Yukon

SR-19-08

Moose Survey

Mayo Moose Management Unit, early winter 2017

December 2019

Moose survey:
Mayo Moose Management Unit, early winter 2017

Government of Yukon
Fish and Wildlife Branch
SR-19-08

Authors
Mark O'Donoghue, Sophie Czetwertynski, Joe Bellmore and Susan Westover

Acknowledgements
Andrew Crane, Melvin Lagersson, and Jules Leonard flew the aerial surveys safely and efficiently in often-difficult conditions. Darrell Lucas, Elizabeth MacDonald, Simone MacDonald, Bruce MacGregor, Reggie McGinty, Stewart Moses, Mike Schlittenbauer, and Gavin Winter-Sinnott provided their keen eyesight and knowledge of the area as observers on the aerial survey crews. The Yukon Fish and Wildlife Branch and the Mayo District Renewable Resources Council provided funding and staff for this survey, and the First Nation of Na-Cho Nyäk Dun provided logistical support and staff.

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

Suggested citation:
O'DONOGHUE, M., S. CZETWERTYNSKI, J. BELLMORE, AND S. WESTOVER. 2018. MOOSE SURVEY: MAYO MOOSE MANAGEMENT UNIT, EARLY WINTER 2017. YUKON FISH AND WILDLIFE BRANCH REPORT SR-18-XX, WHITEHORSE, YUKON, CANADA.

Summary

- We conducted an early-winter survey of moose in the area northeast of Mayo from October 31 to November 9, 2017, using helicopters. The main purposes of this survey were to estimate the abundance, distribution and composition of the moose population.
- We counted all moose in survey blocks that covered about 41% of the entire area. We found a total of 600 moose: 131 adult bulls, 298 adult and yearling cows, 39 yearling bulls, and 132 calves.
- We calculated a population estimate of 719 moose (90% confident that the population was between 681 and 773) for the area. This number is equal to a density of about 144 moose per 1,000 km² over the whole area, or 153 per 1,000 km² in suitable moose habitat. This is low to moderate compared to the range of typical Yukon moose densities of 100-250 moose per 1,000 km².
- We estimated that there were about 51 calves and 30 yearlings for every 100 adult cows in the survey area. These ratios indicate 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 50 adult bulls for every 100 adult cows in the survey area. This adult sex ratio is lower than the Yukon average from surveyed populations, but above the minimum threshold of 30 bulls per 100 cows identified in our moose management guidelines.
- There has been a declining trend in moose numbers in the Mayo area since 2006.
- We estimate that the total harvest of moose in this area is at or above the maximum sustainable level recommended in our moose management guidelines.

Table of Contents

List of Figures

List of Tables

Introduction

This report summarises the results of the early-winter survey of moose in a part of the Mayo Moose Management Unit (MMU; Fig. 1), conducted on October 31 to November 9, 2017. The purpose of the survey was to estimate numbers, distribution, and composition by age and sex of the moose population.

Previous surveys

The Yukon Fish and Wildlife Branch has monitored populations of moose in the Mayo area since the mid-1970s, using a variety of methods and survey areas. We conducted early-winter censuses in different Mayo survey areas (Fig. 2) in 1988 (Larsen et al. 1989; a small part of this area was also re-surveyed in late winter 1989), 1993 (Ward and Larsen 1994), and 1998 (results in Yukon Fish & Wildlife Branch file reports). We conducted early-winter surveys of moose in the same survey area as this year's in 2006 (Ward et al. 2006) and 2011 (O'Donoghue et al. 2012). 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 estimate the proportion of bulls in the population.

We conducted late-winter surveys to measure recruitment of calves in a large area around Mayo (Fig. 2) annually from 1993 to 1999 and in 2003 (Ward and Larsen 1994, Ward and Larsen 1995, Sinnott and O'Donoghue 2003, and Yukon Fish and Wildlife Branch file reports). We also measured recruitment of moose at the end of winter in the same survey area as this year's in 2001 (Fraser et al. 2001), 2002 (O'Donoghue and Sinnott 2003), and 2004 (O'Donoghue 2015). We mapped late-winter distribution of moose in the same survey area in 2014 (O'Donoghue et al. 2016)

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 area have consistently placed a high priority on monitoring the abundance, distribution, and health of the local moose population. This survey was 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 Mayo District Renewable Resources Council provided some of the funding for this survey and staff of the First Nation of Na-Cho Nyäk Dun participated as observers.

