Yukon

SR-26-04

Moose Survey

Teslin River Moose Management Unit, Early-winter 2021

May 2026

Moose Survey
Teslin River Moose Management Unit, Early-winter 2021

Government of Yukon
Fish and Wildlife Branch
SR-26-04

Authors
Kai Breithaupt, Colleen Arnison, Shannon Stotyn, Tyler R. Ross, Sophie Czetwertynski

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

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Summary

- We conducted an early-winter moose survey of the Teslin River Moose Management Unit (MMU) from November 22 to 30, 2021. The purpose of the survey was to estimate the abundance, distribution, and composition (age and sex) of the moose population in the MMU.
- We counted moose in 147 of 457 survey blocks, or about 32% of the total area. We observed a total of 644 moose, including 189 adult bulls; 355 adult and yearling cows; 23 yearling bulls; 75 calves; and 2 unclassified moose.
- We estimated 1,178 (90% confident that the population is between 1,063 and 1,339) moose in the Teslin River MMU. This equates to a density of 172 moose per 1,000 km² of suitable habitat, which is within the typical range for moose densities in the Yukon (100 to 250 moose per 1,000 km² of suitable habitat).
- We estimated 23 calves and 13 yearlings per 100 adult cows, which are both below the averages observed in surveyed population in the Yukon (29 calves and 18 yearlings per 100 adult cows).
- We estimated 57 adult bulls per 100 adult cows, which is above the minimum threshold of 30 adult bulls per 100 adult cows identified in our *Science-based Guidelines for Management of Moose in Yukon.*
- This was the first time the entire Teslin River MMU was surveyed, making it difficult to assess moose population trends overtime. Results from this survey will serve as a baseline against which future surveys will be compared.
- We estimated the sustainable harvest at 35 bulls (10% of the adult bull population). From 2021 to 2025 (excluding 2022 because of covid restrictions) the total harvest (reported licensed plus estimated First Nation subsistence) averaged 55 or 157% of the sustainable harvest.
- Accurate First Nation harvest data is required for evaluating total harvest and to assess by how much it exceeds the sustainable threshold.

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Contents

Introduction

This report summarizes the results of the early-winter aerial survey of moose in the Teslin River Moose Management Unit (MMU; Figure 1). We conducted the survey from November 22 to 30, 2021 to estimate the abundance, distribution and composition of the moose population in the Teslin River MMU. This information is used to assess the sustainability of moose harvest and to inform management decisions in the MMU.

Previous surveys

The Teslin River MMU has existed in its present form since 2017, when the boundaries were expanded to include the former Whitehorse MMU (Game Management Subzones [GMS] 8-13, 8-14, 8-16). As a result of this re-designation, the Teslin River MMU has never been surveyed in its entirety, although large portions have had population and stratification surveys in the past.

Population surveys for abundance and composition were conducted in portions of the MMU in 1999 (Environment Yukon 2000), 2007 (Westover et. al 2008), and 2011 (Taylor et al. 2012; Figure 2). The northeast portion of the MMU was surveyed as part of a stratification survey in 2003 to classify survey blocks as “high” or “low” probability of moose abundance (Environment 2009).

Community involvement

Moose have been a cornerstone of First Nations’ culture and subsistence lifestyles for millennia and today remain the most widely hunted game species by both Yukon First Nation and non-First Nation hunters. The Teslin River MMU falls within the overlapping Traditional Territories of four First Nations: the Ta’an Kwäch’än Council (TKC), Kwanlin Dün First Nation, Teslin Tlingit Council (TTC) and Carcross/Tagish First Nation.

Local experts from Teslin and TTC provided knowledge about early-winter moose distribution in the Teslin River MMU that contributed to the ‘expert opinion’ layer that was used to inform the study design, specifically the selection of survey blocks where observers counted and classified moose. Staff from TKC and the Laberge Renewable Resources Council also participated as observers during the survey.

Study Area

The survey area encompassed the entire Teslin River MMU, which spans an area of approximately 7,697 km^2 and includes GMS 8-11 to 8-17 and 8-25 to 8-27 (Figure 1). The northern border of the MMU is bounded by the South Big Salmon River, and the southern border is bounded by the Alaska Highway. The western extent follows the Alaska Highway and North Klondike Highway to the south end of Lake Laberge, while the eastern border is bounded by the South Canol Road.

Most of the study area (89%; 6,832 km^2) is considered suitable moose habitat. The remaining area, which is considered unsuitable habitat, includes large water bodies (0.5 km^2 or greater in size) and land above 1,524 m (5,000 ft) in altitude. Most of the mountain blocks within the MMU, including Teslin, Joe, Cap, Byng, Streak, Black, Murphy and Slate mountains, contain terrain above 1,524 m. The Yukon River, M'Clintock River, Teslin River and the Squanga Lakes chain—running predominantly north-south—offer most of the low-elevation habitat in the area. Located mostly within the Southern Lakes ecoregion (Yukon Ecoregions Working Group 2004), the climate is generally dry or arid and cool, falling within the rain shadow of the St. Elias-Coast Mountains. Winds are common due to the area's proximity to the Gulf of Alaska. Medium shrubs (willow [*Salix* sp.], and shrub birch [*Betula glandulosa*]) and sub-alpine fir (*Abies lasiocarpa*) dominate higher elevation slopes, whereas lower elevations are often composed of mixed woodland but dominated by lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*). The northeast portion of the survey area lies within the Pelly Mountains ecoregion, which receives greater precipitation, experiences cooler summers and has less severe winters (Yukon Ecoregions Working Group 2004).

Small, isolated fires have occurred throughout the survey area, though, most of the area has remained unburned in recent years (1940 to present; Figure 3). Approximately 391 km^2 (about 5% of the survey area) burned in the last 75 years of monitored fire history (1946 to present). The most recent fires include a 1 km^2 burn north of Squanga Lake (2017) and a 10 km^2 burn between Teslin River and Lake Laberge (2015). The largest fire in recent years burned 183 km^2 near the confluence of Boswell and Teslin rivers (2009). Other notable forest fires include a 46 km^2 burn northwest of Squanga Lake (1999) and two fires along the Teslin River that burned 38 km^2 and 65 km^2 in 1969.

