Yukon

SR-23-02

Moose Survey

Upper Klondike Highway Moose Management Unit early winter 2017

August 2023

Moose survey:
Upper Klondike Highway Moose Management Unit, early winter 2017

Government of Yukon
Fish and Wildlife Branch
SR-23-02

Authors
Mark O'Donoghue and Sophie Czetwertynski

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

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Summary

- We conducted an early-winter survey of moose in the area south-west and west of Mayo and north of Pelly Crossing from October 31 to November 10, 2017, using helicopters. The main purposes of this survey were to estimate the abundance, distribution and composition of the moose population in the survey area and in the entire Upper Klondike Highway Moose Management Unit (MMU).
- We counted all moose in survey blocks that covered about 35% of the survey area. We found a total of 483 moose: 133 adult bulls, 248 adult and yearling cows, 32 yearling bulls, and 70 calves.
- We calculated a population estimate of 700 moose (90% confident that the population was between 619 and 816) for the survey area. This number is equal to a density of about 118 moose per 1,000 km² over the whole area, or 122 per 1,000 km² in suitable moose habitat. This is on the low end of the range of typical Yukon moose densities of 100-250 moose per 1,000 km²of moose habitat.
- We estimated that there were about 35 calves and 29 yearlings for every 100 adult cows in the survey area. These ratios indicate that survival of calves born in 2017 and 2016 were about average and above average, respectively, compared to other Yukon areas surveyed.
- We estimated that there were about 57 adult bulls for every 100 adult cows in the survey area. This adult sex ratio is slightly lower than the Yukon average from surveyed populations, but well above the minimum threshold of 30 bulls per 100 cows identified in our moose management guidelines.
- The 2017 population estimate for the survey area is lower than the last estimate in 2002 and, while the trend is not statistically significant, several lines of evidence suggest that the moose population has declined during that 15-year period.
- Available harvest information suggests that the total harvest of moose in the Upper Klondike Highway MMU is above the maximum sustainable level recommended in our moose management guidelines.

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Introduction

This report summarises the results of the early-winter survey of moose in a part of the Upper Klondike Highway Moose Management Unit (MMU; Fig. 1), conducted October 31 to November 10, 2017. The purpose of the survey was to estimate numbers, distribution, and composition by age and sex of the moose population in the survey area and in the entire Upper Klondike Highway Moose Management Unit (MMU).We use this information with available moose harvest data to evaluate the current harvest rate.

Previous surveys

The Yukon Fish and Wildlife Branch has previously conducted three other surveys in the same area as this survey: a full census in November 2002 (O'Donoghue et al. 2003), an early-winter habitat survey in November 2006 (O'Donoghue 2010), and a late-winter habitat survey in March 2010 (O'Donoghue et al. 2012).

There have also been other surveys in previous years in areas that overlapped with this survey area (Fig. 2). We conducted early-winter surveys that included areas south and west of Mayo in 1988, 1993, and 1998 (results in Larsen et al.1989, Ward and Larsen 1994, and Yukon Fish and Wildlife Branch file reports), and in the Pelly Crossing area in 1995 (results in Yukon Fish and Wildlife Branch file reports). Early winter is the best time of year to estimate abundance of moose because of their concentration in high-altitude open habitats. Bull moose still have antlers at this time of year, so early-winter surveys also allow us to more accurately estimate the proportion of bulls in the population.

We have monitored over-winter survival of moose calves with late-winter surveys in the Mayo area, including the northern part of this year's survey area, from 1993 to 1999 and in 2003 (Sinnott and O'Donoghue 2003 and Yukon Fish and Wildlife Branch file reports). In March 2001, we also flew over all but the northern-most portion of this year's survey area to map late-winter distribution of moose (O'Donoghue 2005). Finally, we have worked with local residents to conduct ground-based monitoring of composition of the Mayo-area moose population each fall since 2001 (O'Donoghue and Bellmore 2014).

Community involvement

Residents of the Mayo and Pelly Crossing areas have consistently placed a high priority on monitoring the abundance, distribution, and health of the local moose populations. Concerns about high hunting pressure and fewer moose seen in this area, which is an important hunting area for both the Selkirk First Nation and First Nation of Na-Cho Nyäk Dun, have been consistently expressed at Northern Tutchone May Gatherings. This survey was also recommended in the *Community-based Fish and Wildlife Management Work Plan for the Na-Cho Nyäk Dun Traditional Territory for 2014-2019*, which was developed cooperatively by the Mayo District Renewable Resources Council, the First Nation of Na-Cho Nyäk Dun, and the Yukon Fish and Wildlife Branch. The Selkirk Renewable Resources Council provided some of the funding for this survey and staff of the Selkirk First Nation and the First Nation of Na-Cho Nyäk Dun participated as observers.

