Yukon

SR-20-20

Moose Survey

Kluane River / Duke River and Koidern moose management units, early-winter 2014

May 2020

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Kluane River / Duke River and Koidern moose management units, early-winter 2014

Government of Yukon
Department of Environment
Fish and Wildlife Branch
SR-20-20

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Summary

- Environment Yukon conducted an early-winter survey of moose in the Kluane River / Duke River Moose Management Unit (KRDRMMU) and the Koidern Moose Management Unit (KMMU) survey areas between November 25 and December 2, 2014. The purpose of this survey was to estimate numbers, distribution, and composition by age and sex of the moose populations. This is the first complete intensive early-winter population survey of these MMUs.
- We counted all moose in 147 survey blocks that covered about 32% of the entire survey area. We found a total of 491 moose: 277 adult cows, 111 adult bulls, 30 yearlings and 71 calves and 2 unclassified moose.
- In the Kluane River/Duke River MMU, we calculated a population estimate of 537 moose (90% confident that the population was between 452 and 641 moose). This number represents a density of 237 moose per 1,000 km^2 in suitable moose habitat.
- In the Koidern MMU, we calculated a population estimate of 265 moose (90% confident that the population was between 223 and 316). This number represents a density of 148 moose per 1,000 km^2 in suitable moose habitat.
- We estimated that there were 40 calves and 6 yearlings for every 100 adult cows in the KRDRMMU, suggesting that calf recruitment into the adult population was above average in 2014 and below average in 2013.
- We estimated that there were 28 calves and 6 yearlings for every 100 adult cows in the Koidern MMU, suggesting that calf survival was average in 2014, and below average in 2013.
- We estimated that there were 31 adult bulls for every 100 adult cows in the KRDRMMU and that there were 41 adult bulls for every 100 adult cows in the Koidern MMU. The adult sex ratio for the Kluane River/Duke River MMU is close to the minimum threshold of 30 adult bulls per 100 adult cows identified in the Science-based Guidelines for the Management of Moose in Yukon (2016).
- Available information suggests that the total harvest of moose in both MMUs is above the recommended sustainable level.

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Introduction

This report summarizes the results of the early-winter survey of moose in the Kluane River / Duke River Moose Management Unit (KRDRMMU) and the Koidern Moose Management Unit (KMMU) conducted 25 November – 2 December 2014. Moose Management Units are the scale at which we manage moose in Yukon. They are generally groupings of Game Management Subzones and were designed to best reflect biologically distinct moose populations while considering management issues such as access and harvest within a given area (Environment Yukon 2016). The purpose of this survey was to:

- estimate numbers (abundance);
- estimate the age and sex composition of the moose population;

Survey results are used to assess the sustainability of current harvest levels.

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 First Nation and non-First Nation hunters. This survey takes place within the traditional territories and area of overlap of the Kluane First Nation (KFN) and the White River First Nation (WRFN).

Since the mid-1990s, KFN and local residents have voiced concerns about perceived declines in moose numbers and low adult bull to cow ratios associated with high harvest rates in parts of the survey area. The survey area has relatively easy access for moose hunters because of the Alaska Highway and various mining roads, trails, and navigable waterways.

Local observations corroborate results from annual Kluane National Park and Reserve (KNPR) moose surveys in the upper Duke River that detected a decline in moose numbers roughly between 1991 and 2007 (Trotter and Wong 2017).

The Duke River Moose Management Steering Committee, consisting of the Kluane First Nation, Dan Keyi Renewable Resources Council (DKRRC), Kluane National Parks and Reserve (KNPR) and Department of Environment, met many times during 2012 to 2016 to work on a strategy to sustainably manage moose in this area. As part of this process, the Steering Committee and contractors conducted comprehensive community interviews in 2012 and 3 community workshops in Burwash between 2012 and 2014.

Discussions during these interviews and meetings focused on suggested solutions such as: decrease harvest (particularly cows), increase wolf trapping efforts, and shift local harvest from areas with concentrated high harvest to areas with lower harvest pressure. Residents recognized the need for accurate harvest information. Many people also expressed strong interest in monitoring moose more frequently while suggested solutions were implemented.

Kluane First Nation, Kluane National Parks and Reserve and the Dan Keyi Renewable Resources Council all provided personnel to help conduct this survey.