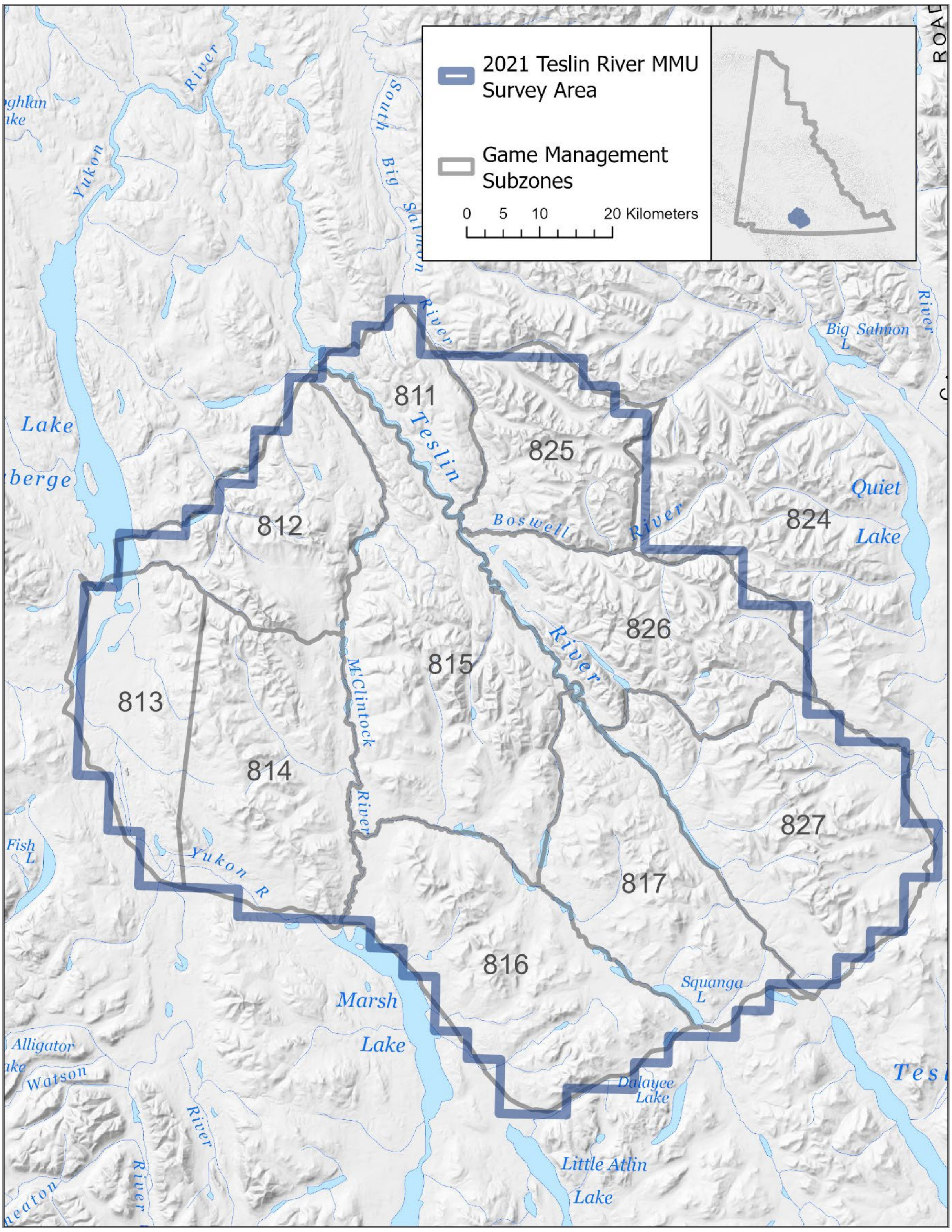

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Figure 1. Survey area encompassing the Teslin River Moose Management Unit (MMU), including Game Management Subzones (GMS), November 2021.

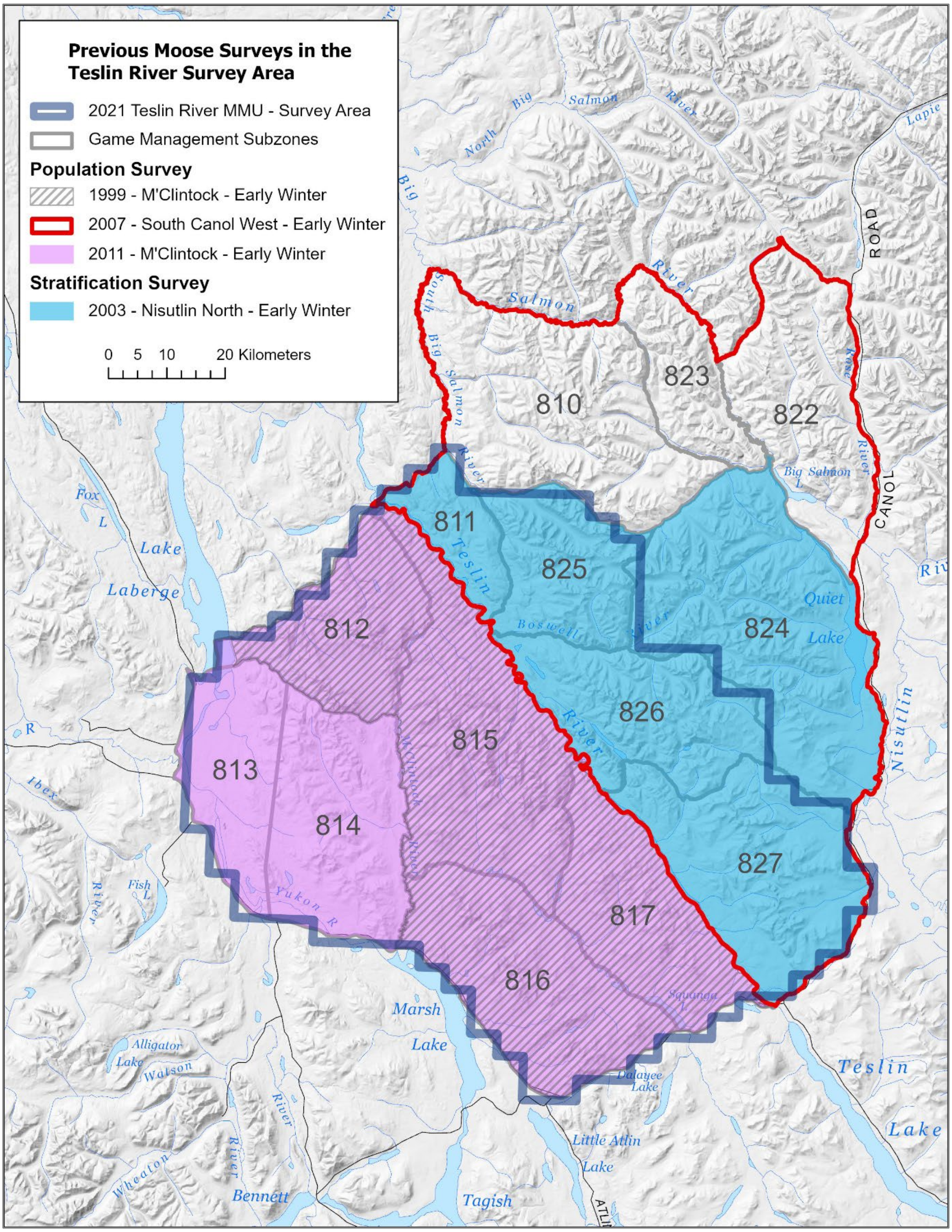

Figure 2. Previous moose surveys in the Teslin River Moose Management Unit (MMU), including Game Management Subzones (GMS).

