Yukon

SR-19-07

Moose survey

Liard Basin Moose Management Unit, early-winter 2016

September 2019

Moose survey:
Liard Basin Moose Management Unit, early-winter 2016

Government of Yukon
Fish and Wildlife Branch
SR-19-07

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Summary

- We conducted an early-winter survey of moose in the Liard Basin Moose Management Unit (MMU) survey area from November 24 to December 3, 2016. The purpose of the survey was to: 1) estimate numbers, distribution, and composition by age and sex of the moose population in the MMU and, 2) to look at population trends in 2 subsets within the survey area where previous survey data is available.
- We counted all moose in survey blocks that covered about 26% of the entire area. We found a total of 885 moose: 301 adult bulls, 383 adult and yearling cows, 64 yearling bulls, 130 calves, and 7 moose of unknown age and sex.
- We calculated a population estimate of 2124 moose (90% confident that the population was between 1822 and 2473) for the area. This number is equal to a density of about 193 moose per 1,000 km² over the entire area, or 206 per 1,000 km² in suitable moose habitat. This is on the higher end of the range of typical Yukon moose densities of 100 to 250 moose per 1,000 km² of suitable moose habitat.
- We estimated that there were about 46 calves and 42 yearlings for every 100 adult cows in the survey area. These ratios suggest that survival of calves born in this area during the past 2 years has been above average compared to other Yukon areas surveyed.
- We estimated that there were about 98 adult bulls for every 100 adult cows in the survey area. This adult sex ratio is well above the minimum threshold of 30 bulls per 100 cows identified in our moose management guidelines.
- Although this is the first survey of the entire Liard Basin, comparison to past census results from subsets within the survey area suggest a stable moose population since the mid 1990's.
- Using multipliers of First Nation subsistence harvest of 1 to 2 times resident licensed harvest, we estimate that the total harvest of moose in this area is near or above the sustainable level recommended in our Moose Management Guidelines. Actual First Nation harvest information is required to accurately assess the harvest pressure in this MMU.

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Introduction

This report summarizes the results of the early-winter survey of moose in the Liard Basin Moose Management Unit (MMU; Figure 1), conducted from 24 November to 3 December, 2016. The purpose of the survey was to estimate numbers, distribution, and composition by age and sex of the moose population. Survey results are used to assess the sustainability of current harvest levels.

Prior to conducting this survey, moose hunting pressure within the Liard Basin Moose Management Unity was believed to be very high, exceeding the maximum sustainable harvest levels as per the Moose Management Guidelines (2016), based on our estimated densities of moose in this area. The majority of harvest in the Liard Basin MMU occurs within the road and river accessible Game Management Subzones (GMS) (i.e., GMS 10-32, 10-20, 11-28, and 11-28). This includes areas along the Liard River and its tributaries and along the Alaska and Robert Campbell highways.

The 2016 survey area was designed to be slightly larger than the Liard Basin MMU to compare subsets within our survey area to historical Liard West and Liard East surveys (Figure 1).

