SR-23-13

Moose Survey

Whitehorse South Survey Area, Early-Winter 2021

September 2023

Moose Survey Whitehorse South Survey Area, Early-Winter 2021

Government of Yukon
Fish and Wildlife Branch
SR-23-13

Authors

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Summary

- We conducted an early-winter moose survey in the Whitehorse South survey area (Fish Lake, Mt. Lorne, and Wheaton River) Moose Management Units (MMU) from November 22-29, 2021. The purpose of the survey was to estimate the abundance, distribution, and composition by age and sex of the moose population in each of these MMUs.

- We counted moose in 201 of 530 survey blocks, or about 38% of the total area. A total of 1208 moose, including 400 mature bulls; 603 mature and yearling cows; 78 yearling bulls; 126 calves; and 1 unclassified adult were observed.

Fish Lake MMU

- We estimated 626 (580-686) moose in the Fish Lake MMU. This equates to a density of 273 moose per 1000 km^2 of suitable habitat, which is higher than the typical range of moose densities observed in surveyed areas in the Yukon (100-250 per 1000 km^2 of suitable moose habitat).
- We estimated 30 calves and 36 yearlings per 100 adult cows, which are above the Yukon averages for surveyed areas (29 calves and 18 yearlings per 100 adult cows).
- We estimated 82 adult bulls per 100 adult cows, well above the threshold of 30 adult bulls per 100 adult cows recommended in our moose management guidelines to prevent impacts to reproductive success.

Mt. Lorne MMU

- We estimated 719 (682-777) moose in the Mt. Lorne MMU. This equates to a density of 340 moose per 1000 km^2 of suitable habitat, which is higher than the typical range of moose densities observed in surveyed areas in the Yukon (100-250 per 1000 km^2 of suitable moose habitat).
- We estimated 22 calves per 100 adult cows, which is below the Yukon average number of calves for surveyed areas (29 calves per 100 adult cows), and 25 yearlings per 100 adult cows, which is above the Yukon average (18 yearlings per 100 adult cows).
- We estimated 70 adult bulls per 100 adult cows, well above the threshold of 30 adult bulls per 100 adult cows recommended in our moose management guidelines to prevent impacts to reproductive success.

Wheaton River

- We estimated 375 (319-439) moose in the Wheaton River MMU. This equates to a density of 177 moose per 1000 km^2 of suitable habitat, which is in the mid-range of typical moose densities observed in surveyed areas in the Yukon (100-250 per 1000 km^2 of suitable moose habitat).

- We estimated 21 calves and 13 yearlings per 100 adult cows, which is below the Yukon averages for surveyed areas (29 calves and 18 yearlings per 100 adult cows).
- We estimated 73 adult bulls per 100 adult cows, well above the threshold of 30 adult bulls per 100 adult cows recommended in our moose management guidelines to prevent impacts to reproductive success.

Comparison Areas

- Our survey results indicate that the number of moose in the Whitehorse South and Carcross comparison areas have increased significantly from the previous surveys in 2010, 1994, and in the 1980s. This result is supported by anecdotal information and local observations.

Harvest

- Resident harvest of moose in the Fish Lake, Mount Lorne, and Wheaton River MMUs is restricted to permit hunts and this, combined with non-resident harvest in the Fish Lake MMU, is well below the estimated sustainable harvest. The 5-year (2017-2021) average licensed harvest is 6% of the sustainable harvest in the Fish Lake MMU, 3% in the Mount Lorne MMU, and 8% in the Wheaton River MMU. First Nation harvest information is required to accurately assess the total harvest pressure in these MMUs.

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Introduction

This report summarizes the results of the early-winter population survey of moose in the Whitehorse South survey area, which consists of the Fish Lake, Mt. Lorne, and Wheaton River Moose Management Units (MMUs; Figure 1). It was conducted between November 22 to 29, 2021. The purpose of this survey was to estimate the abundance, distribution, and composition of the moose population in each of the Whitehorse South MMUs and to use this information to assess the sustainability of the current moose harvest. It was also used to evaluate the population's recovery following historic overharvest.

Regulatory History

The Whitehorse South area (also known as the Coast Mountains) was an important hunting area for moose in the 1970s and early 1980s (Larsen et al. 1989a). In 1979, the first year for which we have reliable statistics, more than 175 harvested moose were reported in the Southern Lakes area (excluding harvest by First Nation hunters). This represented over 20% of the Yukon's total reported moose harvest in less than 3% of its land area. Moose numbers in the Whitehorse South area declined in the mid-1980s, particularly in accessible areas (Larsen at al. 1989). The decline was attributed to over-harvest. Between 1982 and 1987, the average estimated total harvest rate (licensed and First Nation hunters, excluding poaching) ranged between 6.6-8.5%, which was twice the recommended annual allowable harvest rate for a stable population (3-4% of the total population, Larsen et al. 1989).

In response, discussions regarding the possible implementation of a permit hunt authorization (PHA) in Game Management Zones (GMZ) 7 and 9 were initiated in 1982. Cow harvest was prohibited in GMZ 7 and Game Management Subzone (GMS) 9-03 in 1982, with the rest of the Yukon following suit in 1984. In 1984, the hunting season was shortened to 2 weeks (September 1 to 15) for several subzones in GMZ 7 as well as GMS 9-04. This shortened season was adopted for all GMZ 7 and 9 in 1985, and was in place until 1989.

Given the large total harvest observed during the mid-1980s, severe harvest restrictions began in 1989, when a PHA system for moose was finally adopted in GMZ 7 and GMS 9-01 to 9-07, with only 10 permits being issued. This was increased to 20 permits in 1994. Despite these measures, moose numbers remained low; surveys done in 1994 and 1995 showed lower moose populations compared to the early-to mid-1980s. In 1998, the allocation of permits within GMZ 7 and 9 was refined, with specific numbers of permits available for smaller areas. This change made only 11 permits available for GMS 7-13 to 7-36 and 9-01 to 9-07, which includes almost the entire area encompassed within the 2021 Whitehorse South boundary. This allocation of permits is still in place.

Predator Control and Studies

Concurrent to the above legislative changes, the Government of Yukon conducted a large-scale study to identify factors limiting moose population growth. This involved manipulating predator densities in southern Yukon (Larsen et al. 1989). Specifically, 134 adult female moose and 135 calves were collared and monitored between 1983 and 1988, while predator numbers were reduced.

Results of the study indicated grizzly bear predation was the primary cause of overall moose mortality during the study (48% of all deaths), followed by wolves (29%), then hunting (9%). Grizzly bears accounted for most of the calf mortalities (58%), and these occurred within the first 8 weeks after birth (Larsen et al. 1989).

In 1985, based on expert opinion, there was an estimated 16 grizzly bears per 1000 km^2 (Larsen, unpublished data). However, based on the results of a large-scale grizzly bear population assessment in 2016, the density estimate was changed to *approx.* 11 bears per 1000 km^2 (Yukon Fish and Wildlife Branch Report, 2017).

During the same period (1983), wolf densities in the Coast Mountains were high, estimated at 12 wolves per 1000 km^2 (Hayes, Government of Yukon unpublished data). However, this estimate has fluctuated throughout the years (Baer, 2010) and in 2022, it was revised to 6.7 wolves per 1000 km^2 (Government of Yukon, 2022; Knamiller, 2022) Although the 2022 estimate is considerably lower than what was estimated in 1983 (down by 47%), the fluctuating estimates suggest a stable trend for the wolf population.

In other studies, predation was also listed as the main cause for moose mortalities, with bears being the major cause of mortality for moose calves (Ballard et al. 1991, Gasaway et al. 1992, Bowyer et al. 1998, Boertje et al. 2010). However, there is little evidence from these studies that predation, by itself, caused moose populations to decline (Ballard and Larsen, 1987). Rather, the combination of predation and over-harvest can cause severe declines in moose numbers (Gasaway et al. 1992).

Results of the 1983-1988 telemetry study found no change in moose numbers, following a 62% reduction in the wolf population. However, because early calf (first six months) survival did increase after wolf removals, the authors suggested that the wolf reduction would have stimulated population growth had it been carried out over a longer period (Larsen et al. 1989). Grizzly bear reductions averaged 4% over the course of the study and were considered insufficient to increase moose numbers.

These results are consistent with other studies conducted in similar areas, where elevated levels of sustained wolf and/or bear reductions were required to observe an increase in moose populations (Gasaway et al. 1986, Van Ballenberghe 1987, Ballard et al. 1991).

Further, concerns that wolf mortalities may be slowing the recovery of Southern Lakes caribou, triggered an investigation of wolf diet and kill rates in the Coast Mountains in 2020-2021. Results indicated that caribou represent a larger proportion of the wolves' diet than in previous studies; however, this is consistent with the increase in availability of caribou in the area. Overall, moose represented 59% of the winter kill composition across packs and was the dominant prey species in 3 out of the 5 packs studied. In general, kill rates and handling time (the amount of time a wolf pack spends on a kill) were like other low-density prey systems in Alaska (Johnson et al. 2017).

Southern Lakes Moose Recovery

Recognition of the significant moose declines in the Southern Lakes dates to the early 1980s and led to several reports and plans for the management and recovery of moose in the area (Anonymous 1984, Larsen et al. 1985, Larsen and Gauthier 1985, Joe et al. 1990, Government of Yukon, 2003). However, none have been fully implemented, and the harvest regime has remained unchanged since the mid-1990s.

The Southern Lakes Wildlife Coordinating Committee (SLWCC) was established in 2008 and includes representatives from 9 governments: Carcross/Tagish First Nation, Champagne and Aishihik First Nations, Kwanlin Dün First Nation, Ta'an Kwäch'än Council, Taku River Tlingit First Nation, Teslin Tlingit Council, and the governments of Yukon, British Columbia, and Canada. At that time, the SLWCC was tasked with 1) making recommendations to its various member governments with respect to the management of wildlife, such as moose, and their habitat in the Southern Lakes area, and 2) producing a wildlife assessment for the Southern Lakes area (SLWCC, 2012).

Results from the 2010 Whitehorse South Moose survey were used in the assessment of moose populations (SLWCC, 2012; Jessup et al., 2014), and a number of recovery related objectives were identified, including: establishing a moose population recovery goal that is supported by the public and sustainable; continuing to develop and implement a managed harvest framework for Southern Lakes moose; continuing to develop and implement moose monitoring initiatives in support of recovery efforts; identifying and managing important moose habitats; better understanding predator/prey interactions and decreasing moose predation rates where appropriate; and providing education and communication initiatives to support moose recovery.

Recently, moose concerns were highlighted in the Carcross/Tagish Community-Based Fish and Wildlife Work Plan, 2020-2025 (Fish and Wildlife Planning Team, 2020). Objectives to support moose in this plan include: 1) developing a plan to monitor and estimate moose harvest and mortalities and other important indicators (e.g. calf mortality) in the Southern Lakes 2) hosting a series of location specific moose management workshops in Southern Lakes for future planning, and 3) developing a process, identify resources, and begin discussion with Carcross/Tagish First Nation citizens on how to report moose harvest. Guided by this process, the Carcross/Tagish Renewable Resources Council conducted local knowledge surveys of moose in their Traditional Territory (unpublished data, 2023), building on previous local knowledge surveys that were conducted in 2000 (Hayes, 2000).

The survey results (reported herein) form a significant contribution to the above objectives and will inform management discussions moving forward.

Previous Surveys

Early-winter intensive population surveys were conducted in the Whitehorse South comparison area in 1981 (Larsen 1982), 1982 (Johnston and McLeod 1983), 1983 (Markel and Larsen 1987a), 1986 (Jingfors and Markel 1987), 1995 (unpublished data), 2000 (unpublished data), and 2010 (Jessup et al., 2014). While surveys in the Carcross comparison area were conducted in 1980 (Larsen and Nette 1980), 1982 (Markel and Larsen 1983), 1983 (Markel and Larsen 1987b), 1994 (unpublished data), and 2010 (Jessup et al., 2014) (Figure 2). The results of these surveys are presented in the 'Population Status and Trends' section of this report (Tables 4 and 5; Figures 8 to 13).

Less intensive, early-winter stratification surveys that estimated relative abundance and distribution of moose were flown in or south of the Whitehorse South comparison area in 1983 (unpublished data) and 1994 (unpublished data) and in the Carcross comparison area in 2000 (unpublished data). In addition, a stratification survey encompassing both sub-areas occurred in 2004 (Florkiewicz 2004). A population survey encompassing the entire Whitehorse South survey area was initiated in 2005 but was cancelled due to low snow and poor weather conditions.

Late-winter moose reconnaissance surveys to observe moose density, demographics, and habitat use in GMZ 7, which encompasses the Whitehorse South comparison area, were flown in 1973 (Hoefs 1974) and 1979 (Hoefs and Larsen 1979, Larsen 1979, Larsen et al. 1979).

Finally, late-winter recruitment surveys to determine if enough calves were surviving to maintain a stable population were also conducted in and south of the Whitehorse South comparison area in 1999 (Florkiewicz 1999) and 2000 (Domes et al. 2000); in the Carcross comparison area in 1981 (unpublished data) and 2002 (Domes 2002); and in the Whitehorse South and Carcross region in 2004 (Westover 2004).

Community Involvement

Moose are a key subsistence species for Yukon First Nations and are the most widely hunted game species by both Yukon First Nation and licenced hunters. As such, there is ongoing interest from the Carcross/Tagish First Nation, Kwanlin Dün First Nation, Champagne and Aishihik First Nations, Ta'an Kwäch'än Council, and the Taku River Tlingit First Nation to collect and provide updated information on moose populations in their traditional territories. They also have an interest in collaborating on initiatives to recover moose in their areas.

For our survey, knowledge holders and local experts from Carcross/Tagish Renewable Resources Council provided information about early winter moose habits in the Whitehorse South survey area. This information contributed to the 'expert opinion' layer used to inform the study design (selection of survey blocks where observers count and classify moose). Members from Kwanlin Dün First Nation and Carcross/Tagish and Laberge Renewable Resources Councils also participated in the moose survey as aerial observers.

Study Area

The Whitehorse South survey area incorporates the Fish Lake, Mt. Lorne, and Wheaton moose management units (MMUs; Environment Yukon 2016). Moose management units were developed to monitor and manage moose at the scale of populations throughout the territory.

The Whitehorse South survey area is about 9223 km^2 and includes Game Management Subzones 7-13 to 7-36 and 9-01 to 9-07 (Figure 1). The northern border is bounded by the Alaska Highway, and the southern border is bound by the BC/Yukon border, Kusawa Lake in the west and the Atlin Road in the east.

The survey region is in the Traditional Territories of the Kwanlin Dün First Nation, Champagne and Aishihik First Nations, Carcross/Tagish First Nation, Ta'an Kwäch'än Council and Taku River First Nation (Figure 3.).

