Horn River Basin Moose Inventory January/February 2010

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Executive Summary

Moose are the most prevalent ungulate in the north east corner of British Columbia and are important culturally and as a food source for local First Nations and licensed hunters. This survey was initiated to gather baseline population data for moose in light of increasing industrial activity associated with the Horn River Basin shale gas field.

The survey was conducted from January 13 to February 23 in the north east corner of British Columbia entirely within the boreal black and white spruce biogeoclimatic zone. The area was divided into eight survey units (Parker, Paradise, Kiwigana, Tsea, Fortune West, Fortune East, Calender, and Capot Blanc) that roughly corresponded to boreal caribou core areas. The survey units were surveyed individually, but were grouped in a variety of ways (units that represented wildlife management unit 7-55, the Horn River Basin planning area, and the entire study area) that allowed comparisons with previous surveys and addressed the concerns of the impact of industrial activity on the moose in the Horn River Basin.

Distance sampling was chosen as the survey method rather than the standard stratified random block count as it allowed for a larger area to be surveyed for less cost, density estimates for a series of survey units, and provided locations for distribution mapping of moose across the study area. This methodology has not previously been used for moose in British Columbia and holds promise as an efficient and cost effective method for the future. Distance sampling involves flying predetermined transects (for this study UTM eastings spaced at 3 or 6 km intervals) and recording the perpendicular distances to all moose sighted from the transect line to the maximum distance a moose could be seen. For each moose or group of moose sighted a UTM location was recorded and the animals classified as male, female or calf. The location data was used to calculate the distance the moose group was from the transect line. The computer program Distance was used to estimate density and population size for each of the survey units. Incidental species were recorded during the flights.

For the entire survey area the density estimate for moose was 0.116 moose/km^2 (range 0.096 – 0.140 at 95% confidence interval). Density (moose/km^2) in each of the survey units with 95% confidence interval range in brackets was: Parker = 0.246 (0.201 – 0.302), Tsea = 0.172 (0.106 – 0.278), Kiwigana = 0.159 (0.112 – 0.225), Paradise = 0.124 (0.083 – 0.186), Capot Blanc = 0.076 (0.047 – 0.123), Fortune West = 0.049 (0.028 – 0.087), Fortune East = 0.043 (0.026 – 0.071), Calender = 0.018 (0.008 – 0.040). For survey units that represented the Horn River Basin planning unit density was 0.151 moose/km^2 (range 0.125 – 0.183). The ratio of calves : 100 cows ranged from 22 in the Capot Blanc unit to 42 in the Fortune West unit. There was a negative relationship between the number of bull moose : 100 cows and the density of moose in a survey unit. The ratio of bulls : 100 cows ranged from 57 in the Capot Blanc unit to 157 in the Calender unit. There were 154 boreal caribou counted incidentally across the study area.

This was the first survey using distance sampling for moose in north east British Columbia and proved to be an effective and efficient method for collecting density and demographic data. There was a wide range of precision in the estimates that is attributable to the size of the survey units and the level of effort (kilometres of transect flown) applied in each unit. The most precise estimates were derived when multiple survey units were pooled for analysis. A means to estimate the length of transects necessary for a survey unit are described based on the relationship between the density of moose in a survey unit and the number of moose seen per kilometer of transect.

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1 Introduction

1.1 Background

Moose (*Alces alces*) are year-round residents in north eastern British Columbia, and an important traditional food species for local First Nations and other northern communities. Moose hunting is a popular recreational activity pursued by both residents of British Columbia and non-resident hunters. The importance of moose hunting, coupled with increased industrial activity in northern moose ranges, specifically the Horn River Basin (HRB), required an inventory to quantify baseline moose population densities and parameters. Moose population assessment is essential for proper land use and moose population management.

The Horn River Basin is a geological formation in north east British Columbia which holds substantial amounts of shale gas. Shale gas is natural gas trapped between mineral particles in small pores that exist within the fine grained rock. This gas was inaccessible using traditional technologies, however new technology is allowing these reserves to be accessed and extracted. Extraction of shale gas requires substantially more wells and water withdrawls than traditional gas extraction and the impacts of this intense industrial activity on moose is unknown. This survey was planned to determine baseline moose densities within the HRB and surrounding areas to allow comparison with future surveys to determine changes in moose densities.

The extreme north east corner of British Columbia has traditionally had few access routes and is far from major population centers resulting in low hunting pressure from licensed hunters and therefore a reduced need for intensive population monitoring. However, population data exists from previous surveys in Wildlife Management Units 7-55 and 7-56. In February 1988 a systematic aerial survey with random subsampling for moose was conducted by Ministry of Environment in the Fort Nelson area in portions of Management Unit (MU) 7-49, 7-54, 7-55, and 7-56 (Elliot 1988). Elliot estimated a density of moose in the survey area of 0.09 moose/km^2 over the 21,177 km^2 study area. The systematic nature of Elliot's survey showed moose densities to vary across the survey area, suggesting that applying an average density of moose across the area would not reflect the variation in moose densities on the landscape. A combined moose and boreal caribou (*Rangifer tarandus*) inventory was conducted by Ministry of Environment in February of 2004 (Backmeyer 2004). Backmeyer surveyed the entirety of MU 7-55 and 7-56 using a simple random block design to which a post hoc stratification for moose was applied. The survey results were a population estimate of 2998 (+/- 25% at 90% confidence interval) and a density of 0.087 moose/km^2 over the entire survey area. In MU 7-55 there were 32 calves : 100 cows and in MU 7-56 there were 42 calves : 100 cows. In March 2008 a stratified random block count was conducted within a 5475 km^2 area of high industrial interest within the Horn River Basin planning area (Churchill 2008). Churchill found a density of 0.14 moose/km^2 within the surveyed area.

Within the Peace Region, moose surveys designed to estimate abundance and/or density have primarily been conducted using stratified random block counts (Gasaway et al. 1986). These surveys require dividing the study area into a series of blocks based on a systematic grid or habitat polygons. The entire survey area is then flown in a fixed wing aircraft to stratify the blocks into low, medium or high moose densities. Once stratification is complete a more intensive search by helicopter is conducted in a randomly selected number of blocks from each stratum. This method also requires a sightability correction to be applied and is determined by flying a proportion of the randomly selected blocks even more intensively to determine the number of moose missed during the survey, or to forego the sightability correction trials and assume a fixed sightability factor. The Gasaway method is a standard method for surveying moose in BC (Resources Inventory Committee 2002), however other methods, such as distance sampling, exist that may prove to be more efficient and provide a similar level of precision depending on the density of the population and habitat being surveyed (Buckland et al. 2001). Distance sampling requires surveying transect lines along which the decreasing detection probability of moose with increasing distance from the transect line is fitted to the data (Buckland et al. 2001). To estimate densities of moose distance sampling has been used successfully in Alaska (Nielson et al. 2006) and Alberta (Peters and Hebblewhite 2009). Given the openness of the habitat in the Fort Nelson area and the Horn River Basin we decided to use distance sampling rather than the Gasaway method for this survey. The benefits of distance sampling versus a stratified random block count are larger area surveyed for less cost, no pre-stratification is required, densities can be calculated for a variety of survey areas (i.e. individual survey units, HRB, entire study area), distribution mapping of moose across survey areas is possible, and no additional sightability correction factor is necessary.

1.2 Objectives

The objectives of the survey were to obtain:

1) Density and population estimates of moose in eight survey units, the HRB planning area, and the entire survey area with high precision (coefficient of variation for estimates <20% at 95% confidence interval)
2) Age/gender structure of moose population in eight survey units, the HRB planning area, and the entire survey area
3) Count of incidental species, primarily boreal caribou.

2 Methods

2.1 Study Area

The study area was chosen to fully encompass the HRB planning area and land surrounding that was of interest to First Nations and could act as a control to monitor changes in the moose population through time. The study area was divided into eight survey units (Parker, Paradise, Capot Blanc, Fortune West, Fortune East, Calender, Kiwigana, and Tsea) that roughly corresponded to boreal caribou cores (Culling et al. 2004) and the boundary of the HRB (Figure 1).

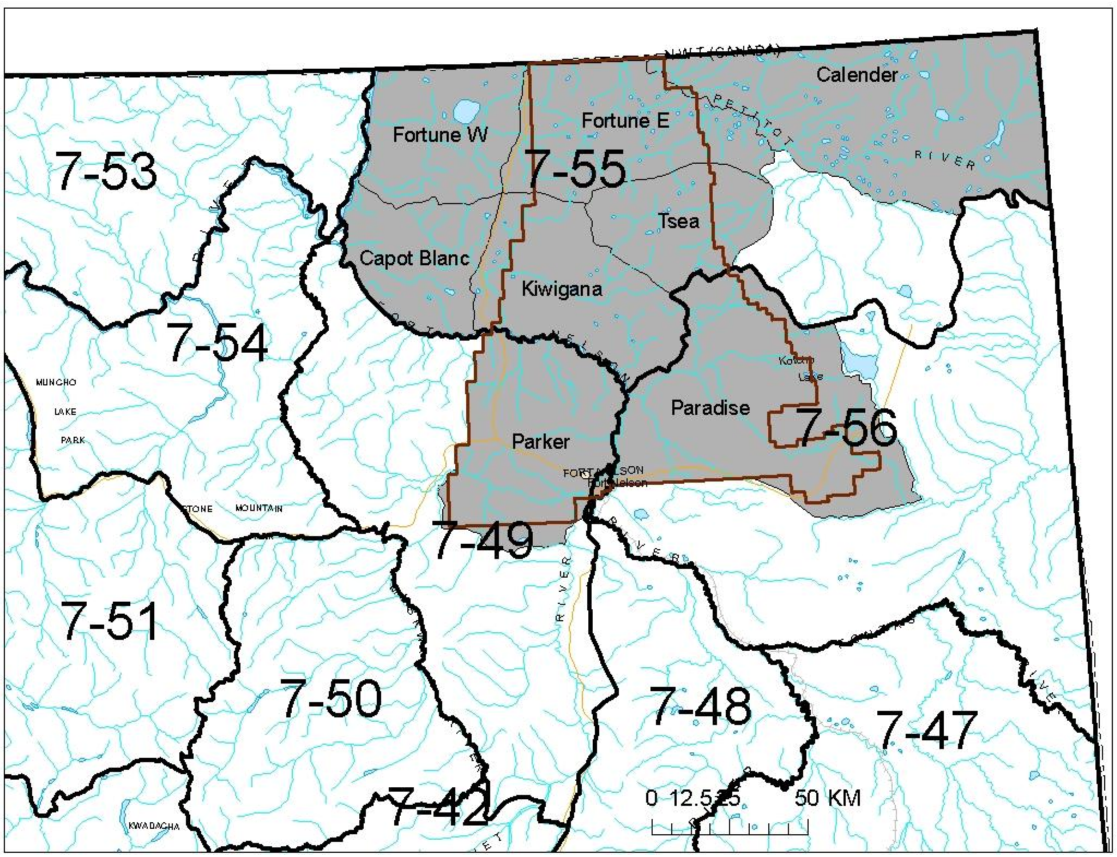

Figure 1 Survey area (labelled gray shaded polygons) for January/February 2010 moose survey in relation to Ministry of Environment wildlife management units (black polygons) and the Horn River Basin planning area (red polygon) in north eastern British Columbia.

The north east corner of the province has low moose densities relative to the majority of the Peace Region (Rowe 2008) and the study area is primarily rated as moderate or low winter habitat capability (Figure 2). The area is composed of five ecosections (Maxhamish Upland, Fort Nelson Lowland, Etsho Plateau, Petitot Plain, and Trout Lake Plain) (Figure 3) within the Boreal Black and White Spruce biogeoclimatic zone. This area is characterized by warm summer months with frequent wildfires and long, cold winters and is composed of a combination of upland forests and low lying peatlands (DeLong et al. 1990).

