Yukon

SR-24-05

Moose Survey

Sifton-Miners Range Moose Management Unit, Early-winter 2021

July 2024

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Government of Yukon
Fish and Wildlife Branch
SR-24-05

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Summary

- We conducted an early-winter survey of moose in the Sifton-Miners Range Moose Management Unit (MMU) from November 20th to 30th, 2021. The purpose of the survey was to update estimates of abundance, distribution and composition of the moose population in the MMU.
- We counted moose in 81 of 215 survey blocks, or about 38% of the total area. We observed a total of 634 moose, including 198 mature bulls; 366 mature and yearling cows; 23 yearling bulls; and 47 calves.
- We estimated 928 (90% confident that the population is between 863 and 1015) moose in the survey area. This number is equal to a density of 258 moose per 1,000 km^2 over the entire area or 278 moose per 1,000 km^2 of suitable habitat, which is above the typical range of moose densities in Yukon (100-250 per 1000 km^2 of suitable moose habitat).
- We estimated 17 calves and 12 yearlings per 100 adult cows, which is at the lower end of recruitment observed in surveyed areas across the Yukon.
- We estimated 50 adult bulls per 100 adult cows, which is above the minimum threshold of 30 adult bulls per 100 adult cows identified in our moose management guidelines.
- The 5-year (2017–2021) estimated average total harvest is above the sustainable limit identified for this MMU.
- Licensed harvest in the MMU will be on a Permit Hunt Authorization (PHA) starting in the 2022/23 hunting season. Results from this survey will inform harvest management and the number of permits available to licensed hunters.

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Introduction

This report summarizes the results of the early-winter survey of moose in the Sifton-Miners Range Moose Management Unit (MMU; Figure 1), also referred to as the Whitehorse North survey area in previous reports. We conducted the survey November 22 to 30, 2021, to estimate the abundance, distribution and composition of the moose population. This information is used to assess the sustainability of the current moose harvest and to inform the number of Permit Hunt Authorizations (PHAs) available to licenced hunters in the MMU.

Previous surveys

Previous moose population surveys in the Whitehorse North survey area were conducted in late-winter 2011 (Czetwertynski et al., 2011), and early-winter in 1982 (Markel and Larsen, 1983) and 1993 (unpublished data, Figure 2).

The 2011 survey was conducted in late-winter after it was delayed in early-winter 2010 due to lack of snow and competing resources with other surveys in the Southern Lakes region. A late-winter survey was accepted under the assumptions that moose movement across survey boundaries between the two seasons would not have a large influence on survey results in this area, and that the differences in the visibility of moose in late-winter versus early-winter habitats would be minimal. This survey utilized a 'Stratified Random Block' survey methodology (Gasaway et al. 1986) where survey blocks are selected randomly within predefined high and low strata.

The area covered during 1982 and 1993 early-winter surveys was slightly smaller than the subsequent survey in 2011 and the 2021 survey presented in this report. The difference in survey extent is a result of the spatial scale of survey blocks. Specifically, the 1982 and 1993 surveys used natural terrain features to delineate survey blocks instead of the 4x4 km grid used in subsequent surveys.

Community involvement

Moose have been a key part of First Nation peoples' subsistence lifestyle for generations and today are the most widely hunted wildlife species by both Yukon First Nation and non-First Nation hunters.

There is ongoing interest from Champagne and Aishihik First Nations (CAFN), Ta'an Kwäch'än Council (TKC) and Kwanlin Dün First Nation (KDFN) to collect and provide updated information on moose populations in their traditional territories, and this information will support ongoing moose management partnerships that rely on accurate population data and harvest estimates.

Knowledge holders and local experts from CAFN provided local knowledge about moose in the Sifton-Miners Range MMU in early-winter that contributed to the 'expert opinion' layer used to inform the study design (selection of survey blocks where observers count and classify moose). Members from CAFN, TKC, KDFN and the Laberge Renewable Resources Council also participated in the moose survey as aerial observers.

Study area

The Sifton-Miners Range MMU is about 3,594 km^2 and includes Game Management Subzones 5-48, 5-49, and 5-50 (Figure 1). The eastern border is bounded by the North Klondike Highway from the Alaska Highway junction to Braeburn Lake. The southern border is bounded by the Alaska Highway and extends north to the Nordenskiold River and Klusha Creek and west to Mendenhall and Hutshi Lakes. Moose management units were developed to monitor and manage moose at the scale of populations throughout the territory.

Most of the study area is suitable moose habitat with only 7% of the study area considered unsuitable, including large water bodies ≥0.5 km^2 and land above 1,524 m (5,000 ft) in elevation.

The survey area lies within the Southern Lakes and Ruby Ranges Ecoregions (Yukon Ecoregions Working Group, 2004) and is characterized by a combination of rolling topography with moderate to deeply incised valleys (750-1,200 m above sea level (ASL)) and mountainous terrain (1,500-2,100 m ASL). Treeline occurs between 1,067 and 1,220 m ASL, above which shrub birch (*Betula* spp.) and willow (*Salix* spp.) are the predominant vegetation. On the lower slopes, white spruce (*Picea glauca*) and lodgepole pine (*Pinus contorta*) are dominant tree species. Aspen (*Populus tremuloides*) is found on steep south-facing slopes often with pockets of black spruce (*Picea mariana*) in moister areas (Yukon Ecoregions Working Group, 2004).

Forest fires have occurred throughout much of the survey area in the last eight decades of recorded fire history in the Yukon. The more productive burns with higher quality moose habitat (usually occurring about 11 to 30 years post-fire; Maier et al. 2005) include a portion of the Fox Lake burn (1998) in the northeastern corner of the survey area. The other burns within the survey area are much older (1940s and 1950s) and are well past early successional regeneration that characterizes higher quality burn habitat preferred by moose (Figure 3). In 1958, a fire burned approximately 80% of the area. Most of the burned areas have regenerated to pine and willow of varying density and composition.