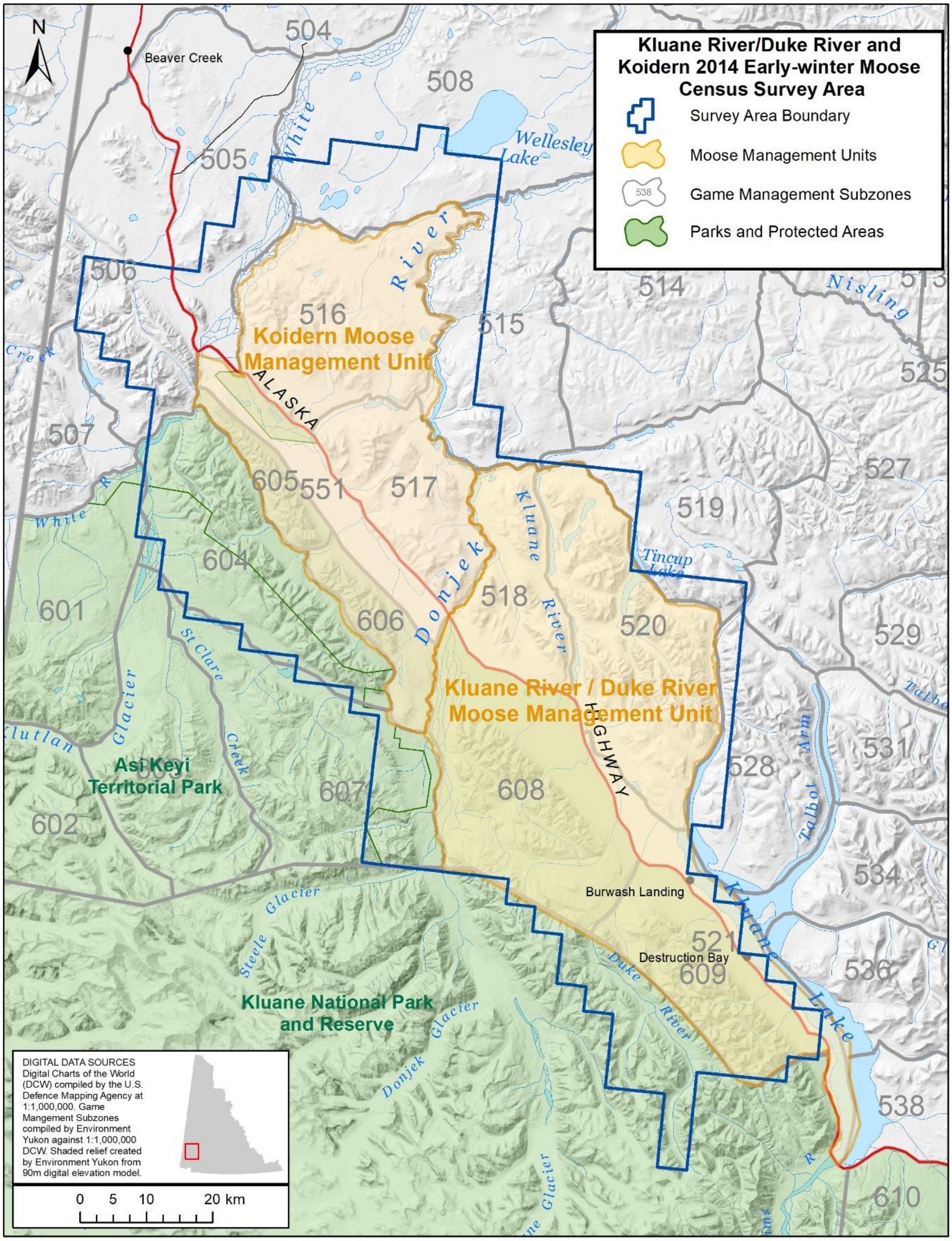

Figure 1. Kluane River/Duke River and Koidern 2014 early-winter moose census survey area, Moose Management Units and Game Management Subzones.

Study area

The 2014 survey area (7,416.4 km^2) straddles the Alaska Highway and extends from the south end of Kluane Lake, north to the White River and Wellesley Lake area (Figure 1). The survey area is within the Boreal Cordillera Ecozone. It encompasses both the relatively young and mountainous sedimentary front ranges of the St. Elias Mountains Ecoregion and the lower mountains, broad valleys, and metamorphic rock of the Ruby Ranges Ecoregion (Yukon Ecoregions Working Group 2004).

The climate ranges between high precipitation and snow loads in the St. Elias Mountains Ecoregion and the dry Ruby Ranges Ecoregion which is in the rain shadow of the St. Elias Mountains. Average annual precipitation in the study area is approximately 279.7 mm (Environment Canada 2013, recorded at Burwash airport). Boreal forest, composed of white spruce, willow, and trembling aspen on warmer sites dominates both ecoregions. Shrub birch and tall willows dominate subalpine communities above 1,200 m. Lichens and ground shrubs occur in the alpine tundra generally above 1,400 m (Yukon Ecoregions Working Group 2004).

This report summarizes survey results in the KRDR and Koidern MMUs; however, the survey area boundaries extended beyond these MMUs. Specifically, the census survey area includes 2 complete Moose Management Units (MMUs): the Kluane River/Duke River MMU in the south GMS 5-18, 5-20, 5-21 and 6-08, 6-09) and the Koidern MMU in the north including GMS 5-16, 5-17, 5-51, and Kluane Wildlife Sanctuary GMS 6-05, and 6-06 (Figure 1). It also includes Kluane Wildlife Sanctuary GMS 6-04, which forms part of the Donjek River/White River MMU.

We expanded the survey area beyond the two MMUs for several reasons. First, to capitalise on information collected by Alaska Department of Fish and Game for the 2014 Chisana moose survey (Wells 2018), and to capture important moose habitat adjacent to the MMUs where no previous survey information was available (Environment Yukon unpublished data). Second, we surveyed a small portion of KNPR that was included in the 2011 census. Landscape characteristics and local knowledge suggest that moose in this area are part of the KRDRMMU population.

Moose in the survey area share the landscape with caribou from the Chisana and Kluane herds. Dall's sheep are common throughout and small bands of mountain goats are found scattered through the St. Elias Mountains and above the Donjek River and Kluane River. Grizzly bears are common in the St. Elias Mountains and major river drainages. Black bears, wolves, wolverine, goats, coyotes, lynx, and red foxes are also present in the area.

Almost all of the 2014 survey area is within 40 km of the Alaska Highway and much of the area is accessible via mining roads, exploration trails, and an ever-expanding network of trails developed for Off-Road Vehicles. Some of the most productive moose habitat in the area can be accessed by boat along numerous prominent waterways (Duke, Kluane, Donjek, Koidern, and White rivers and Brooks Arm and Brooks Creek on Kluane Lake).

This region lies in a "lightning shadow" created by the Saint Elias Mountains. As a result, lightning-caused forest fires have not played a significant agent of habitat change in this region. Recent fire history information (1946 to present) for the survey area show one relatively small human-caused fire in the Burwash area in 1999 and 2 small fires near the White River in 1982 and south of Wellesly Lake near the Donjek River in 2004 (Figure 2).

Previous early-winter surveys

In previous years, we have conducted other early-winter moose surveys that only partially overlap this survey area (Figure 3). Two moose population census surveys were flown in the

Beaver Creek area in early-winter 1998 and 1999 (Hayes and LaRocque 2006). The area of overlap between the Beaver creek surveys and this survey area is relatively small and equivalent to an area roughly 20km by 20km.

A previous survey of these 2 MMUs was conducted in 2011. It also identified concerns about high harvest in the area. However, the wide confidence intervals around the population estimate for the entire area did not allow us to make management recommendations at the MMU scale, and therefore this area was surveyed again in 2014.

A partially overlapping early-winter moose survey was also conducted at a similar timeframe by Alaskans from Nov 14 to 23, 2014, to cover the area occupied by the Chisana caribou herd (McNeill et al., 2018). This survey was flown by fixed wing, and abundance and composition was estimated using the geospatial population estimator (GSPE) method (Kellie and DeLong 2006).

