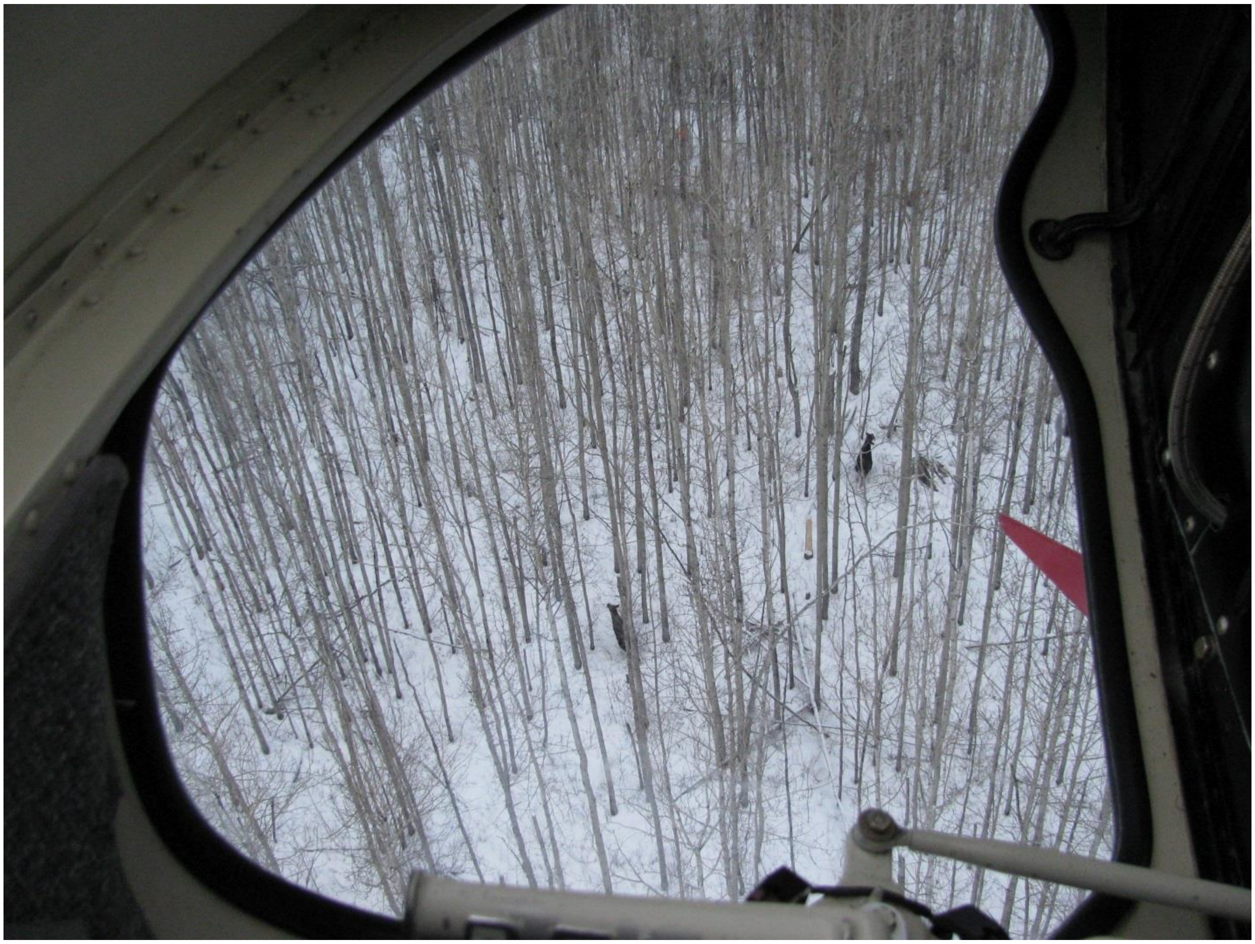
Aerial Ungulate Surveys using Distance Sampling Techniques – Protocol Manual



Alberta Environment and Parks

Environmental Monitoring and Science Division

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1.0 INTRODUCTION

This document is intended to serve as a reference for biologists in the Environmental Monitoring and Science Division (EMSD) of Alberta Environment and Parks conducting aerial ungulate surveys (AUS) using distance sampling techniques. This document contains several excerpts from the Aerial Ungulate Survey Protocol Manual developed by the Alberta Sustainable Resource Development Fish and Wildlife Division (2010), and from the Aerial Ungulate Survey Guide Distance Surveys unpublished report developed by Hannah McKenzie (2013).

Aerial surveys are the primary method used to assess the population size, distribution, population trends and herd composition of ungulates in Alberta. These pieces of information are crucial to the monitoring, effective management and conservation of ungulates. Aerial surveys of ungulates have a long history in Alberta, and have continuously evolved to take advantage of new analytical techniques, aircraft, and knowledge of the abundance and distribution of ungulate species. Currently, aerial surveys are used to monitor all species of ungulates in the province, including white-tailed and mule deer, moose, elk, bison, caribou, pronghorn antelope, mountain goats, and bighorn sheep. Within the Environmental Monitoring and Science Division, the enhanced moose and deer monitoring component involves increasing the number of aerial ungulate surveys within the oil sands region. Aerial surveys provide critical information to assess the population size, distribution and trends in addition to examining the impacts of harvesting, predation or other disturbance related to land use on ungulate populations.

Distance sampling methods for estimating animal density and abundance have been developed and tested across a number of species and jurisdictions, and provide an unbiased estimate of density and abundance when the underlying assumptions are met (Buckland et al. 2001). The theory and application of conventional distance sampling methods are described in Buckland et al. (2001), while various extensions are covered in Buckland et al. (2004). Beginning in 2007, the Government of Alberta has evaluated distance sampling methods for use in Alberta aerial ungulate surveys, both independently and concurrently with random stratified block surveys (Gasaway et al. 1986). Distance sampling methods were found to be statistically robust, efficient, and often more cost effective than the Gasaway method. Furthermore, a properly designed distance survey may provide other advantages over the Gasaway method, including increased robustness to incorrect stratification and unexpected variability in animal density, decreased time needed to achieve required precision, and the ability to include additional covariates, which may help to address sightability concerns. Based on the wide acceptance of distance sampling methods (Thomas et al, 2010) and the success of earlier studies, where appropriate, Alberta is moving towards implementing distance sampling methods for estimating ungulate population density and abundance. Continued improvements to the survey methodology, sightability correction approaches, and analysis techniques are expected as the method is applied more frequently and to more species in different areas of the province (McKenzie 2013).

2.0 SURVEY PLANNING

The EMSD Core Ungulate Monitoring Program is intended to provide a trend of moose populations in the oil sands region of Northeastern Alberta. The objective of this program is to increase the sampling frequency to five year regular intervals to better understand ungulate population trends. The surveys are designed to estimate the population size and density of moose and deer in Wildlife Management Units (WMUs) using distance sampling techniques. The survey results are used to determine age, sex ratios and antler classification of moose and deer where possible. While the protocols for flying line transects and observing animals are similar to other types of aerial surveys described in the AUS Protocol Manual (e.g. Gasaway, strip transect, block area), there are important aspects that differ to obtain the best data possible for the distance sampling method. Some of these are well documented (see Buckland et al., 2001, Buckland et al., 2004), but many of these are based on experience during the distance sampling surveys conducted in Alberta to date (McKenzie 2013). For the detailed distance method and survey design, see Appendix A - Distance Sampling Method.

