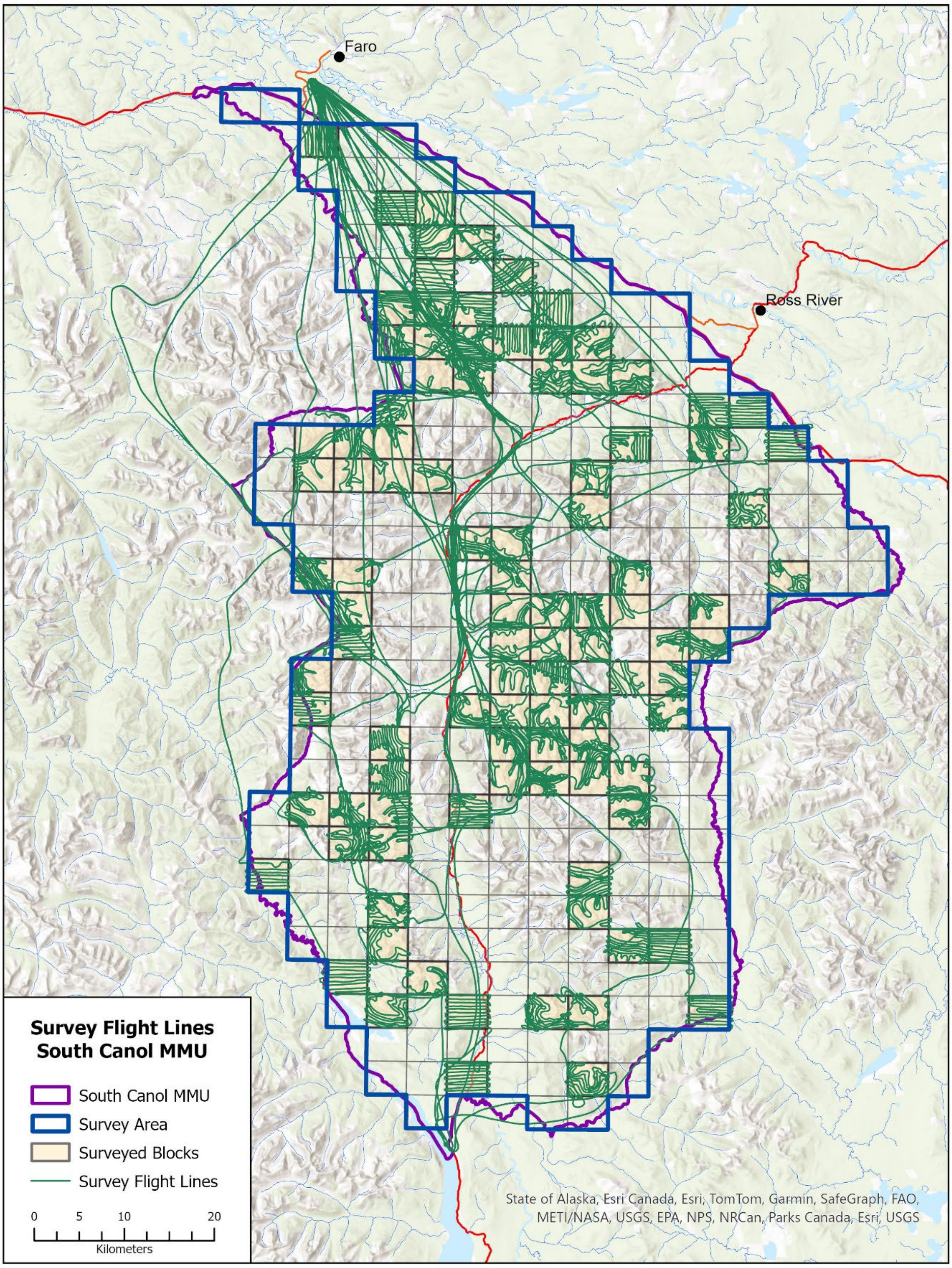

Figure 4. Helicopter flight lines and surveyed blocks from the South Canol Management Unit (MMU) survey, November 2022.