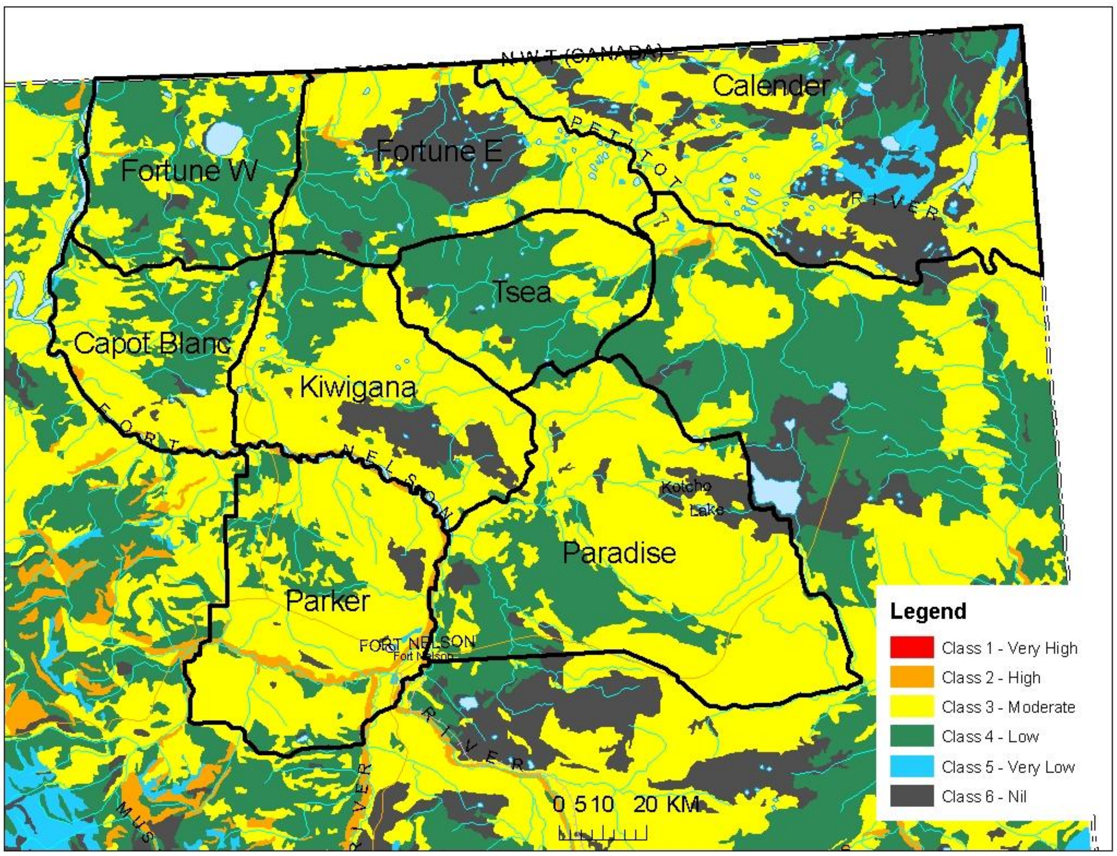

Figure 2 Moose winter habitat capability within the Horn River Basin planning area from BC Ministry of Environment broad ecosystem inventory mapping.

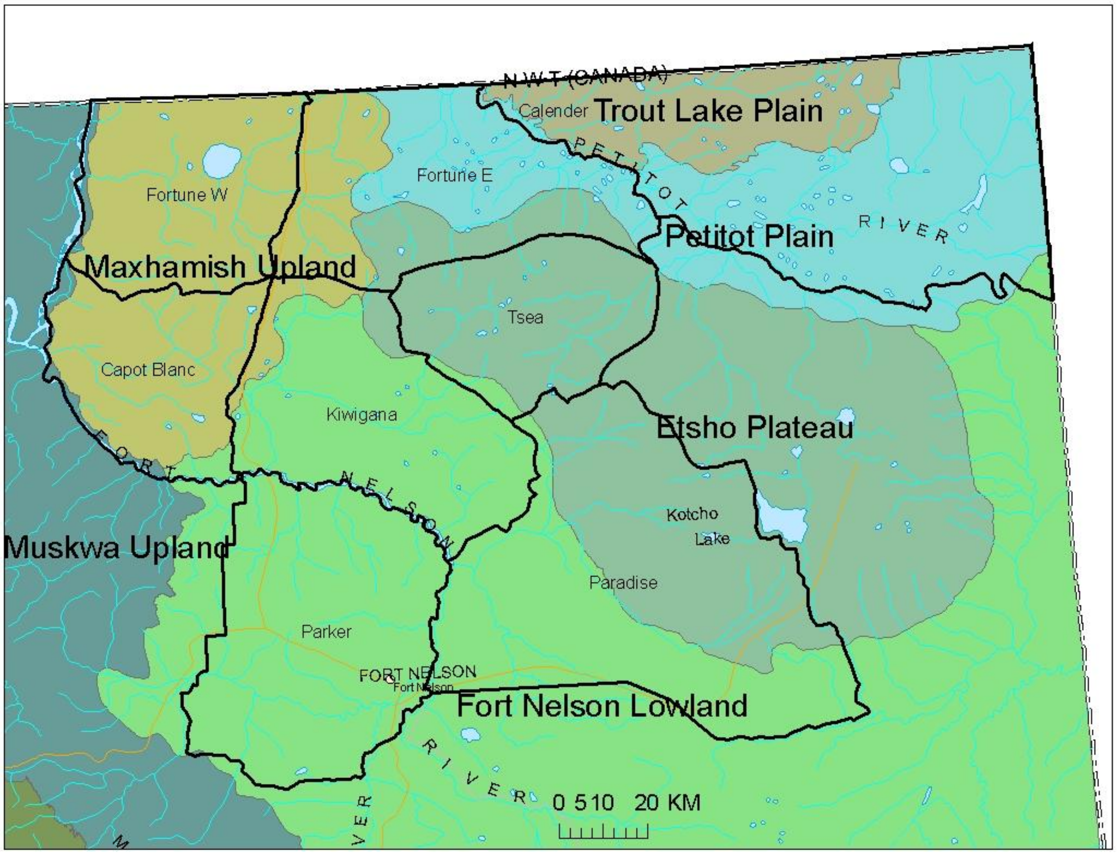

Figure 3 Ecosections in the study area for the 2010 moose survey in the Horn River Basin planning area.

2.2 Survey units and Distance sampling

The study area for this survey is 23,203 km^2, and contains considerable variation in habitat types, levels of anthropogenic disturbance, and moose densities. The most recent moose surveys for this area produced single density estimates for the entire area surveyed which does not provide insight into the variation of moose density. For this survey we divided the study area into eight survey units. Survey units generally describe one or more boreal caribou core areas (Culling et al. 2004) and the exact boundaries were delineated using a combination of topographic features (e.g. heights of land, rivers and creeks), MU boundaries, Horn River Basin planning area boundary, and roads (Figure 5).

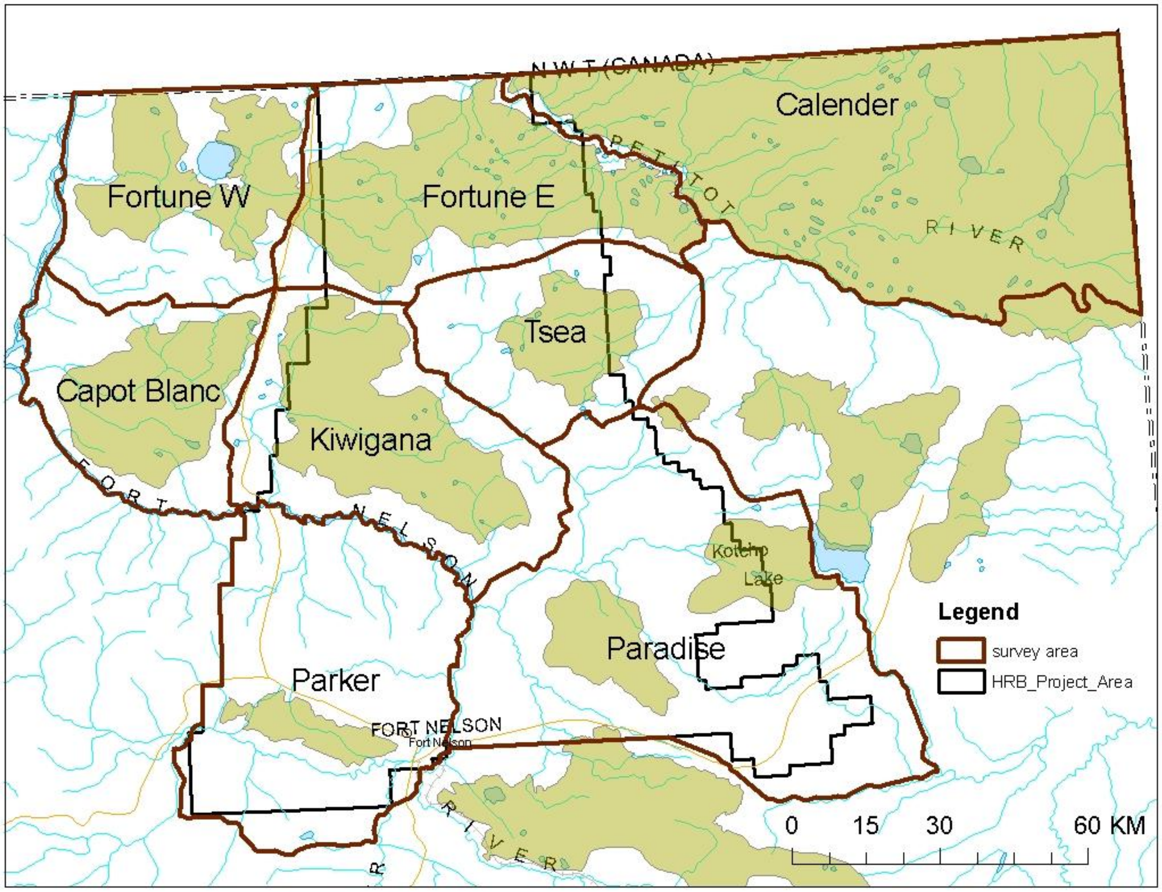

Figure 4 Moose survey units (red polygons) overlaid on boreal caribou core areas (green polygons) and the Horn River Basin planning area (black polygon) for the 2010 moose survey.

Distance sampling requires flying pre-determined transects at consistent altitude and speed across habitat types. It is assumed that all moose directly on the transect line were observed, and moose have decreasing probability of detection with increasing distance from the line. The distance data recorded allowed a detection probability to be calculated and from that a density estimate was derived (Buckland et al. 2001).

Transect lines were spaced every 3 or 6 kilometers running north/south following Universal Transverse Mercator (UTM) zone 10 eastings. A laptop running OziExplorer (Newman; version 3.95.4s) was used to navigate in the helicopter along the transect lines. When moose were spotted their locations were obtained by flying off the transect to mark the UTM coordinate of the moose from the helicopter (Marques et al. 2008) (Figure 5). When more than one moose was observed in a group the UTM location was taken at the midpoint between the moose. Moose > 100 meters apart were considered separate groups. Transects were flown at 80 – 140 km/h depending upon the density of the vegetation and at 120 meters above ground. Height above ground was modulated based on visual reference to the ground and by monitoring the difference between altitude and topographic contours from the GPS map.

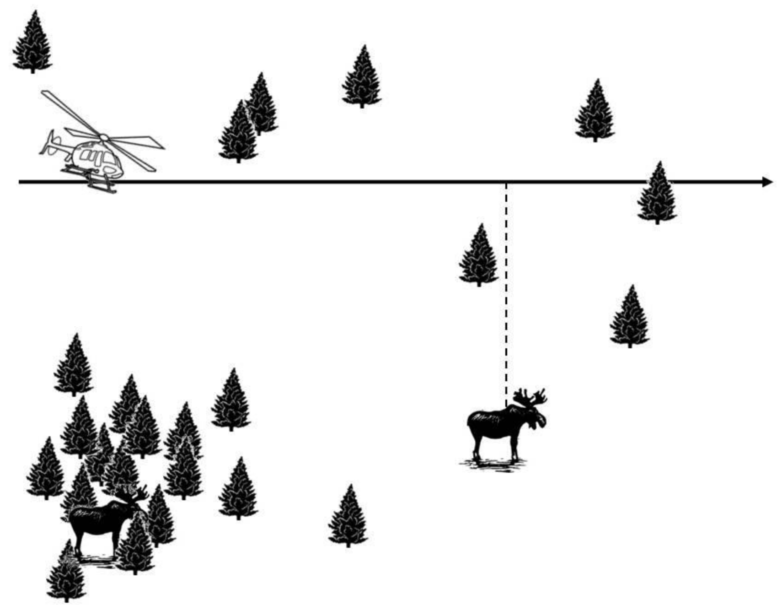

Figure 5 Schematic of distance sampling methodology used in January/February 2010 Horn River Basin moose survey. The solid line represents the transect flight line and the dashed line represents the flight path off transect to collect classification data and the moose distance from transect.

Moose were classified by age and gender according to RISC Level II or III standards (Resource Inventory Committee 1998), dependent upon the presence or absence of antlers. When antlers were not present gender was determined using the presence of the white vulval patch for females and the absence of the vulval patch and/or presence of antler scars for males. When antlers were present males were classified based on their antler architecture (Appendix 1). Moose densities and population estimates were calculated using program Distance (Thomas et al. 2009). A half-normal cosine detection function model was fit to the observations and truncated the largest 5% of distances as suggested by Buckland et al. (2001). No left truncation of data was applied, as it was assumed that visibility directly below the helicopter was sufficient. Separate density and population estimates were calculated for each survey unit and those survey units were pooled and density estimates were calculated for the HRB (Fortune East, Tsea, Kiwigana, Parker and Paradise units), MU 7-55 (Fortune West, Fortune East, Calender, Capot Blanc, Kiwigana, and Tsea units), MU 7-49 (Parker unit), MU 7-56 (Paradise unit), and the entire study area (all survey units). All estimates were calculated at 95% confidence intervals.

Incidental observations of other wildlife species were recorded. Boreal caribou were classified as male (absence of black vulval patch), female (presence of black vulval patch), and calf. Sharp-tailed grouse sightings and tracks were also recorded.

