University of Alberta

Use of Sightability Models and Resource Selection Functions to Enhance Aerial Population Surveys of Elk (*Cervus elaphus*) in Alberta

by

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ABSTRACT

As part of the Central East Slopes Elk Study (CESES), this project was meant to provide meaningful elk population estimates to enhance current wildlife management. Using radio collared elk, a sightability model was developed to correct for elk missed during aerial surveys. During trials, if a radio collared elk was observed, 11 factors were recorded: light intensity, aspect, activity, topography, percent vegetation screening, vegetation class, percent snow cover, elk group size precipitation, temperature and observer experience. If the elk was not observed, the survey crew used telemetry receivers to locate the elk and record the same factors. A logistic regression approach was used to develop a correction based on environmental factors that affected sightability. Significant variables affecting sightability were, elk group size, percent vegetation screening, elk activity, percent snow cover and light intensity. Survey design can also increase precision of population estimates. When there is high spatial variation in animal numbers, spatial stratification is one approach by which the precision of estimates can be increased. This study compared a typical stratified random sample design using tree canopy for stratification to a stratification approach with strata using GIS-based covariates. This approach assumes that sample units with similar environmental covariates will have similar elk densities. GIS- based covariates were used to develop a winter elk resource selection function (RSF). The mean RSF value in each survey cell was used to post-stratify the survey cells for improved precision of the population estimate.

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CHAPTER 1

HISTORICAL PERSPECTIVES AND COMPARISONS OF AERIAL UNGULATE SURVEYS IN ALBERTA

1.1 Introduction

The Fish and Wildlife Policy for Alberta states, "the primary consideration of the government is to ensure that wildlife populations are protected from severe decline and that viable populations are maintained" (Alberta Fish and Wildlife 1982). In the last two decades there is increasing human pressures on elk (*Cervus elaphus*) populations by recreational hunting, disturbance from viewing, photography and general recreation, competition with cattle, and habitat changes from industrial development (Alberta Environmental Protection 1997, Nette and LeBlanc 1985). About 90% of the Clearwater Forest, the area addressed in this study, has been allocated to the timber industry. There were over 1,500 gas and oil well sites built from 1983 to 1997. In 2001, 117 miscellaneous leases (mostly oil and gas well sites), 118 roads, and 130 pipelines were constructed which directly impacted over 1,000 hectares (E. Finlay pers. comm.). Yet, even with an overall decline in hunters in Alberta, the demand for elk licences has increased from about 20,000 hunters in 1995 (Alberta Fish and Wildlife 1995) to over 40,000 Alberta residents applying for 7,963 elk hunting permits in 2003 (Alberta Sustainable Resource Development 2004). With the general elk tags, a total of 25,500 elk hunting licenses were purchased in 2003. These hunters put in over 158,000 days of recreation in pursuit of elk.

Because of these pressures, accurate population estimates through time are necessary to monitor ungulate populations changes and to adjust harvest management to meet the overall objectives of the Fish and Wildlife Policy for Alberta. Although recent studies have provided basic information on elk ecology in the eastern foothills and boreal forest of western Alberta (Morgantini and Hudson 1979, Morgantini 1979, 1988; Gates and Hudson 1983; Morgantini and Russel 1983; Jones 1997), knowledge of elk population sizes has been limited (Jones 1997). Aerial surveys have become common for population surveys of large animals and methods have been studied extensively to recommend standard techniques and protocols that minimize observer bias (Buechner et al. 1951; Petrides 1953; Edwards 1954; Siniff and Skoog 1964; Lovass et al. 1966; Jolly 1969; Caughley 1974; Laresche and Rausch 1974). For example, it has been found that snow cover, height above the ground, aircraft speed, observer fatigue, and time of day influence survey results and need to be standardized in aerial counts (Gilbert and Grieb 1957, Graham and Bell 1969, Caughley et al. 1976, Norton-Griffiths 1976). Some influencing factors can be standardized through survey protocol, but factors related to environmental conditions and group sizes of animals vary between years and can bias population estimates (Jolly 1969, Caughley 1974).

The history of aerial surveys in Alberta has shown several attempts to address the accuracy of population estimates. The first intensive aerial survey of game animals in Alberta was conducted in the winter of 1954 when random searches of wintering areas obtained counts of elk herds in south-western Alberta (Webb 1959). These surveys were intended to provide minimum count data to determine population trends. To determine actual population densities, the first aerial strip transects were flown in 1956 in the

Clearwater Forest to sample moose populations, with total count data obtained from 100 yard wide strips flown in widely spaced parallel transects. Similar approaches were used to survey deer in Alberta's parkland areas and antelope in the prairies. In all cases, statistical confidences in these estimates were not calculated. From 1966 to 1972, strip transects were flown for deer in the aspen parkland near Pine Lake with fixed wing aircraft. Six transects totaling 30.92 km^2 were flown and data were combined to give average deer densities. Again, no statistics for accuracy or precision were calculated. Because of survey costs, only the areas of highest deer densities were sampled even though densities ranged from 0.4 deer/ km^2 to 8.2 deer/ km^2 among transects in the same year. These densities were extrapolated only to the best deer habitat in the study area based on tree cover derived from aerial photographs to provide a population estimate for "deer range". No population estimates were made for areas that were considered less than optimal deer habitat.

In 1962, a block survey design was first used in Alberta to provide population estimates for deer (Webb 1966). While a block design has the potential of providing less variable estimates than the strip transects because they typically are larger, contiguous areas, they too were selected only in areas of good ungulate habitat, not at random nor within strata, thereby providing a biased estimate of animal numbers across the entire landscape. Wishart (1966) noted that large variation in deer counts in both block and transect surveys occurred from year to year because of varying snow depths affecting distribution in the survey area. The counts ranged from 2.4 deer/ km^2 in 1964, a year with low snow fall, to 5.2 deer/ km^2 in 1965 in a high snow fall year. However, he did not quantify snow depth in either year. Wishart (1966) also reported that deer surveys conducted from 1963 to 1966 in the block design were unsatisfactory because of sightability problems associated with varying levels of light and snow in the foothills. He made no mention of other potential sightability factors such as vegetation. In 1972, to determine the sightability of deer, a helicopter was used to repeat counts taken from fixed wing survey on two transects. Counts from the helicopter indicated that observers in the fixed wing survey missed 23% to 55% of the deer (Lees 1973). In 1978, a further development in survey protocol was proposed by Jacobson and Cook (1978) to standardize deer and moose surveys in the province. Random selection of 2.56 km^2 sampling blocks without replacement within habitat strata was recommended for the standard design because it was felt quadrats provided better density figures than strip transects due to observer bias in estimating distances. Stratification was based on habitat features, primarily tree cover for white-tailed deer, but there was adjustment for treeless riparian areas for mule deer. To estimate the number of survey units for sampling a power curve was used to determine sampling needed to achieve confidence intervals of ± 20% at the 95% level. (Jacobson and Cook 1978).

Jacobson and Cook (1978) also proposed an approach to correct for observer bias in detecting animals. The sightability correction was devised by placing one observer behind another in the aircraft, with the second observer recording those animals that the first observer missed (Jacobson and Cook 1978). This "front-back" approach assumed that (1) each group observed is a separate group from all other groups and the visibility bias is calculated for each observed group size, (2) if one member of a group is observed, the entire group is observed with certainty, (3) the distribution of the group numbers per quadrat follows a Poisson distribution. Sightability was calculated separately for each group, with sightability for the k^{th} sub-population being the probability, P_k, that a group of size k is missed. Ratio data from both observers are used to estimate P_k and to produce adjusted estimates of the average number of groups (λ) of size k per quadrat (Jacobson and Cook 1978). This approach provided adjusted estimates for white-tailed deer with confidence intervals (CI) $\pm$ 15%, but with the clumped distribution of mule deer estimates had wider CI ($\pm$ 44%). The disadvantage of the "front-back" observer sightability method is that when observers are on the same side of the aircraft twice the effort is required to cover the same area as with two different observers on opposing sides. The "front-back" method alone also does not account for the environmental factors, such as tree cover and snow cover, that would cause both observers to miss animals (Cook and Martin 1974, Caughley 1974, Cook 1982, Pollock and Kendall 1987). Further, it assumes that if a group is observed, then all members of the group are observed. However, Cogan and Diefenbach (1998) found that helicopter survey crews consistently undercounted elk group sizes during surveys, even on repeated counts.

Because Jacobson and Cook (1978) randomly sampled within a stratified landscape, and they attempted to correct for differences in observers locating animals, their approach was considered an improvement over past surveys and was continued, without the "front-back" sightability, in the agricultural areas where square quadrats could be easily located using fence lines and surveyed roads. Because of the lack of obvious topographic or anthropomorphic features for navigating, this survey approach has not been continued in forested areas of the foothills and boreal forest (Froggatt 1989). Instead, a modified Gasaway survey design was developed for forested habitats in northern Alberta. Gasaway (1981) developed a stratified random design in Alaska, where sample units were stratified by moose density during calibration flights. The calibration flights consisted of widely spaced line transects being flown prior to the surveys and observers making a subjective evaluation of moose densities based on observations and moose sign. Although Gasaway (1981) based his sample units on landscape features, because landscape features in the forested area of Alberta were difficult to navigate, the Gasaway system was modified to sample survey units based on latitude and longitude lines creating blocks. This simplified navigation for easier survey layout in large areas of contiguous habitat (Lynch and Schumaker 1995). Using the Gasaway approach and a 90% precision level, Lynch (1997) found the confidence intervals ranged from 15% to 25% of the mean in the 1996/97 moose surveys in the boreal forests of northern Alberta (Lynch 1997).

The Gasaway approach also incorporated a correction for sightability. Sightability correction was estimated by repeat surveys of portions of a sample unit at an intensive rate immediately following the survey. The general survey rate was 1.6 minutes per square kilometer and the intensive rate was 4.7 minutes per square kilometer. It was recommended that about 20 intensive survey plots of approximately 5 km^2 would be flown to develop the sightability ratio. A population estimate and variance in each stratum was summed to obtain a study area population estimate and the finite population correction factor (1- n/N) reduced the variance as the sample size increased. The ratios from the two surveys, and an assumption that 97% of all the animals (typically moose) were seen during the intensive search, were used to correct survey counts. This assumption was based on a trial in Alaska where 97% of radio-collared moose were observed in an area where intensive sampling was conducted at approximately 4.4

minutes per square kilometer. Using this approach, Lynch (1997) found sightability corrections ranged from 1.0 to 1.11. Lynch (1997) did some intensive surveys in an area with radio collared moose and adjusted the number of moose seen by observers on the intensive survey to 100% because all radio-collared moose were observed. Most moose in northern Alberta are found in muskeg, which consists of little vegetative cover and therefore this approach would not apply to animals in more heavily forested area.

Lynch's approach was modified for surveying ungulates in Alberta's White Zone, which consists of parkland and prairie habitats (Glasgow 2000), by stratifying the area based on habitat features and using sample units of 3x3 latitude/longitude degree units or 3x5 degree units. In 36 survey areas, CI ranged from 13% to 116% (mean = 26%) at 90% confidence level which was similar to the CI found when using the Jacobson and Cook (1978) method (i.e. 27%) for white-tailed deer estimates in Alberta's parkland (Cook 1982). Because the large survey blocks that were plotted by latitude and longitude were easier to navigate, Glasgow (2000) recommended this survey system as the standard for deer and moose in Alberta. However, survey areas with low populations of mule deer, which were distributed in large, clumped herds provided confidence intervals of 40% to 135%.

While survey approaches in Alberta have progressed through several improvements for moose and deer, there has been little effort in improving elk surveys since 1954 when the first random searches of wintering areas obtained minimum count data of elk herds in southwestern Alberta. Winter ranges were picked for trend surveys primarily because elk often concentrate there in winter and extensive tree cover limits visibility of elk in much of the area they inhabit. As winter ranges became identified, the general approach to surveying elk has been to consistently survey important winter ranges. For example, in the Clearwater Forest over 100 winter ranges have been delineated. The Alberta Fish and Wildlife Division has been monitoring elk on a subset of the winter ranges with aerial surveys since 1974 to obtain a minimum count or trend data. In 1985, elk surveys were revised to include only 23 of the most heavily used winter ranges (Bighorn Environmental Design 1997). Core ranges, those with the highest consistent elk counts over time, were sampled first while other ranges were included in the survey if time and funds allowed it.