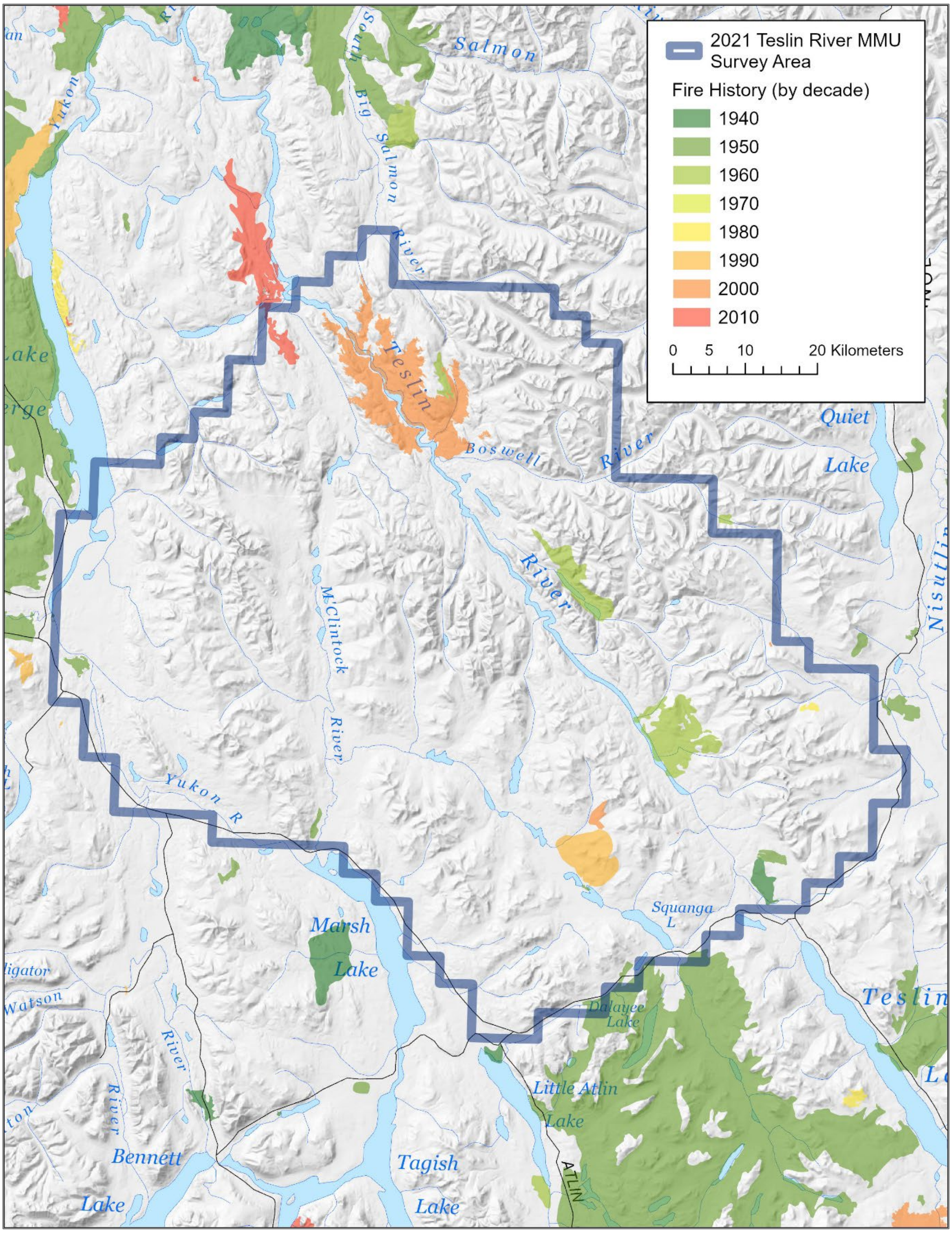

Figure 3. Teslin River Moose Management Unit (MMU) survey area fire history (1946 to present).

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 available 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 composition for the entire area. Advantages of this survey method include the ability to utilize 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 helicopter ferries, all 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 "Sightability Correction Factor" (SCF) 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 3 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. 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. 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

Most days were overcast with patches of localized fog and temperatures that fluctuated between -1°C and -17°C. The lighting conditions were a combination of both flat and bright, with variations occurring throughout each day. There was complete snow cover for the duration of the survey, and snow depths ranged from intermediate (15 cm to 90 cm) to deep (>90 cm). Despite challenging weather conditions, particularly in higher elevation areas, we were able to optimally sample blocks, ensuring visibility was adequate to observe moose.

Coverage

We searched for moose in 147 of 457 survey blocks, or about 32% of the total survey area. We flew 67.6 hours to count moose in the survey blocks using two helicopter crews (36.3 hrs and 31.3 hrs), for an average search intensity of 1.7 minutes per km^2. This lower-than-average search intensity (2 minutes per km^2) resulted from flying a large proportion of alpine blocks with habitat above 1,524 m; therefore, unless moose or tracks were observed in these high elevation areas, only habitat at or below 1,524 m was surveyed. We used another 28.3 hours of helicopter time to ferry between survey blocks, fuel caches and back and forth to Whitehorse (Figure 4).

Observations of moose

We observed a total of 644 moose, including 189 (29%) adult bulls, 355 (55%) adult and yearling cows, 23 (4%) yearling bulls, 75 (12%) calves and 2 (<1%) unclassified moose (Table 1). 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 survey blocks during the Teslin River Moose Management Unit (MMU) early-winter survey, November 2021.

	Total
Number of blocks counted	147
Number of adult bulls	189
Number of adult and yearling cows*	355
Number of yearling bulls	23
Number of calves	75
Number of unclassified	2
Total number of moose observed	644

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

Distribution of moose

The highest concentrations of moose were observed in the western and northern portions of the MMU, specifically in subalpine habitats along Cap, Joe, and Teslin mountains, as well as in the 2009 burn near mount Black and Boswell Mountain. Much of the southeastern portion of the MMU contained lower-quality early-winter moose habitat and correspondingly lower moose densities (Figure 5).

Abundance of moose

The number of moose observed in a survey block was positively correlated with the 'habitat quality' of the block. Specifically, moose selected for mid-elevation (ca. 1,200 to 1,500 m) and mid-slope (ca. 10 to 22°) areas where the dominant land cover was tall shrub, and to a lesser extent areas dominated by a combination of shrub, herbaceous and mixed-forest vegetation (Appendix 1). These results are consistent with previous surveys conducted within the Teslin River MMU as well as in neighbouring MMUs, whereby moose typically 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 1,178, and we are 90% confident that the population was between 1,063 and 1,339 (Table 2). The estimated density of moose across the entire survey area was 153 moose per 1,000 km^2, or 172 moose per 1,000 km^2 of suitable moose habitat (Table 2). These estimates fall within the typical ranges reported for Yukon moose populations—approximately 100 to 250 moose per 1,000 km^2 of suitable habitat (Environment Yukon, 2016).