3 Results

3.1 Moose

The survey was conducted between January 12 and February 23 2010. Temperatures during the survey were slightly warmer than the normals reported for January (normal daily minimum = -25.6°C) and February (normal daily minimum = - 21.7°C) by Environment Canada (Figure 6).

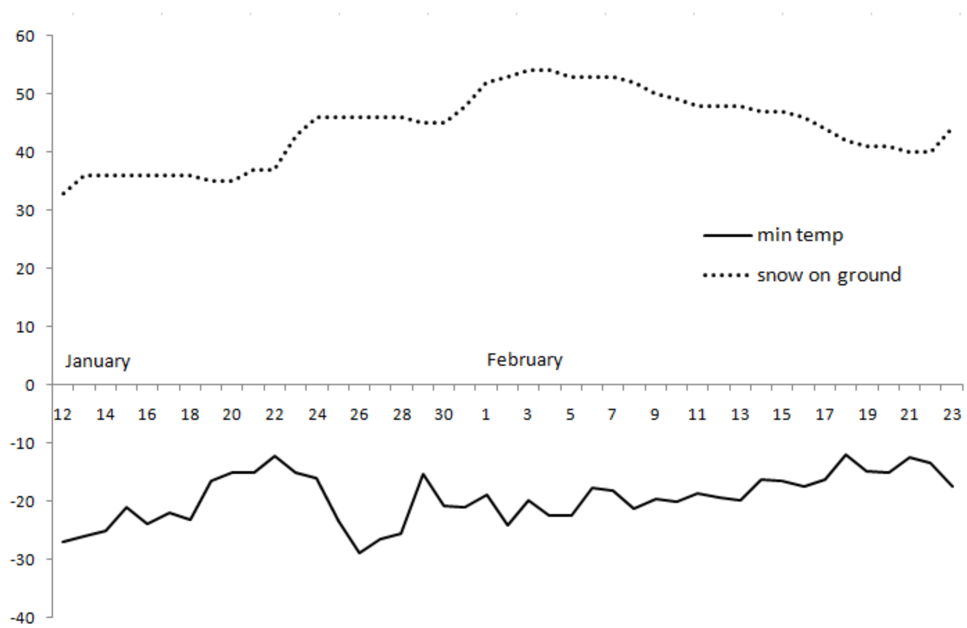

Figure 6 Daily minimum temperatures (°C) and snow on ground (cm) at Environment Canada's Fort Nelson weather station for the survey period in January/February 2010 (source http://climate.weatheroffice.gc.ca/climate_normals/index_e.html)

During the entire survey 6408.9 km's of transect were flown with a range of 558.2 km (Capot Blanc unit) to 1039.6 km (Parker unit) in each individual unit (Table 1). For most units, transects were spaced 3 km apart (Capot Blanc, Tsea, Fortune East, Fortune West, Parker, Kiwigana), however for the largest survey units wider spacing was used (Calender = 6 km, Paradise = primarily 6 km with additional random transects added to increase sample size). The relative sampling effort for each survey unit is better described by the km's of transect flown per km^2 of area within the survey unit (Table 1).

Table 1 Area of each survey unit, sampling effort in each unit (km's of transect flown), km's of transect flown per km^2 of survey area, and the number of moose groups sighted per km of transect flown for the January/February 2010 moose survey in the Horn River Basin planning area.

Survey area	Survey unit area (km^2)	Sampling effort (km)	km of transect/km^2	Moose/km of transect
Capot Blanc	1693.1	558.2	0.330	0.047
Tsea	1702.4	570.8	0.335	0.075
Fortune West	2033.0	670.7	0.330	0.027
Kiwigana	2559.8	851.6	0.333	0.078
Fortune East	2640.5	880.6	0.333	0.026
Parker	3040.1	1021	0.336	0.087
Paradise	4675.7	1039.6	0.222	0.058
Calender	4858.7	816.4	0.168	0.018
MU 7-55 units	15487.5	4348.3	0.281	0.044
HRB survey units	14681.5	4363.6	0.297	0.064
All combined	23203.3	6408.9	0.276	0.053

For the entire survey area we estimated a density of 0.116 moose/km^2 (0.096-0.140 at 95% confidence interval(CI)) which produced a population estimate of 2685 moose (2224-3243 at 95% CI). The coefficient of variation for both estimates was 9.6% indicating the observed data was well represented by the modelled detection probability (Figure 7). The maximum distance moose groups were spotted (after truncation of the farthest 5% of sightings) was 856 meters. For all male moose observed throughout the survey 74% (n = 153) had lost their antlers and 26% (n = 53) retained their antlers which allowed us to classify only ¼ of the male moose by antler architecture during the survey. For moose surveyed in January 29% (n = 51) retained their antlers and 71% (n = 128) were antlerless males. In February only 7% of males still had antlers (n = 2) and 93% were antlerless males (n = 25).

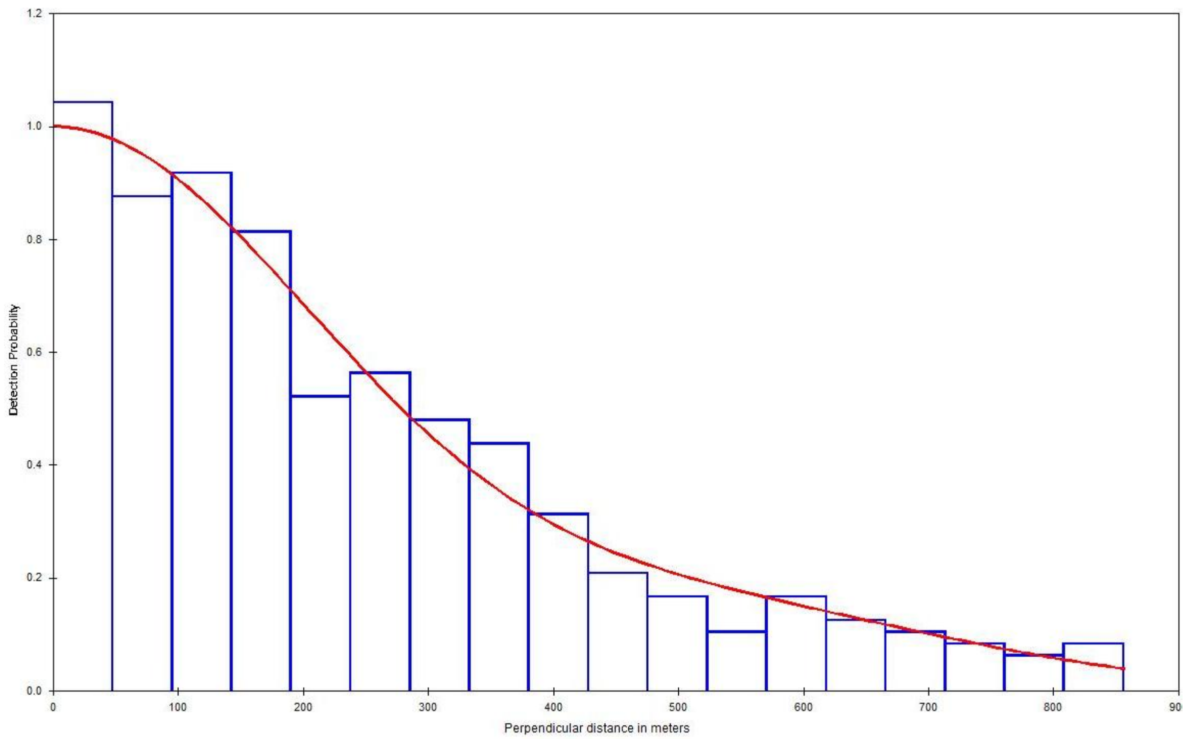

Figure 7 Detection probability plot for moose observations from all survey units combined from the 2010 Horn River Basin moose survey (n = 339 moose groups).

For each of the survey units a density and population estimate were calculated. Densities ranged from 0.018 moose/km^2 in the Calender unit to 0.246 moose/km^2 in the Parker unit (Table 2 and Figure 8). An estimate of the number of moose in each survey unit was calculated from the density estimate and ranged from a high of 749 moose (611 – 918 at 95% CI) in the Parker unit to a low of 85 moose (37 – 195 at 95% CI) in the Calender unit (Table 2 and Figure 9). For each estimate program Distance (Thomas et al. 2009) calculated an estimate of variance described by the percent coefficient of variation. The percent coefficient of variation ranged from 42.6% in the Calender range to 9.6% for the whole survey area estimate (average = 24.9% for the eight individual survey units).

Table 2 Density and population size estimates of moose from the eight survey units, MU 7-55, Horn River Basin (HRB) planning area, and total study area of the January/February 2010 moose survey. Survey units are listed in order from lowest to highest density and pooled survey units are listed last and bolded.

Survey area	Density estimate	Density 95% CI	Population estimate	Population 95% CI	% Coefficient of Variation
Calender	0.018	0.008 - 0.040	85	37 - 195	42.6
Fortune East	0.043	0.026 - 0.071	114	69 - 188	25.6
Fortune West	0.049	0.028 - 0.087	100	57 - 177	28.6
Capot Blanc	0.076	0.047 - 0.123	129	80 - 209	24.2
Paradise (MU 7-56)	0.124	0.0831 - 0.1855	581	389 - 867	20.2
Kiwigana	0.159	0.112 - 0.225	407	287 - 577	21.22
Tsea	0.172	0.106 - 0.278	293	181 - 474	24.4
Parker (MU 7-49)	0.246	0.201 - 0.302	749	611 - 918	12.3
MU 7-55 units	0.082	0.063 - 0.107	1272	972 - 1664	13.73
HRB survey units	0.151	0.125 - 0.183	2210	1823 - 2679	9.8
All combined	0.116	0.096 - 0.140	2685	2224 - 3243	9.6

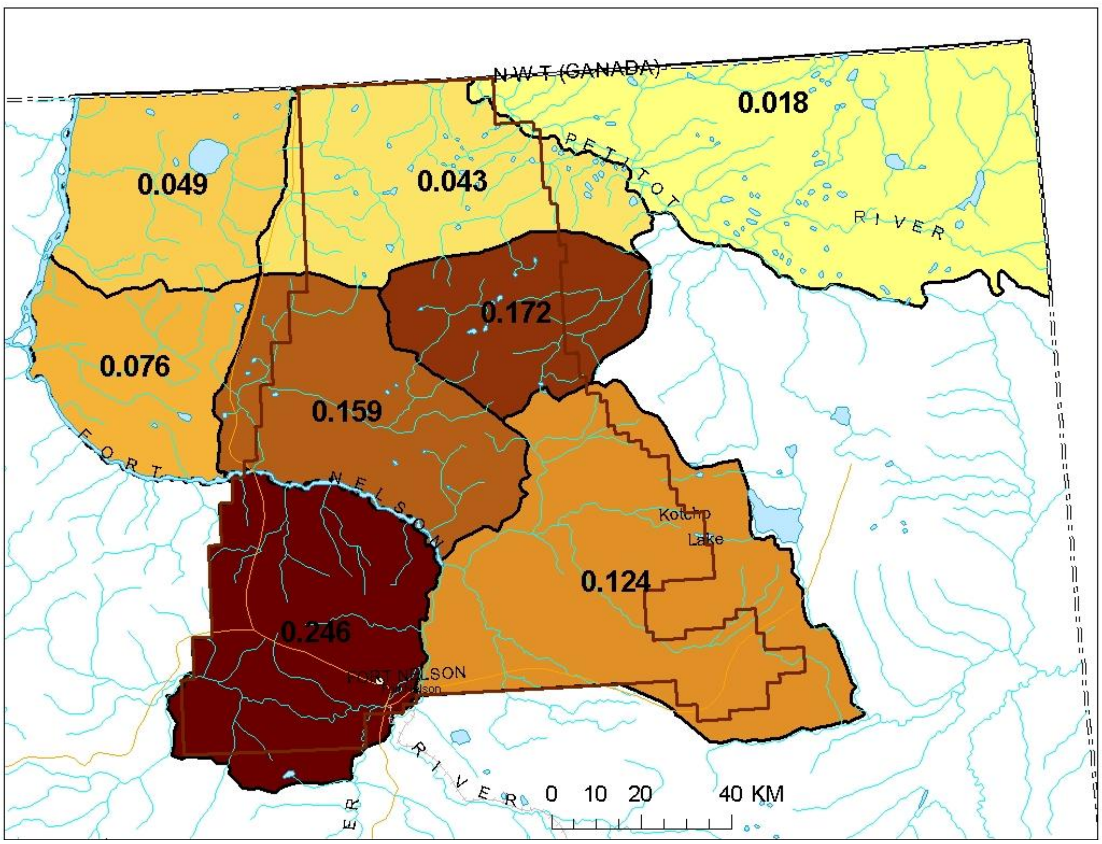

Figure 8 Map of moose densities (moose/km^2) in each of the eight units surveyed during the 2010 Horn River Basin moose survey. Darker shading indicates higher density and lighter shading indicates lower density.