2.1 Survey Timing

Aerial ungulate surveys should be timed to maximize animal sightability, maximize the usefulness of population estimates for resource managers, minimize the stress imposed on the animals due to harassment by the survey aircraft, and avoid negative effects on members of the public that are enjoying the resource. For most species, aerial surveys are best conducted during winter months (December-March) when snowfall improves sightability, hunting seasons are not open, and population estimates can be developed in time for wildlife managers to allocate hunting tags for the following fall seasons. In addition to basic time-of-year considerations, aerial surveys must be conducted when weather conditions allow safe aircraft operation and provide adequate sightability. For example, Allen (2005) recommended conducting elk surveys during periods of flat light and high snow cover, in order to maximize sightability of elk groups. Therefore, surveys should be conducted during periods of high snow cover. This means initiating surveys during weather conditions that are forecasted to be consistent when high snow cover is present. Deteriorating snow conditions during the course of a survey, for example, could result in declining sightability and reduce both the precision and accuracy of final population estimates. In all cases, surveys should occur only when weather conditions allow safe aircraft operation; factors such as high wind and/or cloud cover not only reduce the safety of the surveys, but compromise sightability and can lead to observer fatigue as well. Survey participants should rely on pilot judgment as well as their own experiences and comfort level to determine when survey flights should occur or be prematurely terminated (AUS Protocol Manual 2010).

2.2 Personnel

Surveys should be planned and implemented by staff experienced with surveying the target species in the area of interest. In addition to safety, maximizing the quality of the data collected while simultaneously minimizing stress to the animals should be the primary goals of every survey; this requires that experienced personnel are involved with all aspects of survey planning and delivery. Under some circumstances, this may necessitate collaborating with staff from other regions, hiring former staff members on a contract basis to assist with the survey, or consulting with experts to ensure that the survey design is adequate. Planning the logistics of surveys may also necessitate close collaboration with the aircraft company and/or pilot contracted for the flying, as they often have expert knowledge on the weather and terrain conditions that may affect the survey, the location of fuel caches, and other important logistical considerations. During survey flights, observers should have extensive experience conducting surveys for the species of interest. Gasaway et al. (1986) found that inexperienced observers missed considerably more moose observations as experienced staff. Inexperienced observers may also make substantially more errors in identifying animals, often resulting in circling of ‘stump moose’, for example. This not only decreases the efficiency of the survey, but can unnecessarily increase observer fatigue and risk. Perhaps most importantly, inexperienced observers often have difficulty in accurately classifying animals into proper age and sex classes, which may result in errors in final age and sex ratios or subject the surveyed animals to unnecessary stress due to increased harassment from the survey aircraft during classification attempts. Therefore, inexperienced observers should be limited to 1 per aircraft, and sit on the same side of the aircraft as a highly experienced observer who can aid in herd classification and provide training to the new observer. In addition, integrating inexperienced observers into survey flights should be conducted only as part of long-term staff development and mentoring strategies; most aerial surveys are not an appropriate mechanism to introduce members of the public or non-essential personnel to wildlife population data collection. Similarly, survey staff should recognize the need to train new observers for (ideally) several years prior to the retirement or departure of key staff, and to ensure that enough experienced observers are available to conduct all surveys when conditions are favorable (AUS Protocol Manual 2010).

Basic duties for personnel participating in aerial ungulate surveys have been built upon from the AUS Protocol Manual using the distance sampling method and are as follows:

Pilot

- Responsible for safety decisions
- Monitors weather conditions
- Monitors in-flight hazards
- Follows flight lines
- Navigates to survey areas
- May assist with observing if the lead observer allows
- Responds to observer requests to pursue animals, circle, or hover

Navigator (typically the Lead Observer)

- Ultimately responsible to determine whether flights should begin or continue
- Responsible for safety decisions
- Monitors weather conditions
- Monitors in-flight hazards
- Ensures pilot is following flight lines
- Ensures flight paths are efficient
- Helps pilot navigate to survey areas
- Observe from 0 metres to 50 metres on the transect line
- Determines whether animals are within sample unit boundaries
- Typically records data
- Responsible for quality of data collection

Secondary observers (typically the rear observers)

- Scans for target wildlife species on the right or left side of the aircraft beyond 50 metres
- Counts herd sizes of target wildlife species
- Classifies target wildlife species by sex and age
- Reports all observations to lead observer
- Reports in flight hazards if observed

Most frequently for distance surveys, the navigator sits in the front left of the helicopter and is responsible for navigation and observing all portions of the transect that are visible in the floor of the aircraft and in the central periphery of the left aircraft window. No effort should be made to observe areas of the line transect beyond approximately 50 m from the center of the flight path.

The rear left and rear right observers should focus only on portions of the line transect greater than 50 m from the center of the aircraft. Depending on the height of the front observer, the rear right observer may need to adjust their line of sight based on the visibility of the front observer towards the right hand side of the line transect. In a typical Gasaway survey, the rear left observer is considered either a training seat or a duplication of efforts because both the front left and rear right observers survey the same portion of the line transect. However, experience from previous surveys suggests that if the front left observer deviates from 50 m on either side of the line transect centerline, this will result in a hole at 0 m. It is possible to adjust for this reduction in the number of animals observed at 0 m during the analysis stage. However, this can be avoided by focusing the effort of the front left observer on the area 50 m on either side of the line transect centerline. This is desirable, as it will reduce the need for modifications to the fit of the detection function and increase the reliability of the distance sampling method. Some distance surveys have been conducted in Alberta with one of the rear observers acting as the lead observer and navigator. This reduces the risk of the front left observer missing detections at 0 to 50 m when recording or helping navigate. The pilot normally does not call out observations until after the observers have obviously missed them (McKenzie 2013). Depending on the lead observer’s decision, the pilots’ observations may or may not be used in the analysis. Whatever the lead observer decides, it must remain consistent throughout the survey for every observation the pilot makes.

Based on the recommendations by Buckland et al. (2001), rear observers should spend the majority of their time searching ahead and near the line and to detect objects in advance of any movement in response to the aircraft. The front left observer will focus on the transect line to ensure that detection on the line is certain. Overall, search effort should decrease smoothly with distance from the line (McKenzie 2013).

2.2.1 Observer fatigue

Surveys should be conducted to ensure that observers do not experience excess fatigue, which may affect their ability to observe wildlife and/or record accurate data. In most cases, aircraft should land at least once every 3 hours to allow the survey crew and pilot to rest their eyes, stretch, and recover from motion sickness, if necessary. Work in Wyoming has shown that an observer’s ability to sight wildlife deteriorates after 3 hours; the number of flights exceeding this time should be minimized. While the relatively short flight duration of helicopters ensures regular landing for refueling, these short breaks are not adequate to allow observers to fully recover from observer fatigue. Whenever possible, total daily flight duration should not exceed 6 hours, and a mid-day break of at least 2 hours should be scheduled in order to ensure observers continue to operate effectively. Pressure to complete a survey within a specific timeframe should not outweigh data quality, which can be significantly impacted by observer fatigue.

2.2.2 Pilots

Surveying wildlife is unique from most other types of aircraft operation, often requiring low-level circling, flying at low speeds, maintaining consistent speeds and heights above ground, following rigid transect lines, and pursuing or herding of wildlife to allow herd counts and classification. Whenever possible, all pilots participating in aerial surveys of ungulates should have extensive experience flying in the survey area and have conducted similar types of flying to that required during the survey. Pilots should also operate in a manner that minimizes observer fatigue and motion-sickness; aggressive maneuvers are not necessary for wildlife surveys and can actually reduce the efficiency of data collection by subjecting observers to unnecessary physical stress. Pilots should have an interest in the survey design and a demonstrated commitment to safe flight operations. Ideally, survey staff should establish long-term relationships with local aircraft companies and individual pilots to conduct surveys within their region. Using local companies provides many advantages over using pilots and aircraft from other areas, including expert knowledge of the survey area, company-established fuel caches, and reduced shuttle time and travel-related expenditures. In many cases, total survey budgets are lower when local aircraft are used even if their hourly rates are substantially higher than other companies.