Kluane National Park and Reserve has completed annual early-winter moose trend surveys in the upper Duke River drainage since 1981. These surveys estimate relative moose abundance, population composition, habitat quality, and changes between years (Lee and Sykes 2009).

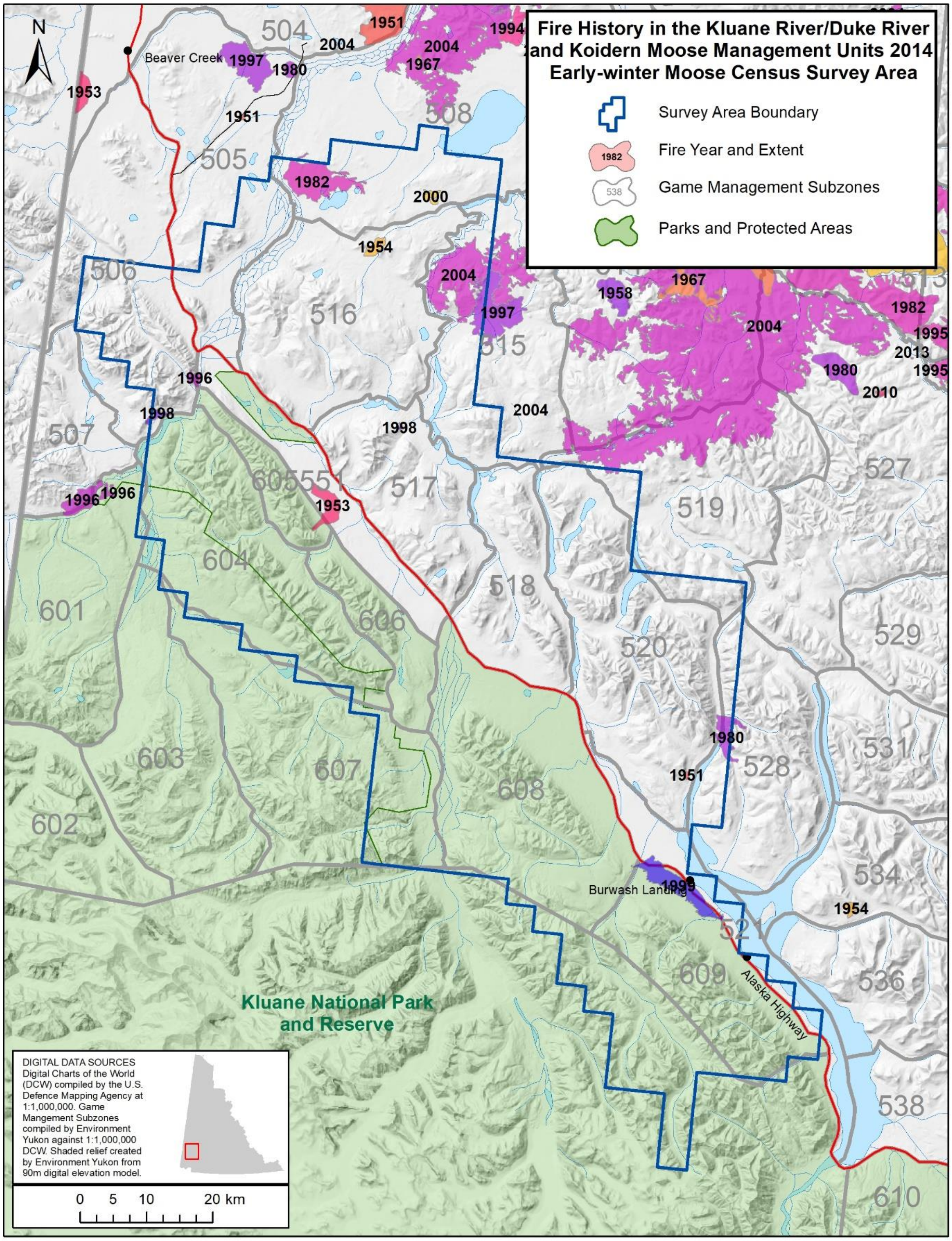

Figure 2. Fire history in the Kluane River/Duke River and Koidern moose management units 2014 early-winter moose census survey area.