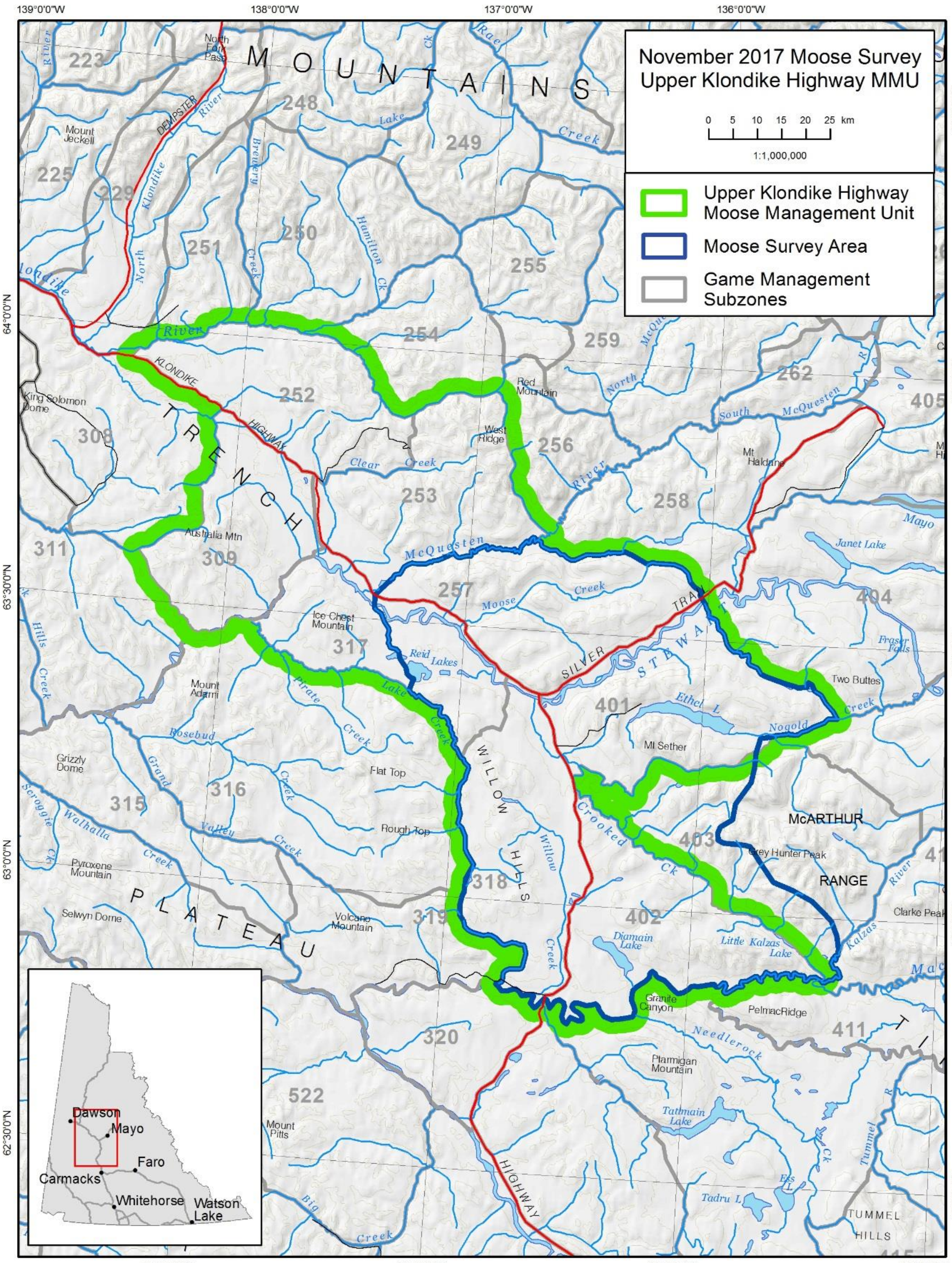

Figure 1. Upper Klondike Highway Moose Management Unit and the October-November 2017 survey area.

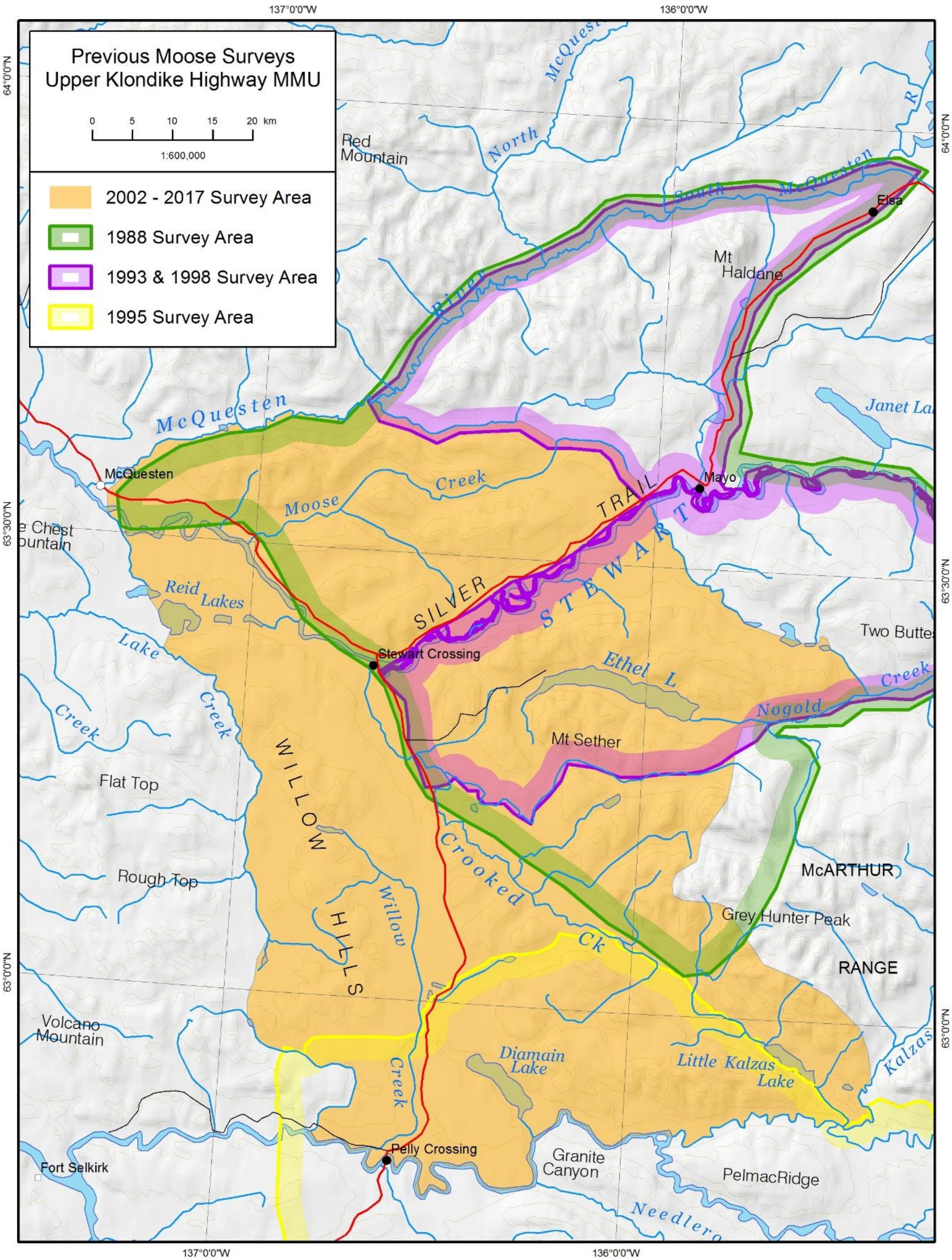

Figure 2 Previous moose surveys in the Upper Klondike Highway Moose Management Unit.

Study area

The Upper Klondike Highway survey area was situated to cover the areas most accessible and used by hunters, and to conform to the boundaries of Yukon Moose Management Units (Environment Yukon 2016). The survey area also includes the western portion of the Ddhaw Ghro Moose Management Unit (Game Management Subzone 403; Fig. 1). Moose management units were developed to monitor and manage moose at the scale of populations throughout the territory.

The Upper Klondike Highway Moose Management Unit is about 8,662 km^2, and includes Game Management Subzones (GMSs) 252, 253, 257, 309, 317, 318, 401, and 402 (Figure 1). The survey area within this Moose Management Unit is about 5,956 km^2 (69% of the MMU). The north border runs east along the McQuesten River and Bear Creek. The eastern border is Talbot Creek, south to Nogold Creek, and along the western flank of the McArthur Range, south to the Macmillan River. The Macmillan and Pelly rivers are the southern border, and Grayling and Lake creeks and Reid Lakes make up the western border.

Most of the study area (about 5,759 km^2) is considered suitable moose habitat, except for approximately 3% of the area, which includes large water bodies (0.5 km^2 or more in size) and land at or over 1,524 m (5,000 feet) in altitude. The study area consists mostly of rolling hills and plateaus, dissected by numerous creeks, in the drainages of the Stewart and Pelly Rivers. Most of the area is forest-covered with black and white spruce, lodgepole pine, aspen, and paper birch. Willow and dwarf birch shrub habitats, alpine tundra, and unvegetated rocky areas typify the higher plateaus, scattered throughout the study area, especially around Ethel Lake, the west flank of the McArthur Range, and the ranges north of the Macmillan River.

Old and recent burns occur throughout the study area (Fig. 3), and these vary in quality as moose habitat. The most recent large fires were a 74 km^2 burn along Crooked Creek in 2015, a 284 km^2 burn south-east of Ethel Lake in 2013, a 503 km^2 burn north-east of Diamain Lake in 2004, a 745 km^2 burn south-west of Stewart Crossing in 1998, and a 90 km^2 burn in the north of the survey area north of Moose Creek in 1998.