Pilot qualifications are outlined as follows:

- Current Canadian Commercial Pilot License for rotor wing.
- Current Pilot Proficiency Check (PPC).
- Pilots must have a minimum of 800 hours flying on type and have previous aerial wildlife survey experience. It is desirable to have 200 hours of wildlife survey experience.
- All pilots must also meet the following competencies:
    - Mountain Flying (When operating along the eastern slopes of Alberta)
    - Hover Exit
    - Confined Landing Assessment
    - Low Visibility Endorsement
    - Other competencies as required to complete the mission.

    For further information on competencies, refer to the Pilot Competencies for Helicopter Wildfire Operations Best Practices Training and Evaluation (Helicopter Association of Canada 2011).

• When flying in mountainous terrain, must have had 100 hours as pilot in command of rotor wing aircraft during low level mountain flying.
• Transport Canada recognized mountain-flying course when flying in mountainous terrain.
• Pilots sent to a survey who do not meet minimum requirements may be refused, with no chargeable hours logged.

2.3 Aircraft

Aerial surveys necessitate the use of aircraft that can operate safely at low speeds and altitudes, offer excellent forward and side-visibility, can carry 1-3 passengers, and have fuel capacities large enough to meet survey goals. In Alberta, virtually all surveys that rely on rotary-wing aircraft make use of the Bell 206 Jet Ranger (B model) or Long Ranger (L model) helicopters, fitted with bubble windows in the rear seats. The Bell 206 has a proven safety record, can carry 3 passengers plus their gear, is economical as compared to other turbine-engine helicopters, and is widely available. In order to maintain consistent sightability between years, all surveys in the province should utilize the Bell 206, whenever possible. While other helicopters such as the Hughes 500 have similar performance characteristics, they have not been as widely used and their use may make survey results incomparable to previous years due to differences in sightability between aircraft.

The aircraft provided will be a Bell Jet Ranger 206 or equivalent (equivalencies to be determined by the Departments designated survey lead) and will have installed rear bubble window with cooling vents. In addition to standard safety equipment required by Transport Canada, each helicopter used for aerial ungulate surveys must be equipped with the following specifications:

• GPS system: pilots must be fully trained on operation, including navigation and storage and retrieval of waypoints.
• Survival gear and first aid kit in accordance with Canadian Aviation Regulations 602.6.
• One crash position indicator of a type currently approved by Transport Canada.
• Each machine must be equipped with an ESRD approved automated flight following (AFF) compliant tracking device with capability for customer access to online tracking.
• Rear doors must be equipped with “bubble” windows.
• Long- range fuel extension (preferred).
• Portable fuel pump.
• Shoulder harnesses for all seats.
• 12-14 volt GPS plug-in.

• Four (4) high-quality headsets, David Clark Model H10-40 or equivalent, to accommodate positions of pilot, observer in front and two observers in rear seat; be complete with dual earpieces for noise reduction to at least FAA TSO C57 Cat. B; and come complete with an electric noise-cancelling microphone.
• Inter-communication capability among pilot and crew.
• In-dash FIRENET radio: ability to communicate on ESRD system.

2.4 Navigation

The lead observer (seated in the left-front seat in most helicopters and the right-front seat in most fixed-wing aircraft) is responsible for ensuring that the survey proceeds in an efficient manner, dead-head time is minimized, all SUs are searched at the appropriate speed and height above ground, and that search patterns follow provincial standards. The lead observer is also responsible for determining whether sighted animals fall within survey unit boundaries, and in most cases, also records all survey data, including the location of ungulate groups. In most cases, the lead observer will rely on a GPS unit (a separate unit from the pilot's GPS) and topographic maps of the study area and/or shapefiles loaded onto the GPS unit. The lead observer should discuss the basic flight route and survey plan with the pilot prior to the initiation of each survey day, to ensure that minimal time is spent dead-heading to and from SUs and fuel caches. The lead observer may also utilize a GPS unit linked to a laptop computer with GIS software installed; this allows real-time tracking of the aircraft position in relation to survey unit boundaries and may allow more efficient use of aircraft time than maps and a GPS alone. Recording the survey flight route on an on-board computer also helps to ensure that no survey areas are missed or surveyed more than once. Diligent use of a GPS unit, particularly those with mapping capabilities, can be used in place of an on-board computer, and have the added advantage of being less prone to software problems and tend to function more reliably during cold weather.

2.5 Data Recording

After safety and basic study design, recording accurate, quality data is the most important aspect of implementing aerial ungulate surveys. Data recorders must ensure that all data necessary for the analysis and interpretation of survey results are recorded legibly and in a manner that allows use by staff that were not present on the survey flight, or may use the data in the future and may not understand aspects of the survey that seem obvious to survey crew members. For an example of data sheets used by EMSD, see Appendix B – Data Sheets.

Currently, standardized survey data forms are not utilized in Alberta, however all surveys must record the following data:

• Date
• Flight start and stop times
• Personnel
• Weather (including temperature and wind speed and direction)
• Percent snow cover
• Aircraft type
• Survey type
• GPS location, herd size, and herd sex and age composition of all sightings of the target species within the sampling area

Variables that are part of the sightability model, such as percent tree cover and percent snow cover, may also be recorded. In addition, all sightings of rare or threatened species (such as sightings of caribou during moose surveys) or other observations of interest should be recorded as long as the survey for the target species is not compromised. Sightings of additional wildlife species which are threatened or endangered species are to be recorded separately in the Alberta Sustainable Resources Development Fisheries and Wildlife Management Information System (FWMIS) data base. A UTM coordinate and description of these sightings should be recorded.

2.6 Equipment

Listed below is the recommended equipment from the AUS Survey Protocol Manual.

Survey equipment
• Topographic Maps
• GPS with map capabilities, loaded with shapefiles of the survey area, transect lines and major landscape features to aid in navigation
• Spare GPS batteries
• Clipboards
• Survey data sheets
• Number 2 lead pencils
• Binoculars

Personal equipment

• Appropriate clothing (includes coveralls, snow pants, winter gloves and toque) and footwear suitable for spending a night in severe weather conditions at the time or location of the survey. Outer clothing should be dark to minimize reflection on aircraft windows.

• CSA approved footwear if participating in refuelling, transporting fuel, or assisting pilots with moving aircraft (e.g. moving helicopter into hangar).

• Safety glasses to wear when outside of the aircraft

• Polarized sunglasses to reduce glare (amber tint may be valuable for overcast days)

• Ear protection (headsets are usually provided by pilot)

• Anti-nausea medication (if required), to be provided by the individual

• A brimmed hat to provide protection from direct sunlight. Hats without a button on the top provide the least discomfort from headsets

• Adequate food and liquid for the day

2.7 Safety

Safety is of the utmost priority during all aerial surveys, greatly exceeding the need to collect data. Safety protocol for aerial surveys in Alberta exceed the scope of this document, however all survey staff should consult and be familiar with the safety procedures outlined in the Delegated Aerial Ungulate Survey Safety Protocol (Alberta Conservation Association and Alberta Sustainable Resource Development 2008).

3.0 CONDUCTING DISTANCE SAMPLING SURVEYS

The main objectives when conducting the survey are to ensure the detection function has a broad shoulder, that objects on the line are detected with certainty, and that animals are detected prior to movement in response to the observer, or their original position can be ascertained (Buckland et al.2001). The survey protocol described below expands on the topics covered in the AUS Protocol Manual in the 'Survey Standards' and 'Species Specific Guidelines' chapters, and is set up to achieve the goals mentioned above (McKenzie 2013).