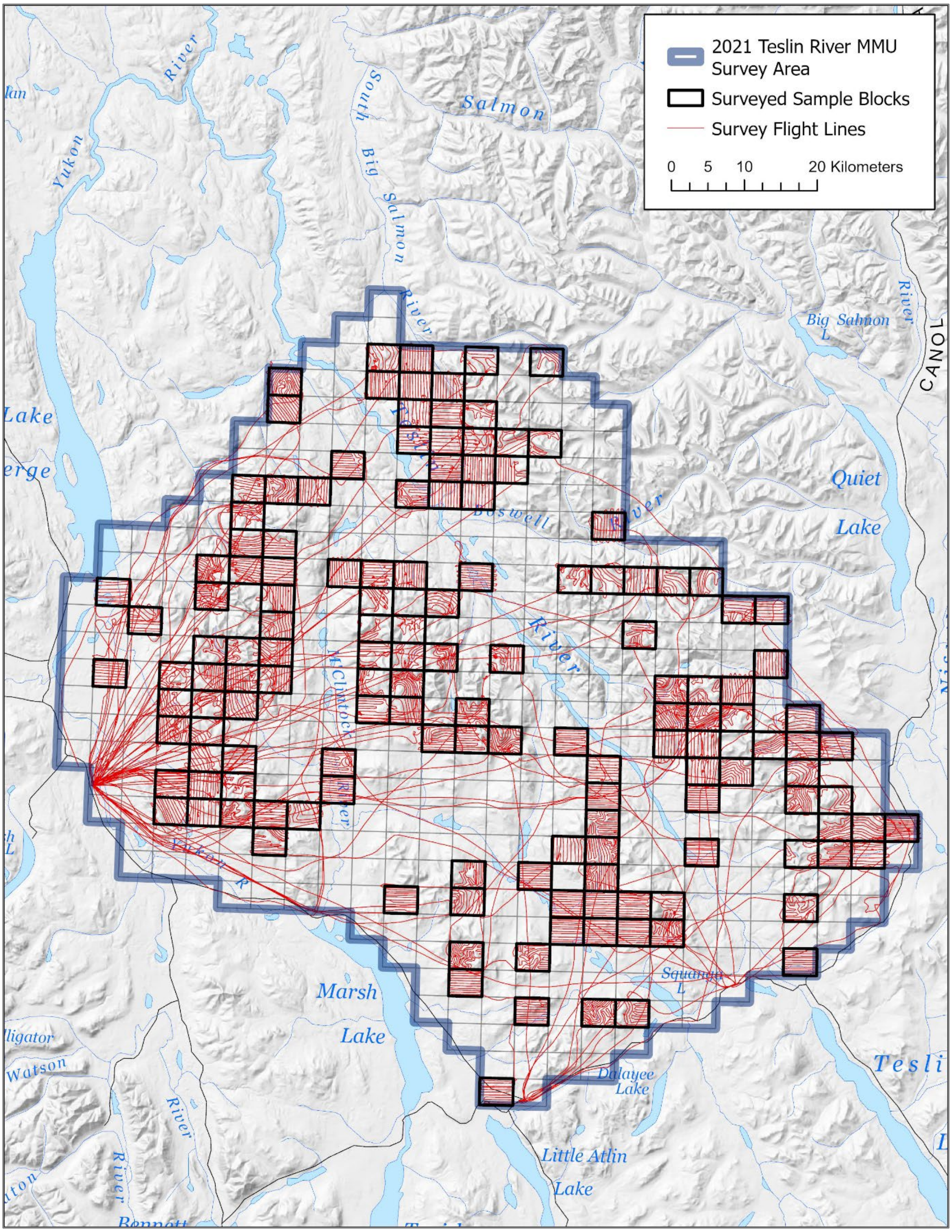

Figure 4. Helicopter flight lines and surveyed blocks from the Teslin River Moose Management Unit (MMU) survey, November 2021. Navigators directed helicopters such that ferry routes covered most of the unsurveyed blocks. This approach allows crews to describe the areas and later evaluate model predictions of moose abundance.

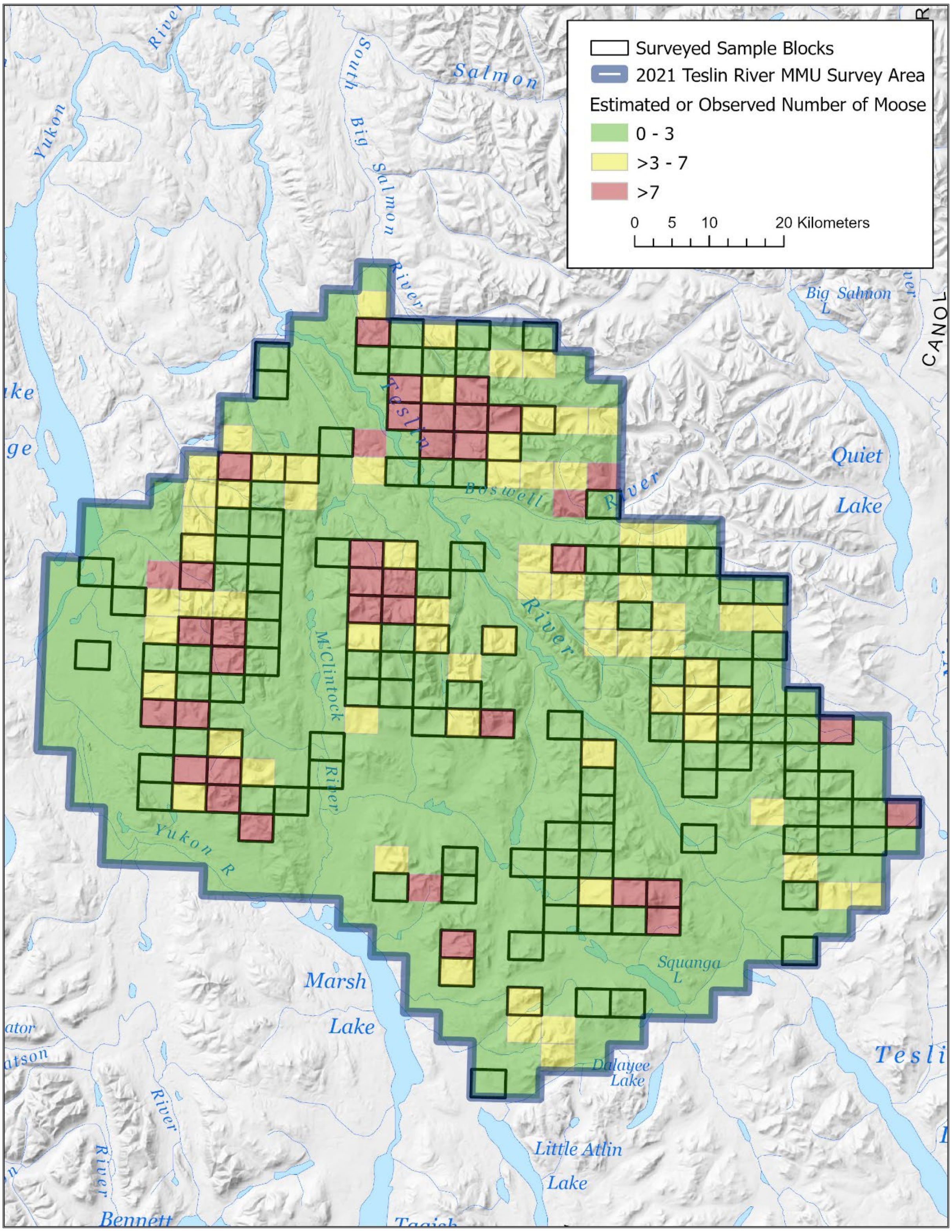

Figure 5. Observed or predicted numbers of moose in the Teslin River Moose Management Unit (MMU) survey area, November 2021.

