Aerial Moose Survey in North East BC 2016

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EXECUTIVE SUMMARY

A distance sampling aerial survey was conducted January 27th to February 4th, 2016 to estimate moose abundance within two Caribou Core Areas (CCA) and one Resource Review Area (RRA) in northeastern British Columbia (BC). The moose abundance data collected during this survey will be used to help inform biologists about the effectiveness of RRAs and CCAs, a component of the Boreal Caribou Implementation Plan (BCIP), for ongoing management of boreal caribou in BC.

The aerial survey was completed via helicopter utilizing distance sampling along a total of 3,345.4 km of transect within a combined study area of 13,909.7 km^2 for an average effort of 0.241 km/km^2. Low snow conditions made observations challenging but helicopter speed was kept consistent typically between 70-110 km/hour along each 80-120 km long transect to ensure the study objectives were obtained. A total of 314 moose were observed (0.094/km of transect) for an overall density estimate of 0.104 moose/km^2 (95% CI 0.080 – 0.136, CV 13.3%) for all areas combined. The estimate of moose population density varied across the areas surveyed, with the lowest estimated density in Clarke (0.074 moose/km^2), Fortune being slightly higher (0.076 moose/km^2) and the highest in Chinchaga (0.151 moose/km^2).

This density result translates to 1,453 moose with a 95% confidence range of 1,119 – 1,888 in the combined study areas. Clarke yielded 395 moose (95% CI 269 - 580), Chinchaga 670 moose (95% CI 419 – 1,072) and Fortune with 331 moose (95% CI 210 – 520). The Clarke and Chinchaga study areas were surveyed together as requested and yielded a combined density of 0.125 moose/km^2 (95% CI 0.090 – 0.174) and a population estimate of 1,198 moose (95% CI 860 – 1,669).

The moose population structure overall was 45 calves:100 cows and 54 bulls:100 cows in the combined study areas (from a minimum of 38 calves:100 cows in Chinchaga to 45 calves:100 cows in Clarke and a minimum of 47 bulls:100 cows in Clarke to 68 bulls:100 cows in Chinchaga). Since this study did not overlap the previous Management Unit level surveys and varied in study area boundaries from 2013 surveys, direct comparisons of moose densities to past surveys are not possible. However, the calf ratios in this study compared to the 2013 survey suggest that juvenile recruitment is still positive in 2016, although slightly less so.

Distance sampling as a methodology for aerial moose inventory is still being developed and improved. During this survey two field methodology changes were implemented to enhance the data collected during the survey. The first change was improving habitat data collection in the field to better quantify sightability. Additional parameters were added to the habitat data form to better capture the vegetation communities observed by collecting habitat type and percent vegetation (i.e. crown closure) on the transect, between the transect and each moose group, and at the moose group. Percent vegetation was also collected in a more comprehensive 5 class range. These covariates were investigated to help improve the sightability estimate for moose observed in different habitat classes. It was determined that the % vegetation from the five classes at the moose did improve model fit, especially when combined with snow cover (which was lower than normal during this survey season). The second change was to expand the extents of the study areas to obtain longer transects, which increased the number of moose groups per transect. Both methodology improvements resulted in more robust estimates during data analysis.

We used the habitat types collected at the moose locations for post-hoc stratification and pooled the observations into 5 broad habitat groups that affected both moose distribution and sightability (wetland, treed wetland, coniferous, deciduous/mixed and disturbed) and stratified the habitat based on moose observations. This data allowed for post-hoc stratification of the data within the software to create density estimates per Habitat Group. The habitat-specific density estimates were then applied to VRI data to

produce population estimates based on these strata. This method produces population estimates very similar to the non-habitat specific density estimates but the habitat group densities could be applied to the smaller CCA and RRA areas to give us estimates for these areas within our overall study area. We demonstrated that while the Clarke CCA has a lower moose density than the surrounding area, both Chinchaga and Fortune had higher densities than the surrounding area. Post-hoc stratification provides habitat-specific estimates of moose density that may be more useful to the management of caribou habitat.

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INTRODUCTION

While the focus of this study was to determine moose (*Alces* alces) abundance, the base need for this data centers on the management of boreal caribou (*Rangifer tarandus caribou*). Boreal caribou have been listed by the federal government as Threatened – a species that is likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation of extinction (Justice Canada 2002). Boreal caribou occur in discrete populations across northeast BC. Caribou Core Areas (CCAs) were established within the ranges of these populations to protect habitat deemed critical to the populations' survival (Heard and Vagt 1998). The CCAs were developed from a joint study between BC Environment and Slocan/Canadian Forest Products Ltd. which compared fine-scale vegetation data with caribou habitat use derived from movement data collected during the joint and prior studies (Culling et al. 2006; BCTAC 2004; Thiessen 2009; Rowe 2007, 2008). CCAs are considered to have high habitat suitability to support caribou and known occurrence of caribou within that area. The CCA designation indicates the habitat is a provincially recognized high-priority area with opportunities to enhance the environmental conditions for caribou. The rationale for this moose survey is because of the link between moose and wolf (*Canis lupus*) densities, which can have cascading effects of predation by wolves and on caribou (Chowns and Gates 2004; Wittmer et al. 2005; Golder Associates 2010)

Funding was provided by the BC Oil and Gas Research and Innovation Society (BC OGRIS) as part of the goal to enhance the understanding and management of impacts related to oil and gas developments in northeast BC (BC OGRIS 2015). Part of this commitment includes monitoring and estimating moose densities in and around CCAs in northeast British Columbia (BC). Moose also provide recreational value, tourist and hunting, and traditional values for residents in northeast BC, and management of moose habitat and populations is required to ensure these values are maintained (Rowe 2008). This project is a continuation of two prior moose population surveys (Thiessen 2010; McNay et al. 2013) using Distance sampling (Buckland et al. 2001, 2004). Each survey provides a snapshot of the moose population within the survey areas and can be compared temporally to determine trends in moose populations and distributions. The abundance of moose and population trends within the CCAs and Resource Review Areas (RRAs) allows biologists to measure the effectiveness of these areas as a component of the Boreal Caribou Implementation Plan (BCIP, Ministry of Environment 2011).

Recent research has indicated wolf populations may be increasing as a result of increasing moose and other primary prey species in habitat within or adjacent to caribou range in other parts of Canada (Wittmer et al. 2007; Serroya et al. 2011; Latham et al. 2011). The increasing beaver populations may create spatial overlap between wolf packs and caribou since wolves appear to prey-switch from moose to beavers during the spring (DeMars and Boutin 2014). Anthropogenic disturbance within boreal caribou habitat may result in early seral habitats, favored by primary prey species and enhanced access for predators (Messier 1995). Boreal caribou are typically secondary prey species for wolves; however, the increasing primary prey species populations and increasing anthropogenic disturbance may increase incidental predation-related caribou mortality rates (Rettie and Messier 1998; Chowns and Gates 2004; Wittmer et al. 2005; Golder Associates 2010; Festa-Bianchet et al. 2011). The high spatial density of linear corridors in northeast BC may allow predators to quickly and easily search for prey (James and Stuart-Smith 2000; McKenzie et al. 2012), and restrict caribou movement and habitat access (Dyer et al. 2001; Dyer et al. 2002, Rowe 2007). Macro analysis of population trends suggests that caribou populations tended to be in decline if the buffered disturbance footprint exceed 35% of the caribou range (Environment Canada 2008; Sorensen et al. 2008).

The management goals for moose and caribou in northeast BC are a complex problem due to the amount of habitat disturbance and increased caribou predation potentially associated with habitat change, increased moose populations and distribution, and wolf populations and distribution. The RRAs were established to manage and monitor the ecological situation by limiting industrial development in the RRAs. Ungulate Winter Ranges (UWRs) were also established to conserve winter habitat values for caribou (Culling and Cichowski 2010). Due to boreal caribou's cryptic nature and associated challenges estimating caribou populations, it was recommended that moose abundance in and around caribou range be used as a performance measure to evaluate the effectiveness of RRAs (Cichowski et al. 2012). The management strategies for caribou, and by association moose, population are the basis for the BCIP (Pasztor and Westereng 2011).

The Research Effectiveness and Monitoring Board (REMB) was established to conduct research and inventory projects, including this aerial moose inventory. Two regions were assessed during the Distance sampling program, Clarke-Chinchaga and Fortune; these two regions encompass the Clarke CCA, Fortune CCA, part of the Calendar CCA, and the Chinchaga RRA. The results of this moose inventory will provide the REMB and biologists data to support management decisions in and around the CCAs and RRAs.

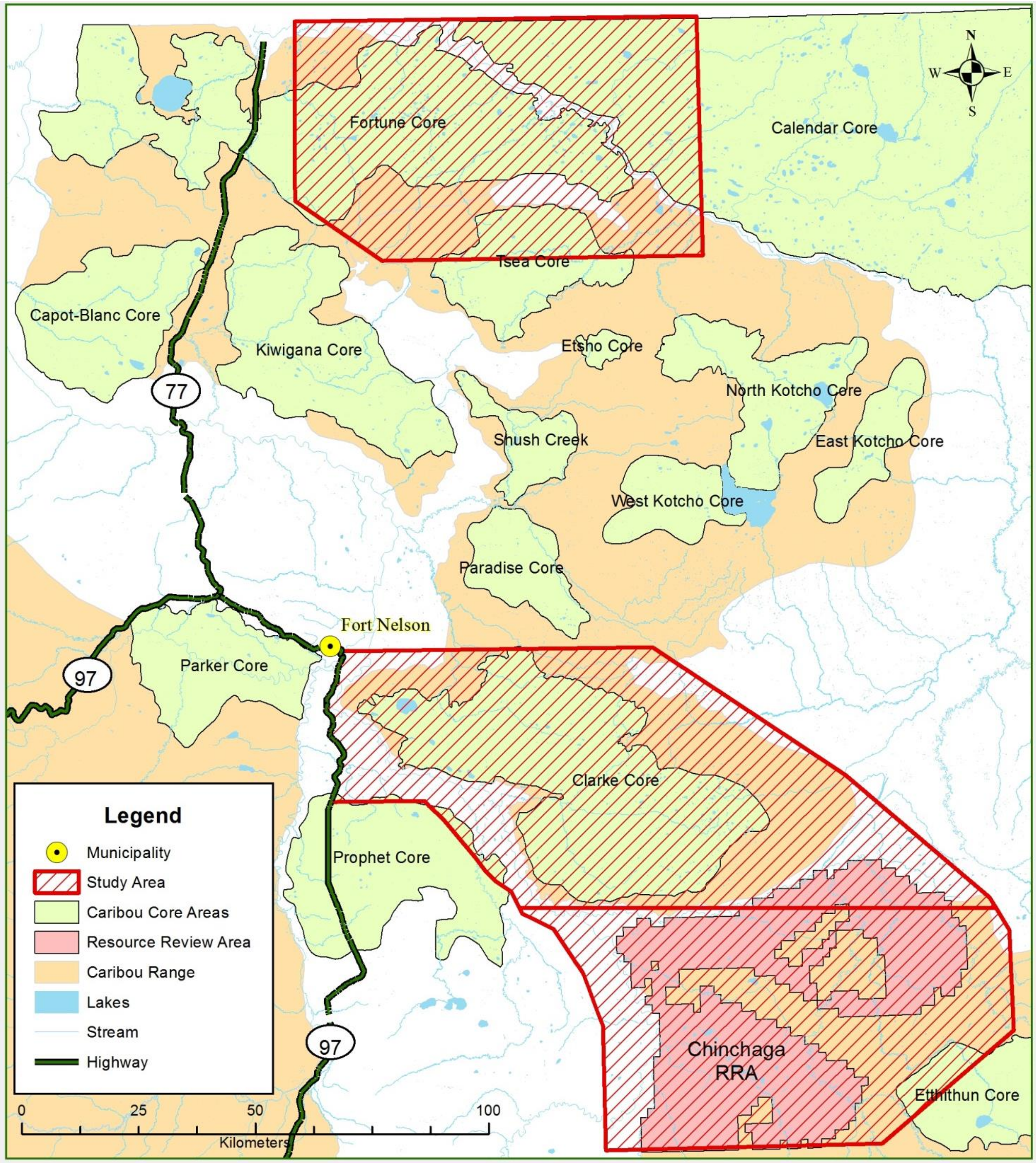
Study Areas

The Clarke-Chinchaga study area is situated in northeast BC southeast of the Horn River Basin (HRB). This study area encompassed the Clarke CCA (1,381 km^2) and the Chinchaga RRA (13,898 km^2). Small portions of the survey transects crossed the Prophet CCA and Etthithun CCA (Culling et al. 2006; Figure 1). CCA and RRA were selected for high value caribou habitat and generally, low value moose habitat occurs within the boundaries of the CCA or RRA (Figure 2). The Chinchaga RRA was established in June 2010 as a management tool for boreal caribou; the intent of the RRA was to prevent new oil and gas, mineral, placer, or coal tenures within the RRA for a minimum of 5 years to provide enhanced caribou habitat when compared to the conditions outside the RRA's boundaries. The effectiveness of the RRA was to be assessed in 2015. The Fortune study area (Figure 1) is located along the north boundary of the HRB and includes the Fortune – East CCA (2,640 km^2) and a portion of the Calendar RRA-C. Since only a small portion of the Calendar RRA-C was surveyed, the data was consolidated into Fortune-East.

The Clarke-Chinchaga study areas overlaps three ecosections. The Clarke CCA is within the Fort Nelson Lowland ecosection. The Fort Nelson Lowland ecosection is a broad lowland area with some gently rolling portions. The lowland area is estimated at ~610 m in elevation along sandstone scarps. Drainage in this ecosection is not well developed and is drained to the north by the Fort Nelson River and to the east by the Hay River. This area can experience long periods of intense cold temperatures in the winter with short days. Black and white spruce is the main forest type in this ecosection, but there are many wetlands and muskeg that are surrounded by black spruce and tamarack. White spruce is generally situated on the alluvial soils along the rivers and drier sites (Demarchi 2011).

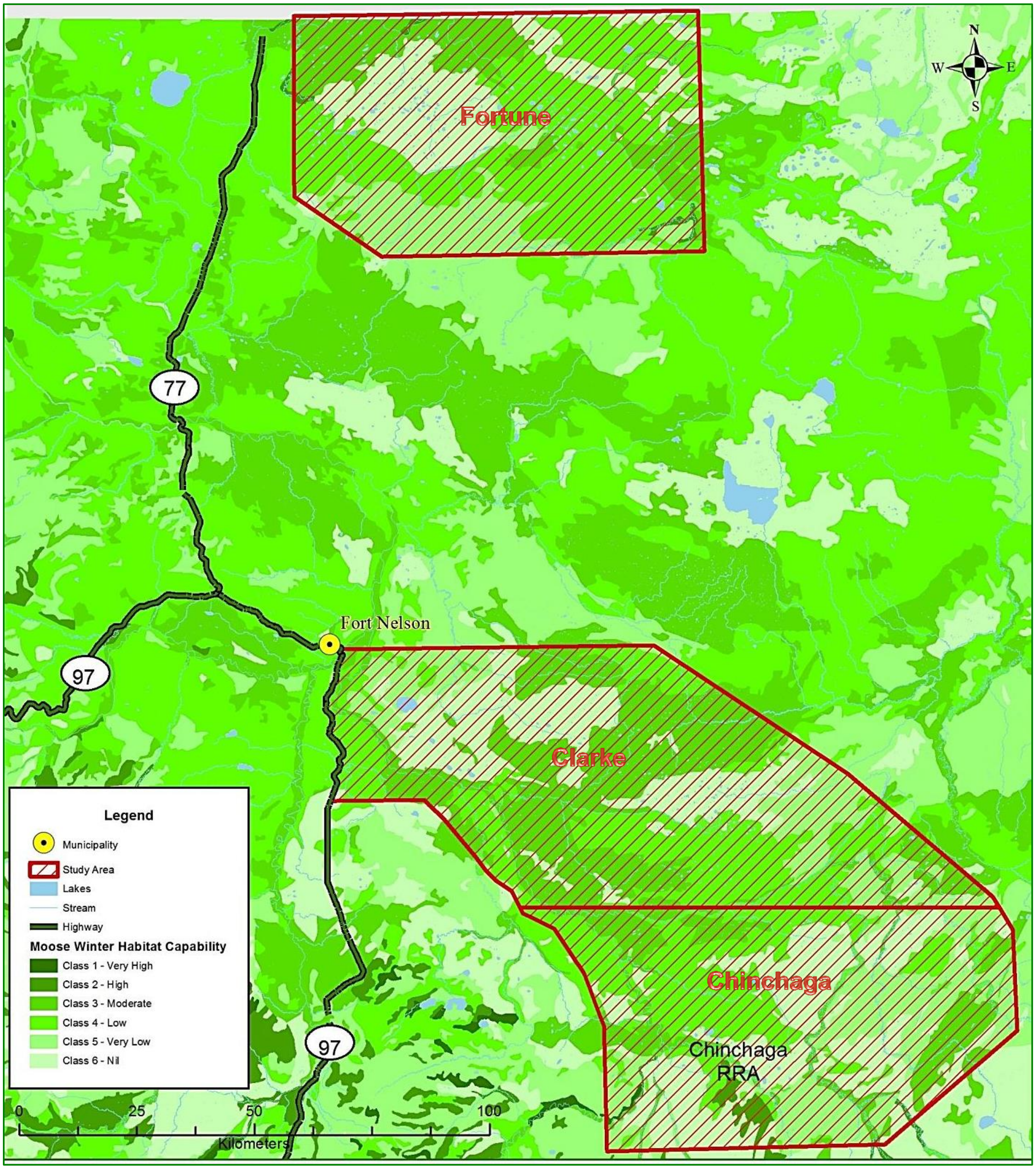
The Chinchaga area overlaps the Fort Nelson Lowland, the Clear Hills, and the Sikanni Chief Upland ecosections. The Clear Hills ecosection is a smooth rolling upland gradually rising in elevation towards the north and east into Alberta. This ecosection receives moist summers and cold dry winters and consists of underlain flat lying sedimentary sandstone that has been buried by the Continental Glaciers. The upland forests are a mix of black and white Spruce with lodgepole pine on drier, well-drained sites. Fire impacted areas result in regeneration of trembling aspen and willow patches (Demarchi 2011). The Sikanni Chief Upland ecosystem is an extensive upland or plateau east of the Rocky Mountain Foothills with a gently rounded surface. This ecosystem is influenced by the surface heating of the wetlands and streams resulting in convective currents with localized showers and high humidity. The low pressure systems centered over northern Alberta force moist air against the mountains creating extreme rain events. Cold arctic fronts create extended periods of extreme cold.

FIGURE 1. CARIBOU CORE AREAS AND RESOURCE REVIEW AREAS (RRAS) IN RELATION TO SURVEY AREAS



The Fortune study area overlaps the Etsho Plateau, Petitot Plain, and Trout Lake Plain ecosections. The Etsho Plateau ecosection is rolling uplands of gentle eastward dipping sandstone that rises steeply. Elevation varies from 750 m to 950 m. The Petitot Plain ecosection is a wide meltwater plain drained by the Petitot River and several streams. The Trout Lake Plains ecosection is a rolling upland plain with an elevation greater than 600 m and is drained by the upper Hasitl Creek in BC. All three ecosections have warm summers with moderate precipitation and winters are very cold often dominated by arctic high pressure systems (Demarchi 2011).

FIGURE 2. MOOSE WINTER HABITAT CAPABILITY MAPPING FROM THE BROAD ECOSYSTEM INVENTORY SHAPEFILES



All of the sampling areas are within the Boreal White-Black Spruce moist-cool (BWBSmk) Biogeoclimatic zone (Meidinger and Pojar 1991). The BWBS is characterized as having frequent outbreaks of arctic air masses, with long, very cold winters and short growing seasons. The mean annual temperature for long-term climatic stations within the zone is -2.9 to 2^{o}C. Annual precipitation averages between 330 and 570 mm with 35-55% of this occurring as snow fall (Meidinger and Pojar 1991). Upland forests are typically trembling aspen-white spruce (*Populus tremuloides* – *Picea glauca*); forested wetlands are dominated by black spruce (*Picea mariana*) or tamarack (*Larix laricina*); non-forested wetland are often scrub birch (*Betula glandulosa*); and moist, rich sites may be dominated by paper birch (*Betula papyrifera*).

Wildlife harvest, and many historic surveys, are managed at a Wildlife Management Unit (WMU) scale across British Columbia; the study areas are within Region 7B Peace-Ominica. The study areas overlap WMU 7-55, 7-56, 7-47, and 7-48. Rowe (2008) further lumps these areas into Game Management Zones (GMZ), of which our study area overlaps the Fort Nelson GMZ (G and H) and North Peace GMZ (C). It is not feasible to delineate the study area based on WMUs since each WMU encompasses a larger geographic area than the CCA or RRA of interest.

Many of the relevant MUs overlapped by these study areas have historically had low recorded densities of moose (Rowe 2008). The recorded density for moose in GMZ subzone G (Clarke study area) was 0.087 moose/ km^2 with ratios of 76.3 bulls/100 cows and 23.7 calves/100 cows (Rowe 2008; Backmeyer 2004). The 2013 moose inventory project (McNay et al. 2013) recorded low densities within the CCAs assessed by the current project. The Clarke CCA had an estimated 0.145 moose/km^2, a recorded calf ratio of 62 calves/100 cows, and 46 bulls/100 cows. The recorded density for MU 7-47 (Chinchaga and Ettithun) was the lowest in the Peace Region at 0.044 moose/km^2 +/- 24.6% and recorded calf ratios of 9.4 calves/100 cows +/- 75.1% and bull ratios of 63.5 bulls/100 cows +/- 44.7% (Rowe 2005; Rowe 2008). Chinchaga was estimated at 0.151 moose/km^2 and Etthithun at 0.044 moose/km^2 with calf ratios of 59 calves/100 cows and bull ratios of 117 bulls/100 cows and 0 calves/100 cows and bull ratios of 17 bulls/100 cows respectively in 2013 (McNay et al.). The Thiessen (2010) inventory included the Fortune-East and Calendar CCAs. The Fortune-East CCA had a density of 0.043 moose/km^2 and the Calendar CCA had a density of 0.018 moose/km^2.

The study area overlaps the Chinchaga, Snake-Sahtaneh, Calendar, and Maxhamish boreal caribou herd ranges. Approximately 1,300 boreal caribou comprise the estimated 21,800 woodland caribou in BC (Culling and Cichowski 2010). Culling et al. (2004) identified a total of 13 Core Habitats within 4 Boreal Caribou Ranges and an additional 2 Core Habitats (Prophet and Parker) without any broader range. The most reliable enumeration of boreal caribou between 2004 and 2013 indicate the BC Chinchaga herd has gone from 483 in 2004, 250 in 2008 and a minimum population estimate in 2013 of 256, indicating a declining population. The BC Snake-Sahtaneh herd has gone from 365 in 2004, 360 in 2008 and a minimum population estimate in 2013 of 321, also indicating a declining population. The BC Maxhamish herd has gone from 306 in 2004, 300 in 2008 and a minimum population estimate in 2013 of 132. (Culling et al 2004; Environment Canada 2008; Culling and Culling 2013) All of these populations have an at risk status of vulnerable.