In addition to moose, other large mammal species in the area include Dall's sheep *(Ovis dalli)*, elk *(Cervus elaphus)*, wood bison *(Bison bison)*, woodland *caribou (Rangifer tarandus caribou)*, grizzly bear *(Ursus arctos)*, black bear *(Ursus americanus)*, wolf *(Canis lupis)* and coyote *(Canis latrans)*.

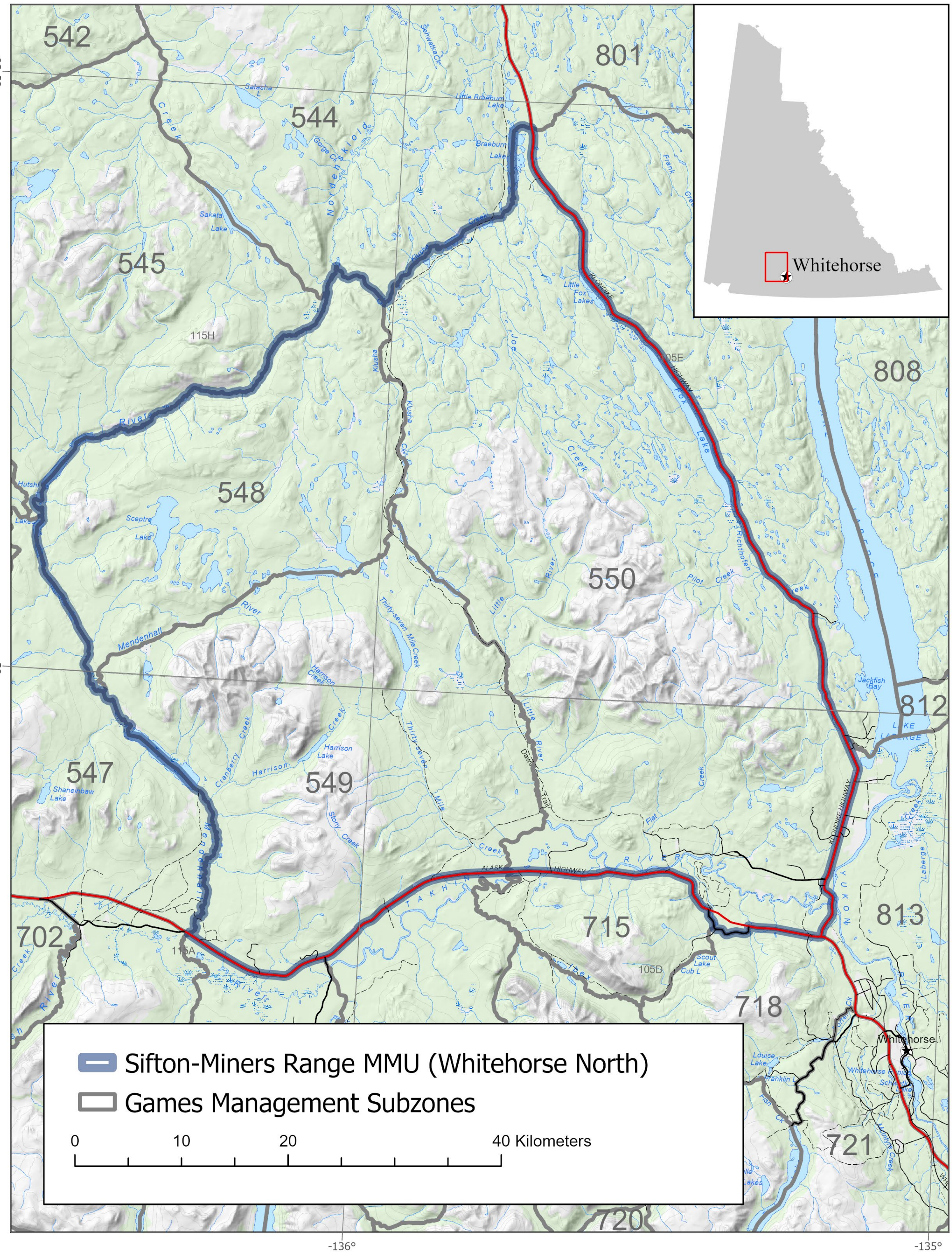


Figure 1. Sifton-Miners Range Moose Management Unit (MMU), November 2021.