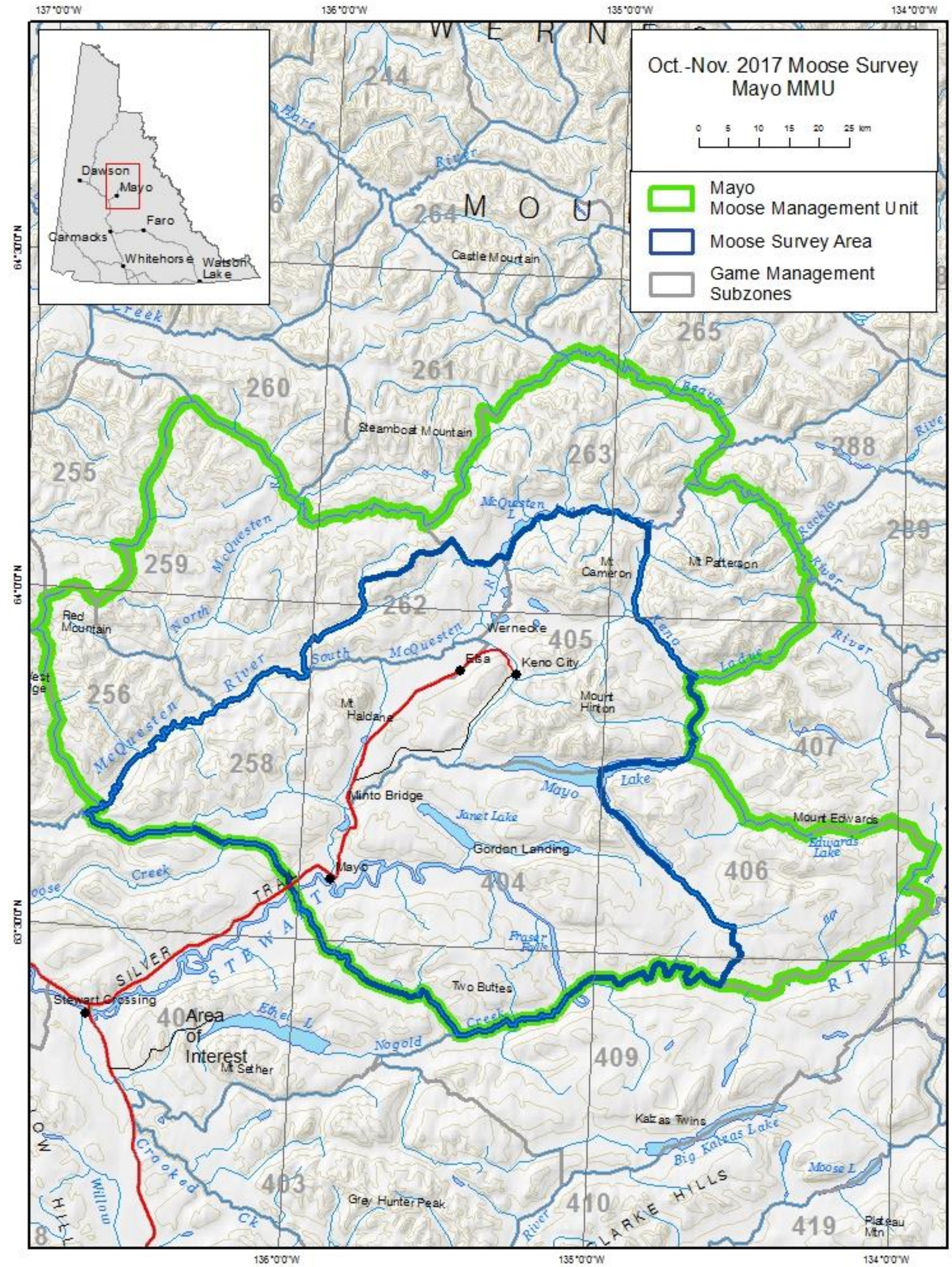

Figure 1. May Moose Management Unit and October-November 2017 survey area.

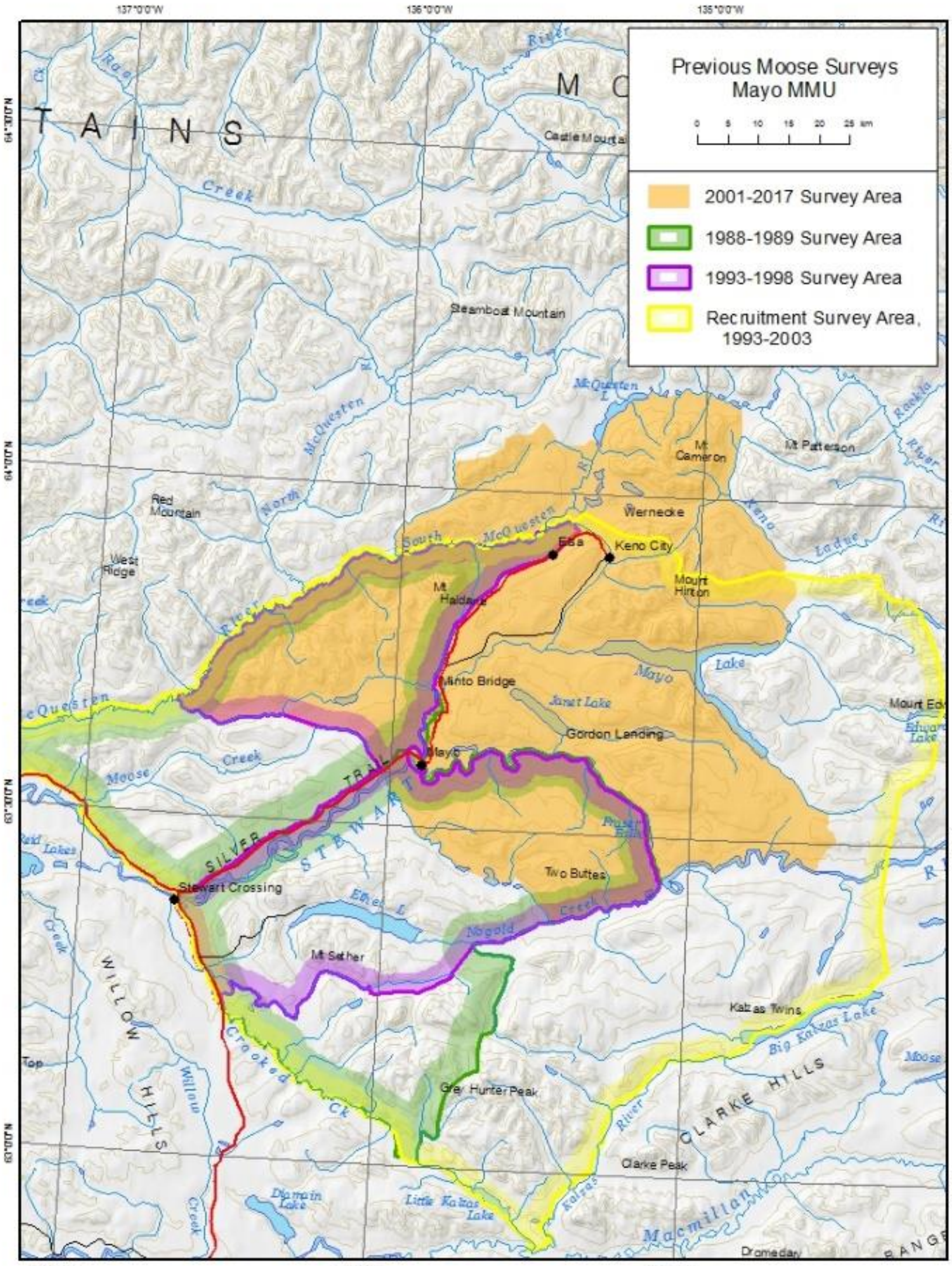

Figure 2 Previous moose surveys in the Mayo Moose Management Unit

Study area

The Mayo survey area was re-located in 2001 to conform to the boundaries of Yukon Moose Management Units (Environment Yukon 2016). Moose management units were developed to monitor and manage moose at the scale of populations throughout the territory. We plan to monitor the status of moose populations in priority moose management units on a regular basis, using both aerial and ground-based surveys.

The Mayo Moose Management Unit is about 9,659 km², and includes Game Management Sub-zones (GMS) 256, 258, 259, 262, 263, 404, 405 and 406 (Fig. 1). The survey area within the Mayo Moose Management Unit is about 5,014 km². The border runs north-east along the McQuesten and South McQuesten rivers to McQuesten Lake. From here, it roughly extends south along the Keno Ladue River to Mayo Lake and then to the Stewart River. The Stewart River and Nogold Creek form the south-east boundary. The south-west boundary runs north-west from Nogold Creek passing to the west of Mayo, and back to the McQuesten River.

Most of the study area (about 4,718 km²) is considered suitable moose habitat, except for approximately 6% of the area, which includes large water bodies (0.5 km² 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 McQuesten 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, and the mountainous area in the north-eastern corner (the Keno area) of the survey area.

Old and recent forest fires have occurred throughout the study area (Fig. 3). The most recent large fires were a 35 km² burn along the Stewart River in the south-east corner of the survey area in 2015, a 55 km² burn north-west of Elsa in 2005, a 71 km² burn south-west of McQuesten Lake in 1998, a 73 km² burn at the south arm of Mayo Lake in 1994, and a 183 km² burn north and west of Janet Lake in 1990.