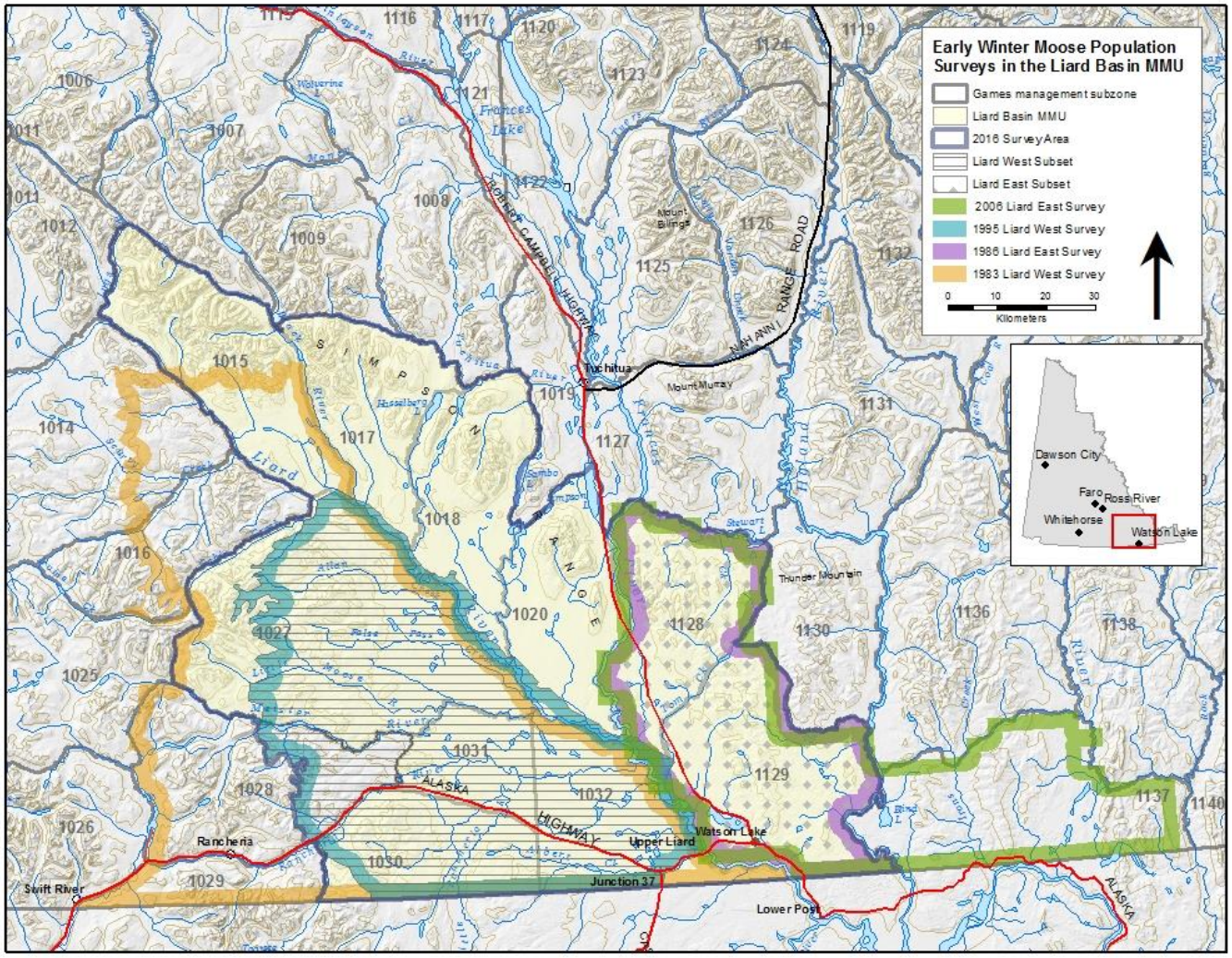

Figure 1. Previous early-winter moose population surveys in the Liard Basin Moose Management Unit.

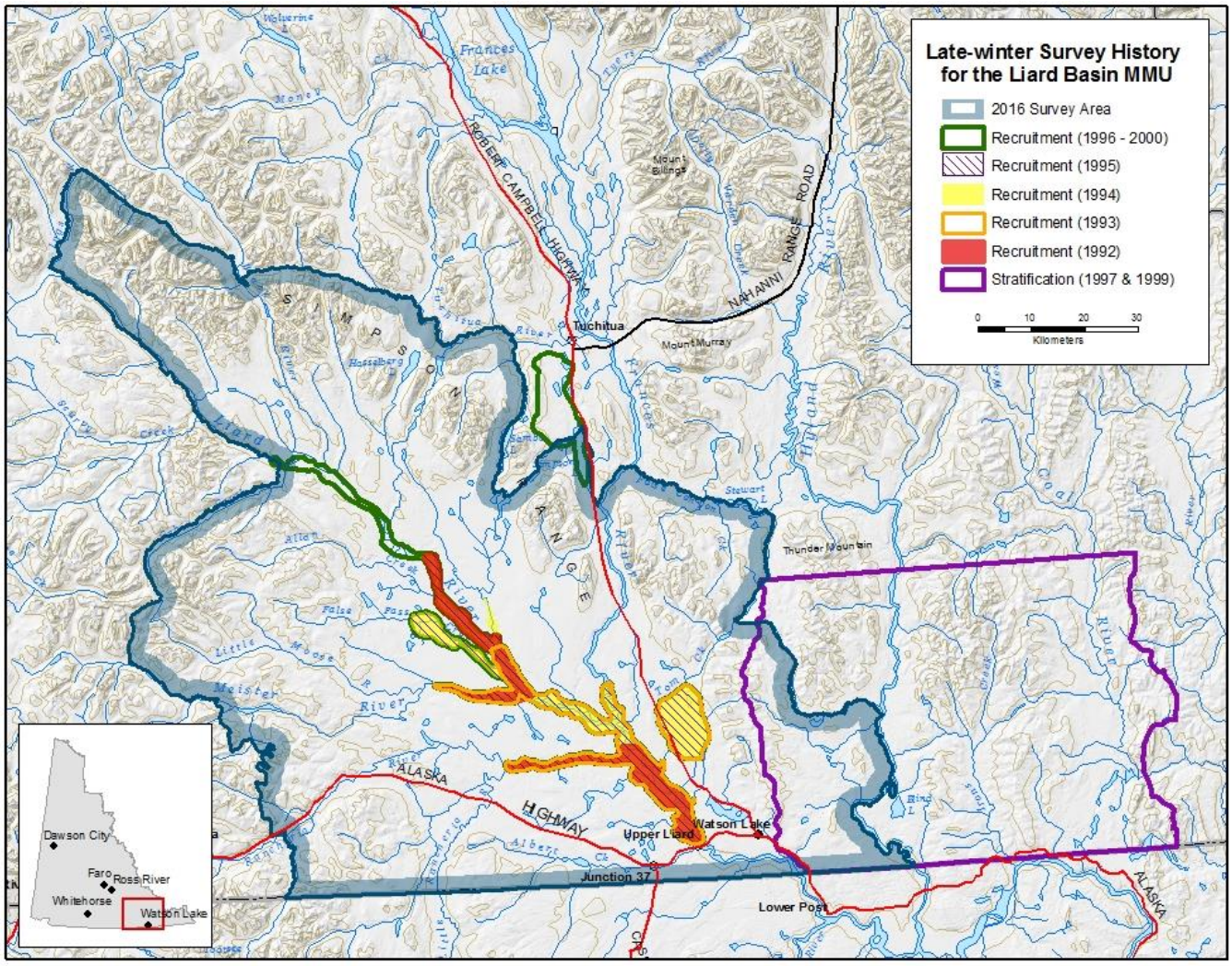

Figure 2. Additional late-winter surveys completed in the 2016 Liard Basin Moose Management Unit survey area.

Previous Surveys

This is the first moose population survey (or census) of the entire Liard Basin Moose Management Unit. Four moose population surveys were previously conducted within different portions of the 2016 Liard Basin Moose Management Unit survey area. These include the Liard West survey in 1983 (Johnston and McEwen 1984) and 1995 (Environment Yukon 2003) and the Liard East surveys in 1986 (Jingfors and Markel 1987) and 2006 (Westover et al. 2007) (Figure 1).

In March 1997 (Foos 1997) and February / March 1999 (Westover 1999), we flew stratification surveys to determine late-winter distribution of moose from the height of land west of the Garden Creek watershed, to the height of land east of the Coal River watershed. This area overlaps with a portion of the 2016 survey area (Figure 2). From 1992 to 2000, we completed annual late-winter recruitment surveys within the Liard River basin, focusing on late winter habitat in the Liard, Rancheria, and Meister river valleys (results in Yukon Fish & Wildlife Branch file reports, Figure 2).