Most of the survey zone (3333 km^2) is considered suitable moose habitat, with only 7% of the area considered unsuitable, including large water bodies (0.5 km^2 or greater in size) and land above 1524m (5000 feet) in elevation.

Much of the survey area is located within the Yukon Southern Lakes ecoregion which is dominated by the Coast Mountains in the southwest and bordered by the large lake systems that are characteristic of this ecoregion (Yukon Ecoregions Working Group 2004). The climate is arid, falling within the rain shadow of the St. Elias-Coast Mountains. Strong winds are common due to the area's proximity to the Gulf of Alaska. The southern portion of the area is in the Yukon Stikine Highlands ecoregion, an area characterized by milder precipitation.

Higher elevations are dominated by willow (*Salix* sp.), shrub birch (*Betula glandulosa*), and sub-alpine fir (*Abies lasiocarpa*). Lower elevations are often composed of mixed woodland, but dominated by lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*). Forest fires have produced some localized patches of sub-climax stands dominated by willow and pine, but fires have not been widespread in the survey area.

Small, isolated fires have occurred dispersed throughout the survey area, though generally, most of the survey area is unburned in recent years (1940-present; Figure 4). Approximately 561 km^2 (about 6% of the survey area) has burned in the last 75 years of monitored fire history (1946-present). The most recent fires include the Windy Arm burn on Tagish Lake across from Conrad in 2018 (approx. 21 km^2). Several small fires around Primrose Lake and River, Johns Lake and the upper Wheaton River from 1998-2003 (ranging in size from 1 to 103 km^2 in size). The northern portion of the survey area around Ibex Valley also overlaps with the 1958 Takhini burn (258 km^2). In 1991, a fire on Haeckle Hill (just west of Whitehorse) burned approximately 7 km^2.

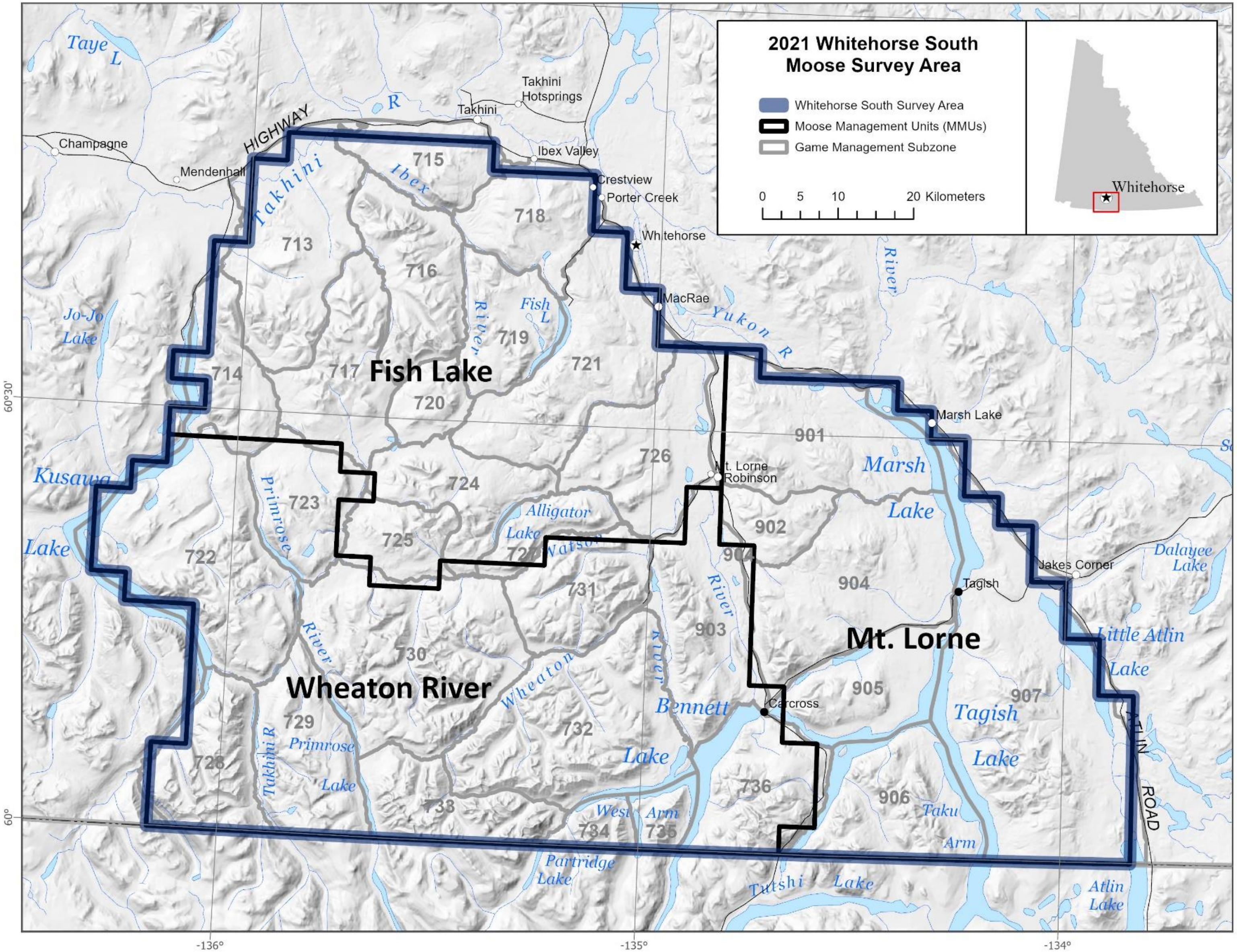

Figure 1. Whitehorse South 2021 early-winter survey area including the Fish Lake, Wheaton River, and Mt. Lorne Moose Management Units (MMUs). Note: GMSs 9-07 has recently been reassigned to the Mt. Lorne MMU from the Teslin Burn MMU to the east.

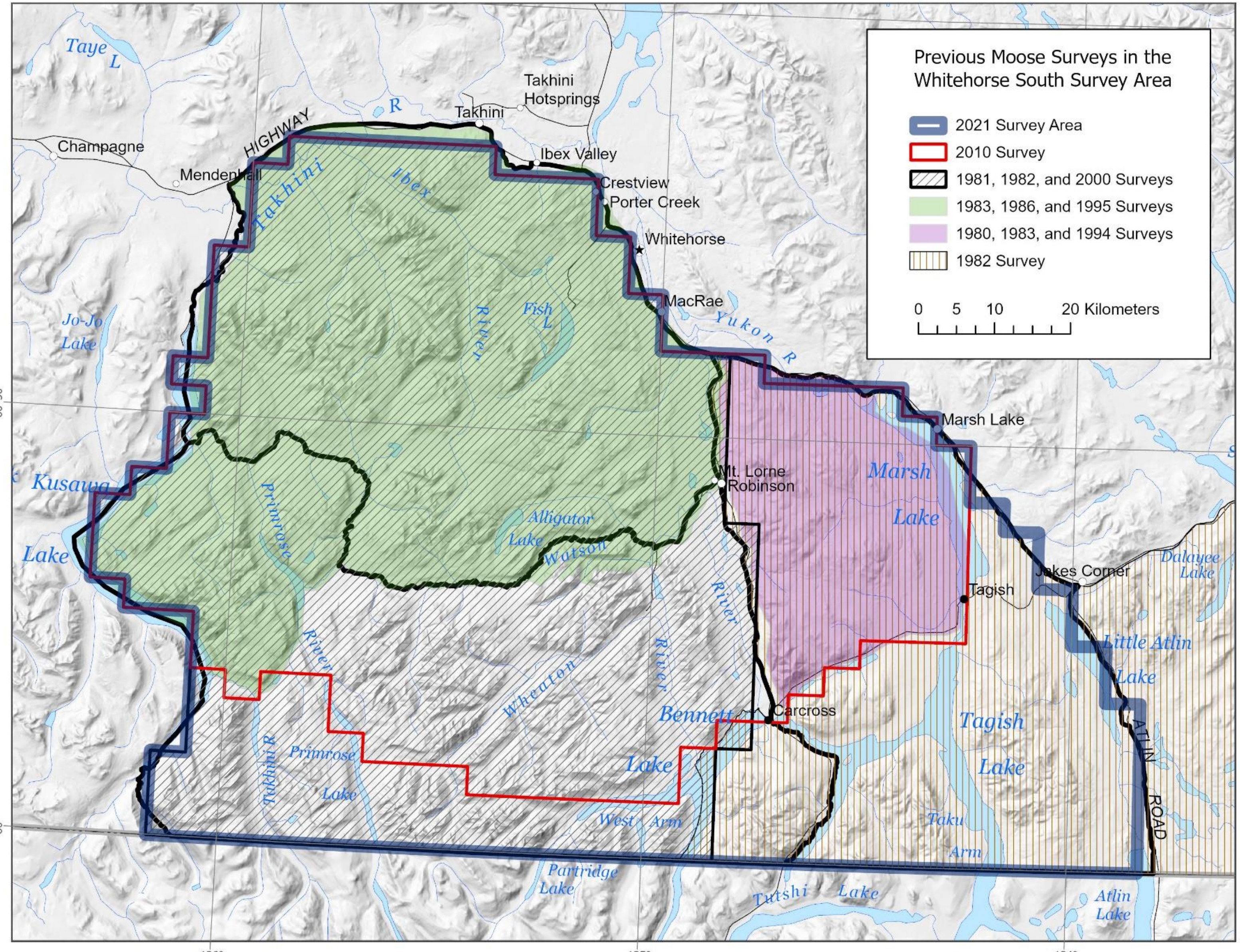

Figure 2. Previous moose surveys in the Whitehorse South survey area, prior to the November 2021

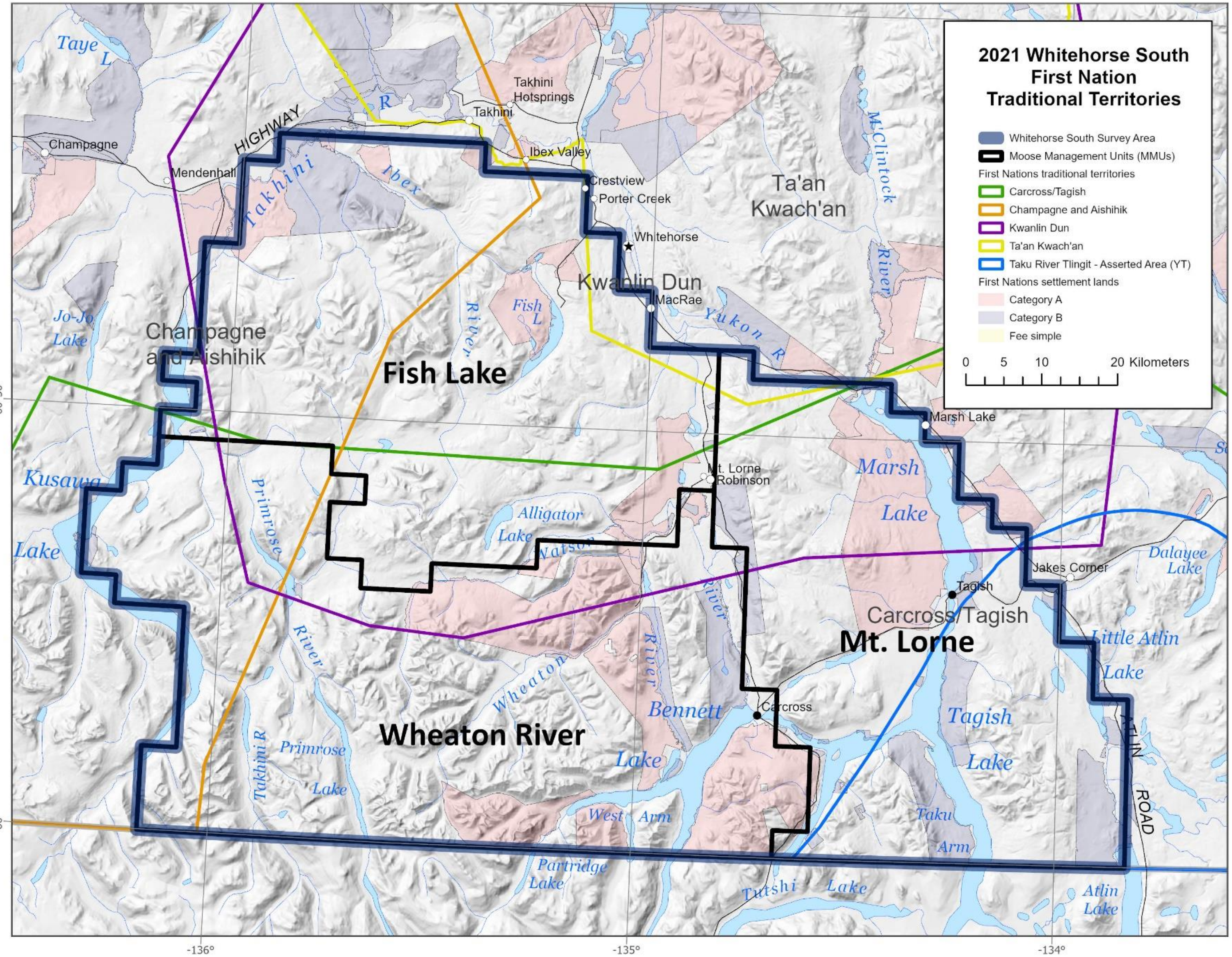

Figure 3. Whitehorse South 2021 early-winter survey area and First Nation Traditional Territories and Settlement Lands.