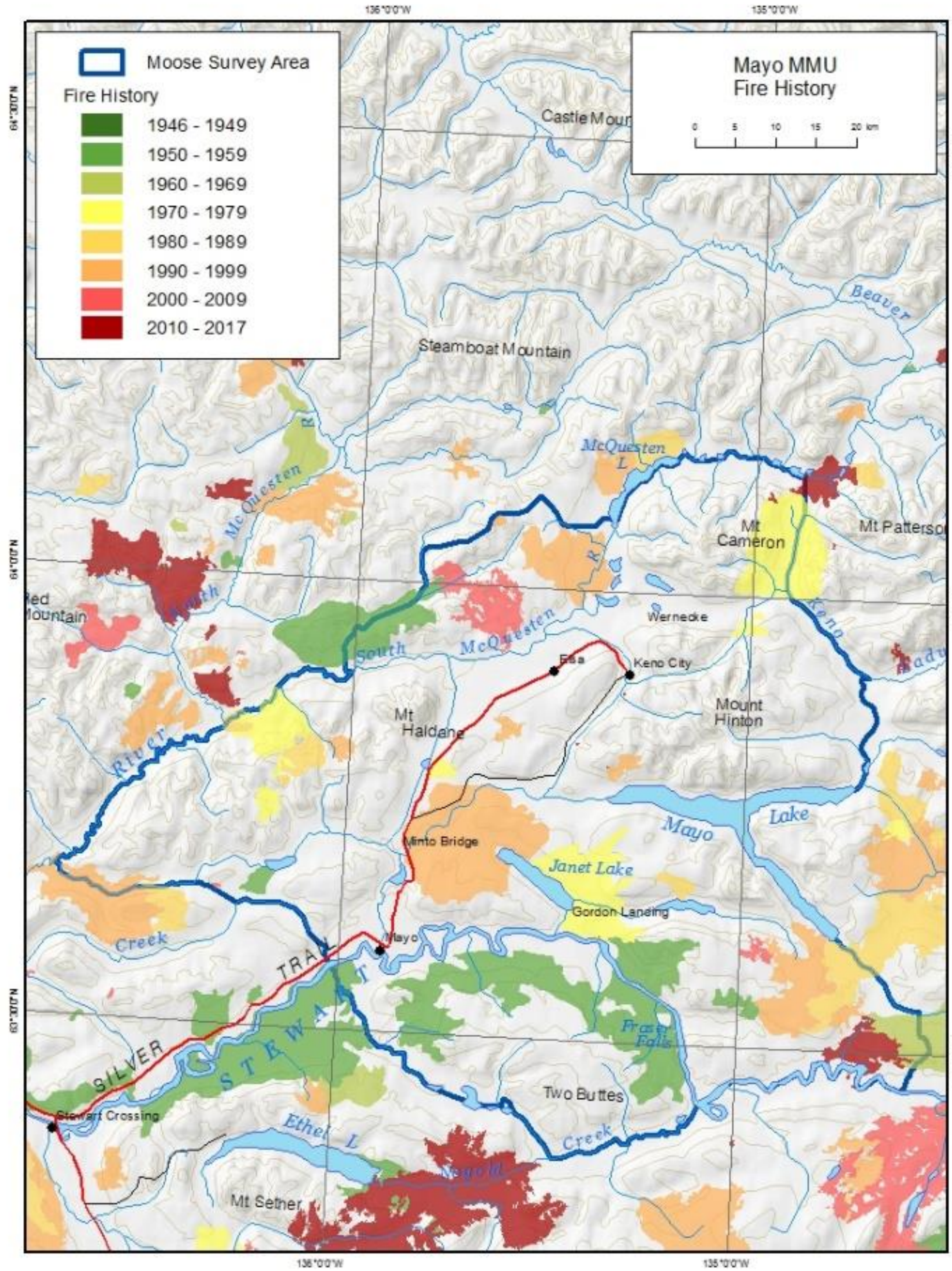

Figure 3 Mayo Moose Management Unit fire history.

Methods

We have recently adopted a new model-based technique to survey moose in the territory (Czetwertynski et al., in prep). Advantages of this method include the abilities to utilise local knowledge, estimate abundance in subsets of the survey area, and target our sampling to areas where uncertainty is greatest. The models relating moose abundance to habitat variables can also be used to predict moose numbers outside the survey area.

Generally, the field sampling is similar to the way we conducted our moose surveys in the past, except that we select blocks to count guided by model predictions rather than randomly.

The survey area is divided into rectangular blocks 15.1-15.5 km² (2' latitude x 5' longitude) in size. Where we are lacking recent information, we conduct a pre-census survey of moose distribution. Observers in fixed-wing aircraft fly over all the blocks quickly, and classify (or "stratify") them as having either high, medium, low, or very low expected moose numbers, based on local knowledge, number of moose seen, tracks, and habitat. This is called the "stratification" part of the survey. For this survey, we did not do a pre-census flight but rather relied on information from previous counts to initially stratify the area (Fig. 4).

Using helicopters, we then try to count every moose within the selected blocks (the "census" part of our survey), at a search intensity of about 2 minutes per km². We classify all moose by age (adult or calf) and sex. In early-winter surveys, it is also possible to reliably distinguish yearling bulls from adults based on antler size, and thus estimate the total number of yearlings in the population. Yearling cows are often difficult to distinguish from adults, so we classify all cows as adults, and later estimate the number of yearling cows that were present among the older cows by assuming it equals the number of yearling bulls we saw.

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

1. In phase 1, we use a combination of landscape characteristics (habitat, access) and local knowledge to generate an initial map predicting the abundance of moose in each of the survey blocks. For this survey we used local knowledge of moose distribution to guide our initial selection of survey units. Based on this information, we select survey blocks to be flown during the first two days of the 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.