Several factors made these trend surveys incomparable between years. First, consistent boundaries for the winter ranges had not been established because elk may move out into the adjoining forest depending on the environmental conditions that year. Recent studies with the Central East Slopes Elk Study indicate radio collared elk ($n = 37$) spend up to 66 ± 21% (mean ± SD) of their time in forested matrix during the winter period that surveys typically occur (J. Frair, unpublished data). Therefore, changes in the population count could be confounded by unmeasured differences in the area surveyed among years (Management Plan for Elk in Alberta 1997). Second, trend counts could not be conducted under strictly comparable environmental conditions, which is an assumption for trend counts (Jolly 1969; Caughley 1974). Third, counting winter ranges assumes a constant proportion of the elk population is in the traditional winter range during the winter. Studies by Morgantini and Russell (1983), and Interior Reforestation Co. Ltd. (1997) as well as the Alberta Fish and Wildlife Division data have shown that the distribution of elk may vary from year to year. In the National Elk Refuge in Wyoming, there was a significant correlation between snow depth and elk census statistics (Sauer and Boyce 1979; Boyce 1989). This correlation is not obvious comparing climatic data to the elk census data from the Clearwater Forest from 1976 to 2002 (Figure 1.1), but the high fluctuation between some years would be biologically impossible for elk.

Finally, in an attempt to survey elk based on stratified random surveys, Glasgow (2000) found that pre-survey flights for stratification were not practical because of the low population density and clumped distribution of elk, nor did intensive surveys provide sufficient data for sightability adjustments due to their low-density. Yet, several studies in the mountainous and foothill areas of North America using radiocollared animals have shown that environmental factor can influence detection of elk during surveys. For example, in Idaho vegetative cover and group size were the primary factors affecting the sightability of elk (Samuel et al. 1987). McCorquodale (2001) found vegetative cover and group size to be the primary variables affecting sightability in Washington and in Wyoming summer elk surveys, Anderson et al (1998) found vegetative cover, group size and elk activity affected sightability. Unsworth et al. (1994) generalized and tested a sightability model for elk based on surveys conducted over known groups, which had radio-collared elk. A logistic regression approach was used to develop a correction based on environmental factors that affected sightability. The advantage of this method over the earlier attempts in Alberta is that radiocollared elk rather than two observers are used and detection is modeled as a function of environmental variables that influence group detection.

My research focuses on two major problems associated to elk census methods. First, sightability models developed in other regions to correct for elk missed during

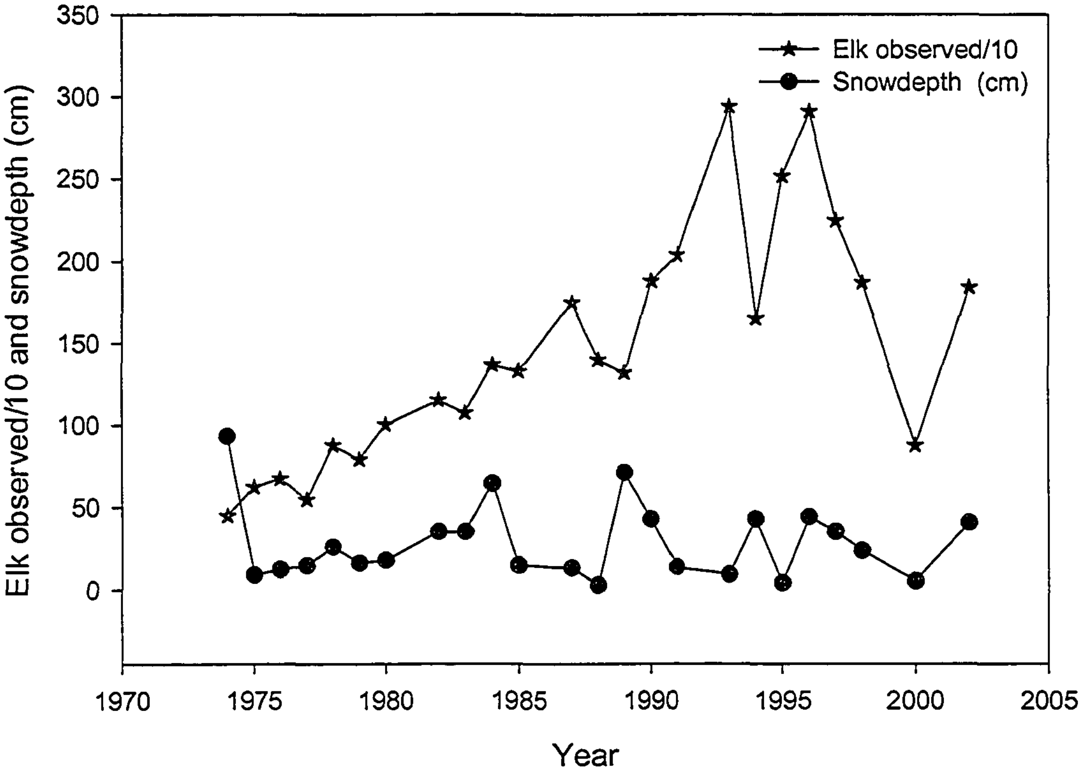

Figure 1.1. Elk observed on winter range trend surveys in the Clearwater Forest compared to winter snowdepth (cm) in Nordegg from 1974 to 2002.

surveys may not be general enough to be used in the foothills of Alberta. Second, stratification of survey units, for animals that have a clumped distribution on the landscape violates the assumption of random distribution when following a stratified random sampling design. Although the estimate may be robust to the violation of this assumption, further stratification based on environmental variables may improve the precision of the sampling design. I addressed these two problems by evaluating the "Idaho" elk sightability model (Unsworth et al. 1994) for use in the central east slopes, and by developing a resource selection function (RSF) using locational data from radiocollared elk. The RSF provides a measure proportional to the relative probability of elk use and the RSF values will be used as a basis for stratifying the area for aerial surveys. This improved stratification with a correction for sightability should improve population estimates of animals with clumped distribution at less cost than the standard random stratified survey.

1.2 Objectives

The specific objectives of this study are to:

1. Develop a sightability model for elk in the Alberta east central foothills and examine a sightability model developed in Idaho (Unsworth et al 1994) to see how it fits for Alberta conditions.
2. To develop a resource selection function (RSF) for winter elk and apply it to the landscape to determine survey blocks within strata for stratified random surveys. This will be compared to stratified random surveys with strata determined from tree cover. The two will be compared for design effects (DEFF) which is a ratio of design variances (Kish 1995).

Over the last 50 years there have been several changes and improvements to aerial surveys in Alberta for deer and moose population estimates. However, there has been little improvement of elk surveys since the first aerial trend surveys of winter ranges in 1954. With the increased demand on elk populations it is necessary to estimate these populations with a degree of precision that will allow managers to monitor changes. This thesis will discuss improving population estimates through development of a sightability model, improved stratification with an elk RSF, followed by a discussion on the use of these techniques for wildlife management.

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CHAPTER 2

ELK SIGHTABILITY AND AERIAL SURVEYS: ALBERTA CENTRAL EAST SLOPES

2.1 Introduction

Aerial surveys have been used to census wild ungulates in Alberta since 1954 (Webb 1959) because of the extensive area over which these species range within the province. While aerial survey approaches in Alberta have progressed through several improvements for moose and deer, there has been little effort towards improving elk surveys since the first random searches of wintering areas obtained minimum count data of elk herds in southwestern Alberta. This has been particularly true in the Rocky-Clearwater Forest in the central east slopes of the Rocky Mountains in Alberta where the Alberta Fish and Wildlife Division has been conducting trend counts for elk on a subset of the winter ranges with aerial surveys since 1974. However, trend counts of elk on winter ranges assumes a constant proportion of the elk population using the traditional winter range during each winter, yet elk distribution may vary from year to year depending on environmental and habitat conditions (Morgantini and Russell 1983, Interior Reforestation Co. Ltd. 1997). In fact, recent studies indicate radio collared elk (n = 37) spend up to 66 ± 21% (mean ± SD) their time in forested matrix during the period of winter when surveys typically occur (J. Frair, unpublished data).

Two major challenges exist to improving the accuracy and precision of aerial surveys for elk in the Rocky-Clearwater Forest area of Alberta. First, the extensive coverage of the landscape by forests of varying canopy closure suggests that elk surveyed may go undetected except in the very open areas. Sightability, or visibility bias, is a major cause of underestimation in aerial surveys of many wildlife species (Morrison 2002). For example, in aerial surveys of ungulates it has been shown that between 12 – 71% of animals known to be present are missed even in open, flat terrain (Caughley 1974).

A number of approaches have been developed to correct for sightability bias (Caughley, 1974; Cook and Martin, 1974; Pollock and Kendall, 1987, Chapter 1), but the approach most commonly used for elk today is the sightability adjustment developed by Samuel et al. (1987). Using logistic regression they developed a sighting model that predicts the probability of sighting a group of elk under different conditions. Sightability models typically are derived from field trials where a sample unit in which a radiocollared elk is present is surveyed, and if the animal is observed, conditions associated with the sighting are recorded. If the elk is not observed, it is found immediately after the survey and the same conditions for the missed elk are recorded. The first sightability trials for elk (n = 111) were conducted in open pine (*Pinus ponderosa*) habitats of north central Idaho (Samuel et al. 1987) and were tested in the mosaic of prairie grasslands and Douglas-fir (*Pseudotsuga menziesii*) of the National Bison range (Unsworth et al. 1990). Group size and tree canopy cover were found to be the most important variables affecting elk sightability. Recognizing that more work was needed in dense forest cover, another 118 sightability trials were completed in northern Idaho. Results from these two sets of trials were pooled (n = 229) and a new elk "Idaho" sightability model was developed. This model included snow cover as a variable and the coefficient for change in tree cover reflected a wider range in tree coverage (Samuel et al. 1987; Leptich and Zager 1993).

The Idaho model was tested at the Starkey Environmental Forest where population changes of 10 – 15 % and greater could be detected (Leptich and Zager 1993). However, Leptich and Zager (1993) cautioned that the Idaho sightability model should not be used in other areas without validation. For example, in Grand Teton National Park in Wyoming, Anderson et al. (1998) found the Idaho model overestimated elk in large groups (30 – 45 elk/ group) in dense (> 30% cover) primarily Douglas-fir and lodgepole pine (*Pinus contorta*) forests. In contrast, in Michigan, where a similar approach was used to develop an elk sightability model, even large groups of elk were missed under the dense (>75%) coniferous forest canopies of white cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), and white pine (*Pinus strobes*) (Otten et al 1993). Further, additional variables that might be important have not been tested. For example, Leptich and Zager (1993) did not include measures of light intensity, but observers at Starkey Environmental Forest suggested that light intensity might influence sightability because of shadowing effects. Light intensity also was felt to be an important factor in moose surveys (LeResche and Rausch 1974, Bisset and Rempel 1991).

The second major challenge to developing a rigorous survey design for elk in the Rocky-Clearwater Forest is that elk densities are not evenly distributed across the landscape. Stratification is commonly used to improve the precision of the estimate when animal densities vary (Hayek and Buzas 1997, Thompson 2002). Ideally, stratification should be done on animal density, but in practice stratification is usually based on surrogates assumed to be related to animal density. For example, preflight observations of animal tracks often have been used to indicate density strata in Alberta for moose (Schumaker 2000). By far the most common method for stratifying areas for ungulate surveys in Alberta has been a measure of habitat quality, which typically has been assumed to be related to tree cover determined from aerial photographs, Alberta Vegetation Inventory, or Prairie Farm Rehabilitation Administration (PFRA) woodlot data (Glasgow 2001, Schumaker 2000). However, in some situations we know a great deal more about what influences the habitat distribution of animals through studies typically using radiotelemetry. These studies have used the resource selection approach to produce maps of the relative probability of occurrence (RSF) of animals in a landscape of interest (Manly et al. 2002). While RSF maps often have been used to assess spatial or temporal changes in habitat selection (Manley et al. 2002, Boyce et al. 2002), to date they have not been used for stratification in design surveys. However, if RSFs developed from radiocollared animals are representative of the population of interest and the RSF is proportional to the probability of use of a resource unit, then RSF values should reflect the population density and stratification by RSFs may lead to improved precision in aerial surveys.