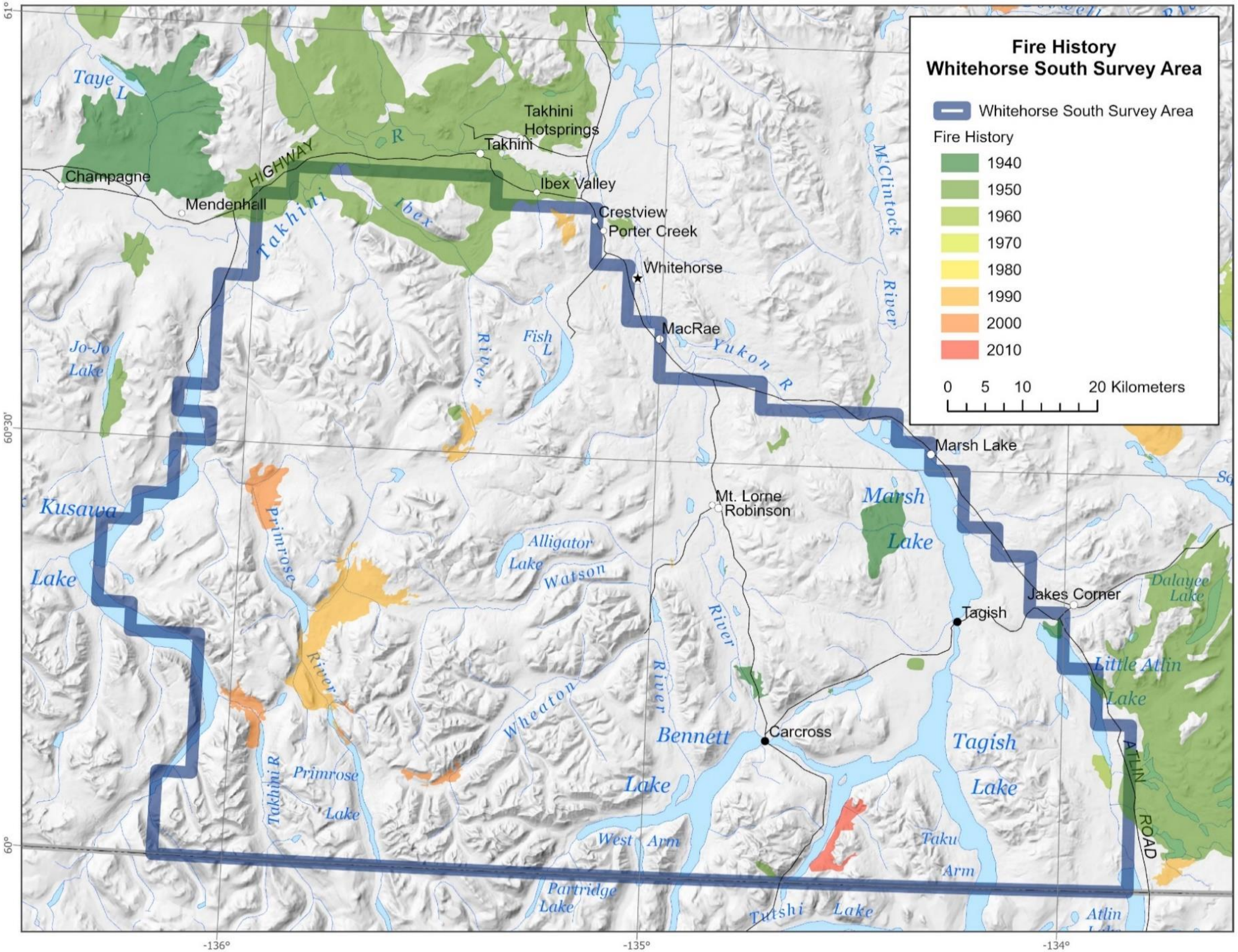

Figure 4. Fire history in the Whitehorse South survey area, November 2021.

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 14.9-15.2 km^2 (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 km^2) and count and classify every moose observed. 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 three phases of the survey:

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 2-3 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.

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.

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.

Weather and snow conditions

The survey was delayed to the latter half of November because of insufficient snow accumulation (i.e. < 10cm). By November 22nd, we had sufficient snow and commenced the survey. Snow continued to accumulate throughout the duration of the survey. Weather conditions were poor at higher elevations. However, weather conditions only grounded crews for a half day. Nevertheless, most survey days required careful selection of sample blocks and timing of flying to avoid heavy fog and poor visibility. Despite challenging weather conditions, we were able to optimally sample blocks, ensuring visibility was adequate to observe moose.

Most days were overcast, with some fog. Temperatures fluctuated between -8°C and -20°C. The lighting conditions were a combination of both flat and bright, with variations occurring throughout each day. The amount of snow cover ranged from 85% to 100%, and snow depths ranged from minimal (less than 6 inches) to intermediate (6 inches to 3 feet).

Results and Discussion

Coverage

We counted moose in 201 of 530 survey blocks, or about 38% of the total Whitehorse South survey area (Figure 5). This included 88 of 176 blocks in the Fish Lake MMU (50% coverage), 50 of 147 blocks in the Mt. Lorne MMU (34% coverage), and 63 of 207 blocks in the Wheaton MMU (30% coverage).

It took us approximately 90 hours to count moose in these blocks, using three helicopter crews (27.2 hrs, 33.4hrs, and 29.7hrs, respectively), for a search intensity of 1.49 minutes per km^2 (Figure 5). We used another 35.1 hours of helicopter time to ferry between survey blocks, our fuel caches, and back and forth to Whitehorse. Our ferry flight paths maximized observations of moose and habitat in the un-surveyed portion of the survey area.

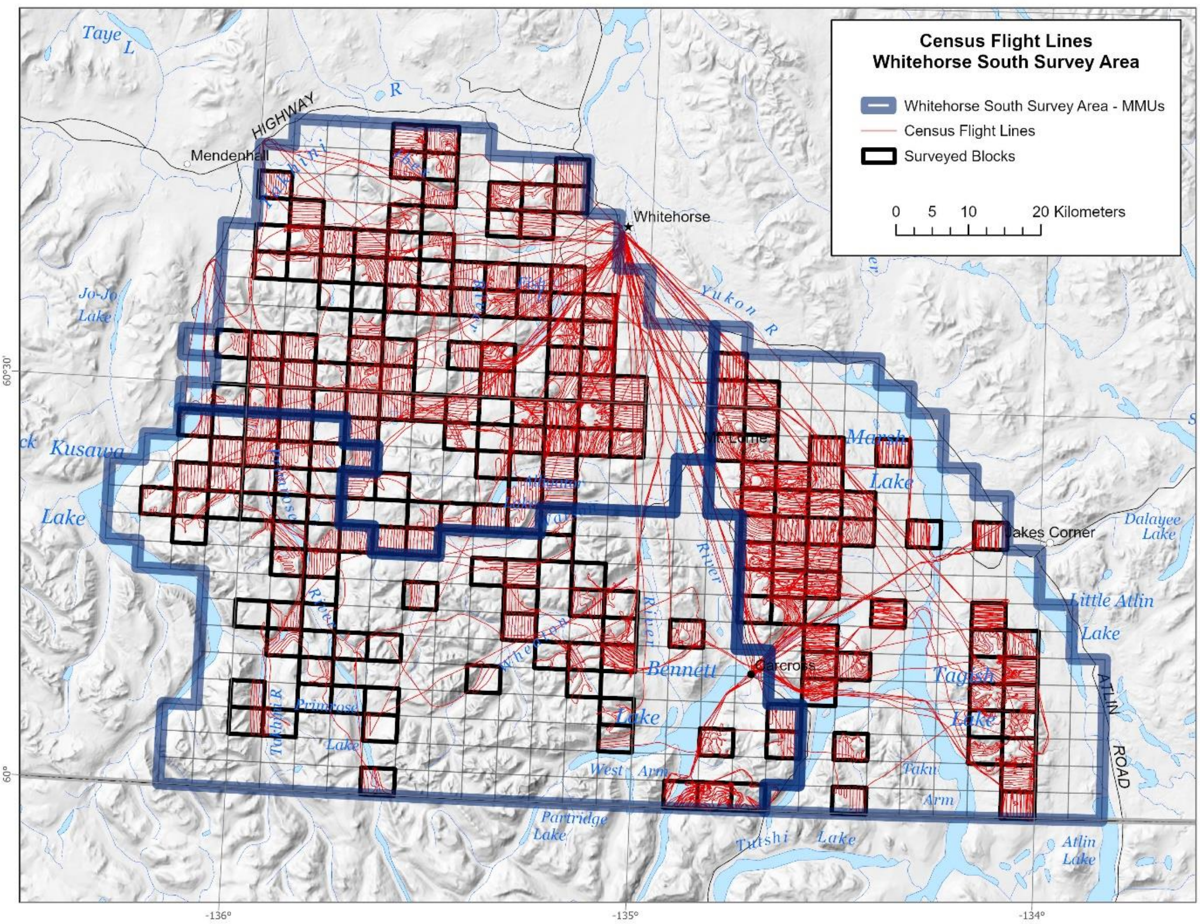

Figure 5. Helicopter flight lines and surveyed blocks from the Whitehorse South survey area, November 2021

Observations of moose

We observed 1208 moose, including 400 (33%) mature bulls, 603 (50%) mature and yearling cows, 78 (6%) yearling bulls, 126 (10%) calves, and 1 (<1%) unclassified adult (Table 1). We counted an average of 356 moose for every 1000 km^2 searched. These values (total number and composition by age and sex) cannot be directly applied as estimates in un-surveyed blocks because our sampling was biased towards blocks with greater numbers of moose.

Table 1. Observations of moose in survey blocks of the Whitehorse South survey area, including Fish Lake, Mt. Lorne, and Wheaton River MMUs, during the November 2021 survey.

	Fish Lake MMU	Mt. Lorne MMU	Wheaton River MMU	Whitehorse South Survey Area Total
Number of blocks counted	88	50	63	201
Number of adult bulls	147	184	69	400
Number of adult and yearling cows*	209	295	99	603
Number of yearling bulls	37	35	6	78
Number of calves	54	55	17	126
Number of unclassified adults	1	0	0	1
Total Number of moose observed	**448**	**569**	**191**	**1208**

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

Fish Lake MMU

Distribution of moose

As expected in early-winter, moose were concentrated in the subalpine and higher elevation open spruce forest with good willow cover. We observed moose throughout the Fish Lake MMU, with higher numbers observed on Mount Sumanik and Ibex Ridge, above Arkell Creek, East of Mount Coudert, and the Alligator and Double Mountains (Figure 6).

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 elevations between 1200 and 1500 m, subalpine habitat with a high proportion of shrubs and moderate slopes. (Appendix 1).

Based on our survey counts and model predictions, we estimated 626 moose in the MMU, and we are 90% confident that the population was between 580 and 686 (Table 2).

We estimated a moose density of 211 moose per 1000 km^2, or 273 moose per 1000 km^2 of suitable moose habitat in the MMU (Table 2). This is on the higher end for Yukon moose densities, which typically range from 100-250 per 1000 km^2 of suitable habitat (Environment Yukon, 2016).

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, yearling bulls, and adult bulls was greatest in blocks with high quality moose habitat. We accounted for this bias when predicting the composition of the moose population in the entire MMU (Appendix 1).

We estimated 30 calves and 36 yearlings for every 100 adult cows in the Fish Lake MMU (Table 3.). The calf survival rate is close to the average observed across surveyed areas in the Yukon, whereas yearling survival was high (29 calves and 18 yearlings per 100 adult cows; Environment Yukon, 2016). However, estimates of recruitment vary among surveys, and survival rates for calves and yearlings can change from year to year.

We estimated 82 adult bulls for every 100 adult cows in the MMU (Table 3). This 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)

Mt. Lorne MMU

Distribution of moose

Moose in the Mt. Lorne MMU were concentrated in the subalpine areas, on open south-facing slopes having good willow cover. We observed the highest number of moose in the subalpine plateaus of Mt. Lorne, Caribou Mountain, and Mt. Lansdowne complex. We also found high numbers in the subalpine and open south-facing slopes on Nares Mountain, Jubilee Mountain, and Montana Mountain (Figure 6).

Abundance of moose

The number of moose observed in a survey block was positively correlated with the "habitat quality" of the survey block. Specifically, moose selected for elevations between 1200 and 1500 m (subalpine habitat), with a high proportion of shrubs and moderate slopes. (Appendix 1).

The estimated number of moose in the MMU, based on our survey counts and model predictions, was 719, and we are 90% confident that the population was between 682 and 777 (Table 2).

The estimated density of moose in the entire survey area was 288 moose per 1000 km^2, or 340 per 1000 km^2 of suitable moose habitat (Table 2). This is above the typical Yukon moose densities of 100-250 per 1000 km^2 of suitable habitat (Environment Yukon, 2016).

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, yearling bulls, and adult bulls was greater in blocks with high-quality moose habitat. We accounted for this bias when predicting the composition of the moose population in the entire MMU (Appendix 1).

We estimated 22 calves and 25 yearlings for every 100 adult cows in the Mt. Lorne MMU (Table 3.). The calf survival is slightly lower than the average observed across surveyed areas in the Yukon. Yearling survival is higher than the average (29 calves and 18 yearlings per 100 adult cows; Environment Yukon, 2016), indicating moderate survival in the previous year.

We estimated 70 adult bulls for every 100 adult cows in the MMU (Table 3). This 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)

Wheaton River MMU

Distribution of moose

In the Wheaton River MMU, the highest concentrations of moose were observed in the subalpine and valleys scattered throughout the northern half of the MMU, in small pockets. We observed the highest numbers of moose south of the Wheaton Valley (i.e. Tally-Ho), Summit Creek, above Primrose Lake, and Sandpiper Creek. Much of the southernmost reaches of the MMU contained lesser quality moose habitat, and we observed few moose in these areas (Figure 6).

Abundance of moose

The number of moose observed in a survey block was positively correlated with the "habitat quality" of the survey block. Specifically, moose selected elevations between 1200

and 1500 m, subalpine habitat with a high proportion of shrubs and moderate slope (Appendix 1).
The estimated number of moose in the MMU, based on our survey counts and model predictions, was 375, and we are 90% confident that the population was between 319 and 439 (Table 2).

The estimated density of moose in the entire survey area was 105 moose per 1000 km^2, or 177 per 1000 km^2 of suitable moose habitat (Table 2). This is within typical Yukon moose densities of 100-250 per 1000 km^2 of suitable habitat (Environment Yukon, 2016).

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, yearling bulls, and adult bulls was greatest in blocks with high-quality moose habitat. We accounted for this bias when predicting the composition of the moose population in the entire MMU (Appendix 1).

We estimated 21 calves and 13 yearlings for every 100 adult cows in the Wheaton River MMU (Table 3.). This is below the averages observed across surveyed areas in the Yukon (29 calves and 18 yearlings per 100 adult cows; Environment Yukon, 2016), indicating lower survival in the previous year.