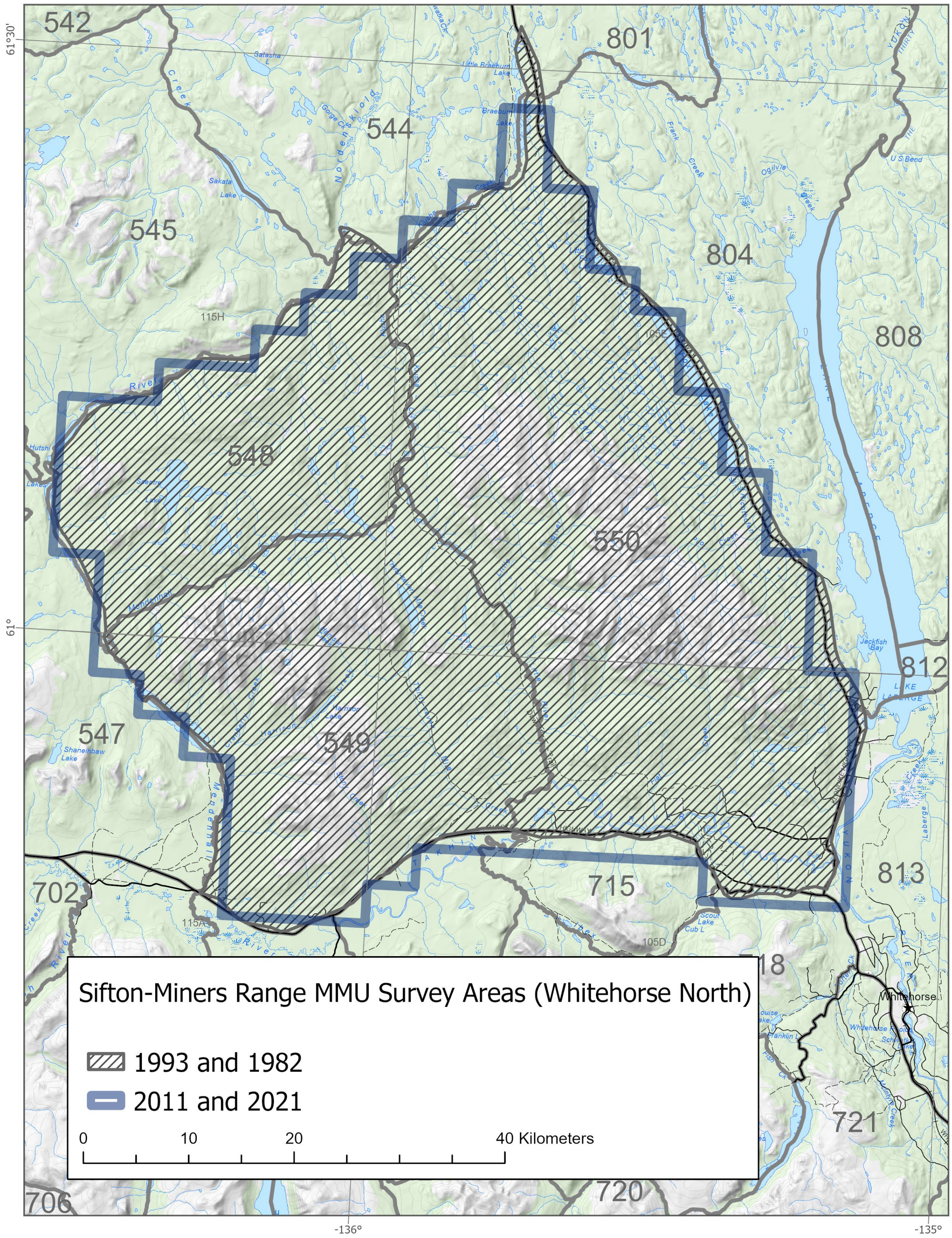


Figure 2. Previous moose surveys in the Whitehorse North survey area.

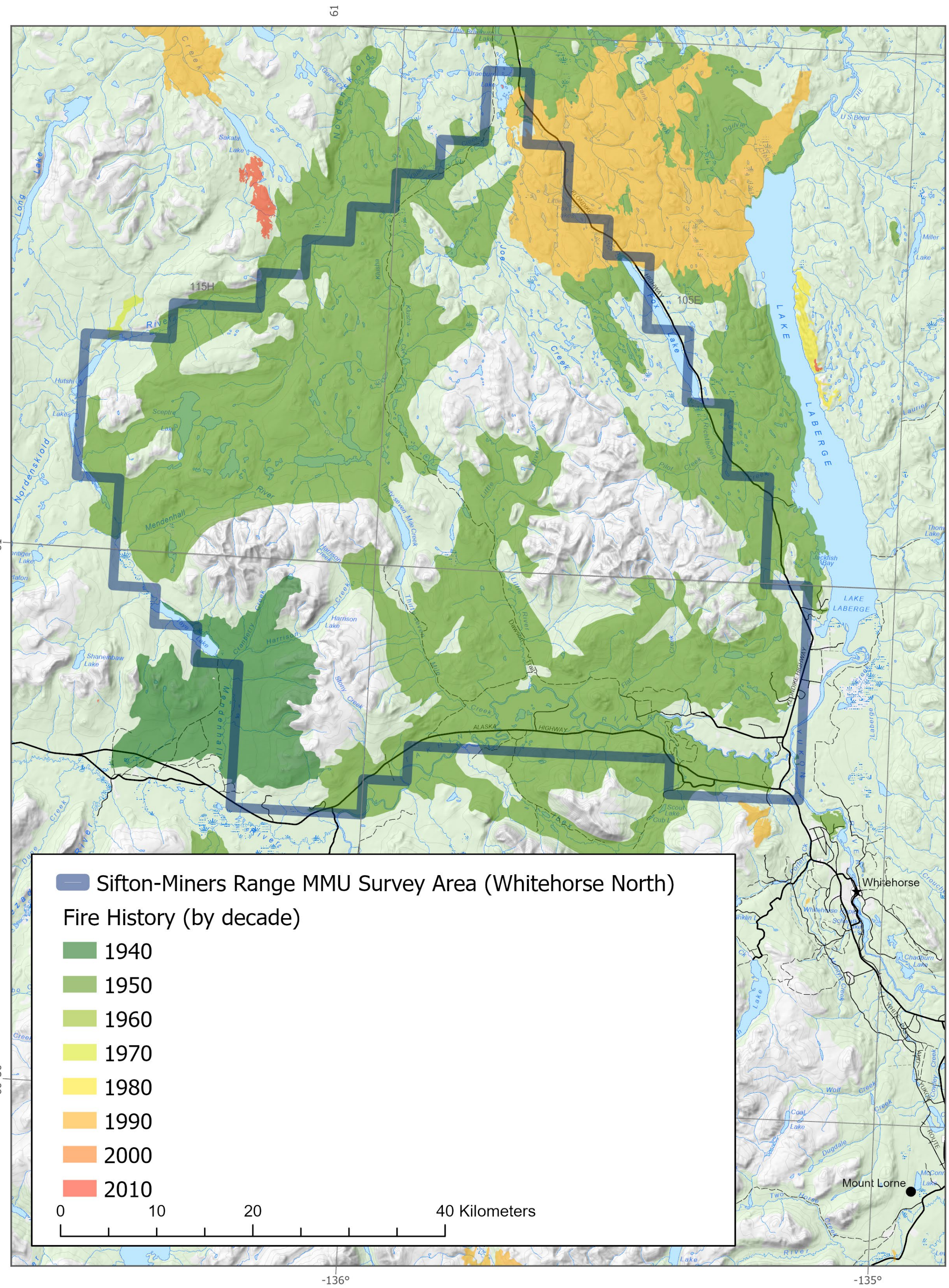


Figure 3. Sifton-Miners Range Moose Management Unit (MMU) fire history.