Anthropogenic disturbances tends to revert habitat to an early seral state which often has low habitat value for caribou due to the removal of older seral states which typically has higher lichen growth. Table 1 presents the amount of anthropogenic disturbance within each of the study areas. We calculated the disturbance area by using BC Forestry and BC Oil and Gas Commission disturbance layers. The Snake-Sahtaneh herd range covers 12,000 km^2; and the Clarke CCA within this herd range covers 1,381 km^2 and 93.5% of the CCA had anthropogenic impacts (Table 1) (Thiessen 2009). The Chinchaga herd range covers 13,879 km^2 and contains the Etthithun CCA, Milligan CCA and Chinchaga RRA. The Chinchaga RRA covers 2,403 km^2 and has 58% anthropogenic impact (Thiessen 2009). The Maxhamish herd range covers 7,095 km^2, with the Fortune CCA covering 2,662 km^2 with 59.7% of anthropogenic disturbance (Thiessen 2009). It should be noted that the Fortune CCA has undergone substantial industrial development since 2009 and may potentially be sitting over the 61% threshold advised by Environment Canada (Environment Canada 2008). Since we do not know the current 2016 levels of anthropogenic disturbance we did not investigate these correlations in this study.

TABLE 1 –AREA (KM^2) OF BOREAL CARIBOU CORES AND ANTHROPOGENIC DISTURBANCE WITHIN THEM, AND THE PERCENT AREA IMPACTED BY DISTURBANCE (ADAPTED FROM ENVIRONMENT CANADA 2008; THIESSEN 2009; CICHOWSKI, CULLING, MCNAY 2012)).

CCA/RRA	Area (km^2)	Disturbance (km^2)	% Impacted
Clarke	1,381	1,292	**93.5**
Chinchaga	2,403	1,393	58
Fortune	2,662	1,589	59.7

Bold numbers indicate Disturbance above the 61% threshold

METHODS

Distance sampling

Distance sampling (Buckland et al. 2001, 2004) has been implemented on many recent moose surveys both in BC (Peters et al. 2010; Thiessen 2010; McNay et al. 2013) and Alberta (Pers. Comm. Moyles 2016) in an attempt to reduce the cost of aerial inventories. Distance sampling was specified for this survey to improve comparisons to previous moose surveys (Thiessen 2010; McNay et al. 2013) and to improve the efficiency of sampling large areas of northeast BC. Distance sampling requires observations to be taken along pre-determined transects with the primary assumption that all sample objects (i.e., moose) occurring on the transect line are observed perfectly (i.e. 100%). There is a decreasing probability of detecting moose with increasing distance from the line and the distance data that are recorded (Figure 3) allow a detection probability to be calculated. It is from that detection probability (P_a) that a population density estimate (D) can be derived (Buckland et al. 2001) where a is the area surveyed calculated as $a = 2wL$, L is the total transect length, and w is the perpendicular distance from the transect at which moose are observed. The expected number of moose, E(n), is equal to the expected number of animals in the survey area, D x a, multiplied by the probability of detection so that D = E(n) / a x P_a (Buckland et al. 2001). The numerator is modified to n x E(s) if observations are recorded as clusters of moose where n becomes the number of observations and E(s) is the expected cluster size. The denominator can also be modified with constants to account for specific survey designs (e.g., observations from only one side of the transect) or covariates (e.g., vegetation cover or snow cover).

Survey unit selection and transect establishment

The survey areas were identified by Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) and encompassed the Clarke CCA and Chinchaga RRA (small portions of survey transects entered the Prophet CCA and Etthihun CCA), the Fortune-East CCA and a portion of the Calendar RRA-C. These survey units had been previously sampled (Thiessen 2010; McNay et al. 2013) and this survey provides additional data to the REMB as they evaluate the effectiveness of the CCAs and RRAs. The recommendations from McNay et al. (2013) that a minimum of 800 km of transect be sampled per survey area were implemented during the design of the 2016 sampling program. This survey incorporated 1,150 km of transect in Clarke, 1,130 km in Chinchaga and 1,050 km in Fortune with the survey areas squared off, and a secondary study area around the area of interest being included. The secondary study area was incorporated to assess habitat adjacent to the CCA or RRA, which may have better suitability for moose, and to ensure transects were a minimum of 40 km long (average transect length was over 80 kms).

We developed a series of primary transects, with a 6 km spacing and east-west orientation. A series of secondary, east-west, transects were also developed to provide an optional 3 km spacing to increase sample effort in areas with low moose density to achieve the desired coefficient of variation (CV) by ensuring adequate moose group detections. All transects were developed using the Universal Transverse Mercator (UTM) zone 10 projection, and World Geodetic System (WGS) 84 datum and GPS units were programmed to have the same projection and datum to ensure accuracy during the survey and post-survey data analysis. The east-west transect orientation was selected to ease navigation along the transects during the survey, and to improve the accuracy of post-survey data analysis (e.g. perpendicular distance from the transect to the animal vs. observation distance; Figure 3). The east-west orientation also assisted in keeping the longest transects around 120 km which ensured observers had a short break every 60-90 minutes during the survey.

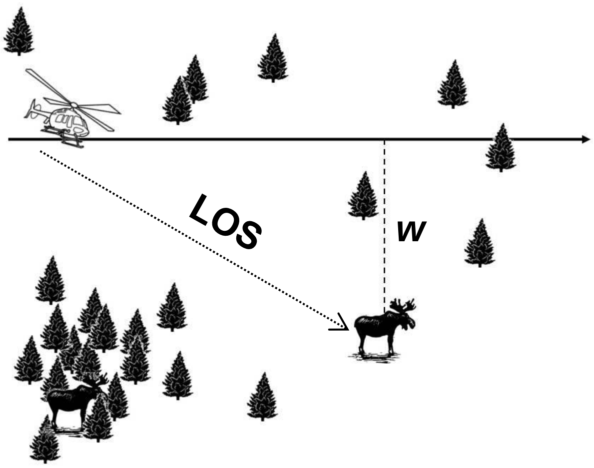


FIGURE 3. A SCHEMATIC OF THE METHODS USED IN DISTANCE SAMPLING (ADAPTED FROM THIESSEN 2010; MCNAY ET AL. 2013)

Sampling

Figure 3 represents a schematic of the methods used in distance sampling (adapted from Thiessen 2010; McNay et al. 2013) where the perpendicular distance (w) is measured between the transect line (solid) and the observed moose when it was first seen along the line-of-sight (LOS) from a helicopter. A laptop running OziExplorer (version 3.95.6p) tethered to a Garmin Montana 650 handheld GPS receiver with auxiliary antenna (+/- 3 to 5 m accuracy expected) was used to navigate along the transect lines. When moose or incidental species were spotted, their locations were obtained by flying off the transect to mark the UTM coordinate of the species from the helicopter. When more than one moose was observed in a group the UTM location was taken at the midpoint among the moose in the group. Moose > 100 meters apart were considered to be separate groups and each given their own UTM coordinate. Transects were flown at a consistent 70 – 110 km/h depending upon wind direction and detections being made and the helicopter height above ground was targeted at 100 meters but adjustments made due to vegetation cover and snow cover. Height above ground was modulated based on visual reference to the ground, by monitoring the difference between altitude and topographic contours from the GPS map, and areas with significantly different vegetation cover.

Moose were classified by age and gender according to RISC Level II or III standards (RIC 2002), dependent upon the presence or absence of antlers. When antlers were not present, gender was determined using the presence of the white vulval hair patch for females and the absence of the vulval hair patch and/or presence of antler scars for males. When antlers were present males were classified based on their antler architecture. Incidental observations of other wildlife species were recorded. Boreal caribou were classified as male (absence of black vulva), female (presence of black vulva), and calf. Wolves were recorded by number and colour to help differentiate sightings of unique packs. Grouse sightings and tracks were also recorded.

Collection of ancillary information

Two data collection forms were used during surveys, one was to used record information regarding the animals observed and environmental conditions, and the second form was used to record habitat data observed on-transect, between the transect and the animals, and at the animals' locations (Appendix 1:

Sample Data Sheet). Temperature, wind speed and direction, cloud cover, and snow depth were recorded at the start of each transect. Temperature, wind speed, and wind direction were measured using the helicopter's instrumentation. Snow depth was estimated based on the amount of low vegetation visible through the snow or depth on observed animals; and were periodically verified with ground measurements while refueling or during a break. Cloud cover was visually estimated at the start of each transect. Visibility categories were broken down into five classes as described in Table 2.

Habitat data that was recorded included slope, vegetation cover, snow cover (Table 3) and habitat type, successional stage, and habitat modifiers at three locations (on transect, between transect and animals, and at the animals) (Table 4).

Sample data forms used during the Distance sampling project are provided in Appendix 1.

TABLE 2 – VISIBILITY CLASS RATINGS AND EXPLANATION OF CRITERIA FOR SURVEYOR RANKING.

Visibility Class	Criteria
Very Poor	Overcast, snowing, dark and grey light conditions, observations restricted to ~100 m from the helicopter
Poor	Overcast, no snow to light snow, light grey light conditions, observations restricted to ~150-200 m from the helicopter. Also, bright sunny conditions with sun low in the sky and extensive shadows.
Moderate	Cloudy, light grey light conditions, observations restricted to ~300-500 m from the helicopter. Also, sunny conditions with shadows.
Good	Light cloud to bright sun with few shadows, observations not restricted laterally.
Very Good	Light cloud, good light conditions with no shadows, no visibility restrictions.

TABLE 3 – PHYSICAL MEASUREMENT CATEGORIES GATHERED AT EACH ANIMAL OBSERVATION

SLOPE			VEGETATION COVER
Code	**% Range**	**Description**	**% Range**
1	0-5%	Flat	0-20
2	5-20%	Minimal Slope	21-40
3	20-50%	Moderate Slope	41-60
4	>50%	Steep	61-80
SNOW COVER			>81
% Range	**Description**		
0-25	poor (bare ground showing)		
26-75	moderate (scattered bare patches)		
76-99	good (some low veg showing)		
100	excellent (complete snow cover)		

TABLE 4 – HABITAT DESCRIPTORS ASSESSED AT EACH ANIMAL OBSERVATION

HABITAT COMMUNITIES					
WA	Water	**BU**	Burn	**DE**	Deciduous
WE	Wetland/Bog	**CU**	Cutblock	**CD**	Coniferous/Deciduous mixed
ME	Meadow	**UV**	Unvegetated	**CS**	Cottonwood/Spruce
RI	Riparian	**RD**	Road	**PS**	Lodgepole pine/Spruce Mixed
WS	Willow/Shrub	**OG**	Oil and Gas Site	**LP**	Lodgepole Pine
TA	Talus Slope	**AR**	Alpine Ridge	**SP**	White Spruce
SU	Subalpine	**AV**	Avalanche Track	**BS**	Black Spruce
SB	Eng. Spruce/Subalp. Fir/Scrub Birch	**TA**	Tamarack		
HABITAT CLASS MODIFIERS					
C	Coarse textured soils	**F**	Fine textured soils	**L**	Shallow soils
M	Moist soils	**G**	Gently sloping	**T**	Moderate sloped and warm
U	Upper elevation and gentle slope	**N**	Cool northerly aspect	**S**	Steep warm southerly aspect
SUCCESSIONAL STAGE					
0	Non-forested units	**1**	Recent disturbance	**2**	Young coniferous forest (<60yrs)
3	Young mixed forests (<60yrs)	**4**	Mature coniferous forest (60-140 yrs)	**5**	Mature mixed forest (60-140 yrs)
6	Young deciduous forest (<60yrs)	**7**	Mature deciduous (60-140 yrs)	**8**	Old growth (>140yrs)

Moose Observation and Vegetation Resource Inventory Stratification Process

British Columbia's Vegetation Resource Inventory (VRI) geospatial data was used for post-hoc habitat stratification and analysis. Five broad habitat types for moose were categorized from the VRI data using an approach adapted from DeMars and Boutin (2014). The 5 Habitat Groups were: 1-Wetland, 2-Treed Wetland, 3-Coniferous, 4-Deciduous/Mixed, and 5-Disturbed. The first four groups were determined using the VRI fields **BCLS Level 4** (Vegetated Cover Type), **BCLS Level 3** (Landscape Position), and **Species Type** (Forest Cover Type) (Table 5). Because disturbances are not necessarily updated in the VRI, group 5-Disturbed was supplemented with additional data for oil and gas developments, pipelines, burns, cutblocks and roads (Appendix 4: VRI Stratification Data). Seismic activity was not included in the disturbance calculations as the wider lines are now old and grown in, while the more recent lines were cut as low impact seismic with narrow line widths. Any of the older seismic lines used for recurring winter access were picked up from the OGC road layer.

Moose observation locations were intersected with the habitat layer to identify habitat associations, calculate the amount of preferred moose habitat available within the study areas, and calculate habitat-specific moose population estimates using the stratified VRI data. The GIS data was verified with field data and more broadly with satellite imagery. Large water bodies were not included within the VRI Data (ie. Kotcho Lake). Also, there were several hectares of upland treed VRI polygons with no filtering data available. The overall Clarke/Chinchaga & Fortune AOI's were therefore reduced to compensate for these exclusions. After correcting for spatial location issues, the Habitat Group classification was correct at 97.1% of the moose observations, which was deemed acceptable for the purposes of this project. The overall Clarke/Chinchaga and Fortune survey areas were therefore adjusted to compensate for small areas of missing VRI data. .

Table 5 – Habitat classification scheme applied to the VRI dataset. Additional geospatial data for oil and gas developments, pipelines, cutblocks and roads was incorporated to define Disturbed

Primary Filtering Field (BCLS Level 4)	Secondary Filtering Field (BCLS Level 3)	Third Filtering Field (Species1 Type)	Final Habitat Group
Wetland	Shrub (ST & SL)		WETLAND
	Herb (HE, HF & HG)		
	Bryoid (BY, BM & BL)		
	(EL) Exposed land/water		
	Coniferous (TC)		TREED WETLAND
	Deciduous/Mixed (TB & TM)		
Upland	Shrub (ST & SL)		WETLAND
	Herb (HE, HF & HG)		
	Bryoid (BY, BM & BL)		
	Coniferous (TC)	(EA) Alaska paper birch	TREED WETLAND
		(EP) Paper birch	
		(LT) Tamarack	
		(SB) Black spruce	
	Coniferous (TC) & Deciduous/Mixed (TB & TM)	(B) Fir (Balsam)	CONIFEROUS
		(BL) Subalpine fir	
		(L) Larch	
		(LAA) Alpine larch	
		(P) Pine	
		(PJ) Jack pine	
		(PL) Lodgepole pine	
		(PLI) Lodgepole pine	
		(S) Spruce	
		(SE) Engelmann spruce	
		(SW) White spruce	
		(SX) Spruce hybrid	
		(T) Yew	
	Coniferous (TC) & Deciduous/Mixed (TB & TM)	(AC) Poplar	DECIDUOUS/MIXED
		(ACB) Balsam Poplar	
		(AT) Aspen	
		(E) Birch	
		(WS) Scouler's willow	
	(EL) Exposed land/water		DISTURBED

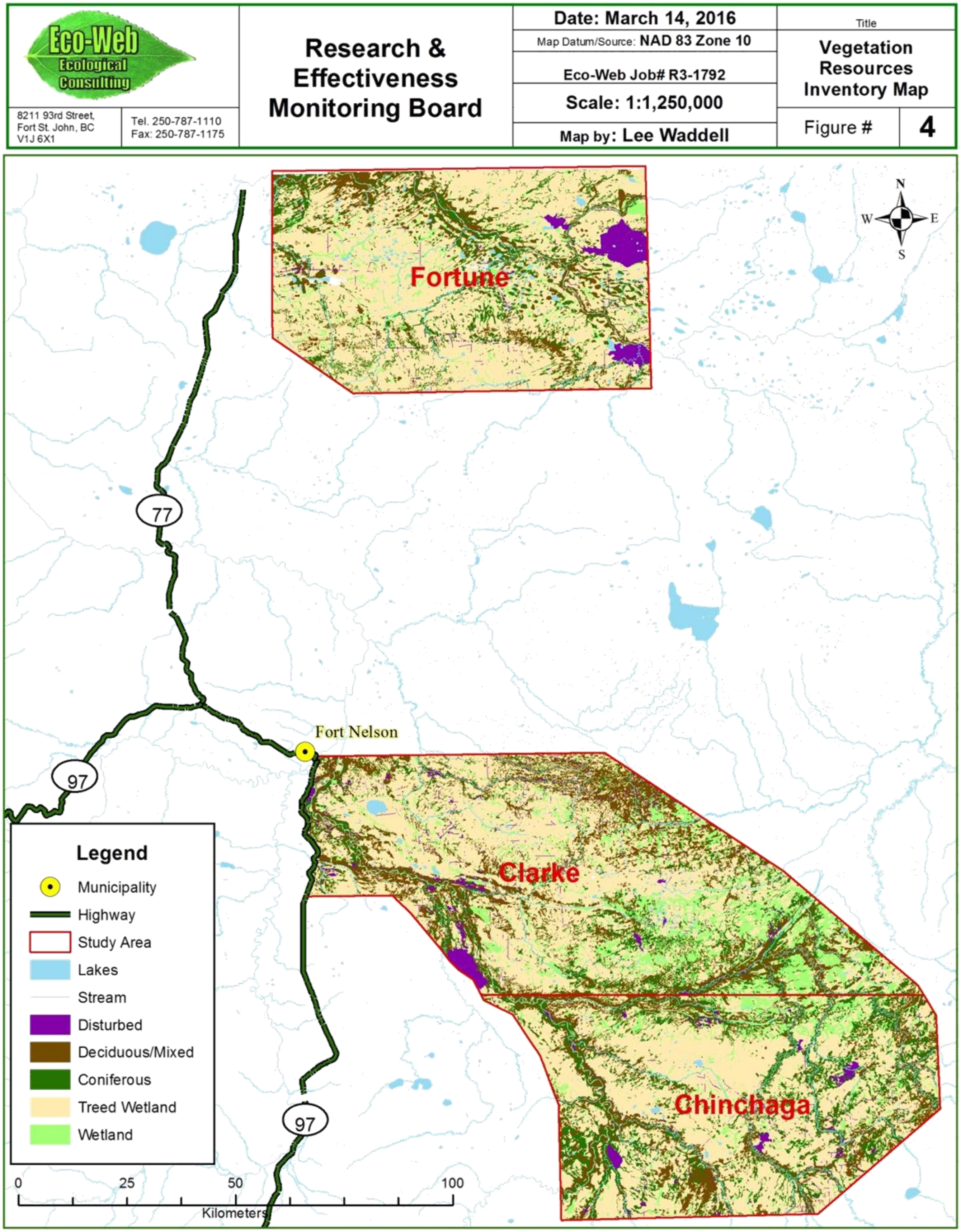


FIGURE 4 – STRATIFICATION MAP OF THE HABITAT GROUPS

Analysis

Population Density

Estimates of moose densities were calculated using the program DISTANCE 6.2 Release 1 (Thomas et al. 2010). Of primary importance for estimating densities based on distance sampling are the assumptions that: (1) all animals located on or near the line are detected with certainty; (2) animals are detected prior to any responsive movement; and (3) measurements are made without errors (Buckland et al. 2007). The data was assessed in two pooled sets (Clarke – Chinchaga - Fortune and Clarke - Chinchaga) and in the three unpooled sets (Clarke, Chinchaga, and Fortune). For the pooled and unpooled areas separately, we plotted distributions of distances measured from transects to observations of moose groups (single or cluster). We used these plots to help determine truncation distances by truncating 5% or 3% of the furthest distances (Buckland et al. 2001) to make better model-fitting assumptions and to help identify and interpret potential biases and limitations of the data. Exploratory analysis was then conducted in the pooled and unpooled data sets to determine if truncation of each data set could improve the model fit of the detection functions (Buckland et al. 2001). We also assessed the data through exploratory analyses of the pooled and unpooled data to determine which model best fit by assessing the key functions and corresponding series expansions. Based upon these results we then also applied multiple covariates to each model using Multiple covariates Distance Sampling within DISTANCE. The covariates considered were snow cover, canopy closure (termed % vegetation at the moose), cluster size and visibility. The best detection function was determined using Akaike's Information Criterion (AIC), which is also compared within each survey and data filter by delta AIC (ΔAIC = AIC – minimum AIC) (Buckland et al. 2001; Burnham and Anderson 2002).

In order to meet the assumptions of DISTANCE 6.2, we attempted 'left-truncation' (i.e. removed observations < a specified distance) of data from both the pooled and unpooled data. We also fit separate models without left truncation. Truncation was assessed at removing 5% of the farthest distances and 3% of the farthest distances. Truncation of 5%-10% of the largest distance observations ('right-truncation') is recommended to improve the fit of the detection function (Buckland et al. 2001); but in the interest of retaining data we first evaluated to see if this made a difference. We used AIC (Burnham and Anderson 1998) to indicate the best fitting model, as assessed by the lowest AIC and ΔAIC closest to zero in a survey unit. We examined the Goodness-of-fit test using the Kolmogrov-Smirnoff GOF test, where lower p-values indicated the difference from the expected model would rarely happen due to sampling, so the higher p equates to a better fit (Buckland et al. 2004). We did not apply a size-bias regression to the estimate of the detection function unless the regression was significant at $\alpha = 0.15$.

We looked at all four key functions (half-normal, uniform, hazard-rate and negative exponential) and applied the available series expansions (cosine, simple polynomial and hermite polynomial) in DISTANCE (Buckland et al. 2001). For the pooled data the uniform function did not fit the data across each data set, while the others did with the negative exponential function having the lowest AIC (ie. best fit). In the unpooled data only the half-normal key function fit reliably across the Clarke, Chinchaga, and Fortune data sets. In DISTANCE 6.2, when considering multiple covariates distance sampling, only the half-normal and hazard rate key functions are available (Buckland et al. 2001). Based upon this the half-normal function with a cosine series expansion was selected as the best fitting model for evaluating our data.

We applied the half-normal key with cosine expansion model form for the detection functions for all survey areas to maintain a common model assumptions set. Estimates of variance were made using the empirical variance estimation approach (Buckland et al. 2001) for all model fits. Bootstrapping the estimate was used with the following exceptions: (1) when fitting cluster size as a covariate and (2) if model convergence errors or other warnings occurred.