We estimated 73 adult bulls for every 100 adult cows in the survey area (Table 3). This is 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)

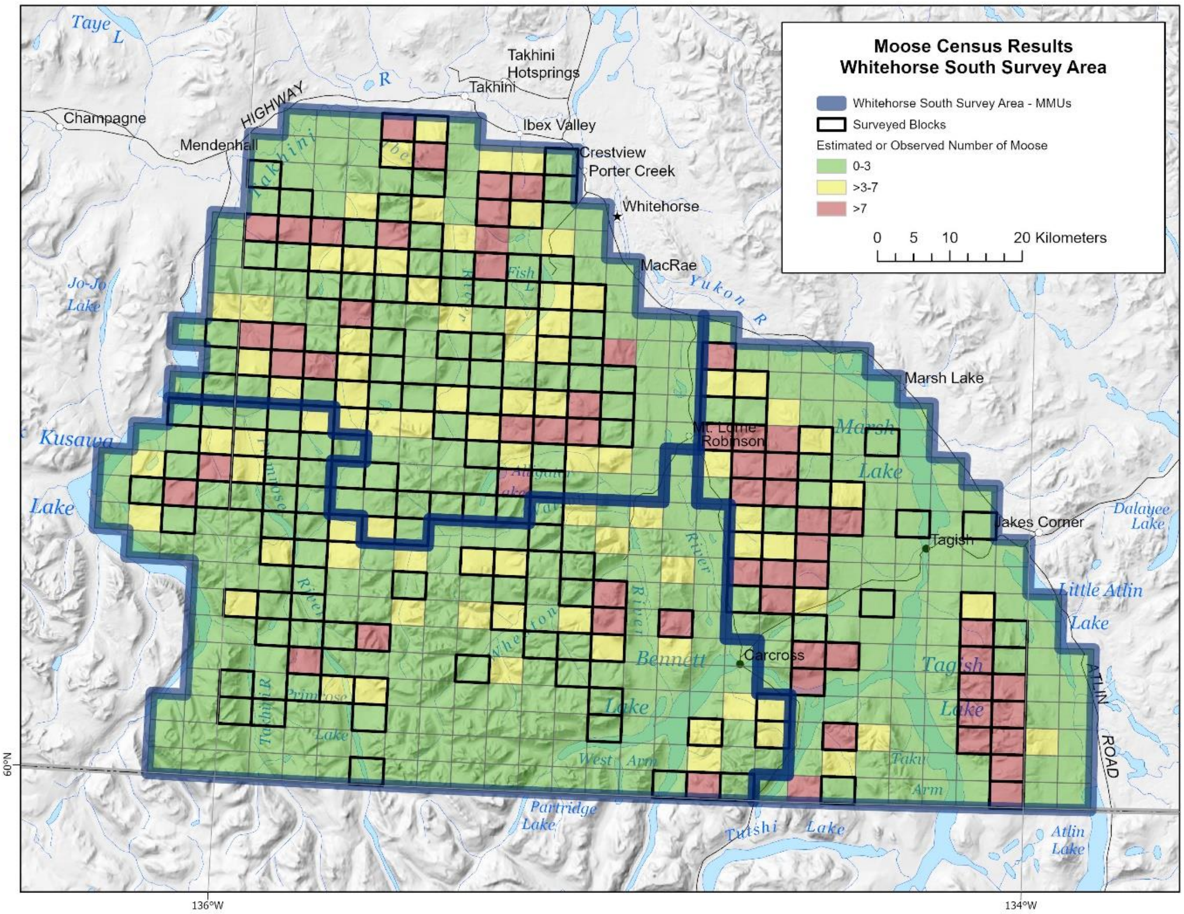

Figure 6. Estimated or observed number of moose in the Whitehorse South survey area, November 2021.

Table 2. Estimated abundance of moose populations, corrected for sightability (SCF=1.09), in the Whitehorse South survey area, November 2021.

	Fish Lake MMU	Mt. Lorne MMU	Wheaton River MMU
Best estimate* (90% prediction intervals**)			
Estimated total number of moose	**626 (580-686)**	**719 (682-777)**	**375 (319-439)**
Adult bulls	207 (190-231)	233 (219-254)	131 (111-155)
Adult cows	252 (229-281)	331 (311-360)	182 (152-219)
Yearlings	92 (84-104)	83 (76-93)	23 (16-33)
Calves	74 (68-84)	73 (67-82)	38 (29-49)
Density of moose (per 1000 km²)			
Whole area	211 (195-231)	288 (273-311)	105 (89-122)
Moose habitat only ***	273 (253-300)	340 (322-367)	177 (151-208)

* 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
** 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 all areas at elevations lower than 1524 m (5000 ft), excluding water bodies 0.5 km^2 or greater in size.

Table 3. Estimated composition of the moose populations in the Whitehorse South survey area, November 2021.

	Fish Lake MMU	**Mt. Lorne MMU**	**Wheaton River MMU**
Best estimate* (90% prediction intervals**)			
% Adult bulls	33 (32-35)	32 (31-33)	35 (32-38)
% Adult cows	40 (38-42)	46 (45-47)	48 (45-51)
% Yearlings	15 (13-16)	12 (11-13)	6 (5-8)
% Calves	12 (11-13)	10 (9-11)	10 (8-12)
Adult bulls per 100 adult cows	82 (76-90)	70 (67-74)	73 (64-82)
Yearlings per 100 adult cows	36 (32-41)	25 (23-28)	13 (9-18)
Yearlings per 100 adults (recruitment rate)	17 (15-18)	13 (12-14)	7 (5-9)
Calves per 100 adult cows	30 (27-33)	22 (20-24)	21 (17-26)
% of cow-calf groups with twins	7 (6-10)	5 (4-8)	3 (0-8)

* 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

Population trends are presented for the Whitehorse South and Carcross comparison areas (Tables 4 and 5; Figures 7 to 13). These areas do not cover the entire 2021 survey area. Specifically, most of the Wheaton River MMU and much of the southern half of the Mt. Lorne MMU are not represented. However, they do represent the entirety of the Fish Lake MMU and much of the most accessible areas of the Mt. Lorne MMU. Additionally, the above two areas have been surveyed many times since the 1980s (eight and six early-winter surveys, respectively), giving us good data on trends for moose abundance.

To make results comparable among years, we present the data without applying sightability correction factors (SCF). Earlier surveys, conducted between 1980 to 1983 and 1986, were not corrected for sightability. Because these comparisons do not use SCF-corrected data, the issues related to the high SCF seen in low-density blocks do not apply to the comparisons. In the following section we discuss trends in abundance and support our interpretations with local observations of moose abundance.

Whitehorse South Comparison Area (GMSs 7-13 to 7-27)

The 2021 total population estimate (with no SCF applied) in the Whitehorse South comparison area was 656 moose (608-717 90% PI) (Table 4; Figure 8). This population estimate is significantly greater than the last estimate in 2010 of 443 moose (343-542) and is similar to estimates in the 1980s, the first survey data available in the area. Our data indicate that this increase in the total population is mostly a result of the significant increase in adult bulls in 2021 compared to previous estimates (Figure 9). Specifically, the adult bull estimate was 107 (70-143) in 1981, 144 (103-184) in 2010, and 222 (203-246) in 2021. We did not observe a similar recovery in adult cows where the 2021 estimate of 269 (245-297) is below the range of adult cow estimates in the 1980s (343-417 between 1981 and 1986). This recovery pattern helps explain the high ratio of adult bulls to adult cows in 2021 (83 adult bulls per 100 adult cows) compared to estimates in the 1980s of 27-41 adult bulls per 100 adult cows (between 1981 and 1986; Figure 10). Recruitment of calves and yearlings in 2021 are consistent with averages observed in other surveyed areas in the Yukon. These results suggest that moose in the Whitehorse south area have recovered to some degree but have not reached levels observed prior to the 1980s. Most importantly, adult cow numbers have not yet recovered to levels in the 1980s.

Carcross Comparison Area (GMS 9-01, 9-02 and 9-04)

The 2021 population estimate (with no SCF applied) in the Carcross comparison area was 328 moose (311-365 90% PI) (Table 5; Figure 11). This population estimate is significantly greater than the estimates from the 3 previous surveys (1980 and 1982 surveys have very wide confidence intervals, so comparisons are not possible). Specifically, estimates for this area were 171 moose (110-231) in 1983, 102 moose (88-177) in 1994, and 153 moose (113-194) in 2010. This pattern is similar for adult bulls and adult cows because these segments of the population have also increased significantly since the previous 3 surveys (Figure 12). We estimated 97 adult bulls (91-110) in 2021 compared to 40 (25-57) in 2010, 35 (28-42) in 1994, and 54 (34-74) in 1983. Similarly, we estimated 170 adult cows (162-189) in 2021 compared to 82 (58-106) in 2010, 49 (40-58) in 1994, and 105 (68-143) in 1983. This increase in adult bulls and adult cows helps explain why we found no significant difference in the ratio of adult bulls to adult cows between years (Figure 13). Overall, we estimated a moose density of 368 (349-409) moose per 1000km^2 of suitable moose habitat, which suggests that moose in this area are approaching the densities of over 400 moose per 1000km^2 estimated prior to the declines in the 1980s.

Wheaton River MMU

Much of the Wheaton River MMU, except for GMS 7-22 and 7-23, is not included in a comparison area (Figure 7), including the most accessible areas that receive greater harvest pressure from First Nation hunters and recreationists such as the Wheaton River valley via the Annie Lake Road and various secondary roads. The Wheaton River valley was included in the 2010 survey area but did not cover the entire Wheaton River MMU (the entire southern portion of the MMU, including GMSs 7-29, 7-33, 7-34 and 7-35, were not included).

Given the above, we made interpretations about population trends in the Wheaton Valley by examining trends in adjacent areas and from anecdotal information from local hunters. The 2021 density estimate of 163 moose per 1000 km^2 (no SCF) of suitable habitat for the Wheaton MMU suggests that the moose population has been slower in recovery compared to its neighbouring Fish Lake and Mt. Lorne MMUs. Our finding is consistent with local knowledge for the area.

GMS 9-07

GMS 9-07 was previously included in the Teslin Burn MMU because the moose population was thought to be, at least geographically, better connected to that MMU. However, it remained an outlying GMS in that it shared the same management regime as the Mt. Lorne MMU (i.e. there are four permits shared between GMS 9-01, 9-02, 9-04 to 9-07). Additionally, it was not included in the 2013 Teslin Burn moose survey, making it a candidate to be included in the 2021 Whitehorse South survey (Figure 3). Since then, the Mt. Lorne MMU boundary has been adjusted to include GMS 9-07. Moose habitat and moose density estimates in GMS 9-07 are like the rest of the Mt. Lorne MMU and the area is accessible via road/trail and waterway. Available information indicates that this area underwent a similar trajectory in its moose population to the remainder of the Mt. Lorne MMU.

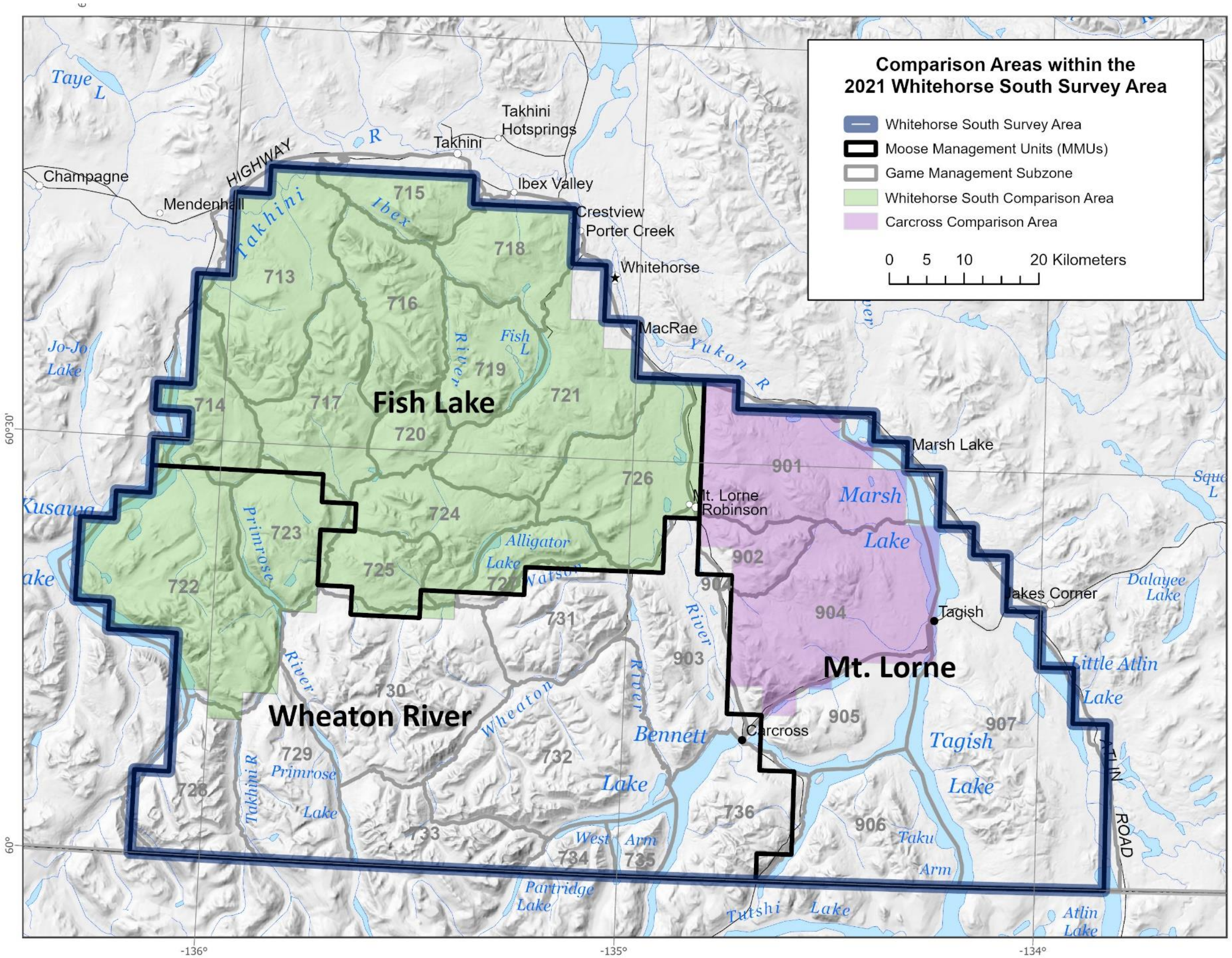

Figure 7. Whitehorse South and Carcross comparison areas.