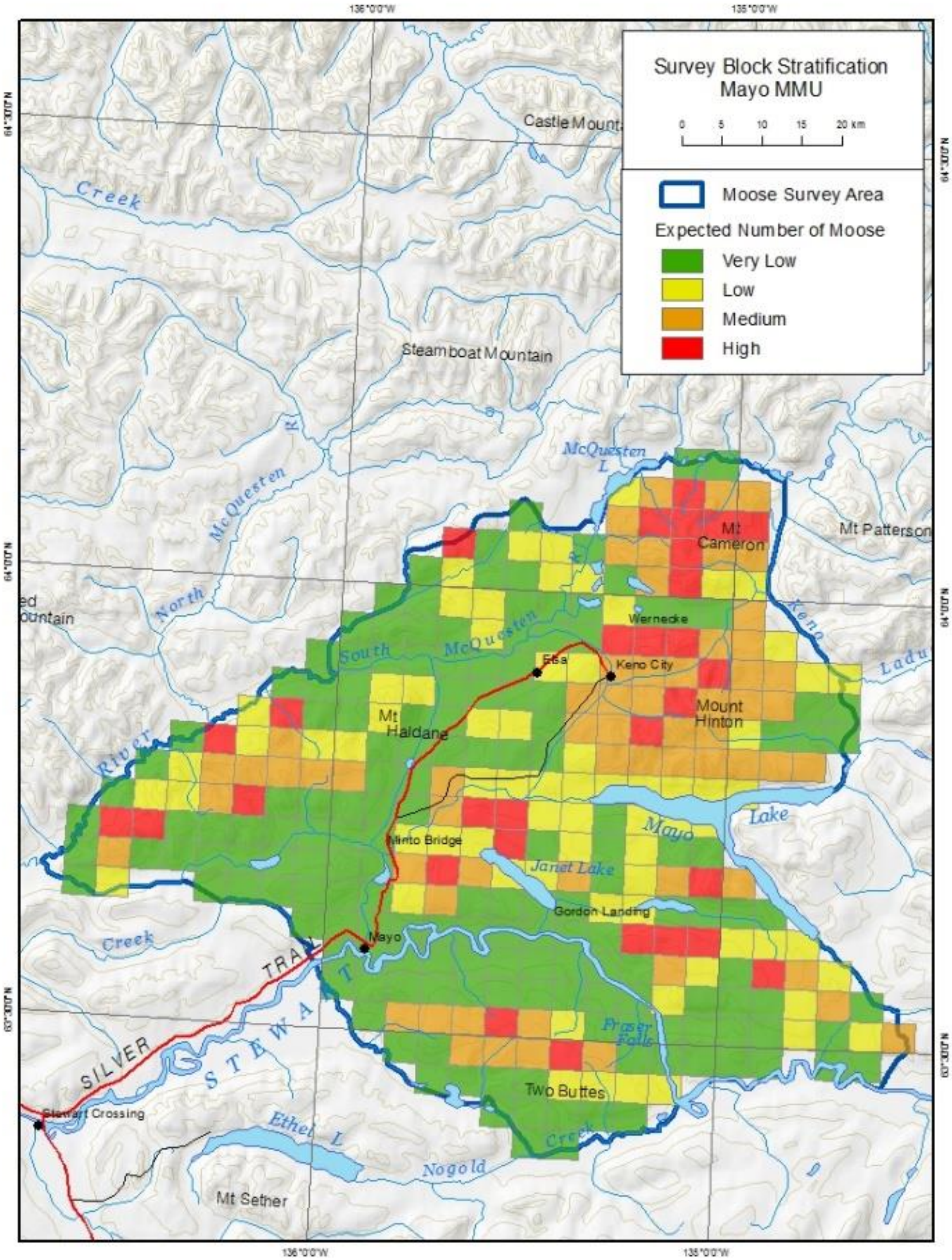

Figure 4 Survey block stratification in the Mayo Moose Management Unit, 2017.

.

2. In phase 2, we use available information (habitat type, access, local knowledge) to fit the best model describing moose abundance in the blocks surveyed to date. We then use this model to predict the number of moose in unsampled 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, 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.

3. In phase 3, we create a map showing the predicted number of moose in unsampled blocks based on the best model and allow the field crew to select units 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.

We usually try to count about a third of the blocks within the survey area. Generally, the more blocks searched during the census part of the survey, the more precise and reliable the resulting population estimate. This total population estimate is then broken down into age and sex classes using a compositional analysis (Czetwertynski et al., in prep). This analysis allows us to incorporate factors found to affect the distribution of different age and sex classes across the landscape.

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 correct our final population estimates accordingly.

Weather and snow conditions

Weather conditions were mixed but mostly good for this survey. Between 31 October and 9 November, we were unable to fly on two full days and part of one afternoon because of low clouds and icing. The weather was mostly clear on six of the eight days we flew, although we did encounter some low-lying fog that we had to work around on some days. Temperatures ranged from 32°C to 1°C. Winds were mostly mild; stronger winds were encountered on only one day, in the afternoon.

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 two days during the survey, which aided in spotting fresh tracks. Light conditions ranged from flat to bright.

Results and discussion

Stratification

We used the results of our 2006 and 2011 surveys to classify the survey blocks by expected density of moose before we started this census. We classified 30 (9%) of the 328 survey blocks as high, 62 (19%) as medium, 71 (22%) as low, and 165 (50%) as very low expected abundance of moose (Fig. 4), based on our previous observations from the air. Most of the blocks with higher expected numbers of moose were located in the mountainous area in the north-eastern part of the survey area and on subalpine ridges scattered elsewhere in the area.

Coverage

We counted moose in 133 of the 328 blocks, or about 41% of the total area (Fig. 5). Overall, we surveyed 93% of the blocks with expected high moose density based on our stratification, 77% of the medium-density blocks, 41% of the low-density blocks, and 17% of the very low-density blocks.

It took us about 72.7 hours to count moose in these blocks, for a search intensity of 2.15 minutes per km². We used another 23.8 hours of helicopter time to ferry between survey blocks, our fuel cache at Keno City, and back and forth to Mayo.