Table 2. Estimated abundance of moose, corrected for sightability (SCF = 1.09), in the Teslin River Moose Management Unit (MMU), November 2021.

	Best estimate*	Estimates within 90% prediction interval **
Estimated total number of moose	1,178	1,063 – 1,339
Adult bulls	349	311 - 396
Adult cows	614	553 - 690
Yearlings	80	65 - 96
Calves	138	120 - 160
Density of moose (per 1,000 km2)		
Whole area	153	138 - 174
Moose habitat only ***	172	156 - 196

* The sum of the estimated numbers of adult bulls, adult cows, yearlings and calves is slightly different that the estimated total number of moose in the study area because we rounded estimates from individual survey blocks in the compositional analysis 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. Our best estimate is near the middle (at the median) of 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.

Ages and sexes of moose

We found that habitat characteristics did not differentially influence the distribution of age-sex classes of moose among surveyed blocks and used this information to predict composition of moose in unsurveyed blocks (Appendix 1).

Our survey results indicate that survival of calves and yearling moose in the survey area during 2020 and 2021 was below average compared to other areas surveyed in the territory. We estimated 23 calves and 13 yearlings for every 100 adult cows (Table 3), compared to the Yukon average of 29 calves and 18 yearlings per 100 adult cows (Environment Yukon, 2016). However, estimates of recruitment from one survey are snapshots in time, and calf and yearling survival rates can vary substantially among years.

We estimated that there were 57 adult bulls for every 100 adult cows in the survey area (Table 3). This is above the minimum level of 30 adult 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 Teslin River Moose Management Unit (MMU) survey area, November 2021.

	Best estimate	Estimates within 90% prediction interval
% Adult bulls	30	28-31
% Adult cows	52	50-54
% Yearlings	7	6-8
% Calves	12	11-13
Adult bulls per 100 adult cows	57	53-61
Yearlings per 100 adult cows	13	11-15
Yearlings per 100 adults (recruitment rate)	8	6-9
Calves per 100 adult cows	23	20-25
% of cow-calf groups with twins	4	3-6

* A '90% prediction interval' means that, based on our survey results, we are 90% sure 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

This was the first time we conducted a population survey of the entire Teslin River MMU. However, results from 2021 can be subset to compare results to previous early-winter M'Clintock population surveys in the MMU in 1999 (Environment Yukon 2000) and 2011 (Taylor et al. 2012). These surveys covered approximately 46% and 65%, respectively, of the southwestern portion of the Teslin River MMU (Figure 2).

Within both comparison areas, we found a significant decline in total moose abundance and the number of adult bulls (Table 4). We also found a significant decline in the number of adult cows between the 2011 and 2021 surveys (Table 4). However, without a previous survey of the entire MMU, it is difficult to assess population trends at the management-unit scale. Results from the 2021 survey will be used to inform management decisions going forward and will serve as a baseline against which future surveys can be compared.

Table 4. Results of the 1999 and 2011 M'Clintock early-winter moose population surveys compared with corresponding subsets based on estimates derived from the 2021 early-winter survey. Estimates are presented along with 90% confidence or prediction intervals in parentheses[1].

	1999	2021	2011	2021
	GMS 812, 815-817		GMS 812-817	
Estimated abundance [2]				
Total moose	798 (681-9914)	402 (344-469)	1,283 (1,043-1,523)	634 (566-712)
Adult bulls (≥ 30 months)	230 (171-289)	121 (102-144)	466 (342-591)	194 (172-223)
Adult cows (≥ 30 months)	294 (228-360)	213 (181-253)	507 (401-614)	336 (296-381)
Yearlings (approx. 18 months)	158 (81-235)	23 (15-33)	179 (119-239)	34 (26-46)
Calves (≤ 12 months)	118 (88-147)	43 (34-54)	147 (104-189)	69 (58-82)
Estimated population ratios				
Adult bulls per 100 adult cows	77 (52-100)	57 (50-65)	92 (68-100)	58 (53-64)
Yearlings per 100 adult cows	54 (25-82)	11 (7-15)	35 (22-48)	10 (8-13)
Calves per 100 adult cows	40 (27-54)	20 (17-25)	28 (21-36)	20 (18-24)
Density of moose (per 1000 km^2)[2]				
Total area	222 (189-254)	112 (110-130)	256 (208-304)	127 (113-142)
Moose habitat only [3]	240 (204-274)	121 (103-141)	267 (217-317)	132 (118-148)
Total area (km^2)	3,595	3,595	5,011	5,011
Habitable area (km^2)	3,332	3,332	4,810	4,810

[1] A "90% confidence or prediction interval" means that, based on our survey results, we are 90% sure that the true number lies within this range.
[2] To allow for comparison across years, no SCF is included in estimates provided.
[3] Suitable moose habitat is considered all areas at elevations lower than 1,524 m (5,000 ft), excluding all water bodies ≥0.5 km^2.

Harvest

In the Yukon, moose are managed by Moose Management Units (MMUs), which are generally groupings of Game Management Subzones that encompass biologically appropriate moose populations to the best extent possible (Environment Yukon, 2016). We estimate sustainable harvest levels for moose populations at the MMU scale. Specifically, in areas where recent survey information is available, we estimate that 10% of the adult bull population can be sustainably harvested annually with a low risk of a population decline (Environment Yukon, 2016). Based on our 2021 survey results, we estimate that 35 bulls (10% of the estimated 349 adult bulls) can be sustainably harvested annually from this population (Table 2).

Licensed harvest includes licensed resident harvest, non-resident special guided harvest, and non-resident (outfitter) harvest (Figure 6) but not moose harvested by First Nation subsistence hunters. The Teslin River MMU falls within the overlapping Traditional Territories of four First Nations and overlaps 2 outfitting concessions with established quotas for moose. The average total licensed harvest between 2021 and 2025 (excluding 2022 because of Covid restrictions that bias that year of harvest data), was 31 bulls or 89% of the recommended sustainable harvest. Prior to the survey, the 5-year average licensed harvest (2016 to 2020) was 39 bulls or 111% of the recommended sustainable harvest. First Nation subsistence harvest information is not available, so we generally estimate it to be equivalent to resident licensed harvest. For this MMU, that would represent an estimated First Nation subsistence harvest of 31 bulls prior to the survey (2016 to 2020) and 24 bulls since the survey (2021 to 2025 but excluding 2022). Accordingly, we estimate the average total harvest (reported licensed plus estimated First Nation subsistence) at 70 bulls prior to the survey (200% of the sustainable harvest 2016 to 2020) and 55 bulls more recently (157% of the sustainable harvest 2021 to 2025 but excluding 2022). Therefore, based on the available population and harvest information, the total harvest rate in this population is above the recommended sustainable rate.