Table 4. Results of the 2021, 2010, 2000, 1995, 1986, 1983, 1982, and 1981 early-winter moose surveys in the Whitehorse South comparison area (GMS 7-13 to 7-27)

Survey Year	2021	2010	2000	1995	1986	1983	1982	1981
	Model-based	Geospatial	Geospatial	Stratified Random Block	Stratified Random Block	Stratified Random Block	Stratified Random Block	Stratified Random Block
Estimated abundance (90% confidence/prediction intervals)								
Total moose	**656 (608-717)**	**443 ± 22% (343-542)**	**359 ± 33% (240-478)**	**442 ± 15% (375-508)**	**736 ± 20% (592-880)**	**656 ± 22% (509-802)**	**675 ± 36% (435-914)**	**608 ± 18% (497-719)**
Adult bulls (≥ 30 months)	222 (203-246)	144 ± 28% (103-184)	89 ± 46% (47-130)	112 ± 26% (84-141)	114 ± 24% (86-142)	154 ± 33% (104-204)	139 ± 44% (78-199)	107 ± 34% (70-143)
Adult cows (≥ 30 months)	269 (245-297)	233 ± 24% (178-288)	169 ± 34% (111-227)	194 ± 21% (154-234)	417 ± 25% (312-522)	374 ± 25% (281-467)	409 ± 32% (280-538)	343 ± 21% (270-416)
Yearlings (approx. 18 months)	88 (80-100)	20 ± 77% (5-35)	48 ± 108% (0-99)	54 ± 44% (30-78)	77 ± 27% (57-98)	16 ± 0% -16	26 ± 110% (0-56)	86 ± 39% (52-119)
Calves (≤ 12 months)	76 (68-85)	52 ± 41% (30-73)	51 ± 48% (26-76)	81 ± 20% (64-98)	127 ± 22% (99-155)	112 ± 53% (53-171)	101 ± 43% (58-143)	72 ± 29% (51-94)
Estimated population ratios (90% confidence/prediction intervals)								
Adult bulls per 100 adult cows	83 (77-90)	60 ± 30% (42-78)	53 ± 41% (31-76)	58 ± 22% (45-71)	27 ± 18% (22-32)	41 ± 43% (24-59)	34 ± 26% (25-43)	31 ± 26% (23-39)
Yearlings per 100 adult cows	33 (29-37)	8 ± 77% (2-15)	28 ± 113% (0-60)	28 ± 55% (12-43)	18 ± 37% (12-25)	4 ± 25% (3-5)	6 ± 90% (1-12)	25 ± 46% (14-36)
Yearlings per 100 adult moose	13 (12-15)	5 ± 79% (1-9)	16 ± 113% (0-33)	15 ± 46% (8-22)	13 ± 31% (23-37)	3 ± 19% (2-3)	5 ± 82% (1-8)	16 ± 40% (9-22)
Calves per 100 adult cows	28 (26-31)	22 ± 42% (13-31)	30 ± 54% (14-46)	42 ± 22% (32-51)	30 ± 23% (23-37)	30 ± 37% (19-41)	24 ± 27% (18-31)	21 ± 29% (15-27)
% of cow-calf groups with twins	7 (5-9)	insufficient data	insufficient data	8 ± 78% (2-14)	-	-	-	-
Density of moose (per 1000 km^2)								
Total area	177	120	97	-	-	~169	~174	~157
Moose habitat only	**233**	**157**	**128**	**156**	**288**	**245**	**252**	**255**
Total area (km^2)	3705	3705.4	3705.4	-	-	~3879	~3879	~3879
Habitable area (km^2)	2812	2812	2812	2824.8	2551.3	2680	2680	2680

[1] SCF was not calculated for the 1981 to 1983 and 1986 surveys. To allow for comparison across years, no SCF is included in estimates provided.

[2] A "90% confidence interval" means that, based on our survey results, we are 90% sure that the true number lies within this range of numbers. The 2021 survey estimates uses prediction intervals to measure level of confidence.

[3] 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. In past surveys (pre 1987) cow and calf data was collcted seperately and a twinning rate could not be calculated.

[4] Suitable moose habitat is considered all areas at elevations lower than 1524m (5000ft), excluding all water bodies 0.5km^2 or greater in size.

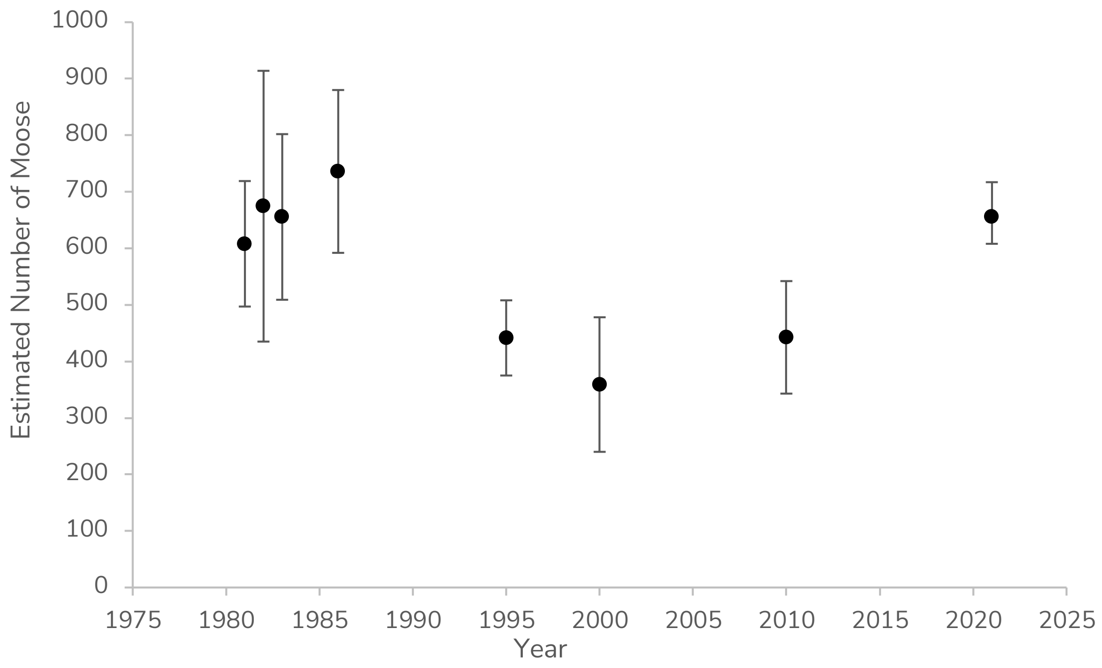

Figure 8. Estimated abundance (dots) with 90% confidence intervals (1981-2010, vertical error bars) or prediction intervals (2021) from moose surveys in the Whitehorse South comparison area from 1981 to 2021.

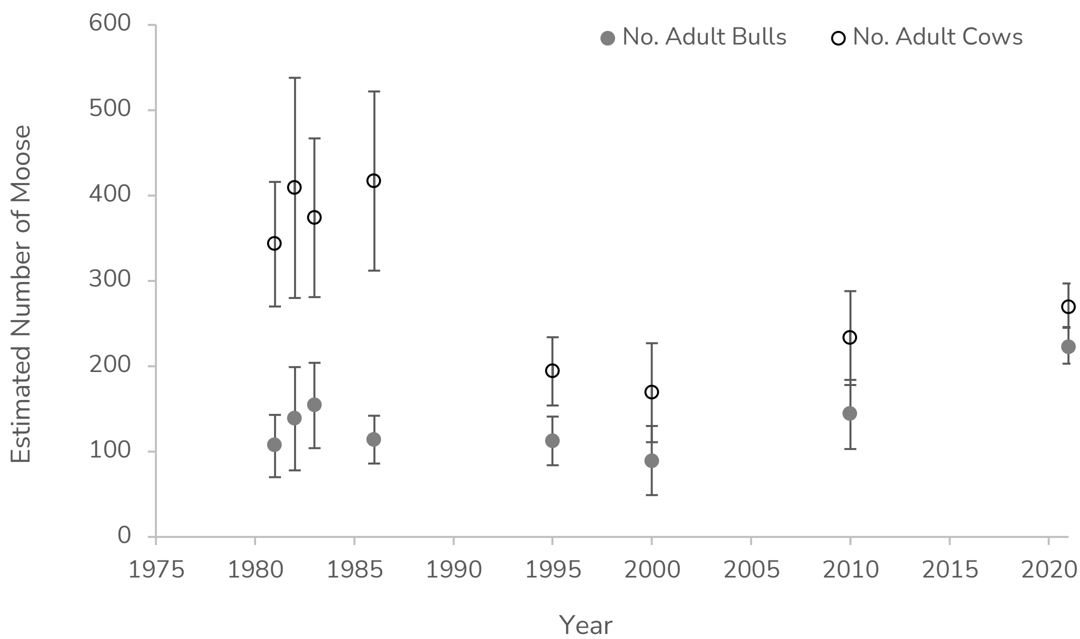

Figure 9. Estimated abundance of adult bulls (grey dots) and adult cows (white dots) with 90% confidence intervals (1981 to 2010, vertical error bars) or prediction intervals (2021) from moose surveys in the Whitehorse South comparison area from 1981 to 2021.

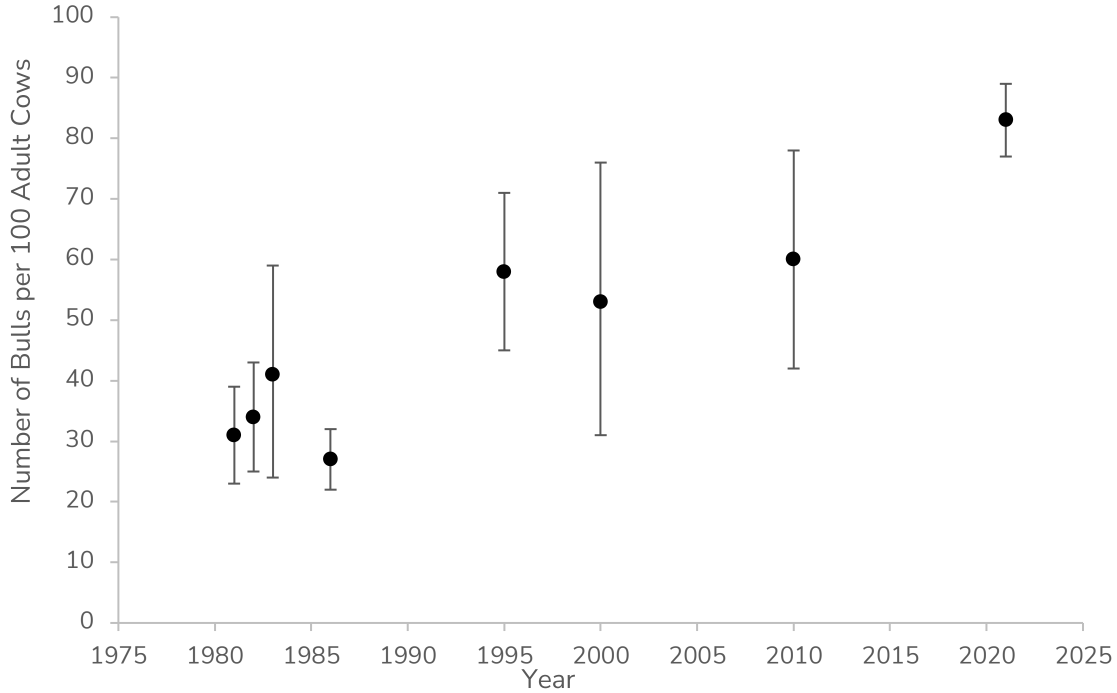

Figure 10. Estimated ratio of bulls per 100 cows (dots) with 90% confidence intervals (1981-2010, vertical error bars) or prediction intervals (2021) from moose surveys in the Whitehorse South comparison area from 1981 to 2021

Table 5. Results of the 2021, 2010, 1994, 1983, 1982, and 1980 early-winter moose surveys in the Carcross comparison area (GMS 9-01, 9-02 and 9-04).

Survey Year	**2021**	**2010**	**1994**	**1983**	**1982**	**1980**
	Model-based	Geospatial	Stratified Random Block	Stratified Random Block	Stratified Random Block	Stratified Random Block
Estimated abundance (90% confidence/prediction intervals)						
Total moose	**328 (311-365)**	**153 ± 26% (133-194)**	**102 ± 14% (88-177)**	**171 ± 35% (110-231)**	**300 ± 74% (79-521)**	**396 ± 63% (147-644)**
Adult bulls (≥ 30 months)	97 (91-110)	40 ± 42% (23-57)	35 ± 19% (28-42)	54 ± 37% (34-74)	124 ± 109% (0-258)	94 ± 49% (48-139)
Adult cows (≥ 30 months)	170 (162-189)	82 ± 29% (58-106)	49 ± 19% (40-58)	105 ± 36% (68-143)	161 ± 68% (52-270)	172 ± 61% (68-276)
Yearlings (approx. 18 months)	38 (36-46)	7 ± 87% (1-13)	8 ± 50% (4-12)	8 ± 100% (0-15)	2 ± 0% (2-2)	68 ± 149% (0-170)
Calves (≤ 12 months)	22 (19-28)	22 ± 40% (13-30)	10 ± 27% (7-13)	4 ± 99% (0-8)	14 ± 125% (0-31)	62 ± 163% (0-163)
Estimated population ratios (90% confidence/prediction intervals)						
Adult bulls per 100 adult cows	57 (54-61)	48 ± 43% (27-68)	72 ± 26% (53-90)	51 ± 20% (41-62)	77 ± 86% (10-143)	54 ± 38% (34-75)
Yearlings per 100 adult cows	22 (20-26)	8 ± 88% (1-16)	17 ± 56% (7-26)	7 ± 82% (1-13)	1 ± 68% (0-2)	40 ± 174% (0-108)
Yearlings per 100 adult moose	12 (12-14)	6 ± 91% (1-11)	9 ± 45% (5-13)	4 ± 83% (1-8)	1 ± 76% (0-1)	20 ± 137 (0-48)
Calves per 100 adult cows	13 (12-16)	28 ± 45% (15-40)	21 ± 26% (15-26)	4 ± 102% (0-7)	8 ± 132% (0-20)	36 ± 104% (0-73)
% of cow-calf groups with twins	0 (0-5)	Insufficient Data	0	-	-	2 ± 165 (0-4)
Density of moose (per 1000 km²)						
Total area	337	158	106	165	-	397
Moose habitat only	**368**	**172**	**111**	**184**	**324**	**-**
Total area (km²)	973	972.6	963.9	1031.9	-	995.7
Habitable area (km²)	892	891.9	926.9	926.9	926.9	-

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

[2] A "90% confidence interval" means that, based on our survey results, we are 90% sure that the true number lies within this range of numbers. The 2021 survey estimates uses prediction intervals to measure level of confidence.

[3] Twinning Rate - the number of cows with 2 calves dividded by the total number of cows with calves. It represents what percentage of cows that had calves, had twins. In past surveys (pre 1987) cow and calf data was collcted seperately and a twinning rate could not be calculated.

[4] Suitable moose habitat is considered all areas at elevations lower than 1524m (5000ft), excluding all water bodies 0.5km² or greater in size.