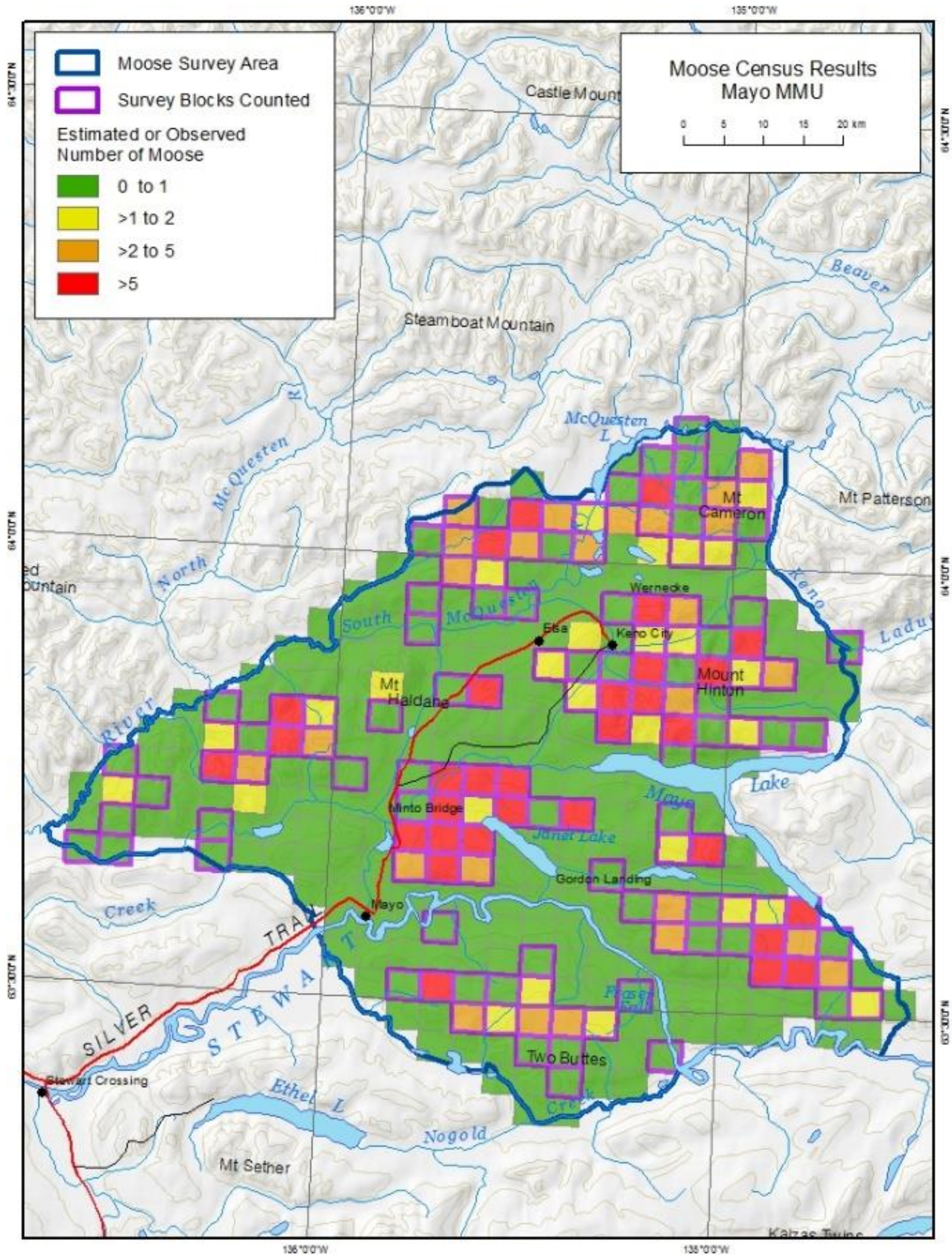

Figure 5 Moose census results in the Mayo Moose Management Unit, 2017.

Table 1. Observations of moose in the Mayo Moose Management Unit during the October-November 2017 survey.

	Total
Number of blocks counted	133
Number of adult bulls	131
Number of adult and yearling cows*	298
Number of yearling bulls	39
Number of calves	132

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

Observations of moose

We counted a total of 600 moose, 22% of them adult bulls, 50% adult and yearling cows, 6% yearling bulls, and 22% calves (Table 1). We observed an average of 296 moose for every 1,000 km² searched. These values (total number and composition by age and sex) cannot be directly used as estimates in unsurveyed 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 mountainous areas to the north, east, and south-east of Keno City; and the high plateaus south of Mayo Lake, north and west of Janet Lake, and south of the McQuesten River in the western part of the survey area (Fig. 5). We saw most moose in areas with good willow cover in the subalpine, and in areas that were burned in the 1990s. We saw relatively few moose in mature spruce, pine, and aspen forested areas and in lowland habitats of any kind.

Abundance of moose

The final model that best predicted moose abundance included two factors positively related to moose numbers: 1) the percentage of subalpine shrub habitats or high-elevation (800-1,500 m) 5-35-year-old burns in each survey block and 2) the expected number of moose in each survey block provided by local knowledge; and one factor negatively related to moose numbers: the percentage of spruce and pine forest in each survey 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 719, and we are 90% confident that population was between 681 and 773 (Table 2).

Table 2. Estimated abundance of moose, corrected for sightability (91%), in the Mayo Moose Management Unit survey area in October-November 2017.

	Best estimate*	**Estimates within 90% confidence interval****
Estimated total number of moose	719	681-773
Adult bulls	155	146-170
Adult cows	309	293-339
Yearlings	94	87-107
Calves	158	149-176
Density of moose (per 1,000 km^2)		
Entire area	144	136-154
Moose habitat only***	153	144-164

* 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% confidence 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.

*** 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.

The estimated density of moose in the entire survey area was 144 per 1,000 km^2, or 153 per 1,000 km^2 of suitable moose habitat (Table 2). This is low to moderate compared to the range of typical Yukon moose densities of 100-250 moose per 1,000 km^2 of suitable habitat (Environment Yukon 2016).

Table 3. Estimated composition of the moose population in the Mayo Moose Management Unit survey area in October-November 2017.

	Best Estimate	**Estimates within 90% confidence interval***
% Adult bulls	22%	21-22%
% Adult cows	43%	42-44%
% Yearlings	13%	12-14%
% Calves	22%	21-23%
Adult bulls per 100 adult cows	50	48-53
Yearlings per 100 adult cows	30	28-34
Yearlings per 100 adults (recruitment rate)	17	16-18
Calves per 100 adult cows	51	49-54
% of cow-calf groups with twins	14%	12-15%

* A "90% confidence 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 habitat type affected the distribution of different age and sex groups of moose. Specifically, we saw more adult bulls in survey blocks with a higher percentage of subalpine shrub habitat, whereas young bulls and cow-calf pairs tended to be found more in lower altitude shrubby habitats (details in Appendix 1). We used these relationships to estimate the composition of the moose population by age and sex in the survey area and account for this observed bias (Table 3).

Our survey results indicate that survival of calves and yearling moose in the survey area in 2016 and 2017 was above average compared to other areas surveyed in the territory. We estimated there were 51 calves and 30 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). However, estimates of recruitment from one survey are snapshots in time and survival varies from year to year. Survival of moose calves in this area was also good in 2006 and 2011, based on our last two censuses (Ward et al. 2006, O'Donoghue et al. 2012).

We estimated that there were 50 adult bulls for every 100 adult cows in the survey area (Table 3). This is lower than the Yukon average of 64 bulls per 100 adult cows, but 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 2006, 2011, and 2017 early-winter moose surveys in the Mayo Moose Management Unit survey area in November 2017.

	2006	2011	2017
Estimated total number of moose	1,061	816	719
Adult bulls	225	166	155
Adult cows	571	408	309
Yearlings	52	80	94
Calves	213	162	158
Adult bulls per 100 adult cows	43	41	50
Yearlings per 100 adult cows	10	20	30
Calves per 100 adult cows	36	40	51
Density of moose (per 1,000 km^2)			
Entire area	212	163	144
Moose habitat only*	225	173	153

* 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 trends

Our moose census results from 2006, 2011, and 2017 indicate that there has been a declining trend in densities of moose in the Mayo Moose Management Unit during that 11-year period (Table 4, Fig. 6). The decline in most pronounced in adults, both bulls and cows. 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).

Survival of calves and yearlings, as measured by numbers per 100 cows, showed increasing trends between 2006 and 2017 (Table 4).

Harvest

Before calculating a sustainable harvest for the Mayo area, we needed to estimate the moose population for the entire Mayo 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 extended areas have a higher percentage of subalpine habitat and less closed lowland forest, so overall predicted densities of moose were higher than in the surveyed blocks (Fig. 7).