3.1 Survey Methods and Timing

Distance surveys are conducted during winter (December-March) when sightability is highest due to leaf-fall and snow cover. Transect lines are flown with a Bell 206 helicopter travelling approximately 100 m above ground level at an average groundspeed of 80 kph. Height above ground and groundspeed will vary with terrain, forest density and snow cover. Areas with taller trees should be searched from a higher altitude to allow observation down into the vegetation. In the absence of good snow conditions when bare-ground may be present, the speed of survey aircraft may need to be reduced in order to ensure adequate sightability.

Distance surveys that include deer occur only in the southern, central and agricultural –dominated WMUs in the boreal portions of the province, where deer densities and recreational demand are highest and relatively sparse forest cover permits good sightability. Where accurate sex ratios or buck size classifications are needed, surveys should be conducted in December to ensure that bucks have not initiated antler drop. Moose are surveyed throughout the parkland, foothills, and boreal regions of Alberta and conducted during winter when snow conditions allow good sightability. Surveys should be conducted after hunting seasons, but before moose begin dispersing from distinct wintering areas that result in clear stratification. In most cases, surveys should occur from December-February, although March surveys may be acceptable during some years when moose remain in wintering areas during this period.

3.2 Sex, Age and Antler Classification Standards

The current standards Alberta currently uses for sex, age and antler classifications and descriptions were adopted from the Aerial-based Inventory Methods for Selected Ungulates: Bison, Mountain Goat, Mountain Sheep, Moose, Elk, Deer and Caribou (Ministry of Sustainable Resource Management 2002). For each species, there is a maximum of three sex classifications; female, male and unknown (Table 1). For each species there are a maximum of four age classes; young of year (YOY), reproductively immature (Juvenile <1yr old), reproductively mature (Adult) and unknown (Table 2). Antler classification is based on three different classes (Class I –III), with each species having varying criteria (Table 3).

Table 1. Recommended sex classification criteria for use in Alberta aerial ungulate surveys for white-tailed deer, mule deer, elk and moose. Sex terminology to be consistently applied and used for inclusion of data into FWMIS database.

Species	Sex	Description
White-tailed Deer **Mule Deer**	Unknown	• Smaller body size and visibly shorter nose, lacks antlers. • Lacks antlers, observation occurs following antler drop, unable to determine sex based on body size
	Female	• Medium size and no antlers • May be accompanied by fawns
	Male	• Larger body size, antlers present as a yearling
Elk	Unknown	• Smaller body size without antlers • Lacks antlers, observation occurs following antler drop, unable to determine sex based on body size
	Female	• Medium size and no antlers • May be accompanied by calves
	Male	• Larger body size, antlers present as a yearling
Moose	Unknown	• Smaller body size without antlers • Lacks antlers, observation occurs following antler drop, unable to determine sex based on body size
	Female	• Medium size, no antlers and short bell • Distinguished by white vulva patch • May be accompanied with a calf
	Male	• Larger body size, antlers present as a yearling

Table 2. Recommended age classification criteria for use in Alberta aerial ungulate surveys for white-tailed deer, mule deer, elk and moose. Age terminology to be consistently applied and used for inclusion of data into FWMIS database.

Species	Age	Description
White-tailed Deer Mule Deer	Juvenile (<1yr)	• Smaller body size and visibly shorter nose, lacks antlers
	Adult (female)	• Medium size and no antlers, may be accompanied by fawns
	Adult (male)	• Larger body size, antlers present as a yearling
	Unknown	• Lacks antlers, observation occurs following antler drop, unable to determine age based on body size
Elk	Juvenile (<1yr)	• Smaller body size without antlers • May accompany an adult female
	Adult (female)	• Medium size and no antlers, may be accompanied by calves
	Adult (male)	• Larger body size, antlers present as a yearling
	Unknown	• Lacks antlers, observation occurs following antler drop, unable to determine sex based on body size
Moose	Juvenile (<1yr)	• Smaller body size without antlers • May accompany an adult female
	Adult (female)	• Medium size, no antlers and short bell • Distinguished by white vulva patch, may be accompanied with a calf
	Adult (male)	• Larger body size, antlers present as a yearling
	Unknown	• Lacks antlers, observation occurs following antler drop, unable to determine age based on body size

Table 3. Recommended antler classification and description for white-tailed deer, mule deer, moose and elk. Antler classifications to be consistently applied and used for inclusion of data into FWMIS database.

Species	Classification	Description
White-tailed Deer and Mule Deer	Small	• Spike or 2-points on one or both antlers
	Medium	• Small to medium size antlers with 3 or more points/antler • Antlers inside ears
	Large	• Large antlers with 4 or >4 points/antler • Antlers outside of ears
Moose	Small	• Antler pole type, usually a spike or fork, if palmated, does not extend beyond ear tip
	Medium	• Antlers palmated, with spread < ½ of body length
	Large	• Antlers palmated, with spread > ½ of body length
Elk	Small	• Spike antlers or with light 1 to 2 point antlers
	Medium (or branch)	• Small antlers with 3 – 5 points per antler
	Large (or trophy)	• Large antlers with 6 or 7 points/antler, massive

All deer should be classified by species and as either juvenile, adult male or adult female (Tables 1 and 2). Mule and white-tailed deer can be readily distinguished based on coloration of the tail, with white-tailed deer having a characteristic white underside to the tail, which is often raised while running, and mule deer having a narrow, white tail with a black tip and white rump. Juvenile deer have a smaller body size and shorter nose than adults, and antlers are absent on both sexes. Adult females are of medium size with no antlers present, and are often accompanied by juveniles. Adult male are typically larger than females with antlers present. Antler-drop for deer begins mid-winter, so accurate sex ratios can be determined only when surveys are conducted early during the survey season in December.

Moose are classified as juveniles (< 1 year old, calf), adult females, and adult males (Tables 1 and 2). Juveniles have a noticeably smaller body size than adults, short nose/muzzle, in effect no bell and typically travel with an adult female. Adult females have no antlers, a short bell, and a distinct white vulva patch that is readily observed from the rear (Figure 1). Adult males lack the white vulva patch, and during early winter surveys often have antlers present. The small size and localized position of the vulva patch on moose requires that all antlerless moose are viewed from the rear in order to confirm sex. Moose will typically turn and run from a rotary-wing aircraft when the aircraft hovers near the moose, allowing a rear view of the animal. Circling a moose will often cause it to continually change position to face the aircraft, preventing the rear view that is necessary for sexing. Therefore, pilots must be capable and willing to hover safely when at nearly full weight capacity when conducting moose surveys. In addition, moose that remain bedded may need to be approached closely to force them to stand and allow sex classification. When a group of moose is encountered, the pilot may need to separate each individual from the group and pursue them independently in order to confirm sex. When antlers are observed, they should be classified as small when antlers are a spike, fork, or do not extend beyond the ear tip, as medium when antlers are palmated but have a spread of <1/2 body length, and as large when palmated with a spread >1/2 body length (Table 3). In addition to sex and age classifications, moose should be rated for intensity of tick infestation (Figure 2).