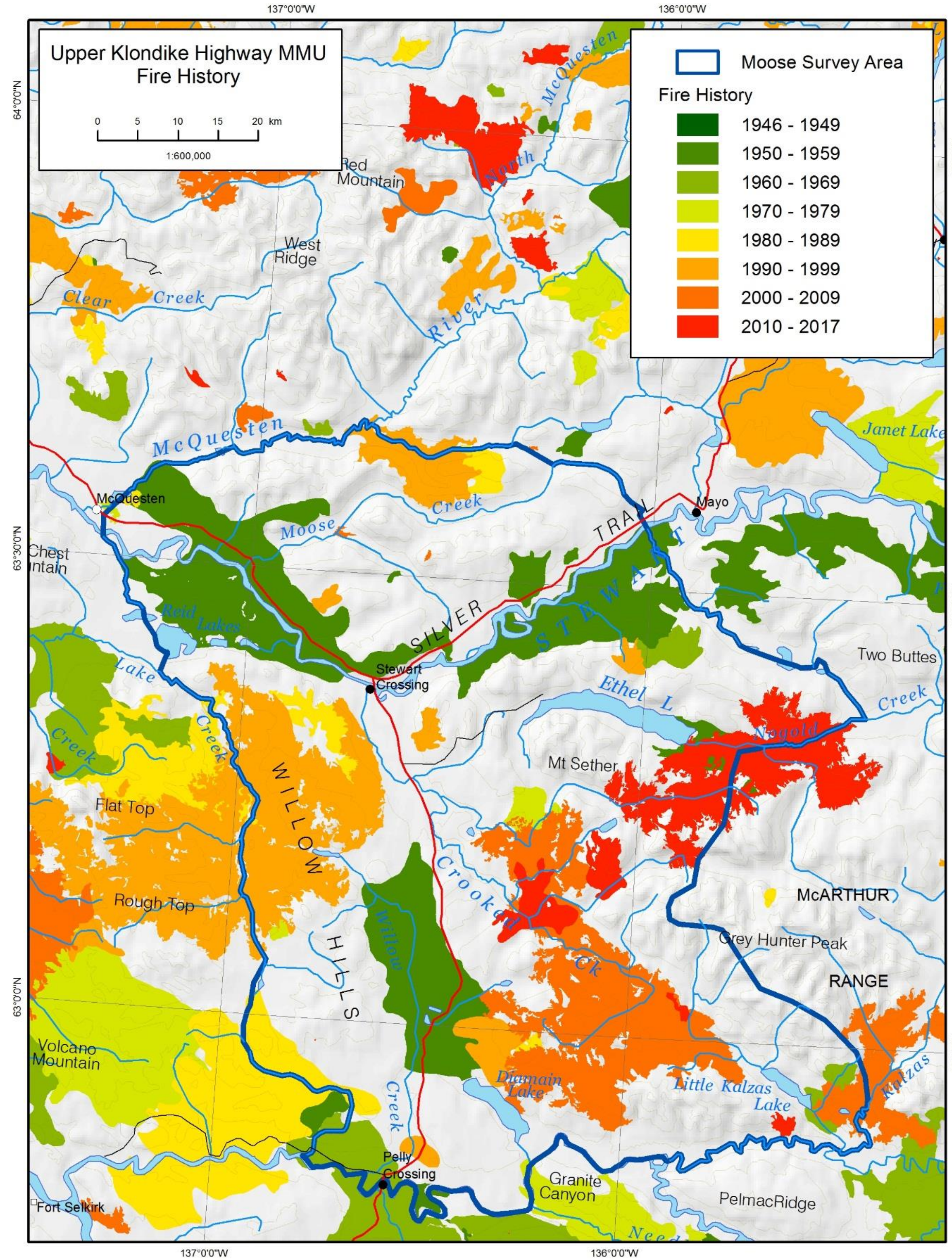

Figure 3 Upper Klondike Highway moose survey area fire history.

Methods

We use a model-based technique to survey and estimate moose populations and composition in the territory (Czetwertynski et al., *in prep,*; Appendix 1). Specifically, we develop models that relate moose abundance to information in individual survey blocks flown during the survey. This information is a combination of available local knowledge and landscape and habitat characteristics. These models are then used to estimate moose abundance over the areas where we did not count moose. We use any observed relationships between 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 15.4-15.8 km² (2' latitude x 5' longitude) in size. We select specific blocks and use helicopters to fly transects that are about 350 to 400 m wide (search intensity of about 2 minutes per km²) and count and classify every moose observed. Generally, we survey approximately 30% of the blocks within a survey area. During ferries, all survey staff record observations about moose habitat quality and moose abundance in as many different survey blocks as possible.

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

In phase 1, we use any available local knowledge and information from previous 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.

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

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

Within blocks selected for sampling, we classify all moose by age (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 confidence intervals or prediction intervals do not overlap.