We fit six detection models for both the pooled data and unpooled data for each survey unit: (1) a model with no covariates; (2) a model using cluster (group) size as a covariate, testing whether larger groups are easier to observe; (3) a model using visibility categories (Table 2) as a covariate, testing the effect of the index of visibility on the probability of observing moose (4) a model using snow cover as a covariate, (5) a model using canopy closure as expressed by one of five categories of % vegetation at the moose as a covariate testing whether observations are affected by the relative density of vegetation cover; and (6) a model using both % vegetation at the moose and snow cover as multiple covariates (see Appendix 3: for exploratory analysis of the covariates). Additional covariates were assessed such as habitat type, snow depth and cloud cover, as well as other multiple covariate models, but all of these were found to either not run reliable across all data sets or produced too many errors.

In each survey set we evaluated candidate models with AIC (Burnham and Anderson 2002) and evaluated the best fit model as having the ∆AIC closest to zero (Burnham and Anderson 2001). Models that ran with convergence warnings or with highly correlated parameters leading to unreliable estimates of AIC and density were excluded. Due to the low snow volumes and variability in canopy closure across the study areas, use of these models was deemed to be the most relevant. We did test to identify if helicopter speed varied with these factors, but found no correlation (Figure 6, Table 10, Table 11 and Table 12), so were comfortable using the models. Estimates of density and extrapolated population estimates were made on the basis of the minimum AIC for a given unit. Pooled density estimates (Clarke-Chinchaga-Fortune and Clarke-Chinchaga), as well as separate estimates for each individual survey area (Clarke, Chinchaga, and Fortune) were calculated. All estimates were calculated with two-sided 95% confidence intervals. The numbers of moose in each survey unit were simple extrapolations of the density estimates based on the area (ha) of each survey unit. We also applied a post-stratification to the analysis replicating the above analyses, to provide a density by strata (Habitat Group) and an alternate means in calculating overall population size, as discussed in greater detail below.

STRATIFICATION

DISTANCE 6.2 allows the user to post-stratify the data after the data has been collected and examined (Buckland et al. 2001). In our examination of covariates as factors, habitat type did not give us reliable density estimates due to generating too many errors. It was decided that this was because there were too many habitat types, resulting in a very low sample size in each habitat type. In order to correct for this we pooled habitat types at each moose group observation into a general habitat group: Wetland, Treed Wetland, Coniferous, Deciduous/Mixed, Disturbed and Mountain (see Table 6). These Habitat Groups were then assigned a stratification level of low, medium or high based upon the number of moose observed per habitat type as compared to the other habitat types. These covariates were then added to the data in DISTANCE and a population density could be calculated for each Stratification Level. When pooled the low, medium and high densities equal that calculated in the total study area. However, due to small sample size in the “low” strata, the overall population size may be over-represented (Buckland et al. 2001). When the Habitat Groups were merged with the VRI data (see above) it was also difficult to distinguish between wetland and treed wetland, so we also calculated density estimates based upon just Habitat Group as the post stratification layer. This provided densities per habitat group as well as per stratification level.

Table 6 – Habitat Type at the moose group broken into Main Habitat Groups and Stratified based upon highest average number of moose observed.

Habitat Group	Habitat Type	Moose Groups	Moose	Stratification
Wetland	**WA** *Water*	0	0	High
	WE *Wetland/Bog*	30	59	
	ME *Meadow*	4	12	
	RI *Riparian*	3	4	
	WS *Willow/Shrub*	85	165	
	Total	122	240	
	Average	24.4	48	
Treed Wetland	**BS** *Black Spruce*	12	24	Medium
	TA *Tamarack*	0	0	
	Total	12	24	
	Average	6	12	
Coniferous	**PS** *Lodgepole Pine/Spruce Mixed*	1	2	Low
	LP *Lodgepole*	0	0	
	SP White *Spruce*	0	0	
	Total	1	2	
	Average	0.33	0.67	
Deciduous/Mixed	**DE** *Deciduous*	5	7	Medium
	CD *Conifererous/Deciduous Mixed*	6	7	
	CS *Cottonwood/Spruce*	5	9	
	Total	16	23	
	Average	5.33	7.67	
Disturbed	**BU** *Burn*	2	6	Medium
	CU *Cut Block*	1	3	
	UV *Unvegetated*	0	0	
	RD *Road*	0	0	
	OG *Oil&Gas Site*	7	16	
	Total	10	25	
	Average	2.00	5.00	
Mountains	**TA** *Talus Slope*	0	0	Nil
	SU *Subalpine*	0	0	
	AR *Alpine Ridge*	0	0	
	AV *Avalanche Track*	0	0	
	SB *Spruce Eng./Subalp Fir/Scrub Birch*	0	0	
	Total	0	0	
	Average	0	0	

Population Structure and Demographics

Standard metrics that characterize moose population structure (i.e., calf:100 cows, calves as percent of the population, and bulls:100 cows) were calculated using Excel. In the previous survey (McNay et al. 2013) we had used estimates of anthropogenic disturbance levels within each study area (as calculated by Thiessen 2009) and linear regression analyses to test for potential effects on observed moose populations (i.e., population density and calf:100 cows). However, it was decided that since the disturbance information was now 7 years out of date, that these calculations would not be relevant (and had not shown a significant correlation previously) so they were not conducted for this survey.

The finite rate of change (λ) for the moose populations assessed in this study could not be calculated on the basis of comparisons to historic population estimates because of the lack of direct correlation with areas assessed. We used the estimated calf:100 cows ratio, an assumed equal sex ratio at birth, and an assumed adult cow total annual mortality rate of 12% (Bergerud and Elliott 1998) to estimate λ for the cow portion of the population. This approach could have included bulls; however, the bull:100 cows ratio tends to vary more due to changes in management approaches (i.e. bull mortality changes with changes to hunting regulations). As an example of the approach, with 40 calves:100 cows, 20 females are recruited per year and 12 adult cows die, leaving the $\lambda_{Cow} = (100+(20-12))/100 = 1.08$. $\lambda > 1$ indicates an increasing population, a $\lambda = 1$ represents a stable population, and $\lambda < 1$ indicates a decreasing population.

RESULTS

Survey Characteristics

The survey was conducted between January 27 – February 4, 2016 with 57.6 hours of helicopter services, 40.4 hours of which were direct survey effort (Clarke 15.4 hours, Chinchaga 13.4 hours, and Fortune 11.6 hours). Visibility ratings were mostly moderate-good; 5.8 hours of poor and moderate-poor conditions were encountered in Clarke due to rain and bright sun and 2.6 hours of moderate-poor conditions were encountered in Fortune. The afternoon of January 29 and all of January 30 could not be flown due to poor-very poor conditions due bright sunlight and clear skies.

The Environment Canada (2016) Fort Nelson weather station data indicated that the temperatures during the survey were warmer than the average and with very shallow snow depths compared to normal (normal minimum January temperature = -24°C and average January snow depth = 47 cm; Figure 5). The snow depth was variable across the sampling areas, but was thinner than the typical snow depth. The snow depth and vegetation at each moose observation influenced the sightability of the moose since the typical contrast expected (e.g. dark moose on a white background) was seldom present. Open areas often had less snow due to higher melt rates than areas with dense vegetation cover.

During the entire survey, 3,345.4 kms of transect were flown (Appendix 2) with a range of 1,133.7 km (Chinchaga) to 1,152.9 km (Clarke) in each individual unit. A total of 161 moose groups containing 314 individuals were observed during the sampling. The sampling effort for each survey unit ranged from 0.22 to 0.27 km of transect per km^2 and an overall total of 314 moose were observed (Table 7).

TABLE 7. MEASURES OF EFFORT BASED ON TRANSECTS FLOWN FOR THE JANUARY 2016 MOOSE SURVEY.

Survey area	Survey unit area (km^2)	Sampling effort (km)	Number of moose groups	Number of moose	Km of transect/km^2	# of moose groups / km	# of moose / km
Clarke	5,303	1,152.9	76	142	0.22	0.066	0.123
Chinchaga	4,275	1,133.7	39	76	0.27	0.034	0.067
Clarke-Chinchaga	9,578	2,286.5	115	218	0.24	0.050	0.095
Fortune	4,331.7	1,058.8	46	96	0.24	0.043	0.091
All combined	**13,909.7**	**3,246.9**	**161**	**314**	**0.23**	**0.050**	**0.097**

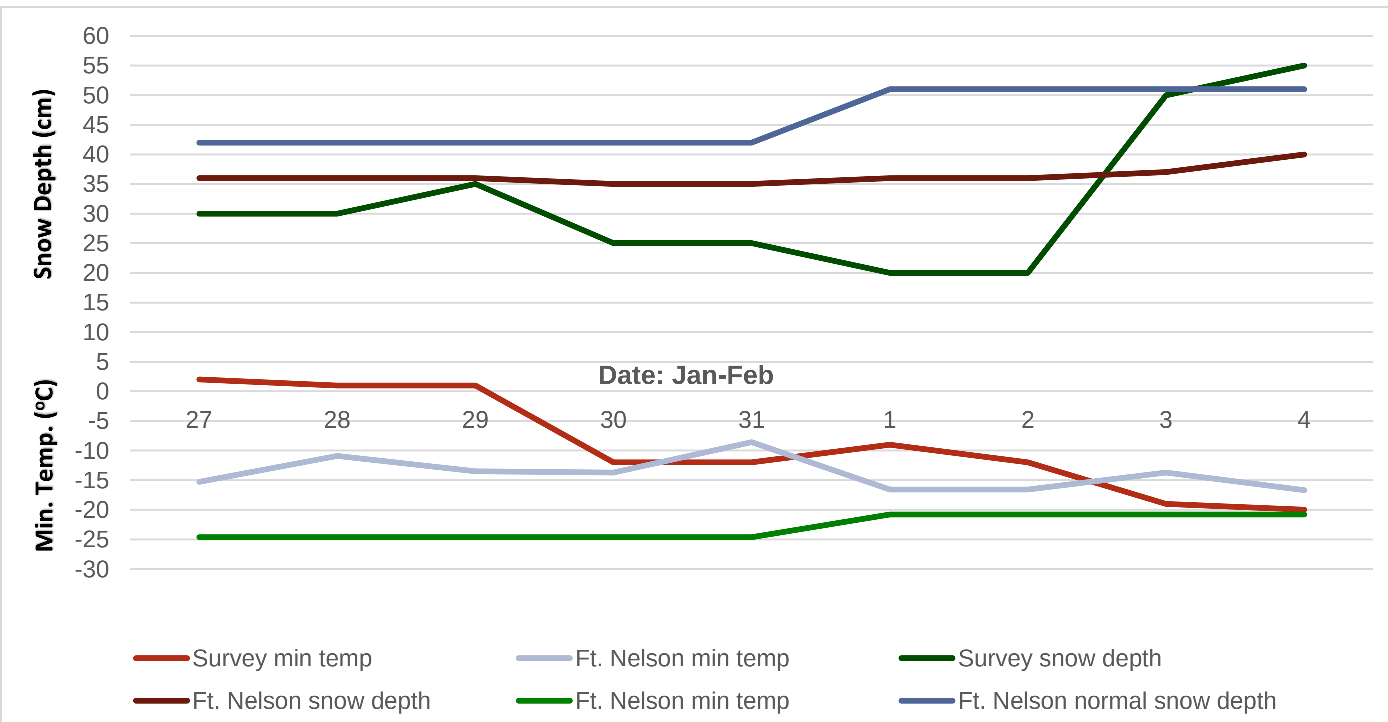


FIGURE 5. DAILY MINIMUM TEMPERATURES (°C) AND SNOW ON GROUND (CM) FROM DATA TAKEN BY THE SURVEY (BLACK LINES), AND AT ENVIRONMENT CANADA'S FORT NELSON WEATHER STATION OVER THE SURVEY PERIOD IN JANUARY AND FEBRUARY 2016.

TABLE 8 – A SUMMARY OF MOOSE (ALCES ALCES) OBSERVATIONS MADE DURING A DISTANCE SAMPLING SURVEY CONDUCTED IN NORTH-EASTERN BRITISH COLUMBIA, JANUARY AND FEBRUARY 2016.

Survey area	Total Moose	# Cows	# Calves	# Bulls	# Unclassified
Clarke	142	73	35	34	0
Chinchaga	76	37	14	25	0
Fortune	96	50	22	24	0
Clarke-Chinchaga	218	110	49	59	0
All combined	**314**	**160**	**71**	**83**	**0**

Exploratory Analyses

The exploratory analysis conducted to determine if truncation of the data could improve the model fit resulted in slight differences between the pooled and unpooled data sets. While this is most likely a function of sample size, it was also noted that there were a great deal more "long distance" sightings in Clarke and much narrower distance observations in Chinchaga (with Fortune being average between the two). This can partly be attributed empirically to the habitat types within Clarke having larger open meadows with moose sighted in them, while Chinchaga yielded more moose in heavy cover type habitat. It was found through the analysis that truncating the data on the pooled data sets did improve the model fit. In the unpooled data it did not significantly improve the model fit and based upon lower sample sizes resulted in less ability to achieve convergence in running the analysis. Based upon this, the pooled data was truncated at 1.25 kms (3% truncation) and the unpooled data was run with no truncation. Exploratory analysis of the four different key functions and series expansions were also run. Based upon these results the half-normal function with a cosine series expansion was selected as the best fitting model for evaluating our data. These settings were then maintained through all model runs.

Verification of DISTANCE Model Assumptions

The three primary assumptions of Distance Sampling discussed in the Population Density section above were tested and found to hold. To ensure all animals on the line were detected we used only qualified, experienced observers, a Jet Ranger helicopter with bubble windows for the best visibility and shut down in poor visibility conditions, which yielded equal sightings port versus starboard, an indication of good spotting. We also found that animals were detected prior to any movement as only 7 of 161 or 4% of moose groups (Table 9) indicated some movement at first sighting. To ensure measurements were made without errors we utilized the moving map software and GPS systems with external antennae, flew on east-west transects for ease of navigation and flew directly to the sighting location to mark the distance first upon all moose group observations. Based upon meeting these primary assumptions, we also looked at testing the assumptions made from our model fits, particularly related to the selected covariates.

Exploratory analyses (Appendix 3) indicated that for the pooled dataset, the distribution of detection distances followed a monotonically decreasing distribution, satisfying a key distributional assumption of the Distance analysis (Buckland et al. 2001, 2007). Detections in Clarke and Fortune showed less frequent detections of moose at shorter distances (e.g., < 200 m) from the transect than detections > 200 m (Fortune 14.6% and Clarke 16.9%, versus Chinchaga 39.5%). This was noted in the 2013 inventory (McNay et al. 2013), with little evidence to suggest potential reasons why detections at the transect were lower than expected. However, in general, observations in the 2016 inventory in Chinchaga were at shorter distances due to more mature forest and upland habitat and very low snow conditions versus the larger meadows and bogs in Clarke and Fortune. We looked at port versus starboard observer bias in moose group observations with no statistical difference between the sides ($X^2_{(2,161)} = 6.27$, $P = 0.509$). However when we looked at port versus starboard in terms of total moose observed there is a difference between sides with the port side observing more moose at the further distances ($X^2_{(2,314)} = 30.18$, $P = 0.00009$). It was noted that all of the moose group observations beyond 1000 m were standing, so we looked at bedded versus standing/movement bias in the moose groups ($X^2_{(4,161)} = 12.28$, $P = 0.932$) with no significant difference in the detections, however when we looked at the total moose numbers we do find a difference biased towards standing ($X^2_{(4,314)} = 66.82$, $P = 0.001$, Table 9). The Garmin Montana 650, with auxiliary antenna, has a typical accuracy of +/- 3 to 5 meters ensuring measurements were collected with the least amount of error technologically implementable for the survey. The exploratory analysis indicates the three assumptions integrated in the DISTANCE model were not violated during the survey and the results are reliable.

TABLE 9 NUMBER OF MOOSE OBSERVATIONS MADE BY DISTANCE CLASS FROM THE TRANSECT AND BEHAVIOR OF MOOSE (TOP) AND SIDE OF HELICOPTER (I.E., OBSERVER). REPORTED AS MOOSE GROUPS, WITH TOTAL MOOSE NUMBERS IN BRACKETS.

	Distance Class (m)								
	0-200	201-400	401-600	601-800	801-1000	1001-1200	1201-1400	1401-2300	Total
Behavior									
Bedded	18 (43)	12 (37)	5 (8)	4 (6)	1 (1)	0	0	0	*40 (95)*
Standing	41 (55)	22 (31)	15 (26)	5 (8)	7 (15)	5 (16)	3 (10)	3 (11)	*101(172)*
Moving	3 (5)	2 (3)	1 (4)	1 (2)	0	0	0	0	*7 (14)*
Bedded/Standing& Moving	6 (15)	3 (6)	3 (7)	1 (5)	0	0	0	0	*13 (33)*
Total	*68 (118)*	*39 (77)*	*24 (45)*	*11 (21)*	*8 (16)*	*5 (16)*	*3 (10)*	*3 (11)*	*161 (314)*
Side of Helicopter									
Port	30 (52)	20 (39)	11 (22)	8 (17)	6 (13)	3 (13)	1 (1)	2 (8)	*81 (165)*
Starboard	38 (66)	19 (38)	13 (23)	3 (4)	2 (3)	2 (3)	2 (9)	1 (3)	*80 (149)*
Total	*68 (118)*	*39 (77)*	*24 (45)*	*11 (21)*	*8 (16)*	*5 (16)*	*3 (10)*	*3 (11)*	*161 (314)*

Additional exploratory analysis was conducted to determine if variable survey speed was correlated to specific cover classes (e.g. reduced survey speed in areas with low snow cover) or to increased sampling effort indicated by increased moose observations (Appendix 3). The median flight speed varied between survey areas: 86.7 km/hr in Clarke-Chinchaga, 95.6 km/hr in Clarke, 79.2 km/hr in Chinchaga, and 92.1 km/hr in Fortune (Figure 6); however, there was not a significant difference in flight speed between any of the survey areas. The mean airspeed in Clarke and Fortune decreased for each increase in vegetation cover class (

Table 10); however, the mean airspeed in Clarke-Chinchaga and Fortune increased with each corresponding increase in vegetation cover. The mean airspeed in Clarke-Chinchaga declined by 13% when the snow cover increased from 26-75% to 76-99%; however, the mean airspeed increased by 4.5% in Clarke and 5.2% in Chinchaga for the same increase in snow cover (Table 11). Approximately 2-5% of moose observations occurred at speeds below 60 km/hr, 20-44% occurred at speeds from 60-85 km/hr, 23-66% at speeds of 85-110 km/hr, and 0-13% of observations occurred at speeds greater than 110km/hr (Table 12).

In order to confirm the variable airspeed did not influence sampling efforts in areas with low snow cover or higher vegetation cover, moose observations were plotted to assess these potential correlations (graphs are presented in Appendix 3):

1. Airspeed : Vegetation Cover
2. Airspeed : Snow Cover
3. Airspeed : Number of moose/group

Although airspeed varied between study areas, there is a very weak correlation between airspeed and moose observations, detailed graphs depicting moose observations, group size, vegetation cover, and snow cover in relation to airspeed are provided in Appendix 3. The graphs do not have large clusters of moose observations at slow airspeeds for any of the potential correlations; the moose observations are distributed across a range of airspeeds which indicates correlations are unlikely to be present. Further confirmation that the sampling assumptions were not violated was indicated by the DISTANCE model; the model refused to run if the selected covariates violated model parameters.

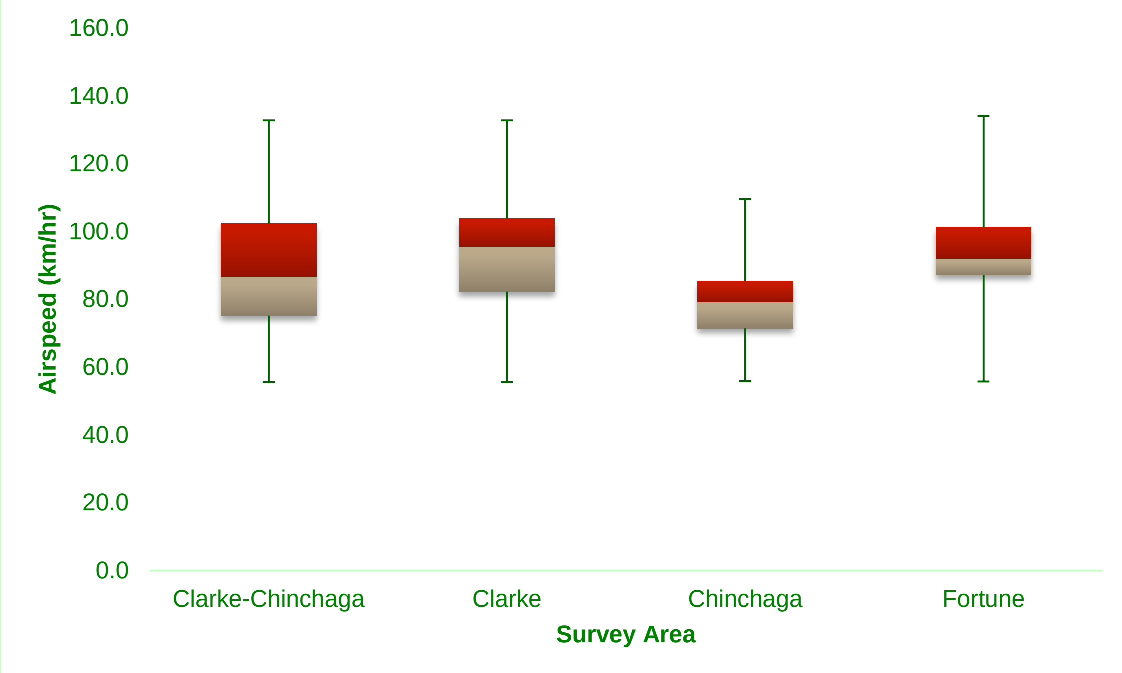


FIGURE 6. THE MEDIAN, MINIMUM, AND MAXIMUM AIRSPEED RECORDED WHILE CONDUCTING MOOSE SAMPLING IN THE SURVEY AREAS.

TABLE 10 SURVEY AIRSPEED IN RELATION TO CHANGING VEGETATION COVER.

	Vegetation Cover								
	0-20%			21-40%			41-60%		
Survey Area	Min (kph)	Max (kph)	Mean (kph)	Min (kph)	Max (kph)	Mean (kph)	Min (kph)	Max (kph)	Mean (kph)
Clarke – Chinchaga	57.4	132.8	96.32	59.5	120.3	77.40	55.6	103.1	80.36
Clarke	57.4	132.8	97.93	61.2	120.3	86.81	55.6	103.1	82.08
Chinchaga	69.7	92.6	75.11	59.5	104.4	77.68	55.9	96.3	83.20
Fortune	76.7	134.1	100.41	55.8	124.7	93.32	90.0	107.1	86.95

TABLE 11 SURVEY AIRSPEED IN RELATION TO CHANGING SNOW COVER.