We conducted a moose telemetry study from 1990 to 1993 to improve our understanding of the seasonal distribution and habitat use of moose within the Liard River basin, as well as to evaluate the effects of forest harvesting practices

on moose (results in Yukon Fish & Wildlife Branch file reports).

Additional, smaller-scale surveys flown in the study area include an early winter stratification survey in 1988, a late winter stratification survey in 1989 in the Meister River valley, and an early winter reconnaissance survey in the Tuchitua River/Hasselberg Lake area. In the early winter of 1975 and late winter of 1976 we completed a reconnaissance survey of Game Management Zone 11 to document all big game (results in Yukon Fish & Wildlife Branch file reports).

Community Involvement

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

The Liard Basin has been a traditionally important hunting area for the Kaska Dena and is a popular hunting area for Yukon residents. Community members from the community of Watson Lake volunteered as wildlife observers during the survey

Study Area

The survey area (11,419 km^2) encompasses the Liard River drainage and contains the entire Liard Basin Moose Management Unit area (11,025 km^2). Moose management units were developed to monitor and manage biologically distinct moose populations throughout the territory (Environment Yukon 2016). The Liard Basin survey area includes Game Management Subzones (GMS) 10-15, 10-17, 10-18, 10-20, 10-27, 10-30, 10-31, 10-32, 11-28, 11-29, and the eastern half of 10-28. The survey area was extended slightly beyond the Moose Management Unit to include previously surveyed areas so results could be compared (Figure 1).

The Alaska Highway runs east-west through the southern portion of the study area and the Robert Campbell Highway runs north through the east side of the study area. Major drainages within the Liard River basin include Albert Creek, Rancheria River, Meister River, Black River, Frances River (lower reaches), and Tom Creek.

The majority of the study area (~10,699 km^2) is considered suitable moose habitat; we exclude land at or above 1,524 m (5,000 feet) in elevation and waterbodies 0.5 km^2 or greater in size. The central and western portions of the survey area lie within the Liard Basin ecoregion and the northern and western portions are within the Pelly Mountains ecoregion (Yukon Ecoregions Working Group 2004). The Liard Basin region is surrounded by mountains and plateaus, with the majority of the region characterized by low hills separated by broad plains. The Pelly Mountains ecoregion is characterized by a rolling plateau with numerous mountain peaks and small rivers.

Old and recent burns occur throughout the study area (Figure 3) and these vary in quality as moose habitat. Most of the recent fires are located in the center of the study area, west of the Robert Campbell Highway. The most recent of the fires occurred in 2015 (70.6 km^2), 2013 (8.6 km^2), 2010 (84.9 km^2) and 2009 (89.5, 7.3, 14.8 and 3.4 km^2 respectively). Potentially more productive burns for moose (~11 to 30 years post-fire; Maier et al. 2005) include the 2004 (132.5 km^2 and 95.6 km^2) and 1989 (44.2 km^2) burns in the central-east part of the study area.

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 available information in individual survey blocks flown during the survey. This information is a combination of available local knowledge and landscape/habitat characteristics. These models are then used to

