MODELING MOOSE SIGHTABILITY IN SOUTH-CENTRAL BRITISH COLUMBIA

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ABSTRACT: We developed a model to correct sightability bias in aerial surveys of moose in the southern interior of British Columbia. Sightability trials were conducted by searching sample blocks where radio-collared moose were known to occur. Relevant attributes that were believed to affect the sightability of moose were recorded and used as independent variables for a logistic regression model of sightability. Univariate analysis revealed that percent vegetative cover, percent snow cover, and daily temperature all significantly influenced the probability of detecting a moose. However, multivariate analysis retained only vegetative cover as the significant variable to predict sightability probability. This mirrors the results of analysis of similar trials done in western Wyoming that used the same independent variables as well as 6 additional ones. Two logistic regression models were developed for moose sightability; one based on 5 classes of vegetative cover and a second, less accurate, based on 3 classes of vegetative cover.

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Aerial surveys are widely used to census moose (*Alces alces*) in British Columbia. It is recognized, however, that aerial surveys underestimate animal abundance due to visibility or sightability bias; the failure to observe all animals from the air (Caughley 1974, LeResche and Rausch 1974, Samuel et al. 1987). The magnitude of sightability bias depends on numerous factors, including animal behaviour and dispersion, observers, weather, vegetation cover and cover type, search rate, snow cover and condition, and equipment. Sightability bias not only limits the usefulness of population estimates, but may also bias estimates of age and sex ratios if habitat selection by bulls, cows, or cows with calves results in different visibility factors (Samuel et al. 1987).

In British Columbia, aerial surveys generally use a stratified random block (SRB) design (Gasaway et al. 1986). The most common means of correcting for sightability bias during SRB surveys is the estimation of a sightability correction factor (SCF); usually the product of an observed SCF (SCFo) and a correction factor constant (SCFc) (Gasaway and DuBois 1987). Both subjective and quantitative methods have been used to estimate SCFc's in British Columbia. These include a modification to Gasaway et al.'s (1986) technique in which high intensity searches are performed at the outset of the survey with the intent of eliminating the necessity for estimating SCFo. The SCFc is then directly applied to the estimated number of animals (Hatter 1992).

Despite these attempts to correct for sightability bias in British Columbia, Hatter (1992) suggested that the problem has not been adequately resolved. Most survey areas in British Columbia contain a mosaic of diverse habitat types ranging from relatively open habitats dominated by deciduous shrubs to closed coniferous forest stands. Best guesses at SCFc, based on survey evaluations, provide no objective assessment of reliability. Most surveys have not had a large enough sample to properly measure sightability bias (sample size bias), and even for more intensive searches, the SCFc's are probably still biased because it is unlikely that searchers see all of the moose (model bias). As well, precision tends to be overestimated when variance estimates for the SCFc are not used when calculating confidence intervals (CI) on a density estimate.

For these reasons, the decision was made to develop a moose sightability model, similar to an elk model developed in Idaho (Samuel 1984, Samuel et al. 1987) and a moose model recently developed in Wyoming (Anderson 1994, Anderson and Lindzey 1996). Aerial trials would be undertaken to determine the influence of environmental and observer factors on the sightability of moose during standard surveys. Trial data would then be used to develop a predictive model of sightability that could be incorporated into a SRB or total count survey design.

STUDY AREA

Sightability trials were conducted on moose winter range within the upper portions of the Deadman River and Criss Creek valleys, 40-50 km northwest of Kamloops, British Columbia. Both drainages are relatively shallow sided in the upper reaches (1,000 - 1,300 m ASL) where trials were conducted. Trials were conducted in the Sub-Boreal Pine-Spruce, Montane Spruce, and Interior Douglas Fir biogeoclimatic zones of the two drainages (British Columbia Ministry of Forests 1992). These 3 zones are characterized by the highest densities of moose in south-central British Columbia (Jury 1992).

The characteristic tree species of the Montane Spruce zone are Engelmann spruce (*Picea engelmannii*) and hybrid spruce (*Picea glauca x engelmannii*) and varying amounts of subalpine fir (*Abies lasiocarpa*). Due to past wildfires, successional forests of lodgepole pine (*Pinus contorta*) and trembling aspen (*Populus tremuloides*) are common. The Sub-Boreal Pine-Spruce zone is also characterized by many even-aged lodgepole pine stands as a result of past fires. A minor amount of white spruce (*Picea glauca*) regeneration occurs as well. At higher elevations in the Interior Douglas Fir zone, fires have frequently created even-aged lodgepole pine stands, but Douglas-fir (*Pseudotsuga menziesii*) is the dominant tree.