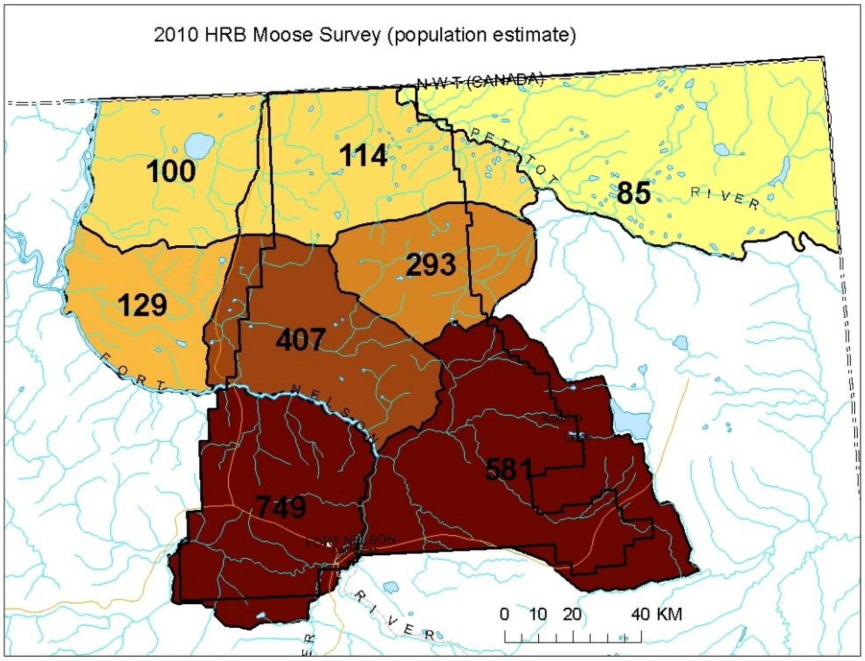

Figure 9 Map of estimated moose numbers in each of the eight units surveyed during the 2010 Horn River Basin moose inventory. Darker shading indicates more moose and lighter shading indicates fewer moose.

Classification data was used to calculate calf:cow and bull:cow ratios in each of the survey units. The number of calves:100 cows ranged from 22 in the Capot Blanc unit to nearly twice as much (42 calves:100 cows) in the Fortune West unit (Table 3 and Figure 10). For all the units combined there were 32 calves:100 cows. The number of bulls:100 cows ranged from 36 in the Parker unit to 157 in the Calender unit and was 72 across the entire study area (Table 3 and Figure 11).

Table 3 Calves:100 cow moose, percent calves in population, and bulls:100 cow moose from the 2010 Horn River Basin moose survey. Survey units are ordered from lowest calf:cow ratio to highest.

Survey area	Calves:100 cows	% calves	Bulls:100 cows	Sample size
Capot Blanc	22	14	57	41
Kiwigana	27	16	72	127
Calender	29	11	157	20
Paradise	29	16	83	102
Tsea	31	16	94	72
Fortune East	31	14	125	41
Parker	41	30	36	147
Fortune West	42	18	133	33
All combined	32	19	72	583

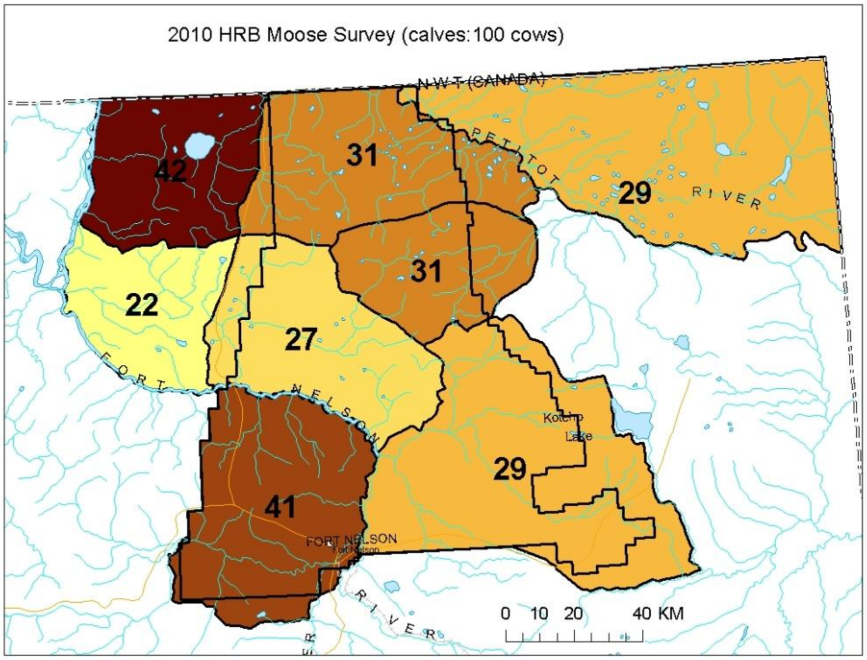

Figure 10 Map of moose calves : 100 cows in each of the eight units surveyed during the 2010 Horn River Basin moose survey. Darker shading indicates higher calf:cow ratio and lighter shading indicates lower calf:cow ratio.

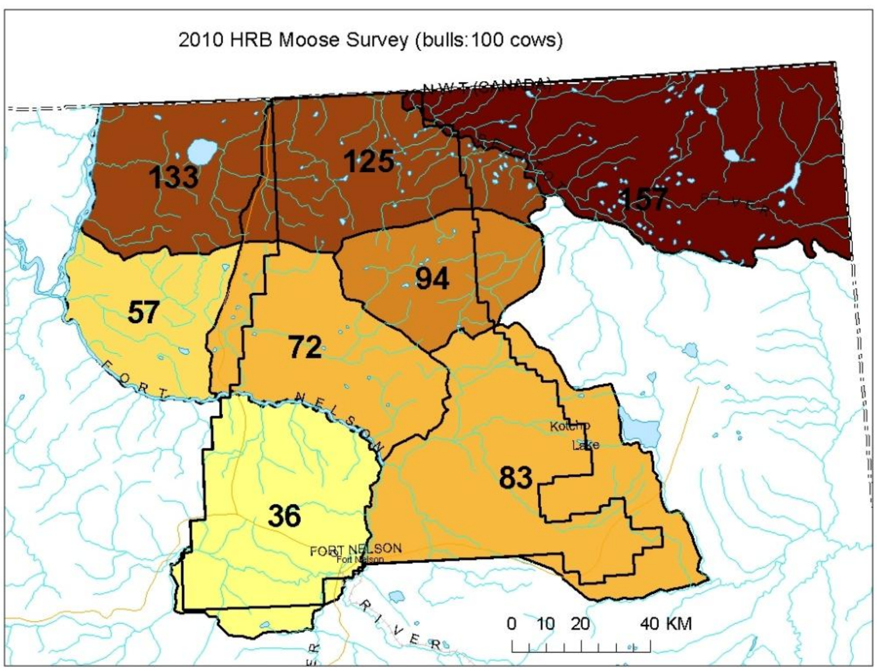

Figure 11 Map of bull moose : 100 cows in each of the eight units surveyed during the 2010 Horn River Basin moose survey. Darker shading indicates higher bull:cow ratio and lighter shading indicates lower bull:cow ratio.

When the number of bulls:100 cows was regressed against the moose density for each survey unit a negative relationship was evident (Figure 12). As density increased the ratio of bulls to cows decreased.

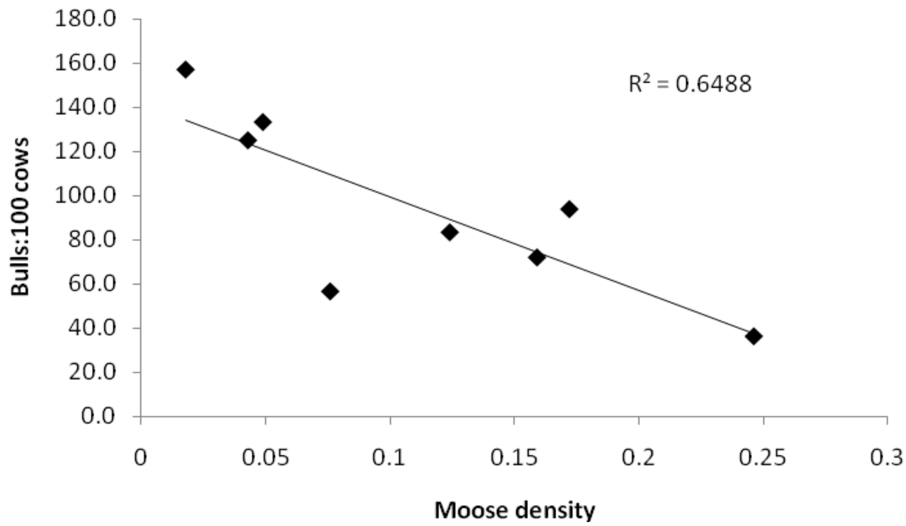

Figure 12 Relationship between moose density and bull:cow ratios in the eight units surveyed during the 2010 Horn River Basin moose survey.

The density of moose in a survey unit did not appear related to the number of calves:100 cows in late winter (Figure 13).

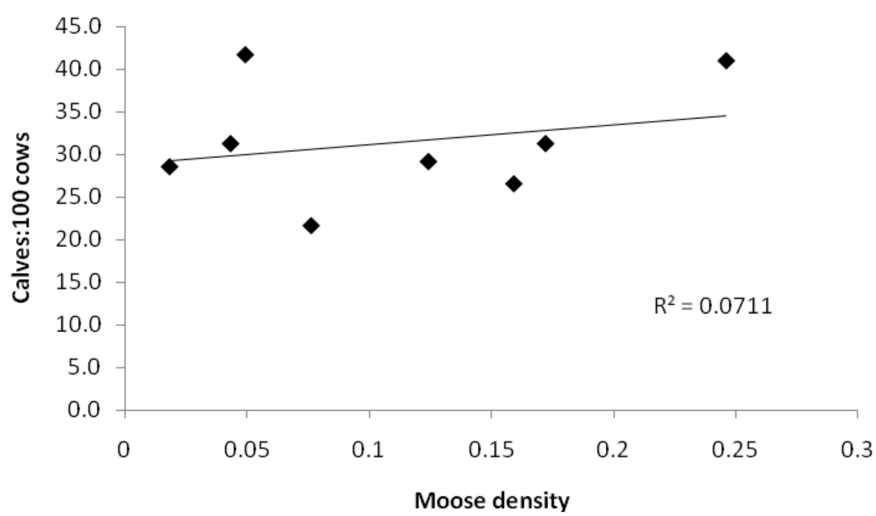

Figure 13 Relationship between moose density and calf:cow ratios in the eight units surveyed during the 2010 Horn River Basin moose inventory.

3.2 Incidental Observations

During the survey a variety of incidental species were sighted and recorded (Table 4). Of primary interest were boreal caribou and large predators. Boreal caribou occurred at densities too low to analyse using distance sampling, however we were able to calculate some demographic parameters from the observations. When all caribou sightings were pooled there were 17 calves:100 cows and 31 bulls:100 cows. The one wolf sighted was on a moose kill. No other wolves were seen associated with the kill, but based on the number of tracks seen it is assumed the other members of the pack were not visible. The elk and white-tailed deer were seen in close proximity to the town of Fort Nelson and the agricultural land surrounding it. Two male wood bison from the Nahanni herd were sighted on an island in the Liard River approximately 7 km downstream of the confluence with the Fort Nelson River (54.64096°/123.9591°). Both wolverine sighted were digging into beaver lodges and two other incidents that appeared to be evidence of wolverines attempting to access beaver lodges were seen. In addition to the lynx we observed areas where snowshoe hare densities appeared to be high, but these areas were not common. Sharp-tailed grouse were counted consistently throughout the survey, and tracks of grouse were recorded. Sign of sharp-tails was evident in all of the survey units.

Table 4 Incidental species sighted during the 2010 Horn River Basin moose survey.

Survey Area	Boreal caribou	Elk	White-tailed deer	Bison	Wolf	Wolverine	Lynx	Sharp-tailed grouse
Calender	31						1	38
CapotBlanc	3			2				2
Fortune East	21						2	
Fortune West							1	20
Kiwigana	31					1	4	4
Paradise	10					1	1	31
Parker Lake	35	52	6		1		4	5
Tsea	23							
Total	154	52	6	2	1	2	13	100

4 Discussion

This survey was the first to use distance sampling for moose in north east British Columbia and proved to be an effective and efficient means of collecting density and demographic data. Distance sampling assumes detection probability directly on the transect is 100% (Buckland et al. 2001), however this assumption is rarely met due to visibility bias (Anderson and Lindzey 1996, Nielson et al. 2006). During this survey no attempt to quantify the variations from this assumption was made, however steps were taken to reduce the possibility of moose on the transect line going unseen (front left observer spent majority of effort watching the line and a short distance from the line and speed along transect was reduced when vegetation density increased). Testing this assumption would be costly requiring radio collaring and sightability trials (Peters and Hebblewhite 2009). Not seeing all the moose on the transect would produce a density estimate that is biased low (Buckland et al. 2001, Buckland et al. 2004), but the relative densities between the survey units would remain comparable.