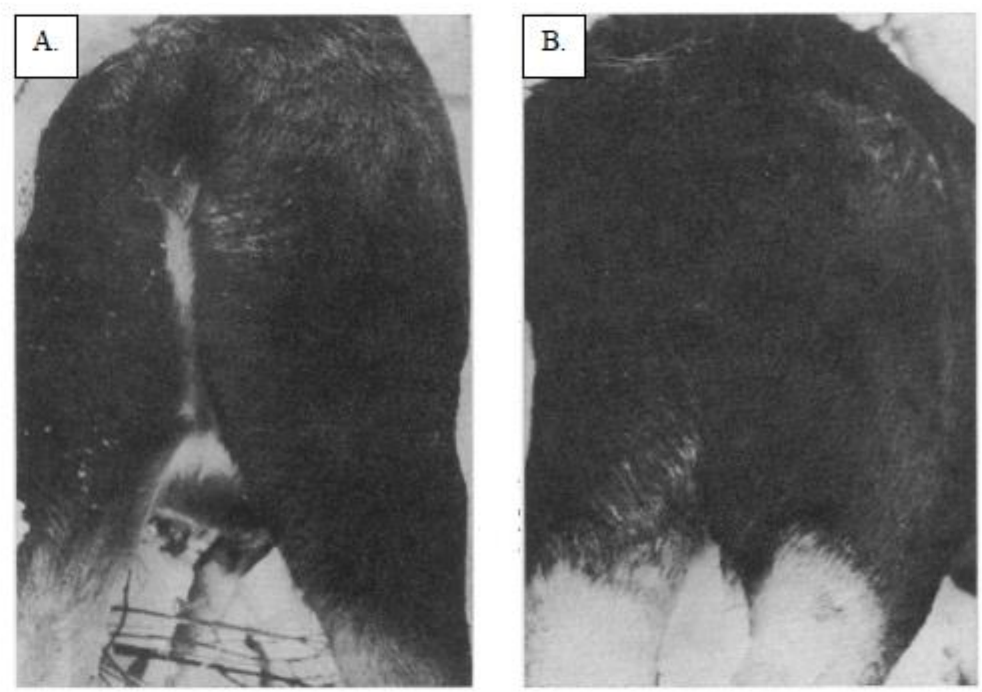

Figure 1. Photos of the white vulva patch on female moose (A) and the lack of a distinct white patch on male moose (B). From Mitchell (1970).

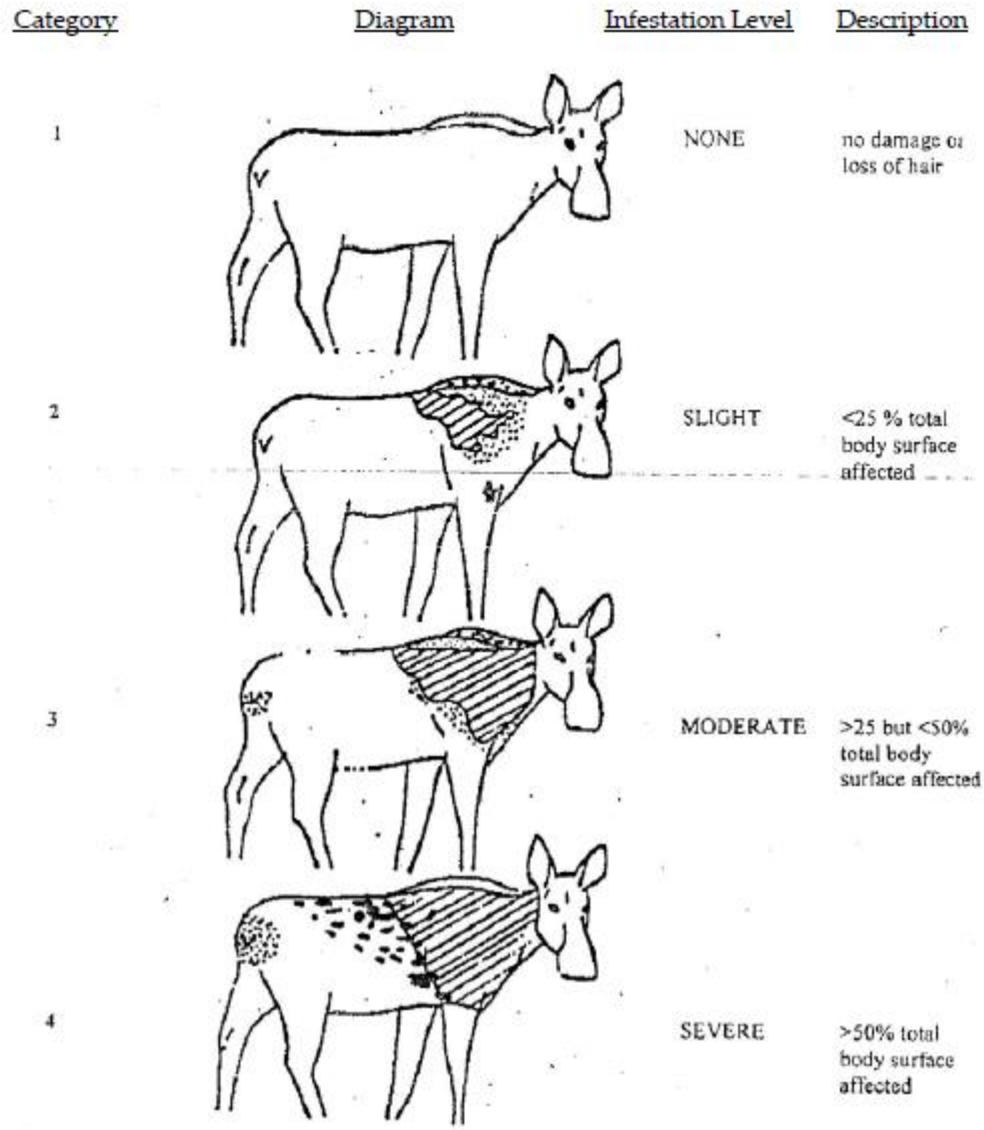

Figure 2. Tick infestation classification categories for moose during aerial surveys in Alberta.

3.3 Detections

The following describes the steps in collecting distance and cluster size data associated with detections. See Appendix C – Distance Survey Protocol Diagram.

3.3.1 Recording detections

Once an animal or cluster of animals is observed from the transect line, a waypoint should be collected immediately. In addition, the location of the cluster at the time of initial detection should be landmarked, and the remaining portion of the transect line should be flown until the flight path is perpendicular to the cluster to avoid missing other detections. Once perpendicular to the cluster the helicopter leaves the transect line to collect a second waypoint as close to the cluster position as possible. The perpendicular distance between these two points represents the distance from the transect line. For example, if transects are oriented north-south, the difference in the easting (UTM) will provide the perpendicular distance to the cluster. While the transect line can be used to calculate the distances in GIS after the survey this is not advisable. It is important to maintain course on the transect line. Further it is important to use the original juxtaposition between the aircraft and the animal group at the time the group observation was first made. For groups of more than one animal, the location should be the estimated geometric center of the group. For example, in a group of 2 the midpoint between the two animals would be the location of the waypoint. While not recommended, flying survey designs where transects are oriented in directions other than cardinal directions will require more sophisticated post-processing than the examples recommended here. If this is the case, refer to the Distance manual for direction (Thomas et al. 2009).

It is important to obtain an accurate count of the animals in the cluster. While turning on groups, all animals within a specified distance can be included in a cluster. Criteria for the distance from the original observation within which newly observed animals are counted within the group should be established beforehand. Based on past experience, we recommend 50 m for moose, and this distance is likely appropriate for other species as well. It is important to establish the acceptable distance prior to flying the survey to avoid the introduction of bias.

Distances should be exact. Therefore, avoid the temptation to express animals that appear to be ‘directly below the aircraft’ using an interval approach, for example 0 m, 10m etc. This is particularly important for the front left observer. Distances can be deceiving from the air and they are often underestimated. In addition, estimates are affected by a number of factors and are highly variable between observers. Although recording data based on distance bands is acceptable (Buckland et al. 2001, p. 259, and see discussion below), the use of an impromptu interval technique can lead to heaping at 0 m, which is difficult to correct during the analysis phase and makes model fitting difficult. Therefore, distances to all clusters should be measured exactly and be accompanied by GPS coordinates from the line transect and from the center of the detected cluster.