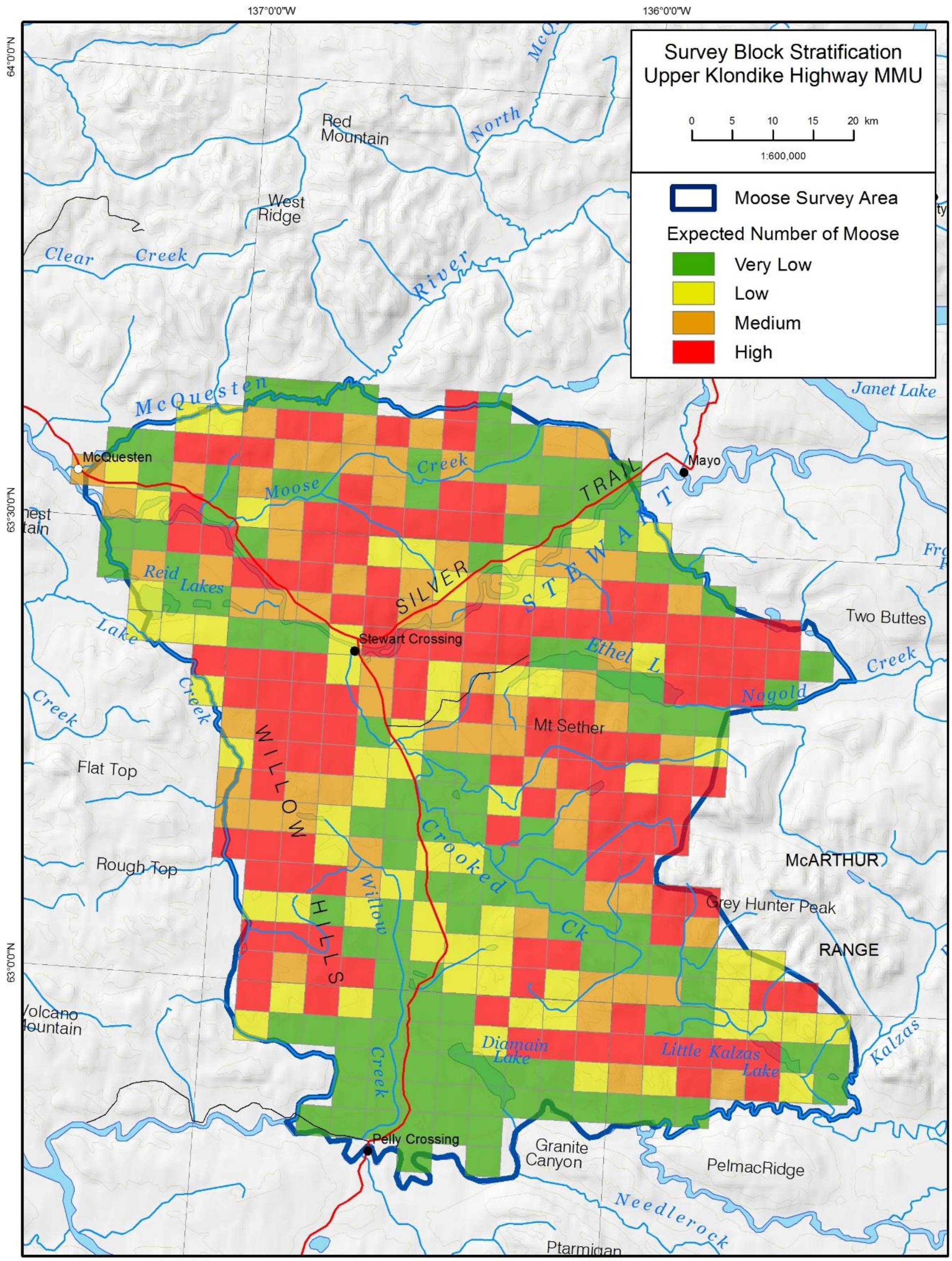

Figure 4 Survey block stratification in the 2017 Upper Klondike Highway moose survey area, based on local knowledge and previous surveys. This data, along with habitat and landscape characteristics, informed selection of blocks to survey.

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Weather and snow conditions

Weather conditions were mixed but mostly good for this survey. Between October 31 and November 10, we were unable to fly on two full days because of low clouds. The weather was mostly clear on six of the nine days we flew, although we did encounter some low-lying fog that we had to work around on some days. Temperatures ranged from -31°C to -1°C. Winds were mostly mild; stronger winds were encountered on only two days of flying.

Snow cover was complete and at low to intermediate depths, but some south-facing slopes had taller ground vegetation still showing. We had fresh snow right before the survey started and on three days during the survey, which aided in spotting fresh tracks. Light conditions ranged from flat to bright.

Results and discussion

Stratification

We classified 125 (32%) of the 383 survey blocks as high, 68 (18%) as medium, 65 (17%) as low, and 125 (32%) as very low expected abundance of moose (Fig. 4).

Most of the blocks with higher expected numbers of moose were located in the mountainous areas along the western flanks of the McArthur Range, around Ethel Lake, north of the Pelly and Macmillan rivers, and north of Stewart Crossing; and in 1990s burns in the Willow Hills. Compared to some other areas with extensive subalpine habitat that attract moose in the early winter, previous surveys have shown that moose tend to be more dispersed in the rolling hills with scattered burns that typify the Upper Klondike Highway Moose Management Unit at this time of year. It was therefore more difficult to accurately stratify the survey blocks.

Coverage

We counted moose in 135 of the 383 blocks, or about 35% of the total area and flew all blocks where our models predicted high numbers of moose (Fig. 5).

It took us about 75.3 hours to count moose in these blocks, for a search intensity of 2.15 minutes per km^2. We used another 37.8 hours of helicopter time to ferry between survey blocks, our fuel cache at Pelly Crossing, and back and forth to Mayo.

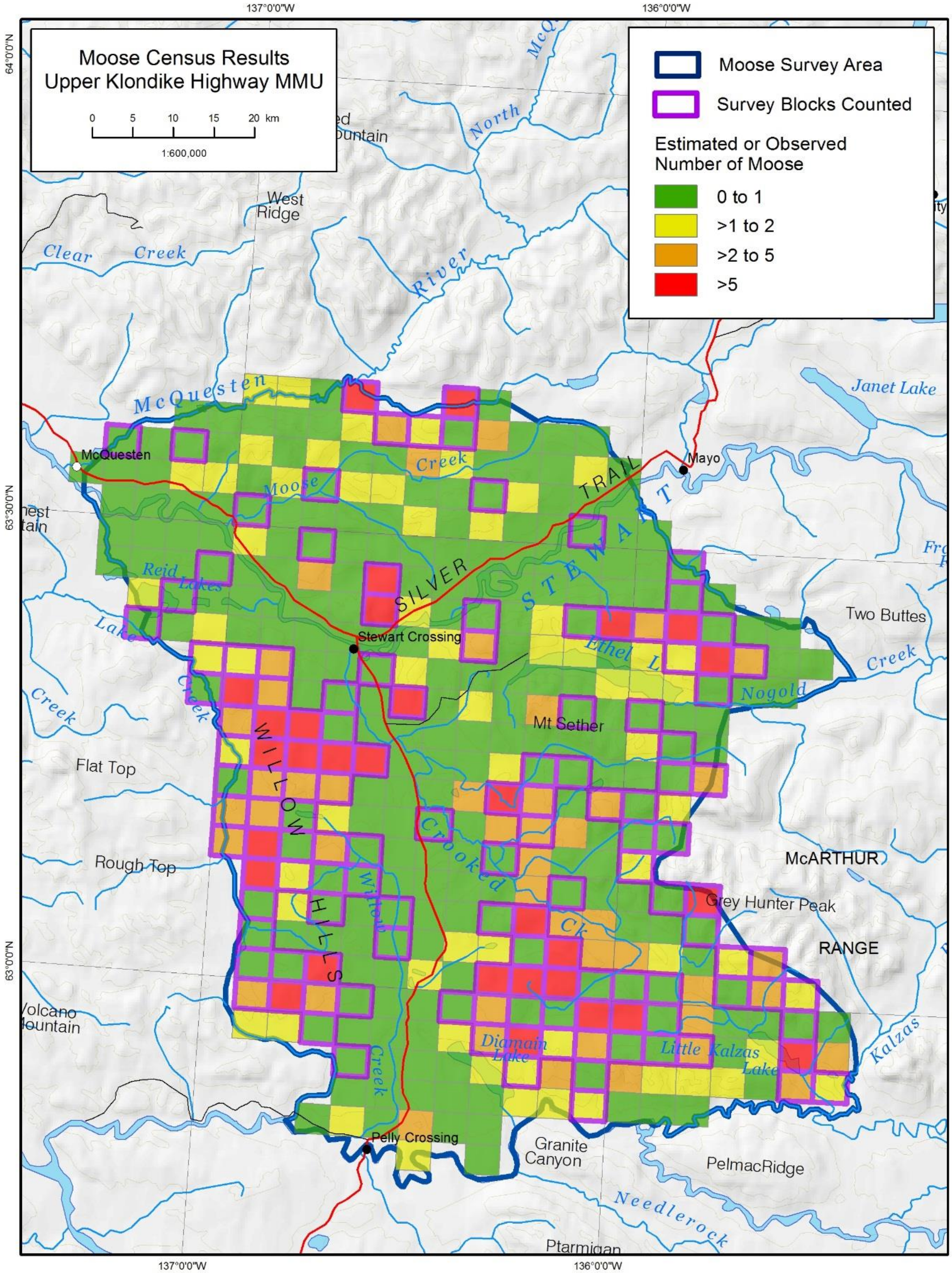

Figure 5 Moose census results in the 2017 Upper Klondike Highway moose survey area. Observed numbers of moose were counted by helicopter. Predicted numbers are based on models developed from the survey information collected.