In this study I addressed the above two challenges for improving elk population surveys for the Rocky-Clearwater Forest. First, I assessed the Idaho elk sightability model (Unsworth et al. 1994) for use in my study area by testing its accuracy on trials conducted in the central Alberta area, with the objective of improving the model if it performed poorly. Second, I used a RSF developed from radiocollared elk to define survey strata for estimating elk population numbers. I expected that stratifying survey units by mean RSF values would increase the precision in population estimates over traditional stratification by tree cover types alone. As a result, I compared the population estimates and precision of survey results obtained using these two stratification approaches.

2.2 Studv Area

The Central East Slopes Elk Study (CESES) area is located west of Rocky Mountain House, about 200 kilometers southwest of Edmonton. It is situated in the Rocky-Clearwater Forest in the west central Alberta foothills (Figure 2.1). Elevation varies between 900 and 1700 m above sea level. The terrain is moderate to steep hills that rise in elevation generally towards the Rocky Mountains in the west. Winter temperatures average –7 °C and winter precipitation averages approximately 175 mm of snow falling from November to March (Strong 1992).

Classification of the vegetation based on satellite imagery (Thematic Mapper 5) shows the study area is predominately forested with mostly small openings of natural lowland and subalpine meadows. The closed conifer vegetation type (39% of study area) is dominated by lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*) while moss, hairy wild rye (*Elymus innovatus*), and bunchberry (*Cornus canadensis*) dominate the understorey. Labrador tea (*Ledum groenlandicum*) is the dominant shrub (Beckingham et al. 1996). The open conifer overstorey (23%) is similar to the closed conifer vegetation type except in lower elevation, wet areas where pine is replaced by black spruce (*P. mariana*) and tamarack (*Larix laricina*). Willow species (*Salix spp.*), bog birch (*Betula gladulosa*), and Labrador tea constitute the dominant shrubs, while the understory layer is predominantly hairy wild rye, and bearberry (*Arctostaphylos uva-ursi*) in drier, well drained areas. Deciduous forest (4%) consisting of aspen (*Populus tremulodies*) and balsam poplar (*P. balsamifera*) overstorey generally occurs at the lower

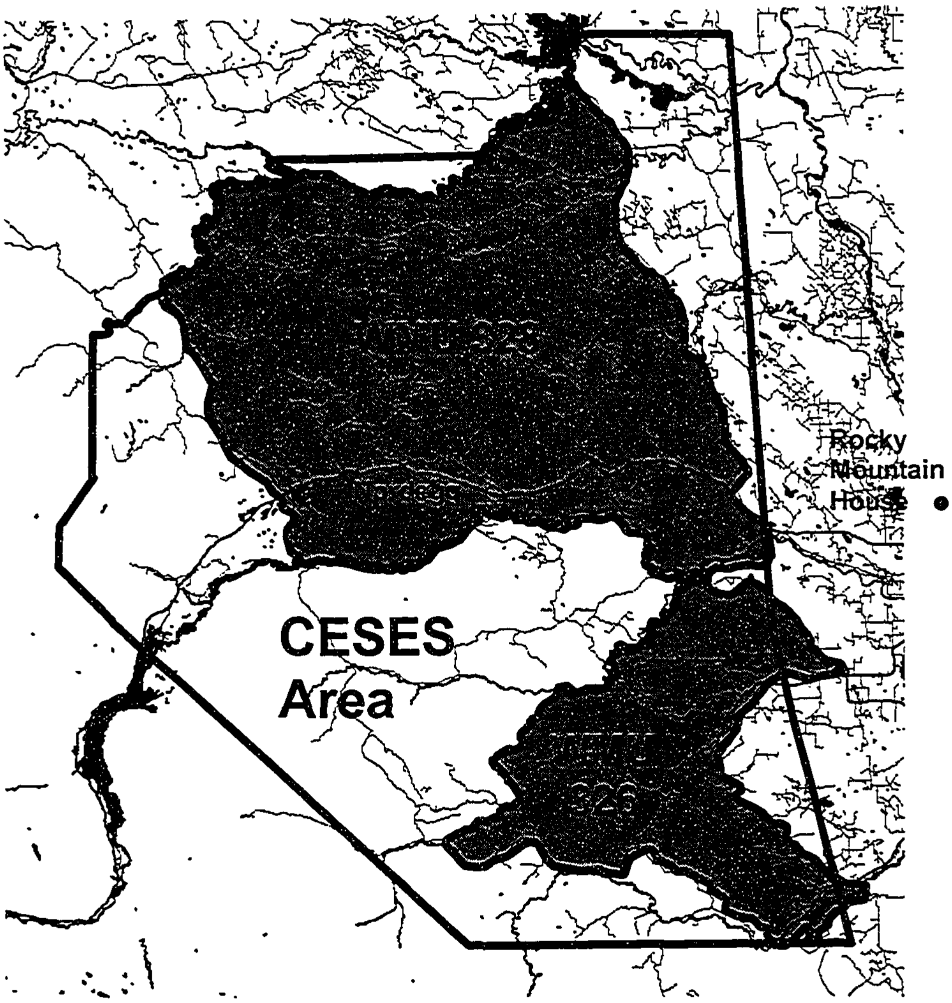

Figure 2.1. Study area for the Central East Slopes Elk Study (CESES) showing Wildlife Management Units (WMU) 326 and 328, study area for elk aerial surveys.

elevations of the study area and the shrub layer includes rose (*Rosa acicularis*), white meadowsweet (*Spirea betulafolia*) as well as seedling aspen and balsam poplars. The mixedwood forest (3%) has an overstorey of lodgepole pine and balsam poplar and the common shrubs are green alder (*Alnus crispa*), rose, willow and buffaloberry (*Sheperdia canadensis*) as well as sapling aspen and balsam poplars. The dry herbaceous grassland and alpine meadows (5%) and wet meadow (2%) areas consist primarily of bluegrasses (*Poa spp.*), northern bedstraw (*Galium boreale*), large leaf avens and Prairie smoke (*Geum* spp.) with dominant shrubs including rose and shrubby cinquefoil (*Potentilla fruticosa*) (Beckingham et al. 1996). The shrublands (2%) of the study area occur most often in moist soil conditions where undergrowth is mostly moss, sedges (*Carex* spp), and rushes (*Juncus* spp.) and shrubs include predominantly willow species and bog birch. The remaining 20% consists of agricultural land, water, roads, bare soil and rock.

The Rocky-Clearwater Forest is owned and managed by the Alberta Government. Most of the area has been allocated to the forest industry for timber management, with Sunpine's Forest Management Area (FMA) making up 56% of the area and Weyerhauser Canada's FMA covering 20% of the study area. Approximately 5% of the managed forest area currently consists of forestry cutblocks less than 40 years old. As well as the timber allocations, there is extensive oil and gas development and several cattle grazing dispositions in the study area. The area receives extensive recreation activity, including all terrain vehicle riding (snowmobiles, quads, motorbikes and off road 4x4 vehicles), random camping, hunting and fishing.

Wildlife in the study area is managed by Wildlife Management Unit (WMU). The study area includes four WMUs (326, 330, 328, 429) but surveys in this study focused on only two of these units. WMU 326 is located in the southern part of the study area and is 873 km^2 in size. Within it are 3 traditional elk wintering ranges covering 5% of the area; forestry activity with cutblocks covering about 15% of the landscape and a forest matrix of primarily coniferous trees covering the remaining 80%. The unit is made up of hilly terrain ranging from 800 m to 2000 m above sea level and lies between two major river valleys, the Ram River and the Clearwater River. WMU 328 lies between the North Saskatchewan River and the Brazeau River and is larger (2651 km^2) than WMU 326. The unit encompasses 3 defined elk winter ranges that make up only 2% of the WMU while cutblocks currently comprise 35% of the landscape, and the remaining 63% is forest matrix. The forest matrix is primarily coniferous/deciduous and mixed forest in the east that transitions to primarily coniferous forests in the west. Topography of the unit is hilly ranging in elevation from 800 to 1,300 m above sea level.

Elk (*Cervus elaphus*), moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), mule deer (*O. heminous*), and feral horses (*Equus caballus*) (Salter and Hudson 1980, Telfer 1994) range throughout the area. Deer and feral horses have not been surveyed in the area, while moose are surveyed using a modified Gasoway method (Schumaker 2000, Gasoway et al. 1981). Trend counts of elk on traditional winter ranges have been conducted approximately every two years since 1974, but there have been no population surveys in the forest matrix and intensity of effort has varied according to budgets and snow cover. Intensive elk radiotelemetry studies in this area began in 2000.

2.3 Methods

2.3.1 Test and Development Of Sightability Models

I conducted sightability trails in March 2000 and February 2001 following the protocols of the Idaho Fish and Game Department (Unsworth et al. 1994). A sightability trial consisted of locating a radiocollared elk by observers in a fixed-wing Cessna 182, *communication* of the location (UTMs) of an offset survey block encompassing the radiocollared elk to a second set of observers in a helicopter, and the immediate count of elk in the survey block by the observers in the helicopter. The location of the 1,000 x 1,000 m-survey block was based on the position of the collared elk, adjusted for a random offset of 0 to ± 800 m from the elk. This adjustment was made to ensure that the survey crew did not anticipate the precise location of the elk. Further, 5 trials were set up where no elk were in the block so that the observing crew did not vary the intensity of searching.

Protocols for surveying elk in the trial block followed those described in the Alberta Fish and Wildlife *Procedures for Aerial Ungulate Surveys* (Schumaker 2001). Trial blocks were flown with a Bell 206 helicopter, fitted with bubble windows and a crew of two observers in the rear seats, and an observer/navigator/recorder and observer/pilot in the front seats. The altitude was maintained 40 m to 50 m above ground and the airspeed between 80 to 100 km per hour. The aircraft flew regular paths across the trial blocks with the flight lines spaced about 300 m apart, allowing each observer to scan 150 m on each side of the aircraft until the entire unit was covered.

If a radiocollared elk was observed, 11 variables were recorded (Table 2.1). If the elk was not observed during the trial, the survey crew immediately used telemetry

Table 2.1. Definition of variables used in the Idaho sightability model (Unsworth et al. 1994) and for developing the Alberta sightability model that were recorded during 80 sightability trials conducted during March 2000 and February 2001 in central east slopes of Alberta.

Variable	Definition
Idaho model	
Group size	A group was defined as the number of animals within 45 m from each other. If a group was further apart than 45 m, then groups were counted as multiple groups.
Percent tree cover	Percent screening cover by the tree canopy visually estimated 45 m around the site where elk was first seen.
Percent snow cover	Percent snow cover visually estimated around 45 m from where the elk was first seen.
Alberta model	
Group composition	Identified as bull or cow, if antlers were present or not, and calf by size.
Bedded	Activity animal was first observed: bedded =1, other = 0
Standing	Activity animal was first observed: standing = 1, other = 0
Moving	Activity animal was first observed: moving = 1, other = 0
Vegetation cover	Conifer forest, deciduous forest, conifer/deciduous mixed wood, shrub, meadow, muskeg, cutblock.
Percent tree cover	Percent screening cover by the tree canopy visually estimated 45 m around the site where elk was first seen.
Percent snow cover	Percent snow cover visually estimated around 45 m from where the elk was first seen.
Light intensity	Reflection of sunlight off the ground: Flat = 0 and bright = 1
Slope	Flat ($\leq 5^\circ$ slope), moderate ($>5^\circ$ and $<20^\circ$), steep ($>21^\circ$) slope
Aspect	N, NE, E, SE, S, SW, W, NW
Precipitation	No precipitation = 0, precipitation = 1 at time of elk observation.
Temperature	Temperature taken outside helicopter at start of trial (°C).
Observer experience	No experience = 0, 1 year experience = 2, 1+ years experience = 3.

receivers to locate the radiocollared elk and record the same factors. These variables were selected either because they were used in the Idaho sightablility model (Unsworth et al. 1994) or they were shown to influence sightability in other studies (Cook and Martin, 1974, Otten et al. 1993, Anderson et al. 1998).