	Snow Cover					
	26-75%			75-99%		
Survey Area	Min (kph)	Max (kph)	Mean (kph)	Min (kph)	Max (kph)	Mean (kph)
Clarke – Chinchaga	55.9	104.4	97.18	55.6	132.8	84.55
Clarke	83.5	87.9	89.43	55.6	132.8	93.43
Chinchaga	55.9	104.4	77.06	59.5	90.9	81.67
Fortune	-	-	-	55.8	134.1	92.28

TABLE 12 NUMBER OF MOOSE GROUPS OBSERVED IN RELATION TO AIRSPEED.

Survey Area	Airspeed (km/hr)			
	0-60	60-85	85-110	>110
Clarke- Chinchaga	4	51	52	8
Clarke	2	23	43	8
Chinchaga	2	28	9	0
Fortune	1	9	30	5

In the Distance analysis we ran cluster size as a covariate and found little supporting evidence that large cluster sizes increased detection at greater distances (i.e. a size-bias effect on detectability) either for all surveys pooled (Appendix 3) or for individual survey areas (Appendix 3), with most models either not running or running improperly. The exception was in Clarke where we had some very long distance sightings, however this model did not produce a significantly better fit than the others, so was rejected.

Models of Detection Probability and Moose Density Estimates

The candidate models (pooled and unpooled survey areas) are shown in Table 13. Estimated probabilities of detection ranged from 0.16-0.49 with an overall estimate of detection probability = 0.34 for all areas pooled. Visibility and cluster size were evaluated as candidate covariates, but models fit with these covariates were not superior to models fit without covariates (Table 13). Snow Cover, % Vegetation at the moose (crown closure) and a combined snow cover and % vegetation at the moose were also evaluated as candidate covariates. In the pooled data the combined covariates resulted in the best model fit, whereas in the unpooled data the best model varied between snow cover and % vegetation at the moose (Table 13). In many cases the models with no covariates resulted in a high probability of Goodness of Fit utilizing the Kolmogrov-Smirnov test (i.e. lower p value indicates the difference from what is expected would happen rarely due to sampling, but a higher p value indicates a better fit) (Buckland et al. 2001). However, in each case the no covariates model did not have the lowest AIC (Burnham and Anderson 2002) and we evaluated the best fit model as having the ΔAIC closest to zero or under 2 (Burnham and Anderson 2001). Table 13 lists out all of the candidate models that were evaluated with the grey shaded model representing the best fit model, i.e. delta AIC of zero. In most cases (except the all pooled and Clarke) this also represented the highest goodness of fit, i.e. high p-value, although none were lower than acceptable.

For the entire survey area (pooled data between Clarke, Chinchaga, and Fortune), we estimated a density of 0.104 moose/km^2 (0.080 - 0.136 at 95% confidence interval (CI)) which produced a population estimate of 1,453 moose (1,119 - 1,888 at 95% CI) (Table 14). The coefficient of variation for the density estimate was 13.3% indicating the observed data over the areas pooled was well represented by the modeled detection probability (Figure 7). Survey area -specific detection functions are presented in Figure 8. The maximum distance moose groups were spotted was 2,367 meters and 1,231 meters (before and after truncation respectively).

Densities ranged from a low of 0.074 moose/km^2 in the Clarke unit to 0.076 moose/km^2 in the Fortune unit to 0.157 moose/km^2 in the Chinchaga unit (Table 14). Extrapolating from these estimated densities on the basis of each unit's area produces estimates of the number of moose ranging from 395 moose in Clarke (269-580 at 95% CI), to 331 moose in Fortune (210-520 at 95% CI) and 670 moose in Chinchaga (419-1,072 at 95% CI) (Table 14).

TABLE 13 - CANDIDATE DETECTION MODELS FIT TO THE SELECTED DISTANCE DATA FOR EACH SURVEY AREA AND FOR ALL AREAS POOLED. GREY HIGHLIGHTED REPRESENTS THE BEST FIT MODEL FOR EACH AREA.

Survey Area	Covariate	*RWE*[1]	*K*[2]	AIC	ΔAIC	P_d[3]	GOF[4]
Clarke	none	Yes	2	42.93	3.69	0.31	*p = 0.380*
	Cluster Size	No	2	32.26	0.02	0.32	*p = 0.362*
	Visibility	Yes	6	42.75	3.51	0.31	*p = 0.272*
	Snow Cover	Yes	5	39.24	0.00	0.31	*p = 0.321*
	% Veg @ Moose	Yes	3	45.23	5.99	0.34	*p = 0.134*
	% Veg @ Moose & Snow Cover	Yes	7	42.61	3.37	0.31	*p = 0.268*
Chinchaga	none	Yes	1	-60.46	2.67	0.21	*p = 0.042*
	Cluster Size	No	2	-58.46	4.67	0.21	*p = 0.044*
	Visibility	Yes	3	-58.38	4.75	0.20	*p = 0.054*
	Snow Cover	No	4	-59.66	3.47	0.19	*p = 0.293*
	% Veg @ Moose	Yes	3	-63.13	0.00	0.18	*p = 0.543*
	% Veg @ Moose & Snow Cover	No	6	-63.09	0.04	0.16	*p = 0.543*
Fortune	none	Yes	1	-8.15	0.94	0.49	*p = 0.618*
	Cluster Size	No	--	--	--	--	--
	Visibility	Yes	4	-7.66	1.44	0.45	*p = 0.553*
	Snow Cover	Yes	2	-9.10	0.00	0.47	*p = 0.585*
	% Veg @ Moose	Yes	3	-5.23	3.87	0.48	*p = 0.462*
	% Veg @ Moose & Snow Cover	Yes	4	-3.40	5.69	0.48	*p = 0.395*
Overall (Clarke-Chinchaga)	none	Yes	2	-29.97	27.49	0.34	*p = 0.228*
	Cluster Size	No	2	-16.57	40.90	0.45	*p = 0.001*
	Visibility	Yes	6	-18.67	38.79	0.43	*p = 0.009*
	Snow Cover	Yes	9	-45.14	12.33	0.34	*p = 0.157*
	% Veg @ Moose	Yes	3	-53.34	4.13	0.34	*p = 0.524*
	% Veg @ Moose & Snow Cover	Yes	11	-57.46	0.00	0.29	*p = 0.660*
Overall (areas pooled)	none	Yes	2	-37.94	23.10	0.36	*p = 0.887*
	Cluster Size	No	2	-28.18	32.86	0.45	*p = 0.040*
	Visibility	No	6	-23.30	37.74	0.44	*p = 0.040*
	Snow Cover	Yes	10	-55.23	5.81	0.36	*p = 0.608*
	% Veg @ Moose	Yes	3	-50.33	10.71	0.40	*p = 0.286*
	% Veg @ Moose & Snow Cover	Yes	12	-61.04	0.00	0.34	*p = 0.434*

[1] *RWE = Ran Without Errors - Yes/No*
[2] *Number of parameters*
[3] *Probability of detection*
[4]*Goodness of fit test results using Kolmogorov-Smirnov tests of the fit of the fitted detection function to empirical data.*

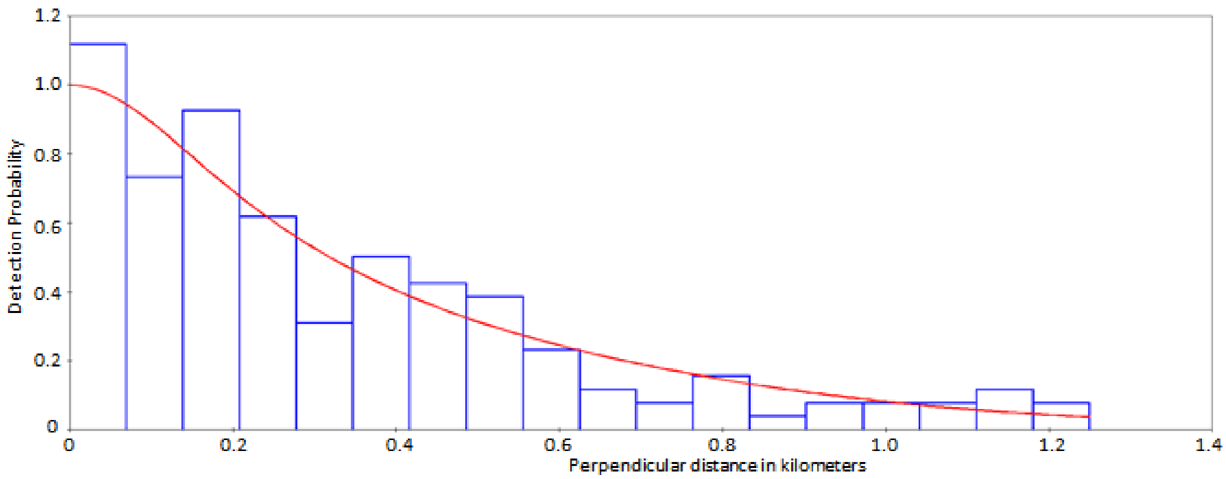


Figure 7. Detection probability plot for moose observations from all survey units pooled from the 2016 NEBC moose survey.

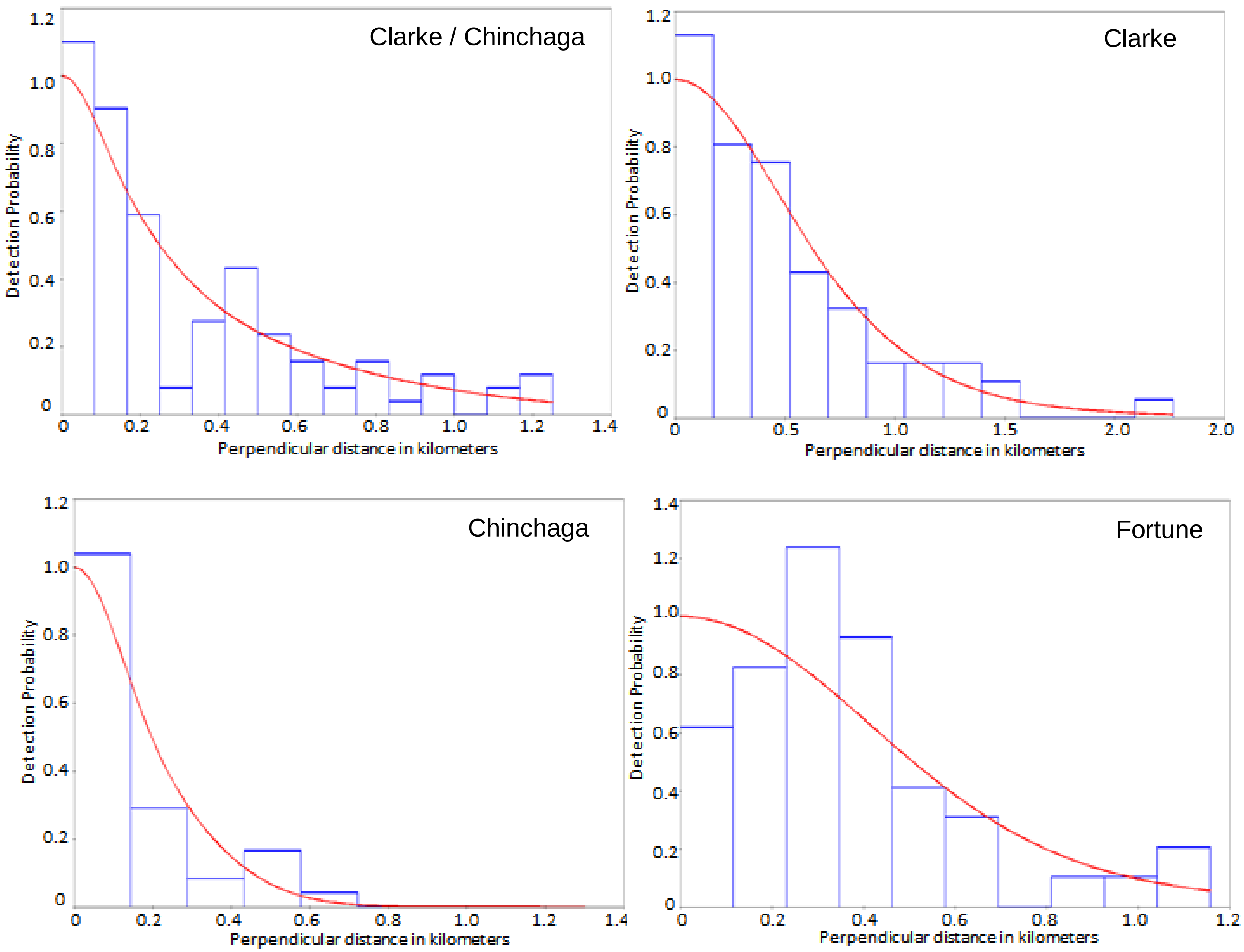


Figure 8. Detection probability plots for moose observations for each of the Clarke/Chinchaga pooled data and each of the 3 areas surveyed during the 2016 NEBC moose survey.

TABLE 14. ESTIMATED DENSITY AND POPULATION SIZE ESTIMATES OF MOOSE FROM EACH UNIT AND TOTAL STUDY AREA OF THE JANUARY 2016 MOOSE SURVEY.

Survey area	Number observed	Population		Density (#/km^2)		% Coefficient of Variation
		Estimate	95% CI	Estimate	95% CI	
Clarke	142	395	269 - 580	0.074	0.051 - 0.109	**19.0**
Chinchaga	76	670	419 - 1072	0.157	0.098 - 0.251	**23.8**
Fortune	96	331	210 - 520	0.076	0.049 - 0.120	**22.4**
Clarke/Chinchaga	218	1,198	860 – 1,669	0.125	0.090 – 0.174	**16.8**
Clarke/Chinchaga/Fortune	314	1,453	1,119 – 1,888	0.104	0.080 - 0.136	**13.3**

The percent CV for all areas pooled was 13.3%. Estimated CVs at the level of the individual survey unit ranged widely from a maximum of 23.8% in the Chinchaga survey area to a minimum of 19.0% in the Clarke survey area.

Moose Population Structure and Demographics

The number of calves:100 cows ranged from 38 in the Chinchaga unit to as many as 48 calves:100 cows in the Clarke unit (Table 15). For all the units combined there were 45 calves:100 cows. The number of bulls:100 cows ranged from 47 in the Clarke unit to 68 in the Chinchaga unit; with an average of 54 bulls:100 cows across the entire study area (Table 15).

TABLE 15. CALVES:100 COW MOOSE, PERCENT CALVES IN POPULATION, AND BULLS:100 COW MOOSE FROM THE 2016 NEBC MOOSE SURVEY

Survey area	Density	Calves:100 cows	% calves	Bulls:100 cows	Number of cows	Cow λ
Clarke	0.074	48	25	47	73	1.12
Chinchaga	0.157	38	18	68	35	1.05
Fortune	0.076	44	23	48	50	1.09
Clarke-Chinchaga	0.125	45	22	54	110	1.10
All combined	**0.104**	**45**	**22**	**54**	**160**	**1.10**

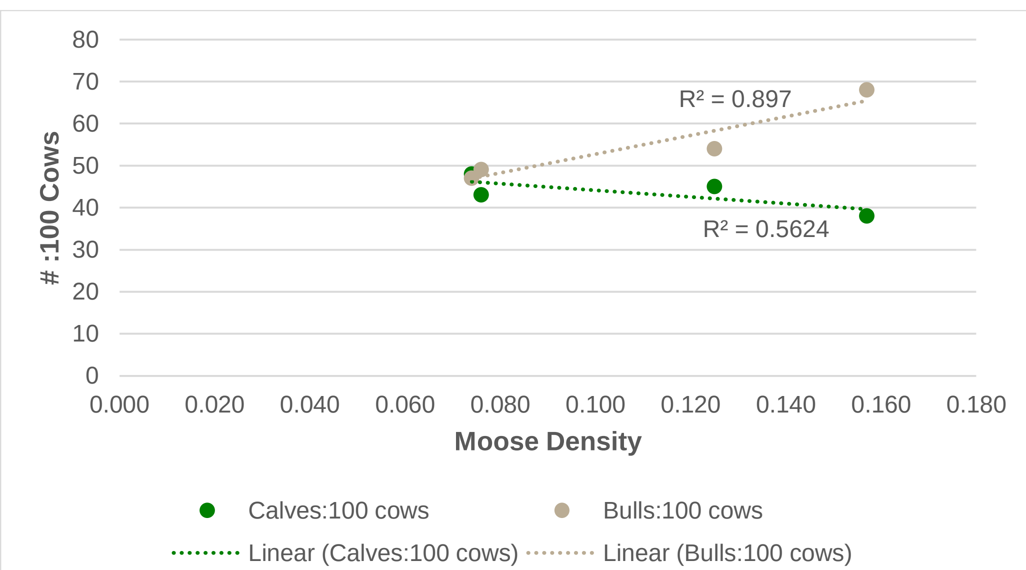


FIGURE 9 - RELATIONSHIP BETWEEN MOOSE DENSITY AND CALF:COW RATIOS AND BULL:COW RATIOS IN THREE UNITS SURVEYED DURING THE 2016 AERIAL MOOSE INVENTORY OF NE BC.

There was a negative relationship between calves:100 cows and moose density and a positive relationship between bulls:100 cows and moose density (Figure 9). Increased predation in more densely populated moose areas would be a possible explanation for this observation, but was not specifically examined in this study. The calculation of population status represented by relative growth rate (λ_{Cow}) indicated that all areas had positive growth (Table 15). In the 2013 Inventory we looked at the number of calves:100 cows as related to anthropogenic disturbance, which was seen to be only weakly related (R^2 = 0.1297) (McNay et al. 2013). However, since the % area impacted by anthropogenic disturbance data came from 2009 (Thiessen 2009), it was not considered relevant for comparison purposes to this 2016 inventory as it does not take into account the disturbance created over the last 7 years, particularly within the Fortune Core.

Post Stratification of Survey

As discussed in the Analysis section, we post-survey stratified the data by grouping the habitat types identified at the moose into five habitat groups and we assigned a stratification of high, medium, low or nil, based upon moose numbers observed in each habitat within the group (Table 6). The Mountain habitat group was not represented by any of the observations so resulted in a Nil rating. This stratification layer was then entered in as an 'Observation' field into DISTANCE and post-stratified using the moose stratification as an observation. The results were density and population estimates for each strata, high, medium and low. As expected the high and medium strata are well represented, but the low strata is under-represented which will result in bias on the low strata density estimate (Buckland et al. 2004).

TABLE 16. ESTIMATED DENSITY AND POPULATION SIZE ESTIMATES OF MOOSE IN THE POST-STRATIFIED DATA. NOTE THESE DENSITIES ARE BASED UPON THE ENTIRE SURVEY AREA AS A WHOLE, NOT THE SPECIFIC STRATA AREA.

Survey area	Number observed	Population		Density (#/km^2)		% Coefficient of Variation
		Estimate	95% CI	Estimate	95% CI	
Clarke (Total)	142	395	271 - 574	0.074	0.051 - 0.108	**18.8**
High		312	207 – 469	0.059	0.039 – 0.089	**26.4**
Medium		78	37 – 162	0.015	0.007 – 0.0305	**14.2**
Low		5	1 - 33	0.00097	0.00015-0.006	**11.3**
Chinchaga (Total)	76	713	432 - 1176	0.167	0.101 - 0.275	**25.9**
High		450	272 – 747	0.105	0.064 – 0.175	**25.5**
Medium		263	115 - 603	0.061	0.027 – 0.141	**41.2**
Fortune (Total)	96	331	222 - 493	0.076	0.051 - 0.114	**20.1**
High		266	172 - 410	0.061	0.040 – 0.095	**33.5**
Medium		65	33 - 127	0.015	0.0076 – 0.029	**17.9**
Clarke/Chinchaga (Total)	218	1,205	860 – 1,688	0.126	0.090 – 0.176	**17.2**
High		879	615 - 1258	0.092	0.064 – 0.131	**18.2**
Medium		315	183 - 543	0.033	0.019 – 0.057	**27.4**
Low		11	2 - 61	0.0011	0.0002 – 0.006	**24.8**
Clarke/Chinchaga/Fortune	314	1,453	1,123 – 1,881	0.104	0.081 - 0.135	**13.1**
High		1092	831 - 1436	0.079	0.060 – 0.103	**13.9**
Medium		352	228 - 542	0.025	0.016 – 0.039	**21.9**
Low		9	2 - 50	0.00067	0.0001-0.0036	**100.9**

Overall the total density and population estimate for each area does not change significantly, however in most cases the CV reduces slightly. We also note the lack of an estimate of low strata in Chinchaga and Fortune, as no moose were counted in these habitats in those two areas.