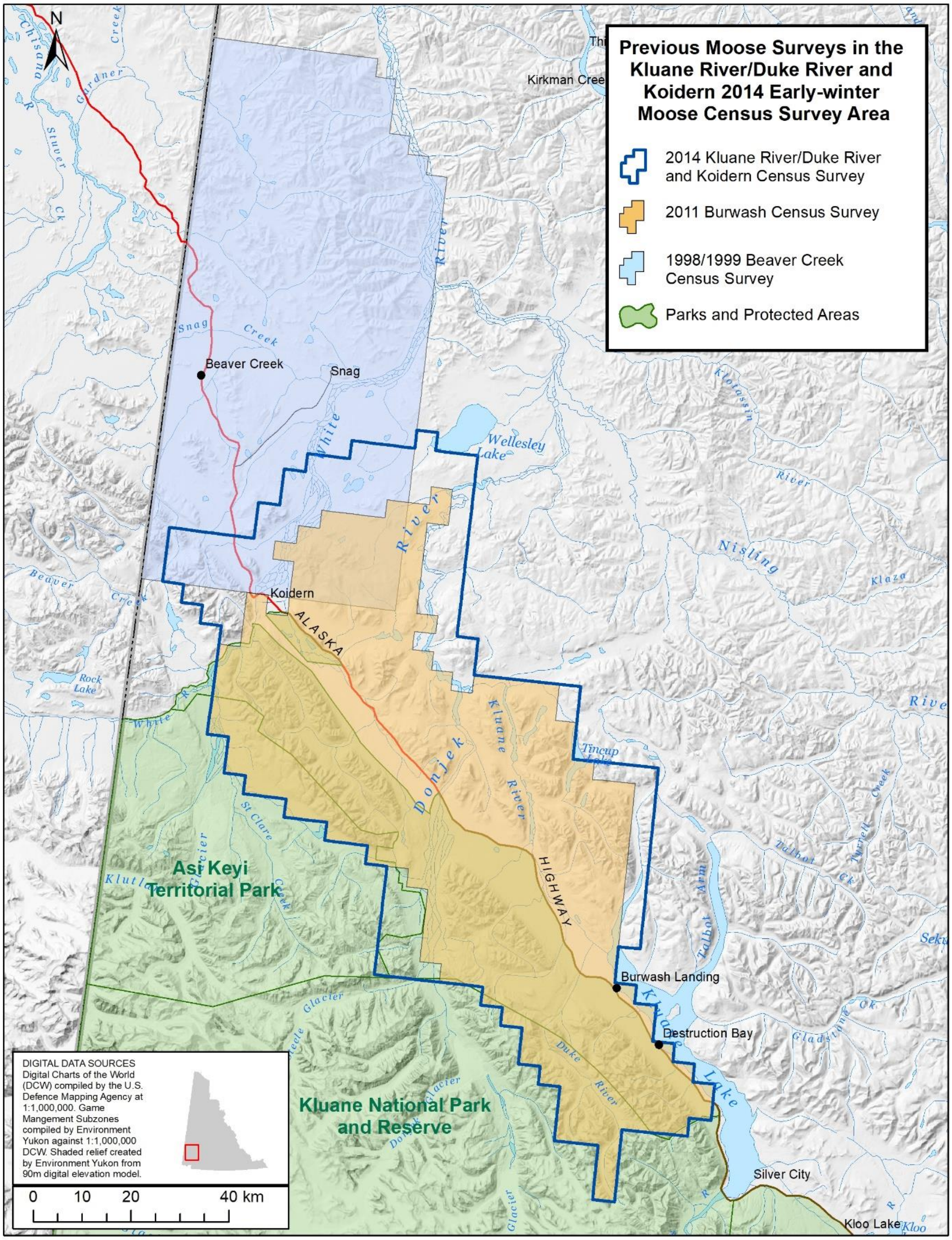

Figure 3. Previous moose surveys in the Kluane River/Duke River and Koidern 2014 early-winter moose census survey area.

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 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 16 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. During 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:

1. 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 2-3 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.
2. 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.
3. 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 were variable during the survey period with temperatures ranging from -1ºC to -31ºC, with warmer temperature inversions in the alpine on some days. Some periods of light snow occurred throughout the survey, and winds were calm to low most days with a bit of turbulence on the last day. One of the main weather challenges for flying was the formation of thick ice-fog created by the still-open Kluane Lake and Kluane River that impeded survey work on the first two days and to a lesser extent later in the survey. A small amount of fresh snow had fallen over most of the survey area in the days leading up to the survey and snow coverage was relatively complete and sufficient for sighting tracks, but at low depth. The relatively low snow accumulation should not have caused significant movements of moose during the survey period.

Results and discussion

Census survey coverage

We conducted the moose population census survey from 25 November – 2 December 2014. We surveyed a total of 147 survey blocks, or 32% of the 453 survey blocks in the entire survey area (Figure 4).

Total survey time was 3,602 minutes (60 hours), not including 1655 minutes (27.6 hours) of ferry time to fuel caches and the Destruction Bay home base, for an average search intensity of 1.49 minutes per km^2. This search intensity is lower than the recommended 2.0 min/km^2 because many survey blocks were in high elevation areas that were not flown. Total flight time (survey and ferry time combined) was 5,257 minutes or 87.6 hours.

We observed 491 moose: 277 adult cows, 111 adult bulls, 30 yearlings and 71 calves and 2 unclassified moose in the 2014 Kluane River/Duke River and Koidern MMUs census survey area.

Distribution of moose

Moose were widely distributed in the survey area; with the highest numbers observed in the north, west-central and east-central areas (Figure 4). We saw moose in relatively typical subalpine habitats with good abundance of willow browse.

Abundance of moose

Final models that best predicted moose abundance in the two Moose Management Units are described below.

In the KRDR MMU, the number of moose in a survey block was positively correlated to information provided by a local expert and negatively correlated with the percent of the block that contained conifer forest (Appendix 1). The estimated number of moose in the MMU, based on our census count and model predictions, was 537 and we are 90% confident that the population was between 452 and 641 moose (Table 2).

In the Koidern MMU, the number of moose in a survey block was positively correlated to moose abundance and predictions from the 2011 survey in the area and negatively correlated with the percent of the block that contained conifer forest (Appendix 1). We estimated that there are 265 moose and we are 90% confident that the population was between 223 and 316 moose (Table 2).

The estimated densities of moose were 237 for the KRDRMMU, and 148 for the Koidern MMU per 1,000 km^2 of suitable moose habitat (Table 2). The Koidern MMU density is toward the lower end of the range, and may be related to relatively easy access by road and river.