The high estimated total harvest rate in this population is consistent with observed declines in moose numbers and increases in harvest rates in the subsets of the MMU with previous survey information (see Population status and trends section). Specifically, in the 2011 M'Clintock subset area (65% of the MMU), the 2011 survey estimated a sustainable harvest of 50 bulls (10% of 504 adult bulls or 3.5% of the total population) and the 5-year average total harvest prior to the survey (2007 to 2011) was estimated at 42 bulls or 3% of the total population (Taylor et al. 2012). At the time, the harvest was considered near the upper limit of what was sustainable and caution was recommended because of the proximity of this moose population to Whitehorse (Taylor et al. 2012). Prior to the 2021 survey, the average licensed harvest in the area increased (Figure 7) and, between 2016 and 2020, the 5-year average licensed harvest was 29 bulls per year or a total harvest (reported licensed plus estimated First Nation subsistence) of 53 bulls per year. This total estimated harvest was just above the recommended sustainable rate in 2011; however, the significant decline of moose in this subset of the MMU suggests that actual harvest in the area could be greater than our estimate and/or that recruitment in this population is consistently lower than the average observed across other surveyed areas. In 2021, calf and yearling recruitment in the MMU was low but these values are variable year to year.

Based on our population estimates, trends in subsets of the MMU, and harvest estimates, the total harvest in the MMU is above sustainable limits and management actions are required to ensure that total harvest is sustainable. Actual First Nation harvest data is required to accurately evaluate and monitor the total harvest in this MMU and ensure that it remains sustainable.

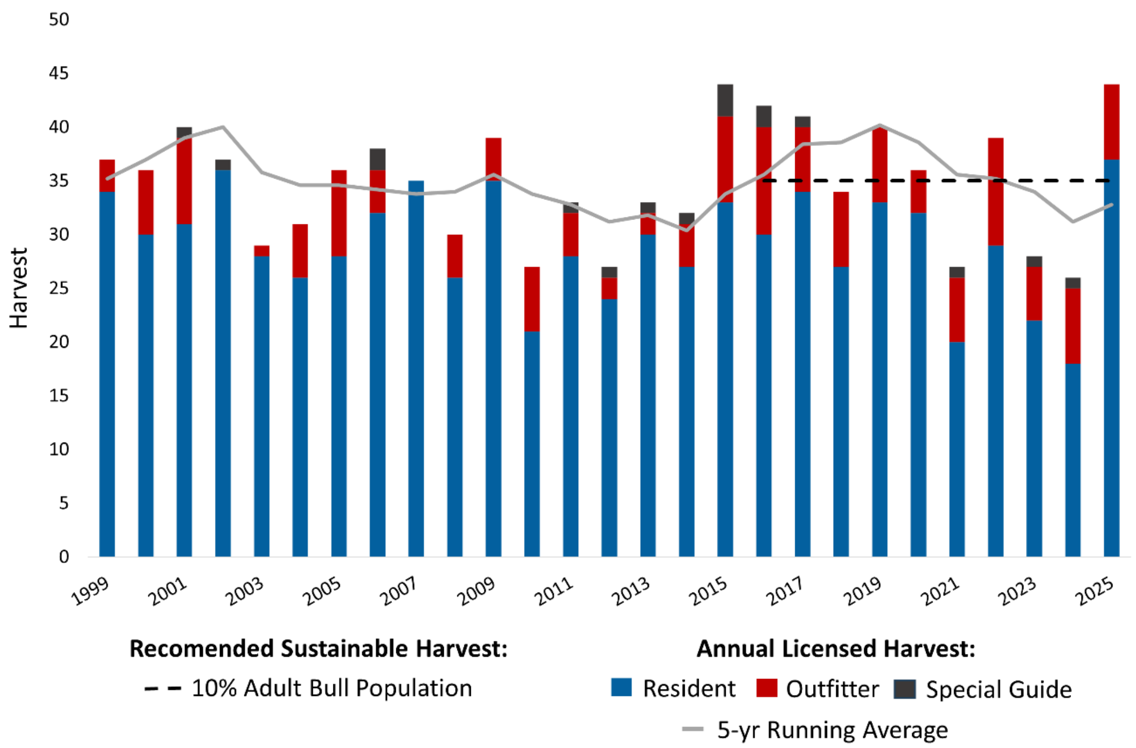

Figure 6. Total annual licensed harvest (resident and non-resident), 5-year running average of licensed harvest, and the 2021 recommended sustainable harvest for the Teslin River MMU. First Nation harvest is not included.