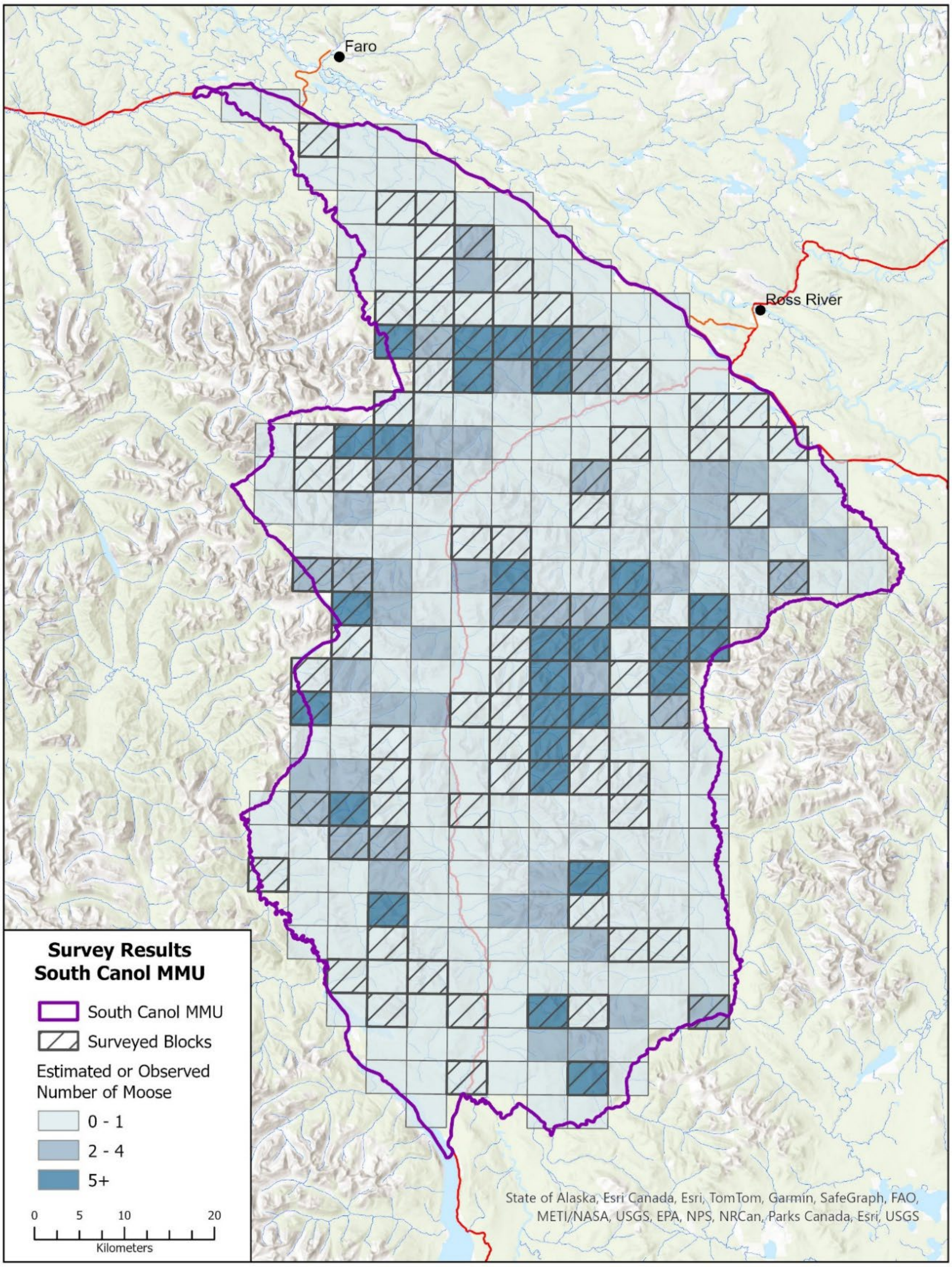

Figure 5. Estimated or observed number of moose in the South Canol Moose Management Unit (MMU), November 2022.