3.3.2 Avoid including new detections made while off-transect

Following a detection from the line transect, the flight path is continued until the aircraft is perpendicular to the detected cluster in order to minimize the frequency of off-transect detections of animals that were not visible from the line transect. However, in the rare cases where new detections are made while off-transect, common-sense should be used to include individuals that would likely have been observed from the line transect. If uncertainty exists, the aircraft can return to the transect line to assess sightability. If uncertainty still exists, then the observation should be recorded, but omitted from analysis. While it is foreseeable that error may be introduced with the subjective nature of this method, previous experience suggests that it is uncommon and therefore unlikely to result in significant error in density estimates, even at relatively high densities. This source of error should be more carefully considered, and perhaps addressed, in species like deer that exhibit more clustered distributions and occur at higher densities.

3.3.3 Avoid gaps in coverage of the line transect

Once all detections have been recorded and classified, it is important that the aircraft returns to the transect line previous to the point where the detection was made. This will avoid missing new animals while re-establishing the trajectory of the line transect. New detections made while on the line transect, but prior to the point for which the last detection was made should be recorded but omitted from the analysis. In low density units it may be advantageous to classify these groups, but they should still be omitted from the analysis to estimate the population density.

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APPENDIX A - Distance Sampling Method

This Distance Sampling Method below is an excerpt from the unpublished report 'Aerial Ungulate Survey Guide Distance Surveys' developed by Hannah McKenzie in 2013.

While distance methods can also be applied to point sampling, line transect sampling is the most appropriate method for surveying ungulates. In line transect sampling, a survey area is sampled by placing a number of lines at random or systematically in the area. An observer then travels along the line and records the animals detected and their distance from the line. If animals occur in clusters, then detections refer to clusters rather than individuals, and the cluster size is also recorded. It is assumed that all animals on the line are detected, but that detection probability decreases with increasing distance from the line. Therefore, it is not necessary to detect all animals. The distribution of distances is used to estimate the proportion of clusters detected, which in turn allows for the estimation of animal density and abundance in the study area. Data collected using distance sampling are analyzed using the freely available software Distance (Thomas et al. 2009).

In order for the distance sampling method described above to provide an unbiased estimate of density and abundance, the following key assumptions must be met (discussed in further detail in Buckland et al. 2001, p. 29-37):

1. *Objects directly on the transect line are detected with certainty.* Buckland et al. (2001) emphasize the importance of ensuring that this assumption is met. If animals on the line are missed, density will be underestimated. They also recommend against the approach of having one observer dedicated to 'guarding the centerline', as it can lead to a distribution of distances with a spike a zero, which makes it difficult to reliably model the detection function. However, previous distance surveys in Alberta have had good results using this approach for the front left observer and only in the context of pooling observations from all three observers in an aircraft[1].

2. *Objects do not move.* Ideally, distance sampling considers a 'snapshot' in which animals are frozen and then distances and cluster sizes are measured. However, in practice movement of animals does not cause problems unless the animal is detected multiple times along the same transect, if it is moving half the speed of the observer or faster, or if its movement is not random with respect to the observer. For example, if animals tend to move either away from or towards the observer, and it is not

[1] The potential bias of this approach will need to be carefully considered in those analysis designs that include stratification by the observer (i.e. different detection function for each observer) or where varying effort occurs across survey aircraft.

possible to ascertain their original location. In all cases, distance measurements should be taken based on the animal's original location.

3. *Measurements of distances and cluster size are exact.* Care must be taken to ensure the coordinates of the transect line and the observed animal group are as accurate as possible. It is particularly important that measurements near the line are not consistently rounded to zero, potentially causing a spike, which results in an overestimate of density.

In addition to the above assumptions, the objects must be randomly distributed with respect to the transect lines, and detections of clusters are assumed to be independent events. It is not necessary for objects to have a Poisson distribution (Buckland et al. 2001, p. 29) and the analysis methods are robust to non-independent detections, particularly if empirically based estimates of sampling variance are used (Buckland et al. 2001, p. 36). Finally, distance sampling theory performs best when the detection function has a 'shoulder' near the line. This means that detection is certain on the line, almost certain close to the line, and decreases with increasing distance from the line. If the distribution of distances falls off sharply near the line, estimation tends to be poor (Buckland et al. 2001, p. 36).

The success of the distance sampling method relies on a valid survey design, an adequate sample size, and proper field methods. We consider each of these in the following sections.

Sample Size and Total Transect Length

In distance sampling, the sample size is the number of clusters encountered. A cluster is a group of animals, with a single animal constituting a group of one. For the distance method, it is the absolute sample size that matters, not the fraction of the population being sampled. Once the target sample size is determined, this can be translated into a total transect length necessary to survey. Several factors will affect the sample size and total transect length, including desired precision, population density and distribution, expected encounter rate, and expected cluster size. These are discussed in detail in Buckland et al. (2001) and Guenzel (1997), but we briefly review considerations for each of these factors here.

Desired precision

The desired precision is a major determinant of sample size. Adequate sample size is important for estimating the shape of the detection function. In addition, variation in encounter rate between lines typically accounts for a large proportion of variation in the density estimate, and therefore affects the precision of the estimate.

Population density and distribution

Adequate sample sizes are easier to obtain for a given amount of effort when population density is higher, as animals are encountered more frequently. Stratification or exclusion of very low density areas (essentially unoccupied habitats) from the study area may help. When encounter rates are lower and more variable, larger samples are required in order to encounter a sufficient number of clusters to meet sample size requirements for a given level of precision. While very high densities may require extremely low survey effort, in these instances care should be taken to ensure that the random sample is spatially representative of the survey area. The risk of a randomly generated sample providing poor spatial coverage is increased for low survey effort. This risk can be reduced by increasing survey effort and/or having using shorter transects.

Variation in cluster size also increases variation in density estimates. For populations with smaller clusters, the encounter rate may be higher (e.g. given equal densities for both species, encounter rates for moose will be higher than for deer). However, the smaller clusters may be more difficult to see, leading to sightability concerns. If the distribution of clusters is highly clumped, more sampling may be required to estimate the population within the required level of precision. This relates to the encounter rate considerations mentioned above.

Buckland et al. (2001) suggest that the sample size should be at least 60-80 clusters to reliably estimate the detection function. However, if the population is highly clustered, or the variance in cluster size is large, the sample size will usually need to be larger to obtain similar precision.

If something is known about the population to be surveyed, Buckland et al.(2001, p 240-248) provide several methods for estimating the sample size and total transect length required in order to achieve a desired level of precision. In addition, based on data from Gasaway pre-stratification flights in Alberta and previous distance surveys, a model has been constructed to estimate the total transect length needed to encounter a given number of clusters as a function of expected density. This model will continue to be refined and expanded to other species (e.g. mule deer and elk).

Survey Design

As with all surveys, distance sampling designs must appropriately address replication, randomization, sampling coverage, stratification, and sampling geometry. We briefly review these principles in the context of distance sampling below.

Replication

Multiple transects should always be used as opposed to a single long transect. This is necessary to estimate empirical variance in encounter rates between transects and to construct confidence intervals. At a minimum, 10-20 transects should be surveyed (Buckland et al. 2001, p. 232). If you plan on constructing bootstrapped confidence intervals, which provide better coverage and enable the incorporation of model selection uncertainty into the precision estimates, surveying more transects is advised.