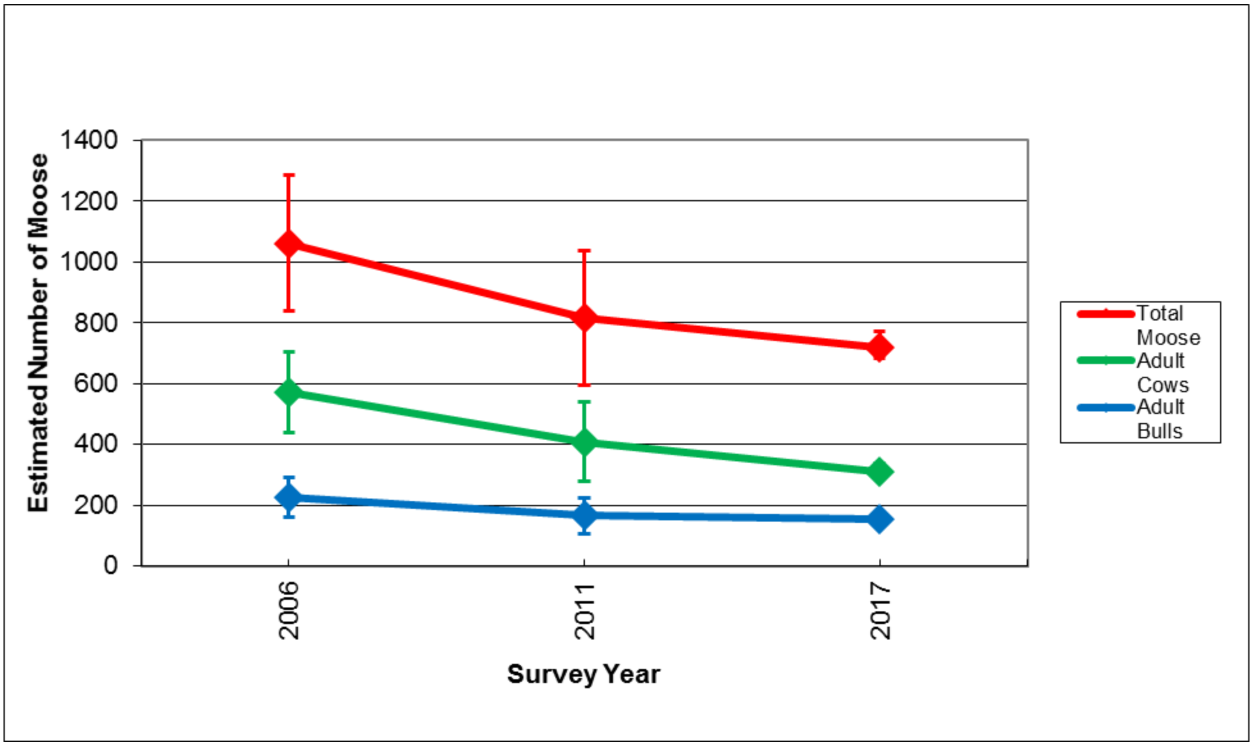

Figure 6 Trends in numbers (with 90% confidence intervals) of total moose, adult cows, and adult bulls, based on surveys in the Mayo Moose Management Unit in 2006, 2011, and 2017.

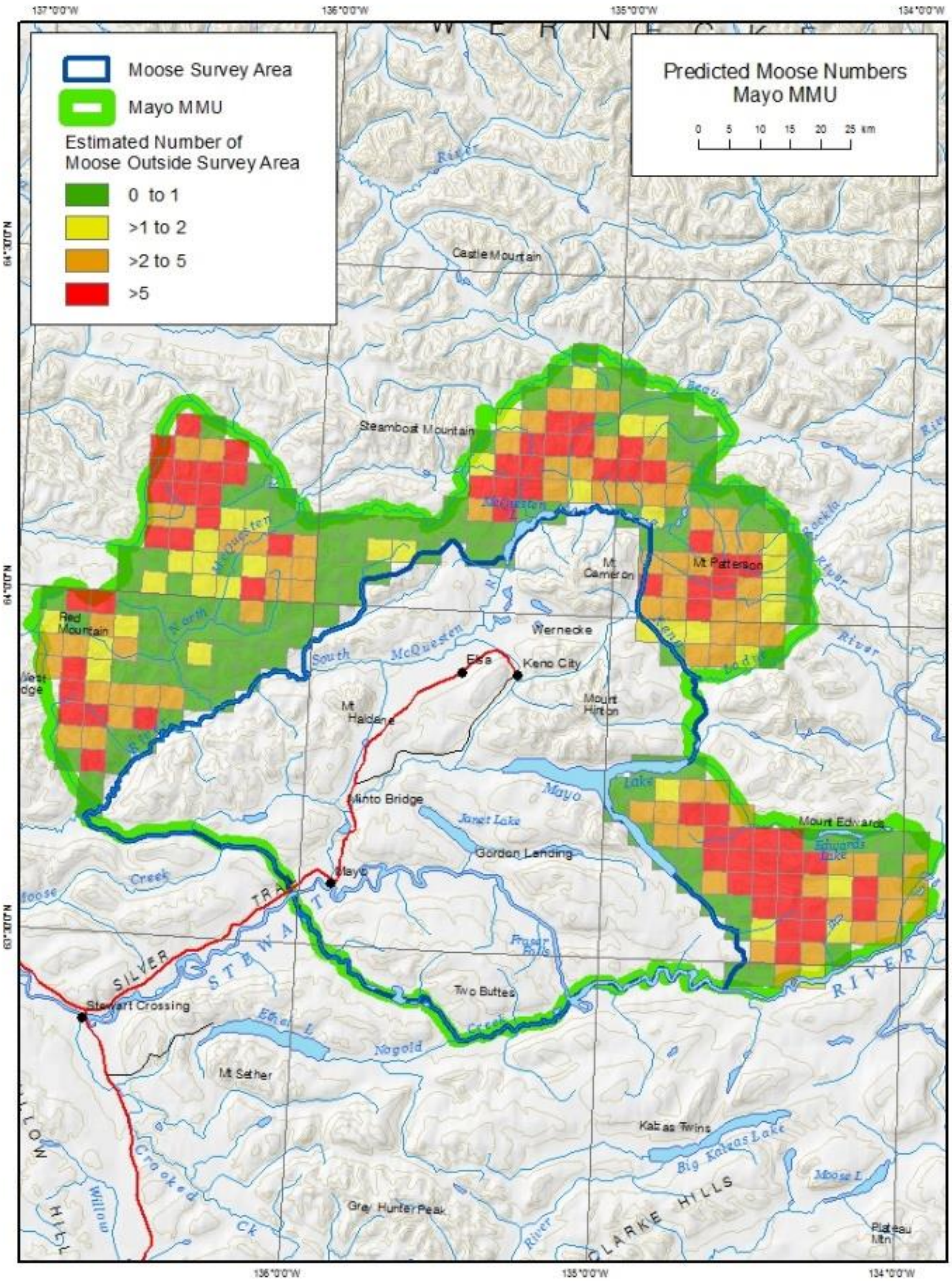

Figure 7 Predicted moose numbers in the Mayo Moose Management Unit outside the 2017 survey area, based on the best model from census results