Table 2. Estimated abundance of moose, corrected for sightability (SCF = 1.09) in the South Canol Moose Management Unit (MMU), November 2022.

	Best estimate[1]	90% prediction intervals[2]
Estimated total number of moose	681	585-802
Adult bulls	214	185-254
Adult cows	326	276-385
Yearlings	69	60-83
Calves	73	56-96
Density of moose (per 1,000 km^2)		
Entire area (4,806.9 km2)	142	122-167
Moose habitat only (3,891.8)[3]	175	150-206

[1]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 estimates of total moose in each block to the nearest moose for the compositional analysis.

[2]A '90% prediction interval' means that, based on our survey results, we are 90% confident that the true number lies within this range. Our best estimate is near the middle (at the median) of this range.

[3]Suitable moose habitat is considered to be all areas at elevations lower than 1,676 m (5,500 ft.), excluding water bodies 0.5 km^2 or greater in size.

Ages and sexes of moose

The distribution of different age and sex classes of moose in surveyed blocks varied across the MMU. We found that the proportion of lone cows, adult bulls and yearling bulls in a survey block was greater in blocks with higher numbers of moose. We accounted for this bias when predicting the composition of the moose population in the entire MMU. (Appendix 1).

Our survey results indicate that the survival of calf moose in 2022 was below average compared to other areas surveyed in the territory. However, the survival of yearling moose was above the Yukon average. We estimated 23 calves and 21 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 can vary significantly from year to year.

We estimated 66 adult bulls for every 100 adult cows in the survey area (Table 3), which is just over the Yukon average of 64 bulls per 100 adult cows in other areas surveyed in the territory, and is 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).

Table 3. Estimated composition of the moose population in the South Canol Moose Management Unit (MMU), November 2022.

	Best estimate	90% prediction intervals[1]
% Adult bulls	31	30-33
% Adult cows	48	45-50
% Yearlings	10	9-12
% Calves	11	9-12
Adult bulls per 100 adult cows	66	61-72
Yearlings per 100 adult cows	21	18-25
Yearlings per 100 adults (recruitment rate)	11	10-13
Calves per 100 adult cows	23	19-27
% of cow-calf groups with twins	3	1-5

[1]A "90% prediction interval" means that, based on our survey results, we are 90% confident that the true number lies within this range, and that our best estimate is near the middle (at the median) of this range.

Population status and trends

We present population and composition information from the 2013 and 2022 surveys in the South Canol MMU in Table 4. To make results comparable among years, we present the data without applying sightability correction factors (SCF). Results from the 2022 survey indicate that the total moose population remained stable between the two surveys and that the number of adult bulls increased significantly from an estimate of 139 (112- to 166) in 2013 to 196 (170 to 233) in 2022 (Table 4).

Table 4. Results of the 2022 and 2013 early-winter surveys in the South Canol Moose Management Unit (MMU).

Survey year	**2022**[1]	**2013**
Survey timing	early-winter	early-winter
Survey method	model-based (helicopter)	SRB[2] (helicopter)
Estimated abundance[3] (90% confidence or prediction interval)[4]		
Total moose	625 (537-736)	474 ± 15% (401-547)
Adult bulls	196 (170-233)	139 ± 19% (112-166)
Adult cows	299 (253-353)	244 ± 16% (205-283)
Yearlings	63 (55-76)	28 ± 41% (16-39)
Calves	67 (51-88)	63 ± 21% (50-76)
Estimated population composition (90% confidence or prediction interval)[4]		
% Adult bulls	31 (30-33)	29 ± 11% (26-32)
% Adult cows	48 (45-50)	51 ± 5% (49-54)
% Yearlings	10 (9-12)	6 ± 37% (4-8)
% Calves	11 (9-12)	13 ± 16% (11-15)
Adult bulls per 100 adult cows	66 (61-72)	57 ± 14% (49-65)
Yearlings per 100 adult cows	21 (18-25)	11 ± 40% (7-16)
Yearlings per 100 adults	11 (10-13)	7 ± 38% (4-9)
Calves per 100 adult cows	23 (19-27)	26 ± 17% (21-30)
% of cow-calf groups with twins[5]	3 (1-5)	2 ± 98% (0-5)
Density of moose (per 1,000 km^2)		
Total area (4,806.9 km^2)	130 (112-153)	99 (83-114)
Moose habitat only (3,891.8 km^2)[6]	161 (138-189)	121 (103-140)