The probability of detection of each radiocollared elk in a trial block was predicted from the Idaho sigthtability model using the data collected during the sightability trials. The Idaho model is a logistic regression model which predicts sightability with:

$$P_I = \frac{\exp(u)}{1+\exp(u)} \quad \textbf{(1)}$$

where P_I is the sighting probability and

$$u = 1.433 + (0.2041 groupsize) - (0.7002 tree\operatorname{cov} er) + (0.0084 snow\operatorname{cov} er) \quad \textbf{(2)}$$

To evaluate the overall reliability of the Idaho model for predicting the detectability of elk in my study area, I compared the predicted probability of detecting a radiocollared elk in the 80 sightability trials based on the environmental conditions in which the animal was found (i.e., group size, tree cover, snow cover) to whether it was actually observed. The optimal threshold cutoff for prediction was determined using sensitivity and specificity analysis of nonparametric correlation (StataCorp 2003) and the area under the Receiver Operating Curve (AUC) was used to measure goodness of fit (McPherson et al. 2004).

Next, I developed a new sightability model, called the *Alberta* model, using data from 60 of the sightability trials and withholding data from 20 trials for model validation. The dependent variable of the logistic regression was whether the elk was observed (1) or not observed (0) during the sightability trial. Logistic regression was used to estimate the probability of observing a group of elk from an aircraft based on the covariates measured at the site where the first elk was observed. The following form of the logistic regression model was used to predict elk presence:

$$P_A = \frac{\exp(b_0 + b_1x_1 + b_2x_2 + ... + b_kx_k)}{1 + \exp(b_0 + b_1x_1 + b_2x_2 + ... + b_kx_k)} \quad (3)$$

where P_A is the probability of sighting an animal and $x_{i...k}$ are the variables defined in Table 2.1. A natural log transformation was made on group size, and snow was transformed as percent snow cover $^3/10{,}000$ (Samuel et al. 1987). The categorical variables for slope, aspect and observer experience (Table 2.1) were entered one at a time. Akaike's Information criterion (AIC_c) was used to select the best model among 10 *a priori* models (Burnham and Anderson 2002). The area under the AUC was used to measure goodness of fit (McPherson et al. 2004) and nonparametric correlation determined the sensitivity and specificity of the optimal threshold for predicting the accuracy of the model. For a further comparison of the predictions of the Alberta model to those of the Idaho model, the 80 trials were sorted into 4 sets of 20 trials and mean difference in prediction rates for the two models were tested using a 1-tailed Wilcoxon paired-sample test (Zar 1999). The hypothesis tested was that across thresholds the percent correctly classified was no different between the Alberta and the Idaho sightability models.

2.3.2 Elk Surveys

2.3.2.1 Surveys stratifying by tree cover

Survey units were established by placing a grid of 2 minutes latitude by 2 minutes longitude units (approximately 2 km x 4 km, or 8 km^2) over the WMU being surveyed. Percent forest cover within a survey unit was derived from a Geographical Information

System (GIS) (ARCINFO 8.0) TM-based vegetation classification (Beyer 2004) which had been converted to 10 vegetation classes (Table 2.2). I collapsed open conifer, closed conifer, deciduous and mixed forest into "forest cover" type. The amount of forest cover in each survey unit was totaled and the unit was assigned to high, medium, and low stratum. High strata were defined as survey units that had ≤ 20% forest cover and these were typically traditional winter ranges that were surveyed in the past. Medium density strata had 21% to 50 % tree cover and were comprised primarily of cutblocks within forest cover. Low-density strata had 51% to 100 % tree cover and was made up of primarily forest matrix of continuous forest with small openings (Appendix I).

The numbers of sample units surveyed within each stratum were selected randomly with replacement in proportion to estimated elk densities to obtain an optimum allocation of sampling effort. Under optimal allocation, the number of survey units U_h in stratum h was equal to:

$$U_h = {U * M_i}/{M_t} \qquad (4)$$

where U is the total number of survey units that can be flown as determined by budget, M_i is the estimated number of elk in each stratum and M_t is the total estimated number of elk in the study area (Gassaway et al. 1981, Thompson 2002, Lehtonen and Pahkinen 1994). For WMU 326, qualitative elk density estimates of 2 elk/km^2 were derived for the high density stratum from prior winter range trend counts. Because there had never been any surveys in the forest matrix, no densities estimates were available for the other two strata. Therefore, densities were assumed to be 1.5 elk/km^2 in the medium stratum and 0.6 elk/ km^2 in the low stratum, based on personal observations. For WMU 328, densities

Table 2.2. Definition of variables used for developing the elk RSF from locations of 17 GPS-collared and 148 VHF-collared elk in the central east slopes of Alberta.

Variable	Definition
Vegetation class	0 = no vegetative value, 1 = wet herbaceous, 2 = dry herbaceous, 3 = herbaceous reclaimed, 4 = shrub, 5 = open conifer, 6 = closed conifer, 7 = deciduous, 8 = mixed forest, 9 = cutblock, 10 = recent burn.
Slope	Flat ($\leq 5^\circ$ slope), moderate ($>5^\circ$ and $\leq 20^\circ$), steep ($>21^\circ$)
Aspect	N, NE, E, SE, S, SW, W, NW
Elevation	Digital elevation model from TM imagery at 30 meter
Herbaceous forage	All herbaceous biomass (g/m^2)
Herbaceous forage X 1000	All herbaceous biomass (g/m^2) within 1 km^2 centered on telemetry or random point
Predation risk	Winter predation risk
Access density	Pipelines, cut lines, unimproved trails within 1 km^2 centered on telemetry or random point (km/km^2)
Road density	Improved road density within 1 km^2 centered on telemetry or random point (km/km^2)
Vegetation type diversity	Number of the 10 vegetation types listed above within 1 km^2 centered on telemetry or random point
Hillshade	Shaded areas of the landscape based on the illumination angle of the sun

were estimated similarly to be 3 elk/ km^2in the high stratum, 1 elk/km^2 in the medium stratum and 0.5 elk/km^2 in the low stratum.

Survey units were flown with the same aircraft and methods as used during the sightability trials, which are the standard survey methods used by Alberta Fish and Wildlife (Schumaker 2001).

To compare the results based on stratification by tree cover to post-stratification by RSF values (see below), I also *post-stratified* the survey units using two schemes. First, I used three equal strata (Froggatt 1989). Second, I used a ratio of 20:60:20 of the total units in high: medium: low strata (Glasgow 2000). Thus, I present results for one pre-stratification scheme and two post-stratification schemes based on tree cover.

2.3.2.2 Surveys poststratifying by RSF

To stratify survey units based on RSF values, I first used a model selection approach to pick the best RSF model developed using locations of radiocollared elk. I then used the best model to predict the RSF value for all 28.5m cells in the each survey unit, and used the average RSF value for each survey unit as a basis for stratifying survey units. To develop the RSF, I used locations of radiocollared elk that resided in the four foothills WMU's, and I limited the set of locations to those obtained during 07:00-17:00 hours in January to March to coincide with the times aerial surveys were conducted over the period 2000 to 2002. Radiocollared elk used in this study were either captured using netguns from a helicopter or were translocated elk released into the study area (Animal Care Protocol # 300-401). Translocated elk were used only if the elk had resided in the study area for over a year after release and their movement showed that they had habituated to the area. Elk were fitted with either VHF collars (n = 148 elk, 1 to 18 locations/elk) or GPS collars set at 2-hr locational (n = 17 elk, 353 to 1981 locations/elk) for a total of 12,320 locations. The elk locations were given a frequency weight in the analysis to account for the differences in sample size among individual elk and the available points were weighted by one. To determine resource availability, 25,453 random points were placed over the CESES area. I used the entire study area as the domain of availability so that the RSF could be use to stratify all areas in the study area for surveying.

At each elk location and random point, vegetation cover type was recorded from a GIS layer of 10 vegetation classes. This layer was derived from a land cover map produced based on Thematic Mapper (TM) satellite imagery acquired in September 2001 and auxiliary GIS data on terrain, hydrology, and anthropogenic features (Beyer 2004). Winter forage in each 28.5 m cell in the landscape was predicted based on vegetation models derived by Visscher et al. (2004) based on relationships between field measurements, elevation, vegetation class, and Julian date. The models predicted total herbaceous biomass estimated on October 15 and adjusted for a linear decline based on the predicted biomass value at the end of the growing season and the start of the growing season in the following year (Visscher et al. 2004). The boundaries of cutblocks were delineated using timber harvest records and the TM image and four seral stages within cutblock boundaries. For each seral stage, estimates of forage biomass were adjusted for time since cut, using data from an additional set of 159 transects (Visscher et al. 2004). The resulting GIS layer predicted herbaceous biomass in g/m^2 within each 28.5 m cell. Further, the number of the 10 vegetation types and the average forage biomass within a square of 1,000 m centered on each elk location was determined. The forage biomass model, when measured as a fit to the transects, had an accuracy of $r^2 = 0.7879$.

I used an estimate of the risk of predation by wolves based on the relative probability of occurrence of wolves (e.g., RSF) developed by Frair et al. (2004) from telemetry locations of collared wolves in the study area in the 1980s. The predation risk model indicated selective use of subalpine, wet herbaceous areas, areas of low slope except under deciduous forest, southwest aspects, areas further than 250 meters away from utility corridors, and areas having an intermediate density of low use roads. The predation risk model was applied to the 2001/02 landscape with the wolf predation risk RSF calculated for each cell.

I recorded elevation of each elk location to the nearest 30 m interval from a digital elevation model (DEM) developed by Alberta Environment Resource Data Division (RDD) at a 30 m grid cell. Aspect was recorded as one of 8 cardinal points, degree of slope was derived from the DEM. Hillshade, which is the shaded relief value based on the illumination angle of the sun and may serve as an index of winter elk use, was developed in the GIS (ARCMAP 8.0).

Roads and linear industrial disturbances typically had a width less than the minimum mapping unit of the TM image. The central line of all linear clearings was mapped using Indian Radar Satellite Imagery having a 5 m resolution to provide road and access layers measured in kilometers of linear disturbance per square kilometer (km/km^2) (Friar et al. 2004). The road layer included improved all weather roads and the access layer was linear disturbances which would be accessible by all terrain vehicles and included pipelines, cutlines and trails. The variables considered for the RSF are in Table 2.2.

Prior to developing the elk RSF for the survey area, I examined variables for co-linearity, and if a correlation coefficient of 0.70 or greater was found between variables, they were not used in the same model. Fifteen *a priori* candidate models were evaluated using corrected Akaike's Information Criterion (AIC_c) (Burnham and Anderson 2002, Johnson and Omland 2004). Prediction success of models were evaluated using K-fold cross validation, in which I divided the data into 5 subsets, each containing 20% of the data (Boyce et al. 2002). In turn, for each subset of observations withheld the remaining 80% of the data was used to develop an RSF. A Spearman-rank correlation, $r_{s,}$ was obtained for the relationship between RSF bin ranks and area adjusted frequencies for model sets. The average of these five r_s was used as a measure of prediction success.

I used the best model to predict the RSF value for every 28.5 m cell in each 8 km^2 survey unit and used the average RSF value in the survey unit rank survey units for post-stratification. I compared the results of three schemes to grouping surveys units into three strata based on the RSF values: (1) equal number of survey units per stratum (Froggatt 1989), (2) a 20:60:20 ratio (Glasgow 2000), and (3) natural "breaks" based on Jenks optimization as calculated in ARCMAP 8.0.