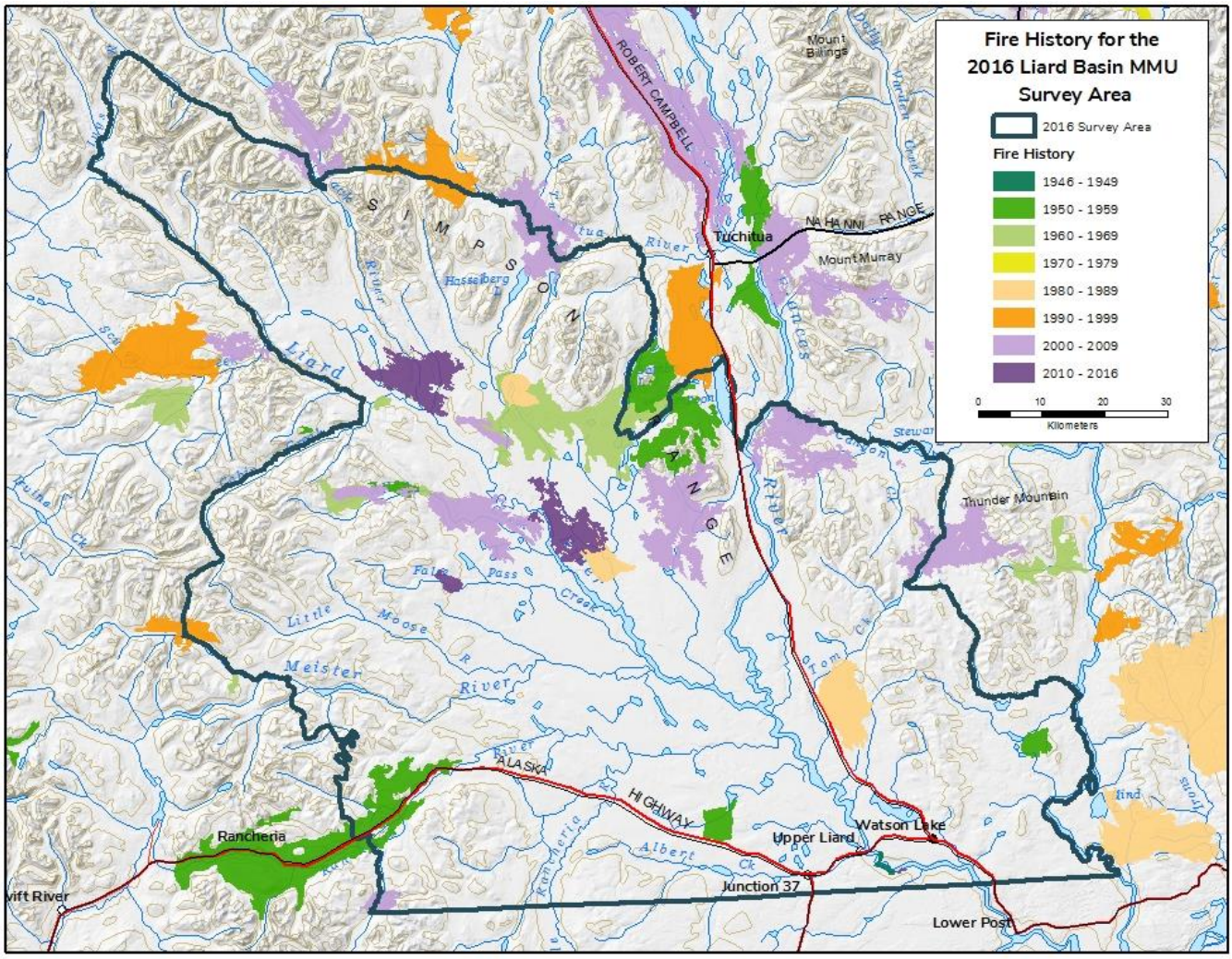

Figure 3. Liard Basin Moose Management Unit survey area fire history.

estimate moose abundance over the areas where we did not count moose. We next use any observed relationship between composition and the habitat/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 uniform rectangular blocks about 17 km² (2' latitude x 5' longitude) in size. We select certain blocks where we use helicopters to fly transects that are about 350 to 400m wide (search intensity of about 2 minutes per km²) and count/classify every moose observed. Generally, we survey approximately 30% of the blocks within a survey area. We use georeferenced maps on ipads to ensure that ferrying routes fly over as many different unsampled blocks as possible. During these ferries, all survey staff record observations about moose habitat quality and moose abundance in as many survey blocks as possible.

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

In phase 1, we use a combination of landscape characteristics (habitat, access) and

local knowledge to generate predictions of moose abundance in each of the survey blocks. Based on this information, we select survey blocks to be flown during the first 2 to 3 days of the survey (approximately 30% of the total number of blocks we anticipate to survey). Blocks are selected such that they are distributed across the survey area and cover the range of available habitat types and areas of different expected densities of moose.

In phase 2, we use available information (habitat type, access, local knowledge) 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 anticipate 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 allow the field crew to 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 reevaluated 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, we can reliably distinguish yearling bulls from adults based on antler size. Therefore, we use the yearling bull estimate to account for yearling cows that cannot be identified from the air (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 and/or prediction intervals do not overlap.

Weather and Snow Conditions

Weather conditions ranged from moderate to good for this survey. It was primarily overcast with low-lying clouds and fog that we had to work around on several days. Temperatures ranged from -1°C to -20°C. Winds were generally calm; however, stronger winds were encountered on two days.

Snow cover varied from low with vegetation showing, to complete coverage at low to intermediate depths. We had light snow falls throughout the survey which aided in spotting fresh tracks. Light conditions were generally flat.

Results and Discussion

Coverage

We counted moose in 175 (26%) of the 671 blocks in the entire survey area (Figure 5). During ferrying to and from Watson Lake and fuel caches, we flew over the majority of un-sampled blocks (Figure 4).

It took us about 101 hours to count moose in these blocks, for an average search intensity of 2.04 minutes per km². We used another 47 hours of helicopter time to ferry between survey blocks, our fuel caches, and back and forth to Watson Lake.

Observations of Moose

We counted a total of 885 moose, 34% of them adult bulls, 43% adult and yearling cows, 7% yearling bulls, 15% calves, and ~1% were unclassified moose (Table 1).