[1] Prediction intervals for 2022 survey estimates are based on asymmetrical distributions, therefore only a range of error is provided.
[2] A Stratified Random Block (SRB) method was used in 2013 where survey blocks are randomly selected across high and low stratum (see Fontaine et al. 2016 for details).
[3] To allow for better comparison across years, no sightability correction factor (SCF) is included in estimates.
[4] This means that we are 90% confident that the true number of moose in the area lies within the range of moose numbers given in the brackets.
[5] Twinning Rate = the number of cows with two calves divided by the total number of cows with calves. It represents what percentage of cows that had calves, had twins.
[6] Suitable moose habitat is considered all areas at elevations lower than 1,676 m (5,500 ft), excluding water bodies 0.5 km^2 or greater in size.

Harvest

In the Yukon, we estimate sustainable harvests for moose populations at the MMU scale (Environment Yukon, 2016). Specifically, in areas where information from a single recent survey is available, we estimate that 10% of the adult bull population can be sustainably harvested annually based on simulation models using moose data from Yukon populations (Environment Yukon, 2016). This recommended harvest rate is consistent with other jurisdictions managing predator-limited moose populations, recognizing that this is an average across populations and will vary (upwards and downwards) in individual MMUs and over time. Successive surveys in an MMU take into account area-specific conditions (climate, access, variation in recruitment and survival, predation, road kills, etc.). In areas with successive early-winter aerial surveys, we can use the trend in the moose population to determine if total harvest (reported licensed and estimated First Nation subsistence) is sustainable (Environment Yukon, 2016). This approach is important in areas where licensed harvest is more than 50% of the sustainable harvest and First Nation harvest in unknown. Therefore, based on our 2022 survey results and the information from the 2013 survey, the observed population trend indicates that total harvest (licensed plus First Nation subsistence) between surveys, prior to implementation of harvest restrictions, was sustainable.

Licensed harvest includes licensed resident harvest, non-resident special guided harvest, and non-resident (outfitter) harvest but not moose harvested by First Nation subsistence hunters (Figure 6). In 2013, the sustainable harvest was estimated to be 15 bulls (10% of the estimated 152 adult bulls, Fontaine et al. 2016). At that time, the average annual licensed harvest (2009 to 2013) was 12.6 bulls (or 84% of the sustainable harvest of 15 bulls) and, based on the best available information at the time, First Nation subsistence harvest was estimated to be 19.6 bulls (Fontaine et al. 2016). As a result, the total average harvest was estimated to be 32.2 bulls per year and well above the sustainable limit estimated at 15 bulls per year. Through the 2019 regulatory change process, a Permit Hunt Authorization (PHA) was put in place in 2022 and a quota established for the outfitter to restrict licensed harvest. Ten permits were made available annually to licensed resident hunters across the entire MMU and a quota was established for the outfitter.

The average licensed harvest between the two early-winter aerial surveys and prior to harvest restrictions (2014 to 2021) was 14.4 bulls per year (range of 10 to 19, Figure 6). More recently and prior to implementation of the PHA, the 5-year average total licensed harvest (2017 to 2021) was 15.6 bull moose. Licensed harvest patterns within the MMU appear to have changed since the 2013 survey where 84.1% of the harvest occurred in GMS 8-22, 10-02, and 10-03 (Fontaine et al. 2016). More recently and prior to licensed harvest restrictions (2017 to 2021), the 5-year average licensed harvest was more evenly distributed across most of the MMU with the exception of GMS 10-02 that had the highest harvest and GMS 8-20 with the lowest harvest (Figure 7). This licensed harvest pattern could be driven by a number of factors, including moose distribution, landscape, and the level of access and activity in individual GMSs.