The moose winter range in the upper Deadman and Criss Creek valleys is characterized by extensive riparian bottomlands of willow (*Salix* spp.) and red osier dogwood (*Cornus stolonifera*). These heavily used forage areas are bordered by dense stands of Engelmann spruce that provide important security and thermal cover. The valley slopes, low hills, and ridge tops support mixed stands of trembling aspen, lodgepole pine, and Douglas fir, important foraging and resting habitats during the early and mid-winter period. Moose are observed to move into dense conifer stands scattered throughout their winter range after mid-February.

METHODS

Sightability Trials

Moose were captured and radio-collared during the winters of 1991/92 and 1995/96. Animals were darted from a helicopter and immobilized with 3.6 - 3.9 mg of carfentanil. Individual moose were ear-tagged with a unique color combination of tags and radio-collared (Lotek Engineering Inc., Newmarket, Ontario). The sex of each moose was determined and its age estimated before 400 mg of the carfentanil antagonist, naloxone hydrochloride (Narcan), was administered to aid recovery.

During sightability trials, attempts were made to standardize all factors that were controllable, such as, aircraft, pilot, and observers. A Bell 206 helicopter was used for all trials, and standard roles were assigned to observers. The navigator sat next to the pilot and they radio-located moose, delineated block boundaries, searched for moose, and recorded data. The primary observer sat behind the navigator and was responsible for determining the height and speed of the search and making the final decision on data to be recorded. An additional observer sat behind the pilot during all trials. Temperature was recorded at the beginning of each day.

The trial procedure differed from that used by Samuel et al. (1987) and Anderson (1994). The general location of the animal was used to define the survey block boundaries. The navigator determined the general location of one or more radio-collared moose by flying over them at 700 - 1,000 m above the ground. The navigator, or in later trials, the pilot, got a rough idea of where the moose were located, but not a specific location. The other observers could not hear the radio receiver, so remained unaware of the animal's general location. A rectangular survey block encompassing 1.0 - 5.5 km^2 was drawn around the moose's general location on a 1:60,000-scale air photo. Prominent terrain features were used as sides or corners. Block boundaries were drawn such that the moose could have been anywhere within the block.

Once a block was defined, an intensive search of the block was flown at approximately 100 - 200 m above ground (depending on habitat type) at a ground speed of 80 - 95 km/hr. As much as possible, search intensity was kept consistent and equal within and between sample blocks. All observers searched the block and when a group (i.e., $\geq$ 1 moose) was seen, the observer directed the attention of the pilot and other observers to the area. The activity of (i.e., moving, standing, or bedded) and percent vegetative cover surrounding the first animal sighted in the group was immediately noted. Moose were closely examined to determine whether they were collared or not. Whenever a radio-collared moose was observed, animal activity, percent vegetative cover, cover type, and percent snow cover were recorded.

Estimating percent vegetative cover from the helicopter required a certain amount of mental averaging. Figures developed by Unsworth et al. (1991) were used to help in these estimations. The percent cover of vegetation was considered to be the average canopy cover within a 10 m radius of the first moose sighted in a group, even if the first moose seen in a group was not the radio-collared moose. It was rationalized that the rest of the moose in the group would have remained unseen if not for the conditions associated with the first moose seen. Any vegetation that blocked the observers' view of the moose was considered part of the canopy (Unsworth et al. 1991). Cover was generally estimated at an oblique angle from the height that the search was conducted. Cover type was recorded in this study but was not recorded by Samuel et al. (1987). Although 9 cover types were previously described by MacHutchon and Jury (1994), these were reduced to 3 cover types for statistical analyses: (1) open meadow/shrub; (2) deciduous/mixed forest; and (3) conifer forest. For surveys prior to 1999, the search time was noted upon the completion of the search, including the time spent circling groups of moose looking for a radio-collar. Group composition was not consistently documented for all trials, and so these data are not complete.