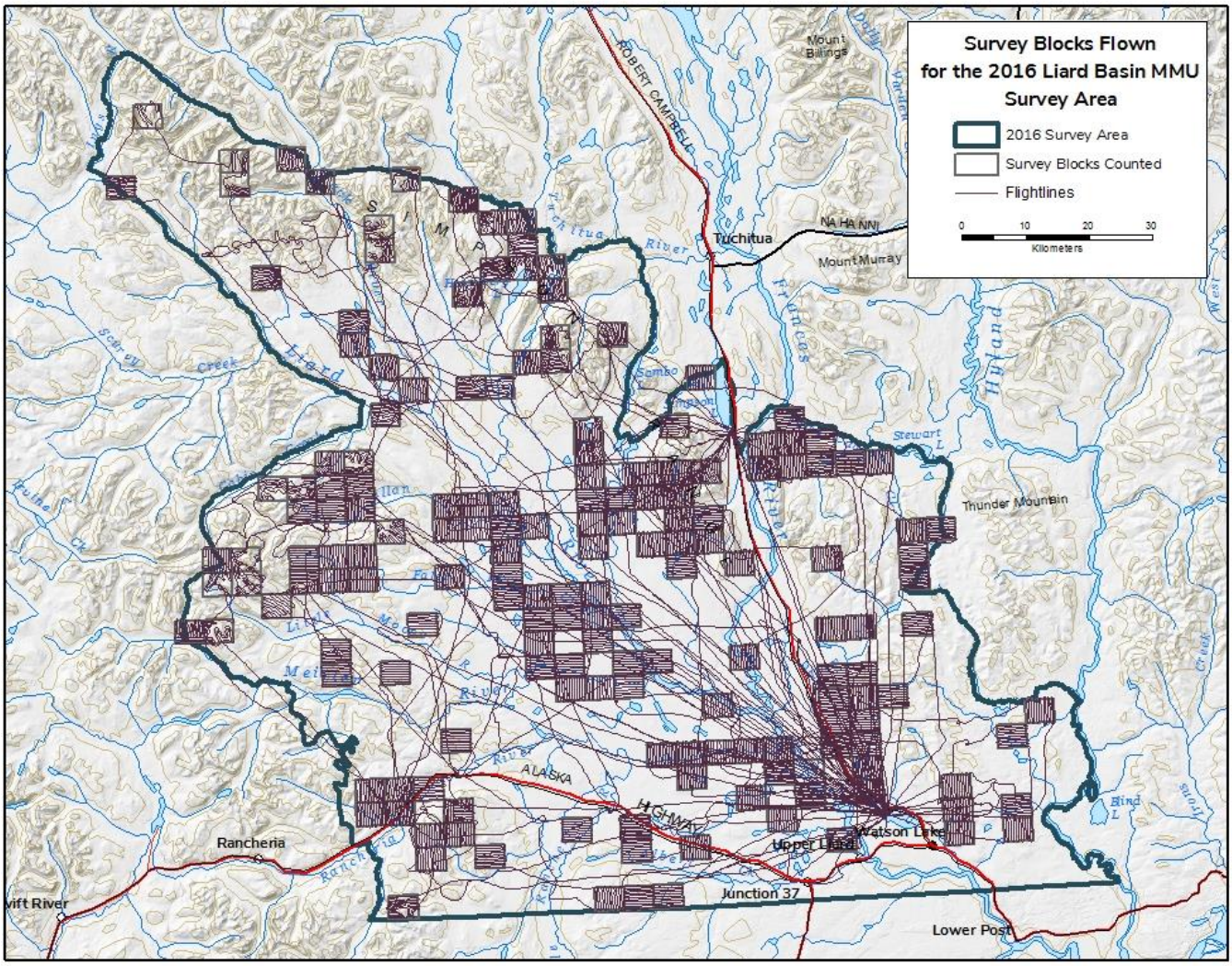

Figure 4. Flight paths during the 2016 Liard Basin Moose Management Unit survey area. Navigators attempted to fly over as much of the survey area as possible. Observations help verify model predictions.

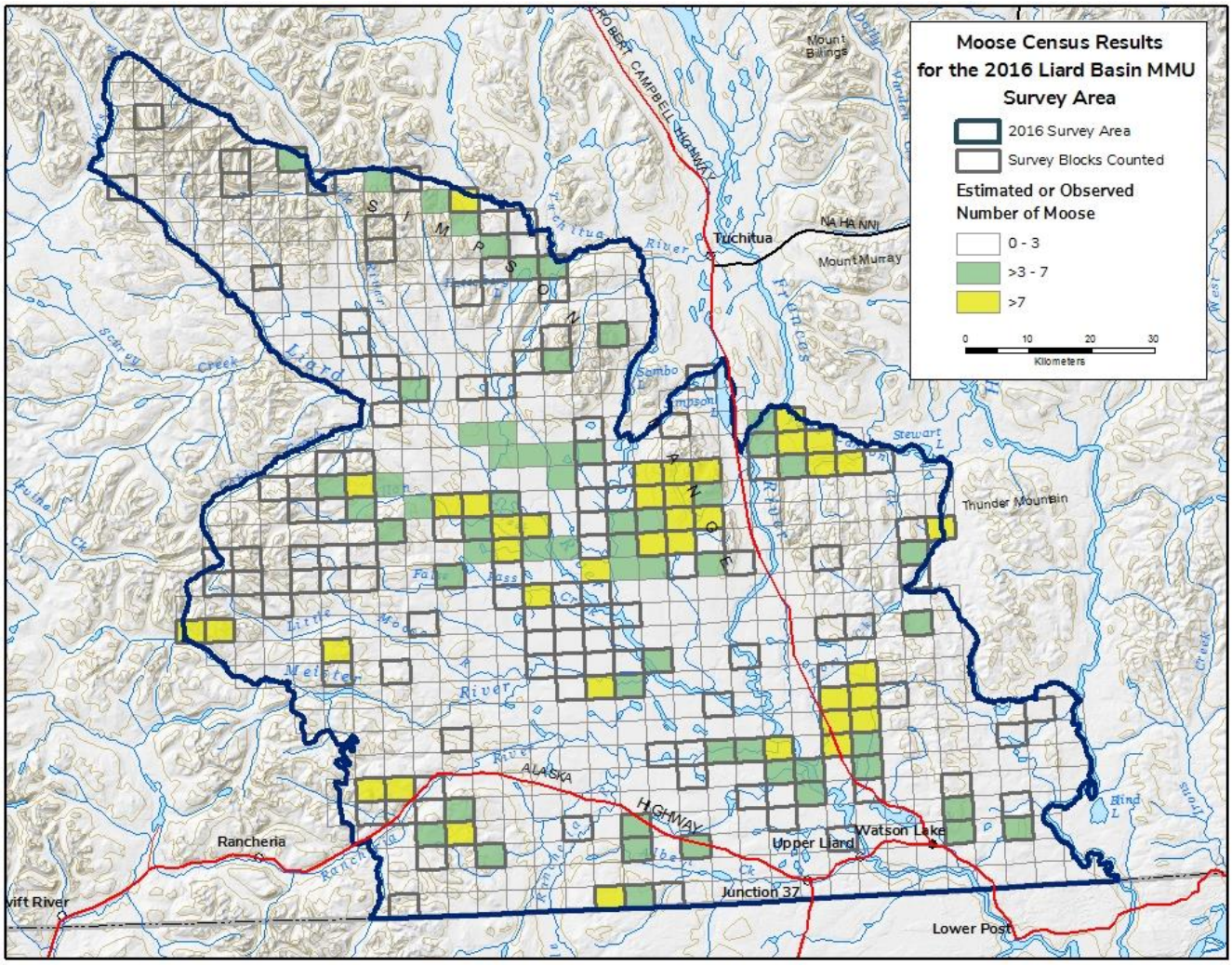

Figure 5. Moose Census results in the Liard Basin Moose Management Unit survey area, 2016.

Table 1. Observations of moose in the Liard Basin Moose Management Unit survey area during the November/December 2016 survey.

	Total
Number of blocks counted	175
Number of adult bulls	301
Number of adult and yearling cows*	383
Number of yearling bulls	64
Number of calves	130
Unclassified	7

Distribution of Moose

Moose were distributed throughout the survey area; with the highest numbers observed in the central and south-east, and few moose were observed in the north and west parts of the study area (Figure 5). We observed most moose in areas that burned between 1980 and 2009 (Figures 3 and 5); with moderate numbers located along creeks and rivers associated with the southern end of the Liard River system, and in the Rancheria Mountain area. We saw relatively few moose in mature spruce and pine forested habitats.