First Nation subsistence harvest information is not available. We generally estimate it at 1 x resident licensed harvest or 12.2 moose (2017 to 2021). Given the stable trend of this moose population and the level of licensed harvest, the actual subsistence harvest is likely lower than this number. The observed population trend indicates that a licensed harvest of 15 bulls per year is sustainable if subsistence First Nation annual harvest remains similar to what it was between 2014 and 2021. Actual First Nation harvest data is required to accurately evaluate and monitor the total harvest in this MMU and ensure that it remains sustainable.

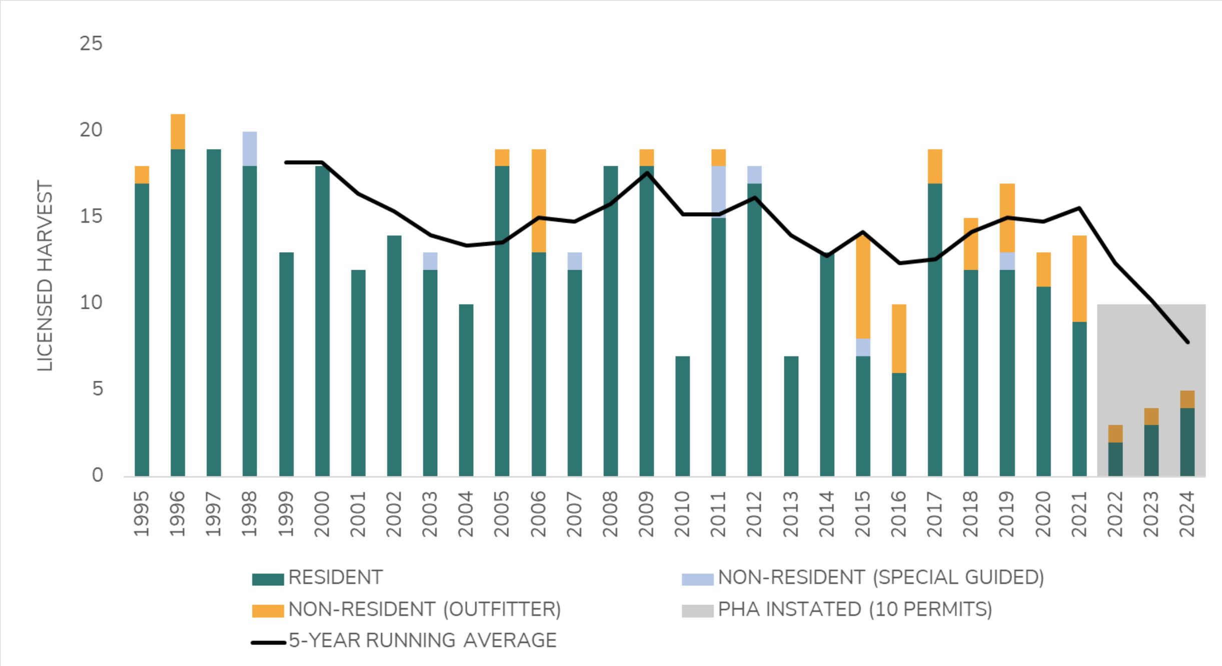

Figure 6. Total licensed harvest of moose in the South Canol Moose Management Unit (MMU). Permit Hunt Authorization (PHA) instated in 2022. First Nation harvest is not included.