There was a wide range of precision (42.6% to 12.3% coefficient of variation) in the density and population estimates from the eight survey units that can be partially attributed to the sample size observed in each survey unit. Buckland et al. (2001) suggest a minimum sample size of 60 – 80 groups in order to achieve a reasonable precision in the estimates. The most precise estimate was calculated for the Parker unit (n = 89 moose groups) and the least precise occurred in the Calender range where only 15 groups of moose were sighted. When the sample size of moose groups was regressed against the precision of the estimates (measured as percent coefficient of variation) there was a relationship between sample size and percent CV that supported Buckland et al.'s (2001) suggestion of a sample size of 60 – 80. When fewer than 60 groups of moose were sighted in a survey unit the CV was greater than 20%, and when more than 60 moose groups were sighted precision was better than 20% CV (Figure 14). To determine the length of transect required to obtain a sufficiently precise estimate of density for future surveys it is necessary to know the number of moose groups expected to be sighted per kilometer of transect for different densities of moose. For areas where little information exists for the population a pilot survey can be used to estimate the length of transect necessary (Buckland et al. 2001). For north east British Columbia there was a strong linear relationship between the density of moose found in a survey unit and the number of moose sighted per kilometer of transect (Figure 15). From the relationship in Figure 15 the length of transects necessary for achieving a minimum sample size at a given level of precision for moose distance sampling in north east British Columbia can be estimated where the density of moose can be estimated from past surveys:

$$L = n/(0.3299*d_e + 0.0154)$$

Where L = transect length, n = number of moose groups necessary to achieve a desired level of precision, and d_e = estimated density of moose in the area. If a subsequent moose inventory using distance sampling were to occur within the survey units from the 2010 Horn River Basin survey area the above calculation could be used to plan the survey to achieve more precise estimates than those from the 2010 survey. However, in some instances the value of a precise estimate may be overshadowed by the cost in achieving that level of precision. For example, in the Calender unit 861 kilometers of transect were flown in 2010, but to achieve a 20% CV it would be necessary to fly over 2800 km's of transect which would be very costly and likely not provide additional information that would be of real management value. Knowing with great precision that there is very few moose may not be any more useful that knowing there are very few moose with low precision.

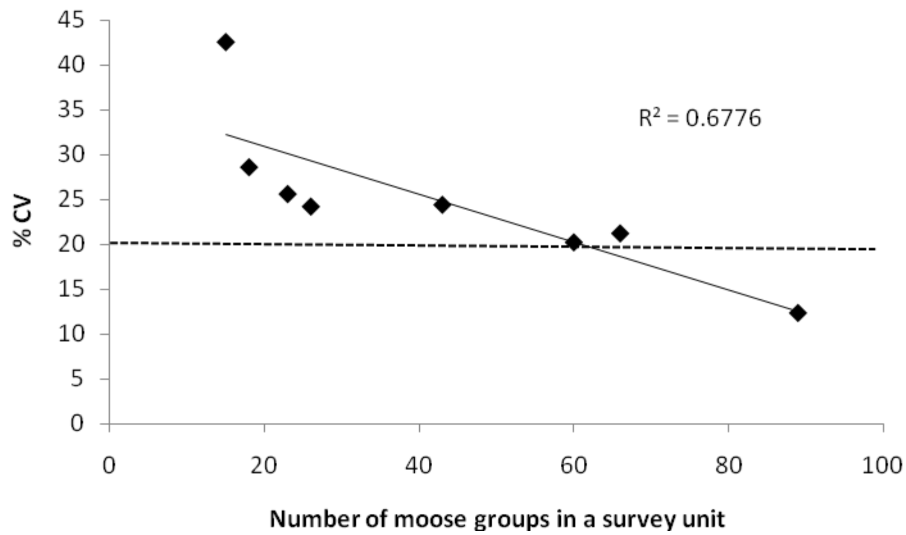

Figure 14 Relationship between the sample size of moose groups sighted in eight survey units and precision of the density estimate (measured as the percent coefficient of variation(CV)) for the 2010 Horn River Basin moose survey. The solid line represents the linear regression and the dashed line represents the desired level of precision in estimates (CV = 20% at 95% confidence interval).

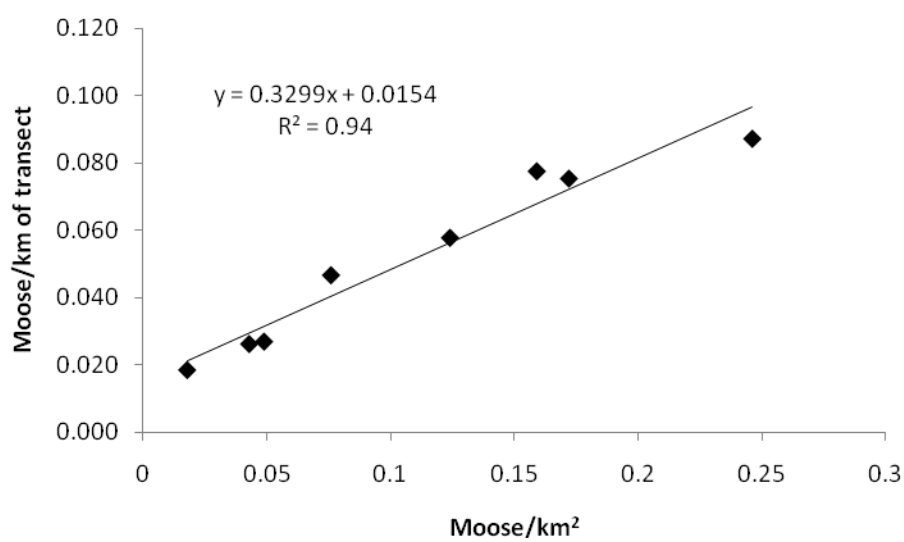

Figure 15 Relationship between the estimated density of moose per km^2 and the number of moose groups observed per kilometer of linear transect in each of the eight survey units during the 2010 Horn River Basin moose survey.

Backmeyer's 2004 survey estimated moose density in MU 7-55 and 7-56 combined at 0.087 moose/km^2, which is very similar to the estimate produced in this survey of 0.082 (range: 0.063 – 0.107 at 95% confidence interval) for the majority of MU 7-55. However the estimate from the 2010 survey was higher for the northwest 1/3 of MU 7-56 (0.124 moose/km2) than Backmeyer's, but it is important to note that in 2010 the entire management unit was not surveyed and it's possible the unsurveyed portion of MU 7-56 could be lower density which would reduce the estimate for that management unit. Elliot's 1998 survey estimated 0.09 moose/km^2 for an area that corresponds with the Fortune West, Capot Blanc, Parker, Kiwigana units from this survey. Churchill (2008) estimated 0.143 moose/km^2 from a stratified random block count in the center of the HRB planning area which is similar to the estimate we produced for the HRB survey units (0.151 moose/km^2 , range: 0.125 – 0.183 at 95% confidence interval).

Overall, the survey provided precise data on moose densities and demographics that can be used to examine trends in the population through time.

5 Recommendations

- The study area should be resurveyed a minimum of every five years to monitor trends in moose density in relation to increased access and industrial activity. To minimize annual cost it would be possible to choose a subsample of the survey units to survey annually such that the entire area was surveyed every five years.
- The relationship between moose density and boreal caribou populations should be examined.
- In extremely low density moose areas achieving a 20% CV may be cost prohibitive and unnecessary depending on the objectives of the survey and management relevance.
- This method will be effective for estimating moose densities in other areas of British Columbia, especially areas with relatively open canopy cover.
- There is value in experimenting with distance sampling for other species and habitat types in British Columbia.

6 Acknowledgements

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8 Appendices

Appendix 1 Data sheet used for January/February 2010 moose survey in the Horn River Basin planning area.

Horn River Basin Moose Survey

Pilot:____________________
FL:____________________
RL:____________________
RR:____________________

Date:____________/2010
Survey Area:______________________

Cloud Cover (/10):______ Temp (°C):_______ Wind (kph):______
Days since snow:_____ Snowcover (%):_________
Comments:____

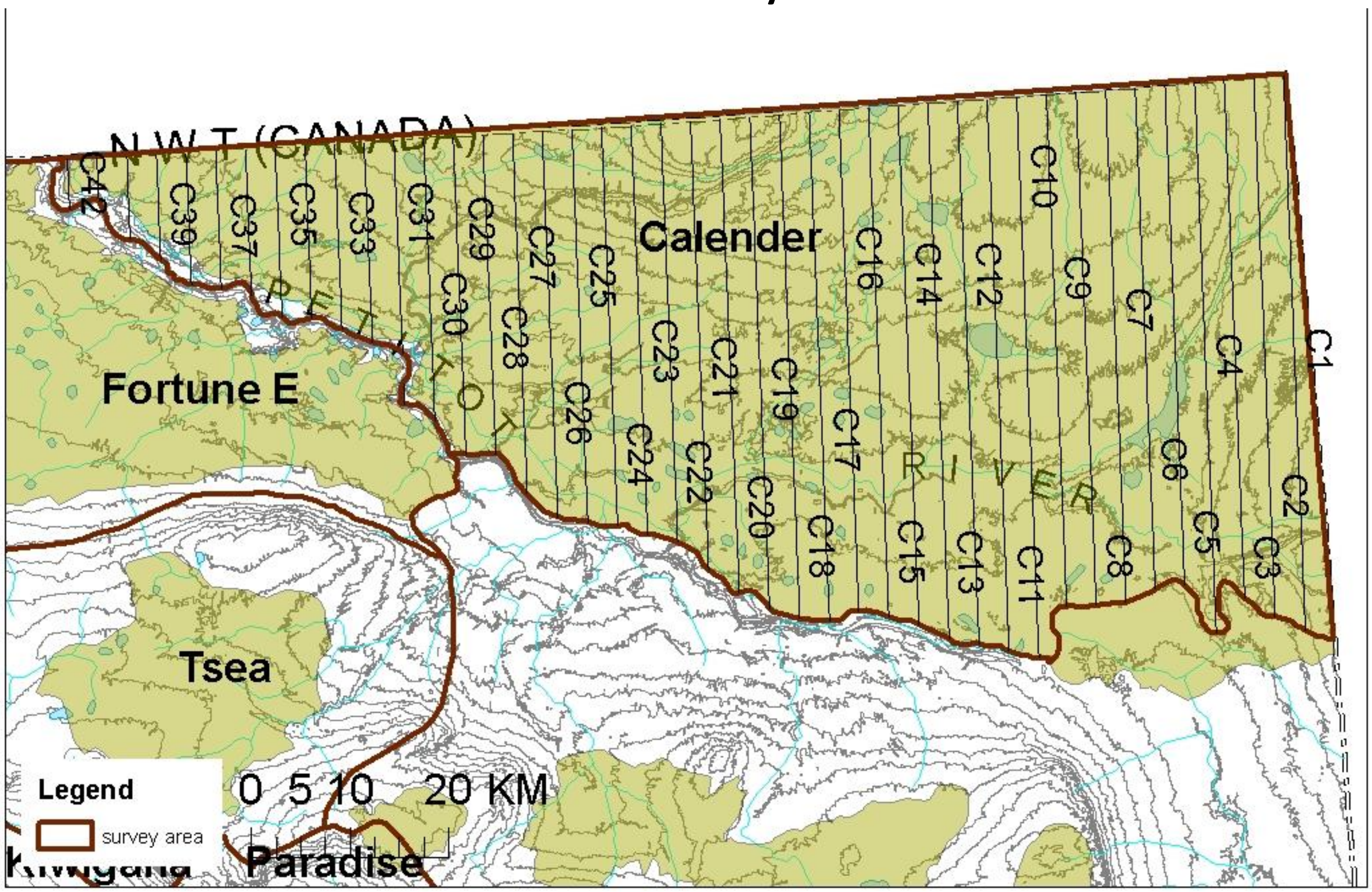
							Bulls				
Transect	SPP	WPT	Total	COW	CALF	YM	I	II	III	drop	Comments

Appendix 2 Classifications from RISC Standards (Resource Inventory Committee 1998). Level 3 and 4 followed for this survey.

Class	Criteria	Code	Level 1	Level 2	Level 3	Level 4
Adult	• ≥ 1 year of age	a	X			
Calf	• < 1 year of age • small body size without antlers	j	X	X	X	**X**
Adult Bull	• antlers or antler scars • absence of white vulval patch	m		X		
Adult Cow	• no antlers and short bell, medium size • distinguished by white vulval patch • usually has light brown face colour • sometimes accompanied by calf	f		X	X	**X**
Mature Bull	• bull with palmated antlers	mm			X	
Yearling Bull	• antler, if palmated, does not extend beyond eartip • antler pole-type usually a spike or fork	ym			X	**X**
Class I Bull	• antlers palmated, extends beyond tip of ear; • brow tine a spike or fork	I				**X**
Class II Bull	• antler palmated, extends beyond tip of ears • brow tine palmated with usually more than 2 points • inner most points of brow palm close over face	II				**X**
Class III Bull	• antlers palmated, but smaller than Class II • brown tine usually a spike or fork, like Class I	III				**X**

Appendix 3 Survey area maps with transects labelled (note that not all transects were flown for all survey units). Green polygons are boreal caribou core areas. Tables associated with maps list UTM locations for start and ends of each transect.