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 and/or expert 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 14.9-15.2 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. 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" 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:

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. In cases where previous survey data is available, we generate

predictive maps of abundance. We use this information to select survey blocks to be flown during the first 2-3 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.

2. In phase 2, we use a combination of landscape characteristics (land cover, slope and 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.

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 survey to select additional blocks to count. This phase generally represents a proportion of the last day 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

Weather conditions were mostly poor during the survey but did not limit our ability to observe moose because we were able to optimally sample blocks with adequate visibility.

The survey was delayed until late November, as snow coverage earlier in the month remained low. On November 20th, we conducted a reconnaissance flight in the survey area and determined that snow coverage was adequate to start the survey. Snow cover was between 80-100% and snow depth was low (<15 cm.) to intermediate (15-100 cm) in the sampled units. Snow age was fresh (<3 days since last snowfall) for the duration of the survey.

The survey was flown continuously and without delays, though most days were overcast with flat light. Flying conditions on 20 and 28 November, however, were partly sunny and had excellent visibility. Temperatures ranged from -8°C to -22°C.

Coverage

We counted moose in 81 of 215 survey blocks, or about 38% of the total area (Figure 4). We exceeded the 30% coverage because many of the blocks surveyed contained alpine habitat not suitable for moose. Further, we surveyed nearly all the subalpine blocks in the survey area 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 36.8 hours to count moose in survey blocks using one helicopter, for an average search intensity of 1.63 minutes/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 where visibility was very high and moose could be easily counted and sexed. We used another 19.7 hours of helicopter time to ferry between survey blocks, fuel caches and between Whitehorse and the survey area.

Observations of moose

We observed a total of 634 moose, including 198 (31%) mature bulls, 366 (58%) yearling and adult cows, 23 (4%) yearling bulls, 47(7%) calves (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 survey blocks during the Sifton-Miners Range Moose Management Unit (MMU) early-winter survey, November 2021.

	Total
Number of blocks counted	81
Number of adult bulls	198
Number of adult and yearling cows*	366
Number of yearling bulls	23
Number of calves	47
Total Number of moose observed	**634**

*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 and higher elevation open spruce forest areas with good willow cover. We observed the highest numbers of moose in the subalpine areas of the Sifton and Miners ranges, including the Pilot Mountain complex, the mountain complex north and south of Harrison Lake, as well as Mount Cooper north of Sceptre Lake (Figure 5). We counted few moose in lowland and forested areas.

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 and mid-elevations (1,200-1,500 m). In addition, higher proportions of subalpine habitat in the survey block increased the likelihood of observing larger groups of moose (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 counts and model predictions, was 928, and we are 90% confident that the moose population was between 863 and 1,015 (Table 2).

The estimated density of moose in the entire survey area was 258 moose per 1,000 km^2, or 278 per 1,000 km^2 of suitable moose habitat (Table 2). This is above typical Yukon moose densities of 100-250 per 1,000 km^2 of suitable habitat (Environment Yukon, 2016).