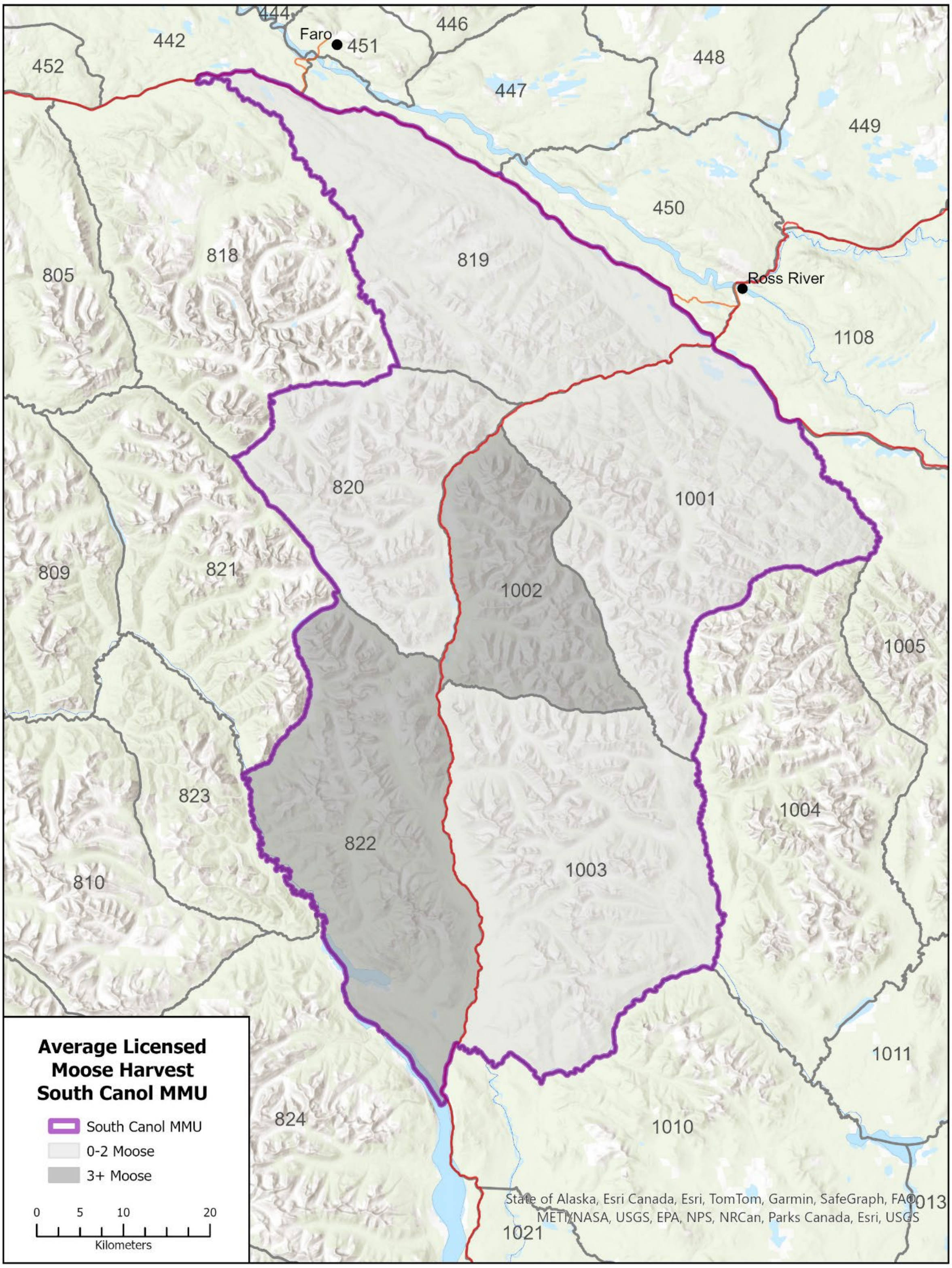

Figure 7. Bull moose licensed harvest rates in the South Canol Moose Management Unit (MMU),2017 to 2021.

Other wildlife sightings

In addition to the 416 moose we saw during the survey, we counted 55 moose in 27 groups outside of the surveyed blocks, while travelling between blocks or outside of the survey area. We also saw 213 caribou in 37 groups. The caribou were likely from the Pelly caribou herd, with the majority located in GMS 8-19, and a few groups observed in GMS 8-20, GMS 10-01 and GMS 10-02. Two groups of thinhorn sheep, one group of five sheep and one group of eight sheep, were observed in GMS 8-19 and GMS 10-01, respectively. Finally, we observed one lynx, one bear den and one kill site.