Abundance of Moose

The number of moose in a survey block was positively correlated to (1) the percent of the survey block burned between 1980 and 2009, (2) the percent of the survey block that contained broadleaf, mixed forest, or shrub type habitat with a slope of less than 10 degrees, and (3) information provided by a previous Liard Regional Biologist who predicted the survey blocks to have either high or low numbers of moose (Appendix 1).

The estimated number of moose in the entire Liard Basin Moose Management Unit was 2124, and we are 90% confident that the population was between 1822 and 2473 (Table 2). The estimated density of moose in the entire area was 193 per 1,000 km² of total area, or 206 per 1,000 km² of suitable moose habitat (Table 2). This is moderately high compared to the range of typical Yukon moose densities of 100 to 250 moose per 1,000 km² of suitable habitat (Environment Yukon 2016).

Table 2. Estimated abundance of moose, corrected for sightability (91%), in the Liard Basin Moose Management Unit in November/December 2016.

	Best estimate*	Estimates within 90% prediction interval**
Estimated total number of moose	2124	1822-2473
Adult bulls	723	615-844
Adult cows	739	623-859
Yearlings***	310	255-371
Calves***	344	285-410
Density of moose (per 1,000 km^2)		
Entire area	193	
Moose habitat only****	206	

* 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. Our best estimate is near the middle (at the median) of this range.

*** To account for yearling cows that cannot be identified from the air, the total number of yearlings is assumed to equal twice the estimated number of yearling bulls in the population. We use this assumption to estimate the total number of adult cows in the survey area by subtracting the number of yearling bulls observed from the total number of cows counted.

**** Suitable moose habitat is considered to be all areas at elevations lower than 1,524 m (5000 ft), excluding glaciers and water bodies 0.5 km^2 or greater in size.

Table 3. Estimated composition of the moose population in the Liard Basin Moose Management Unit in November/December 2016.

	Best Estimate	Estimates within 90% prediction interval*
% Adult bulls	34	33-35
% Adult cows	35	33-37
% Yearlings	15	13-16
% Calves	16	15-17
Adult bulls per 100 adult cows	98	91-106
Yearlings per 100 adult cows	42	36-48
Yearlings per 100 adults (recruitment rate)	17	16-19
Calves per 100 adult cows	46	42-51
% of cow-calf groups with twins	3%	2-5%

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

Ages and Sexes of Moose

We found that survey blocks with a higher percentage of coniferous forest had proportionally fewer lone adult cows in them compared to survey blocks with a low proportion of coniferous forest (details in Appendix 1). This is consistent with other areas in Yukon where cows with calves are more likely to be observed in treed areas. We incorporated this bias into our analysis to predict the composition of the moose population by age and sex (Table 3).

Our survey results indicate that survival of calves and yearling moose in the survey area in 2015 and 2016 was well above average compared to other areas surveyed in the territory. We estimated there were 46 calves and 42 yearlings for every 100 adult cows in the population (Table 3), whereas Yukon averages for surveyed areas are 29 calves and 18 yearlings per 100 adult cows (Environment Yukon 2016). However, estimates of recruitment from one survey are snapshots in time and survival varies from year to year.

We estimated that there were 98 adult bulls for every 100 adult cows in the survey area (Table 3). This value is likely inflated because many moose were counted in treed blocks where bulls with antlers are more visible than cows. However, given the high sex-ratio, we consider the composition to be 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).

Moose Population Trends

Survey results in the Liard West and Liard East subsets indicate that there has been no change in the total number of moose since the previous surveys in 1995 and 2006 (Table 4). Earlier, we detected significant increases in these subsets during the 1980s to mid-2000's (Environment Yukon 2003, Westover et al. 2007, Table 4).

Yearling and calf to 100 adult cow ratios in the Liard West and Liard East comparable areas have remained above the Yukon average of 18 yearlings and 29 calves per 100 adult cows (Environment Yukon 2016) since 1995 in Liard West, and since 1986 in Liard East (Table 4).

Table 4. Estimated abundance and composition of moose in the Liard West survey area in 1983, 1995, 2016, and the Liard East survey area in 1986, 2006, and 2016*.

Liard West Survey Area	Survey Year		
	1983	1995	2016**
Estimated total number of moose	370 (266-474)	712 (604-820)	714 (600-850)
Adult bulls	125 (87-136)	145 (111-180)	242 (200-287)
Adult cows***	206 (131-280)	318 (243-393)	227 (187-278)
Yearlings***	17 (0-37)	102 (52-152)	110 (88-138)
Calves	23 (6-40)	147 (115-179)	128 (104-155)
Adult Bull : 100 adult cows	61 (40-81)	46 (33-59)	106 (94-120)
Yearlings : 100 adult cows	8 (0-18)	32 (12-52)	49 (39-61)
Calves : 100 adult cows	11 (3-20)	46 (36-56)	56 (48-64)
Density of moose (per 1,000 km^2)			
Entire area	-	-	162 (136-193)
Moose habitat only****	88 (63-112)	166 (141-192)	166 (139-197)

Liard East Survey Area	Survey Year		
	1986	2006	2016**
Estimated total number of moose	329 (260-398)	484 (412-556)	482 (408-576)
Adult bulls	99 (69-129)	110 (85-135)	158 (132-190)
Adult cows***	122 (77-167)	223 (188-257)	165 (139-199)
Yearlings***	46 (24-66)	49 (32-66)	74 (58-94)
Calves	62 (46-78)	104 (86-122)	82 (66-103)
Adult Bull : 100 adult cows	81 (50-112)	49 (36-63)	95 (83-110)
Yearlings : 100 adult cows	37 (13-61)	22 (14-30)	45 (35-56)
Calves : 100 adult cows	51 (32-69)	46 (36-57)	49 (41-59)
Density of moose (per 1,000 km^2)			
Entire area	~135	191 (163-220)	190 (161-228)
Moose habitat only****	140 (111-170)	195	194 (164-232)

*No sightability correction was applied to any of the results to allow for comparison between years.