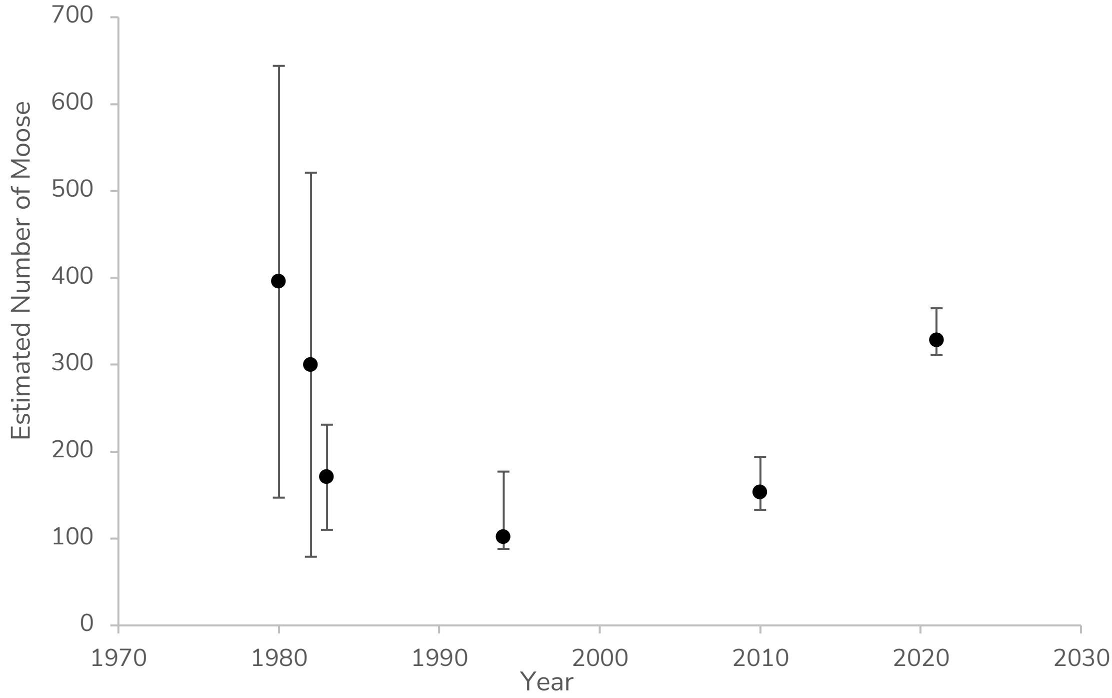

Figure 11. Estimated abundance (dots) with 90% confidence intervals (1981-2010, vertical error bars) or prediction intervals (2021) from moose surveys in the Carcross comparison area from 1980 to 2021.

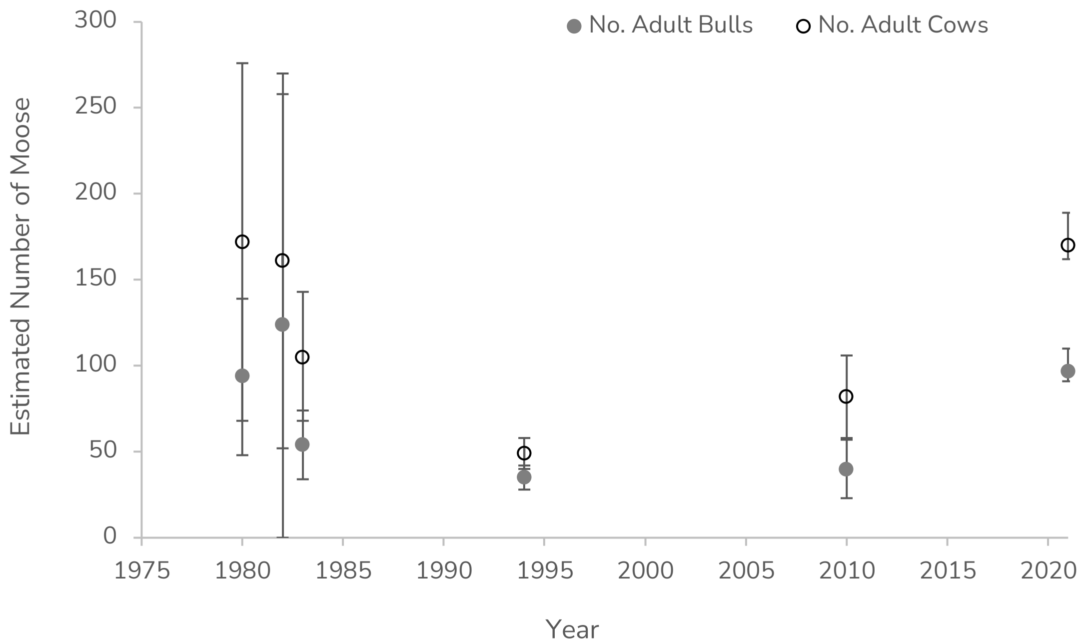

Figure 12. Estimated abundance of adult bulls (grey dots) and adult cows (white dots) with 90% confidence intervals (1981-2012, vertical error bars) or prediction intervals (2021) from moose surveys in the Carcross comparison area from 1980 to 2021.

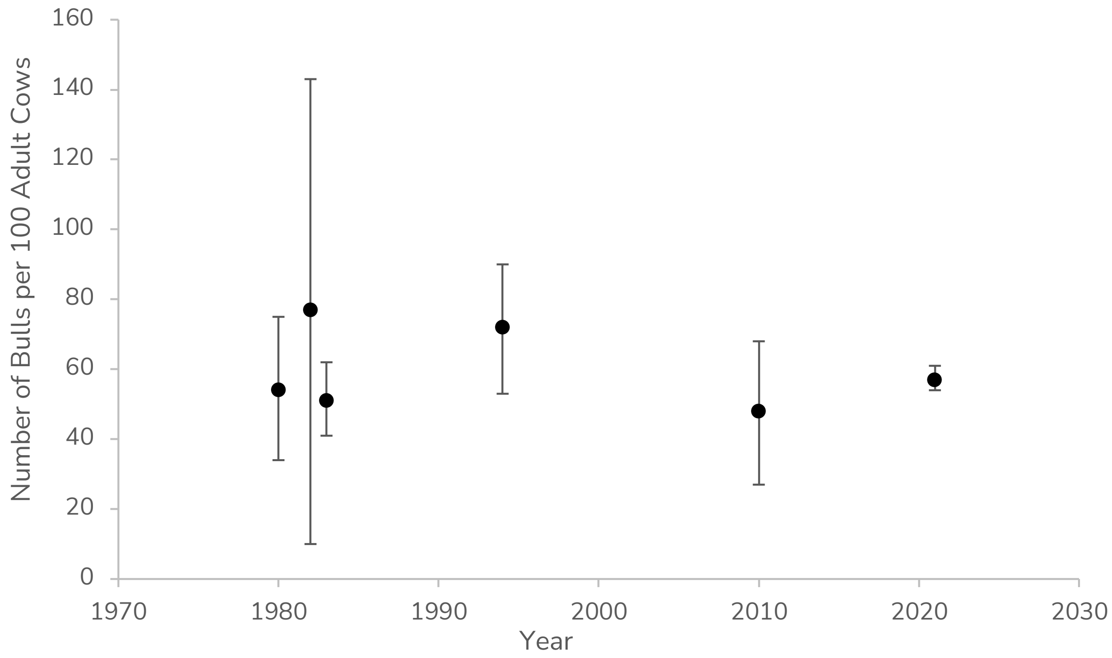

Figure 13. Estimated ratio of bulls per 100 cows (dots) with 90% confidence intervals (1981-2010, vertical error bars) or prediction intervals (2021) from moose surveys in the Carcross comparison area from 1980 to 2021.

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 harvests for moose populations at the MMU scale. Specifically, in areas where survey information is available, we estimate that 10% of the adult bull population can be sustainably harvested annually with minimal risk of a population decline (Environment Yukon, 2016).

Harvest data for licensed hunters (including resident, non-resident, and special guided hunters) in the entire Whitehorse South survey area has been recorded since 1979 (Figure 14). Moose harvest in the Fish Lake, Mt. Lorne, and Wheaton River MMUs has been restricted for licensed harvesters since 1989. Permits for licensed harvest in these areas are issued through a Permit Hunt Authorization (PHA) lottery. A total of three resident permits are issued annually in the Fish Lake MMU, four in the Mt. Lorne MMU, and four in the Wheaton River MMU, with a 5-year average (2017-2021) of 1.2, 0.8, and 1 bull(s) harvested, respectively. Additionally, a very small number of bulls are harvested in the Fish Lake MMU by non-resident hunters (an average of 1 from 2017 to 2021).

The total licensed harvest numbers for each MMU are far lower than the estimated sustainable harvest. However, our estimates do not include moose harvested by First Nation hunters, of which there are five whose Traditional Territories overlap with the Fish

Lake, Mt. Lorne, or Wheaton River MMUs. Although some First Nation governments are collecting voluntary harvest information and/or field observations, this information is incomplete or unavailable for much of the Whitehorse South area. Complete First Nation harvest data are needed to establish the total harvest rate in these 3 MMUs.

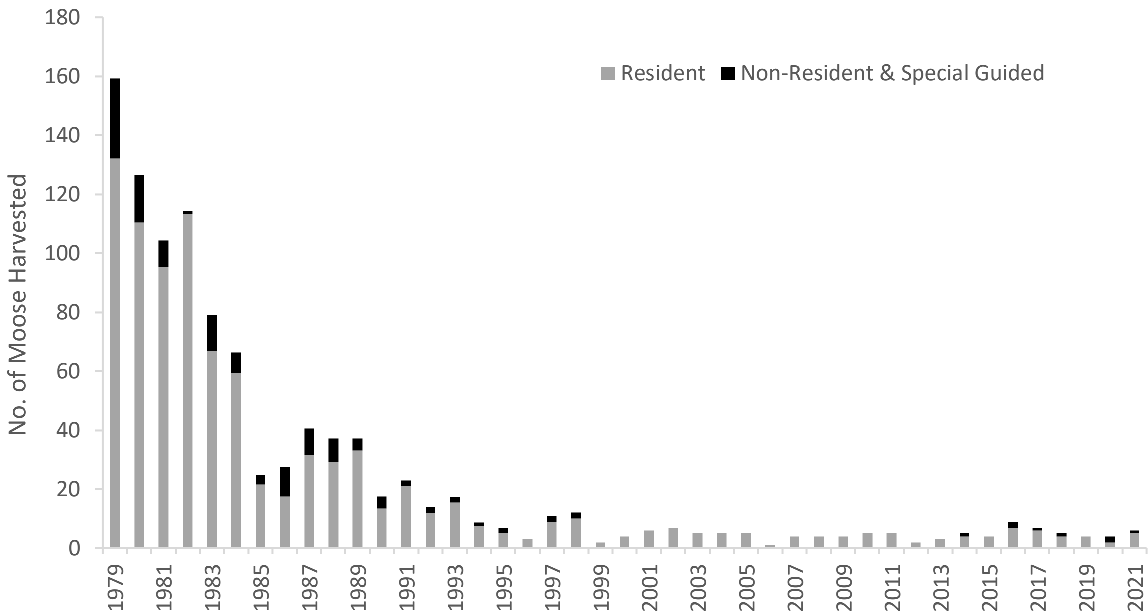

Figure 14. Annual reported licensed moose harvest from 1979 to 2021 in the entire Whitehorse South survey area (GMSs 7-13 to 7-36, and 9-01 to 9-07) by Yukon resident, non-resident and special-guided hunters. Note: the number of moose harvested does not include First Nation subsistence harvest. Prior to 1994, licensed hunters were not required to report their harvest in non-Permit Hunt Authorization (PHA) areas.

Fish Lake

Based on our results from the 2021 early-winter moose survey in the Fish Lake MMU, we estimate that 21 bulls (10% of the estimated 207 adult bulls) can be sustainably harvested annually from this population.

The 5-year average total licensed harvest (2017-2021) in the Fish Lake MMU is 2.2 bulls or 6% of the estimated sustainable harvest (Figures 15 and 16). This includes harvest from both resident hunters (5-year average, 2017-2021, is 1.2 bulls) and non-resident hunters (5-year average, 2017-2021, is 1 bull). Subsistence hunters from Kwanlin Dün First Nation, Champagne and Aishihik First Nations, Carcross/Tagish First Nation and Ta'an Kwäch'än Council also harvest moose from the Fish Lake MMU.

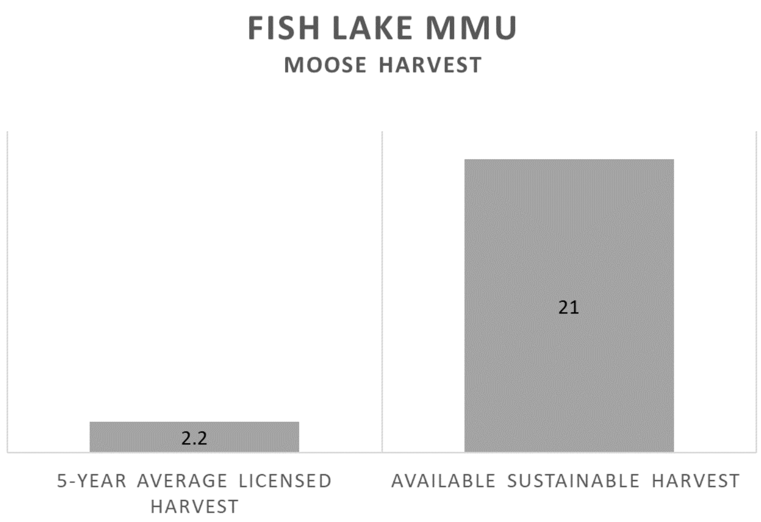

Figure 15. The average 5-year licensed harvest (2017-2021, does not include First Nation harvest) in the Fish Lake MMU. The sustainable limit of 21 bulls is based on the 2021 survey data.

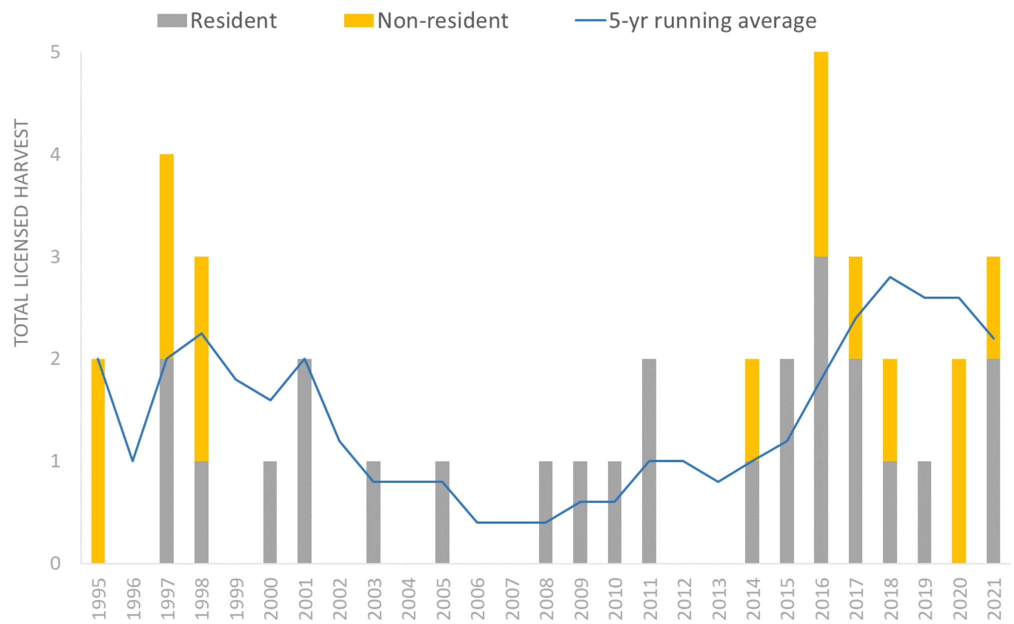

Figure 16. Total licensed harvest of moose in the Fish Lake MMU with 5-year running average. First Nation harvest is not included.