2.3.3 Population Estimation

To estimate the population for each stratification approach I used the Horvitz-Thompson estimator:

$$t = \sum_{k}^{l} \frac{1}{p_k} \sum_{i}^{nk} \frac{m_{i(k)}}{\pi_{i(k)}} \qquad (5)$$

where l is the number of survey units sampled and n_k is the number of groups observed in the k^{th} survey unit. The sightability probability in the k^{th} survey unit is $\pi_{i(k)}$ where $\pi_{i(k)}$ = $1/\mathrm{P_A}$ from Eq. 3, and p_k is the probability of selecting the k^{th} survey unit to be surveyed. The number of animals in the i^{th} group of the k^{th} land unit is $m_{i(k)}$. The approach assumes that the population is geographically closed, groups of animals are sampled independently without replacement, observed groups are completely counted, and that sightability can be estimated. To meet these assumptions the survey was done continuously over a three day period to minimize the chance of elk entering or leaving the study area and double counting was prevented by marking all elk groups with a GPS points. To ensure a total count, when an elk was observed the helicopter circled to complete the count.

Total variance of the population estimate (Eq. 7) is the sum of sample variance and the sightability variance (Thompson 2002, Stienhorst and Samuel 1994):

$$Total\,\mathrm{var}iance = \left(\frac{N-n}{N}\right)\frac{s_t^2}{n} + \sum_k^l \frac{1}{p_k^2}\sum_i^{n_k}\frac{1-\pi_{i(k)}}{\pi_{i(k)}^2} m_{i(k)}^2 \qquad (6)$$

Sample variance can be calculated using the Horvitz-Thompson variance estimator (Thompson 2002):

$$\mathrm{var}(\hat{\mathrm{T}}_\pi) = \left(\frac{N-n}{N}\right)\frac{s_t^2}{n} \qquad (7)$$

where n is the sample size, N is the number of survey units and

$$s_t^2 = [1/n-1]\sum_{i=1}^{n}\left(t_i - \hat{\mathrm{T}}_\pi\right)^2 \qquad (8)$$

where t_i = the estimate of the population total in the i^{th} sample unit.

Sightability variance was determined using a formula developed by Stienhorst and Samuel (1994):

$$\sum_{k}^{l} \frac{1}{p_k^2} \sum_{i}^{n_k} \frac{1-\pi_{i(k)}}{\pi_{i(k)}^2} m_{i(k)}^2 \qquad \textbf{(9)}$$

where *l* is the number of survey units sampled, $\pi_{i(k)}$ is the sightability probability in the k^{th} survey unit. P_k is the probability of selecting the k^{th} survey unit in the survey, and $m_{i(k)}$ is the number of animals in the i^{th} group of the k^{th} land unit.

2.3.4 Comparison of Survey designs

Survey designs were compared for their statistical efficiency in three steps. First, I graphically compared the relative ranking of survey units based on each stratification approach to understand how the approaches influenced the groupings of survey units within strata. Second, I compared confidence intervals (CI) of the population estimates. Confidence intervals were determined following Gasaway et al. (1981):

$$CI = \hat{T} \pm (t_{\alpha,v})\sqrt{Var(\hat{T})} \qquad \textbf{(10)}$$

where $\hat{T}$ is the total population estimate, $t_{\alpha,v}$ is Students *t* distribution with α being the probability level, *v* is the degrees of freedom, and $\sqrt{Var\ (\hat{T})}$ is the total population variance. Third, I use the design effect (DEFF) to compare efficiencies of the stratification approaches (Lehtonen and Pahkinen 1994). In stratified sampling the DEFF is the within strata variance divided by the total variance (the sum of the within plus the between strata variance). Therefore by definition, as within stratum variances become smaller, DEFF becomes smaller. The DEFF for random stratified surveys (Lehtonen and Pahkinen 1994) is:

$$DEFF_{str} = \frac{\sum_{h}^{H} W_h S_h^2}{S^2} \tag{11}$$

where S_h^2 are intra-stratum variances and S^2 is the total population variance (sum of the within stratum variance and the between stratum variance) and is measured:

$$S^2 = \sum_{h=1}^{H} W_h \left[S_h^2 + \left(\overline{Y}_h - \overline{Y} \right)^2 \right] \tag{12}$$

where $\overline{Y}_h$ is the population mean in stratum h and $\overline{Y}$ is the total population mean.

Finally, $W_h = N_h / N$ is the weighting factor for survey unit selection according to proportional allocation.

Improved stratification would result in more homogeneity of elk densities within strata making the variances within strata smaller, leading to a smaller DEFF (Lehtonen and Pahkinen 1994).

2.4 Results

2.4.1 Sightability Trials

A total of 85 sightability trials were conducted: 40 in March 2000 and 45 in February and March 2001. Five of the trials had no radiocollared elk occurring in the trial block because they were set up so the observers did not vary their intensity in searching. Of the 80 usable trials, the group with the radiocollared elk in it was missed in 31 (39%) and observed in 49 (61%) trials. The data for all the sightability trials is in Appendix II.

2.4.1.1 Validation of Idaho Sightability Model

The Idaho model (Unsworth et al. 1994) successfully predicted 66% of the 80 sightability trials at its optimal threshold probability of 0.65.

2.4.1.2 Alberta Sightability Model

The top 10 models consistently included group size, percent tree cover and light intensity as variables influencing elk sightability (Table 2.3), and the top four models had $\Delta AIC_c \leq 4$, which indicates that all four models should be considered (Burnham and Anderson 2002). The areas under the operating curve (AUC) in these top four models were above 0.80. Model 2 was selected as the best model because it had the lowest log-liklehood, the highest AUC (0.86), a $\Delta AIC_c = 0.01$, and included percent snow cover, which has been identified as an important variable in sightability. Based on the model that included snow, the probability of detecting an elk increased as group size (Fig. 2.2A) and snow cover (Fig. 2.2B) increased, whereas the probability of detection declined when percent tree cover (Fig. 2.2C), light intensity (Fig. 2.2D) and inactivity (elk were bedded) decreased (Table 2.2E). The Alberta model 2 (Table 2.3) successfully predicted 74% of the 80 sightability trials at its optimal threshold probability of 0.56.

2.4.1.3 Comparison of Sightability Models

The Wilcoxon paired-sample test indicated there was no difference in the percent of sightability trials correctly classified across threshold values between the Idaho model and the Alberta model ($P > 0.84$, $df = 20$). With the Idaho model AUC= 0.78 (0.68-0.88, 95%CI) while the Alberta model had AUC= 0.86 (0.78-0.93, 95%CI) (Table 2.3). Even though these models are not mutually exclusive, because the confidence intervals overlap, the Alberta model does perform better. Further, the model including only the variables used in the Idaho model was ranked ninth (Table 2.3). The Alberta model (Model #2: Table 2.3) was selected to use for population estimate corrections. Table 2.4 gives the coefficients of the variables in Alberta model 2.

Table 2.3. Ten models derived from 80 sightability trials conducted in Alberta's central east slopes. Provided are variables in the model (see Table 1) log likelihood (LL), the difference in AIC_c values between any model and the model with the lowest AIC_c (ΔAIC_c), Akaike weights (W_i) representing 100% of the weights and values for area under the curve (AUC).

Variables*	LL	ΔAIC_c	W_i	AUC
1) Group size, bedded, percent tree cover, light intensity	-36.42	0.00	0.29	0.84
2) Group size, bedded, percent tree cover, light intensity, percent snow cover	-35.26	0.01	0.28	0.86
3) Group size, percent tree cover, light intensity, moving	-36.70	0.55	0.22	0.84
4) Group size, percent tree cover, light intensity, percent snow cover, temperature	-36.45	2.41	0.09	0.84
5) Group size, light	-41.01	4.68	0.03	0.81
6) Group size, percent tree cover, light intensity	-39.92	4.72	0.03	0.82
7) Group size, percent tree cover, percent snow cover, light intensity, moving	-37.64	4.77	0.03	0.84
8) Group size	-42.23	4.96	0.02	0.80
9) Group size, percent tree cover, percent snow cover**	-40.71	6.30	0.01	0.78
10) Group size, percent tree cover	-41.95	6.56	0.01	0.80

* See Table 2.1 for definitions

** Same variables used in Idaho model

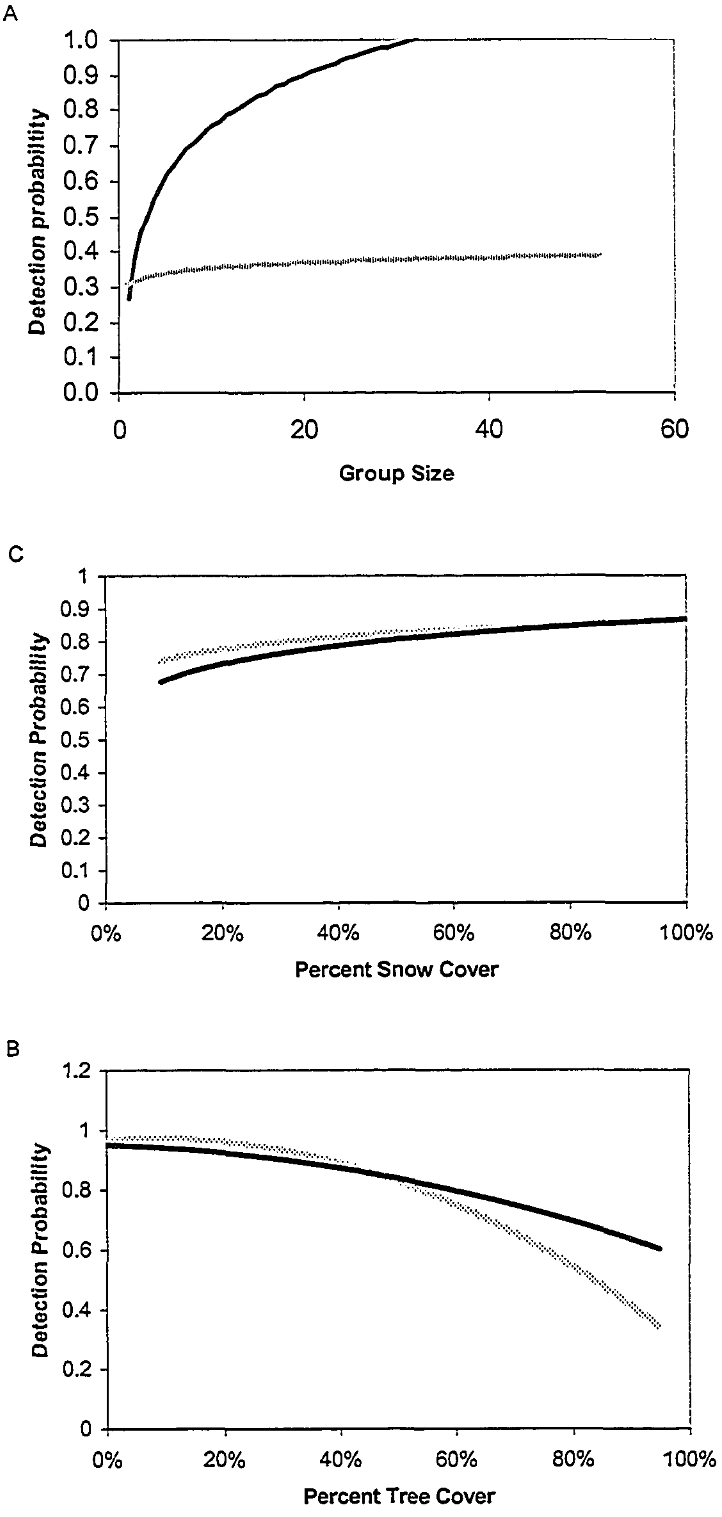

Figure 2.2.A,B,C. The Idaho sightability model (grey line) and the Alberta sightability model (black line) showing the effect of elk group size (A), percent snow cover (B), and percent tree canopy (C) on the probability of detection of elk during 80 sightability trials in the central east slopes of the Rocky Mountains of Alberta in 2001 and 2002.