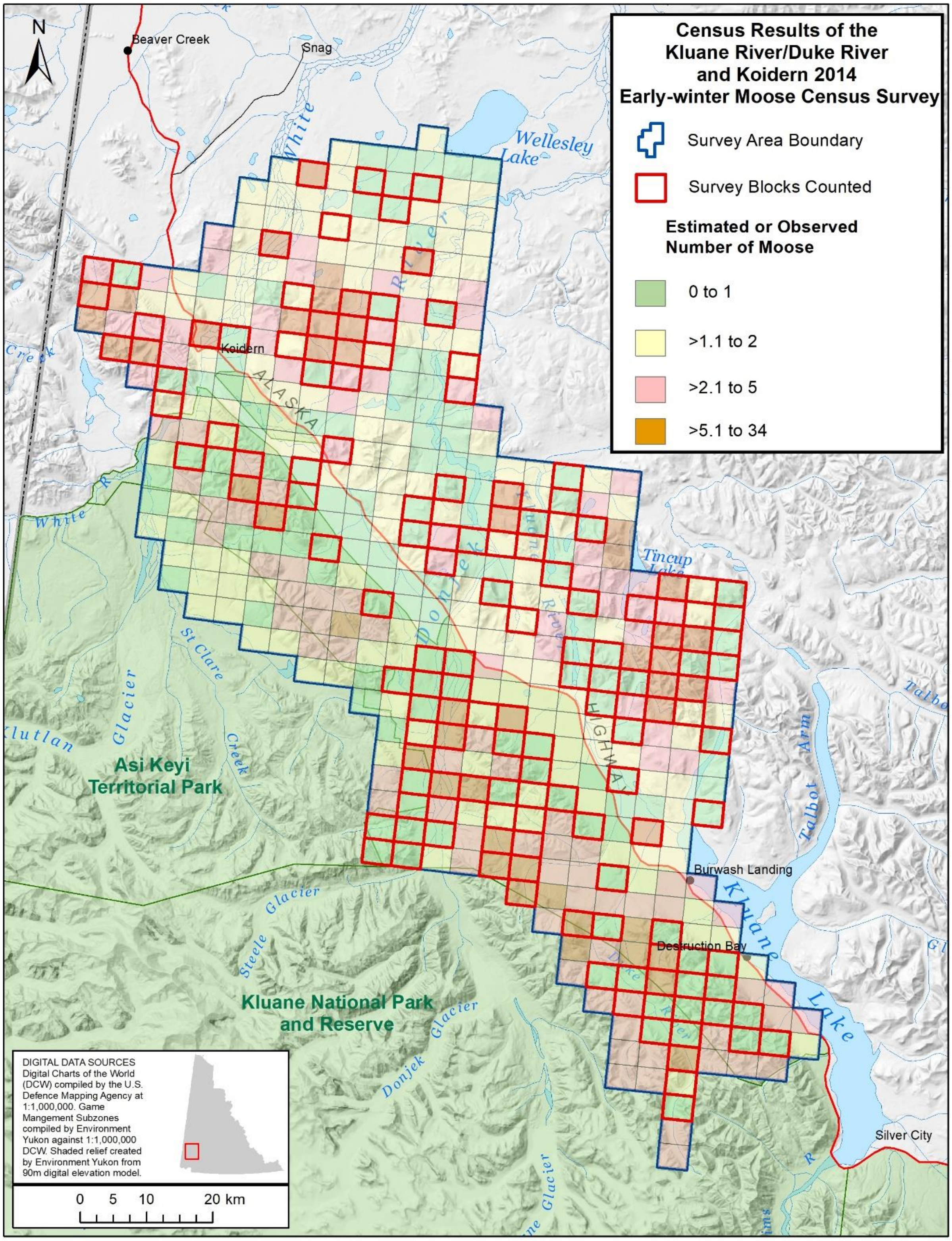

Figure 4. Census results of the Kluane River/Duke River and Koidern moose management units 2014 early-winter moose census survey area.

Table 1. Observations of moose in the Kluane River/Duke River and Koidern moose management units during the early-winter 2014 survey.

	Total
Number of blocks counted	147
Number of adult bulls	111
Number of adult and yearling cows*	277
Number of yearling bulls	30
Number of calves	71
Number of unclassified moose	2

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

Table 2. Estimated abundance of moose, corrected for sightability (91%), in the Kluane River/Duke River and Koidern moose management units (MMUs) during the early-winter 2014 survey.

	Kluane River/Duke River MMU		Koidern MMU	
	Best Estimate*	**90% Prediction Interval****	**Best Estimate***	**90% Prediction Interval****
Estimated Total Number of Moose	537	452 – 641	265	223 – 316
Adult Bulls	93	81 – 109	62	53 - 73
Adult Cows	298	253 – 361	152	130 - 183
Yearlings***	17	N/A	9	N/A
Calves	120	90 – 158	43	28 - 60
Density of Moose (per 1,000 km^2)				
Total Area	194		142	
Moose Habitat only****	237		148	

* 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, and that 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 1,600 m (5,249 ft.), excluding glaciers and water bodies 0.5 km^2 or greater in size.

Table 3. Estimated composition of the moose population in the Kluane River/Duke River and Koidern moose management units (MMUs) during the early-winter 2014 survey.

	Kluane River/Duke River MMU		Koidern MMU	
	Best Estimate	**90% Prediction Interval***	**Best Estimate**	**90% Prediction Interval***
Composition				
% Adult Bulls	18%	16-20%	23%	20-26%
% Adult Cows	56%	54-59%	57%	54-60%
% Yearlings	3%	3-4%	3%	3-4%
% Calves	23%	20-26%	16%	12-20%
Adult Bulls per 100 Adult Cows	31	27-35	41	35-47
Yearlings per 100 Adult Cows	6	5-7	6	5-7
Calves per 100 Adult Cows	40	34-47	28	20-35
% of Cow-Calf Groups with Twins	2%	2%	0%	0-0%

* 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

In both MMUs, we found that survey blocks with more than 2 moose were more likely to contain proportionally more lone adult cows and lone adult bulls in them compared to survey blocks with 1 or 2 moose (details in Appendix 1). This is consistent with other areas in Yukon where cows with calves are more likely to be isolated from larger groups and in more forested 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 to the early winter was average (28 calves/100 adult cows in the Koidern MMU) to high (40 calves/100 adult cows in the KRDRMMU) in 2014, and low in 2013 (6 yearlings/100 adult cows in both MMUs; Table 3). However, estimates of recruitment from one survey are snapshots in time and survival can vary widely from one year to the next. In Yukon, averages for surveyed areas are 29 calves and 18 yearlings per 100 adult cows (Environment Yukon 2016).

We estimated that there were 31 adult bulls per 100 adult cows in the KRDRMMU, and 41 adult bulls per 100 adult cows in the Koidern MMU (Table 3). The adult bull/cow ratio for the Kluane River/Duke River MMU is near the minimum level of 30 adult bulls per 100 adult cows recommended in the Yukon Moose Management Guidelines (Environment Yukon 2016).

Harvest

In Yukon, we estimate sustainable harvests for moose populations at the Moose Management Unit 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). Total harvest includes licensed harvest and First Nations subsistence harvest.