Any radio-collared moose that were not

seen within the survey block during the standard search were located with the telemetry receiver. Once the moose was located, group composition, animal activity, percent vegetative cover, cover type, and percent snow cover were recorded.

Model Development

The first step in model development was to determine the visibility of moose for the different classes of each independent variable, such as sex/age class, primary observer, animal activity, cover type, group size, vegetative cover, snow cover, and search rate.

Univariate analyses, using the maximum number of observations available for each variable, were used to statistically test the relationship between the independent variables above and the dichotomous dependent variable; i.e., moose groups seen or missed (Anderson and Lindzey 1996). Categorical or discrete independent variables (i.e., sex/age class, primary observer, animal activity, and cover type) were tested using likelihood ratio chi-square analysis (also called the G-test) (StatSoft Inc. 1996). Continuous independent variables (i.e., group size, % vegetative cover, % snow cover, and search rate) were tested using univariate logistic regression (SAS Inc. 1996; sensu Anderson 1994).

Pearson correlation coefficients were used to evaluate the correlation between variables that significantly influenced sightability. Other interactions involving continuous variables were examined using *t*-tests and analysis of variance techniques; chi-square contingency analysis was used to compare categorical variables (StatSoft Inc. 1996).

Multivariate analyses were conducted using stepwise logistic regression (SAS Inc. 1996) to determine which independent variables had a significant influence on the dependent variable (i.e., groups seen or missed; Samuel et al. 1987, Anderson and Lindzey 1996). A variable was considered to be important in predicting sightability when its stepwise improvement chi-square exceeded a 5% significance level based on improvement in the likelihood ratio (Samuel et al. 1987).

In logistic regression, the probability of an event, y, occurring is directly estimated from the model, which can be written as:

$$P(y)=\frac{e^{z}}{1+e^{z}}$$

where Z is the linear combination $Z=B_0+B_1X_1+B_2X_2+\ldots+B_pX_p$; B_0 and B_1 $\ldots B_p$ are coefficients estimated from the data; $X_1 \ldots X_p$ are the independent variables; and e is the base of the natural logarithms, approximately 2.718. The inverse of P(y) is the correction factor applied to each group observed during surveys (Anderson and Lindzey 1996).

RESULTS

Sightability Trials

Forty-five moose were captured and radio-collared, 23 males and 22 females. Most moose were involved in at least one sightability trial. Trials were flown in January, February, March, and December 1993; January and March 1994; February and December 1996; and March 1999. Ninety-eight blocks containing 1-3 radio-collared moose were surveyed for a total of 105 trials. Ninety-four of these trials had a complete set of variables. The remaining 11 trials were incomplete as the focal moose had been moving, thereby not allowing estimation of the percent vegetative cover at its initial position. Trials were discarded for animals missed during the initial search that were found moving once a receiver was used to locate them. This raised a concern that the activity "moving" could only be reliably recorded for moose that were not missed during trials. As a result, standing and moving were amalgamated into one activity (i.e., active) in the analyses, to eliminate this potential bias.

The helicopter pilot was the same during 1993, 1996, and 1999, but different during 1994; however, differences in pilots did not appear to affect sightability ($\chi^2 = 0.007$, $P = 0.935$).

Model Development

Sightability data were obtained on 105 groups of moose under a variety of conditions (Table 1). Overall sightability was 49% for these 105 groups. There was no significant difference in the visibility of bull groups or cow groups ($\chi^2 = 0.59$, $P = 0.4436$). Although data collected in 1999 did not separate out cow/calf groups, analysis of data prior to 1999 revealed no difference in visibility of bull groups (50%, $n = 26$), cow groups (72%, $n = 18$), and cow/calf groups (42%, $n = 12$; $\chi^2 = 3.37$, $P = 0.185$). In addition, there was no difference in the average vegetative cover used by bull groups ($\overline{X} = 47\%$, SD = 21%, $n = 38$) versus cow groups ($\overline{X} = 41\%$, SD = 21%, $n = 56$; $t = 1.25$, $P = 0.214$). Cow groups appeared to use non-conifer cover types more than bulls, reflected by a significant difference in the use of the 3 habitat cover types by cows and bulls ($\chi^2 = 8.00$, df = 2, $P = 0.018$).