Table 1. Observations of moose made in survey blocks during the Upper Klondike Highway Moose Management Unit survey, October-November 2017.

	Total
Number of blocks counted	135
Number of adult bulls	133
Number of adult and yearling cows*	248
Number of yearling bulls	32
Number of calves	70

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

Observations of moose

We counted a total of 483 moose, 28% of them adult bulls, 51% adult and yearling cows, 7% yearling bulls, and 14% calves (Table 1). We observed an average of 230 moose for every 1,000 km² searched. These values (total number and composition by age and sex) cannot be directly used as estimates in un-surveyed blocks because our sampling was biased towards blocks with greater numbers of moose.

Distribution of moose

Moose were widely distributed in the survey area; with the highest numbers observed in the Willow Hills, especially in the northern 1998-burned area, in the hilly terrain west of the McArthur Range that burned in 2004, and in the 1998 burn north of Moose Creek (Fig. 5). We also saw good moose numbers in several hilly areas with open coniferous habitat and good willow cover in the southern Willow Hills, on the ridges north and north-east of Ethel Lake, and on Ferry Hill north of Stewart Crossing. We saw relatively few moose in the 2013 and 2015 burns, in closed mature spruce, pine, and aspen forested areas and in lowland habitats of any kind.

Abundance of moose

The model that best predicted moose abundance included factors positively related to moose numbers: 1) moose selected for old burns (5 to 35 years old; moose mostly in 13 and 19-year-old burns), shrub habitats, and mixed coniferous-deciduous forests (typically, open spruce with tall willow understories, but moose seldom in mature spruce-aspen forest), 2) hilly terrain at mid-elevations (800-1200 metres), and 3) slopes less than 12˚. We also found a higher likelihood of observing no moose in a survey block if there was a high proportion of spruce and pine forest in the block (model details are in Appendix 1). This model is consistent with our observations that most moose move to higher elevation habitats with abundant willows during the early winter.

The estimated number of moose in the entire survey area, based on our census counts and model predictions, was 700, and we are 90% confident that population was between 619 and 816 (Table 2).

The estimated density of moose in the entire survey area was 118 per 1,000 km², or 122 per 1,000 km² of suitable moose habitat (Table 2). This is on the low end of the range of typical Yukon moose densities of 100-250 moose per 1,000 km² of suitable habitat (Environment Yukon 2016).

Table 2. Estimated abundance of moose, corrected for sightability (91%), in the Upper Klondike Highway moose survey area in October-November 2017.

	Best estimate*	Estimates within 90% prediction interval**
Estimated total number of moose	700	619-816
Adult bulls	180	163-203
Adult cows	362	317-418
Yearlings	92	79-107
Calves	111	95-133
Density of moose (per 1,000 km^2)		
Entire area	118	104-137
Moose habitat only***	122	108-142

* The sum of the estimated numbers of adult bulls, adult cows, yearlings, and calves is slightly different than the estimated total number of moose in the study area because we rounded off estimates from individual survey blocks in the compositional analysis to estimate numbers in each age and sex category of moose.

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

*** Suitable moose habitat is considered to be all areas at elevations lower than 1,524 m (5,000 ft.), excluding water bodies 0.5 km^2 or greater in size.

Table 3. Estimated composition of the moose population in the Upper Klondike Highway moose survey area in October-November 2017.

	Best Estimate	Estimates within 90% prediction interval*
% Adult bulls	26%	24-27%
% Adult cows	45%	43-47%
% Yearlings	13%	12-15%
% Calves	16%	15-17%
Adult bulls per 100 adult cows	57	57-62
Yearlings per 100 adult cows	29	25-33
Yearlings per 100 adults (recruitment rate)	15	14-17
Calves per 100 adult cows	35	32-39
% of cow-calf groups with twins	22%	18-27%

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

Ages and sexes of moose

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

Our survey results indicate that survival of calves born in 2017 and 2016 were about average and above average, respectively, compared to other Yukon areas surveyed. We estimated there were 35 calves and 29 yearlings for every 100 adult cows in the population (Table 3), whereas Yukon averages are 29 calves and 18 yearlings per 100 adult cows (Environment Yukon 2016). Estimates of recruitment from one survey are snapshots in time and survival varies from year to year. However, results from our last census in 2002 (O'Donoghue et al. 2003), aerial monitoring of recruitment between 1993 and 2002 (Sinnott and O'Donoghue 2003), and annual ground-based monitoring of moose since 2001 (O'Donoghue and Bellmore 2014) all suggest that long-term recruitment levels in this area are adequate to maintain a stable population.

We estimated that there were 57 adult bulls for every 100 adult cows in the survey area (Table 3). This is slightly lower than the Yukon average of 64 bulls per 100 adult cows, but well above the minimum level of 30 bulls per 100 cows recommended in the *Science-based Guidelines for Management of Moose in Yukon* (Environment Yukon 2016).

Table 4 Comparison of the results* of the 2002 and 2017 early-winter moose surveys in the Upper Klondike Highway moose survey area.

	2002	**2017**
Estimated total number of moose	846	642
Adult bulls	246	165
Adult cows	404	291
Yearlings	57	84
Calves	150	102
Adult bulls per 100 adult cows	61	57
Yearlings per 100 adult cows	14	29
Calves per 100 adult cows	37	35
Density of moose (per 1,000 km^2)		
Entire area	142	118
Moose habitat only**	147	122

* For this comparison, survey results were not corrected for sightability.
** Suitable moose habitat is considered to be all areas at elevations lower than 1,524 m (5,000 ft.), excluding water bodies 0.5 km^2 or greater in size.

Moose population trend

We did not detect a statistically significant decline in the moose population within the survey area (Table 4, Fig. 6). However, several lines of evidence lead us to believe that this population did decline between 2002 and 2017.

First, our 2002 estimate is likely biased low because we flew this survey with Super Cub aircraft instead of helicopters and likely missed more animals than during the 2017 survey.

Second, the harvest rate estimated in 2002 was 5% of the total population (O'Donoghue et al. 2003) which is above recommended levels for Yukon moose populations (Environment Yukon 2016). Similarly, the harvest rate estimated in 2017 is at or above the sustainable rate (see below). In addition, there has been a decline in the number of moose taken by resident hunters in the past 20 years.

Lastly, the confidence intervals around the 2002 estimate are wide (Fig. 6) and would require a reduction of 40-50 percent in the moose population for the change to be statistically significant.

Therefore, based on the lower detection of moose in 2002, relatively high harvest rates, and the low moose density estimated in 2017, we believe that there has been a biological decline in the number of moose in the survey area. We saw a decline in estimated numbers of all age and sex categories except yearling moose (Table 4). This is consistent with observations from interviews of local residents of declining numbers of moose, number of bulls, and population health during the past decade (O'Donoghue 2018).