Conclusions and recommendations

- We estimate that there is an average-density moose population in the South Canol Moose Management Unit (MMU) compared to other areas surveyed in the territory.
- The ratio of adult bulls to adult cows is well above the recommended minimum of 30 adult bulls per 100 adult cows identified in our moose management guidelines.
- Based on our 2022 survey results and the information from the 2013 survey, the observed population trend indicates that total harvest (reported licensed plus estimated First Nation subsistence) between surveys, prior to implementation of harvest restrictions, was sustainable.
- We will continue to monitor harvest patterns for licensed harvesters in the South Canol MMU and make management recommendations that reflect available First Nation harvest and moose population information.
- Harvest management and the collection of First Nation harvest data should be discussed with the affected First Nations and Renewable Resource Councils to ensure the total harvest does not exceed sustainable levels.
- We should continue to monitor this moose population.

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Appendices

Appendix 1. Analyses and models used to estimate the abundance and composition of moose in the South Canol Moose Management Unit from 2022 early-winter survey data.

We estimated abundance and composition of moose in the South Canol Moose Management Unit (MMU) 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.

For all analyses, potential covariates were screened/sampled to ensure that they met model assumptions, were spatially representative, and 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) and AIC weights (Wagenmakers and Farrell 2004).

1) Abundance estimation

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).

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. Our dataset included 382 moose locations and we generated 37,818 random locations (approximately 100 random points for each moose location). We restricted random locations to sub-blocks that were within sampled survey blocks and within sub-blocks 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 400m scale.

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 400 m scale included 3 covariates (Table 2). Specifically, moose selected for sub-blocks where the majority landcover (400 m scale) was *Tall Shrub* (see Land 1, Table 1). Moose further selected for mid-elevations (1,300 to 1,700 m), and slopes less than 20 degrees (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 block-level RSPF values then represented a general "habitat quality" covariate used in further analyses (*Summed RSPF*).

We tested the fit of Negative Binomial (NB) models, Zero-Inflated Negative Binomial regression models (ZINB), and Hurdle Negative Binomial (HNB) models 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 was a ZINB model that included 1 count model coefficient and 1 coefficient in the zero-inflation component (Table 4). The number of moose observed in a survey block was positively correlated to *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 *Summed 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*). This approach enables us to generate realistic estimates of subsets of the survey area when required and allows for meaningful stakeholder participation.

<u>2) Composition estimation</u>

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 a *group size* covariate that accounted for the greater proportion of lone adult cows, adult bulls, and yearlings in survey blocks with higher numbers of moose (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 South Canol Moose Management Unit (MMU), November 2022.

Covariate Name	Description	Source
Land1	Categorical covariate of the majority Landcover class within sub-blocks reduced to 4 classes (conifer, tall shrub, other habitat, and non-habitat).	ABoVE Landsat-derived dominant landcover 2020, 30 m x 30 m resolution, NASA.
Land2	Categorical covariate of the majority Landcover class within sub-blocks reduced to 5 classes (Conifer, deciduous or mixed forest, shrubland, other habitat, and non-habitat).	North American Land Cover 2015, 30 m x 30 m resolution, Canada Center for Remote Sensing (CCRS), Natural Resources Canada.
Elevation	Mean elevation in km of the sub-block.	Canadian Digital Elevation Model, 30 m x 30 m resolution. Natural Resources Canada.
TallShrub01	Categorical covariate (0/1) of presence or absence of Tall Shrub in the sub-block.	ABoVE Landsat-derived dominant landcover 2020, 30 m x 30 m resolution, NASA.
Slope	Mean slope in degrees of the sub-block.	Canadian Digital Elevation Model, 30 m x 30 m resolution. Natural Resources Canada.
Perc. Subalpine	Percent of the survey block with subalpine habitat.	Bioclimate Map from the Yukon Ecological Landscape Classification (ELC) Program.

Perc. Tall Shrub	Percent of the survey block with tall shrub habitat.	ABoVE Landsat-derived dominant landcover 2020, 30 m x 30 m resolution, NASA.
Group size	Total number of moose in a survey block either observed or predicted by the count model.	Total number of moose observed in the survey block or the mean of predictions based on count models (Tables 4 and 5).

Table 2: List of best models describing the Resource Selection of moose observed in survey sub-blocks (approximately 400 m x 400 m) in the South Canol Moose Management Unit (MMU) (November 2022) with associated AIC scores and model weights.