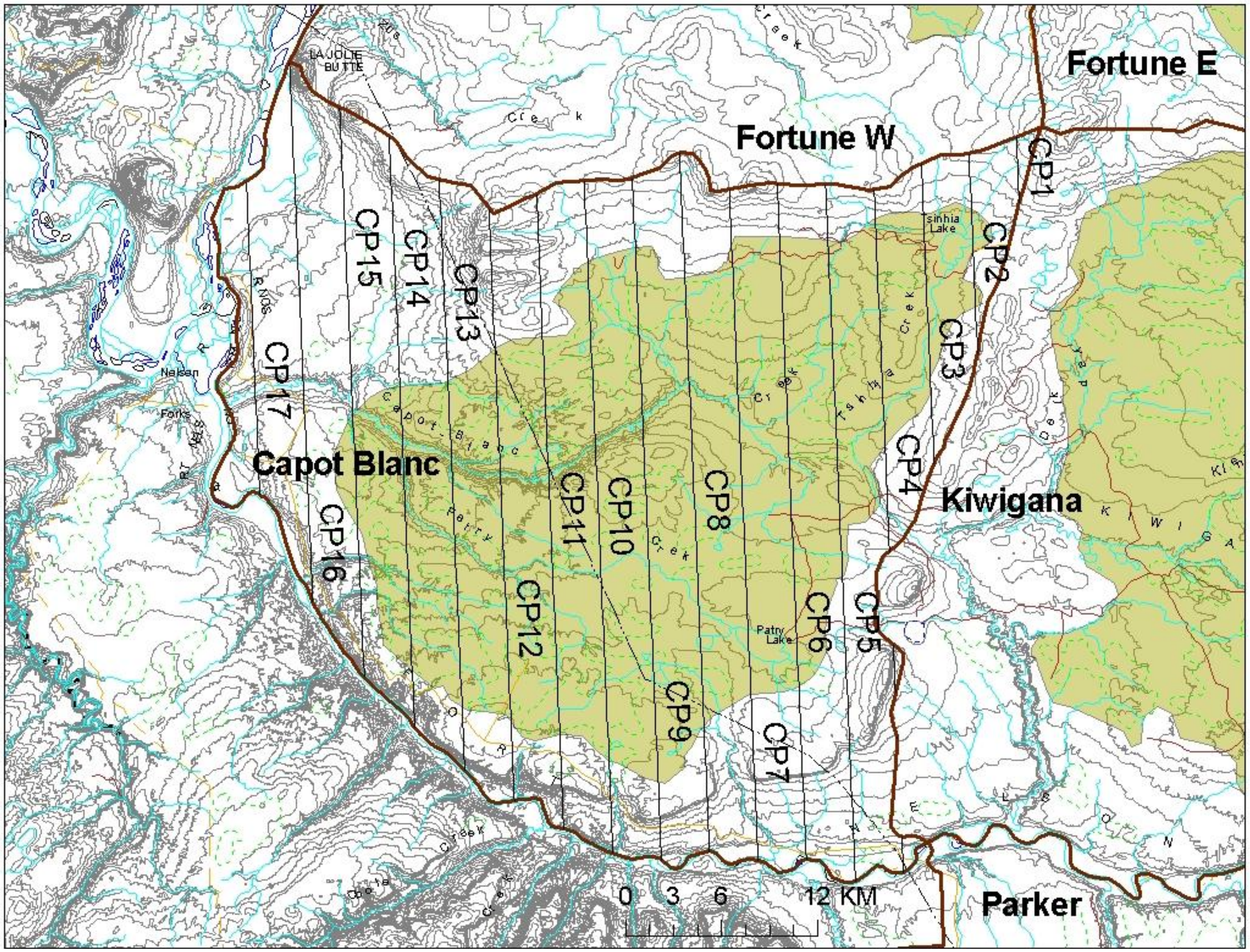
Calender survey unit



Calender survey unit transect start and end UTMs. (e.g. C1S is Calender transect 1 south end)

End	Easting	Northing
C1S	667000	6598840
C1N	666999	6655192
C2S	664000	6600301
C2N	664000	6655058
C3S	660999	6602345
C3N	661000	6654925
C4S	658000	6598877
C4N	657999	6654796
C5S	655000	6603905
C5N	654999	6654668
C6S	652000	6603640
C6N	652000	6654543
C7S	649000	6602429
C7N	648999	6654421
C8S	646000	6602265
C8N	645999	6654301
C9S	643000	6602228
C9N	642999	6654183
C10S	640000	6597165
C10N	640000	6654068
C11S	637000	6597977
C11N	637000	6653956
C12S	633999	6598764
C12N	633999	6653844
C13S	631000	6599416
C13N	631000	6653738
C14S	627999	6601022
C14N	627999	6653632
C15S	625000	6601901
C15N	625000	6653530
C16S	622000	6602631
C16N	621999	6653429
C17S	618999	6601756
C17N	619000	6653331
C18S	616000	6602108
C18N	615999	6653235
C19S	613000	6603269
C19N	613000	6653142
C20S	610000	6604980
C20N	609999	6653051
C21S	607000	6607387
C21N	606999	6652963
C22S	604000	6610327
C22N	603999	6652877
C23S	601000	6611187
C23N	601000	6652793
C24S	598000	6612224
C24N	597999	6652713
C25S	595000	6612726
C25N	594999	6652634
C26S	591999	6613397
C26N	591999	6652559
C27S	589000	6615861
C27N	588999	6652485
C28S	585999	6620013
C28N	585999	6652414
C29S	582999	6620051
C29N	583000	6652345
C30S	580000	6623691
C30N	580000	6652279
C31S	576999	6625511
C31N	577000	6652033
C32S	573999	6631818
C32N	574000	6652153
C33S	571000	6633240
C33N	570999	6652094
C34S	567999	6634513
C34N	567999	6652038
C35S	565000	6634696
C35N	564999	6651984
C36S	562000	6637116
C36N	561999	6651932
C37S	558999	6637892
C37N	558999	6651883
C38S	555999	6638442
C38N	556000	6651836
C39S	553000	6641084
C39N	552999	6651792
C40S	549999	6643256
C40N	549999	6651750
C41S	546999	6647218
C41N	547000	6651711
C42S	543999	6646522
C42N	543999	6651673

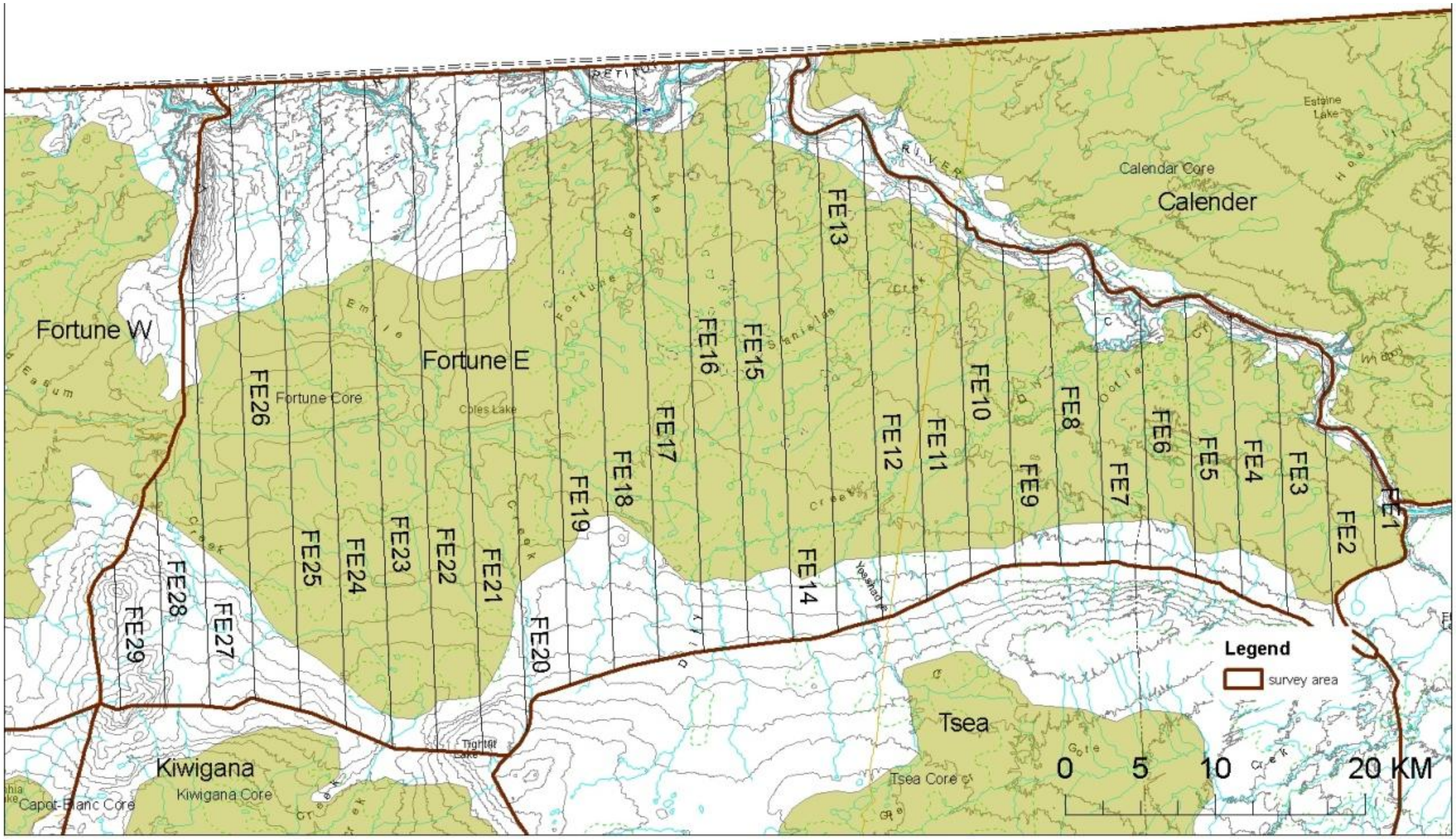
Capot Blanc survey unit



Capot Blanc survey unit transect start and end UTMs.

End	Easting	Northing
CB1N	492999	6609863
CB1S	492999	6605763
CB2N	489999	6608968
CB2S	489999	6596462
CB3N	486999	6608452
CB3S	487000	6589701
CB4N	484000	6606968
CB4S	483999	6564362
CB5N	480999	6607420
CB5S	480999	6563883
CB6N	478000	6607605
CB6S	478000	6565376
CB7N	474999	6607370
CB7S	475000	6565440
CB8N	471999	6609792
CB8S	471999	6566118
CB9N	469000	6608346
CB9S	468999	6565693
CB10N	465999	6608295
CB10S	465999	6566251
CB11N	462999	6607567
CB11S	462999	6567951
CB12N	460000	6606839
CB12S	460000	6569780
CB13N	456999	6608798
CB13S	457000	6571840
CB14N	454000	6611597
CB14S	454000	6574657
CB15N	450999	6613532
CB15S	450999	6577950
CB16N	447999	6616460
CB16S	447999	6582785
CB17N	444999	6609157
CB17S	444999	6589602