Applying the Stratified Data to the Habitat

Based upon the densities calculated for the strata we then attempted to apply these more specific densities to the actual landscape. The data in Table 16 provides us a density per strata, but is based upon the entire study area. In order to get a density per habitat, we needed to apply these to our habitat group layers created by combining the habitat types to the VRI data, so we have an actual area for each habitat group. We did this by applying the strata-specific density estimates to the Habitat Groups in GIS and then applying area weighted estimates across the study areas. From the polygons created for each of the habitat groups (that also could have the stratification of high, medium, low and nil applied to them). Based upon the areas of the polygons we are then able to estimate a population size based upon habitat and area, rather than just area. It was noted in applying the VRI data to the habitat groups that "wetland" and "treed wetland" were not easy to distinguish, even though there is a distinct difference in moose utilization. Based upon this, we decided to not use the pooled low, medium and high strata (Table 6), but rather to leave the data as habitat groups and calculate a density per habitat group using the following ratio:

$$\frac{(D_A * A_T)}{A_S} = D_{HG}$$

Where: D_A = density per overall area
D_{HG} = density of the Habitat Group
A_T = total area
A_S = area of the strata

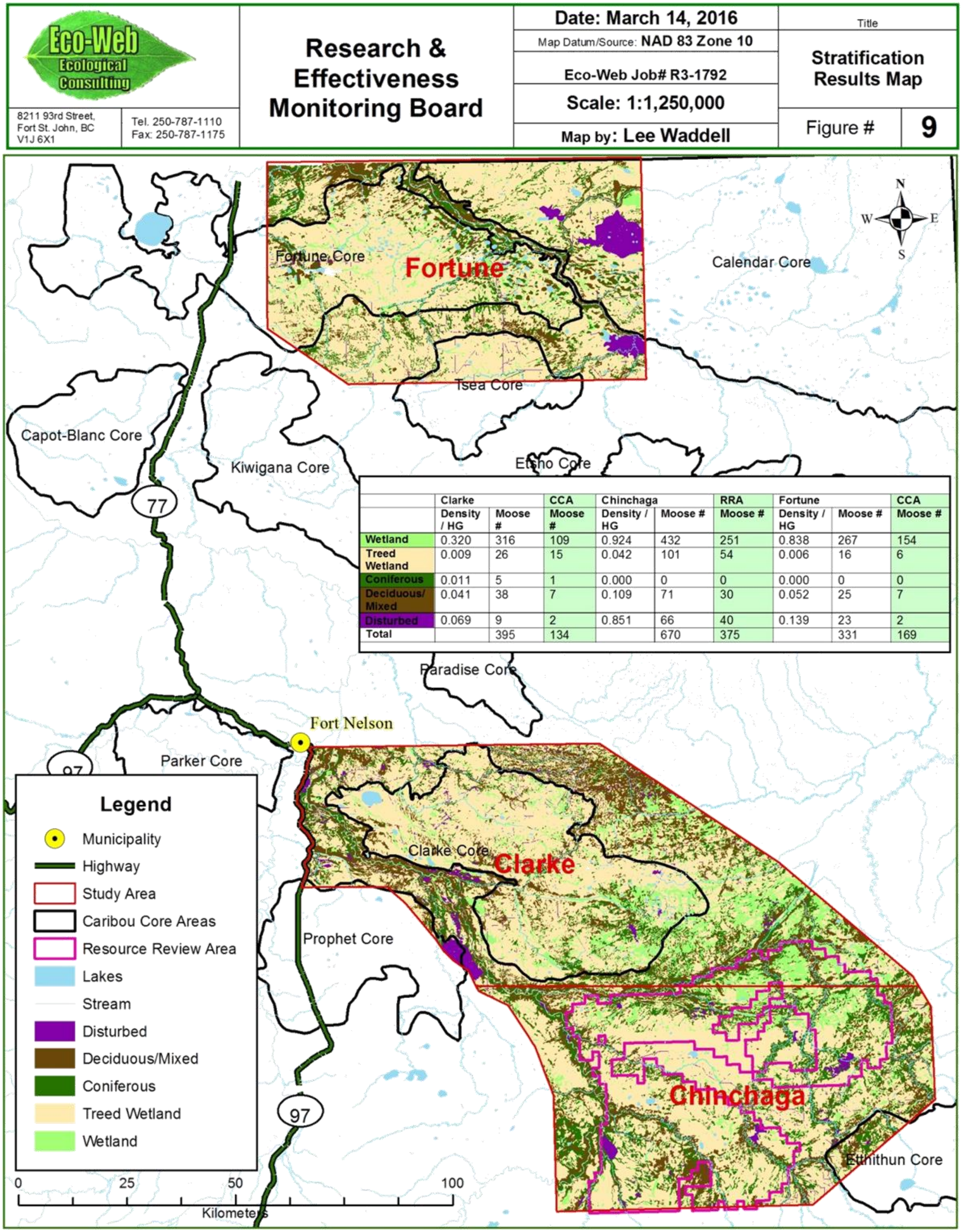
With these densities and by clipping out the CCA's and RRA's as areas of interest, we were also able to calculate the estimated number of moose per CCA or RRA and a density within these areas.

Table 17 provides a summary of these estimates and the full calculations including the pooled data sets can be found in Appendix 5. Perhaps the most interesting aspect of this is in converting the numbers back into a density estimate so that we can compare the overall study areas to the CCA's and RRA. When we do this we see that in Clarke the density was 0.074 moose/km^2, but in the Clarke CCA the density was 0.060 moose/km^2. The Chinchaga study area on the other hand had a density of 0.157 moose/km^2, while the RRA was 0.169 moose/km^2. The Fortune study area has a density of 0.076 moose/km^2, while the Fortune CCA (covered by this study) had a density of 0.106 moose/km^2. In Clarke we had lower moose densities in the CCA than the overall area, while in Chinchaga and Fortune we had higher densities in the RRA and CCA respectively.

TABLE 17 – CALCULATED DENSITY IN EACH HABITAT GROUP PER STUDY AREA AND CALCULATED MOOSE POPULATION ESTIMATES FOR THE AREA AND THE SMALLER CCA'S AND RRA.

	Clarke		CCA	Chinchaga		RRA	Fortune		CCA
	Density / HG	Moose #	Moose #	Density / HG	Moose #	Moose #	Density / HG	Moose #	Moose #
Wetland	0.320	316	109	0.924	432	251	0.838	267	154
Treed Wetland	0.009	26	15	0.042	101	54	0.006	16	6
Coniferous	0.011	5	1	0.000	0	0	0.000	0	0
Deciduous/ Mixed	0.041	38	7	0.109	71	30	0.052	25	7
Disturbed	0.069	9	2	0.851	66	40	0.139	23	2
Total		395	134		670	375		331	169

Figure 10 below illustrates the polygons across the area.



	Clarke		CCA	Chinchaga		RRA	Fortune		CCA
	Density / HG	Moose #	Moose #	Density / HG	Moose #	Moose #	Density / HG	Moose #	Moose #
Wetland	0.320	316	109	0.924	432	251	0.838	267	154
Treed Wetland	0.009	26	15	0.042	101	54	0.006	16	6
Coniferous	0.011	5	1	0.000	0	0	0.000	0	0
Deciduous/ Mixed	0.041	38	7	0.109	71	30	0.052	25	7
Disturbed	0.069	9	2	0.851	66	40	0.139	23	2
Total		395	134		670	375		331	169

FIGURE 10 – STRATIFICATION RESULTS WITHIN STUDY AREAS AND CCAS/RRAS

Incidental Observations

During the survey, incidental observations of species other than moose were recorded. Due to the linkage in this study with the BCIP, boreal caribou and large predators were scanned for and noted. As expected, boreal caribou densities were too low to analyze using Distance sampling; however, we did calculate some demographic parameters from the observations. All caribou sightings from Clarke, Chinchaga, and Fortune were pooled totaling 40 individuals, of which 5 were unclassified. Of the 35 that were identified for sex, there was a ratio of 47 calves per 100 cows and 80 bulls per 100 cows. The calves per 100 cows is similar to the 2013 survey which had 47.7 calves: 100 cows (McNay et al.) and triple the ratio observed by Thiessen in 2010. The bulls per 100 cows is nearly triple the 2013 and 2010 surveys. A consistently higher calf ratio was observed in 2016 across all study areas (Table 18); however, due to the small number of caribou observed during the survey, this number may not accurately represent the caribou populations.

Anecdotally the caribou populations appear to be in a steady decline across the survey areas; 46 caribou were observed in Clarke and 28 were observed in Chinchaga during the 2013 survey; however, 28 caribou and 5 caribou were observed during the 2016 survey in these respective areas. A similar decline may be occurring in Fortune between the 2010 survey which documented 21 caribou and the current survey which observed 7 caribou (Table 19).

Three separate wolf groups were observed, one contained a single wolf, one contained 12 wolves, and the third 2 wolves. A recent caribou and wolf study indicated wolf populations in areas with low moose densities may be higher than the estimates made using moose inventories and biomass conversions (Serrouya et al. 2015). While this was not investigated in this survey specifically, there was visual evidence of wolf packs touring between beaver dams and lodges frequently in the main drainages in the area. One elk was observed in Chinchaga, one fisher and one lynx were observed in Fortune. One dead moose was observed during the survey, most of the carcass was consumed and wolf predation is suspected. Sharp-tailed grouse were evident in the majority of the survey units (Table 18).

TABLE 18. INCIDENTAL SPECIES SIGHTED DURING THE 2016 NEBC MOOSE POPULATION SURVEY.

Survey Area	Boreal caribou				Wolf	Lynx	Fisher	Sharp-tailed Grouse
	Total	Calves:100 cows	Bulls:100 cows	% Calves				
Clarke	28	38	69	18	15	0	0	41
Chinchaga	5[1]	-	-	-	0	0	0	33
Fortune[2]	7	100	150	29	0	1	1	100
Clarke -Chinchaga	33	-	-	-	15	0	0	74
Total	**40**	**47**	**80**	**18**	**15**	**1**	**1**	**174**

[1] Unclassified
[2] Fortune had a very small sample – 2 cows, 2 calves, 3 bulls

TABLE 19. CHANGES TO CARIBOU POPULATIONS DOCUMENTED BY 3 SURVEYS (THIESSEN 2010; MCNAY ET AL. 2013, THIS SURVEY).

Survey Area	Year			
	2010	2013	2016	% Change from previous survey
Clarke	Not Assessed	46	28	**-39**
Chinchaga	Not assessed	28	5	**-82**
Clarke - Chinchaga	Not assessed	74	33	**-55**
Fortune	21	Not Assessed	7	**-66**

DISCUSSION

Distance sampling as a methodology for aerial moose inventory is still being developed and improved. Advanced distance sampling methodologies can be used to improve not only the accuracy of the estimates, but the efficiency of collection and usefulness in application as a management tool (Buckland et al. 2004). During this survey two field methodology changes were implemented to enhance the data collected.

1. Improved habitat and crown closure data at each moose group to better determine sightability.
2. Spatially squaring off the area to maximize transect length and increase habitat type coverage.

The improved habitat and crown closure data enables us to analyze these covariates more effectively, given that the data is collected properly. Squaring off the area comes at the cost of 'contaminating' the CCA with better moose habitat around the edges which is only partly offset by habitat specific density estimates.

To better determine sightability we improved the habitat data collected during the survey by collecting habitat type and % vegetation (i.e. crown closure) on the transect, between the transect and the moose group, and at the moose group. Percent vegetation was also collected in a more comprehensive 5 class range (Quayle et al. 2001; RIC 2002) at 0-20, 21-40, 41-60, 61-80 and >81% vegetation cover (Table 4). These covariates were investigated to help improve the sightability estimate for moose observed in different habitat classes. It was determined that the % vegetation from the five classes at the moose did improve model fit, especially when combined with snow cover (which was lower than normal during this survey season). In the pooled data both % vegetation at the moose and snow cover improved the model fit and the unpooled data was improved by one or the other covariate. The second change to survey design, having longer transects, was critical to obtaining samples sizes adequate to run the analyses and support the habitat covariates. The sample size per area was sufficient to allow for these covariates to be run, which can be attributed to the second improvement, longer transects.

The 2013 survey report (McNay et al. 2013) recommended a minimum of 800 km of transect to be sampled in Clarke and Chinchaga in order to assure that a suitable number of moose groups were obtained. This survey was designed with 1,150 km of transect in Clarke, 1,130 km in Chinchaga and 1,050 km in Fortune with the survey areas squared off, and a secondary study area around the area of interest being included. The transects were an average of 80 km in length. Additionally, the extent of the survey area was expanded to include habitat peripheral to the RRA and CCAs; this data may provide additional guidance for the biologists implementing the BCIP. These longer transects ensured a minimum number of moose groups per transect were recorded. Both field methodology improvements resulted in more robust data during the analytical phase. It might have been interesting to treat the CCA and secondary areas as different strata and derive population estimates that way; however there was not time or budget to analyze the data both ways, so that may be a consideration for future studies.

During post-hoc analysis we were able to utilize the habitat types collected at the moose to pool the observations into habitat groups and stratify the habitat based on moose observations. This allowed for post-stratification of the data within the analytical software to create density estimates per habitat group. This was extrapolated to VRI data to produce population estimates based on the habitat groups. This produced population estimates equivalent to those calculated for each overall area. More significantly though, the habitat group densities could be applied to the smaller CCA and RRA areas to give us density estimates and population estimates for these areas. We were able to see that while the Clarke CCA has a lower moose density than the surrounding area, both Chinchaga and Fortune were higher than the surrounding area (Table 17). Post stratification provides spatial moose density data that may be more useful to the management of caribou habitat.

Previous surveys had found that it difficult to distinguish between candidate detection models fit with no covariates, or with visibility and cluster size as covariates (McNay et al. 2013). It had been recommended to try and create a covariate, sightability correction factor (SCF) more similar to that used in Stratified Random Block surveys (Quayle et al. 2001) instead of the simplified % vegetation cover. While this was examined in the study design, it was decided that increasing the % vegetation cover to the 5 class model, as well as collecting the data at the moose, transect and in-between would be an easier fit to the problem. We did see a more robust estimate of density and lower CVs from this approach, as the covariates were able to be applied to this end.

The Probability of Detection (Pd) did vary somewhat over the survey areas (Clarke 0.31, Chinchaga 0.18, and Fortune 0.47). We tested to see if observer bias or animal behavior, could account for this, but the data did not support these hypotheses. Since we had broken out the moose group observations by habitat type into the habitat groups, we were also able to analyze whether the habitat group influenced the probability of detection between the areas. Detection rates of moose groups did not differ between habitat groups (X^2 = 8.65, P = 0.372). When we looked at just the percent of moose groups observed in the high strata we found that the larger percent of observations in the high strata is still not significant (X^2 = 0.057, P = 0.972). So the lower probability of detection in Chinchaga may be related to less moose groups observed in the more open Wetland habitat group, although this could not be supported statistically. From the habitat mapping we also know that Clarke is 19 % wetland, Chinchaga 11 %, and Fortune 7 %, so relatively small portions of each study area.

TABLE 20 – MOOSE GROUP OBSERVATIONS BY STUDY AREA AND HABITAT GROUP AND RESULTING % OF STRATA

		Habitat Group					% Occurrence by Strata		
	Pd	Wetland	Treed Wetland	Coniferous	Deciduous/ Mixed	Disturbed	% high	% Med	% Low
Clarke	0.31	60	5	1	8	2	79%	20%	1%
Chinchaga	0.18	25	5	0	4	5	64%	36%	0%
Fortune	0.47	37	2	0	4	3	80%	20%	0%

Estimate of Moose Population Density

The aerial survey of the 13,909.7 km^2 study area produced an estimate of moose abundance of 1,453 moose with a 95% confidence range of 1,119 – 1,888. Clarke yielded 395 moose (95% CI 269 - 580), Chinchaga 670 moose (95% CI 419 – 1,072) and Fortune 331 moose (95% CI 210 – 520). A total of 314 moose were observed (0.094/km of transect) for an overall density estimate of 0.104 moose/km^2 (95% CI 0.080 – 0.136, CV 13.3%) for all areas combined. The estimate of moose population density varied across the areas surveyed, with the lowest estimated density in Clarke (0.074 moose/km^2), Fortune being slightly higher (0.076 moose/km^2) and the highest in Chinchaga (0.151 moose/km^2). The Clarke and Chinchaga study areas were surveyed together and yielded a combined density of 0.125 moose/km^2 (95% CI 0.090 – 0.174) and a population estimate of 1,198 moose (95% CI 860 – 1,669).

Moose habitat capability mapping showed the majority of the study areas to be of quite low habitat value for moose (Figure 2). Our moose Habitat Group maps showed that while Clarke had a lower percentage of wetland habitat (the high stratification), both Chinchaga and Fortune had more wetlands, resulting in an observed higher density of moose in these RRA and CCA (Appendix 5). Overall there are large tracts of low capability moose habitat associated with the core caribou ranges which is consistent with the behaviour of caribou spacing themselves in the environment away from other ungulates and their predators (Bergerud and Elliot 1998; Latham et al. 2011). The supposition has been that as habitat is altered, more suitable conditions for moose are created. However, the underlying capability for moose in most of these areas is generally low so improvements through conversion to an early seral landscape may only result in small increases in moose habitat. This was seen in that the "Disturbed" habitat group was only selected as a 'medium' stratum and so does not apparently represent the most suitable habitat for moose. However, we recognize that the Disturbed habitat includes a variety of vegetation types that offer varying suitability to moose. Both Chinchaga and Fortune had relatively high densities of moose in the disturbed habitat groups (0.851 and 0.139 moose/ km^2 respectively), although this is based upon low sample sizes.

The overall density and population estimates had relatively small CV's (Table 14). Post-stratification did help to slightly reduce these CV's (Table 16) and give us densities that could be applied to certain habitats. Still, the overall estimate of moose density was quite low which is consistent with the fact that the survey was conducted primarily within areas of high value for caribou and low value for moose. From the 2013 survey (McNay et al. 2013) it was recommended to broaden the extent of the study areas so that the peripheral areas adjacent to the CCAs could also be assessed as these areas may be better quality for moose. This survey accomplished this with the result of improved density estimates and being able to support models with covariates to improve sightability.

A comparison of our density estimates to previous surveys is provided in Table 21. The Clarke area has apparently seen a substantial decrease in overall moose density, while Chinchaga has seen a slight increase and Fortune a large increase. So by looking at a wider area and the adjacent habitat we develop a better picture of how moose are using these areas. Our stratification allowed us to extrapolate densities for the CCA/RRA areas that indicate the above noted effects are actually higher in the caribou areas. This may indicate that in caribou management, Clarke has improved (i.e. lower moose numbers), while Chinchaga and Fortune have gotten worse (i.e. higher moose numbers).

TABLE 21 – CHANGE IN MOOSE DENSITY FROM 2013 TO 2016

Survey area	2013 Density (#/km^2)		2016 Density (#/km^2)		% Change	Stratified Corrected Density
	Estimate	95% CI	Estimate	95% CI		
Clarke	0.145	0.094 – 0.225	0.074	0.051 - 0.109	**-49%**	**0.060**
Chinchaga	0.151	0.09 – 0.246	0.157	0.098 - 0.251	**+4%**	**0.169**
Fortune (East)*	0.043	0.026 – 0.071	0.076	0.049 - 0.120	**+76%**	**0.106**

* Data from Thiessen 2010 as Fortune was not surveyed in 2013

Moose Population Structure and Demographics

The moose age and sex ratios overall yield 45 calves:100 cows and 54 bulls:100 cows in the combined study areas (from a minimum of 38 calves:100 cows in Chinchaga to 45 calves:100 cows in Clarke and a minimum of 47 bulls:100 cows in Clarke to 68 bulls:100 cows in Chinchaga). The pooled data had relatively low CV's while the unpooled data was slightly higher.

The population demographics in 2016 varied from the previous survey (McNay et al. 2013) which estimated the northern CCA's having lower calf ratios and higher bull ratios, while the southern CCA's had higher calf ratios and similar bull ratios to this survey. During this 2016 survey the Fortune area (northern) had 42 calves:100 cows and 46 bulls:100 cows while the southern area (Clarke-Chinchaga) had 34 calves:100 cows and 66 bulls:100 cows. However, comparing the 2013 and 2016 surveys and the results from the Horn River study area (Thiessen 2010) needs to be contextualized by the 2010 study being a more broadly based WMU area survey while the 2013 study targeted caribou CCA's and this study targeted the CCA's plus a surrounding buffer.

The Clarke study area had 0.074 moose/km^2, the highest calves:100 cows ratio of 48 and 47 bulls:100 cows. In 2013 the Clarke CCA surveyed had 0.145 moose/km^2, 63 calves:100 cows and 46 bulls:100 cows (McNay et al 2013). Backmeyer (2004) calculated a density for GMZ subzone G (overlapping the Clarke Study area) of 0.087 moose/km^2 and ratios of 23.7 calves:100 cows and 76.3 bulls:100 cows. To interpret this we must understand that the 2004 survey incorporated the WMU, the 2013 survey just the CCA and the 2016 survey the CCA plus a buffer. Based on this we cannot directly compare them, but we do see that it is likely that the density of moose in the CCA may actually be higher than in the two larger, encompassing areas. In 2013, the λ for Clarke was 1.19 indicating a predicted increase in moose density should occur over time; however, the λ decreased to 1.13 in 2016 which indicates the moose density should increase at a slower pace than 2013. Since we did not have actual cow mortality numbers in our precise study areas for these calculations, these λ values are just estimates and the trends implied be used with caution.

The Chinchaga study area had 0.157 moose/km^2, with 38 calves:100 cows and the highest bulls:100 cows ratio of 68. In 2013 the Chinchaga RRA had a density of 0.157 moose/km^2 and 59 calves:100 cows with a large 117 bulls:100 cows. In 2013 the λ for Chinchaga was 1.175, however this has gone down to 1.05, which while still slightly increasing may be a factor in the lower calf numbers and may indicate increases in predation. The last time MU 7-47 (MU overlapped by Chinchaga) was inventoried the density was 0.044 moose/km^2 and recorded calf ratios of 9.4 calves/100 cows and bull ratios of 63.5 bulls:100 cows (Rowe 2005, 2008). These differences are again a factor of the wider area MU 7-47 incorporates, which includes some lower quality moose habitat. The trend appears to be for declining moose in the Chinchaga area over time and based upon the lower calf: Cow ratio, this trend may be related to predation.

The Fortune study area had 0.076 moose/km^2, with 44 calves:100 cows ratio and the 48 bulls:100 cows. Thiessen (2010) inventoried a similar area in Fortune East and found a density of 0.043 moose/km^2 and 31 calves:100 cows, with 94 bulls:100 cows. The λ was not calculated in 2010, but based upon this survey is slightly increasing at 1.09, which is consistent with the difference between the two inventories.

All three study areas have a cow λ greater than 1.0 which indicates the moose populations are increasing based upon the calf recruitment. This survey and the 2013 survey did not sample across the entire WMUs studied but, targeted the Core Caribou Area and in this survey, a large buffer of surrounding habitat. The CCA's tends to include some much lower quality habitat for moose (Figure 2) and so we see predictably low overall densities. When we look at the pooled data of all three areas the calves:100 cows ratio has slightly decreased from 2013 to 2016 going from 51 to 45 and the bulls:100 cows has reduced from 60 to 54. Based on different study area boundaries direct comparison between surveys is limited and we would tend to look at the cow λ which is still showing an increasing trend to the population. This is of interest because this apparent increase is found within the CCAs and RRAs where we would have expected lower population density relative to the broader region. What is missing from our analysis is a corresponding population estimate for wolves and caribou in the CCA's and RRA's. We can speculate that predation has increased due to the lower calf ratios, but the data does not discount other factors, not the least of which is the difference in study areas between inventories.

Other Learnings

Thiessen (2010) recommended that in subsequent moose inventories a minimum sampling effort is calculated to improve the coefficient of variance (CV), this calculation was conducted at the end of the 2013 study (McNay et al. 2013), and implemented for the 2016 sampling program. The 2013 study (McNay et al.) recommended a minimum sampling effort of 800km in Clarke and in Chinchaga to improve the coefficient of variance (CV) from 24.2%. The 2013 survey flew 669.38 km and the 2016 survey flew 1,152.87 km in Clarke, a 70.25% effort increase from the 2013 survey. The increased sampling effort resulted in a CV of

19.0%, a 12.04% decrease from the prior survey. The 2013 survey flew 677.18 km in Chinchaga and 1,035.10 km in 2016, the sampling effort increased by 54.64%. The CV improved from 24.2% to 23.8%, a change of 1.65%. Thiessen's 2010 survey of Fortune East sampled 880 km and had a CV of 25.6%; the 2016 survey of the area 1,058.91 km and had a CV of 22.4%. Although sampling effort was increased by 20.33%, the CV only improved by 12.5%. The disproportionately small improvement in CV in relation to increased sampling effort suggests the 2016 survey passed the equilibrium where increased effort is proportionate to the increased benefits or the CV is more correlated to the number of moose groups observed. If the latter holds true, moose group sightability exerts greater influence on the CV than increased sampling effort.