Univariate analyses suggested that percent vegetative cover, percent snow cover and daily temperature significantly influenced moose sightability (Table 1). Correlations between daily temperature, percent snow cover, and percent vegetative cover were insignificant with the exception of a significant, but weak, correlation between daily temperature and percent vegetative cover ($r = 0.23$, $P < 0.05$). As well, neither animal activity nor habitat type were significantly affected by daily temperature ($F = 0.34$, $P = 0.562$ and $F = 0.096$, $P = 0.759$, respectively), although the density of vegetative cover in which moose occurred differed significantly by month of year ($\chi^2 = 18.821$, df = 10, $P = 0.04264$) with moose occupying more dense vegetative cover in late winter (Table 2).

Habitat type was insignificant even though moose in openings or in open forest were more visible than those in conifer forest (Table 1), and there was a significant difference ($t = 3.69$, $P = 0.001$) in mean vegetative cover at moose locations in spruce dominated forest ($\overline{X} = 60\%$, SD = 23%, $n = 18$) versus pine dominated forest ($\overline{X} = 40\%$, SD = 21%, $n = 35$). Activity was also not related to sightability, although bedded moose occupied significantly greater ($t = 2.05$, $P = 0.043$) vegetative cover ($\overline{X} = 47\%$, SD = 21%, $n = 30$) than did active moose ($\overline{X} = 36\%$, SD = 25%, $n = 74$). Primary observer was held constant for the majority of surveys (81%) and did not influence sightability. Similarly, search rate did not have a significant influence on sightability, although search rates were often higher for conifer-dominated blocks, exceeding 5.00 min/km^2 in 53% of the cases ($n = 49$).

Multiple logistic regression analysis of the 94 complete trials indicated that percent vegetative cover was the only important predictor of moose sightability (Table 1). None of the other variables significantly influenced sightability once percent vegetative cover was entered into the stepwise model. Under certain vegetative cover, moose had a very low probability of being seen, as sightability decreased substantially when vegetative cover approached 60% (Fig. 1). Of 18 moose in closed forest stands with >60% cover, only 1 was detected. In 3 cases, extensive searches with the telemetry receiver were conducted and the moose still could not be seen. The observers had to land, search the location site, and backtrack to where the moose had

Table 1. Moose sightability trial results by independent variable for the Deadman River and Criss Creek study area, south-central British Columbia.

Variable	n	% Seen	Univariate[1] χ^2	Univariate[1] P	Multivariate[2] χ^2	Multivariate[2] P
DISCRETE						
SEX:			0.588	0.443	0.214	0.644
Bull(s)	41	44				
Cow(s)	64	52				
PRIMARY OBSERVER:		3.50	0.061	1.22	0.268	
Observer1 85	53					
Not Observer1 20	30					
ANIMAL ACTIVITY:			2.41	0.121	2.84	0.092
Bedded	30	37				
Active	74	54				
COVER TYPE:			8.28	0.159	0.165	0.685
Open Meadow/Shrub	4	100				
Deciduous/Mixed Forest	36	61				
Conifer Forest	58	44				
CONTINUOUS						
VEGETATIVE COVER (%):			40.625	<0.001	40.625	<0.001
0-20	18	89				
21-40	31	77				
41-60	27	37				
61-80	11	9				
>80	7	0				
SNOW COVER (%):			8.050	0.005	1.47	0.226
0-25	1	0				
26-75	1	0				
76-99	12	25				
100	88	58				
DAILY TEMPERATURE (°C):			13.16	<0.001	3.79	0.051
-12 to -10	21	81				
-9 to -5	37	49				
-4 to 0	41	39				
>0	6	0				
SEARCH RATE (min/km^2)[3]:			0.46	0.497	1.38	0.240
2.00-4.99	23	48				
5.00-7.99	17	47				
8.00-10.99	5	40				
11.00-13.99	4	75				

[1] Univariate results from χ^2 contingency analyses of discrete independent variables (G Test) and logistic regression analyses of continuous independent variables.

[2] Final significance of independent variables after stepwise logistic regression with only percent vegetative cover included in the model ($P<0.05$, $n=94$).

[3] Univariate and multivariate analyses with search rate include fewer trials as these data were not collected after 1996.