Mt. Lorne

We estimate that 23 bulls (10% of the estimated 233 adult bulls) can be sustainably harvested annually from this population.

The 5-year average total licensed harvest (2017-2021) in the Mt. Lorne MMU is 0.8 bulls or 3% of the estimated sustainable harvest (Figures 17 and 18). Subsistence hunters from Carcross/Tagish First Nation, Kwanlin Dün First Nation, Taku River Tlingit First Nation and Ta'an Kwäch'än Council also harvest moose from the Mt. Lorne MMU.

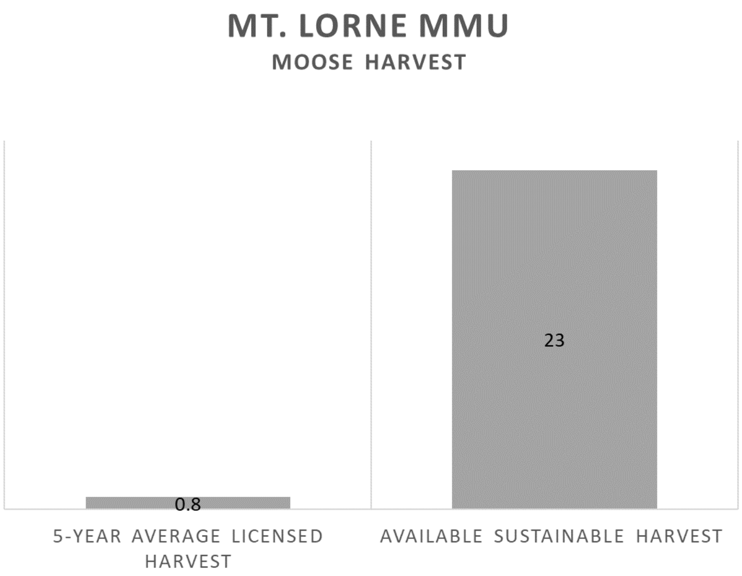

Figure 17. The average 5-year (2017-2021) licensed harvest in the Mt. Lorne MMU (does not include First Nation harvest). The sustainable limit of 23 bulls is based on the 2021 survey data.

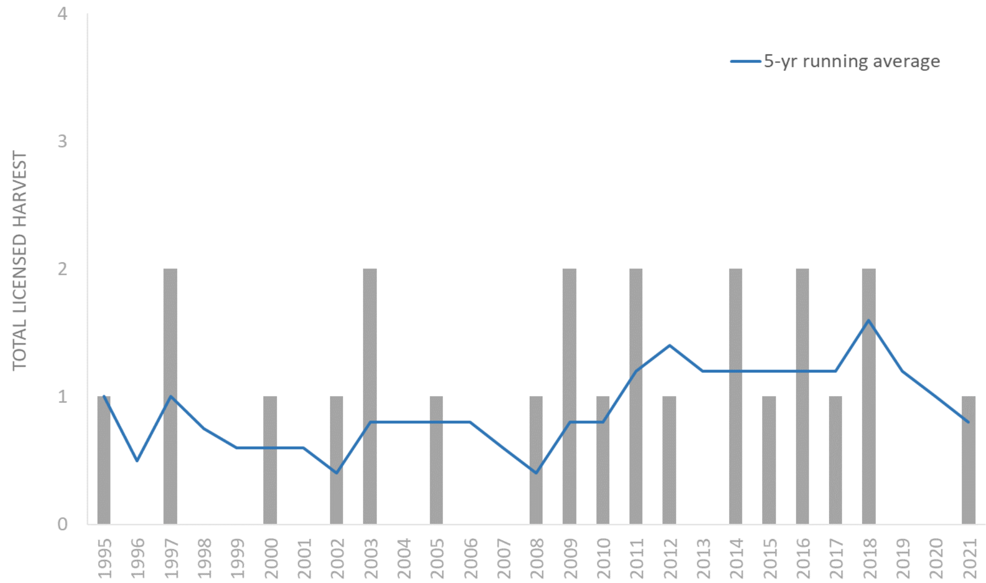

Figure 18. Total licensed harvest of moose in the Mt. Lorne MMU with 5-year running average. Non-resident harvest has not occurred in this MMU since prior to 1995. First Nation harvest is not included.

Wheaton River

We estimate that 13 bulls (10% of the estimated 131 adult bulls) can be sustainably harvested annually from this population.

The 5-year average total licensed harvest (from 2017-2021) in the Wheaton River MMU is 1.0 bull or 8% of the estimated sustainable harvest (Figures 19 and 20). Subsistence hunters from Carcross/Tagish, Kwanlin Dün, and the Taku River Tlingit First Nations also harvest moose in the Wheaton River MMU.

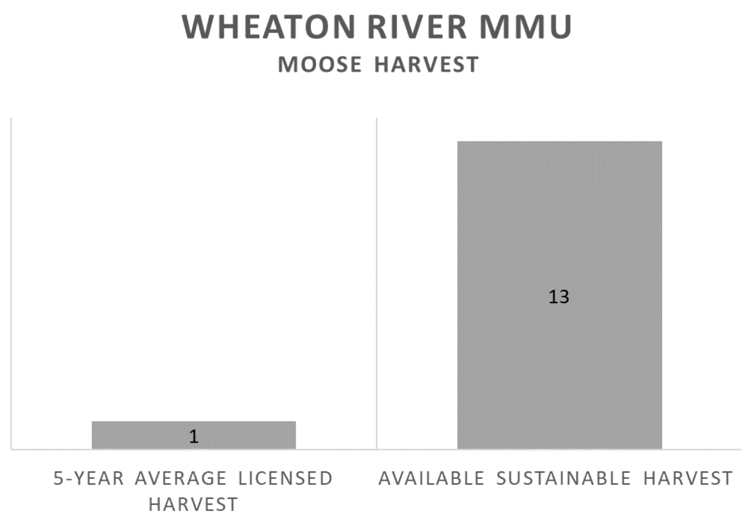

Figure 19. The total 5-year (2017-2021) licensed harvest in the Wheaton River MMU (does not include First Nation harvest). The sustainable limit of 13 bulls is based on the 2021 survey data.

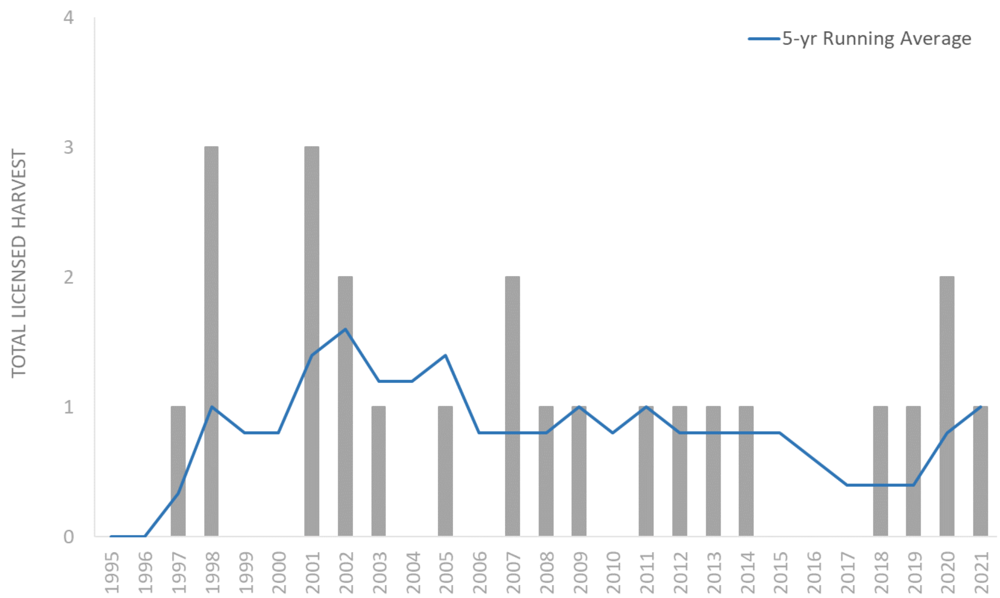

Figure 20. Total licensed harvest of moose in the Wheaton River MMU with 5-year running average. Non-resident harvest has not occurred in this MMU since prior to 1995. First Nation harvest is not included.

Access

The Whitehorse South survey area is the backyard for many recreational enthusiasts that live in or near the city of Whitehorse. Since the 1960s, access to the backcountry has been facilitated by the construction of several roads, such as the Kusawa Lake, Fish Lake, Coal

Lake, Copper Haul, and Annie Lake roads. Subsequently, roads such as these also led to the development of vast trail networks. This access, in addition to off-road vehicle technology and a growing human population, increased access for hunting as more people have been able to reach previously inaccessible areas.

Licensed hunters are restricted by PHA for all ungulate species in the Whitehorse South area, which limits the number of people accessing these areas for hunting. However, other methods of backcountry recreation (such as hiking, skiing, snowmobiling, fishing, and ATVing) are growing in popularity throughout the area. In 2021, the Government of Yukon implemented new regulations governing the use of off-road vehicles. These new regulations restrict off-road vehicle access to elevations below 1200 m, unless using a previously established trail, to reduce trail expansion and habitat degradation in alpine environments. PHAs and off-road vehicle regulations do not apply to First Nation citizens who are subsistence hunting in their traditional territories.

Other wildlife sightings

In addition to the 1208 moose that we observed within surveyed blocks, we also counted an additional 212 moose in 98 groups outside of our surveyed blocks or while travelling between blocks. However, it is notable that many of these moose may have been double counted as incidentals or later counted in surveyed blocks, so these observations cannot be added to the moose observed during the survey count. We also saw approximately 1031 caribou in 131 groups from both the Carcross and Ibex herds and 126 sheep were observed in 19 groups. Twenty-five wolves, from 5 separate packs, were observed during the survey. Three of these wolves were observed on a moose kill. Finally, we observed 34 goats, 13 deer, 1 fox, and 9 horses.

Conclusions and Recommendations

- We found the moose population densities in the Mt. Lorne MMU and the Fish Lake MMU to be above the typical range of moose densities found in the Yukon. Our results indicate that moose are recovering in these MMUs but have not yet reached historical levels.

- We found the moose density in the Wheaton River MMU is within the mid-range of typical moose densities found in the Yukon. Our results suggest that the moose population in this MMU is slower to recover, particularly in accessible areas.

- The ratio of adult bulls to adult cows in all three MMUs is high and well above the recommended minimum of 30 adult bulls per 100 adult cows identified in our Moose Management Guidelines.

- Resident harvest of moose in the Fish Lake, Mount Lorne, and Wheaton River MMUs is restricted to permit hunts and this harvest combined with non-resident harvest in Fish Lake MMU is well below the sustainable harvest. First Nation harvest information is required to assess the total harvest in these MMUs.

- Harvest management and the collection of harvest data should be discussed with the affected First Nations and Renewable Resources Councils to ensure harvest does not exceed sustainable levels.

- Moose populations should continue to be monitored closely in the Whitehorse South area.

- It is recommended that co-management partners continue to work together to develop and adopt a harvest management regime, through regulatory processes, that supports the continued growth and sustainable harvest of moose populations in the Whitehorse South area.

References

Anonymous. 1984. Current management of ungulates and their predators in the Yukon Territory. Yukon Fish and Wildlife Branch internal report. 31 pp.

Baer, A. 2010. Wolf survey in the Coast Mountains, 2009. Yukon Fish and Wildlife Branch Report TR-10-01, Whitehorse, Yukon, Canada.

Ballard, W. B. and D. G. Larsen. 1987. Implications of predator-prey relationships to moose management. Swedish Wildlife Research, Suppl. 1:581-602.

Ballard, W. B., J. S. Whitman, and D. J. Reed. 1991. Population dynamics of moose in south-central Alaska. Wildlife Monographs No. 114.

Becker, E. F. and D. J. Reed. 1990. A modification of a moose population estimator. Alces 26:73-79.

Boertje, R. D., M.A. Keech, and T.F. Paragi. 2010. Science and values influencing predator control for Alaska moose management. Journal of Wildlife Management 74:917-928.

Bowyer, R. T., V. Van Ballenberghe, and J. G. Kie. 1998. Timing and synchrony of parturition in Alaskan moose: long-term versus proximal effects of climate. Journal of Mammalogy 79:1332-1244.

Czetwertynski, S., S. Lele, and P. Solymos. In prep. Model-based optimal sampling for the estimation of abundance and composition of low-density moose populations.

Domes, C., R. Florkiewicz, and A. Baer. 2000. March 2000 Coast Mountain moose recruitment survey. Fish and Wildlife Branch file report. Department of Renewable Resources, Government of Yukon.

Domes, C. 2002. March 2002 Coast Mountain moose recruitment survey. Fish and Wildlife Branch file report. Department of Renewable Resources, Government of Yukon.

Environment Yukon. 2016. Science-based guidelines for management of moose in Yukon. Yukon Fish and Wildlife Branch Report MR-16-02, Whitehorse, Yukon, Canada.

Fish and Wildlife Planning Team. 2020. Community-based fish and wildlife work plan for the Carcross/Tagish Traditional Territory. Government of Yukon, Department of Environment, Whitehorse, YT. 40 pages.

Florkiewicz, R. 1999. 1999 Whitehorse South moose composition survey. Fish and Wildlife Branch, memo to file, April 3, 1999. Department of Renewable Resources, Government of Yukon.

Florkiewicz, R. 2004. Stratification flight of Southern Lakes Coast Mountains. Fish and Wildlife Branch memo to file, November 22, 2004. Department of Environment, Government of Yukon.

Gasaway, W. C., S. D. DuBois, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. University of Alaska, Institute of Arctic Biology, Biological Paper No. 22.

Gasaway, W. C., R. D. Boertje, D. V. Grangaard, D. G. Kellyhouse, R. O. Stephenson, and D. G. Larsen. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildlife Society Monographs No. 120.

Government of Yukon. 2022 (in prep). Coast Mountain Wolf Population Survey. Yukon Fish and Wildlife Branch Report SR-XX). Government of Yukon, Whitehorse, Yukon, Canada.

Government of Yukon. 2012. Yukon Wolf Conservation and Management Plan. Environment Yukon. Whitehorse, Yukon, Canada.

Government of Yukon, 2003. Recovery Plan for Moose in the Whitehorse/Southern Lakes Area, *DRAFT.* Environment Yukon. Whitehorse, Yukon, Canada.