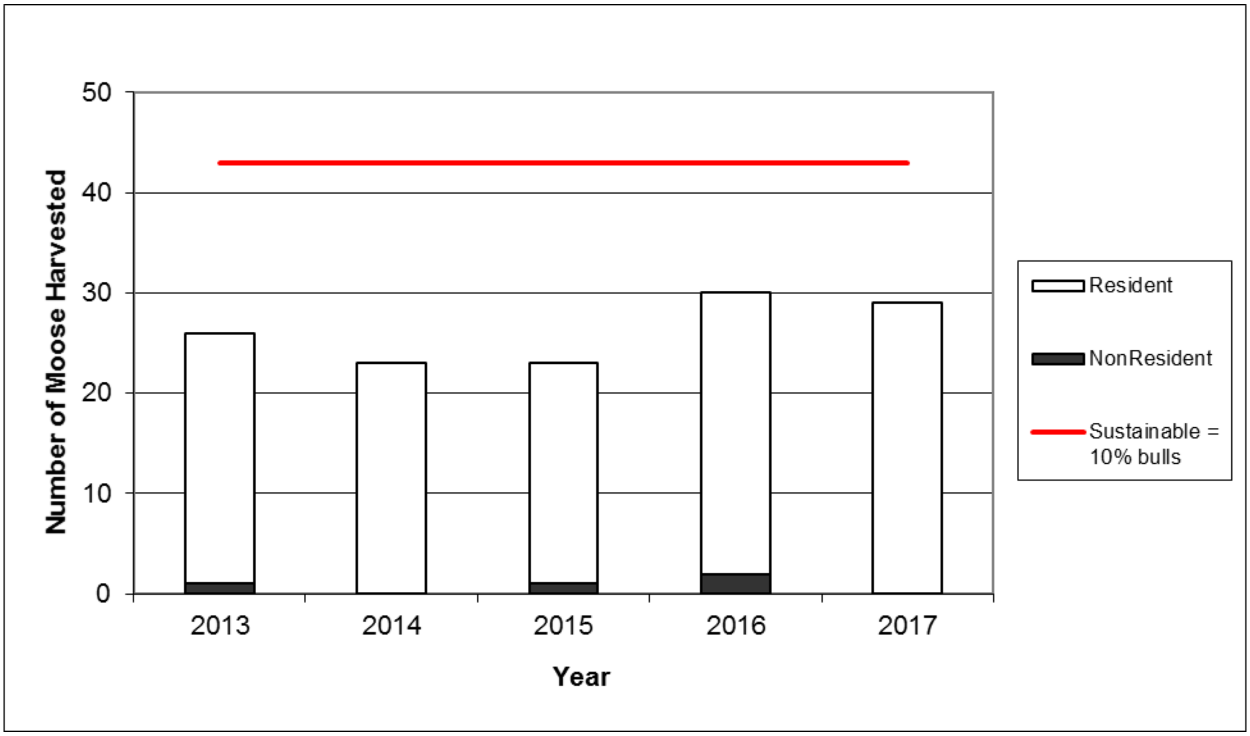

Figure 8 Harvest of moose by licenced hunters in the Mayo Moose Management Unit from 2013 through 2017. Resident harvest includes special-guided permits. The estimated total sustainable harvest is 43 bulls per year. First Nation harvest in the central Yukon is generally similar to licenced resident harvest.

Based on these projections, we estimate the population of moose to be 1,780 in the Mayo Moose Management Unit, with 430 adult bulls. The sustainable harvest is estimated at 10% of bulls (Environment Yukon 2016), or 43 animals.

During the 5 hunting seasons preceding this survey (2013 to 2017), the reported harvest of moose by licenced hunters in the Mayo Moose Management Unit averaged about 26 moose per year (see Fig. 8). This is the same as the long-term average of 26 moose harvested per year by licenced hunters in this area in the previous 34 years (1979-2012) for which we have harvest records. This figure does 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 at or above the recommended maximum sustainable rate for this moose management unit.

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

Other wildlife sightings

In addition to the 600 moose we counted during the 2017 census, we saw 70 moose in 39 groups outside the surveyed blocks or while travelling between blocks.

We also saw 7 wolves during the census. Six of them were at or near the kill site of a moose west of Two Buttes. The other was a lone wolf seen near Keno City. We saw a second site where a moose had been killed by wolves south of McQuesten Lake.

We also saw 1 lynx, 1 red fox, and at least 1 swan (on the south arm of Mayo Lake).

Conclusions and recommendations

- We estimated that there was a low to moderate-density moose population in the Mayo Moose Management Unit compared to other areas surveyed in the territory.
- There has been a declining trend in moose numbers in the Mayo area since 2006.
- Survival of calves and yearlings was relatively high in 2016 and 2017 in the Mayo Moose Management Unit, as it has been in previous surveys.
- The ratio of adult bulls to adult cows in the survey area has been lower than the Yukon average between 2006 and 2017.
- Present harvest of moose is at or above to the maximum sustainable level for this area.
- We should discuss harvest management in the area with the affected First Nation and Renewable Resource Council to ensure harvest does not exceed sustainable levels.
- We should continue to monitor moose populations in this area using aerial and ground-based monitoring.

References

CZETWERTYNSKI, S., S. LELE, AND P. SOLYMOS. in prep. Model-based optimal sampling for the estimation of abundance and composition of low-density moose populations. Yukon Fish and Wildlife Branch Report, Whitehorse, Yukon, Canada.

FRASER, V., M. O'DONOGHUE, AND S. WESTOVER. 2001. Mayo Moose Management Unit: Summary of late-winter 2001 moose survey, 2-5 March 2001. Yukon Fish and Wildlife Branch Report SR-01-01, Whitehorse, Yukon, Canada.

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

LARSEN, D. G., R. L. MARKEL, AND R. M. P. WARD. 1989. Moose population characteristics in the Mayo and Pelly Crossing areas, 1988-1989. Yukon Fish and Wildlife Branch Report PR-89-02, Whitehorse, Yukon, Canada.

O'DONOGHUE, M. 2015. Moose survey: Mayo Moose Management Unit, late-winter 2004. Yukon Fish and Wildlife Branch Report, Whitehorse, Yukon, Canada.

O'DONOGHUE, M. 2018. Mayo Community Ecological Monitoring Project local knowledge interviews: 2016-2017 summary. Yukon Fish and Wildlife Branch File Report, Whitehorse, Yukon, Canada.

O'DONOGHUE, M., AND J. BELLMORE. 2014. Mayo Community Moose Monitoring Project: 2001-2013 review. Yukon Fish and Wildlife Branch Report TR-14-07, Whitehorse, Yukon, Canada.

O'DONOGHUE, M., J. BELLMORE, S. CZETWERTYNSKI, AND S. WESTOVER. 2016. Moose survey: Mayo Moose Management Unit, late winter 2014. Yukon Fish and Wildlife Branch Report SR-16-05, Whitehorse, Yukon, Canada.

O'DONOGHUE, M., J. BELLMORE, R. WARD, AND S. WESTOVER. 2012. Moose survey: Mayo Moose Management Unit, early winter 2011. Yukon Fish and Wildlife Branch Report TR-12-32, Whitehorse, Yukon, Canada.

O'DONOGHUE, M., AND K. SINNOTT 2003. Mayo Moose Management Unit: Summary of late-winter 2002 moose survey, 4-10 March 2002. Yukon Fish and Wildlife Branch Report SR-03-10, Whitehorse, Yukon, Canada.

SINNOTT, K, AND M. O'DONOGHUE. 2003. Late-winter moose recruitment survey in the Mayo area, 11-13 March 2003. Yukon Fish and Wildlife Branch Report SR-03-09, Whitehorse, Yukon, Canada.