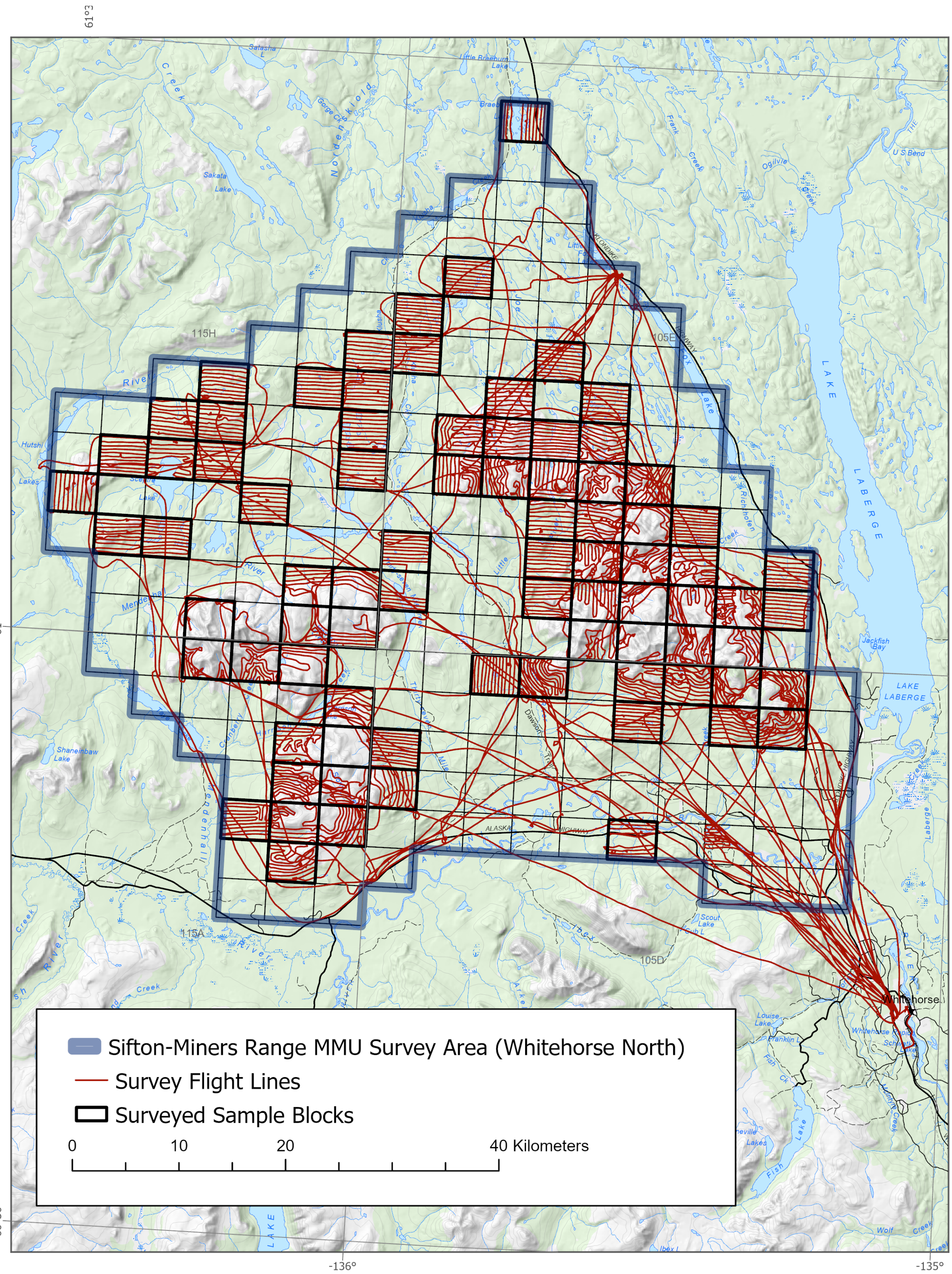


Figure 4. Helicopter flight lines and surveyed blocks from the Sifton-Miners Range Moose Management Unit (MMU) survey, November 2021. Navigators direct helicopters such that ferry routes cover most of the unsurveyed blocks. This approach allows crews to describe the areas and later evaluate model predictions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

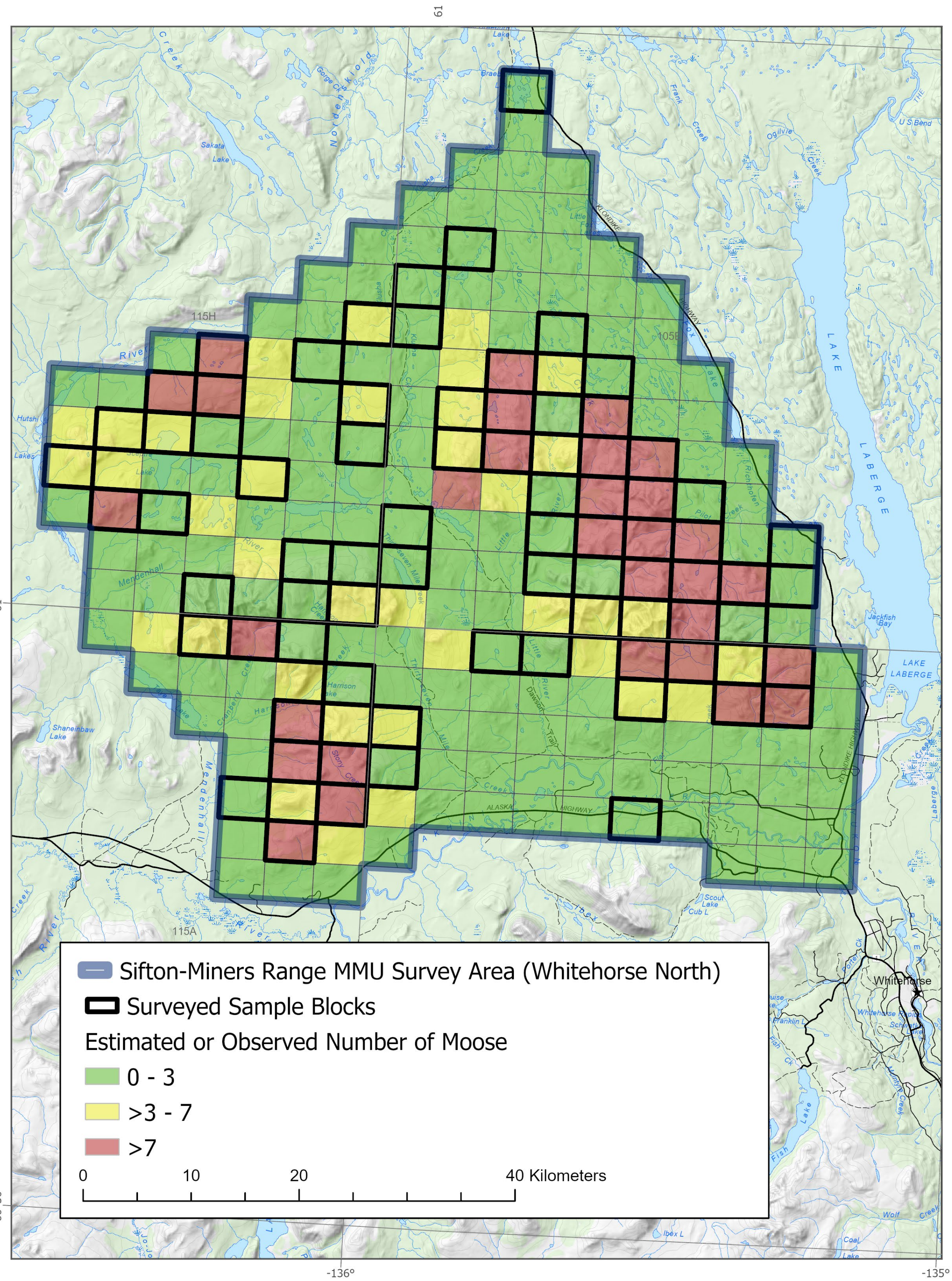


Figure 5. Observed or predicted numbers of moose in the Sifton-Miners Range Moose Management Unit (MMU), November 2021

Table 2. Estimated abundance of moose, corrected for sightability (91%), in the Sifton-Miners Range Moose Management Unit (MMU), November 2021.

	Best estimate*	90% prediction intervals **
Estimated total number of moose	928	863 – 1,015
Adult bulls	258	244 – 278
Adult cows	519	475 – 569
Yearlings	61	52 – 70
Calves	88	74 – 105
Density of moose (per 1,000 km2)		
Entire area	258	240 – 282
Moose habitat only ***	278	259 – 304

* 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 off estimates of total moose in each block to the nearest moose for the compositional analysis
** 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.
*** Suitable moose habitat is considered to be all areas at elevations lower than 1524 m (5000 ft), excluding water bodies 0.5 km^2 or greater in size.

Ages and sexes of moose

The distribution of different age/sex classes of moose in surveyed blocks varied across the MMU. We found that the proportion of lone adult cows and adult bulls was greater in blocks with high quality moose habitat compared to blocks with lower quality habitat. Conversely, younger bulls and cows with calves occurred in greater proportion in lower elevation areas with less abundant high quality willow habitat compared to blocks with lower quality habitat. We accounted for these biases when predicting the composition of the moose population in the entire MMU (Appendix 1).