Kluane River/Duke River MMU:

Our survey results indicate that there are 93 adult bulls (P.I.: 81-109) in the Kluane River/Duke River MMU (Table 2) and therefore a total sustainable harvest of 9 bulls annually. During the 4 hunting seasons preceding this survey (2011 to 2014), the total harvest of moose by all hunters in the KRDRMMU averaged 21 (range: 14-29) bulls per year (Figure 5). This total harvest is substantially greater than our recommended sustainable harvest for this population.

We added reports of licensed and subsistence harvest to obtain Total harvest in the Kluane River/Duke River MMU. Subsistence harvest was available from Kluane First Nation only and not available for 2010. Harvest information for White River First was not available but deemed to be low.

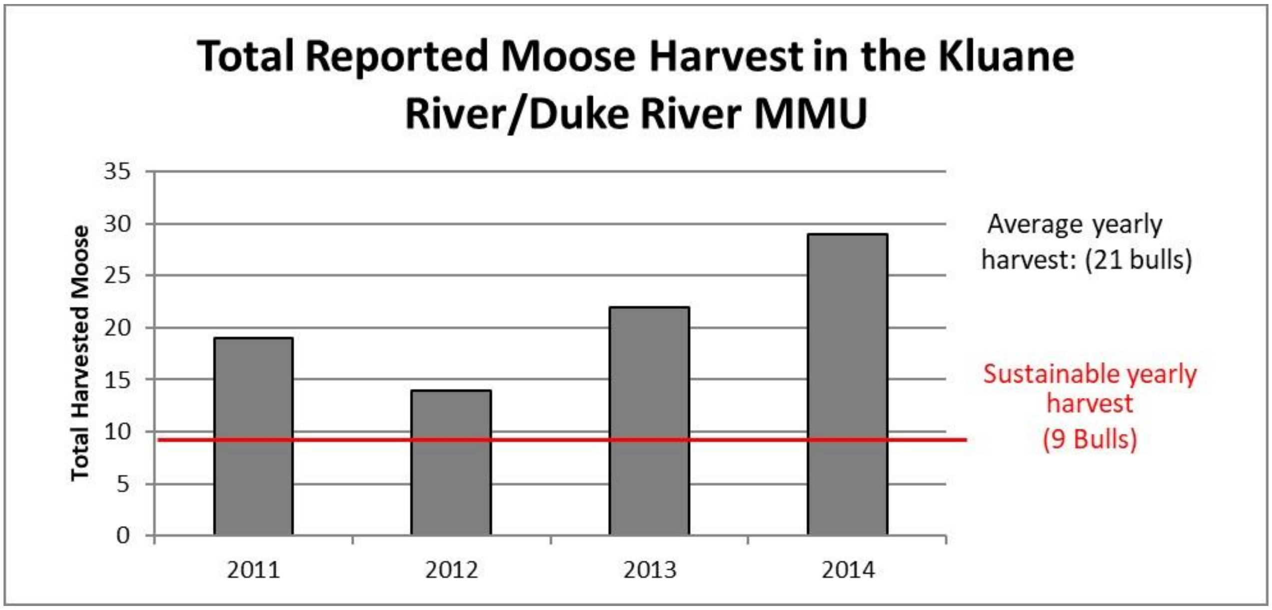

Figure 5. Total reported moose harvest in the Kluane River/Duke River Moose Management Unit 2011-2014. Note: First Nation harvest data was not available in 2010.

Koidern MMU:

Our survey results indicate 62 (P.I. 53-73) bulls in the MMU and therefore a total sustainable harvest of 6 bulls annually. Our best estimate of total average harvest for the 5 years (2010-2014) prior to the survey is 14 bulls (Figure 6). This estimated total harvest is substantially greater than the sustainable harvest for this MMU.

Harvest records from First Nations in this area were not available. We calculated the subsistence harvest component of the total harvest from multipliers developed by Quock and Jingfors (1988, 1989). We multiplied resident licensed harvest by a factor of 1.6 to estimate FN harvest in this MMU. We acknowledge that these are estimates only. We continue to work with our First Nation partners to encourage recording and reporting of harvest in this area.

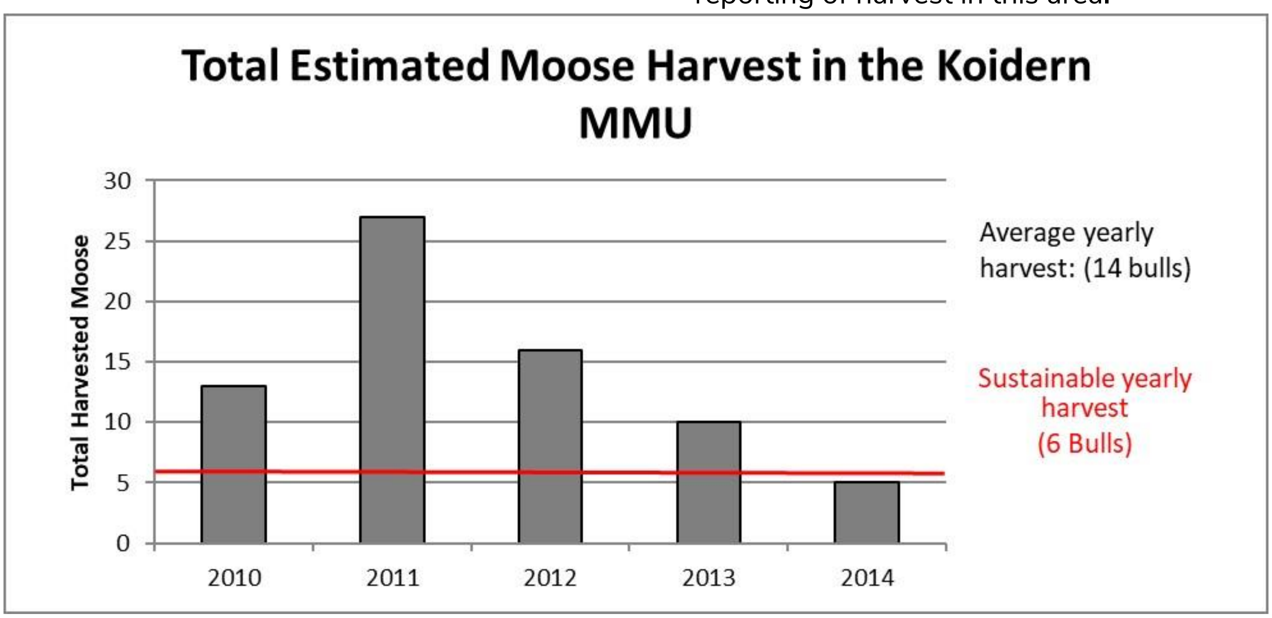

Figure 6. Total estimated moose harvest in the Koidern Moose Management Unit 2010-2014.