Hayes, K.A. 2000. Moose in the Yukon's Coast Mountains: observations and local knowledge of long-time residents. Prepared for Yukon Fish and Wildlife Branch, 37pp.

Hoefs, M. 1974. Game surveys in south-central Yukon and an evaluation of the present degree of exploitation. Yukon Game Branch report PR-74-1. Yukon Territorial Government, Whitehorse, Yukon, Canada.

Hoefs, M. and D. Larsen. 1979. Game Management Zone 7 – moose winter survey. Wildlife Branch file 3997-5-14. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada

Jessup, L. G., S. Taylor, S. Westover, M. Clarke, K. O'Donovan, S. Czetwertynski, and R. Ward. 2014. Moose survey, Whitehorse south early-winter, 2010. Fish and Wildlife Branch technical report TR-13-14.Whitehorse, Yukon, Canada.

Jingfors, K. and R. Markel. 1987. Abundance and composition of moose in the Whitehorse south, Nisutlin and Liard east areas, November, 1986. Fish and Wildlife Branch progress report PR-87-2. Department of Renewable Resources, Government of Yukon.

Joe, L., C. Pugh, and T. Wagner. 1990. Report of The Moose and Caribou recovery Plan Subcommittee to Yukon Fish and Wildlife Management Board. Internal report to The Yukon Fish and Wildlife Management Board. 9 pp.

Johnson I, Brinkman T, Lake B and Brown C. 2017. Winter hunting behavior and habitat selection of wolves in a low-density prey system. Wildlife Biology 2017: wlb.00290.

Johnston, G. W. and H. A. McLeod. 1983. Population dynamics and early winter habitat utilization by moose (*Alces alces*) in the southwest Yukon Territory. Northern Biomes Ltd. Progress report PRC-83-3. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Kellie, K. A. and R. A. DeLong. 2006. Geospatial survey operations manual. Division of Wildlife Conservation, Alaska Department of Fish and Game. Fairbanks, Alaska, USA.

Larsen, D. 1979. Moose survey – G.M.Z. 7 – March 3, 1979. Wildlife Branch file 3997-1-11. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Larsen, D. 1982. Moose inventory in the southwest Yukon. Fish and Wildlife Branch progress report PR-82-1. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Larsen, D.G, and D.A. Gauthier. 1985. Options for increasing moose numbers, southern Yukon. Yukon Fish and Wildlife Branch internal report. 45 pp.

Larsen, D. G., D. A. Gauthier, R. L. Markel, and R. D. Hayes. 1989. Limiting factors on moose population growth in the southwest Yukon. Yukon Fish and Wildlife Branch report TR-89-7. Whitehorse, Yukon, Canada.

Larsen, D., D. Linklater, and H. Kohler. 1979. Moose survey – G.M.Z. 7 – March 1, 1979. Wildlife Branch file 3997-1-11. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Larsen, D.G., R. Markel, and R. Hayes. 1985. Management of moose and their predators in southwest Yukon – a summary of current information. Yukon Fish and Wildlife Branch internal report. 75 pp.

Larsen, D. and T. Nette. 1980. Moose census in the Lorne-Caribou Mountain area, November, 1980. Fish and Wildlife Branch report. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Maier, J.A.K., J.M.V. Hoef, A.D. McGuire, R.T. Bowyer, L. Saperstein, and H.A. Maier. 2005. Distribution and density of moose in relation to landscape characteristics: effects of scale. Canadian Journal of Forest Research. 35: 2233-2243.

Markel, R. L. and D. G. Larsen. 1983. Southwest Yukon moose survey results, November 1982 (Whitehorse north, Mt. Lorne, Teslin burn). Moose Population Research and Management Studies in Yukon. Progress Report 1983. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Markel, R. L. and D. G. Larsen. 1987a. Summary of the 1983 moose surveys in the Kluane, Haines Junction, Whitehorse south, Teslin burn and Mt. Lorne areas. Fish and Wildlife Branch progress report PR-87-5. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Markel, R. L. and D. G. Larsen. 1987b. Southwest Yukon moose survey results, November, 1982. Fish and Wildlife Branch progress report PR-87-6. Department of Renewable Resources, Government of Yukon. Whitehorse, Yukon, Canada.

Southern Lakes Wildlife Coordinating Committee. 2012. Regional Assessment of Wildlife in the Yukon Southern Lakes Region: Volume 2: Species Status Assessment. Environment Yukon, Whitehorse, Yukon.

Van Ballenberghe, V. 1987. Effects of predation on moose numbers: a review of recent North American studies. Swedish Wildlife Research, Suppl. No. 1, 431-460.

Van Ballenberghe, V., and W. B. Ballard. 1994. Limitation and regulation of moose populations: the role of predation. Canadian Journal of Zoology 72: 2071-2077.

Westover, S. 2004. Whitehorse South/Carcross moose recruitment survey. Fish and Wildlife Branch file report. Department of Environment, Government of Yukon.

Yukon Ecoregions Working Group, 2004. Yukon Plateau-Central. *In:* Ecoregions of the Yukon Territory: Biophysical properties of Yukon landscapes, C.A.S. Smith, J.C. Meikle and C.F. Roots (eds.), Agriculture and Agri-Food Canada, PARC Technical Bulletin No. 04-01, Summerland, British Columbia, p. 187-188

Yukon Ecoregions Working Group, 2004. Yukon Southern Lakes. *In:* Ecoregions of the Yukon Territory: Biophysical properties of Yukon landscapes, C.A.S. Smith, J.C. Meikle and C.F. Roots (eds.), Agriculture and Agri-Food Canada, PARC Technical Bulletin No. 04-01, Summerland, British Columbia, p. 207-218

Yukon Fish and Wildlife Branch Report 2017. Grizzly bear population in the Southern Lakes region 2012–2013: Final report on population analysis. SR-17-01, Whitehorse, Yukon, Canada.

Appendices

Appendix 1. Analysis and models used to estimate the abundance and composition of MMUs and comparison areas in the Whitehorse South Survey Area from November 2021 survey data.

Overview

We estimated abundance and composition of moose in 3 Moose Management Units (MMUs, Mount Lorne, Fish Lake, and Wheaton River) and 2 comparison areas with a three-staged approach using data from the Whitehorse South survey area (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 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 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 1082 *Used* sub-blocks and 120,500 *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 400 m scale included 4 covariates (Table 2). Specifically, moose selected for sub-blocks where the majority landcover (30 m scale) was shrub. Moose further selected for elevations between 1,200 m and 1,500 m, slopes between 5 and 25 degrees, and sub-blocks with the presence of tall shrub (30 m 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 (4 km x 4 km 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 subalpine or boreal high 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 subalpine and boreal high habitat in the survey block.

We used these abundance models to predict the number of moose in the remaining unsurveyed blocks. Estimates for the Fish Lake MMU, Wheaton River MMU, and the Whitehorse South comparison area used the combined data from these 2 MMUs (Table 5). Estimates for the Mount Lorne MMU and the Carcross comparison area used data from the entire survey area (Table 6). 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 7). Estimates for the Fish Lake MMU, Wheaton River MMU, and the Whitehorse South comparison area used the combined data from these 2 MMUs (Table 8). Estimates for the Mount Lorne MMU and the Carcross comparison area used data from the entire survey area (Table 9). We applied these models to un-surveyed 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 Whitehorse South survey area, 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, 30 m x 30 m resolution, Canada Center for Remote Sensing (CCRS), Canadian National Fire Database. Natural Resources Canada.
Elev	Mean elevation in km of the sub-block.	Canadian Digital Elevation Model, 30 m x 30 m resolution. Natural Resources Canada.
Slope	Mean Slope in degrees of the sub-block.	Canadian Digital Elevation Model, 30 m x 30 m resolution. Natural Resources Canada.
TallShrub_01	Binary covariate describing the presence (1) or absence (0) of tall shrub cover type.	ABoVE Landsat-derived Dominant landcover 2014, 30 m x 30 m resolution, NASA.
Subalpine	Percent of the survey block with subalpine habitat.	Bioclimate Map from the Yukon Ecological Landscape Classification (ELC) Program.
Subalpine_BorealH	Percent of the survey block with subalpine or boreal high habitat.	Bioclimate Map from the Yukon Ecological Landscape Classification (ELC) Program.

Table 2. List of top-ranking models describing the Resource Selection of moose at the 400m scale in the Whitehorse South survey area (November 2021) with associated AIC scores and model weights.

Model	*df*	AIC	ΔAIC	*w*
Landcover5 + Elev + Elev^2 + Slope + Slope2 + TallShrub_01	10	12174.4	0.0	1.00
Landcover5 + Elev + Elev^2 + TallShrub_01	8	12191.7	17.2	0.00
Landcover5 + Elev + Elev^2 + Slope + Slope2	9	12245.5	71.0	0.00
Landcover5 + Elev + Elev^2	7	12259.6	85.2	0.00
Landcover5 + TallShrub_01	6	12623.0	448.6	0.00
Landcover5 + Slope + Slope^2	7	12733.6	559.2	0.00
Landcover5	5	12800.8	626.4	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 Whitehorse South survey area, November 2021 (n = 1082, Log-likelihood =-6077.2). We used this model to generate RSPF values for unsurveyed sub-blocks.

	Estimate	Standard Error	*Z*	*P*
(Intercept)	-35.191	2.392	-14.71	0.000
Landcover5				
Deciduous or Mixed Forest	0.060	0.188	0.32	0.748
Shrub	0.371	0.070	5.31	0.000
Other Habitat	-0.585	0.103	-5.67	0.000
Non-Habitat	-1.505	0.183	-8.23	0.000
Elev	44.428	3.729	11.92	0.000
$Elev^2$	-16.379	1.439	-11.38	0.000
TallShrub_01	0.924	0.120	7.72	0.000
Slope	0.074	0.019	3.81	0.000
$Slope^2$	-0.002	0.001	-2.95	0.003

Table 4: List of best models describing the number of moose observed in survey blocks in the Whitehorse South survey area (November 2021) with associated AIC scores and model weights.

Model		Distribution	*df*	AIC	ΔAIC	*w*
Count Covariates	ZI Covariates					
Summed RSPF + Subalpine	Subalpine_BorealH	ZINB	6	752.5	0.00	0.88
Summed RSPF	Subalpine_BorealH	ZINB	4	751.8	5.29	0.05
Summed RSPF		NB	3	756.8	16.37	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 Fish Lake Moose Management Unit (MMU), Wheaton River MMU, and Whitehorse South comparison area, November 2021 (n = 151; Log-likelihood =-362.5).

	Estimate	Standard Error	*Z*	*P*
Count model coefficients (negbin with log link):				
(Intercept)	0.935	0.271	3.455	0.001
Summed RSPF	0.389	0.216	1.802	0.072
Subalpine	0.587	0.440	1.335	0.182
Log(theta)	0.238	0.322	0.739	0.460
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	2.282	1.137	2.007	0.045
Subalpine_BorealH	-5.144	2.143	-2.401	0.016

Table 6. Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed blocks (approximately 16 km^2) in the Mount Lorne Moose Management Unit (MMU), and Carcross comparison area, November 2021 (n = 201; Log-likelihood =-539.6).

	Estimate	Standard Error	*Z*	*P*
Count model coefficients (negbin with log link):				
(Intercept)	0.992	0.221	4.483	0.000
Summed RSPF	0.649	0.191	3.401	0.001
Subalpine	0.314	0.383	0.821	0.412
Log(theta)	-0.020	0.168	-0.121	0.904
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	3.047	1.360	2.240	0.025
Subalpine_BorealH	-8.036	3.120	-2.575	0.010

Table 7. List of top-ranking models describing the composition of moose observed in the Whitehorse South survey area (November 2021) with associated AIC scores.

Model	AIC	ΔAIC	*w*
Summed RSPF	876.4	0.0	0.48
Null	877.6	1.2	0.27
Subalpine	877.7	1.3	0.25

Table 8. Compositional model regression estimates for moose in the Whitehorse South survey area, November 2021 (n = 151, Log-likelihood =-428.2). This model was used to generate the composition and related prediction intervals for the Fish Lake Moose Management Unit (MMU), Wheaton River MMU, and Whitehorse South comparison area.

	Estimate	Standard Error	*Z*	*P*
(Intercept):BULL_LARGE	1.038	0.335	3.102	0.002
(Intercept):BULL_SMALL	-1.838	0.547	-3.363	0.001
(Intercept):COW_1C	-0.069	0.421	-0.165	0.869
(Intercept):COW_2C	-3.287	1.329	NA	NA
(Intercept):LONE_COW	1.228	0.329	3.728	0.000
SUM_RSPF_F:BULL_LARGE	0.057	0.251	0.227	0.820
SUM_RSPF_F:BULL_SMALL	0.984	0.364	2.700	0.007
SUM_RSPF_F:COW_1C	-0.042	0.318	-0.131	0.896
SUM_RSPF_F:COW_2C	0.326	0.940	0.346	0.729
SUM_RSPF_F:LONE_COW	-0.005	0.248	-0.019	0.985

Table 9. Compositional model regression estimates for moose in the Whitehorse South survey area, November 2021 (n = 151, Log-likelihood =-428.2). This model was used to generate the composition and related prediction intervals for the Mount Lorne Moose Management Unit (MMU) and Carcross comparison area.

	Estimate	Standard Error	*Z*	*P*
(Intercept):BULL_LARGE	0.556	0.255	2.179	0.029
(Intercept):BULL_SMALL	-1.928	0.401	-4.806	0.000
(Intercept):COW_1C	-0.059	0.316	-0.188	0.851
(Intercept):COW_2C	-3.370	1.002	-3.362	0.001
(Intercept):LONE_COW	0.679	0.250	2.719	0.007
SUM_RSPF_F:BULL_LARGE	0.478	0.192	2.486	0.013
SUM_RSPF_F:BULL_SMALL	1.082	0.271	3.993	0.000
SUM_RSPF_F:COW_1C	-0.050	0.245	-0.203	0.839
SUM_RSPF_F:COW_2C	0.388	0.718	0.540	0.589
SUM_RSPF_F:LONE_COW	0.530	0.188	2.815	0.005

Literature Cited:

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodal inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Czetwertynski, S., S. Lele, and P. Solymos. *In Prep.* Model-based optimal sampling for the estimation of abundance and composition of low density moose populations.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Wagenmakers, E.-J., and S. Farrell. 2004. AIC model selection using Akaike weights. Psychonomic Bulletin & Review 11(1), 192-196.

Yee T. W. 2010. The VGAM Package for Categorical Data Analysis. Journal of Statistical Software 32(10), 1-34. URL http://www.jstatsoft.org/v32/i10/.

Zeileis, A., C. Kleiber, S. Jackman. 2008. Regression Models for Count Data in R. Journal of Statistical Software 27(8). URL http://www.jstatsoft.org/v27/i08/