**The sum of the estimated numbers of adult bulls, adult cows, yearlings, and calves for the 2016 data 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.

*** To account for yearling cows that cannot be identified from the air, the total number of yearlings is assumed to equal twice the estimated number of yearling bulls in the population. We use this assumption to estimate the total number of adult cows in the survey area by subtracting the number of yearling bulls observed from the total number of cows counted.

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

Harvest

In Yukon, we estimate sustainable harvests for moose populations at the MMU scale (Environment Yukon 2016). Specifically, in areas where survey information is available, we estimate that 10% of the adult bull population can be sustainably harvested annually (Environment Yukon 2016). Our survey results indicate 723 (C.I: 615 - 844) bulls in the MMU (Table 2) and therefore a total sustainable harvest of 72 bulls annually.

Total harvest includes licensed harvest and First Nations subsistence harvest. During the 5 hunting seasons preceding this survey (2012 to 2016), the reported harvest of moose by licensed hunters in the Liard Basin MMU averaged 29 (range: 26 - 33) moose per year (Figure 6). This is similar to the long term average of 27 (range: 12 - 43) moose harvested per year in this area in the past 33 years (1979 to 2011).

We do not have reported First Nation moose harvest for this area. As a general rule, we estimate First Nation harvest to be equal to 1 to 2 times licensed resident hunters. As a result, we estimate the First Nation harvest in the MMU to be 29 to 58 moose. Therefore, we estimate the total harvest in the Lard Basin MMU to be 58 to 87 bulls.

These estimates suggest that 8 to 12% of the bulls in the MMU are hunted annually. Therefore, the harvest rate is near or above the sustainable limit established for the MMU. Actual First Nation harvest information is required to accurately assess the sustainability of the harvest in the Liard Basin MMU.

Other Wildlife Sightings

In addition to the 885 moose we counted during the survey, we saw 143 moose in 84 groups outside of the surveyed blocks or while travelling between blocks.

We also saw 249 caribou in 39 groups, mostly north of the Alaska Highway in the northern part of the Little Rancheria caribou herd. Several caribou were observed in GMS 10-27 near Lookout Hill, that are most likely from the Wolf Lake caribou herd. In addition, we observed 29 wolves in 5 groups, 1 Great Gray Owl, 1 Gyrfalcon, and 1 Peregrine falcon in various locations within the study area.

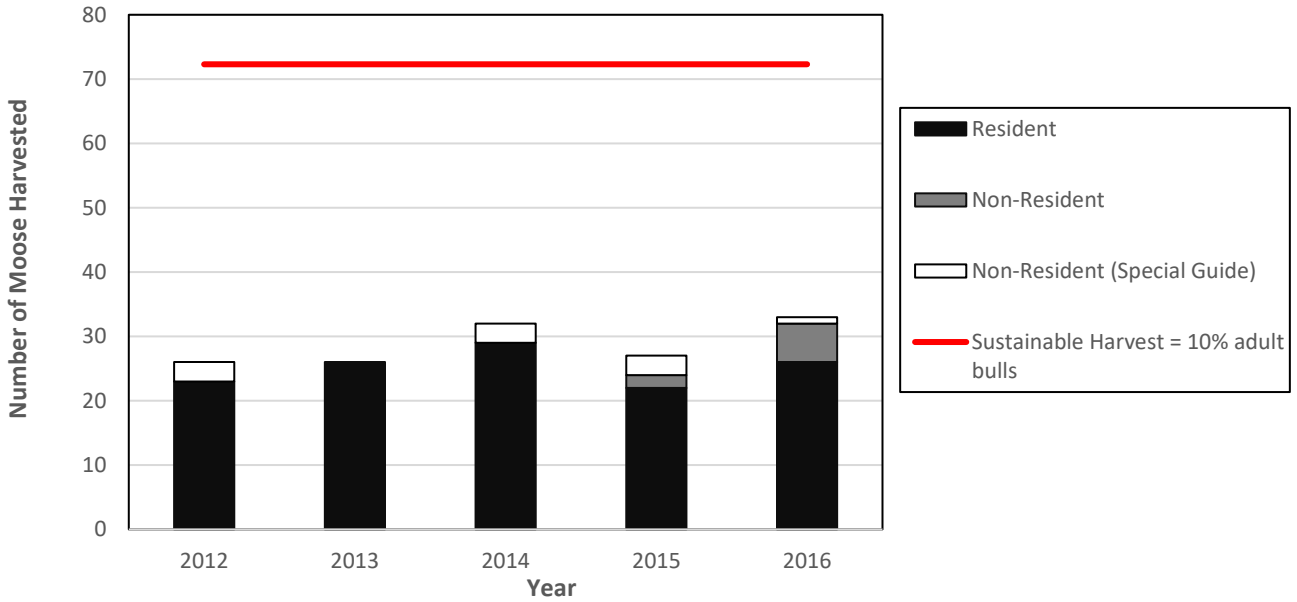

Figure 6. Harvest of moose by licensed hunters in the Liard Basin Moose Management Unit from 2012 through 2016. The red line is equivalent to the estimated sustainable harvest; 10% the adult bull population, or 72 bulls.

Conclusions and Recommendations

- We estimated a moderately high-density moose population in the Liard Basin Moose Management Unit compared to other areas surveyed in the territory.
- There has been an increasing trend in moose numbers from the 1980s to mid-2000's and no change in moose abundance to 2016, in both the Liard West and Liard East comparable survey areas.
- Survival of calves and yearling moose in the survey area in 2015 and 2016 was above average compared to other areas surveyed in the territory, and has generally been above average in previous surveys.
- The ratio of adult bulls to adult cows in the survey area is well above recommended levels in our Moose Management Guidelines.
- The current harvest rate is near or above the sustainable limit established for the MMU. Actual First Nation harvest information is required to accurately assess the sustainability of the harvest in the Liard Basin MMU.
- We need subsistence harvest data to work collaboratively with local First Nations to ensure total harvest is sustainable.
- We should continue to monitor moose populations in this area using aerial surveys.