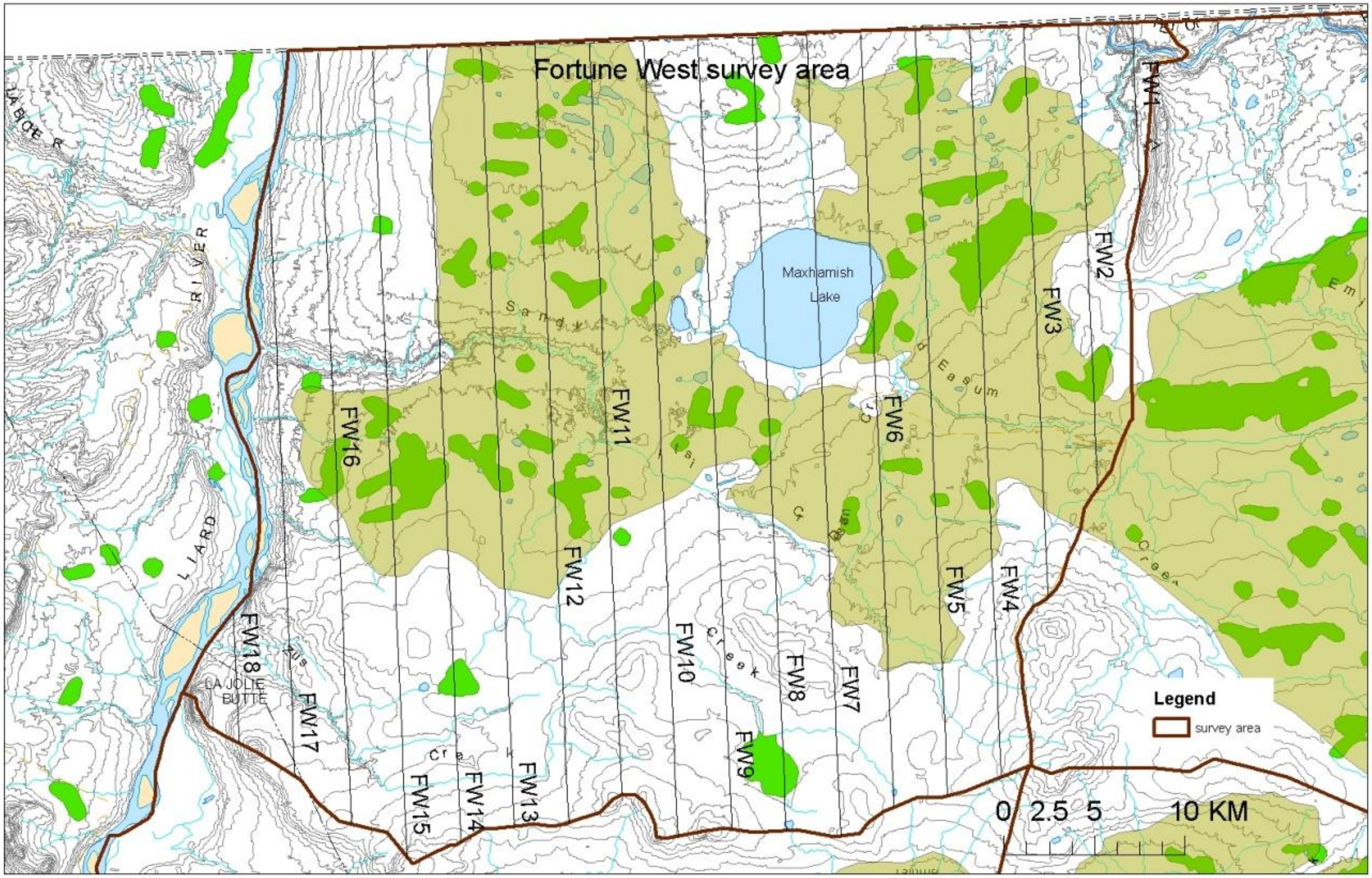
Fortune East survey unit



Fortune East survey unit transect start and end UTMs.

End	Easting	Northing	End	Easting	Northing
FE1S	579999	6615859	FE21S	520000	6606014
FE1N	580000	6623691	FE21N	520000	6651437
FE3S	573999	6613084	FE22S	517000	6606316
FE3N	573999	6631818	FE22N	517000	6651413
FE4S	571000	6614380	FE23S	514000	6606644
FE4N	571000	6633240	FE23N	513999	6651390
FE5S	568000	6615830	FE24S	510999	6608100
FE5N	567999	6634513	FE24N	511000	6651366
FE6S	565000	6616528	FE25S	507999	6609417
FE6N	565000	6634696	FE25N	508000	6651343
FE7S	562000	6617018	FE26S	504999	6610315
FE7N	562000	6637116	FE26N	505000	6651320
FE8S	558999	6616999	FE27S	502000	6609934
FE8N	558999	6637892	FE27N	502000	6641431
FE9S	556000	6617090	FE28S	499000	6610102
FE9N	555999	6638442	FE28N	498999	6625606
FE10S	553000	6616243	FE29S	496000	6610024
FE10N	553000	6641084	FE29N	496000	6619707
FE11S	549999	6615005	FE2S	577000	6611387
FE11N	549999	6643256	FE2N	576999	6630583
FE12S	547000	6613905			
FE12N	546999	6647218			
FE13S	543999	6613157			
FE13N	543999	6646522			
FE14S	540999	6612701			
FE14N	540999	6651639			
FE15S	537999	6612499			
FE15N	538000	6651607			
FE16S	534999	6612202			
FE16N	534999	6651578			
FE17S	532000	6611758			
FE17N	531999	6651537			
FE18S	528999	6611200			
FE18N	528999	6651509			
FE19S	526000	6610361			
FE19N	526000	6651485			
FE20S	523000	6607416			
FE20N	522999	6651461			

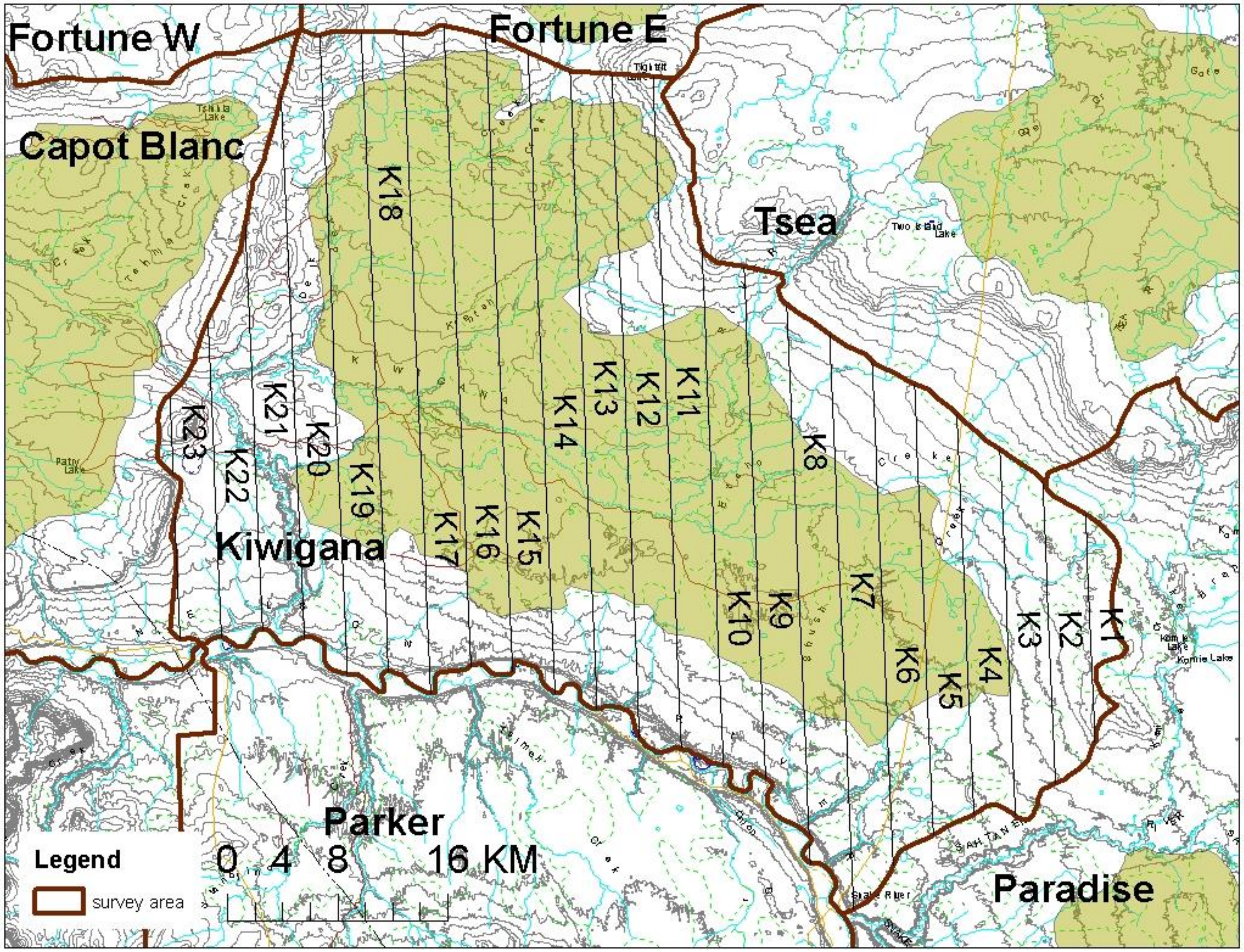
Fortune West survey unit



Fortune West survey unit transect start and end UTMs.

End	Easting	Northing
FW1S	502000	6641431
FW1N	501999	6651383
FW2S	498999	6625606
FW2N	499000	6651412
FW3S	496000	6619707
FW3N	496000	6651414
FW4S	492999	6609863
FW4N	493000	6651418
FW5S	489999	6608968
FW5N	489999	6651425
FW6S	486999	6608452
FW6N	486999	6651435
FW7S	483999	6607001
FW7N	484000	6651445
FW8S	480999	6607420
FW8N	481000	6651460
FW9S	478000	6607605
FW9N	477999	6651476
FW10S	474999	6607370
FW10N	475000	6651496
FW11S	471999	6609792
FW11N	471999	6651517
FW12S	469000	6608346
FW12N	468999	6651542
FW13S	465999	6608295
FW13N	465999	6651568
FW14S	462999	6607567
FW14N	462999	6651597
FW15S	460000	6606839
FW15N	460000	6651628
FW16S	456999	6608798
FW16N	456999	6651662
FW17S	454000	6611597
FW17N	453999	6645256
FW18S	450999	6613532
FW18N	451000	6620845

Kiwigana survey unit

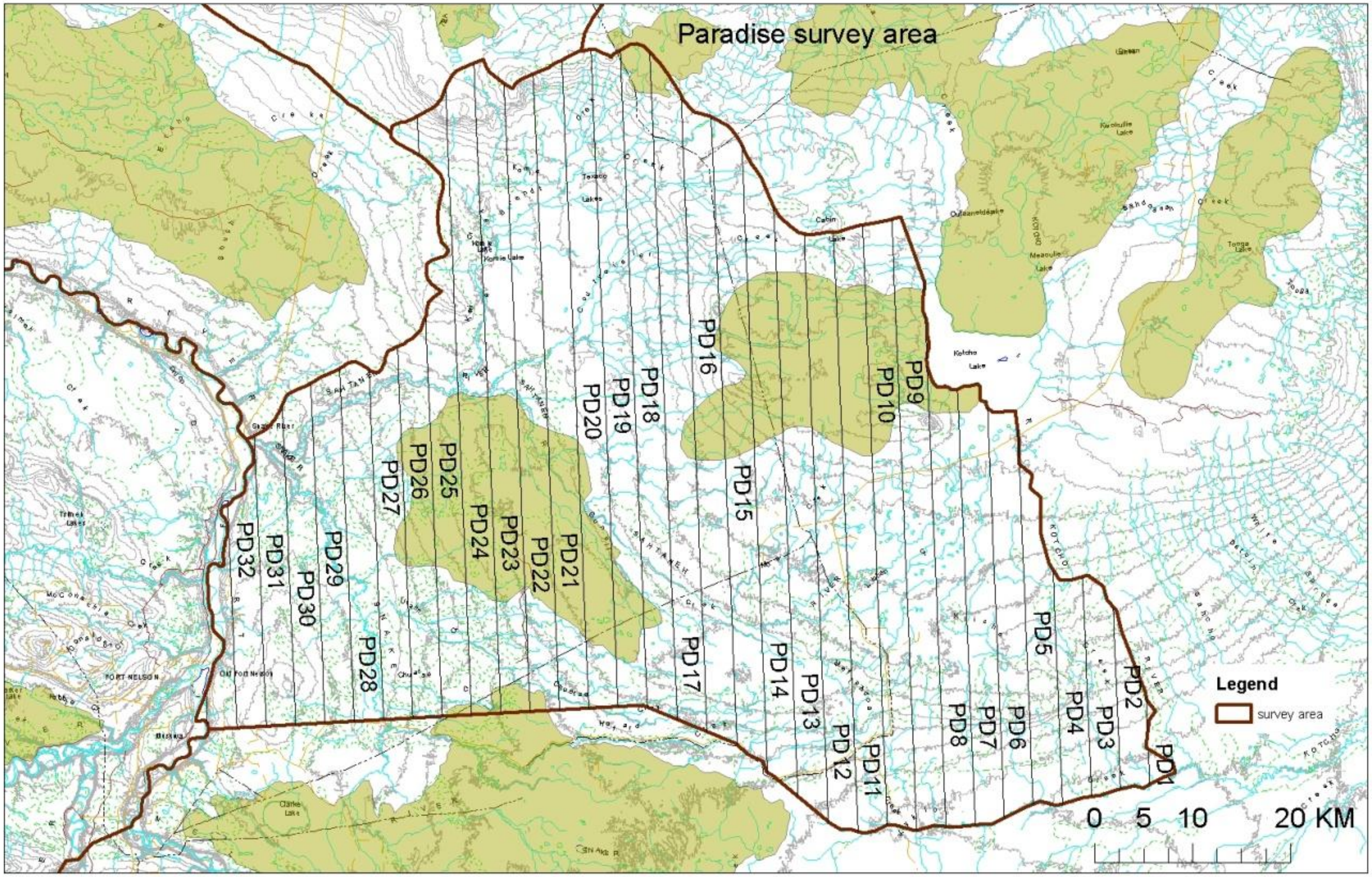


Kiwigana survey unit transect start and end UTMs.