Other wildlife sightings

In addition to the 491 moose we counted during the 2014 census, we observed 51 moose outside the surveyed blocks or while travelling between survey blocks. Other ungulates observed included 5 goats, 47 sheep and 3 caribou. Carnivores observed included 1 wolf, 2 coyotes and 1 fox. Birds recorded were 1 bald eagle, 19 dusky grouse, 2 sharp tailed grouse, 673 white-tailed ptarmigan in 30 groups and 498 ptarmigan (willow or rock ptarmigan) in 17 groups.

Conclusions and recommendations

- We estimated a relatively high-density moose population in the Kluane River/Duke River Moose Management Unit (KRDRMMU) and a moderately-low density moose population in the Koidern MMU compared to other areas surveyed in the Yukon
- Our harvest information indicates that the total harvest of moose in both MMUs is above levels recommended in our Moose Management Guidelines
- The adult bull/cow sex-ratios in both MMUs are low and consistent with moose populations experiencing high harvest rates
- Long-term data from adjacent Kluane National Park indicates that the moose population declined between 1991 and 2007
- Since the mid-1990s, KFN and local residents have voiced concerns about perceived declines in moose numbers and low adult bull to cow ratios associated with high harvest rates in parts of the survey area
- Therefore, all available lines of evidence suggest that harvest is unsustainable in both MMUs and needs to be reduced to stop/prevent population declines
- We should continue to work with Kluane First Nation and White River First Nation to annually collect accurate harvest information.
- We should work with all partners to develop total harvest management plans for all users and reduce harvest to sustainable levels

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APPENDIX 1 Analyses and models used to estimate the abundance and composition of moose in the Koidern and Kluane River/Duke River moose management units from 2014 survey data.

Our dataset included survey data from the 2014 Koidern and Kluane River/Duke River (KRDR) survey flown between November 25th and December 2nd 2014 (Figure 1); and additional data from an Alaskan moose survey that overlapped with our survey area, conducted just prior to our survey from November 9th to November 23rd (Wells 2018). The Alaskan data augmented our dataset with 39 additional survey blocks. They counted a total of 107 moose: 59 adult cows, 23 adult bulls, 14 yearlings, and 11 calves. The Koidern and KRDR Moose Management Units (MMUs) are subsets within the northern and southern survey areas (Figure 1).

We used a combination of expert opinion and landscape/habitat covariates to estimate the number and composition of moose in the Koidern and KRDR MMUs (Table 1). Models were estimated independently at the scale of the northern and southern survey area boundaries (Figure 1), and MMU population results presented in the main section of this report are subsets of analyses presented here. Specifically, the Koidern MMU is a subset of the northern survey area and the KRDR MMU is a subset of the southern survey area. 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 blocks in early winter. 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 final population estimates and bootstrapped confidence 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 (in this case for the 2 MMUs) 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). The best model is then applied to unsurveyed sample blocks 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*).

Northern survey area population and composition models

The model that best described the data in the northern survey area (Figure 1) included 2 count model coefficients (Table 2). First, the number of moose observed in a survey block was positively correlated to *Burwash2011_SM5km*, a spatially averaged prediction of moose on the landscape based on survey data from 2011 (Environment Yukon files). Specifically, we generated a ZINB model using 2011 survey results and the Stratification data as the only covariate. This model produced cell-based predictions that we then averaged across a distance of 5km to account for spatio-temporal changes of moose groups in adjacent high blocks. Second, the number of moose observed in a survey block was negatively correlated to *Conifer*, the percent of the survey block with conifer cover. This model (Table 3) was used to predict the distribution of moose in unsurveyed blocks of the survey area, and generate a population estimate and bootstrapped prediction intervals. Finally, these model results were subset to provide estimates for the Koidern MMU.

We found that group size was the strongest covariate predicting the composition of moose in the survey area. Specifically, the proportion of lone cows and adult bulls in the survey blocks increased significantly in survey blocks with more than 2 moose (Table 4). This model (Table 5) was then applied to unsurveyed sample blocks to predict the distribution of composition of the moose population in subsets of the survey area including the Koidern MMU.

Southern survey area population and composition models

The model that best described the data in the southern survey area included 2 count model coefficients (Table 6). Specifically, the number of moose observed in a survey block was 1) positively correlated to *ExpertDD*, a binary covariate that describes whether a local expert expects to find high (1) or low (0) numbers of moose in a survey block, and 2) negatively correlated to *Conifer*, the percent of the survey block with conifer cover. This model (Table 7) was used to predict the distribution of moose in unsurveyed blocks of the survey area, and generate a population estimate and bootstrapped prediction intervals. Finally, these model results were subset to provide estimates for the KRDR MMU.

Similar to the northern area, we found that group size was the strongest covariate predicting the composition of moose in the southern survey area. Specifically, the proportion of lone cows and adult bulls in the survey blocks increased significantly in survey blocks with more than 2 moose (Table 8). This model (Table 9) was then applied to unsurveyed sample blocks to predict the distribution of composition of the moose population in subsets of the survey area including the KRDR MMU.

Table A1. Description of selected list of coefficients considered for models of abundance and composition of moose in the northern and southern survey areas in the Koidern and Burwash area, November 2014.