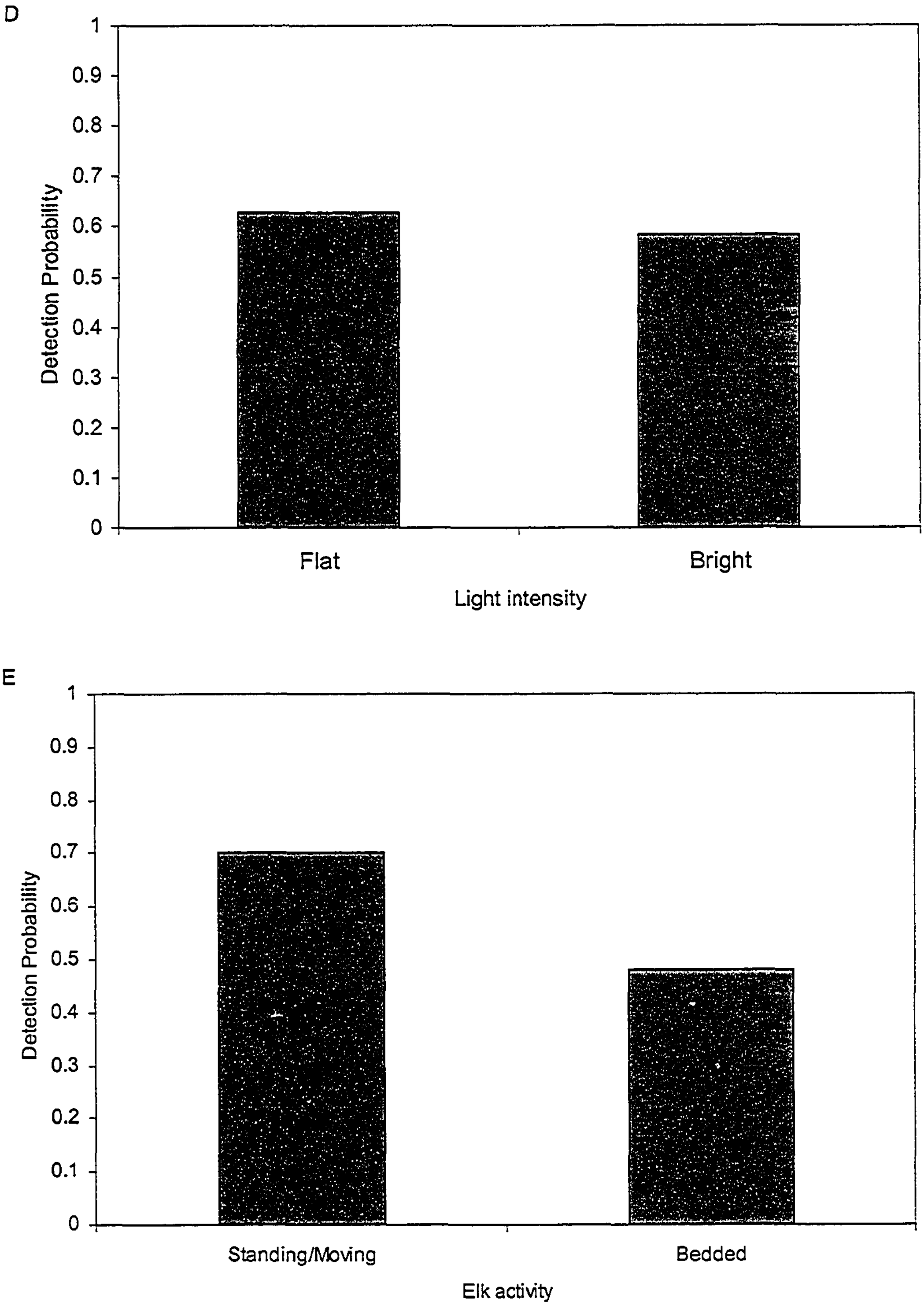

Figure 2.2.D, E. The Alberta sightability model showing the effect of light intensity (D) and elk activity (E) on the probability of detection of elk during 80 sightability trials in the central east slopes of the Rocky Mountains of Alberta in 2001 and 2002.

Table 2.4. Parameter coefficients ± SE of variables in the Alberta elk sightability model developed in the east slopes of central Alberta.

Variable	Coefficient	Std. Error (95% CI)	Odds ratio
Constant	1.6740	1.5670	
Group size	0.2094	0.0630	1.2329
Percent tree cover	-3.5337	1.6296	0.0292
Percent snow cover	1.8125	1.2293	6.1258
Light intensity	-1.4457	0.7253	0.2355
Bedded	-1.9534	0.7439	0.1418

2.4.2 Elk Survey Design

2.4.2.1 Comparison Of Stratification Approaches

Allocation of survey units to strata depended on the allocation scheme. Percent tree cover per survey unit ranged from 5% to 100% in both WMU's and resulted in an pre-stratification allocation in WMU 326 of 4, 22 and 101 survey units and in WMU 328 of 23, 84 and 216 survey units in the high, medium, and low density strata, respectively. All designs of post stratification in both WMU's increased sampling in the high strata and the medium strata but decreased it in the low strata (Table 2.5).

For post-stratification using an RSF approach, I used Model 1 because there was a difference of > 4 in the ΔAIC_c between this model and all others, it had the highest Akaike weight ($W_i = 0.75$), which was about 9 times better than the next closest weight (Table 2.6). The model indicated that the relative probability of elk use increased as forage biomass within a km^2 area around a site increased, with the presence of a cutblock, and as road density (km/km^2) increased (Table 2.7).

To compare the stratification of survey unit by RSF to tree cover, I plotted the total percent tree cover in a survey unit to the mean RSF value of the same survey unit and found no correlation between these indices in WMU 326 (Fig. 2.3: $r = 0.00$, $P = 0.13$, $n = 127$) and WMU 328 (Fig. 2.4: $r < 0.00$, $P = 0.11$, $n = 323$).

2.4.2.2 Comparison of Population Estimates

In 2001, 32 survey units of 127 or 25.2% of the survey units in WMU 326 were surveyed, while 46 survey units out of 323 or 14.5% of WMU 328 were surveyed in 2002. Re-allocation of survey units with different stratification schemes increased the number of units within high and medium strata (with the exception of Jenks in WMU

Table 2.5. Number of survey units selected and sampled with different stratification methods, with survey units classified with percent tree canopy (TC) and elk RSF in WMU326 and WMU 328. The original strata by TC was prestratified, post stratification methods are 3 equal numbers of units per strata, an allocation ratio of 20:60:20 and Jenks optimization of natural breaks.

WMU	Total survey units	Units sampled	Percent sampled
326	127	32	25
328	323	46	14

		High		Medium		Low	
Stratification		Units	Units sampled	Units	Units sampled	Units	Units sampled
326 - TC	Equal numbers	42	14	43	10	42	8
	Allocation 20:60:20	25	10	77	18	25	4
	Original Strata	4	3	22	10	101	19
326 - RSF	Equal numbers	42	19	43	8	42	5
	Allocation 20:60:20	25	14	77	14	25	4
	Jenks	9	8	42	14	76	10
328 - TC	Equal numbers	108	17	107	13	108	16
	Allocation 20:60:20	65	12	193	21	65	13
	Original Strata	23	5	84	12	216	29
328 - RSF	Equal numbers	108	21	107	14	108	11
	Allocation 20:60:20	65	16	193	23	65	7
	Jenks	43	9	81	14	199	23

Table 2.6. Variables entering the top 10 RSF models predicting the relative probability of occurrence of elk developed from locations of 17 GPS-collared and 148 VHF-collared elk in the central east slopes of Alberta. Provided are variables in the model (see Table 1) log likelihood (LL), the difference in AIC_c values between any model and the model with the lowest AIC_c (ΔAIC_c), Akaike weights (W_i) representing 100% of the weights and Spearman rank correlation with variance.

Variables*	LL	ΔAIC_c	W_i	Average Spearman Rank (K-fold)	Variance (Spearman rank)
1. Herbaceous forage X 1000, cutblocks, road density	-1087.06	0.00	0.75	0.86	0.00
2. Herb forage, cutblocks, vegetation type diversity	-1089.31	4.50	0.08	0.79	0.04
3. Herb forage, cutblocks, predation risk	-1089.84	5.57	0.05	0.68	0.01
4. Herbaceous forage X 1000, cutblocks, elevation, vegetation type diversity, access density	-1088.04	5.97	0.04	0.98	0.18
5. Herbaceous forage X 1000, cutblocks, elevation, access density	-1089.82	7.53	0.02	0.62	0.00
6. Herbaceous forage X 1000, cutblocks	-1091.92	7.72	0.02	0.92	0.02
7. Herbaceous forage X 1000, cutblocks, elevation	-1090.95	7.79	0.02	0.62	0.01
8. Herbaceous forage X 1000, cutblocks, access density	-1091.08	8.05	0.01	0.92	0.00
9. Herbaceous forage X 1000, road density	-1092.45	8.78	0.01	0.94	0.00
10. Herbaceous forage X 1000, cutblocks, vegetation class	-1091.75	9.39	0.01	0.78	1.88

* Variable definitions in Table 2.2.

Table 2.7. Parameter coefficients ± SE of variables in the elk RSF model developed in the east slopes of central Alberta.

Variable	Coefficient	SE (95%)	Odds ratio
Constant	4.4346	0.0272	
Herbaceous forage X 1000	0.0022	0.0001	1.0022
Cutblocks	0.9009	0.0555	2.4618
Road density	0.3069	0.0231	1.3592

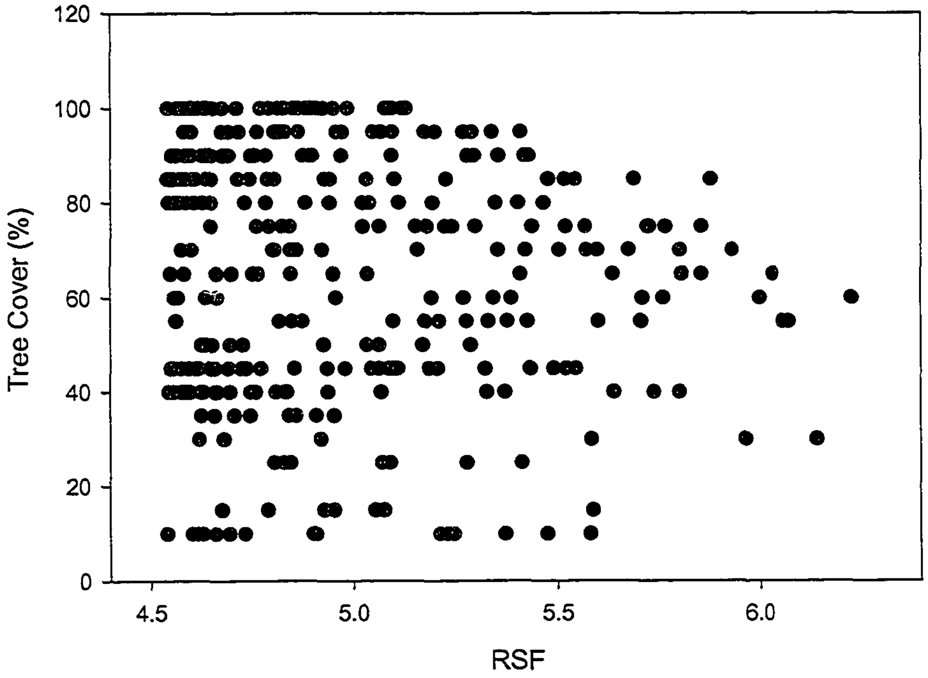

Figure 2.3. Relationship of tree cover (%) and mean RSF within survey units in WMU 326 in the central east slopes of Alberta.