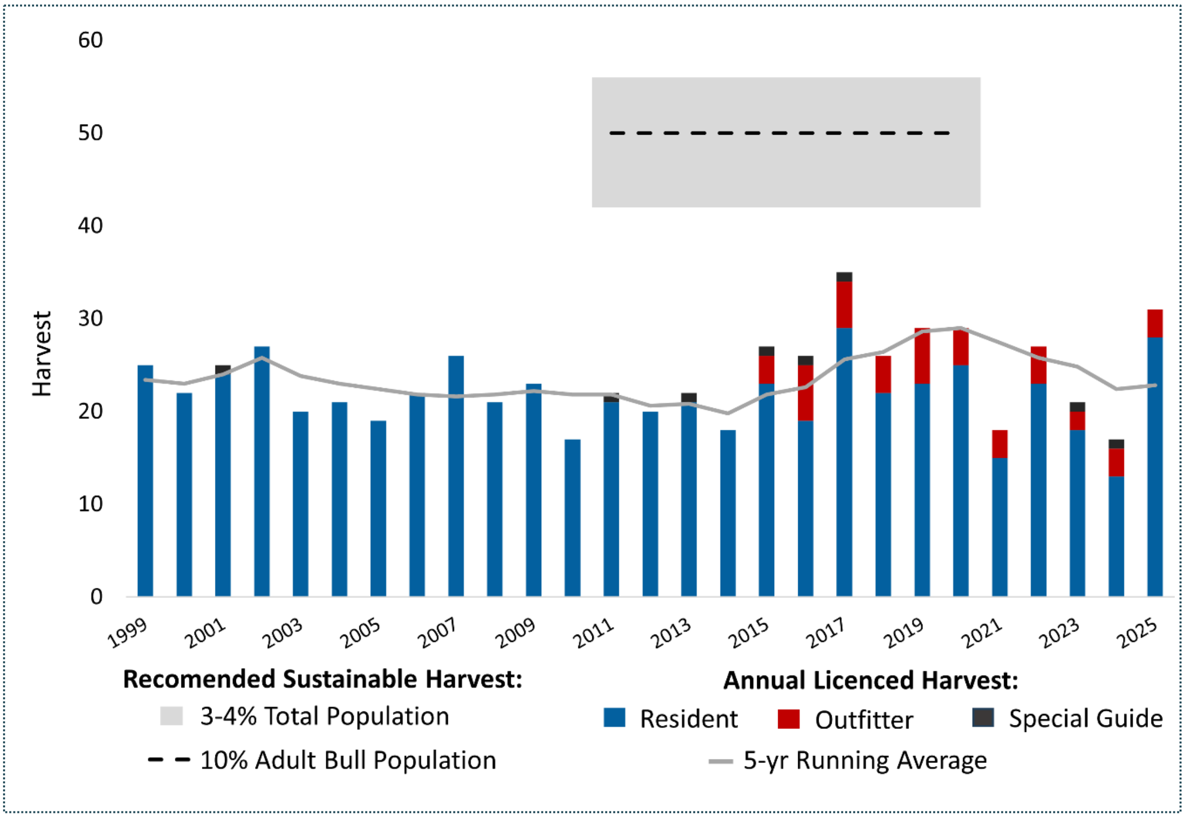

Figure 7. Total annual licensed harvest (resident and non-resident), 5-year running average of licensed harvest, and the recommended sustainable harvest for the M'Clintock comparison area based on 2011 survey results (GMS 8-12 through 8-17). First Nation harvest is not included.

Other wildlife sightings

In addition to the 644 moose we saw during the survey, we counted 153 moose in 84 groups outside of the surveyed blocks or while travelling between blocks. However, it should be noted that many of these moose may have been double counted as incidental observations or later counted in surveyed blocks, so these observations cannot be added to the 644 moose observed during the survey as a minimum count. Beyond moose, we observed 143 caribou in 33 groups from the Carcross, Laberge, and Pelly herds. We also observed 29 sheep, 4 deer, 3 raptors and 1 wolf pack consisting of 9 wolves.

Conclusions and recommendations

- We estimate that there is an average-density moose population in the Teslin River MMU compared to other areas surveyed in the territory.

- The ratio of adult bulls to adult cows is above the recommended minimum of 30 adult bulls per 100 adult cows.
- We found a decline in total moose abundance and the number of adult bulls within 2 comparison areas with previous surveys.
- First Nation harvest information is required to accurately assess the sustainability of total harvest; however, current estimates, combined with reported licensed harvest, indicate that total harvest exceeds sustainable limits.
- 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 used to estimate the abundance and composition of moose in the Teslin River Moose Management Unit, November 2021.

Overview

We estimated abundance and composition of moose in the Teslin River Moose Management Unit (see Study Area section for details). We first used moose locations in surveyed blocks within the survey area to generate resource selection probability functions (RSPFs) at the scale of moose locations. This information was then scaled up to the survey block scale to generate count models and provide estimates of moose abundance for unsampled survey blocks. Lastly, we used predicted and observed moose abundance with moose composition information from surveyed blocks to estimate the age/sex composition of moose over the entire survey area.

For all analyses, we included biologically relevant and spatially representative covariates expected to influence moose occurrence and composition. We used these covariates to generate candidate models and based further inference on the highest-ranking model determined using Akaike's Information Criterion (AIC; Burnham and Anderson 2002) and AIC weights (Wagenmakers and Farrell 2004).

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 (i.e., third order selection; Johnson 1980). We queried each sub-block for landscape and vegetation characteristics that could potentially influence moose occurrence/abundance. All covariates deemed biologically relevant were considered in candidate models (Table 1). We identified sub-blocks as *used* or *unused* based on whether they contained a moose location.

To estimate the RSPF, we considered only the sub-blocks located within surveyed blocks. When intersecting sub-blocks with moose locations, we assumed habitat selection was similar for all age/sex classes excluding calves. Thus, cow-calf groups were considered as a single location and lone calves (n = 0) were excluded. Therefore, the final dataset included 644 *used* sub-blocks and 64,400 *unused* random sub-blocks (100 random, unused sub-blocks for each used sub-block).

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 7 covariates (Table 2). Specifically, moose were most likely to occur in sub-blocks dominated by tall shrub and recent burns, and to a lesser extent in mixed-vegetation habitats. Occurrence was highest at mid-elevations (1,100 to 1,500 m) on moderate slopes (10-20˚) and increased in sub-blocks containing riparian habitat (Table 3). We used this model to predict RSPF values for sub-blocks within unsampled survey blocks and then summed all RSPF values within each survey block (4 km x 4 km scale). These block-level summed RSPF (*Sum_RSPF*) values then represented a general 'habitat quality' index used in subsequent count and composition analyses.

We fit negative binomial (NB), hurdle negative binomial (HNB), and zero-inflated negative binomial (ZINB) regression models to relate the number of moose counted in surveyed blocks with selected covariates. These models best describe low density and spatially aggregated moose distribution across survey blocks in Yukon because they account for overdispersion (NB models) and excess zeros (HNB and ZINB models). Hurdle models account for excess zeros by modeling the probability of observing a zero count versus a non-zero count, separating the zero and non-zero count processes within the model. In contrast, zero-inflated models assume two distinct processes generating counts: one for the zero counts and another for the non-zero counts, allowing for explicit modeling of both processes in the same model. Models were formulated and run using the `pscl` package for the R environment for statistical computing (Zeileis et al., 2008; R Core Team, 2023). The most parsimonious model included the *Sum_RSPF* variable and the proportion of the block with tall shrub (*TallShrub_PER*) in the count component combined with the log-transformed *Sum_RSPF* variable (*log(SUM_RSPF)*) in the zero-count component (Table 4). Therefore, the number of moose observed in a survey block was positively correlated with *Sum_RSPF*, or the overall 'habitat quality' of the survey block and the proportion of the survey block comprised of tall shrub habitat. In addition, there was a greater likelihood of observing 0 moose in survey blocks with lower 'habitat quality' (*log(Sum_RSPF)*).

We used the top-ranking abundance model to predict the number of moose in the remaining unsurveyed blocks (Table 5). We obtained the final population estimate and bootstrapped prediction intervals by combining the number of observed moose in sampled survey blocks with the distributions of predictions from unsurveyed blocks generated from 1,000 bootstrap iterations (Czetwertynski et al., *in prep*). This approach enables us to generate realistic estimates of subsets of the survey area when required.

Composition estimation

We used a compositional analysis to describe the age/sex composition of the moose population in the surveyed blocks using the `VGAM` package for the R environment for statistical computing (Yee 2010). The *null* model, which included no covariates, was the most parsimonious of the candidate models considered in our analysis, suggesting habitat alone had a minimal influence on the distribution of moose composition in the Teslin River area (Table 6). We applied this model (Table 7) to unsurveyed blocks where the median number of moose was predicted by the HNB count model (*Sum_RSPF + TallShrub_PER |*

log(Sum_RSPF)). We obtained the final composition estimates and associated prediction intervals of the surveyed area by iteratively bootstrapping (1,000 runs) the count and composition models (Czetwertynski et al., *in prep*).

Table 1: Description of selected covariates considered for Resource Selection Probability Functions (RSPFs) and models of abundance/composition of moose in the Teslin River Moose Management Unit, November 2021.