Our survey results indicate that the survival of calves and yearling moose in the survey area in 2020 and 2021 was below average compared to other areas surveyed in the territory. We estimate that there were 17 calves and 12 yearlings for every 100 adult cows in the population (Table 3), whereas Yukon averages are 29 calves and 18 yearlings per 100 adult cows (Government of Yukon, 2016). However, estimates of recruitment from one survey are snapshots in time and survival varies from year to year.

We estimated that there were 50 adult bulls for every 100 adult cows in the survey area (Table 3). This is below the Yukon average of 64 bulls per 100 adult cows in other areas surveyed, but still well above the minimum level of 30 bulls per 100 cows recommended in the Science-based Guidelines for Management of Moose in Yukon (Government of Yukon, 2016).

Table 3. Estimated composition of the moose population in the Sifton-Miners Range Moose Management Unit (MMU), November 2021.

	Best Estimate	90% prediction intervals
% Adult bulls	28	26-29
% Adult cows	56	55-58
% Yearlings	7	6-7
% Calves	10	8-11
Adult bulls per 100 adult cows	50	46-53
Yearlings per 100 adult cows	12	10-14
Yearlings per 100 adults (recruitment rate)	7	6-8
Calves per 100 adult cows	17	15-19
% of cow-calf groups with twins	3	2-6

* 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 all previous surveys in the Sifton-Miners Range MMU in Table 4. However, because surveys varied in survey coverage, seasonal timing, design and methodology, the results are not directly comparable. Therefore, we cannot determine the moose population trend for this area (i.e. whether increasing, decreasing or stable). Our objective is to focus on the most recent survey results (2021) to inform management decisions for moose in this area.

Table 4. Results of the 2021 early-winter, 2011 late-winter, and 1982 and 1983 early-winter surveys in the Whitehorse North (Sifton-Miners Range MMU) survey area.

Survey Year	2021[8]	2011	1993	1982
Survey Timing	early-winter	late-winter[7]	early-winter	early-winter
Survey Method	model-based (helicopter)	Geospatial[3] (helicopter)	stratified random block (fixed-wing)	stratified random block (helicopter)
Estimated Abundance[2]				
(90% Confidence or prediction Interval)[4]				
Total Moose	851 (792-931)	316 ± 12% (278-355)	292 ± 27% (215-370)	533 ± 22% (418-648)
Total Adult Bulls	237 (224-255)	109 ± 29% (78-141)	128 ± 34% (85-172)	158 ± 26% (117-199)
Total Adult Cows	555 (501-618)	154 ± 16% (130-178)	110 ± 33% (74-147)	353 ± 27% (258-447)
Yearlings	56 (48-64)			
Calves	81 (68-96)	45 ± 32% (31-60)	51 ± 28% (37-66)	22 ± 65% (8-37)
Unknown age/sex			3 ± 88% (0-5)	
Estimated Population Composition				
(90% Confidence Interval)				
% Adult bulls	28 (26-29)	35 ± 28% (25-44)	44 ± 17% (36-51)	30 ± 22% (23-36)
% Adult cows	56 (55-58)	48 ± 15% (41-55)	38 ± 16% (32-44)	66 ± 10% (59-73)
% yearlings	7 (6-7)			
% calves	10 (8-11)	14 ± 30% (10-19)	18 ± 25% (13-22)	4 ± 62% (2-7)
Total bulls / total cows	53 (50-56)	71 ± 33% (48-94)	116 ± 32% (80-153)	45 ± 32% (30-59)
Calves / total cows	16 (15-19)	30 ± 30% (21-39)	46 ± 30% (33-60)	6 ± 66% (2-11)
% of cow-calf groups with twins[5]	3 (2-6)	7 ± 131% (0-15)	12 ± 78% (3-21)	0
Density of Moose (per 1,000 km^2)[2]				
Total Area	237	93	not avail.	~149
Moose Habitat Only[6]	255	101	92	167
Total Area (km^2)	3,594	3,392.4	not avail.	~3,587.0
Habitable Area (km^2)[6]	3,333	3,137.6	3,187.8	3,184.1

[1] Because of differences in survey area, methodology and timing (see text) results are not directly comparable between surveys.

[2] To allow for better comparison across years, no SCF is included in estimates.

[3] For geospatial data, the difference between total estimated numbers of moose and the sum of total bull, cow and calf numbers is because individual age/sex classes are unlikely to exhibit the same spatial correlation as that found in the sum of all observed moose in sampled units. The two sums may differ as a result.

[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 2 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 1,524 m (5,000 ft), excluding water bodies 0.5 km^2 or greater in size.
[7] The 2011 survey was conducted in late-winter when yearlings are hard to distinguish from adults, moose could not be distinguished by age, and instead are classified into total bulls, total cows, and calves. As a result, composition ratios are not directly comparable to the other surveys.
[8] Prediction intervals for 2021 survey estimates are based on asymmetrical distributions, therefore only a range of error is provided.

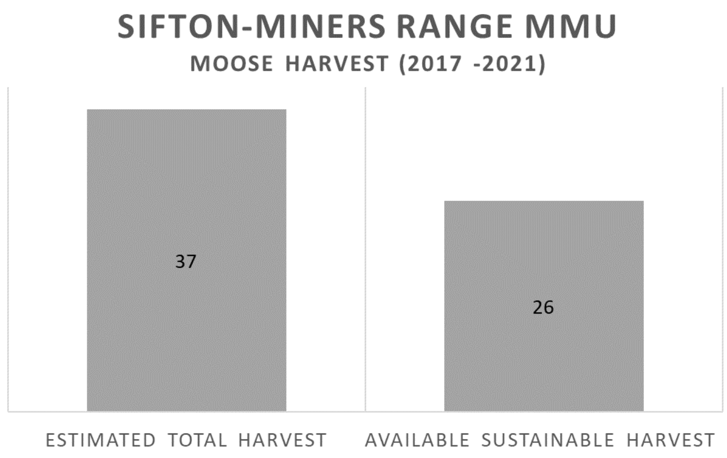
Harvest

In the Yukon, we estimate sustainable harvests for moose populations at the MMU scale (Government of Yukon, 2016). Specifically, in areas where recent survey information is available, we estimate that 10% of the adult bull population can be sustainably harvested annually (Government of Yukon, 2016). Based on our survey results, we estimate that 26 bulls (10% of the estimated 258 adult bulls) can be sustainable harvested annually from the Sifton-Miners Range MMU population.