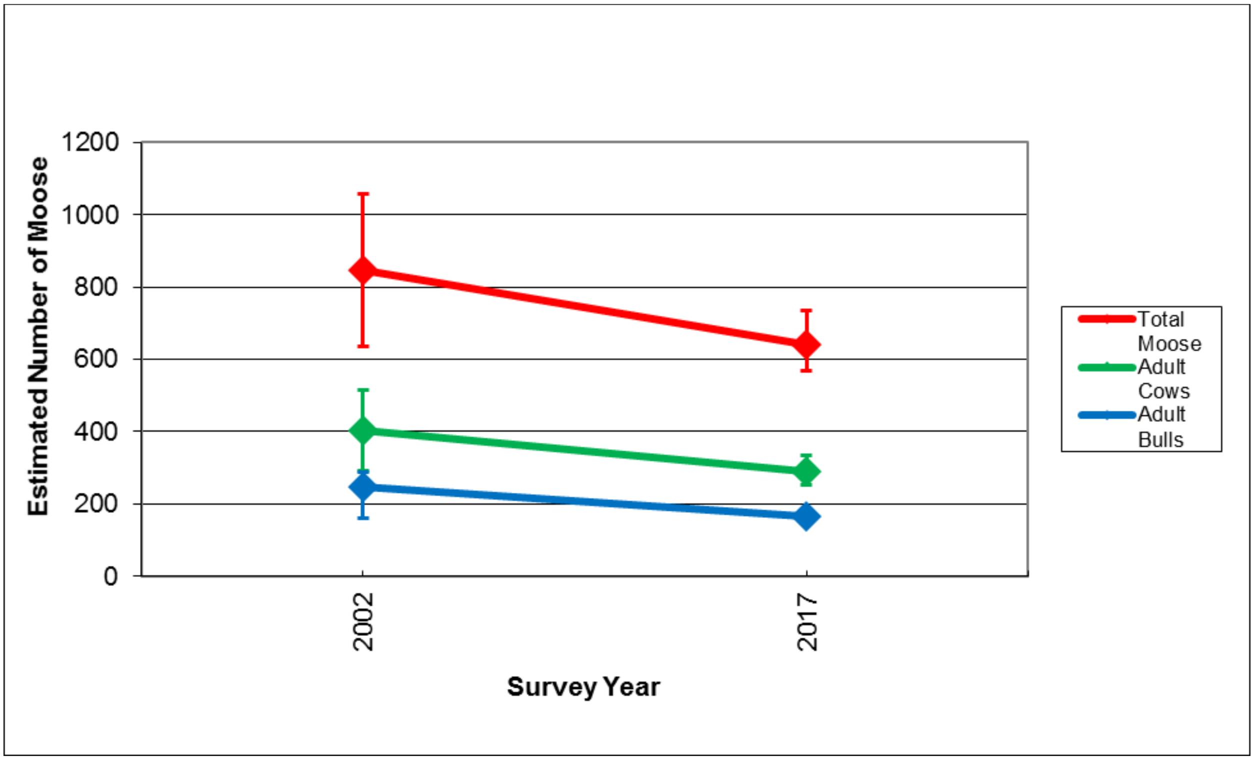

Figure 6 Trends in numbers (with 90% confidence and prediction intervals) of total moose, adult cows, and adult bulls, based on surveys in the Upper Klondike Highway Moose Management Unit in 2002, and 2017.

Harvest

Before calculating a sustainable harvest for this area, we needed to estimate the moose population for the entire Upper Klondike Highway Moose Management Unit, including unsurveyed areas (Fig. 1). We used the final model relating moose abundance to habitat characteristics in our survey area to predict moose numbers in the areas we did not survey. The unsurveyed part of the Upper Klondike Highway Moose Management Unit was north-west of the survey area (Fig. 1). It included few areas (less than 150 km²) of burns of optimal age from the 1990s and 2000s and little extensive subalpine shrub habitat, so overall predicted densities of moose were lower than in the surveyed blocks (Fig. 7).

Based on these projections, we estimate the population of moose to be 837 (90% prediction interval 683-1029) in the Upper Klondike Highway Moose Management Unit, with 198 (166-238) adult bulls. The sustainable harvest is estimated at 10% of adult bulls (Environment Yukon 2016), or 20 bulls per year.

During the 5 hunting seasons preceding this survey (2013 to 2017), the reported harvest of moose by licenced hunters in the Upper Klondike Highway Moose Management Unit averaged about 13 moose per year (Fig. 8). There has been a declining trend in harvest by licenced hunters in this area during the past 15-20 years, with average harvests of 33 in 1998-2002, 22 in 2003-2007, and 20 in 2008-2012. These figures do not include harvest data from First Nation hunters, which are reported annually at Northern Tutchone May Gatherings. First Nation harvest rates are generally similar to those of licenced resident hunters in much of the central Yukon. Total harvest is therefore likely above the recommended maximum sustainable rate for this moose management unit.