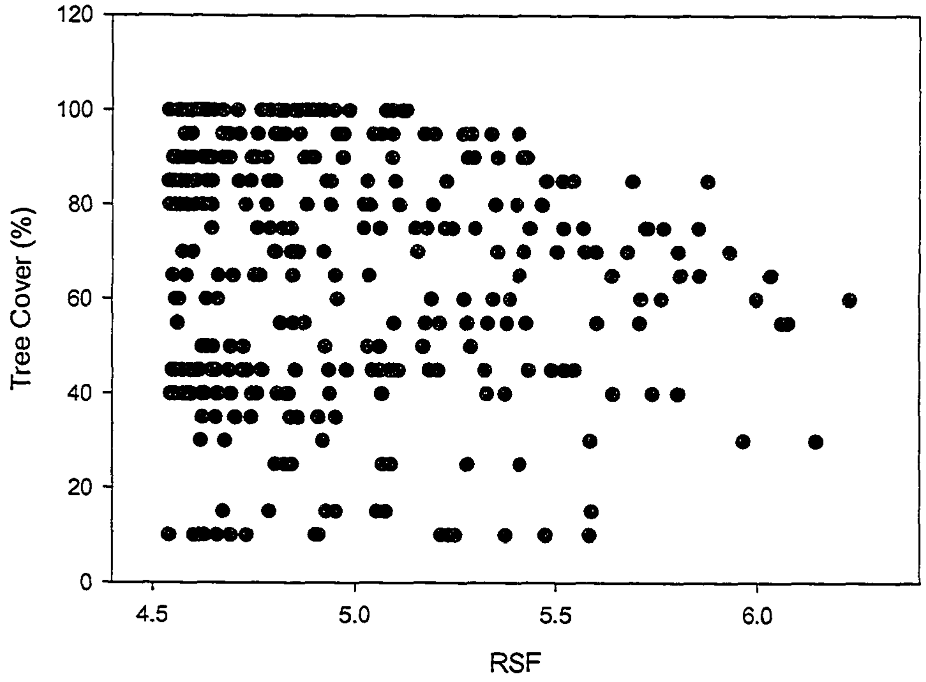

Figure 2.4. Relationship of tree cover (%) and mean RSF within survey units in WMU 328 in the central east slopes of Alberta.

328) and decreased the units in low strata. Sampled units were also redistributed in a similar way (Table 2.7).

In WMU 326 there was a small sample size (only 7 observation of elk) with most observations (n = 5) in the traditional winter ranges. In WMU 328, the sample size was larger (observations = 28) and the elk observations were distributed across landscape types. This made a difference in the post stratification population estimates. Post stratifying tree cover in WMU 326 resulted in higher population estimates (Table 2.8). Because most of the elk observations were in the winter ranges, they remained in the high strata in all stratification schemes, but more units were placed in the high strata so the population estimate increased. Tree cover post stratification in WMU 328 resulted in a small increase in population estimate because of the redistribution of survey and sampled units within strata. The equal number of survey units per strata gave results under the desired ± 20% with improved DEFF, and in WMU 328 the 20:60:20 allocation also achieved these results.

Post stratifying with RSF values, based on CI and DEFF, had the most accurate population estimates, in both WMU's with Jenks optimization (Table 2.8) In WMU 328, original strata by TC was prestratified, post stratification methods are three equal numbers of units per strata, an allocation ratio of 20:60:20 and Jenks optimization of natural breaks. Three equal and 20:60:20 also gave results within the desired limits, but they did not provide the same precision with CI and DEFF in WMU 326.

In WMU 326, the 2001 elk population estimate with RSF values stratified by Jenks optimization is 327 + 15% (90%CI) elk (Table 2.8). The 2001 elk population assessed by Alberta Fish and Wildlife, based on trend surveys, is 250 elk (no confidence

Table 2.8. Population estimates with confidence intervals (CI), coefficient of variation (%) and design effects (DEFF), using different stratification methods, with survey units classified with percent tree canopy (TC) and elk RSF in WMU326 and WMU 328. The original strata by TC was prestratified, post stratification methods are 3 equal numbers of units per strata, an allocation ratio of 20:60:20 and Jenks optimization of natural breaks.

Stratification		Pop. Estimate	CI (90%)	CV (%)	DEFF
326 - TC	Equal numbers	483	90	19	0.12
	Allocation 20:60:20	437	127	29	0.38
	Original Strata	247	58	24	0.23
326 - RSF	Equal numbers	381	123	27	0.36
	Allocation 20:60:20	335	96	29	0.39
	Jenks	327	49	15	0.06
328 - TC	Equal numbers	1238	179	14	0.13
	Allocation 20:60:20	1406	187	13	0.10
	Original Strata	1326	304	23	0.25
328 - RSF	Equal numbers	1123	192	17	0.12
	Allocation 20:60:20	1163	444	38	0.16
	Jenks	1200	213	18	0.10

intervals). In WMU 328, the 2002 elk population from stratified random surveys using RSF values and Jenks optimization is 1,200 + 18% (90% CI) elk, while the Alberta Fish and Wildlife trend surveys estimated 1,000 elk. Trend surveys underestimated elk in both WMUs.

2.5 Discussion

I expected the Idaho model, which was based on a large number (n = 229) of sightability trials across a broad range of habitat conditions, to make more accurate predictions of elk detection than the sightability model I developed from a smaller set of trials (n = 80). However, there was no difference in the prediction rate between the two models. The Alberta model ranked much higher using AIC_c than the variables used in the Idaho model. The model developed based on variables used in the Idaho model scored ninth, indicating it was not likely be a candidate for consideration (Burnham and Anderson 2002). The variables included in the Alberta model that were not included in the Idaho model were light intensity and elk activity (bedded). Although light intensity was not measured as a variable in the Idaho sightability trials, Leptich and Zager (1993) recommended measuring it in future efforts because bright sun reflecting from snow cover causes observer fatigue and also darkens shadows, negatively affecting sightability. Bedding behavior of elk may not have had an effect in the Idaho trials because only 12% of the observations in the early Idaho trials were of bedded elk (Samuel 1987), while in my study elk were bedded in 22% of the trials. It is possible that regular over-flights by telemetry crews or aircraft associated with oil and gas exploration and forestry in my study area may habituate elk resulting in more bedded observations.

I found that elk group composition, cover type, topography, aspect, precipitation, temperature, and observer experience did not enter any of the best models. Because radiocollared cows were used for sightability trials, herd composition of elk groups was primarily cows and calves so a sex ratio bias in sightability would not have been detected. However, McCorquodale (2001) conducted sightability trials in Washington and did not find that sex of the animal influenced their sightability. When elk were in open habitats, the sightability correction using the Alberta sightability model was very low for two reasons. First, both the lack of tree cover and larger group sizes both contributed to high detection. Where sightability contributed to group size adjustment most was in the habitats with more closed canopies where the group sizes typically were also smaller. The Alberta model increased the elk numbers only 1% in WMU 326 because most of the observations were in large herds and open habitats. Figure 2.1A shows that the elk number correction at low percentages of tree cover is close to 1.0. In WMU 328, the Alberta model adjustment resulted in an increase of 20% because more observations were of smaller elk groups in areas with more tree cover. In contrast, adjustments based on the Idaho model were higher, with an increase in elk numbers of 8% in WMU 326, and 58% in WMU 328. Comparisons of sightability adjustments on survey data, between the Idaho and Alberta models can be found in Appendix II.

Tree cover was originally used to stratify the survey units because wintering elk tend to be associated with open meadows and clearcuts (Jones and Hudson 2002). In fact, I found that the relative probability of use (RSF values) of an area in winter to be a function of the presence of clearcuts and of high forage biomass, which typically is the case in upland and wet meadows. However, I did not find that the mean RSF value was closely related to tree cover of a survey block. The lack of correspondence between tree cover and the mean predictions of RSF of a survey unit may have been related to the high forage abundance found in open coniferous and mixed wood tree stands. Further, the density of roads may also explain the lack of correspondence. However, I originally expected that roads would have a negative effect the relative presence of elk, but I found a positive effect. Friar et al. (2004) found that elk foraged close to linear disturbances and roads, but rested > 50 + meters away from them, which might explain the positive effect of road density in the model. My scale of road density of linear km/km^2 was too coarse to differentiate between the foraging and resting areas.

A problem created in poststratification occurred when no elk were seen within a stratum. This resulted in a low CI and DEFF. In WMU 326 this occurred when areas were poststratified based on tree cover with either three equal or the 20:60:20 allocation of survey units. In contrast, RSF values stratified by Jenks optimization gave the best CI and DEFF (WMU 326) or tied for best (WMU 328). It must be noted, however, that even though a smaller CI gives a greater measure of precision, it does not ensure higher accuracy. Accuracy cannot be measured because the true number of elk in these units is unknown. As well, even though the RSF improved precision and can be a useful way to stratify for aerial surveys it must be used with caution in the future as it may not react to some variables through time.

The ability to detect meaningful changes in a wildlife population is important for wildlife management. In Alberta, elk trend surveys have not been able to meet this expectation. Application of RSF as a basis for stratification with a correction for sightability can enhance population estimates for elk management. The recommended CI to strive for is 90% with outer limits of ± 20% of the population estimate (Gasaway et al. 1981, Glasgow 2000). For elk, wildlife management agencies, on average, desire CI of ± 17 percent (Vermeire et al 2004). Ideally, to achieve the desired CI, strata should be selected according to elk density. In reality, stratification is usually based on variables quantified from vegetation maps that hopefully are highly correlated with elk density. Tree cover provided reasonable estimates using three equal strata by tree cover. Overall, the post stratification by RSF produced a more precise estimate of population indicating that it better captured the spatial variance in elk population distribution.

Innovative ways of analyzing wildlife resources are becoming available to researchers and managers with the relatively recent development of global positioning technology (GPS) and geographical information system (GIS) software. As related technology and software applications develop, population sampling can also advance to provide better information for wildlife management

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CHAPTER 3

MANAGEMENT IMPLICATIONS OF POPULATION SURVEYS

3.1 Introduction

"Census is the first step in management"(Leopold 1933).

The Fish and Wildlife Policy for Alberta (Alberta Fish and Wildlife 1982) provides the policy framework for wildlife management in Alberta and the Management Plan for Elk in Alberta (Alberta Environmental Protection 1997) set elk population goals to achieve a desired abundance to allow for a harvestable surplus that is consistent with subsistence, recreation and commercial (guide/outfitting) interests and in some areas to keep the population at a level low enough to minimize crop depredation or habitat degradation (Teer 1997, White et al. 1998, McInenly 2003). Determining the desirable size for an elk population requires that the interests of all groups be considered, and in some areas conflicts between users can be high. Wildlife management agencies using elk trend surveys are not satisfied with their current accuracy levels and jurisdictions with higher human populations and impacts desire higher accuracy levels from elk population assessments (Vermeire et al. 2004). The increased industrial and recreational impacts in the Clearwater Forest are placing many pressures on elk, affecting population dynamics and distribution. Providing enhanced elk population estimates using sightability correction and providing precision estimates with surveys will give elk managers in Alberta the confidence to react quicker to population changes to meet policy goals and meet the expectations of users of the elk resource.

3.2 Sightability

Sightability models are a useful tool for reducing bias in population estimates and should be flexible enough to adapt to many areas and survey designs. If applied in other areas, the model requires that counts be conducted using the same flying techniques following protocols recommended in Alberta Fish and Wildlife's: *Procedures for Aerial Ungulate Surveys* (Schumaker 2001). Variables of percent tree cover, percent snow cover, group size, light intensity, and elk activity should be recorded consistent with the method was collected during sightability trials for application of the model (Table 2.1). This model could be used in most vegetation types if percent tree cover can be accurately estimated, but future testing may be required in the event that type of tree cover alters the detection of elk. Some diagrams which are useful for estimating tree cover in various habitat types can be found in *Aerial Survey: User's Manual* (Unsworth et al. 1999). Further, if elk behaviors appear to differ substantially from the range of the variables under which the model was developed (Appendix III), it should be validated. Future sightability trials could be conducted during aerial surveys at minimal cost if there are radiocollared elk in the survey area. A pre-survey with a fixed wing aircraft to locate radiocollars and relocation of those animals after the survey, with either a fixed wing or the survey helicopter, could be used to add sightability information. Additional sightability trails from radiocollared elk could be continually added to this model to enhance it particularly under different snow conditions. Applying the sightability adjustment to a survey of an elk population of a known size would allow the model to be tested for accuracy by comparing predicted elk numbers to known elk numbers. Application to other wild ungulates would not be appropriate because of animal size differences and behavior differences, which influence sightability. Developing sightability models for other species or using models developed in other jurisdictions would improve present wildlife population estimates in Alberta. Sightability models for other species that could be tested in Alberta are moose (Anderson 1994; Anderson and Lindzey 1996), mule deer (Ackerman 1988), and bighorn sheep (Bodie et al. 1995).