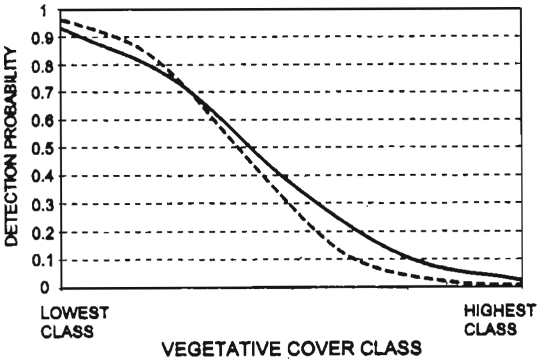

Fig. 1. Probability of detecting moose by vegetative cover class. Solid line is probability curve for south-central British Columbia, as described by the logistic regression, $Z = -4.2138 + 1.5847$(Vegetative Cover Class 1 - 5), based on 5 cover classes, 20% intervals between 0 and 100% cover. Dashed line is probability curve for Wyoming from Anderson and Lindsey (1996), based on 6 cover classes, 17.5% intervals between 0 and 100%.

been bedded. No moose were seen in >70% cover.

Anderson and Lindzey (1996) felt it was necessary to group percent vegetative cover into broader classes. This would reduce covariate patterns, thus reducing computational complexity and allowing P-values to be obtained for imbalanced categorical variables included in the model, and reduce the potential bias from field estimation errors of percent vegetative cover. Anderson and Lindzey (1996) used 17.5% intervals; however, the classes used for percent vegetative cover in this paper are based on categories of 20% as this produced the greatest χ^2 value when logistically regressed against sightability (compared to $\chi^2 = 37.47$ at 17.5% and $\chi^2 = 40.51$ at 10%). These classes were then treated as a continuous variable in regression analysis.

Preliminary Sightability Models for South-Central B.C.

Our initial sightability model used vegetative cover classes of 20% as outlined in Table 1. The linear regression portion of this model was:

$Z = -4.2138 + 1.5847$(Vegetative Cover Class 1 - 5).

The estimated standard errors for the intercept and vegetative cover class were 0.8844 and 0.3339, respectively. This model correctly classified 78% of 51 observations where a moose was seen and 79% of 43 observations where a moose was not seen; overall correctly classifying 79% of the total 94 observations as seen or missed. Graphically displayed, the 5-class model follows a more shallow curve than the 6-class, Wyoming model of Anderson and Lindsey (1996) in which the probability of detecting a moose decreases close to zero at > 70% cover (Fig. 1).

A second sightability model was developed in which vegetative cover was categorized into just 3 classes, < 30% (87% seen),

Table 2. Crosstabulation showing the percentage of moose that occurred in each vegetative class by month. Vegetative cover classes are based on 20% intervals between 0 and 100% cover.

Month	Vegetative Cover Class					
	1	2	3	4	5	*n*
December/ January	23	42	15	15	4	26
February	44	28	22	6	0	28
March	8	30	38	12	12	50

30 - 60% (55% seen), and > 60% (6% seen). Using fewer categories was intended to reduce observer bias in estimating cover in the field, as well as reduce the time and cost necessary to classify each moose group seen. The linear regression portion of this model was:

$Z = -4.3179 + 2.1972$(Vegetative Cover Class 1 - 3).

The estimated standard errors for the intercept and vegetative cover class were higher than the 5-class model, at 0.9485 and 0.4792, respectively. This model underestimated the number of moose seen, correctly classifying only 53% of 51 observations where a moose was seen. In contrast, it correctly classified 91% of 43 observations where a moose was not seen, and overall, correctly classified 70% of the total 94 observations as seen or missed.

DISCUSSION

Estimates of sightability based on univariate analysis alone will tend to overestimate the number of significant factors, usually because these factors are correlated with the dominant variables; in this case, percent vegetative cover (Samuel et al. 1987, Anderson and Lindzey 1996). This was the case in model development from the south-central British Columbia data. Univariate analysis revealed that 3 variables were significant to sightability: percent vegetative cover, snow cover, and daily temperature. The first two of these have obvious influences on an aerial observer's ability to detect a moose, by obscuring the line of sight between observer and moose, and affecting the continuity of the contrasting, white background. However, multivariate analyses indicated that percent vegetative cover was the main factor influencing the sightability of moose, so much so that snow cover and daily temperature became insignificant. In a similar study, Anderson and Lindzey (1996) evaluated the relationship of 12 biological and procedural variables to the sightability of 104 moose groups containing radio-collared individuals on 3 study areas in western Wyoming. After multivariate analysis, they found percent vegetative cover to be the only variable with significant influence on sightability. In addition to the variables used in this study, Anderson and Lindzey (1996) also included topography, light intensity, group size, time of day, study area, and distance of the moose group to the flight.