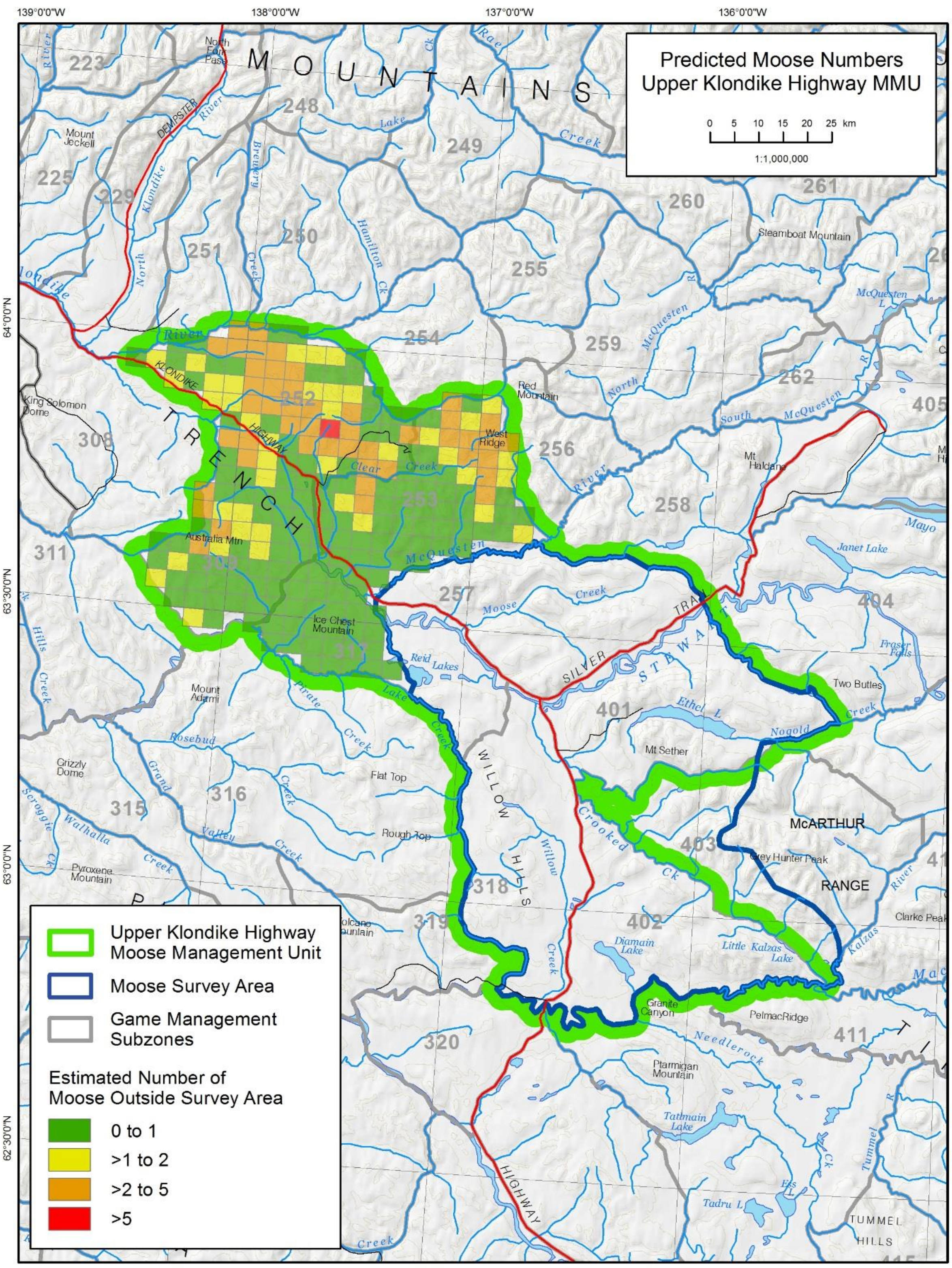

Figure 7 Predicted moose numbers in the Upper Klondike Highway Moose Management Unit outside the 2017 survey area, based on the best model from census results.

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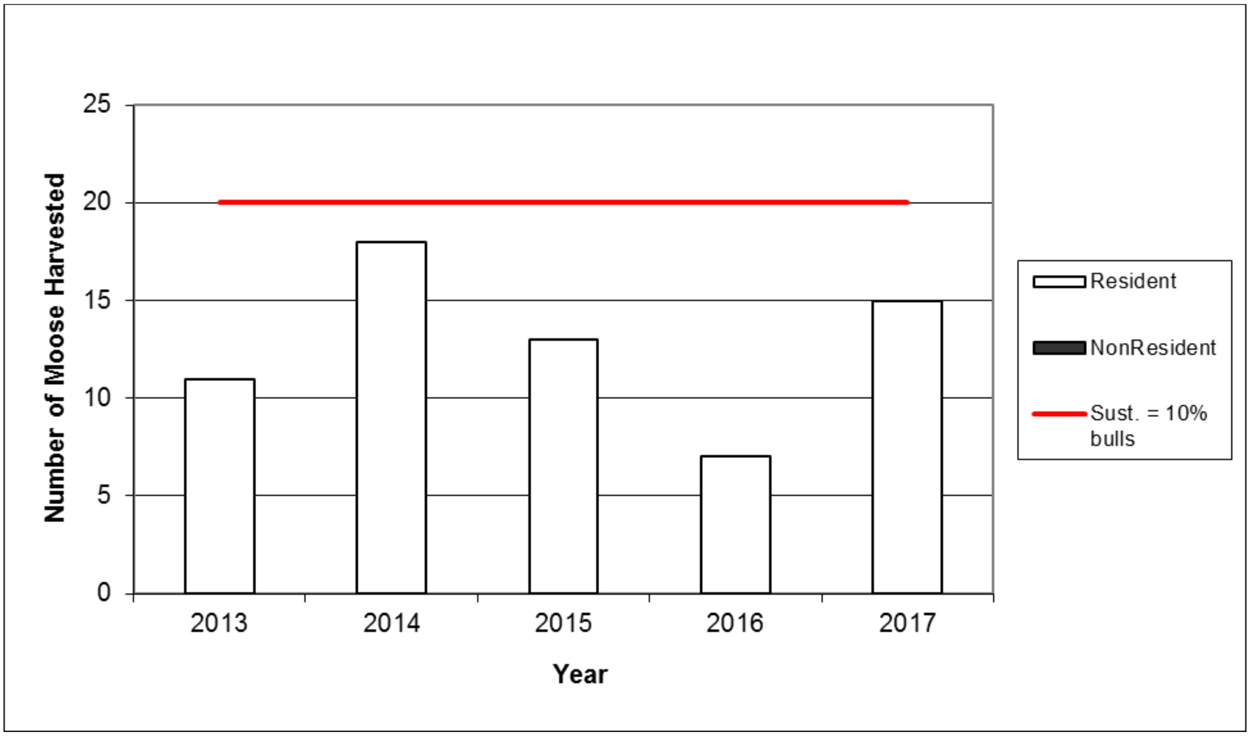

Figure 8 Harvest of moose by licenced hunters in the Upper Klondike Highway Moose Management Unit from 2013 through 2017. Resident harvest includes special-guided permits. The estimated total sustainable harvest is 20 bulls per year. First Nation harvest in the central Yukon is generally similar to licenced resident harvest.

This area is an important and accessible one for hunters from the Selkirk First Nation, First Nation of Na-Cho Nyäk Dun, as well as resident licenced hunters.

Other wildlife sightings

In addition to the 483 moose we counted during the 2017 census, we saw 108 moose in 49 groups outside the surveyed blocks or while travelling between blocks.

We also saw 153 caribou in 24 groups in alpine and subalpine habitats on the western flanks of the McArthur Range, on Mount Sether, and north-east of Ethel Lake. We saw one group of 10 thinhorn sheep on an alpine ridge west of Little Kalzas Lake. We found one grizzly bear feeding on a moose carcass north of Moose Creek and observed a pack of nine wolves chasing three caribou on Mount Sether. We also saw 2 lynx, 1 red fox, and a snowy owl.

Conclusions and recommendations

- We estimated that there was a fairly low-density moose population in the Upper Klondike Highway Moose Management Unit compared to other areas surveyed in the territory.
- We believe that the moose population in the survey area declined between 2002 and 2017.
- Survival of calves and yearlings was relatively high in 2016 and 2017 in the Upper Klondike Highway Moose Management Unit, as it has been in previous surveys.
- The ratio of adult bulls to adult cows in the survey area was slightly lower than the Yukon average.
- Present harvest of moose is likely above the maximum sustainable level for this area.
- We should discuss harvest management in the area with the affected First Nations and Renewable Resources Councils to ensure harvest rates stay within sustainable limits in this moose management unit.
- We should continue to monitor moose populations in this area using aerial and ground-based monitoring.

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Appendix 1 – Analyses and models used to estimate the abundance and composition of moose in the Upper Klondike Highway survey area and Moose Management Unit from 2017 early-winter survey data.

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

For all analyses, potential covariates were screened/sampled to ensure that they met model assumptions, were spatially representative, and biologically relevant. We used screened covariates to generate potential models and selected the best model based on Akaike's Information Criterion (AIC; Burnham and Anderson 2002) and AIC weights (Wagenmakers and Farrell 2004).

<u>1) Abundance estimation</u>

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

Our initial dataset included 413 moose locations and we generated 41,100 random locations (approximately 100 random points for each moose location). We restricted random locations to sub-blocks that were within sampled survey blocks and within sub-blocks where we observed no moose (unused sub-blocks). We intersected the moose and random locations within sub-blocks to describe the landscape and vegetation characteristics for each point location at the 400-m scale.