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APPENDIX 1 Details of models used to estimate the abundance and composition of the 2016 Liard Basin Moose Management Unit survey area moose population

We considered a combination of expert opinion and landscape/habitat covariates to estimate the number and composition of moose in the Liard Basin Moose Management Unit (MMU) survey area (Table 1). For all analyses, individual 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).

We first used Zero-Inflated Negative Binomial regression Models (ZINB) to describe the distribution of the number of moose counted in sampled survey units in early winter. These models best describe low density and spatially aggregated moose distribution across survey units 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 3 count model coefficients (Table 2). The number of moose observed in a survey unit was positively correlated to 1) *PFire_1980_2009*, the percent of the survey unit burned between 1980 and 2009, 2) *PDes_Shr_10d*, the percent of the survey unit containing the "Broadleaf", "Mixwood", or "Shrub" habitat classes with a slope of less than 10 degrees, and 3) RegBio_01, information provided by a previous Liard Regional Biologist who predicted survey units to have high or low numbers of moose. This model was used to predict the number of moose in unsurveyed units of the survey area (Table 3). The final population estimate and bootstrapped confidence intervals were obtained by combining the actual number of observed moose in sampled survey units with predictions from unsampled survey units (Czetwertynski et al., *in prep*). This approach enables us to generate realistic estimates of subsets of the survey area when required (in this case for each of the 2 subsets within the survey area with historical survey data) and allows for meaningful stakeholder participation.

We next 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 *PNeedle* covariate that accounted for the lesser proportion of lone cows in survey units with predominantly conifer habitat (Table 4). This model (Table 5) 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 confidence intervals of the moose population in the survey area (Czetwertynski et al., *in prep*).

Table A 1. Description of selected list of coefficients considered for predicting the number of moose in survey units (approximately 16 km^2) and the population composition in the Kluane survey area, November 2016.

Covariate Name	Description	Source
RegBio_01	Binary covariate describing whether the Regional Biologist predicted high (1) or low (0) numbers of moose in the survey unit.	Rob Florkiewicz (Liard Regional Biologist 1990-1998).
Access_01	Binary covariate describing whether the survey unit is accessible (1) or not (0) to hunters via trails or waterways.	Al Fontaine (Liard Regional Biologist 2012-2017).
PFire1980_2009	Percent of survey unit burned between 1980 and 2009.	Canadian National Fire Database.
PDes_Shr_10d	Percent of area within each survey unit with Broadleaf, Deciduous, or Shrubland habitat types with slopes lesser than 10 degrees.	North American Land Cover 2010, Canada Center for Remote Sensing (CCRS), Natural Resources Canada and Digital Elevation Map (DEM) from Natural Resources Canada.
PNeedle	Percent of the survey unit with Needleleaf forest cover type.	North American Land Cover 2010, Canada Center for Remote Sensing (CCRS), Natural Resources Canada.

Table A 2. List of best models describing the number of moose observed in survey units in the Liard survey area (November 2016) with associated AIC scores and model weights.

Model	*df*	AIC	ΔAIC	*w*
PFire1980_2009 + RegBio_01 + Pdes_Shr_10d	6	868.0	0.000	0.460
PFire1980_2009 + RegBio_01	5	869.0	0.980	0.282
PFire1980_2009 + RegBio_01 + Access_01	6	870.3	2.270	0.148
PFire1980_2009 + RegBio_01 + PNeedle	6	870.9	2.870	0.109

Table A 3. Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed sample units (approximately 16 km^2) in the Liard survey area, November 2016 (n=175, Log-likelihood=-428.0)

	Estimate	Standard Error	*Z*	*P*
Count model coefficients (negbin with log link):				
(Intercept)	0.830	0.218	3.798	<0.001
PFire1980_2009	2.028	0.322	6.307	<0.001
RegBio_01	0.231	0.180	1.283	0.199
Pdes_Shr_10d	0.750	0.446	1.683	0.092
Log(theta)	0.236	0.305	0.773	0.439
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	-2.067	0.820	-2.520	0.012

Table A 4. List of top models describing the composition of moose observed in the Liard survey area (November 2016) with associated AIC scores and model weights.

Model	AIC	ΔAIC	*w*
PNeedle	1140.6	0.000	0.432
GR_SM4*	1141.7	1.086	0.251
PFire1980_2009	1142.7	2.105	0.151
Null	1143.5	2.904	0.101
GR_SM5*	1144.6	4.010	0.058
GR_SM3*	1148.9	8.311	0.007

*These covariates are a binary description of group sizes counted in survey units. GR_SM3, GR_SM4, and GR_SM5 represent group sizes lesser than (1) or greater than (0) 3, 4 and 5 respectfully.

Table A 5. Compositional model regression estimates for moose in the Liard survey area, November 2016 (n=175, Log-likelihood=-557.9.5).

	Estimate	Standard Error	Z	P
(Intercept):BULL_LARGE	1.120	0.206	5.435	<0.001
(Intercept):BULL_SMALL	-0.470	0.294	-1.601	0.109
(Intercept):COW_1C	0.007	0.250	0.030	0.976
(Intercept):COW_2C	-5.072	1.661	-3.054	0.002
(Intercept):LONE_COW	1.180	0.208	5.676	<0.001
PNeedleF:BULL_LARGE	-0.565	0.341	-1.656	0.098
PNeedleF:BULL_SMALL	-0.465	0.496	-0.937	0.349
PNeedleF:COW_1C	-0.119	0.408	-0.291	0.771
PNeedleF:COW_2C	2.074	2.190	0.947	0.344
PNeedleF:LONE_COW	-1.033	0.353	-2.925	0.003

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