The importance of vegetation cover on ungulate sightability has been stressed by numerous studies (Samuel et al. 1987), and so its significance in a British Columbia model is not unexpected. In several other studies, vegetation appears to influence sightability in concert with behavioral variables such as activity and group size. Drummer and Aho (1998) found vegetation cover, as well as activity and group size, to influence sightability in Michigan. Samuel et al. (1987) found that group size and vegetation cover were the most important influences on elk sightability during helicopter surveys in Idaho. Gasaway et al. (1985) suggested that habitat type, group size, and activity were the main influences on moose sightability in Alaska. They felt group size and activity might be correlated, but they didn't address the relationship between habitat characteristics and other factors (Anderson and Lindzey 1996). Anderson and Lindzey (1996) suggested that habitat type and group size were correlated with vegetative cover in Wyoming and that moose activity was not important. Activity was similarly unimportant in this study, although the significant difference in the percent vegetative cover for bedded versus active moose hints at a possible interaction between activity and cover. Anderson and Lindzey (1996) suggested that the differences between their results and Gasaway et al. (1985) might have been because Gasaway et al. (1985) used fixed-wing aircraft and they used helicopters. Crête et al. (1986) had earlier reported that moose behavior was more sensitive to fixed-wing aircraft surveys than helicopter surveys. Helicopters were also used during this study.

Although it has no direct influence over sightability, it is possible that daily temperature might track changes in secondary variables, such as activity and habitat type, which alone did not influence sightability but may cumulatively have an effect. This reasoning was supported by some sets of observations, such as the exclusive occurrence of moose in habitats without tree cover when temperatures were colder than -10°C, the minimum for the data (range: -12 to +1°C), and, indirectly by the relationship between month and vegetative cover class. The latter suggests that more moose may have been detected when air temperature was colder because of survey timing; moose were surveyed in more open habitats during January and February, and less open ones in March. This may offer some explanation why daily temperature did not significantly affect animal behavior or habitat, and had only a weak correlation to percent vegetative cover. Trends may have been stronger if temperature had been recorded at the beginning of each trial rather than simply at the start of the day. Apparently, whatever aspect of daily temperature explains variation in sightability was shared by percent vegetative cover in the multivariate analysis.

Snow cover had a significant univariate, but not multivariate, effect on sightability in this study, and other authors have suggested it can be an important factor (LeResche and Rausch 1974, Gasaway et al. 1986). Like Samuel et al. (1987) and Anderson and Lindzey (1996), we believe snow cover was not a factor in our multivariate model because of the limited range of snow cover tested. Snow cover was 80% or greater at all but 2 moose locations. By early March at lower elevations and mid-March at higher elevations, however, there were increasingly large bare patches in some of the survey blocks, particularly around the base of trees. Radio-collared moose were never seen on the bare patches, even though these bare, often dark patches were believed to distract observers and hamper their search efficiency.

Many previous studies that examined observer differences over a wide range of observer experience have found important differences (Anderson and Lindzey 1996). Recent studies using multivariate analyses have found that differences among experienced observers are usually correlated with other factors (Samuel et al. 1987, Ackerman 1988, Anderson and Lindzey 1996). In all cases, however, researchers have stressed the importance of using experienced observers. Factors that were controllable during this study, such as primary observer, pilot, and helicopter, were kept constant as much as possible, so there was little chance of seeing an influence of these factors on moose sightability in the analyses. As well, tenacity and vigilance may have been unusually high for observers used in this study due to the expectation of a radio-tagged moose on a survey plot. In real survey situations, however, observers may be more subject to fatigue and distraction, and it may not be possible to have the same primary observers during stratified random block surveys over a number of days. If alternate observers have to be used then they should be as experienced as possible.