To estimate the RSPF, we assumed that habitat selection is similar for all age/sex animals excluding calves so calf-cow groups were considered as 1 location. Therefore, the final dataset included 355 moose locations and 4110 random locations. For simplicity, we used logistic regression to estimate coefficients for the RSPF model because of our used and unused sub-block design. The model that best described moose habitat selection at the 400-m scale included 3 covariates (Table 2). Specifically, moose selected for sub-blocks where the majority land cover (30-m scale) was burns (5 to 35 years old, Maier et al. 2005), shrubland, or mixed-forest. Moose further selected for mid-elevations elevations of 800 to 1200 meters and slopes of less than 12 degrees (Table 3). We used this model to predict RSPF values for sub-blocks in unsampled survey blocks and then summed all RSPF values within each survey block. These block-level RSPF values then represented a general "habitat selection" covariate used in further analyses and are denoted "*Sum_RSPF*".

We used Zero-Inflated Negative Binomial regression Models (ZINB) to describe the distribution of the number of moose counted in sampled survey blocks. These models best describe low density and spatially aggregated moose distribution across survey blocks in Yukon because they account for overdispersion and excess zeros. We estimated models with the zeroinfl() function in the pscl package for R (Zeileis et al. 2008). The model that best described the data included 1 count model coefficient and 1 coefficient in the zero-inflation component (Table 4). The number of moose observed in a survey block was positively correlated to *Sum_RSPF*, the "habitat selection" descriptor of the survey block. In addition, there was a greater likelihood of observing 0 moose in a survey block in blocks with greater than 80% conifer cover (*Conifer*). This model was used to predict the number of moose in unsurveyed units of the survey area (Table 5). The final population estimate and bootstrapped prediction intervals were obtained by combining the actual number of observed moose in sampled survey blocks with predictions from unsampled survey blocks (Czetwertynski et al., *in prep*). This approach enables us to generate realistic estimates of subsets of the survey area when required and allows for meaningful stakeholder participation.

<u>2) Composition estimation</u>

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

Table 1: Description of selected list of coefficients considered for Resource Selection Probability Functions (RSPFs) and models of abundance/composition of moose in the Upper Klondike Highway survey area, November 2017.

Covariate Name	Description	Source
Landcover6	Categorical covariate of the majority land cover class within sub-blocks reduced to 6 classes (conifer, deciduous, mixed forest, shrub, other, burns 5 to 35 years prior to survey).	North American Land Cover 2010 30 m x 30 m resolution, Canada Center for Remote Sensing (CCRS), Natural Resources Canada. Canadian National Fire Database.
Elevation	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
Conifer	Percent of the survey block with conifer cover type.	North American Land Cover 2010 30 m x 30 m resolution, Canada Center for Remote Sensing (CCRS), Natural Resources Canada. Canadian National Fire Database.
Selected Elev	Proportion of the survey block with elevations of 800-1200 m.	Canadian Digital Elevation Model 30 m x 30 m resolution, Natural Resources Canada.

Table 2: List of best models describing the Resource Selection of moose observed in survey sub-blocks (approximately 400 m x 400 m) in the Upper Klondike Highway survey area (November 2017) with associated AIC scores and model weights.

Model	df	AIC	ΔAIC	w
Landcover6	6	2537.8	86.7	0
Landcover6 + $Elevation^2$	8	2489.8	38.7	0
Landcover6 + $Elevation^2$ + Slope	9	2451.1	0.0	1

Table 3: Logistic regression estimates for the Resource Selection Probability Function (RSPF) used to describe locations of moose observed in surveyed sub-blocks (approximately 400 m x 400 m) in the Upper Klondike Highway survey area, November 2017 (Log-likelihood=-1216). We used this model to generate RSPF values for unsurveyed sub-blocks.

	Estimate	Standard Error	*Z*	*P*
(Intercept)	-9.267	1.158	-8.00	<0.001
Landcover6				
Deciduous	0.838	1.041	0.80	0.421
Mixed	1.232	0.233	5.29	<0.001
Shrubland	1.413	0.349	4.05	<0.001
Other	0.229	0.560	0.41	0.683
Burns(5 to 35 years old)	1.851	0.161	11.53	<0.001
Elevation	11.076	2.416	4.58	<0.001
$Elevation^2$	-4.509	1.229	-3.67	<0.001
Slope	-0.065	0.011	-6.02	<0.001

Table 4: List of best models describing the number of moose observed in survey blocks in the Upper Klondike Highway survey area (November 2017) with associated AIC scores and model weights (n=135).

Model		Distrib.	df	AIC	ΔAIC	w
Count Covariates	Zero Inflation Cov.					
Sum_RSPF	Conifer	ZINB	5	576.7	0	0.97
Sum_RSPF	Sum_RSPF	ZINB	5	584.0	7.3	0.03
Sum_RSPF + Conifer		NB	4	597.3	20.6	0.00
Sum_RSPF		NB	3	601.5	24.8	0.00
Sum_RSPF		ZINB	4	602.8	26.1	0.00

Table 5: Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed sample blocks (approximately 16 km^2) in the Upper Klondike Highway survey area, November 2017 (n=135, Log-likelihood=-70). We used this model to generate the population estimate and prediction intervals for the Upper Klondike Highway survey area and Moose Management Unit (MMU).

	Estimate	Standard Error	*Z*	*P*
Count model coefficients (negbin with log link):				
(Intercept)	0.412	0.610	0.676	0.499
Sum_RSPF	0.077	0.044	1.753	0.080
Log(theta)	-0.034	0.255	-0.134	0.893
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	-11.803	5.678	-2.079	0.038
Conifer	19.475	7.996	2.436	0.015

Table 6: List of best models describing the composition of moose observed in the Upper Klondike Highway survey area (November 2017) with associated AIC scores and model weights (n=135).

Model	AIC	∆AIC	w
Sum_RSPF	754.1	0.0	0.87
Selected Elev (800-1200m)	758.7	4.7	0.08
Burns (5 to 35 years old)	760.3	6.2	0.04
Null	763.6	9.5	0.01
Conifer	769.4	15.3	0.00

Table 7: Compositional model regression estimates for moose in the Upper Klondike Highway survey area, November 2017 (n=135, Log-likelihood=-367). We used this model to generate the composition and related prediction intervals for the Upper Klondike Highway survey area and Moose Management Unit (MMU).

	Estimate	Standard Error	*Z*	*P*
(Intercept):BULL_LARGE	-0.491	0.340	-1.44	0.149
(Intercept):BULL_SMALL	-1.591	0.503	-3.16	0.002
(Intercept):COW_1C	-0.610	0.397	-1.54	0.124
(Intercept):COW_2C	-1.424	0.598	-2.38	0.017
(Intercept):LONE_COW	0.271	0.301	0.90	0.369
Sum_RSPF:BULL_LARGE	0.093	0.026	3.61	<0.001
Sum_RSPF:BULL_SMALL	0.069	0.037	1.85	0.064
Sum_RSPF:COW_1C	0.018	0.032	0.55	0.584
Sum_RSPF:COW_2C	-0.034	0.054	-0.64	0.524
Sum_RSPF:LONE_COW	0.063	0.024	2.62	0.009

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