Covariate name	Description	Source
ABoVE_Reclass_1	Categorical covariate of the majority landcover class within sub-blocks reduced to 4 classes: conifer; deciduous or shrubland; tall shrub and recent burns (5-35 years old); and non-habitat).	ABoVE Landsat-derived Dominant landcover 2014, 30m x 30m resolution, NASA.
ABoVE_Reclass_2	Categorical covariate of the majority landcover class within sub-blocks reduced to 3 classes: conifer; deciduous, shrubland and recent burns (5-35 years old); and non-habitat).	ABoVE Landsat-derived Dominant landcover 2014, 30m x 30m resolution, NASA.
Elevation (DEM)	Mean elevation in km of the sub-block.	Canadian Digital Elevation Model, 30m x 30m resolution. Natural Resources Canada.
Slope	Mean Slope in degrees of the sub-block.	Canadian Digital Elevation Model, 30m x 30m resolution. Natural Resources Canada.
TallShrub (BIN)	Binary covariate describing the presence (1) or absence (0) of tall shrub cover type.	ABoVE Landsat-derived Dominant landcover 2014, 30m x 30m resolution, NASA.

Covariate name	Description	Source
TallShrub (PER)	Percentage of survey block comprised of tall shrub.	ABoVE Landsat-derived Dominant landcover 2014, 30m x 30m resolution, NASA.
TallShrub_SA (PER)	Percentage of survey block comprised of tall shrub in the subalpine.	ABoVE Landsat-derived Dominant landcover 2014, 30m x 30m resolution, NASA.
TallShrub_BH (PER)	Percentage of survey block comprised of tall shrub in boreal high.	ABoVE Landsat-derived Dominant landcover 2014, 30m x 30m resolution, NASA. Bioclimate Map from the Yukon Ecological Landscape Classification (ELC) Program.
Subalpine (BIN)	Binary covariate describing the presence (1) or absence (0) of subalpine habitat.	Bioclimate Map from the Yukon Ecological Landscape Classification (ELC) Program.
Riparian Habitat (RIP)	Binary covariate describing the presence (1) or absence (0) of riparian habitat (10 m buffer surrounding all watercourses).	50K resolution watercourse shapefile from Yukon Government / GeoYukon.

Table 2: List of top-ranking models describing resource selection of moose at the 400 m scale in the Teslin River survey area (November 2021) with associated Akaike's Information Criterion (AIC) scores, AIC values relative to the most parsimonious model (∆AIC), and model weights (w).

Model	**K**	**AIC**	**∆AIC**	**w**
Above_Reclass_1 + DEM + DEM^2 + Slope + Slope^2 + TallShrub_BIN + RIP	10	6556.78	0.0	1.00
Above_Reclass_1 + DEM + DEM^2	6	6618.87	62.10	0.00
Above_Reclass_2 + DEM + DEM^2 + Slope + Slope^2 + TallShrub_BIN + RIP	9	6619.36	62.58	0.00
Above_Reclass_2 + DEM + DEM^2	7	6676.05	119.27	0.00
Above_Reclass_1 + DEM + Slope	6	6696.27	139.49	0.00

Table 3: Logistic regression coefficient estimates and associated error for the resource selection probability function (RSPF) used to describe selection in sub-blocks (approximately 1.6 km^2) within surveyed blocks (approximately 16 km^2) in the Teslin River survey area, November 2021. We used this model to generate RSPF values for unsurveyed sub-blocks.

Covariate	Estimate	Standard error	*z*	*p*
(Intercept)	-19.573	1.698	-11.004	< 2e-16 ***
ABoVE_Reclass_1 - 3	1.774	0.097	17.486	< 2e-16 ***
ABoVE_Reclass_1 – 4	0.790	0.121	6.494	5.76e-11 ***
ABoVE_Reclass_1 – 5	-1.341	0.445	-3.010	0.002602 **
DEM	20.943	2.804	7.018	8.12e-14 ***
DEM^2	-8.132	1.145	-6.712	1.22e-12 ***
Slope	0.126	0.028	4.347	1.38e-05 ***
$Slope^2$	-0.003	0.001	-3.608	0.000295 ***
TallShrub_BIN	0.309	0.099	3.014	0.001866 **
RIP	0.497	0.084	6.818	3.13e-9 ***

Table 4: List of top-ranking models describing the number of moose observed in survey blocks in the Teslin River survey area (November 2021) with associated Akaike's Information Criterion (AIC) scores, AIC values relative to the most parsimonious model (ΔAIC), and model weights (w).

Model		**Dist.**	***K***	**AIC**	**ΔAIC**	**w**
Count Covariates	Zero Count Covariates					
Sum_RSPF + TallShrub_PER	log(Sum_RSPF)	HNB	7	667.86	0.00	0.51
Sum_RSPF + TallShrub_SA_PER	log(Sum_RSPF)	HNB	7	668.75	0.89	0.33
Sum_RSPF + TallShrub_SA_or_BH_PER	log(Sum_RSPF)	HNB	7	671.79	3.93	0.07
Sum_RSPF	log(Sum_RSPF)	HNB	6	672.59	4.73	0.05
Sum_RSPF + SA_BIN	log(Sum_RSPF)	HNB	7	672.95	5.09	0.04

Table 5: Coefficient estimates for top-ranking model (*Sum_RSPF + TallShrub_PER* | log(*Sum_RSPF*) relating the habitat covariates with the number of moose observed in surveyed blocks (approximately 16 km^2) the Teslin River survey area (November 2021).

Covariate	**Estimate**	**Standard error**	***z***	***p***
Count model coefficients (negbin with log link):				
(Intercept)	0.0498	0.3340	0.1490	0.8814
Sum_RSPF	0.8489	0.1961	4.3290	0.0000 ***
TallShrub_PER	0.0628	0.0245	2.5640	0.0104 *
Log(theta)	0.2580	0.2958	0.8720	0.3830
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	1.4494	0.2501	5.7960	0.0000 ***
log(Sum_RSPF)	2.8217	0.5923	4.7640	0.0000 ***

Table 6: List of top-ranking models describing the composition of moose observed in the Teslin River survey area (November 2021) with associated Akaike's Information Criterion (AIC) scores.

Model	**AIC**	**ΔAIC**	**w**
Null	798.70	0.00	0.56
Sum_RSPF	799.61	0.91	0.36
Sum_RSPF + TallShrub_PER	804.63	5.93	0.03
Sum_RSPF + SA_PER	804.73	6.03	0.03
Sum_RSPF + TallShrub_SA_PER	805.03	6.33	0.02

Table 7: Compositional model coefficient estimates for moose in the Teslin River survey area, November 2021.

Covariate	**Estimate**	**Standard error**	***z***	***p***
(Intercept):BULL_LARGE	0.924	0.136	6.773	0.000 ***
(Intercept):BULL_SMALL	-1.182	0.238	-4.959	0.000 ***
(Intercept):COW_1C	-0.083	0.167	-0.500	0.617
(Intercept):COW_2C	-3.219	0.589	-5.467	0.000 ***
(Intercept):LONE_COW	1.321	0.130	10.163	0.000 ***

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