We saw 49% of 105 groups with radio-collared moose. This detection rate was lower than 59% of 104 groups seen by Anderson and Lindzey (1996), yet surveys in this study occurred earlier in the winter with a higher average search rate (where it was recorded: British Columbia; $\overline{X} = 5.62$

min/km^2, SD = 2.79 min/km^2 versus Wyoming; $\overline{X}$ = 4.7 min/km^2, SD = 1.2 min/km^2). Despite the lower overall detection rate in this study, 24% of moose groups in vegetative cover > 40% and 43% in conifer dominated stands were seen, while Anderson and Lindzey (1996) saw only 14% of moose groups in vegetative cover > 40% and 33% in conifer dominated stands. The British Columbia study area appears to have had a much higher percentage of conifer dominated habitat than the 3 Wyoming study areas (Anderson 1994). This may contribute to the lower overall detection rate. However, the occurrence of radio-collared moose in conifer-dominated habitat differed only slightly between British Columbia (59%) and Wyoming trials (56%). The overall detection rate during this study was also lower than the 43-68% of LeResche and Rausch (1974), the 57% of Thompson (1979), the 64% of Rolley and Keith (1980), the 73% of Crête et al. (1986), and the 78% of Peterson and Page (1993). Direct comparisons among studies are difficult, however, because of differences in aircraft type, number of observers, search intensity, and moose habitat use.

Two moose sightability models were developed from the British Columbia data. The models differ by their amount of simplification of the percent vegetative cover classes. As vegetative cover classes were simplified, the standard errors of the model coefficients increased, which would likely increase the confidence limits around each group estimate and decrease the precision of the population estimates. As a result, there appear to be significant trade-offs in precision associated with simplifying the model, reflected in the diminished ability of the 3-class model to predict moose sightability, particularly for moose that were seen. We do not recommend this model as it appears to introduce additional error to sightability correction through oversimplification. In addition, Anderson and Lindzey (1996) cautioned that, despite having simplified vegetative cover classes in their sightability model, percent vegetative cover should be estimated using 5% categories during actual surveys to guard against inaccurate estimates of the vegetative cover class.

The 5-class model appears promising. The model should generally be applied only in conditions that fall within the limits of the data on which it is based. This includes daily temperatures ranging from -12 to +1°C and snow cover greater than 80% (preferably 100%). As well, when moose shift from open to dense canopy habitats, sightability and confidence in estimating moose population parameters decreases, resulting in larger confidence intervals. A careful sampling design, including timing surveys for January and February when moose are most likely to use open habitats, will be important to obtain the most precise population estimates (Anderson and Lindzey 1996) and minimize bias caused by the low probability of detecting moose in dense vegetative cover. Only experienced observers should be used during aerial surveys of moose. If all observers are experienced then their individual differences appear to be correlated with other sightability influences (Samuel et al. 1987, Ackerman 1988, Anderson and Lindzey 1996). Sampling protocols used during the development of a moose sightability model should be rigorously followed during application of the model (Anderson and Lindzey 1996). This will require incorporating moose sightability into stratification during survey design.

Implementation of the model is greatly facilitated by an existing computer program, Aerial Survey, developed at the University of Idaho (Unsworth et al. 1994). This program corrects SRB data for sightability bias, adjusting the numbers of animals in each observed group based on its context. To accomplish this, Aerial Survey is designed to access regression-based models described in separate files provided with the software. A user with moderate computer expertise can modify the coefficients, variances, and data structures contained within these files to allow Aerial Survey to calculate corrected population estimates and confidence intervals based on a new model, such as the 5-class British Columbia model. This is an efficient approach given the complexity of the formulas used to calculate the sampling, visibility and model error associated with sightability correction (Steinhorst and Samuel 1989). A notable limitation of Aerial Survey, however, is that it provides estimates of population size (i.e., the number of animals) rather than density, which may produce error when sample block sizes are unequal.

It appears questionable whether a model could be developed using a combined data set from both south-central British Columbia and Wyoming, especially as there are differences in survey protocol between the 2 data sets. As well, there appears to be a greater abundance of habitats with dense vegetative cover in British Columbia and the resulting model is less sensitive to changes in vegetative cover, particularly where it exceeds 70%. This will produce a slightly more conservative correction when 1 or 2 moose are seen in dense habitat. Pooling the data may mask regional differences that originally motivated the development of the British Columbia specific model.

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