End	Easting	Northing
K1S	550000	6556253
K1N	549999	6572873
K2S	547000	6553374
K2N	546999	6575435
K3S	543999	6551180
K3N	544000	6577815
K4S	541000	6551379
K4N	540999	6580545
K5S	537999	6550001
K5N	537999	6582834
K6S	534999	6547889
K6N	534999	6584619
K7S	531999	6544861
K7N	531999	6586653
K9S	526000	6554630
K9N	525999	6591897
K10S	523000	6555732
K10N	522999	6593463
K11S	520000	6557050
K11N	520000	6606014
K12S	516999	6557946
K12N	517000	6606316
K13S	513999	6560132
K13N	514000	6606644
K14S	511000	6561417
K14N	510999	6608100
K15S	507999	6563129
K15N	507999	6609417
K16S	505000	6563674
K16N	504999	6610315
K17S	501999	6561849
K17N	502000	6609934
K18S	499000	6563552
K18N	499000	6610102
K19S	496000	6563448
K19N	496000	6610024
K20S	493000	6566283
K20N	492999	6605763

End	Easting	Northing
K21S	490000	6566960
K21N	489999	6596462
K22S	487000	6566520
K22N	487000	6589701
K23N	483999	6584333
K23S	484000	6566605
K8S	529000	6548263
K8N	529000	6588922

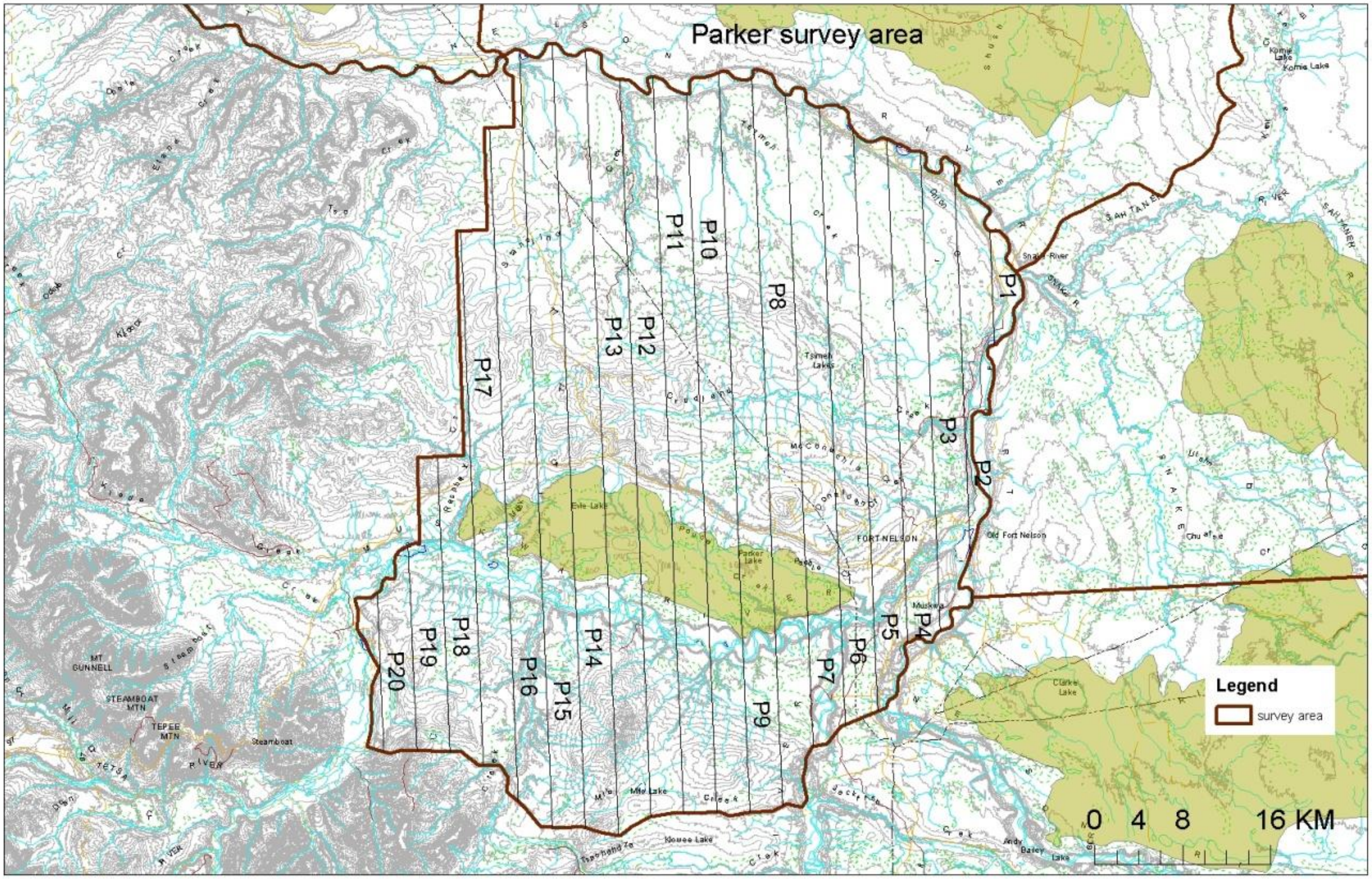
Paradise survey unit



Paradise survey unit transect start and end UTMs.

End	Easting	Northing	End	Easting	Northing
PD1N	622000	6514633	PD20S	564999	6515544
PD1S	621999	6505580	PD20N	565000	6581994
PD2S	618999	6505071	PD21S	562000	6515506
PD2N	619000	6523659	PD21N	562000	6580660
PD3S	616000	6504457	PD22S	559000	6515468
PD3N	616000	6526902	PD22N	558999	6579853
PD4S	612999	6503806	PD23S	555999	6515430
PD4N	613000	6527786	PD23N	556000	6582056
PD5S	609999	6503770	PD24S	553000	6515392
PD5N	610000	6542446	PD24N	553000	6579644
PD6S	606999	6502589	PD25AS	549999	6572873
PD6N	607000	6544645	PD25AN	549999	6576945
PD7S	603999	6502027	PD25BS	549999	6515255
PD7N	603999	6546600	PD25BN	550000	6556253
PD8S	601000	6502242	PD26S	546999	6515317
PD8N	600999	6557996	PD26N	547000	6553374
PD9S	597999	6501651	PD27S	543999	6515279
PD9N	598000	6564345	PD27N	543999	6551180
PD10S	594999	6502314	PD28S	540999	6515242
PD10N	594999	6563893	PD28N	541000	6551379
PD11S	591999	6501786	PD29S	537999	6515204
PD11N	591999	6563176	PD29N	537999	6550001
PD12S	589000	6502958	PD30S	534999	6515167
PD12N	589000	6563183	PD30N	534999	6547889
PD13S	585999	6505677	PD31S	531999	6515130
PD13N	586000	6566144	PD31N	531999	6544861
PD14S	583000	6508232	PD32S	529000	6515093
PD14N	582999	6572524	PD32N	528999	6537906
PD15S	580000	6511195	PD33S	525999	6515598
PD15N	580000	6575545	PD33N	525999	6518886
PD16S	576999	6512633			
PD16N	577000	6577860			
PD17S	573999	6514010			
PD17N	573999	6582455			
PD18S	571000	6515387			
PD18N	570999	6582783			
PD19S	567999	6515583			
PD19N	567999	6582935			

Parker survey unit

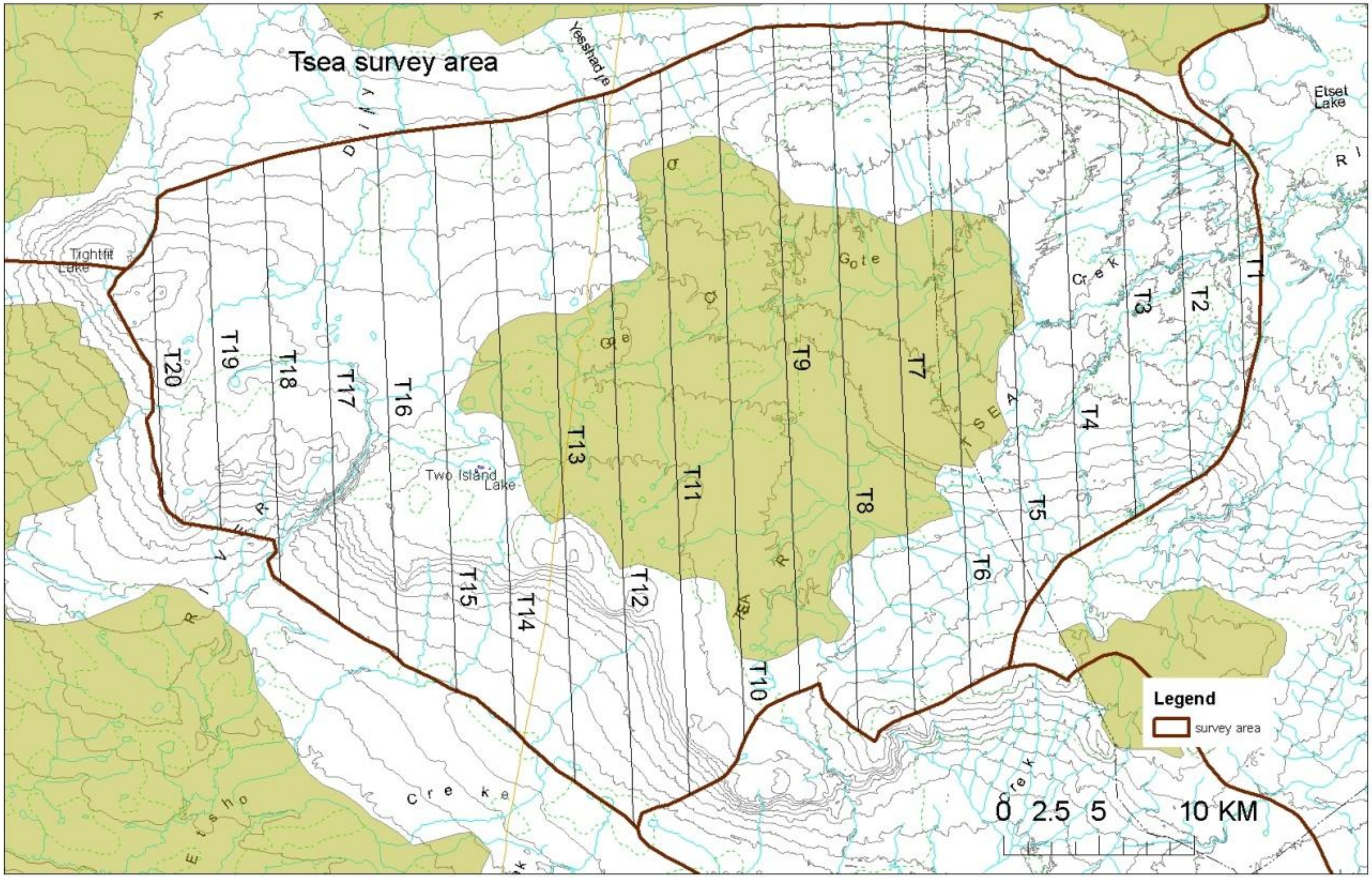


Parker survey unit transect start and end UTMs.

End	Easting	Northing
P1S	529000	6538023
P1N	529000	6548480
P2S	525999	6518886
P2N	526000	6554822
P3S	523000	6512159
P3N	523000	6555732
P4S	520000	6511232
P4N	520000	6557050
P5S	516999	6505127
P5N	516999	6557946
P6S	513999	6504007
P6N	513999	6560132
P7S	510999	6502161
P7N	511000	6561417
P8S	508000	6496880
P8N	507999	6563129
P9S	504999	6496391
P9N	505000	6563674
P10S	502000	6496572
P10N	501999	6561849
P11S	499000	6496574
P11N	499000	6563552
P12S	495999	6496380
P12N	496000	6563448
P13S	492999	6494841
P13N	493000	6566283
P14S	490000	6495637
P14N	490000	6566960
P15S	487000	6495842
P15N	487000	6566520
P16S	484000	6498322
P16N	484000	6559550
P17S	481000	6501738
P17N	481000	6550288
P18S	478000	6503112
P18N	478000	6529907
P19S	474999	6503315
P19N	475000	6521930

End	Easting	Northing
P20S	471999	6503315
P20N	471999	6517764

Tsea survey unit



Tsea survey unit transect start and end UTMs.

End	Easting	Northing
T1S	580000	6596553
T1N	580000	6610054
T2S	577000	6592260
T2N	576999	6611331
T3S	573999	6590504
T3N	573999	6613084
T4S	571000	6588914
T4N	571000	6614380
T5S	567999	6585641
T5N	568000	6615830
T6S	565000	6581994
T6N	565000	6616528
T7S	562000	6580660
T7N	562000	6617018
T8S	558999	6579853
T8N	558999	6616999
T9S	556000	6582056
T9N	556000	6617090
T10S	553000	6579644
T10N	553000	6616243
T11S	549999	6576865
T11N	549999	6615005
T12S	546999	6575435
T12N	547000	6613905
T13S	544000	6577815
T13N	543999	6613157
T14S	540999	6580545
T14N	540999	6612701
T15S	537999	6582834
T15N	537999	6612499
T16S	534999	6584619
T16N	534999	6612202
T17S	531999	6586653
T17N	532000	6611758
T18S	529000	6588984
T18N	528999	6611200
T19S	525999	6591897
T19N	526000	6610361
T20S	522999	6593463
T20N	523000	6607416