The following represents some suggestions related to this inventory and the additional research projects underway (ie. moose collaring and mortality investigations):

- It is recommended that there is a minimum of two week separation between the end of a capture-collaring program and the start of a Distance sampling program. The temporal separation will minimize the effects of capture-related behavioral modifications (DeMars and Boutin 2014).
- The inventory should take place in late December to early January to take advantage of typically colder weather and grouping of moose. If collaring is to take place, it is recommended that it be scheduled for December to ensure adequate time in between.
- Develop an estimate of wolf densities across the study areas to be able to better understand the relationship between moose densities and predation.
- Documenting the number of beaver lodges encountered during the survey program may allow biologists and managers the opportunity to monitor changes to beaver distribution and address a wolf's seasonal prey switch from moose to beavers and wolves are pursuing beavers into caribou habitat.
- Keep the survey areas consistent going forward to allow for comparisons between inventories.
- To reduce time spent in ferrying between transects, consider a zig zag alignment of transects. While this increases the time required post-survey to determine the perpendicular distances it would increase the overall search time and effort, which would need to be weighed against potential overlap of transects (Buckland et al 2004).
- Ensure fuel is evenly available across the study areas to minimize transit time and maximize time flying transects. Place your flight bases at remote camps near the fuel caches and inventory areas.

Adaptive Distance Sampling

Since we have seen that there are limits in how much we can decrease our CV based upon length of transect, it may be worth considering an Adaptive Distance Sampling Survey as described in Buckland et al. (2004). While distance sampling works well for surveying animals that are sparsely distributed in a large area, we can get low detection numbers and a high variance if the animals are in small patches, because we spend a great deal of time surveying areas away from these patches (Buckland et al. 2004; Thompson and Seber 1996). We have seen that moose are not uniformly distributed across the landscape. As noted in Table 20, approximately 80% of the sightings were in the "wetland" habitat group, which also represented the only "high" strata in our stratification. These habitats tend to follow the drainages and thus are not evenly scattered across the landscape, they create "patches" where moose encounters are highest.

In order to create a design-unbiased adaptive line transect survey one could start with a systematic set of transects across the study area. These would be the primary survey units, which would then be divided into shorter secondary units. Upon flying the primary units, when there is a detection, the secondary units on either side would be sampled. This would allow the surveyor to expand their search when "patches" of higher quality moose habitat are encountered (Figure 11). As noted the overall distance of our transects were higher than previous surveys but, this only resulted in modest decreases to CV. By shortening the primary units to allow for flying more secondary units, a more definitive area could be flown with better detection based on where we are finding moose in this landscape.

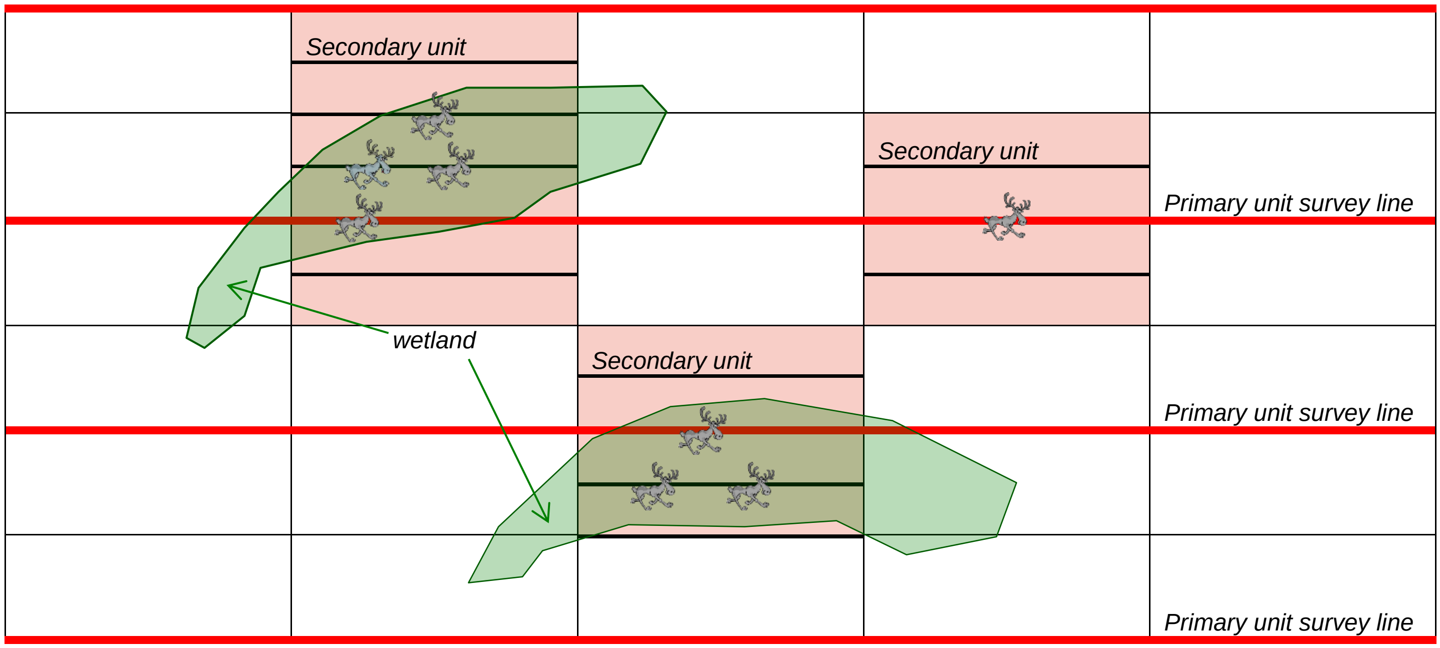


FIGURE 11 - AN ADAPTIVE LINE TRANSECT SURVEY (ADAPTED FROM BUCKLAND ET AL. 2004)

The adaptive survey would also help to provide a more comprehensive search of moose habitat by expanding the search laterally when moose are encountered in a specific habitat. It was noted that often when investigating a single moose observation, additional moose were found beyond the first. The end result would be an increased number of detections which should increase survey accuracy.

Testing Distance Sampling

The standard procedure for estimating moose population density is by stratified random block (SRB) surveys (Gasaway et al. 1986) and is the recommended method for moose (RIC 2002). The RIC (2002) inventory manual describes the sampling methods for SRB surveys in the methods for determining absolute abundance in Section 3.6.2. In order to effectively evaluate how comparable the Distance Sampling estimates are from the SRB survey it would be useful to conduct both procedures in one or more survey areas. If the estimates are comparable, then the most cost effective method could be used going forward. However, if they are not comparable, then the method which demonstrates the most accuracy may need to be selected for further surveys, depending on the objectives of the survey.

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Personal Communications

Moyles, D. 2016. Alberta Environment and Sustainable Resource Development, Peace River, AB

APPENDIX 1: SAMPLE DATA SHEETS

Animal Observation Form

Habitat Observation Form

Animal Observation Form - Ungulate (Aerial) Transect - Distance Sampling

Page ___/___

Project **Survey** **Study Area**

Transects on this form: ____________________ **Trans Comment** ____________________

Obs Date _____/_____/_______

Pilot: __________
Front Left: __________
Rear Left: __________
Rear Right: __________
Other: __________

Transect Name	Length	Start UTM	End UTM	6 km or 3km	Time (Start/Stop)	Cloud Cover	Wind	Temp (^{o}C)	Precipitation	Snow Depth	Snow Cover	Visibility*
					/							
					/							
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* **Very Poor**: Overcast, snowing, dark and grey light conditions, observations restricted to ~100 m from the helicopter; **Poor**: Overcast, no snow to light snow, light grey light conditions, observations restricted to ~150-200 m from the helicopter. Also, bright sunny conditions with sun low in the sky and extensive shadows. **Moderate:** Cloudy, light grey light conditions, observations restricted to ~300-500 m from the helicopter. Also, sunny conditions with shadows. **Good:** Light cloud to bright sun with few shadows, observations not restricted laterally. **Very Good:** Light cloud, good light conditions with no shadows, no visibility restrictions.

Transect	WPT	Observer (FR,FL, RR, RL)	Species	Group Total	Ungulate Classification									Activity (B=bedded, S=Standing, M=Moving)	Comments
					unclass-ified	Cow	Calf	Yearling Male	MM drop	Bulls					
										I	II	III	IV		
														B S M	
														B S M	
														B S M	
														B S M	
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														B S M	

Transect	WPT	Observer (FR,FL, RR, RL)	Species	Group Total	Ungulate Classification									Activity (B=bedded, S=Standing, M=Moving)	Comments
					unclass-ified	Cow	Calf	Yearling Male	MM drop	Bulls					
										I	II	III	IV		
														B S M	
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Habitat Observation Form - Ungulate (Aerial) Transect - Distance Sampling Page ___/___

Project **Survey** **Study Area**

Transects on this form: ____________________ **Trans Comment** ____________________

Obs Date ____/____/______ **Habitat Observer** ____________________

*** Habitat Code (Include class modifier & Successional Stage)**

WA *Water*	**BU** *Burn*	**DE** *Deciduous*
WE *Wetland/Bog*	**CU** *Cut Block*	**CD** *Conifererous/Deciduous Mixed*
ME *Meadow*	**UV** *Unvegetated*	**CS** *Cottonwood/Spruce*
RI *Riparian*	**RD** *Road*	**PS** *Lodgepole Pine/Spruce Mixed*
WS *Willow/Shrub*	**OG** *Oil&Gas Site*	**LP** *Lodgepole*
TA *Talus Slope*	**AR** *Alpine Ridge*	**SP** White *Spruce*
SU *Subalpine*	**AV** *Avalanche Track*	**BS** *Black Spruce*
SB *Spruce Eng./Subalp Fir/Scrub Birch*		**TA** *Tamarack*

**** Slope Code**

1	**0%**	*Flat*
2	**5-20%**	*Minimal Slope*
3	**20-50%**	*Moderate Slope*
4	**>50%**	*Steep*

****** % Snow Cover**

0-25	**poor (bare ground showing)**
26-75	**moderate (scattered bare patches)**
76-99	**good (some low veg showing)**
100	**excellent (complete snowcover)**

***** % Vegetation Cover**

0-20
21-40
41-60
61-80
>81

Transect Name	Length	Start UTM	End UTM

Any vegetation that blocks the view of the moose; based on % of ground not being visible in a 10 m diameter around the moose initially sighted in a group.

Habitat Class Modifiers

c = coarse-textured soil; f = fine-textured soils; l = shallow soils; m = moist soils; g = gently sloping; t = moderate sloped & warm; u = upper elevation gentle slope; n = cool northley aspect; s = steep warm southerly aspect

Successional Stage

0 = non-forested units (alpine, wetlands); 1 = recent disturbance; 2 = young coniferous forests (<60 years); 3 = young mixed forests (<60 years); 4 = mature coniferous forest; 5 = mature mixed forest; 6 = old growth (>140 years)

Transect	WPT	Slope *code***	Aspect	Elevation *meters*	Habitat Type I* *On Transect*	Habitat Type II* *In Between*	Habitat Type III* *At Moose Group*	% Vegetation Cover***			% Snow Cover ****				Comments
								On transect	In Between	At Moose Group	0-25	26-75	76-99	100	

*** Habitat Code (Include class modifier & Successional Stage)**

WA *Water*	**BU** *Burn*	**DE** *Deciduous*
WE *Wetland/Bog*	**CU** *Cut Block*	**CD** *Conifererous/Deciduous Mixed*
ME *Meadow*	**UV** *Unvegetated*	**CS** *Cottonwood/Spruce*
RI *Riparian*	**RD** *Road*	**PS** *Lodgepole Pine/Spruce Mixed*
WS *Willow/Shrub*	**OG** *Oil&Gas Site*	**LP** *Lodgepole*
TA *Talus Slope*	**AR** *Alpine Ridge*	**SP** White *Spruce*
SU *Subalpine*	**AV** *Avalanche Track*	**BS** *Black Spruce*
SB *Spruce Eng./Subalp Fir/Scrub Birch*		**TA** *Tamarack*

**** Slope Code**

1	**0%**	*Flat*
2	**5-20%**	*Minimal Slope*
3	**20-50%**	*Moderate Slope*
4	**>50%**	*Steep*

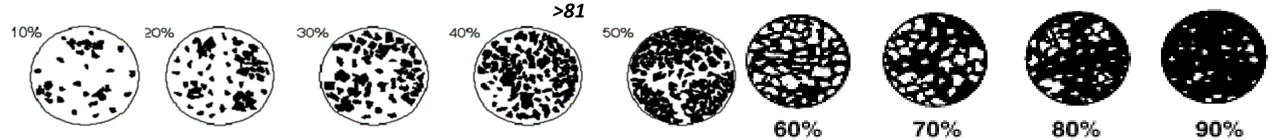
***** % Vegetation Cover**

0-20
21-40
41-60
61-80
>81

Any vegetation that blocks the view of the moose; based on % of ground not being visible in a 10 m diameter around the moose initially sighted in a group.

****** % Snow Cover**

0-25 **poor (bare ground showing)**
26-75 **moderate (scattered bare patches)**
76-99 **good (some low veg showing)**
100 **excellent (complete snowcover)**



Habitat Class Modifiers

c = coarse-textured soil; f = fine-textured soils; l = shallow soils; m = moist soils; g = gently sloping; t = moderate sloped & warm; u = upper elevation gentle slope; n = cool northley aspect; s = steep warm southerly aspect

Successional Stage

0 = non-forested units (alpine, wetlands); 1 = recent disturbance; 2 = young coniferous forests (<60 years); 3 = young mixed forests (<60 years); 4 = mature coniferous forest; 5 = mature mixed forest; 6 = old growth (>140 years)

Transect	WPT	Slope	Aspect	Elevation	Habitat Type I*	Habitat Type II*	Habitat Type III*	% Vegetation Cover***			% Snow Cover ****				Comments
		*code***		*meters*	*On Transect*	*In Between*	*At Moose Group*	**On transect**	**In Between**	**At Moose Group**	**0-25**	**26-75**	**76-99**	**100**	

APPENDIX 2: SURVEY AREA MAPS AND TRANSECTS

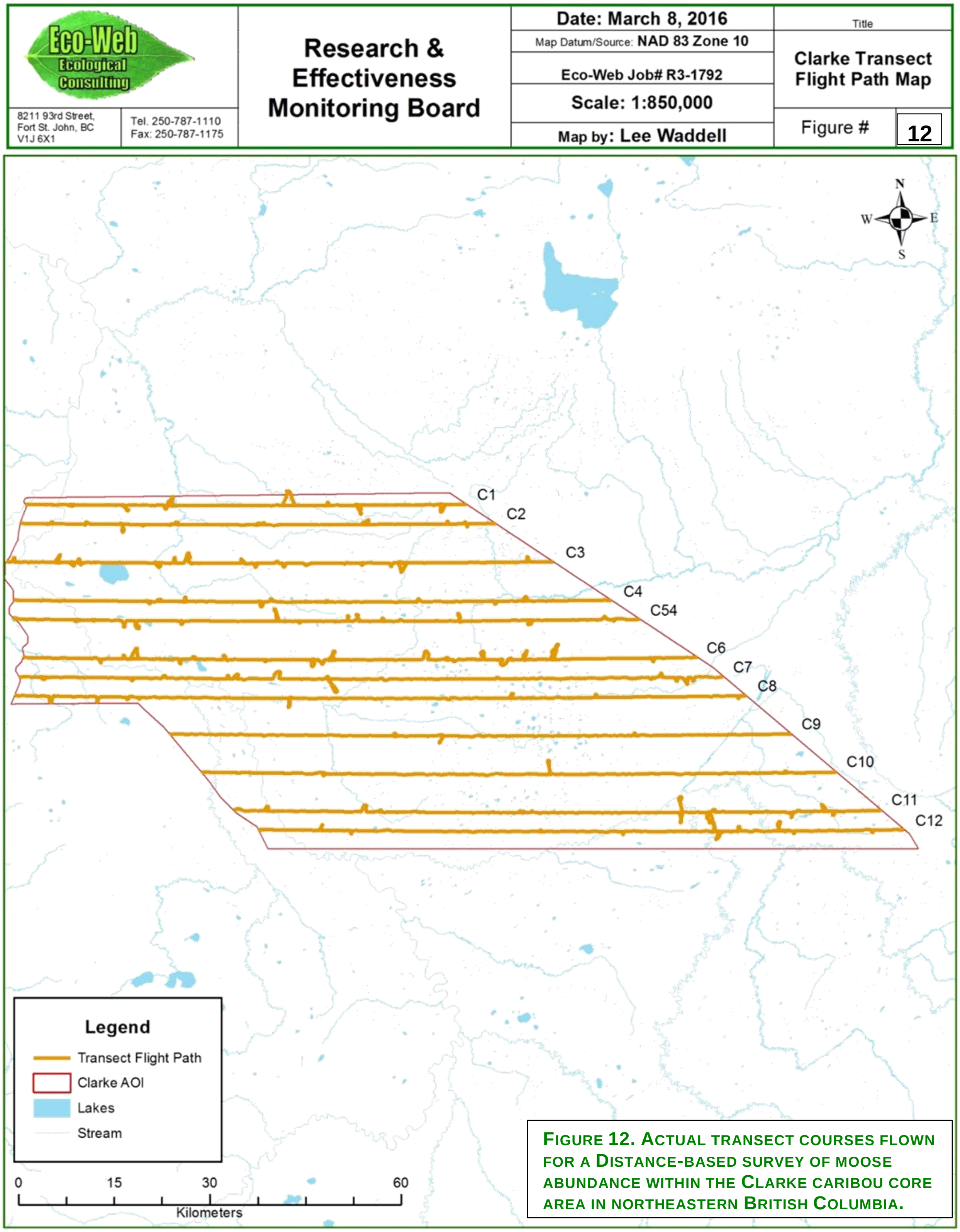


FIGURE 12. ACTUAL TRANSECT COURSES FLOWN FOR A DISTANCE-BASED SURVEY OF MOOSE ABUNDANCE WITHIN THE CLARKE CARIBOU CORE AREA IN NORTHEASTERN BRITISH COLUMBIA.

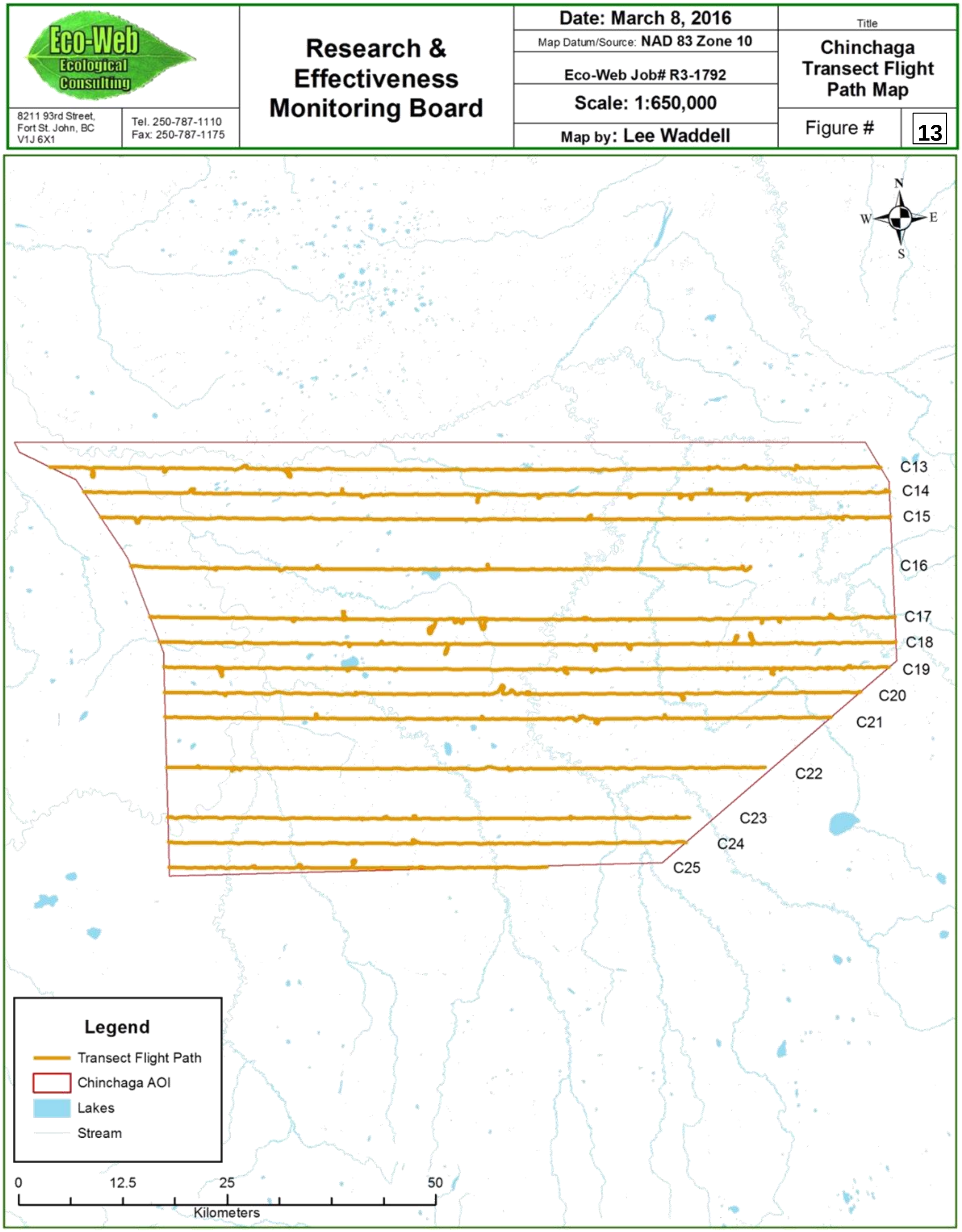


FIGURE 13. ACTUAL TRANSECT COURSES FLOWN FOR A DISTANCE-BASED SURVEY OF MOOSE ABUNDANCE WITHIN THE CHINCHAGA CARIBOU CORE AREA IN NORTHEASTERN BRITISH COLUMBIA.