The 5-year average reported licensed harvest preceding this survey (2017-2021) is 19.2 bulls or 74% of the estimated sustainable harvest. In this case, licensed harvest includes licensed resident harvest, and non-resident special guided harvest. There has been no non-resident (outfitter) harvest in the Sifton-Miners Range MMU (GMS 5-48, 5-49 and 5-50) since 1997.

Licensed harvest does not include moose harvested by First Nation hunters. To account for First Nation harvest and estimate the total harvest in this moose population, we make assumptions based on previous information or local knowledge. In this case, we use a multiplier of 1.0 times the resident licensed harvest. Therefore, the estimated average total harvest in the MMU is 37 bulls or 14% of the adult bull population. In recognition of this estimated unsustainable harvest, a permit hunt authorization (PHA) was issued in the Sifton-Miners Range MMU for licensed harvesters starting in the 2022-23 hunting season. Results from this survey will inform the number of permits available to licensed hunters while providing for subsistence harvest by First Nation hunters.

a)



b)

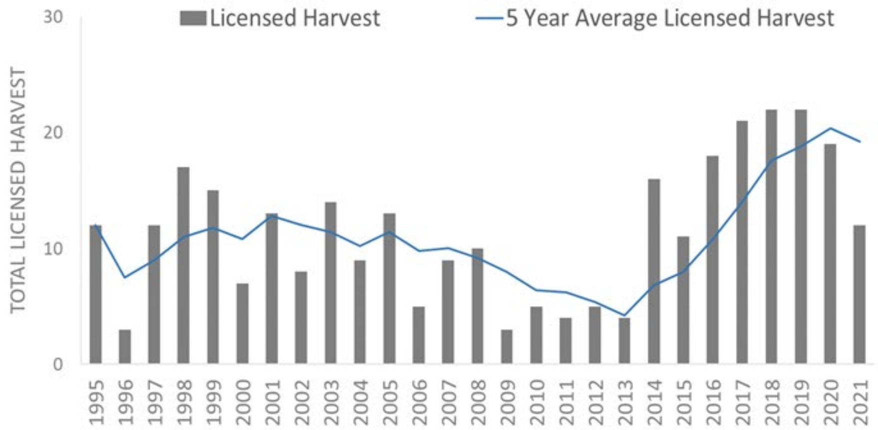


Figure 6. a) The total estimated harvest includes both known licensed harvest and estimated First Nation harvest. The sustainable limit of 26 bulls is based on the 2021 Sifton-Miners Range Moose Management Unit (MMU) survey data. b) Total reported licensed harvest of moose in the Sifton-Miners Range MMU.

Other wildlife sightings

In addition to the 634 moose we saw during the survey, we counted 98 moose in 51 groups outside of the surveyed blocks or while travelling between blocks.

We also saw 327 bison in 32 groups, many around Sceptre Lake, Thirty-seven Mile, Little River and Klusha Creek areas. Additionally, 48 sheep were observed in 11 groups in the Miners and Sifton ranges; 34 elk from the Takhini herd were observed near the Alaska Highway or Takhini River; and seven wolves were observed, including a group of two in the Sifton Range and group of five in the Miners Range. Finally, we observed 12 deer, five wild horses, four coyotes, three foxes and one lynx.

Conclusions and recommendations

- We found a relatively high density moose population in the Sifton-Miners Range MMU compared to other areas surveyed in the territory.
- Survival of calves and yearlings was below average for 2020 and 2021.
- The ratio of adult bulls to adult cows is above the recommended minimum of 30 adult bulls/100 adult cows identified in our *Science-based guidelines for management of moose in Yukon*.
- The current total estimated harvest of moose (reported licensed and estimated First Nation) is above the sustainable level.
- Actual First Nation harvest information is required to accurately assess the sustainability of total harvest.
- We will continue to monitor harvest patterns following the implementation of a permit hunt authorization (PHA) for licensed harvesters in the Sifton-Miners Range MMU starting in the 2022/23 hunting season.
- 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 Sifton-Miners Range Moose Management Unit (MMU) from November 2021 survey data.

Overview

We estimated abundance and composition of moose in the Sifton-Miners Range Moose Management Unit (MMU) with a three-staged approach using data from the 2021 early-winter survey (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 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 4km x 4km) there were 100 sub-blocks (approximately 400m x 400m). 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 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 (16 km^2). 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 587 *Used* sub-blocks and 60,000 *Unused* random sub-blocks (approximately 100 random 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 400m scale included 3 covariates (Table 2). Specifically, moose selected for sub-blocks where the majority landcover (30m scale) was shrub. Moose further selected for elevations between 1,200m and 1,500m, and sub-blocks with the presence of tall shrub (30m scale, 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 (4km x 4km scale). These block-level summed RSPF (*Summed RSPF*) values then represented a general "habitat quality" covariate used in subsequent count and composition analyses.

We fit Negative Binomial (NB) and Zero-Inflated Negative Binomial regression Models (ZINB) to relate the number of moose counted in surveyed blocks with selected coefficients. 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 (ZINB models). We estimated models with the zeroinfl() function in the pscl package for R (Zeileis et al. 2008; R Core Team, 2023). The most parsimonious model included the *Summed RSPF* variable and the proportion of the block with subalpine habitat in the count component combined with the proportion of the block composed of shrub habitat in the zero-inflation component (Table 4). Therefore, the number of moose observed in a survey block was positively correlated to *Summed RSPF* (the "habitat quality") of the survey block and the proportion of subalpine habitat. In addition, there was a greater likelihood of observing 0 moose in a survey block at lower proportions of shrub habitat in the survey block.