Covariate Name	Description	Source
ExpertDD	Binary covariate describing whether a local expert predicted high (1) or low (0) numbers of moose in the survey block.	Daniel Drummond (Haines Junction District Conservation Officer 1985-2007).
ExpertDix	Binary covariate describing whether a local expert predicted high (1) or low (0) numbers of moose in the survey block.	David Dixon (Dixon Outfitters Ltd. Whitehorse Yukon)
Burwash2011_SM5km	Estimated number of moose based on survey results from 2011.	Cell-based estimate of predicted number of moose based on a ZINB model using 2011 survey results and the Strat data as the only covariate and smoothed at a 5km scale.
Conifer	Percent of the survey block with Needleleaf forest cover type.	North American Land Cover 2010, Canada Center for Remote Sensing (CCRS), Natural Resources Canada.
Subalpine	Percent of the survey block with Subalpine biotic zone.	Ecological and Landscape Classification Technical Working Group. Bioclimate Zones and Subzones of Yukon Version 1.0. GeoTiff-30-m pixel. Government of Yukon.

Table A2. List of best models describing the number of moose observed in survey blocks in the northern survey area (November 2014) with associated AIC scores and model weights.

Model	df	AIC	ΔAIC	w
Burwash2011_SM5km + Conifer	5	385.2	0	0.550
Burwash2011_SM5km + Conifer + ExpertDix	6	387.2	1.91	0.212
Burwash2011_SM5km + Subalpine	5	387.7	2.42	0.164
Burwash2011_SM5km + Subalpine + ExpertDix	6	389.5	4.23	0.066
Subalpine + Conifer + ExpertDix	6	393.8	8.51	0.008

Table A3. Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed sample blocks (approximately 16 km^2) in the northern survey area, November 2014 (n=89, Log-likelihood=-188). This model was used to generate the population estimate and prediction intervals for the Koidern Moose Management Unit (MMU).

	Estimate	Standard Error	Z	P
Count model coefficients (negbin with log link):				
(Intercept)	0.726	0.407	1.782	0.075
Burwash2011_SM5km	0.194	0.059	3.282	0.001
Conifer	-2.001	1.107	-1.808	0.071
Log(theta)	0.263	0.449	0.587	0.558
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	-1.6361	0.8459	-1.934	0.053

Table A4. List of best models describing the composition of moose observed in the northern survey area (November 2014) with associated AIC scores and model weights.

Model	AIC	ΔAIC	w
Null Model	404.3	0	0.854
MGr2	408.9	4.57	0.087
MGr3	410.9	6.62	0.031
MGr4	411.1	6.86	0.028
Conifer	419.7	15.42	0.000

*These covariates are a binary description of group sizes counted in survey blocks. MGr2, MGr3, and MGr4 represent group sizes lesser than (1) or greater than (0) 2, 3 and 4 respectfully.

Table A5. Compositional model regression estimates for moose in the northern survey area, November 2014 (n=89, Log-likelihood=-192.15). This model was used to generate the composition and related prediction intervals for the Koidern Moose Management Unit (MMU).

	Estimate	Standard Error	Z	P
(Intercept):BULL_LARGE	-0.588	0.56	-1.054	0.292
(Intercept):BULL_SMALL	-17.350	1182.00	-0.015	0.988
(Intercept):COW_1C	0.000	0.47	0.000	1.000
(Intercept):COW_2C	-17.350	1182.00	-0.015	0.988
(Intercept):LONE_COW	-0.118	0.49	-0.242	0.808
MGr2:BULL_LARGE	1.553	0.61	2.558	0.011
MGr2:BULL_SMALL	16.810	1182.00	0.014	0.989
MGr2:COW_1C	-0.087	0.56	-0.156	0.876
MGr2:COW_2C	14.170	1182.00	0.012	0.990
MGr2:LONE_COW	1.800	0.53	3.368	0.001

Table A6. List of best models describing the number of moose observed in survey blocks in the southern survey area (November 2014) with associated AIC scores and model weights.

Model	df	AIC	∆AIC	w
ExpertDD + Conifer	5	431.1	0	0.481
ExpertDD + Conifer + Subalpine	6	432.6	1.51	0.226
ExpertDD + Conifer + Burwash2011_SM5km	6	433.0	1.90	0.186
ExpertDD + Subalpine + Burwash2011_SM5km	6	434.1	3.00	0.107

Table A7. Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed sample blocks (approximately 16 km^2) in the southern survey area, November 2014 (n=105, Log-likelihood=-210.5). This model was used to generate the population estimate and prediction intervals for the Kluane River/Duke River Moose Management Unit (KRDR MMU).

	Estimate	Standard Error	*Z*	*P*
Count model coefficients (negbin with log link):				
(Intercept)	1.380	0.333	4.145	<0.001
Expert DD	0.851	0.331	2.568	0.010
Conifer	-2.420	0.996	-2.430	0.015
Log(theta)	-0.431	0.534	-0.807	0.420
Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	-1.184	0.953	-1.243	0.214

Table A8. List of best models describing the composition of moose observed in the southern survey area (November 2014) with associated AIC scores and model weights.

Model	AIC	ΔAIC	w
MGr2	412.2	0	0.664
MGr4	414.6	2.44	0.196
MGr3	416.6	4.42	0.073
Conifer	416.8	4.61	0.066
Null Model	426.0	13.79	0.001

*These covariates are a binary description of group sizes counted in survey blocks. MGr2, MGr3, and MGr4 represent group sizes lesser than (1) or greater than (0) 2, 3 and 4 respectfully.

Table A9. Compositional model regression estimates for moose in the southern survey area, November 2014 (n=105, Log-likelihood=-196.1). This model was used to generate the composition and related prediction intervals for the Kluane River/Duke River Moose Management Unit (KRDR MMU).

	Estimate	Standard Error	Z	P
(Intercept):BULL_LARGE	-1.012	0.58	-1.733	0.083
(Intercept):BULL_SMALL	-17.350	1070.00	-0.016	0.987
(Intercept):COW_1C	0.000	0.43	0.000	1.000
(Intercept):COW_2C	-17.350	1070.00	-0.016	0.987
(Intercept):LONE_COW	-0.319	0.46	-0.685	0.493
MGr2:BULL_LARGE	1.517	0.62	2.451	0.014
MGr2:BULL_SMALL	15.790	1070.00	0.015	0.988
MGr2:COW_1C	-0.111	0.49	-0.228	0.820
MGr2:COW_2C	14.410	1070.00	0.013	0.989
MGr2:LONE_COW	1.630	0.50	3.264	0.001

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