Randomization

Buckland et al. (2004, p. 191) strongly advocate for using automated design algorithms to design surveys. They have found that subjective designs, and even random designs that have been modified for practical reasons, do not always provide even coverage probability and can introduce a surprisingly large bias into the results. Random or systematic designs may be appropriate depending on several factors including the expected density and encounter rate in the study area, the shape and size of the study area, and the geographic variability or gradient of factors across the study area that may affect the encounter rate. Buckland et al. (2001) concludes that both approaches provide similar precision, although systematic may provide better precision in some cases. The foremost advantage of a randomized approach is that it is possible to evaluate the precision of your estimate at any level of sampling effort, as long as the random seed order is adhered to.

Sampling coverage

Standard distance sampling analysis methods assume that all parts of the study area have equal probability of being sampled (Buckland et al. 2001). More, shorter transects provide better spatial coverage over less, longer transects. Designs with non-uniform coverage can still be valid, but require special analysis to correctly account for this. Therefore, we recommend against creating designs with non-uniform coverage, with the exception of stratified designs.

Stratification

Stratification provides a method for improving precision and also enables estimates to be obtained for smaller areas within the overall study area which may be of particular interest to managers. Stratified designs are best implemented if the survey unit is stratified based on anticipated densities. The intent of stratification is to account for variability in the encounter rate between strata. Without the advantage of a pre-stratification flight, stratification may be based on expected differences in density due to habitat type (e.g. ecological subregion) or sightability (e.g. agricultural versus forested). Stratification by dividing the survey area into discrete areas rather than assigning transects to strata is preferred to maintain the ability to scale the relative densities to a population estimate. Buckland et al. (2001, p. 234) caution against over stratifying, as gains in precision will only be great when density differences between stratum are large. There is also a risk that precision will be reduced if the density during the survey does not match the estimates used for sample allocation between the strata. In addition, adequate sample sizes within each stratum must be obtained to allow for reliable estimates of abundance. Buckland et al. (2001, p. 234) suggests that if little is known about the densities within each strata, samples should be allocated based on stratum area. If densities are known, Buckland et al. (2001, p. 247) provide some guidance on optimal allocation of sampling effort between strata. It is also possible to use post-stratification to investigate other questions of management interest.

If there is little information to inform the stratification, it is often best to avoid stratification. A survey design with no stratification is often better than poor stratification. It may require slightly more flying to achieve precision but this is considered a more conservative approach.

Sampling geometry.

The transect layout depends on the study area, the efficiency and logistics of data collection, and the knowledge of density gradients or patterns within the study area. There are many options for transect layout (Buckland et al. 2001, Buckland et al.2004). The current approach in Alberta is to use a simple random sample of 10 km north-south (preferably) or east-west transects that appropriately addresses edge effects. In some cases, for example in small stratum or geometrically complex study areas, a systematic approach may be more appropriate. Transects layouts can be generated in ArcGIS.

Data Analysis

Data collected using distance survey methods are analyzed using the freely available software Distance (Thomas et al, 2009). As there is no 'cookbook method' for analyzing this type of data, we follow the flexible strategy for analysis recommended by Buckland et al. (2001, p.48) and also discussed in Thomas et al. (2010). This strategy has 3 phases: Exploration, Model Selection, and Final Analysis & Inference. We briefly highlight the main steps in each phase here.

Exploration

Starting this phase while the data are still being collected allows for early identification of any issues with data collection and provides an opportunity to fix these. The goal of this phase is to understand the data and to prepare the data for modeling by selecting the appropriate truncation points and groupings. A good approach is to create histograms of the data using 10-20 groups so as to get a good picture of the distribution of observed distances. Look for evidence of heaping, evasive movement, “guarding the line”, and outliers. Buckland et al. (2001) recommend right-truncating 5-10% of the largest observations, even if there are no obvious outliers. These observations contain little information about density and will create difficulties in model fitting. However, due to the potential effects of sightability throughout the data, we suggest only truncating if obvious outliers exist. During this phase, do not worry about fitting any particular model, but focus on understanding the data.

Model Selection

This phase begins once the data are appropriately right-truncated. Consider fitting several robust models. Examine the resulting output for each model and apply the tools of model selection to objectively choose the best model for the data, for example goodness of fit tests and AIC. Recall that the fit near the transect is the most important, so favor models that fit the ‘shoulder’ well over those that do a better job fitting the tail. This process may be iterative, with results suggesting other choices of truncation or groupings.

During model selection, keep in mind the principal of Occam’s razor. In the case of competing models, choose the simplest model, unless a more complex model provides an appreciative increase in explanatory power.

Final Analysis & Inference

Once the best model for the data is selected, proceed with obtaining estimates for density and abundance, as well as measures of precision for these estimates, including the coefficient of variation and confidence intervals.

Reporting Survey Results

Systematic reporting of results is essential to ensure that the appropriate data are present to critique and interpret the analysis, to facilitate comparisons with previous and subsequent surveys, and to provide data to help replicate or improve surveys (Guenzel 1997, p. 121). In addition, reporting on cost and flight time is useful for planning future surveys. The above information for all ungulate surveys done in Alberta using the distance sampling method should be summarized including (1) the raw data obtained during the survey, (2) the results of the analysis using Distance, including the final estimates and measures of precision, and (3) the cost and flight time. The raw data, as well as analysis, and final report should be submitted to FWIMS.

Interpretation of Distance Estimates for Density and Abundance

As with all survey estimates, density and abundance estimates obtained using distance sampling methods are subject to error and uncertainty. Distance sampling methods have been found to work well where surveys are properly designed and constructed, and where sample sizes are adequate. However, results are more variable in small, low density areas where sample sizes are small, or errors were made during data collection or analysis (Guenzell, 1997 p. 11). Therefore, managers should evaluate the acceptability of the density estimates in the context of the Distance output and other available management data.

APPENDIX B – Data Sheets

WILDLIFE SURVEY FORM –Daily Cover Sheet

IMPORTANT: NAVIGATOR MUST RECORD!!

Please complete clearly and carefully. Fill out one of these forms for each day of the survey no matter how short the flight (e.g. if you take off and are forced to return to base without actually surveying). We need this information. Fill in the blanks and circle the appropriate answer for the rest.

DATE:_________________ GENERAL AREA:____

PILOT:_________________ AIRCRAFT:________________ REGISTRATION:________________

NAVIGATOR:____________________ OBSERVING? YES NO Sometimes

OBSERVERS: Left Rear:______________________ Right Rear: ________________________

Estimated Meteorological variables

	Temp (°C)	Wind (kph)	Wind Direction	Tenths Cloud	Visibility	Visibility categories
START						E - Excellent
NOON						G - Good
FINISH						F - Fair
						P- Poor

AVERAGE ALTITUDE (m):____________(m=3.28 ft) AVERAGE AIRSPEED (kph): __________(mi = 1.61 km)

SNOW COVER: _________ Options: POOR – ground not completely covered by snow
GOOD – all ground covered by snow
EXCELLENT – fresh snow covering ground but not on trees

TYPE OF SURVEY: Antelope Deer Elk Goat Moose Sheep Other__________

SURVEY METHOD: Quadrat (circular or transect) Straight Line Transect Drainages Watercourses Random Distance

CREW RATING: Pilot: ________ Navigator:_________ Left Rear:_________ Right Rear: __________
A: Experienced – current (has observed within last two years)
B: Experienced – not current (longer than two years)
C: Inexperienced – (has never observed before)

Record times left to right.
TAKE OFF: ____________ LANDING: ___________ TAKE OFF: ____________ LANDING: ___________
TAKE OFF: ____________ LANDING: ___________ TAKE OFF: ____________ LANDING: ___________

TOTAL DEADHEADING TIME (base to area; area to base):__________ + TOTAL BETWEEN QUADRATS: __________ + TOTAL ON QUADRAT: ____________ = TOTAL FLYING TIME FOR DAY:______________

COMMENTS:

Observation Sheet

WMU:	Transect(s):	Date:	Page: of:
Start time:	End time:	Aircraft/Notes:	GPS Id:
Temp: Precip:	Cloud cover %:	Light intensity: Flat Bright	Snow Cover: L M H
Front Right:	Front Left:	Back Right:	Back Left:

			Obsevation Details										
				Male Antler Size									
Transect	WPT on Line	WPT on Group	Species	N/A	Small	Med	Large	Female	YOY	Unk.	Seen by (FR, FL, BR, BL)	Activity	Other
												B S M	
												B S M	
												B S M	
												B S M	
												B S M	
												B S M	
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YOY: young of year (calf or fawn)
Activity (when first observed): B = Bedded, S = Standing, M = Moving

APPENDIX C - Distance Survey Protocol Diagram

Steps (see Fig 1):

1. Begin flying the transect line and searching for animals:

Aircraft Roles (see Fig 2):

- Front left (FL) observer is responsible for navigation and observing all parts of the transect visible through the floor and in the central periphery of the left window. Effort should be restricted to within 50 m on either side of the transect line.
- Rear Left (RL) and Rear Right (RR) observers focus only on the area further than 50 m on either side of the aircraft.
- Pilot is responsible for flying the aircraft. The pilot should only point out animals once it is clear they were missed. These animals can be classified, but should not be included in the distance survey analysis.

2. Once an animal/group of animals is sighted:

- Take a waypoint immediately (LineWPT) and record this waypoint name on the datasheet.
- Landmark the group location (prior to any movement if possible).
- Continue flying and searching until the aircraft is perpendicular with the animal/group location.

3. Once perpendicular with the animal/group, leave the transect, fly over and:

- Take a waypoint at the geometric center of the group (GrpWPT) and record this waypoint name on the datasheet.
- See Fig 3 for how LineWPT and GrpWPT are used to calculate the distance.
- Count the number of animals in the group (include all animals within a predetermined distance, 50 m suggested, as part of the same group).
- Record sightability covariates within 10 m of where first animal seen was standing (see Fig 4 for canopy cover classification).

4. Once all observations are recorded:

- Return to the transect line earlier than where you left it and continue searching for animals. Only record those animals that you observe after passing the point where you left the line. Other animals seen may be noted, but do not include in distance analysis.

Fig 1: Survey steps.

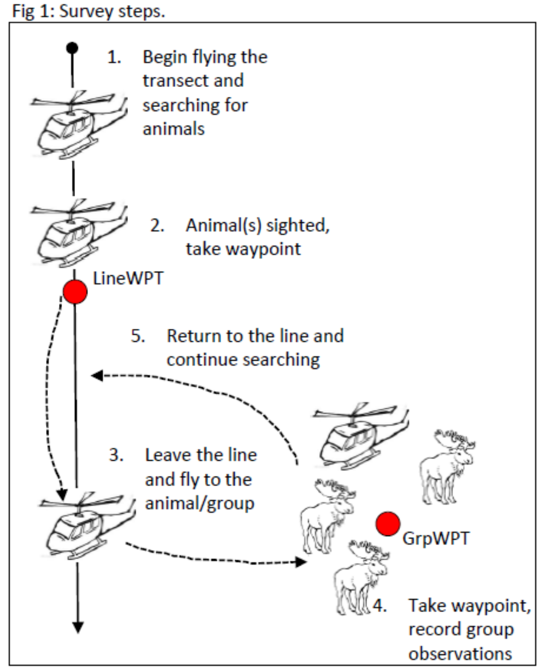


Fig 2: Aircraft roles.

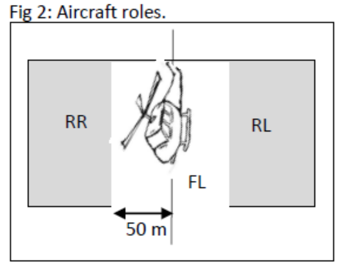


Fig 3. Canopy classification guide (based on area within 10 m of first animal seen).
(Christ, A. 2011. Sightability Correction for Moose Population Surveys, Appendix E. Alaska Department of Fish and Game, Division of Wildlife Conservation. Anchorage, Alaska.)

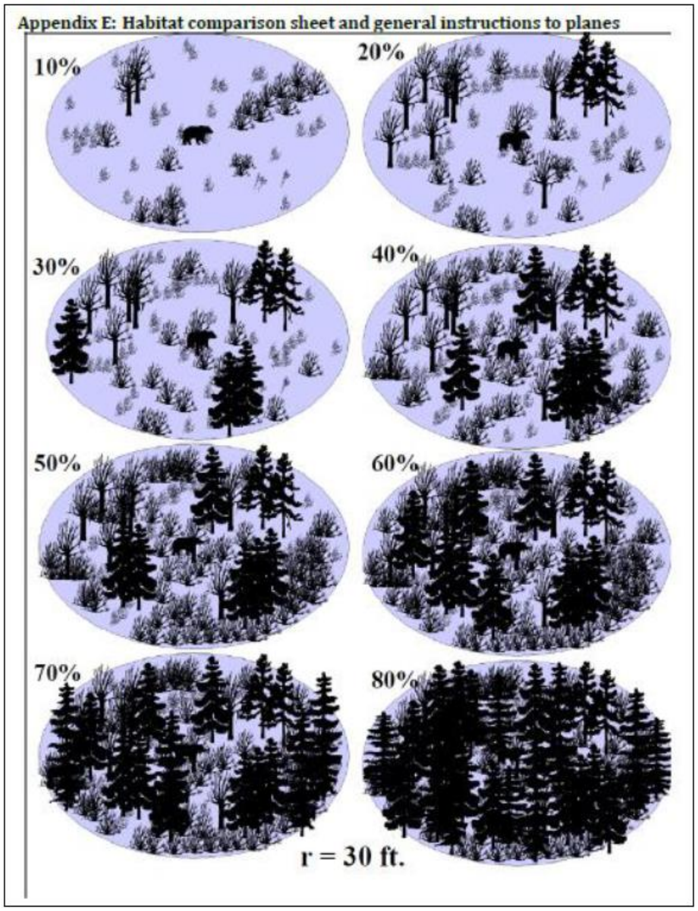
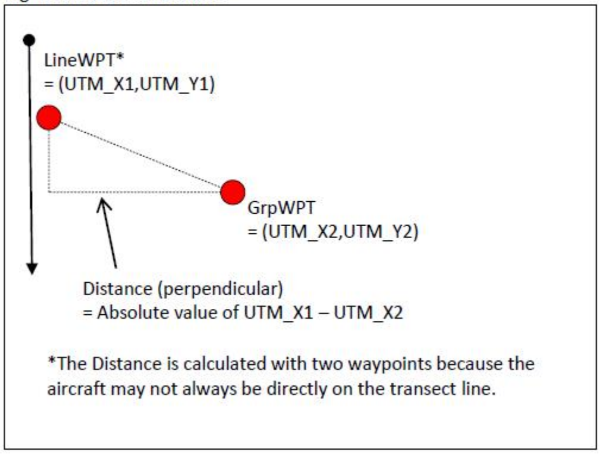


Fig 4. Distance calculation.



Other notes:

- As much as possible ensure that all animals directly on the transect line are detected.
- Distances should be exact. Avoid the temptation to classify distances near the transect line 'by eye'.
- Avoid including new detections made while off-transect. If you see an animal after you've left the transect line, use your discretion as to whether to include it or not, based on whether or not it would have been visible from the transect line.
- Avoid gaps in the transect by returning previous to where you left off. New detections prior to the point of the last detection should be recorded, but not included in the distance survey analysis.
- For more details, see the Distance chapter of the Aerial Ungulate Survey Protocol Manual (currently in draft).