We used this 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 actual number of observed moose in sampled survey blocks with the distributions of predictions from unsurveyed blocks generated from 1,000 bootstraps (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 vglm() function in the VGAM package for R (Yee 2010). The "habitat quality" (*Summed RSPF*) significantly affected the distribution of moose composition in the survey area (Table 6). Bulls and lone cows represented a greater proportion of moose in blocks with greater *Summed RSPF* values (Table 7). We applied this model to unsurveyed blocks where the median number of moose was predicted by the ZINB count model. 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*). Lastly, the results were subset for the individual MMUs and comparison areas to provide estimates for management purposes.

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

Covariate Name	Description	Source
Landcover5	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, 30m x 30m resolution, Canada Center for Remote Sensing (CCRS), Natural Resources Canada.
Elev	Mean elevation in km of the sub-block.	Canadian Digital Elevation Model, 30m x 30m resolution. Natural Resources Canada.
TallShrub_01	Binary covariate describing the presence (1) or absence (0) of tall shrub cover type in the sub-block.	ABoVE Landsat-derived Dominant landcover 2014, 30m x 30m resolution, NASA.
Subalpine	Percent of the survey block with subalpine habitat.	Bioclimate Map from the Yukon Ecological Landscape Classification (ELC) Program.
Perc_Shrub	Percent of the survey block with shrub habitat.	North American Land Cover (NALC) 2015 30m x 30m resolution, Canada Center for Remote Sensing (CCRS), Natural Resources Canada.
Perc_Needle	Percent of the survey block with needle forest habitat.	North American Land Cover (NALC) 2015 30m x 30m resolution, Canada Center for Remote Sensing (CCRS), Natural Resources Canada.

Table 2: List of top-ranking models describing the Resource Selection of moose at the 400m scale in the Sifton-Miners Range Moose Management Unit (MMU, November 2021) with associated AIC scores and model weights.

Model	df	AIC	ΔAIC	w
Landcover5 + Elev + $Elev^2$ + TallShrub_01	8	6193.82	0.00	0.98
Landcover5 + Elev + $Elev^2$	7	6201.68	7.86	0.02
Landcover5 + Subalpine	6	6416.69	222.88	0.00
Landcover5 + TallShrub_01	6	6487.33	293.51	0.00
Landcover5	5	6510.59	316.77	0.00

Table 3: Logistic regression estimates 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 Sifton-Miners Range Moose Management Unit (MMU), November 2021 (n = 587, Log-likelihood =-3089.0). We used this model to generate RSPF values for unsurveyed sub-blocks.

		Estimate	Standard Error	Z	P
(Intercept)		-50.689	4.321	-11.73	0.000
Landcover5					
	Deciduous or Mixed Forest	-0.325	0.312	-1.04	0.297
	Shrub	0.829	0.128	6.47	0.000
	Other Habitat	-0.191	0.197	-0.97	0.332
	Non Habitat	-2.034	0.728	-2.79	0.005
Elev		68.491	6.792	10.08	0.000
$Elev^2$		-25.495	2.630	-9.69	0.000
TallShrub_01		0.547	0.186	2.94	0.003

Table 4: List of best models describing the number of moose observed in survey blocks in the Sifton-Miners Range Moose Management Unit (MMU, November 2021) with associated AIC scores and model weights.

Model		Distribution	*df*	AIC	ΔAIC	w
Count Covariates	ZI Covariates					
Summed RSPF + Subalpine	Perc_Shrub	ZINB	5	441.36	0.00	0.75
Summed RSPF	Perc_Shrub	ZINB	4	443.80	2.44	0.22
Summed RSPF	Perc_Needle	ZINB	4	448.48	7.12	0.02
Summed RSPF + Subalpine	Summed RSPF	ZINB	5	450.58	9.22	0.01
Summed RSPF	Summed RSPF	ZINB	4	454.17	12.81	0.00
Summed RSPF	.	NB	3	457.20	15.84	0.00

Table 5: Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed blocks (approximately 16 km^2) in the Sifton-Miners Range Moose Management Unit (MMU, n = 81, Log-likelihood =-214.7).

	Estimate	Standard Error	*Z*	*P*
Count model coefficients (negbin with log link):				
(Intercept)	0.690	0.208	3.320	0.001
Summed RSPF	0.852	0.185	4.606	0.000
Subalpine	0.994	0.467	2.128	0.033
Log(theta)	0.907	0.241	3.765	0.000
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	4.110	2.098	1.959	0.050
Perc_Shrub	-57.043	29.371	-1.942	0.052

Table 6: List of top-ranking models describing the composition of moose observed in the Sifton-Miners Range Moose Management Unit (MMU, November 2021) with associated AIC scores.

Model	AIC	ΔAIC	w
Summed RSPF	635.1	0.0	1.00
Perc_Shrub	652.9	17.8	0.00
Null	657.5	22.5	0.00
Subalpine	660.0	24.9	0.00
Perc_Needle	665.1	30.0	0.00

Table 7: Compositional model regression estimates for moose in the Sifton-Miners Range Moose Management Unit (MMU), November 2021 (n = 81, Log-likelihood =-307.54.2).

	Estimate	Standard Error	*Z*	*P*
(Intercept):BULL_LARGE	-0.332	0.414	-0.801	0.423
(Intercept):BULL_SMALL	-2.419	0.757	-3.197	0.001
(Intercept):COW_1C	-0.027	0.479	-0.057	0.955
(Intercept):COW_2C	-3.900	1.910	NA	NA
(Intercept):LONE_COW	0.827	0.373	2.218	0.027
SUM_RSPF_F:BULL_LARGE	1.255	0.290	4.325	0.000
SUM_RSPF_F:BULL_SMALL	1.214	0.478	2.540	0.011
SUM_RSPF_F:COW_1C	-0.052	0.360	-0.144	0.886
SUM_RSPF_F:COW_2C	0.571	1.272	0.449	0.654
SUM_RSPF_F:LONE_COW	0.815	0.271	3.006	0.003

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