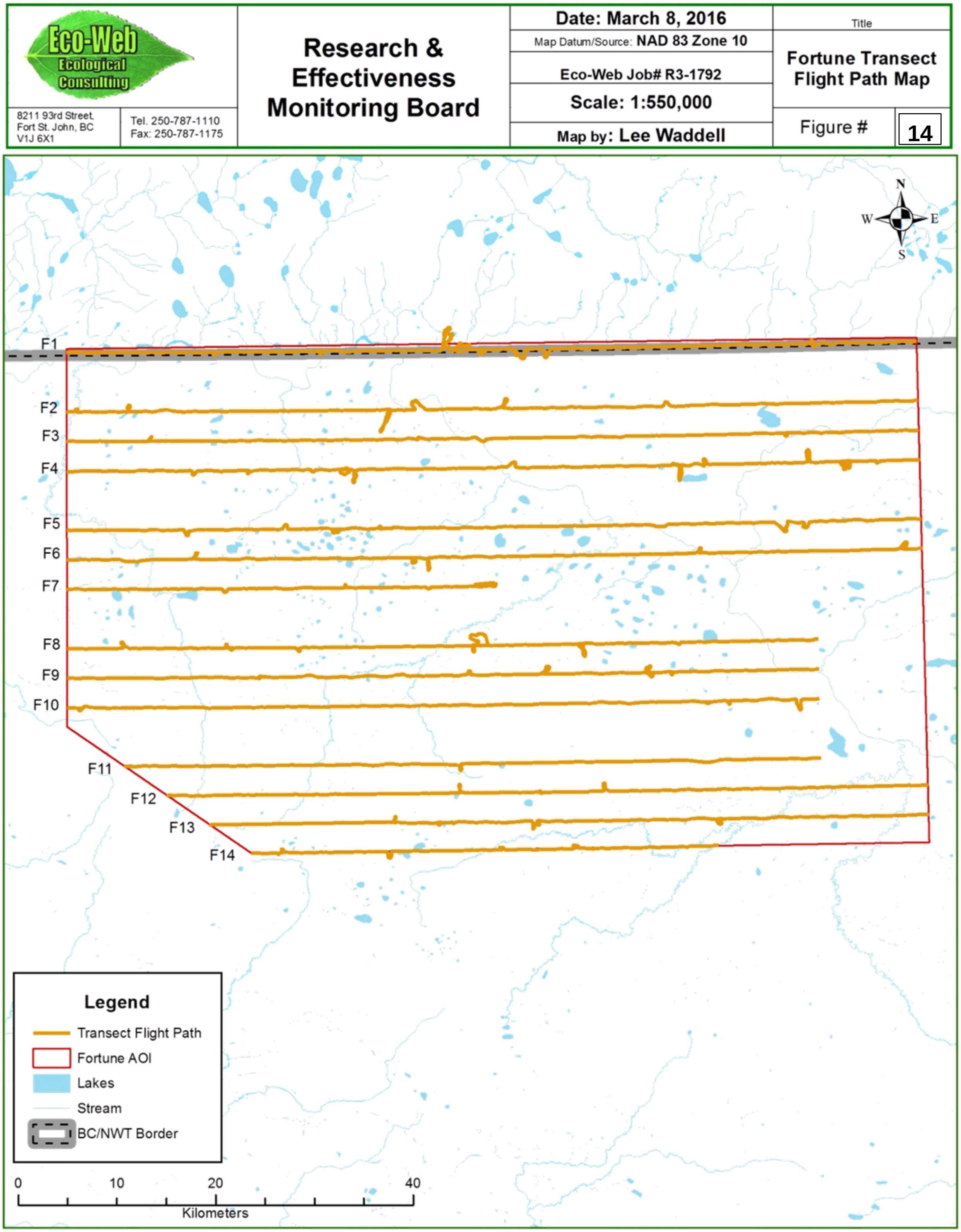


FIGURE 14. ACTUAL TRANSECT COURSES FLOWN FOR A DISTANCE-BASED SURVEY OF MOOSE ABUNDANCE WITHIN THE FORTUNE CARIBOU CORE AREA IN NORTHEASTERN BRITISH COLUMBIA.

APPENDIX 3: EXPLORATORY DATA ANALYSIS RESULTS FOR THE KEY OBSERVED VARIABLES.

Below are shown the data results of the exploratory analysis used to determine the models constructed for density estimation in Distance 6.2 for the pooled data and unpooled data. As discussed above the half-normal key with cosine expansion model was chosen first. We examined the data with no covariates, with cluster size as a covariate, visibility, snow cover, % vegetation at the moose and snow cover and % vegetation at the moose. We also then added a moose stratification layer of high, medium and low, based upon the 5 common habitat groups and moose occurrences within them. Density estimates were completed for each of these stratified models as well (note: table does not provide the density based on stratification, see Table 16 above).

In order to confirm the variable airspeed did not influence sampling efforts in areas with low snow cover or higher vegetation cover, moose observations were plotted to assess these potential correlations:

1. Airspeed : Vegetation Cover
2. Airspeed : Snow Cover
3. Airspeed : Number of moose/group

= test ran normally | = test ran with errors | = too many errors to run | = selected Best Fit test

Clarke-Chinchaga-Fortune

Status	Name	# para	AIC	Delta AIC	D	D LCL	D UCL	D CV	N	N LCL	N UCL	N CV	P	GOF K-S p
1	Half-Normal Cosine no covariates <1.25km	2	-37.94	23.10	0.10	0.08	0.12	0.13	1351	1053	1733	0.13	0.36	0.89
1	Half-Normal Cosine MCDS Cluster Size	2	-28.18	32.86	0.08	0.00	0.00	0.00	1115	0	0	0.00	0.45	0.04
2	Half-Normal Cosine MCDS Visibility 1	6	-23.30	37.74	0.08	0.06	0.10	0.12	1105	875	1395	0.12	0.44	0.04
1	Half-Normal Cosine MCDS Snow Cover	10	-55.23	5.81	0.10	0.07	0.12	0.13	1323	1031	1696	0.13	0.36	0.61
1	Half-Normal Cosine MCDS % Veg @ Moose	3	-50.33	10.71	0.09	0.07	0.12	0.12	1299	1016	1661	0.12	0.40	0.29
1	Half-Normal Cosine MCDS % Veg @ Moose _Snow Cover	12	-61.04	0.00	0.10	0.08	0.14	0.13	1453	1119	1888	0.13	0.34	0.43
1	Half-Normal Cosine no covariates <1.25km Post Strat	2	-37.9	23.10	0.10	0.08	0.12	0.12	1351	1057	1726	0.12	0.36	0.89
2	Half-Normal Cosine MCDS Visibility Post Strat	6	-23.3	37.74	0.08	0.06	0.10	0.12	1105	879	1389	0.12	0.44	0.04
1	Half-Normal Cosine MCDS Snow Cover Post Strat	10	-55.2	5.81	0.10	0.07	0.12	0.12	1323	1036	1689	0.12	0.36	0.61
1	Half-Normal Cosine MCDS % Veg @ Moose Post Strat	3	-50.3	10.71	0.09	0.07	0.12	0.12	1299	1020	1654	0.12	0.40	0.29
1	Half-Normal Cosine MCDS % Veg @ Moose _Snow Cover Post Strat	12	-61	0.00	0.10	0.08	0.14	0.13	1453	1123	1881	0.13	0.34	0.43

Clarke-Chinchaga

Status	Name	# para	AIC	Delta AIC	D	D LCL	D UCL	D CV	N	N LCL	N UCL	N CV	P	GOF K-S p
1	Clarke-Chinchaga - HNK- no covariates	2	-29.97	27.49	0.11	0.08	0.14	0.15	1021	765	1361	0.15	0.34	0.23
2	Clarke-Chinchaga - HNK- MDCS - Cluster Size	2	-16.57	40.90	0.08	0.00	0.00	0.00	785	0	0	0.00	0.45	0.00
1	Clarke-Chinchaga - HNK- MDCS - Visibility	6	-18.67	38.79	0.08	0.06	0.11	0.14	813	613	1078	0.14	0.43	0.01
1	Clarke-Chinchaga - HNK- MDCS - Snow Cover	9	-45.14	12.33	0.11	0.08	0.15	0.15	1036	766	1402	0.15	0.34	0.16
1	Clarke-Chinchaga - HNK- MDCS - % Veg @ Moose	3	-53.34	4.13	0.11	0.08	0.15	0.16	1037	759	1417	0.16	0.34	0.52
1	Clarke-Chinchaga - HNK- MDCS - % Veg @ Moose_Snow Cover	11	-57.46	0.00	0.13	0.09	0.17	0.17	1198	860	1669	0.17	0.29	0.66
1	Clarke-Chinchaga - HNK- no covariates Post Strat	2	-30	27.49	0.10	0.08	0.14	0.15	993	743	1326	0.15	0.34	0.23
1	Clarke-Chinchaga - HNK- MDCS - Visibility Post Strat 1	6	-18.7	38.79	0.08	0.06	0.11	0.15	813	611	1082	0.15	0.43	0.01
1	Clarke-Chinchaga - HNK- MDCS - Snow Cover Post Strat	9	-45.1	12.33	0.11	0.08	0.15	0.16	1036	763	1408	0.16	0.34	0.16
1	Clarke-Chinchaga - HNK- MDCS - % Veg @ Moose Post Strat	3	-53.3	4.13	0.11	0.08	0.15	0.16	1037	756	1422	0.16	0.34	0.52
1	Clarke-Chinchaga - HNK- MDCS - % Veg @ Moose_Snow Cover Post S	11	-57.5	0.00	0.13	0.09	0.18	0.17	1205	860	1688	0.17	0.29	0.66

Clarke

Status	Name	# para	AIC	Delta AIC	D	D LCL	D UCL	D CV	N	N LCL	N UCL	N CV	P	GOF K-S p
1	Clarke - HNK - no covariates no truncation	2	42.93	3.69	0.08	0.05	0.11	0.18	406	279	590	0.18	0.31	0.38
1	Clarke - HNK - MCDS - Cluster Size	2	32.26	0.00	0.08	0.00	0.00	0.00	403	0	0	0.00	0.32	0.36
2	Clarke - HNK - MCDS - Visibility	6	42.75	3.51	0.08	0.05	0.11	0.19	399	270	590	0.19	0.31	0.27
1	Clarke - HNK - MCDS - Snow Cover	5	39.24	0.00	0.07	0.05	0.11	0.19	395	269	580	0.19	0.31	0.32
1	Clarke - HNK - MCDS - %Veg @ moose	3	45.23	5.99	0.07	0.05	0.10	0.18	364	251	529	0.18	0.34	0.13
2	Clarke - HNK - MCDS - %Veg @ moose_Snow Cover	7	42.61	3.37	0.07	0.05	0.11	0.19	396	269	583	0.19	0.31	0.27
1	Clarke - HNK - MCDS - no covariates - Post Strat	2	42.93	3.69	0.08	0.05	0.11	0.18	406	283	583	0.18	0.31	0.38
2	Clarke - HNK - MCDS - Visibility Post Strat	6	42.75	3.51	0.08	0.05	0.11	0.19	399	273	584	0.19	0.31	0.27
1	Clarke - HNK - MCDS - Snow Cover - Post Strat	5	39.24	0.00	0.07	0.05	0.11	0.19	395	271	574	0.19	0.31	0.32
1	Clarke - HNK - MCDS - % Veg @ Moose - Post Strat	3	45.23	5.99	0.07	0.05	0.10	0.18	364	253	523	0.18	0.34	0.13
2	Clarke - HNK - MCDS - %Veg @ moose_Snow Cover Post Strat	7	42.61	3.37	0.07	0.05	0.11	0.19	396	272	577	0.19	0.31	0.27

= test ran normally = test ran with errors = too many errors to run

= selected Best Fit test

Chinchaga

Status	Name	# para	AIC	Delta AIC	D	D LCL	D UCL	D CV	N	N LCL	N UCL	N CV	P	GOF K-S p
1	Chinchaga - HNK - no covariates - <0.6kms	1	-60.46	2.67	0.13	0.09	0.20	0.19	576	398	835	0.19	0.21	0.04
2	Chinchaga - HNK - MCDS - Cluster Size	2	-58.46	4.67	0.14	0.00	0.00	0.00	578	0	0	0.00	0.21	0.04
1	Chinchaga - HNK - MCDS - Visibility	3	-58.38	4.75	0.14	0.09	0.22	0.22	596	387	919	0.22	0.20	0.05
2	Chinchaga - HNK - MCDS - Snow Cover	4	-59.66	3.47	0.15	0.09	0.23	0.22	626	404	970	0.22	0.19	0.29
1	Chinchaga - HNK - MCDS - % Veg @ Moose	3	-63.13	0.00	0.16	0.10	0.25	0.24	670	419	1072	0.24	0.18	0.54
2	Chinchaga - HNK - MCDS - % Veg @ Moose_ Snow Cover	6	-63.09	0.04	0.17	0.11	0.28	0.24	736	458	1180	0.24	0.16	0.54
1	Chinchaga - HNK - CDS - no Covariates - Post Strat	1	-60.5	2.67	0.13	0.09	0.20	0.21	571	378	864	0.21	0.21	0.04
1	Chinchaga - HNK - MCDS - Visibility Post Strat	3	-58.4	4.75	0.14	0.09	0.22	0.24	596	370	960	0.24	0.20	0.05
2	Chinchaga - HNK - MCDS - Snow Cover Post Strat	4	-59.7	3.47	0.15	0.09	0.24	0.24	626	387	1012	0.24	0.19	0.29
1	Chinchaga - HNK - MCDS - % Veg @ Moose Post Strat	3	-69.9	0.00	0.17	0.10	0.28	0.25	713	432	1176	0.25	0.36	0.53
2	Chinchaga - HNK - MCDS - %Veg @ Moose_ Snow Cover Post Strat	6	-63.1	0.04	0.17	0.10	0.29	0.26	733	437	1230	0.26	0.16	0.54

Fortune

Status	Name	# para	AIC	Delta AIC	D	D LCL	D UCL	D CV	N	N LCL	N UCL	N CV	P	GOF K-S p
1	Fortune - HNK - no covariates - <1.15kms	1	-8.15	0.94	0.07	0.05	0.11	0.22	307	198	478	0.22	0.49	0.62
3	Fortune - HNK - MCDS - Cluster Size													
1	Fortune - HNK - MCDS - Visibility	4	-7.66	1.44	0.08	0.05	0.12	0.24	331	206	530	0.24	0.45	0.55
1	Fortune - HNK - MCDS - Snow Cover	2	-9.10	0.00	0.08	0.05	0.12	0.22	331	210	520	0.22	0.47	0.58
1	Fortune - HNK - MCDS - % Veg @ Moose	3	-5.23	3.87	0.07	0.05	0.11	0.23	314	199	496	0.23	0.48	0.46
1	Fortune - HNK - MCDS - % Veg @ Moose_Snow Cover	4	-3.40	5.69	0.07	0.05	0.12	0.23	317	201	502	0.23	0.48	0.40
1	Fortune - HNK - CDS - no covariates Post Strat 1	1	-8.15	0.94	0.07	0.05	0.10	0.19	307	209	452	0.19	0.49	0.62
1	Fortune - HNK - MCDS - Visibility Post Strat	4	-7.66	1.44	0.08	0.05	0.12	0.21	331	217	504	0.21	0.45	0.55
1	Fortune - HNK - MCDS - Snow Cover Post Strat	2	-9.1	0.00	0.08	0.05	0.11	0.20	331	222	493	0.20	0.47	0.58
1	Fortune - HNK - MCDS - % Veg @ Moose Post Strat	3	-5.23	3.87	0.07	0.05	0.11	0.20	314	210	470	0.20	0.48	0.46
1	Fortune - HNK - MCDS - % Veg @ Moose_Snow Cover Post Strat	4	-3.4	5.69	0.07	0.05	0.11	0.21	317	211	477	0.21	0.48	0.40

TABLE 22 – EXPLORATORY ANALYSIS RESULTS FOR ALL MODELS, COVARIATES AND POST-STRATIFICATION TESTED

FIGURE 15. DISTRIBUTION OF MOOSE OBSERVATIONS IN RELATION TO AIRSPEED AND VEGETATION COVER FOR EACH SURVEY AREA.

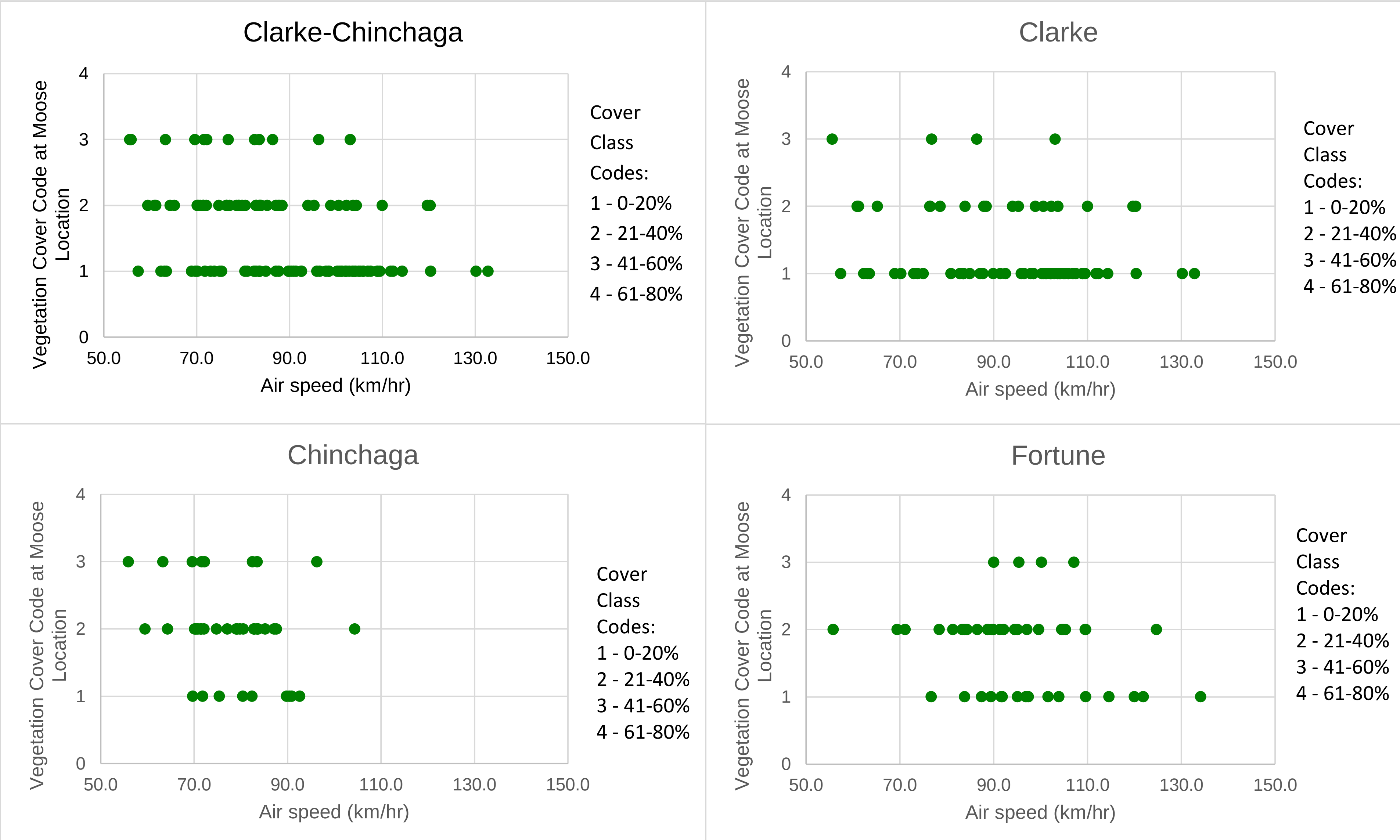


FIGURE 16. DISTRIBUTION OF MOOSE OBSERVATIONS IN RELATION TO AIRSPEED AND SNOW COVER FOR EACH SURVEY AREA.