WARD, R. M. P., AND D. G. LARSEN. 1994. Summary of 1993 moose surveys in the Big Salmon, Mayo, Aishihik-Onion Creek and Dawson areas. Yukon Fish and Wildlife Branch Report SR-94-03, Whitehorse, Yukon, Canada.

WARD, R. M. P., AND D. G. LARSEN. 1995. Summary of 1992 moose surveys in the Aishihik, Onion Creek, Big Salmon, Mayo and Dawson areas. Yukon Fish and Wildlife Branch Report PR-95-02, Whitehorse, Yukon, Canada.

WARD, R., M. O'DONOGHUE, AND V. FRASER. 2006. Mayo Moose Management Unit: Summary of early-winter 2006 moose survey. Yukon Fish and Wildlife Branch Report SR-06-01, Whitehorse, Yukon, Canada.

APPENDIX 1 Details of models used to estimate the abundance and composition of the Mayo 2017 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 Mayo 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 weighted 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 the low density and spatially aggregated moose distribution across survey units in Yukon because they account for over dispersion and excess zeros. To account for the strong effect of outliers on parameter estimates, we used weighting such that each data point was assigned a weight of 1/abs(likelihood difference). The likelihood difference is the difference between the full likelihood minus the likelihood based on the removal of that data point. Therefore, the greater the change in the likelihood the smaller the weight because it is highly influential. 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) PELCSubalpine_Fire8212DEM815, the percent of the survey unit with subalpine habitat or high elevation burns (800-1500m) between 1982 and 2012, and 2) LKStrat_01, a layer that combined information provided by the local Regional Biologist and knowledgeable local residents who predicted survey units to have high or low numbers of moose. In addition, the number of moose observed was negatively correlated to PNeedle, the percent of the survey unit with needle leaf trees. 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 as well as extrapolate outside the survey area when appropriate, 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 PELC_Subalpine covariate that accounted for the greater proportion of adult bulls observed in a survey unit with increasing percentage of subalpine 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 km2) and the population composition in the Mayo survey area, November 2017.

Covariate Name	Description	Source
LKStrat_01	Binary covariate describing whether local experts predicted high (1) or low (0) numbers of moose in the survey unit.	Regional staff and information from knowledgeable local residents (First Nations, trappers, hunters).
PNeedle	Percent of the survey unit with Needleleaf forest cover type.	North American Land Cover (NALC) 2010 from the Canada Center for Remote Sensing (CCRS).
PELC_Subalpine	Percent of the survey unit with subalpine habitat.	Bioclimate Map from the Yukon Ecological Landscape Classification (ELC) Program.
PSubShrub250	Percent of the survey unit with subalpine shrub habitat (where shrub pixels were buffered by 250m before intersection with subalpine habitats).	Bioclimate Map from the Yukon ELC Program, and NALC 2010 from the CCRS.
PFire8212_DEM815	Percent of the survey unit with high elevation burns (800-1500m) between 1982 and 2012.	Natural Resources Canada (NRC) National Fire Database and Digital Elevation Model (DEM) from NRC.
PELCSub_Fire8212DEM815	Percent of the survey unit with either subalpine habitat or high elevation burns (800-1500m) between 1982 and 2012.	Bioclimate Map from the Yukon ELC Program, DEM from NRC, and the NRC National Fire Database.
PSubShrub250_Fire8212DEM815	Percent of the unit with either subalpine shrub habitat (where shrub pixels were buffered by 250m), or high elevation burns (800-1500m) between 1982 and 2012.	Bioclimate Map from the Yukon ELC program, NALC 2010 from the CCRS, DEM from NRC, and the NRC National Fire Database.

Table A 2. List of best models describing the number of moose observed in survey units in the Mayo survey area (November 2017) with associated AIC scores and model weights.

Model	df	AIC	ΔAIC	w
(PELCSub_Fire8212DEM815) + LKStrat_01 + PNeedle	6	341.0	0	0.981
(PSubShr250_Fire8212DEM815) + LKStrat_01 + PNeedle	6	348.9	7.9	0.019
(PSubShr250_Fire8212DEM815) + LKStrat_01	5	364.6	23.5	0
(PELCSub_Fire8212DEM815) + LKStrat_01	5	367.3	26.3	0

Table A 3. Weighted Zero-Inflated Negative Binomial (ZINB) regression estimates for counts of moose observed in surveyed sample units (approximately 16 km2) in the Mayo survey area, November 2017 (n=133, Log-likelihood=-309.2)

	Estimate	Standard Error	Z	P
Weighted Count model coefficients (negbin with log link):				
(Intercept)	0.829	0.332	2.500	0.012
PELCSub_Fire8212DEM815	2.850	0.902	3.160	0.002
PNeedle	-2.643	0.742	-3.562	<0.001
LKStrat_01	0.667	0.434	1.536	0.125
Log(theta)	-1.047	0.186	-5.631	<0.001
Weighted Zero-inflation model coefficients (binomial with logit link):				
(Intercept)	-5.825	14.991	-0.389	0.698

Table A 4. List of top models describing the composition of moose observed in the Mayo survey area (November 2017) with associated AIC scores and model weights.

Model	AIC	ΔAIC	w
PELC_Subalpine	805.2	0.000	0.602
PSubShrBuff250	806.2	1.075	0.351
Null	810.8	5.606	0.036
PFire8212_DEM815	814.5	9.341	0.006
LKStrat_01	816.9	11.758	0.002
PELCSubalp_Fire8212DEM815	816.5	11.320	0.002
PNeedle	817.8	12.691	0.001

Table A 5. Compositional model regression estimates for moose in the Mayo survey area, November 2017 (n=133, Log-likelihood=-392.6)

	Estimate	Standard Error	Z	P
(Intercept):BULL_LARGE	-0.231	0.160	-1.449	0.148
(Intercept):BULL_SMALL	-0.983	0.209	-4.693	<0.001
(Intercept):COW_1C	-0.238	0.162	-1.466	0.143
(Intercept):COW_2C	-2.241	0.342	-6.545	<0.001
(Intercept):LONE_COW	0.240	0.143	1.676	0.094
PELC_Subalpine:BULL_LARGE	1.031	0.466	2.211	0.027
PELC_Subalpine:BULL_SMALL	-1.761	0.921	-1.913	0.056
PELC_Subalpine:COW_1C	-0.230	0.537	-0.428	0.668
PELC_Subalpine:COW_2C	0.643	0.985	0.653	0.514
PELC_Subalpine:LONE_COW	0.418	0.445	0.938	0.348

Literature Cited:

BURNHAM, K. P., AND D. R. ANDERSON. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

CZETWERTYNSKI, S., S. LELE, AND P. SOLYMOS. *in prep.* Model-based optimal sampling for the estimation of abundance and composition of low density moose populations.

WAGENMAKERS, E.-J., AND S. FARRELL. 2004. AIC model selection using Akaike weights. Psychonomic Bulletin & Review 11(1), 192-196.

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

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