Model	df	AIC	ΔAIC	w
Land1 + DEM + DEMSQ + Slope + SlopeSQ	8	3507.2	0.0	1.00
Land1 + DEM + DEMSQ	6	3574.7	67.5	0.00
Land2 + DEM + DEMSQ + TallShrub01 + Slope + SlopeSQ	10	3580.3	73.1	0.00
Land2 + DEM + DEMSQ + TallShrub01	6	3678.6	171.4	0.00
Land2 + DEM + DEMSQ	7	3691.0	183.9	0.00
Land1	4	3914.8	407.6	0.00
Land2	5	3983.4	476.2	0.00

Table 3. Logistic regression estimates for the Resource Selection Probability Function (RSPF) used to describe locations of moose observed in surveyed sub-blocks (approximately 400 m x 400 m) in the South Canol survey area, November 2022 (n = 382, Log-likelihood = -1745). We used this model to generate RSPF values for unsurveyed sub-blocks.

		Estimate	Standard error	Z	P
(Intercept)		-122.230	11.735	-10.420	<0.001
Land1					
	Tall Shrub	1.352	0.138	9.800	<0.001
	Other Habitat	-0.262	0.153	-1.710	0.087
	Non Habitat	-1.125	0.292	-3.850	<0.001
Elevation		155.763	16.067	9.690	<0.001
$Elevation^2$		-51.479	5.476	-9.400	<0.001
Slope		0.194	0.053	3.650	<0.001
$Slope^2$		-0.008	0.002	-4.840	<0.001

Table 4. List of best models describing the number of moose observed in survey blocks in the South Canol survey area (November 2022) with associated AIC scores and model weights.

Model		Distribution	df	AIC	ΔAIC	w
Count Covariates	ZI Covariates					
Summed RSPF	Summed RSPF	ZINB	4	431.5	0.0	0.95
Summed RSPF	Log Summed RSPF	HNB	4	437.6	6.8	0.04
Summed RSPF	.	NB	3	441.6	10.1	0.01

Table 5. Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed sample blocks (approximately 16 km^2) in the South Canol survey area, November 2022 (n = 100, Log-likelihood = -211). We used this model to generate the population estimate and prediction intervals for the South Canol Moose Management Unit (MMU).

Model	Estimate	Standard error	Z	P
Count model coefficients (negbin with log link)				
(Intercept)	0.650	0.383	1.699	0.089
Summed RSPF	0.951	0.286	3.329	0.001
Log(theta)	0.075	0.295	0.254	0.800
Zero-inflation model coefficients (binomial with logit link)				
(Intercept)	2.180	0.821	2.655	0.008
Summed RSPF	-3.785	1.127	-3.360	0.001

Table 6. List of best models describing the composition of moose observed in the South Canol survey area (November 2022) with associated AIC scores and weights.

Model	AIC	∆AIC	w
Group size	449.2	0.0	0.97
Null	456.9	7.7	0.03
Summed RSPF	460.1	10.9	0.00
Perc. Tall Shrub	465.1	15.9	0.00
Perc. Subalpine	465.9	16.6	0.00

Table 7. Compositional model regression estimates for moose in the South Canol survey area, November 2022 (n = 100, Log-likelihood = -215). This model was used to generate the composition and related prediction intervals for the South Canol Moose Management Unit (MMU).

	Estimate	Standard error	Z	P
(Intercept):BULL_LARGE	0.519	0.381	1.362	0.173
(Intercept):BULL_SMALL	-1.825	0.627	-2.913	0.004
(Intercept):COW_1C	-0.051	0.461	-0.111	0.911
(Intercept):COW_2C	-3.678	1.961	NA	NA
(Intercept):LONE_COW	0.638	0.370	1.725	0.085
GroupSize:BULL_LARGE	0.064	0.030	2.171	0.030
GroupSize:BULL_SMALL	0.114	0.042	2.743	0.006
GroupSize:COW_1C	-0.001	0.038	-0.024	0.981
GroupSize:COW_2C	0.014	0.153	0.093	0.926
GroupSize:LONE_COW	0.084	0.029	2.902	0.004

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