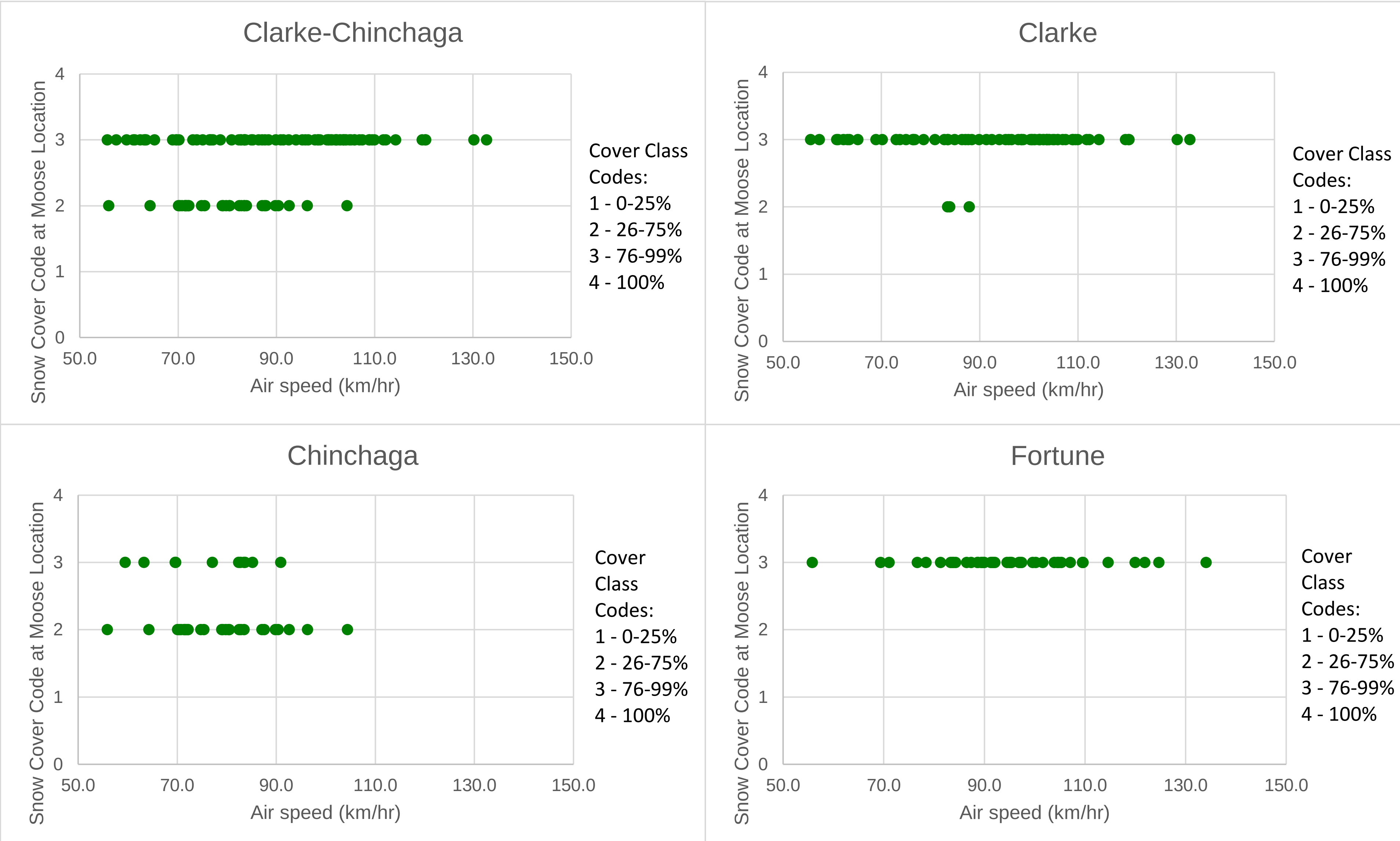
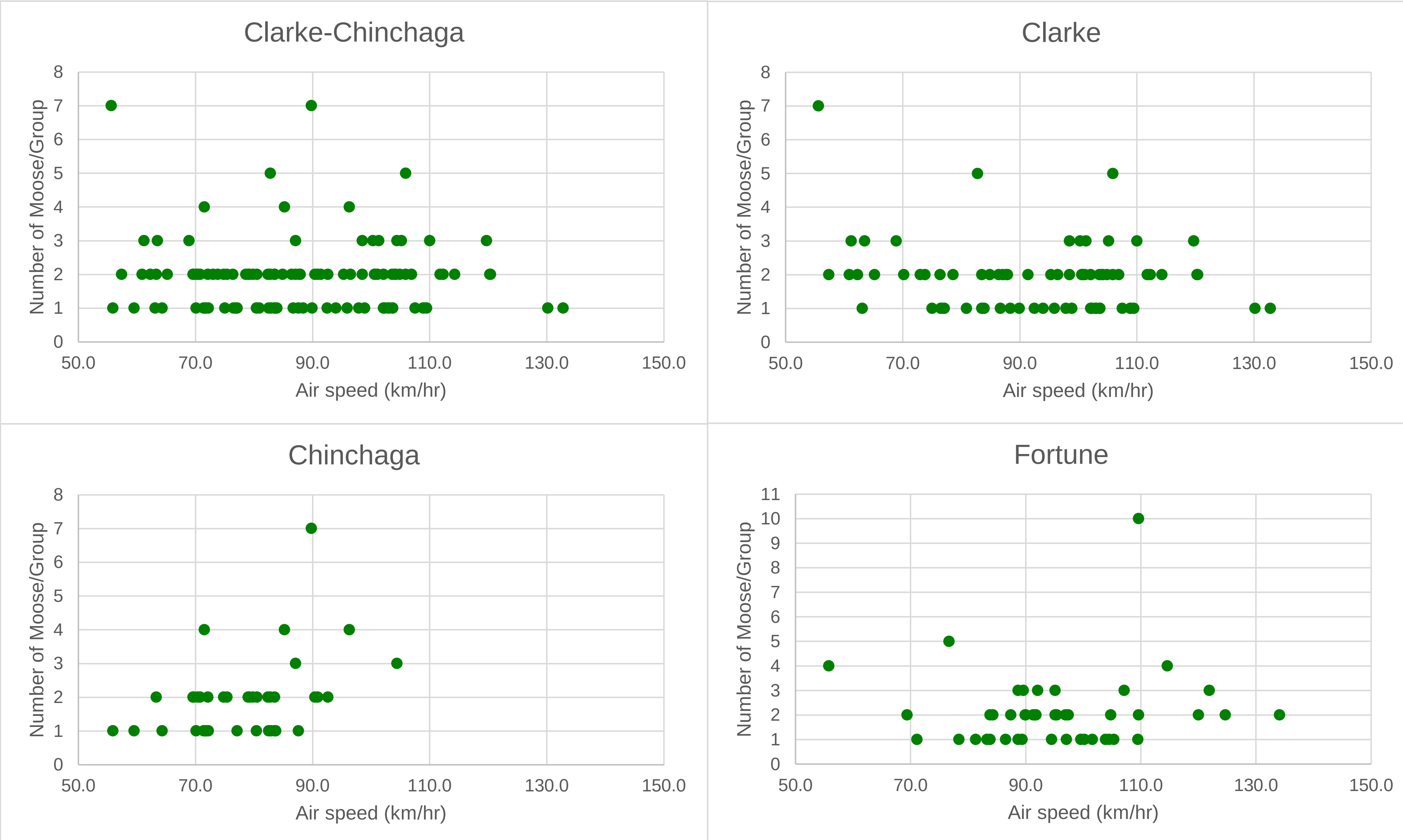


Figure 17. Number of Moose/Group in relation to airspeed for each survey area.



APPENDIX 4: VRI STRATIFICATION DATA

As discussed above in the Methodology section, the VRI data for the study areas was accessed and the stand polygons broken down to fit into the habitat groups (Canfor, 2015; DataBC, 2014). Each moose observation point was drilled down into the VRI layer at the observation point location. The VRI data was then stratified with the following process. The BC Land Cover Classification Scheme (BCLCS) and the Species Population Layers were used to stratify the Moose Observation Points with the VRI data. Stratification was organized in the following format;

- **BCLS Level 4** (Vegetated Cover Type) was the first level of stratification, used to filter the moose observation points into the 5 Habitat Groups (1-Wetland, 2-Treed Wetland, 3-Coniferous, 4-Deciduous/Mixed, & 5-Disturbed).
- **BCLS Level 3** (Landscape Position) was then used to further stratify into Wetland & Treed Wetland Groups.
- **Species Type** was then used to refine stratification into the necessary Habitat Groups.

Of the 220+ moose observation points 25 showed confliction with what was identified in the VRI data set. A 30m buffer was then placed around the moose observation point to confirm/deny potential for observations to adjacent VRI polygons. This process resulted in 7 data conflicts of 171 Moose observation sample points. VALTUS LandSat Imagery was used in addition to the 30m buffer to confirm/deny observations.

Wetlands did not require tertiary (Species Type) filtering. Upland Treed Wetland, Coniferous and Deciduous/Mixed VRI data were further filtered via the Species Type. The following 5 observation points did not correlate with the VRI data results; 143, 146, 154, 159 & 213. These points fall within the factor of error of 2.9%.

NOTE: As stated within the VRI User Manual (Canfor, 2015), there are limitations to the VRI dataset. Some tables within the VRI data may not be based on data that is truly representative of the area being inventoried. At an operational level this can result in some level of dissatisfaction.

The oil and gas, road, burn and cutblock polygons were added in to create the “disturbed” habitat group (DataBC, 2014). Disturbed area was calculated by combining the following data:

- Cutblocks - (WHSE_FOREST_TENURE.FTEN_CUT_BLOCK_POLY_SVW & MISC. data sets) acquired FEB 2016 & older forestry data. (No cutblocks identified within the Fortune AOI)
- Burn areas – (WHSE_LAND_AND_NATURAL_RESOURCE.PROT_CURRENT & HISTORICAL_FIRE_POLYS_SP) acquired FEB 2016
- Pipelines – (OGC FTP) acquired FEB 2016
- Facilities & Well sites - (OGC FTP) acquired FEB 2016
- Crown ROW – (WHSE_TANTALIS.TA_CROWN_RIGHTS_OF_WAY_SVW) acquired march 2016
- OGC Ancillary – (OGC FTP) acquired FEB 2016
- Roads & Access – (OGC FTP, Forestry & CANVEC) acquired FEB 2016 (as these are linear features a number of sample measure3ments were taken via air photography to determine an average 15m ROW)

Seismic activity was not included in the disturbance calculations as much of it that is recent is considered low impact seismic. Large water bodies were not included within the VRI Data (ie. Kotcho Lake). Also, there were several hectares of upland treed VRI polygons with no filtering data available. The overall Clarke/Chinchaga & Fortune AOI’s were therefore reduced to compensate for these exclusions.

The following charts show the area calculations for the pooled and unpooled data.

Fortune, Clarke & Chichaga

Feature	Total Area Km²
Overall Area of Intrest	13908.048
Wetlands	1774.008
Treed Wetlands	8065.422
Coniferous	1562.636
Deciduous/Mixed	2073.696
Disturbed	384.363

Fortune

Feature	Total Area Km²
Overall Area of Intrest	4331.259
Wetlands	318.46
Treed Wetlands	2830.078
Coniferous	481.85
Deciduous/Mixed	479.196
Disturbed	168.543

Clarke & Chichaga

Feature	Total Area Km²
Overall Area of Intrest	9576.789
Wetlands	1455.548
Treed Wetlands	5235.344
Coniferous	1080.786
Deciduous/Mixed	1594.5
Disturbed	215.82

Clarke

Feature	Total Area Km²
Overall Area of Intrest	5301.536
Wetlands	988.334
Treed Wetlands	2815.991
Coniferous	419.832
Deciduous/Mixed	943.547
Disturbed	137.893

Chinchaga

Feature	Total Area Km²
Overall Area of Intrest	4275.253
Wetlands	467.214
Treed Wetlands	2419.353
Coniferous	660.954
Deciduous/Mixed	650.953
Disturbed	77.927

Overall area vs. Features area

	Total Feature	Diffrence
Fortune	4278.127	53.132
Clarke	5305.597	-4.061
Chinchaga	4276.401	-1.148
Total	13860.125	47.923

The table below provides the final breakdown where the habitat observed at each moose group is matched to the VRI classifications. Green indicates an immediate match at BCLS Level 4. Light green indicates a secondary match at BCLS Level 3. Light tan indicates a tertiary match at the Species level. Red indicates a discrepancy with no match identified.

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moose point	field observations		VRI & Field Observation Sort		VRI Land Cover Class		Landscape		
	code	classification	Revision Class w/landscape	Species	classification	code	classification	code	notes
SP_100	CD5	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TC	Upland	U	
SP_101	WE	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_102	WE	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_103	WE	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_103	WE	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_106	WS	Wetland	Wetland	LT	Wetland	SL	Upland	U	
SP_107	WE	Wetland	Wetland	LT	Wetland	HG	Upland	U	
SP_108	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_109	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_110	WS	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_111	WE	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_112	WS	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_113	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_115	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_116	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_118	WS	Wetland	Treed Wetland	SX	Coniferous	TC	Wetland	W	
SP_119	BS2	Treed Wetland	Treed Wetland	SX	Coniferous	TC	Wetland	W	
SP_121	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_122	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Upland	U	
SP_123	WS	Wetland	Wetland	SW	Wetland	ST	Upland	U	
SP_124	WS	Wetland	Treed Wetland	SB	Deciduous/mixed	TM	Upland	U	
SP_125	WE	Wetland	Treed Wetland	AC	Deciduous/mixed	TB	Upland	U	within 40m of wetland
SP_126	WS	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_128	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_132	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_133	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_134	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Upland	U	
SP_135	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_136	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_138	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_139	OG	Disturbed	Disturbed		Wetland	SL	Upland	U	
SP_140	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_141	WS	Wetland	Wetland				Wetland	W	no data but in water
SP_142	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_143	WS	Wetland	No Match	AT	Deciduous/mixed	TB	Upland	U	
SP_144	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Upland	U	
SP_145	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_146	CD4	Deciduous/mixed	No Match	EP	Treed Wetland	TM	Upland	U	
SP_147	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_148	BU	Disturbed	Disturbed	SB	Coniferous	TC	Upland	U	
SP_149	WS	Wetland	Wetland		Wetland		Wetland	W	
SP_15	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_150	OG	Disturbed	Disturbed	SB	Coniferous	TC	Upland	U	
SP_151	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_153	CS4	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TB	Upland	U	
SP_154	CD4	Deciduous/mixed	No Match	SB	Coniferous	TC	Upland	U	
SP_156	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Upland	U	
SP_157	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_158	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_159	CS5	Deciduous/mixed	No Match	SW	Coniferous	TM	Upland	U	
SP_16	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_160	OG	Disturbed	Disturbed	SB	Coniferous	TC	Upland	U	
SP_161	CU	Disturbed	Disturbed	SB	Deciduous/mixed	TM	Upland	U	
SP_162	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_163	DE6	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TB	Upland	U	
SP_164	DE6	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TB	Upland	U	
SP_165	WS	Wetland	Wetland	SB					No VRI DATA, in territories
SP_166	WS	Wetland	Wetland	SB					No VRI DATA, in territories
SP_167	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_167	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_169	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_17	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_170	WS	Wetland	Wetland	SB					No VRI DATA, in territories
SP_172	RI	Wetland	Wetland		Wetland	SL	Upland	U	
SP_173	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_176	WS	Wetland	Wetland	LT	Wetland	ST	Wetland	W	
SP_177	WS	Wetland	Treed Wetland	SB	Deciduous/mixed	TM	Upland	U	
SP_18	WE	Wetland	Wetland	LT	Wetland	ST	Wetland	W	
SP_180	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_181	WE	Wetland	Wetland	SB	Wetland	ST	Upland	U	
SP_182	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_182	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_183	BU	Disturbed	Disturbed	SB	Coniferous	TC	Upland	U	
SP_184	WS	Wetland	Wetland	SB	Wetland	SL	Upland	U	
SP_185	WS	Wetland	Wetland	LT	Wetland	HG	Wetland	W	
SP_185	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_186	WS	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_187	OG	Disturbed	Disturbed	SB	Coniferous	TC	Upland	U	
SP_188	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_189	WE	Wetland	Wetland	SB	Wetland	HG	Upland	U	
SP_189	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_19	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_191	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_192	DE6	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TB	Upland	U	
SP_195	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_196	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	

Aerial Moose Survey in North East BC 2016 Submitted to: Research and Effectiveness Monitoring Board (REMB) – Inventory Project BC Oil and Gas Research and Innovation Society

moose point	field observations		VRI & Field Observation Sort		VRI Land Cover Class		Landscape		
	code	classification	Revision Class w/landscape	Species	classification	code	classification	code	notes
SP_197	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_198	WS	Wetland	Wetland	LT	Wetland	SL	Wetland	W	
SP_199	WS	Wetland	Wetland	SB	Wetland	ST	Wetland	W	
SP_20	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Upland	U	
SP_200	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_201	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_202	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_203	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_206	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Upland	U	
SP_207	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Upland	U	
SP_209	WS	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_21	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_210	WS	Wetland	Treed Wetland	EA	Deciduous/mixed	TM	Upland	U	
SP_211	BS2	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_212	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_213	CD5	Deciduous/mixed	No Match	SW	Coniferous	TM	Upland	U	
SP_214	WS	Wetland	Wetland		Wetland	SL	Upland	U	
SP_216	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_217	WE	Wetland	Wetland	SB	Wetland	SL	Upland	U	
SP_219	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_219	WS	Wetland	Wetland	SB	Wetland	TC	Wetland	W	
SP_22	WS	Wetland	Wetland		Wetland	TM	Wetland	W	
SP_220	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_221	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_222	OG	Disturbed	Disturbed	SB	Coniferous	TC	Upland	U	
SP_23	WS	Wetland	Wetland	SB	Wetland	SL	Upland	U	
SP_24	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_25	PS	Coniferous	Coniferous	P	Coniferous	TM	Upland	U	
SP_26	RI	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_27	BS2	Treed Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_28	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TM	Wetland	W	
SP_29	CS5	Deciduous/mixed	Deciduous/mixed	AC	Deciduous/mixed	TB	Upland	U	
SP_30	WS	Wetland	Treed Wetland	SW	Coniferous	TM	Wetland	W	
SP_31	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_32	WE	Wetland	Wetland		Wetland	ST	Wetland	W	
SP_33	WS	Wetland	Wetland		Wetland	ST	Wetland	W	
SP_35	WS	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_36	WS	Wetland	Treed Wetland	SB	Deciduous/mixed	TM	Upland	U	
SP_38	WE	Wetland	Wetland		Wetland	HE	Upland	U	
SP_40	DE	Deciduous/mixed	Treed Wetland		Wetland	HG	Wetland	W	
SP_40	DE	Deciduous/mixed	Treed Wetland		Wetland	SL	Wetland	W	
SP_42	OG	Disturbed	Treed Wetland	AT	Deciduous/mixed	TB	Wetland	W	
SP_44	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_45	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_46	WE	Wetland	Treed Wetland	PL	Coniferous	TC	Wetland	W	
SP_47	WS	Wetland	Wetland		Wetland	SL	Upland	U	
SP_47	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Wetland	W	
SP_48	WS	Wetland	Wetland	SB	Wetland	SL	Upland	U	
SP_48	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_50	CS5	Deciduous/mixed	Deciduous/mixed	SW	Coniferous	TM	Upland	U	
SP_51	CS5	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TM	Upland	U	
SP_52	WS	Wetland	Wetland		Wetland	TM	Wetland	W	
SP_54	WE	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Wetland	W	
SP_54	WE	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_57	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_58	BS4	Treed Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_59	WE	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_64	WS	Wetland	Wetland	EP	Wetland	ST	Wetland	W	
SP_65	WS	Wetland	Wetland	LT	Wetland	ST	Wetland	W	
SP_66	CD3	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TM	Upland	U	
SP_67	WE	Wetland	Wetland	SB	Wetland	TC	Wetland	W	
SP_68	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_69	ME	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_70	ME	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_72	CD5	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TB	Upland	U	
SP_73	WE	Wetland	Treed Wetland	EP	Deciduous/mixed	TM	Upland	U	
SP_74	ME	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_75	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_76	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TM	Upland	U	
SP_78	WS	Wetland	Wetland	EP	Wetland	ST	Wetland	W	
SP_79	ME	Wetland	Wetland		Wetland	SL	Wetland	W	
SP_80	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Upland	U	
SP_81	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Upland	U	
SP_83	WS	Wetland	Wetland	SB	Wetland	ST	Upland	U	
SP_84	WS	Wetland	Wetland	SB	Wetland	ST	Upland	U	
SP_87	WS	Wetland	Wetland	LT	Wetland	SL	Wetland	W	
SP_88	RI	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_89	BS4	Treed Wetland	Wetland		Wetland	HE	Wetland	W	
SP_90	DE7	Deciduous/mixed	Deciduous/mixed	AT	Deciduous/mixed	TB	Upland	U	
SP_92	WS	Wetland	Treed Wetland	LT	Coniferous	TC	Wetland	W	
SP_93	WS	Wetland	Treed Wetland	EP	Deciduous/mixed	TB	Wetland	W	
SP_94	WS	Wetland	Wetland	SB	Wetland	SL	Wetland	W	
SP_95	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Upland	U	
SP_96	WS	Wetland	Treed Wetland	SB	Coniferous	TC	Wetland	W	
SP_98	OG	Disturbed	Disturbed	EP	Deciduous/mixed	TM	Upland	U	

APPENDIX 5: STRATIFICATION DENSITY CALCULATIONS

Fortune, Clarke & Chinchaga

Feature	Total Area Km²	% of area	Density per Area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	*13908.048*	*100%*	*0.104*	*N/A*	1452.978
Wetlands	1774.008	13%	0.071	0.560	993.619
Treed Wetlands	8065.422	58%	0.012	0.021	169.275
Coniferous	1562.636	11%	0.000	0.004	6.842
Deciduous/Mixed	2073.696	15%	0.013	0.087	179.803
Disturbed	384.363	3%	0.007	0.269	103.430
				Total	1452.968

Clarke & Chinchaga

Feature	Total Area Km²	% of area	Density per Area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	9576.789	*100%*	*0.126*	*N/A*	1204.856
Wetlands	1455.548	15%	0.081	0.532	774.896
Treed Wetlands	5235.344	55%	0.017	0.032	165.573
Coniferous	1080.786	11%	0.001	0.008	8.593
Deciduous/Mixed	1594.5	17%	0.018	0.109	173.484
Disturbed	215.82	2%	0.009	0.381	82.298
				Total	1204.844

Clarke

Feature	Total Area Km²	% of area	Density per Area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	5301.536	*100%*	*0.074*	*N/A*	394.742
Wetlands	988.334	19%	0.060	0.320	316.056
Treed Wetlands	2815.991	53%	0.005	0.009	26.227
Coniferous	419.832	8%	0.001	0.011	4.745
Deciduous/Mixed	943.547	18%	0.007	0.041	38.222
Disturbed	137.893	3%	0.002	0.069	9.490
				Total	394.740

Chinchaga

Feature	Total Area Km²	% of area	Density per Area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	4275.253	*100%*	*0.157*	*N/A*	670.163
Wetlands	467.214	11%	0.101	0.924	431.715
Treed Wetlands	2419.353	57%	0.024	0.042	100.981
Coniferous	660.954	15%	0.000	0.000	0.000
Deciduous/Mixed	650.953	15%	0.017	0.109	71.157
Disturbed	77.927	2%	0.016	0.851	66.309
				Total	670.163

Fortune

Feature	Total Area Km²	% of area	Density per Area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	4331.259	*100%*	*0.076*	*N/A*	330.709
Wetlands	318.46	7%	0.062	0.838	266.745
Treed Wetlands	2830.078	65%	0.004	0.006	15.594
Coniferous	481.85	11%	0.000	0.000	0.000
Deciduous/Mixed	479.196	11%	0.006	0.052	24.976
Disturbed	168.543	4%	0.005	0.139	23.391
				Total	330.706

Fortune, Clarke & Chinchaga CCA & RRA

Feature	Total Area Km²	% of area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	*6032.981*	*100%*		
Wetlands	797.003	13%	0.560098	446.400
Treed Wetlands	3976.56	66%	0.020988	83.459
Coniferous	562.465	9%	0.004378	2.463
Deciduous/Mixed	583.822	10%	0.086707	50.621
Disturbed	89.799	1%	0.269095	24.164
			Total	607.107
			Overall Density	0.101

Clarke & Chinchaga CCA & RRA

Feature	Total Area Km²	% of area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	4438.443	*100%*		
Wetlands	612.858	14%	0.532	326.270
Treed Wetlands	2859.014	64%	0.032	90.419
Coniferous	422.526	10%	0.008	3.359
Deciduous/Mixed	450.044	10%	0.109	48.965
Disturbed	76.573	2%	0.381	29.199
			Total	498.213
			Overall Density	0.112

Clarke CCA

Feature	Total Area Km²	% of area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	2223.084	*100%*		
Wetlands	341.671	15%	0.320	109.262
Treed Wetlands	1565.481	70%	0.009	14.580
Coniferous	113.388	5%	0.011	1.282
Deciduous/Mixed	173.293	8%	0.041	7.020
Disturbed	29.767	1%	0.069	2.049
			Total	134.192
			Overall Density	0.060

Chinchaga RRA

Feature	Total Area Km²	% of area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	2215.359	*100%*		
Wetlands	271.187	12%	0.924	250.582
Treed Wetlands	1293.533	58%	0.042	53.991
Coniferous	309.138	14%	0.000	0.000
Deciduous/Mixed	276.751	12%	0.109	30.252
Disturbed	46.806	2%	0.851	39.828
			Total	374.653
			Overall Density	0.169

Fortune CCA

Feature	Total Area Km²	% of area	Density per Strata	Moose # per Habitat Group
Overall Area of Interest	1594.538	*100%*		
Wetlands	184.145	12%	0.838	154.241
Treed Wetlands	1117.546	70%	0.006	6.158
Coniferous	139.939	9%	0.000	0.000
Deciduous/Mixed	133.778	8%	0.052	6.973
Disturbed	13.226	1%	0.139	1.836
			Total	169.207
			Overall Density	0.106