3.3 Management of Aerial Surveys

The present system of bi-annual trend surveys of important winter ranges have allowed for long term monitoring of populations in specific areas but have not been able to provide timely information on population changes and no information on elk populations in the forested areas of the central east slopes where the most dramatic human disturbances are now happening. In the past, the east slopes had poor human access and low levels of industrial development. Recent industrial activity has increased access and increased human disturbance on elk makes it increasingly important for wildlife managers to obtain elk population data with estimates of variance that allow stronger inferences on population changes, both from year to year and from area to area.

My study shows that stratified random sampling based on RSF can provide more precise elk population estimates in the Clearwater Forest. There are 6 WMUs in the Clearwater Forest that would benefit from these surveys. Several of the smaller units have similar habitats and hunting regulations and it would be feasible to survey them as a group. One third of the area could be surveyed each year on a rotational basis to completely survey the whole area over three years. This would take about 15 hours of helicopter flying time per year as opposed to the historical trend surveys that take 15 hours of helicopter time to complete every second year. I submit that although the cost of the surveys would about double, implementation of annual surveys following this approach are efficient and are necessary to provide effective management of elk populations. In WMU 328, 65% of the variance (RSF/Jenks stratification) was attributed to the high strata. Flying a higher percentage of high strata units could provide the desired CI with fewer survey units sampled overall, and provide a potential cost savings.

Elk surveys, to be most effective, should be conducted with the following standards:

1) Primary observers should be experienced in aerial elk surveys and survey time should be limited to 5 hours per day (2 to 2.5 hour sessions) to allow observers to maintain high search intensity.
2) Surveys should be flown with the type of helicopter used in these surveys, a Bell 206 Jet Ranger with bubble windows. This will ensure that sightability effects of the helicopter stay similar.
3) Even though the model adjusts for snow cover, snow cover of 100% would be the best condition to conduct aerial surveys.
4) High overcast cloud cover, which produces flat light, would be most desirable for survey conditions.
5) Surveys should be done in the winter months (January to March), when elk are most likely to occupy more open habitats.

3.4 Future Directions for Aerial Surveys

Using RSF appears to be a useful approach to stratification. For other wildlife species, RSF's built on telemetry data may not be practical, but the RSF could also be built with past aerial survey data, which would provide use/available data points (Manly et al. 2002). Location information from stratified random surveys should provide a wide enough range of animal densities and distribution to make a representative RSF. Locational information from winter range surveys would be biased towards a particular habitat type and animal distribution.

Boyce and McDonald (1999) propose using RSF's to determine wildlife populations in a different manner. RSF's are proportional to the probability of use of a resource unit; therefore using a reference area of known population density, RSF's can be used to extrapolate a population in a new area based on the area of resource units. Alternatively, the RSF can be adjusted, based on sampling intensity, to a resource selection probability function (RSPF), which can be estimated over the study area and summed to estimate population size (Boyce and McDonald 1999). In this study, the small sample size obtained over a large study area made it difficult to relate elk density to the RSF value, but over time multiple locations from aerial surveys could be used to approximate elk densities to RSF values. A smaller concentrated study area may provide the RSF/elk density links needed for the regression analysis. This method offers future research opportunities for elk population assessment.

RSF's could also be used for other survey designs as well. For example, in the ratio approach a continuous auxiliary variable to the population, such as an RSF value, could be used to provide a constant across the population for an efficient population estimation (Lehtonen and Pahkinen 1994). Enhancement of RSF's so that they would be constant in relation to elk densities would be required to further this method. Other variables linked to elk densities, such as winter ranges, could also be used in the ratio method, but again, linking them to elk densities would require future research. Another approach would be to use logistic regression models to predict groups of elk on the landscape based on environmental variables that influence elk distribution or an RSF value to represent elk distribution. The distribution of elk would approximate a Poisson distribution, which describes random occurrences when the probability of an occurrence is small (Zar 1999). The logistic model predicts the number of groups of elk. Some research is required to convert the number of groups to the number of elk, and provide a population estimate with confidence intervals.

Alternatively, the elk population could be predicted with a model. Exploration of this occurred using the same survey data collected for the design-based. The entire survey area was divided into 0.25 km^2 cells and the number of elk observed in a cell during the surveys was recorded as the independent variable. Location was determined using the global positioning system (GPS). For each cell the environmental variables developed and used in the RSF stratification were calculated (Chapter 2). The statistical model for predicting elk included three major components: predicting the number of groups of elk, group size adjustment and cell size adjustment. The distribution of elk approximated a Poisson distribution, which is important in describing random occurrences when the probability of an occurrence is small (Zar 1999). This distribution is very similar to a binomial distribution where the number is large but the probability small. Because of the large number of cells that will contain zero elk, a zero inflated Poisson (ZIP) regression will be used. This is a practical way to model count data with both zeros and large counts and has been used to predict manufacturing flaws (Lambert 1992) and traffic accidents (Miaou 1994). Sample sizes from the two elk surveys were too small to get meaningful results from this method, but this method showed some promise and is worth exploring in future research.

Enhanced sampling methods can improve our knowledge and management ability for wildlife. Further exploration of RSF's and modeling of population estimates could provide new future avenues for data collection and analysis.

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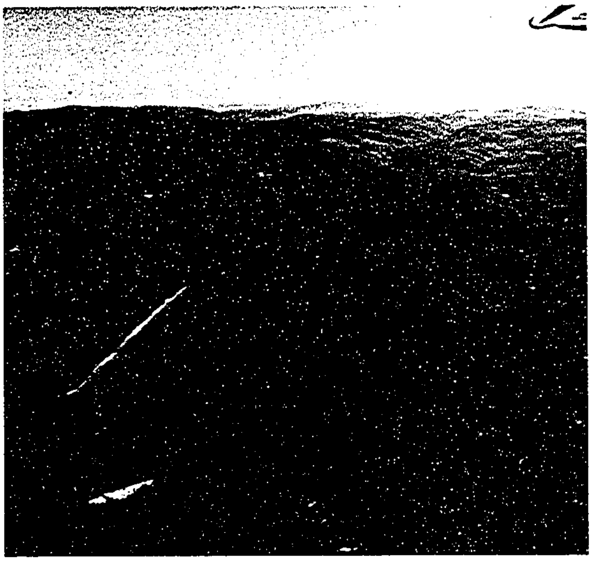
Appendix I. Examples of Tree Cover for Stratification for Aerial Elk Surveys.

1. High strata were defined as survey units that had ≤20% forest cover and these were typically traditional winter ranges.

2. Medium density strata had 21% to 50 % tree cover and were comprised primarily of cutblocks within forest cover.

3. Low-density strata had 51% to 100 % tree cover and were up primarily forest matrix of continuous forest with small openings .



Appendix II. Comparisons of sightability corrections using the Idaho and the Alberta sightability models from survey data collected in WMU's 326 and 328.

WMU	group size	bedded	%veg cover	veg class	% snow	light int	Alta	Idaho
326	4	0	60	5	100	0	4	10
326	30	0	0	1	100	0	30	30
326	22	0	0	1	100	0	22	22
326	67	0	0	1	100	0	67	67
326	18	0	0	1	100	0	18	18
326	10	0	0	1	100	0	10	10
326	5	0	75	5	100	0	6	11
328	1	0	20	2	100	1	1	1
328	2	0	20	2	100	1	3	3
328	12	0	20	2	100	1	12	12
328	7	0	20	2	100	1	8	8
328	19	0	20	2	100	1	19	19
328	4	0	20	2	100	1	5	5
328	1	1	80	6	100	0	3	7
328	2	0	0	1	100	0	2	2
328	3	1	20	2	100	0	4	4
328	10	0	40	4	100	0	10	12
328	3	0	0	1	50	0	3	4
328	4	0	80	6	100	0	5	16
328	5	0	70	5	100	0	6	11
328	7	0	80	6	100	0	8	19
328	7	0	80	6	100	0	8	19
328	21	0	80	6	100	0	21	23
328	11	0	80	6	100	0	12	19
328	1	0	20	2	100	0	1	1
328	5	0	90	7	100	0	6	30
328	7	0	80	6	100	0	8	19
328	18	0	0	1	100	0	18	18
328	3	1	20	2	100	0	4	4
328	9	1	0	1	100	1	11	9
328	10	1	0	1	100	1	12	10
328	8	1	0	1	100	1	10	8
328	2	1	0	1	100	1	4	2
328	13	1	50	4	100	1	18	15
328	1	1	90	7	100	1	14	12
Total	353						393	480

Appendix III. Results of sightability trials conducted in the central east slopes of Alberta in 2001 and 2002.

Observed = 1, Missed = 0;	Group = no of elk observed;
Bedded = 1; standing/moving = 0	PCVeg = percent tree cover;
Pcsnow = percent snow cover;	Light: Flat = 1; Bright = 0

Trial	OBSERVED	GROUP	bedded	PCVeg	pcsnow	LIGHT
1	0	1	1	75	100	1
2	0	14	1	50	95	0
3	0	5	1	50	100	0
4	0	4	1	40	100	1
5	0	1	1	94	75	1
6	0	15	1	60	95	0
7	0	6	1	50	75	0
8	0	6	1	65	95	0
9	0	6	1	60	35	0
10	0	13	1	40	100	1
11	0	18	1	70	90	1
12	0	14	1	80	100	1
13	0	1	1	70	90	1
14	0	3	1	60	80	1
15	0	2	0	80	100	1
16	0	5	0	80	100	1
17	0	1	0	94	35	1
18	0	5	0	80	100	1
19	0	15	0	80	75	0
20	0	20	0	65	75	0
21	0	4	0	65	35	1
22	0	6	0	70	100	1
23	0	4	0	95	100	1
24	0	4	0	50	75	0
25	0	2	0	50	75	0
26	0	2	0	50	75	0
27	0	2	0	35	75	1
28	0	1	0	80	100	1
29	0	2	0	50	35	1
30	0	1	0	50	75	1
31	0	6	0	60	95	0
32	1	12	1	80	100	1
33	1	16	1	40	100	0
34	1	13	1	60	100	0
35	1	37	1	40	100	0
36	1	10	1	60	75	1

Trial	OBSERVED	GROUP	bedded	PCVeg	pcsnow	LIGHT
37	1	9	1	20	75	1
38	1	23	1	20	95	1
39	1	36	1	0	75	1
40	1	32	1	0	75	0
41	1	52	1	0	35	0
42	1	7	1	20	35	1
43	1	9	1	70	100	1
44	1	7	1	80	100	1
45	1	6	0	80	100	1
46	1	10	0	70	100	1
47	1	33	0	40	100	1
48	1	38	0	10	100	1
49	1	2	0	40	100	1
50	1	31	0	0	100	0
51	1	19	0	40	100	0
52	1	3	0	75	100	0
53	1	3	0	40	100	0
54	1	20	0	20	100	0
55	1	31	0	50	100	0
56	1	29	0	70	100	0
57	1	7	0	35	75	1
58	1	13	0	20	75	1
59	1	27	0	20	75	1
60	1	8	0	94	75	1
61	1	33	0	35	75	1
62	1	6	0	20	35	0
63	1	13	0	20	10	1
64	1	2	0	35	75	1
65	1	23	0	65	75	1
66	1	9	0	35	95	0
67	1	15	0	35	95	0
68	1	42	0	0	90	1
69	1	5	0	50	80	1
70	1	10	0	80	50	1
71	1	5	0	80	100	1
72	1	6	0	70	100	1
73	1	14	0	90	100	1
74	1	12	0	0	100	0
75	1	14	0	50	100	0
76	1	12	0	80	75	1
77	1	13	0	80	75	1
78	1	14	0	50	75	1
79	1	13	0	70	30	1
80	1	2	0	75	100	1