Moose Monitoring Protocol for the Southwestern Alaska Network

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I. Sampling Design

Rationale for Selecting this Sampling Design over Others

Because animals are missed during aerial surveys (Caughley 1974), it is important to adjust the observed counts for the lack of 100% detectability. Animals may be missed in aerial surveys for one of two reasons (Pollock et al. 2004). Some animals may be missed due to perception bias, wherein an observer team simply misses the animal(s) for any number of reasons: heavy cover, looking in the other direction, or intense light. Availability bias occurs when an animal has zero probability of being detected. This occurs when, for example, marine mammals are submerged, or animals occupy a den. It is difficult to think of circumstances where this could happen for moose. Pollock and Kendall (1987) review methods for accounting for perception bias, which we refer to as detectability less than 100%. The Gasaway procedure (Gasaway et al. 1986), which was used at Lake Clark National Park and Preserve (LACL), provides one method for estimating a correction factor by conducting a second intensive survey of selected sampling units. The difficulty with this method is that the intensive surveys do not guarantee 100% detectability, thereby producing a biased estimate of overall detectability. To overcome perception bias, we therefore recommend the use of a sightability model (Drummer and Aho, 1998; Steinhorst and Samuels, 1989) to account for missed animals. Sightability models can incorporate covariates such as group size and ground cover that influence the probability of detection. It is believed (Drummer in prep.) that using a constant detection rate produces biased estimates of population size, so it is important to account for this variability in sightability.

During the 2000-01 and 2001-02 winter seasons, 177 sightability trials were conducted at LACL using radio-collared moose, multiple pilots, and multiple observers. Analysis of those data indicated that group size, ground cover (3 point scale), and snow cover (2 point scale) affected detectability, and these variables were included in the sightability model which is described in **Appendix One**. This model will be used in 4 of the 5 park units in the Southwestern Alaska Network (SWAN), so no additional costs will be incurred. Habitat and cover types are similar in most of these parks, so the sightability model should be applicable.

Survey Area Selection/Population Being Monitored

The survey area at LACL has been defined, but this needs to be done at other park units in SWAN. The study area at LACL consists of 4190 km^2 (1,509 square miles) and is divided into three primary units which are surveyed on a rotational basis. The size and scope of the survey area should be based on biological and economic considerations, as well as the recognition that it may not be possible to define a study area that contains 100% of the moose in a park. Still, widespread geographic coverage is both desirable and manageable through the use of sampling. At the start of the monitoring program, biologists should identify all areas of viable moose habitat and include those areas in the initial definition of the study area. The study area may have to be redefined at a later point commensurate with available resources

Survey Timing

The sightability model used at LACL was fitted to data collected during early winter (mid-November through December) which is when the LACL surveys take place. We recommend that all surveys be conducted during this time period to allow sex/age identification and to allow for any migration to occur. Although complete snow cover is desirable, the sightability model does incorporate a snow cover variable (< 66% snow cover, > 66% snow cover), with high snow cover yielding higher detectability. We recommend a minimum of 50% snow cover for surveys because the number of sightability observations conducted under < 50% snow cover was very small.

There is some evidence (Drummer unpublished data) that sightability of moose groups declines as winter progresses due to moose seeking heavier ground cover, presumably to avoid deep snow. The LACL sightability model used to adjust for undercounts incorporates a ground cover variable that presumably accounts for heavier ground cover, so this should not be a problem. Still, age/sex identification becomes difficult after January so we recommend the use of early winter surveys.

Stratification

Overton and Stehman (1996) note that in a long-term monitoring program the sampling plan inevitably becomes out of date. It may be the case that the study area changes, and habitat changes can certainly occur over time. There are advantages, therefore, to adopting a simple plan that can be modified as the need arises. We believe that some form of stratification is needed, perhaps to improve precision of the estimator but also to obtain good spatial coverage of the study area. We recommend geographic stratification rather than stratification by habitat because habitat, and consequently, moose density can change.

The LACL study area has been subdivided into three primary geographic units with areas comprising 794, 1200, and 2197 km^2 (286, 432, and 791 square miles). Within each unit, geographic strata were formed, with at least 4 strata within each unit. Sampling from within each stratum allowed for coverage of the entire unit and yields abundance estimates for each stratum if that is desired. Stratification by density reduces the sampling variance of the estimate if the stratification is properly done. It may be possible to stratify a study area by density immediately preceding the survey by conducting stratification flights, but this may reduce the number of days of flight available for doing the survey. The study area can also be stratified based on harvest considerations. It may be the case that some areas are more subject to harvest pressure than other areas and therefore may need more intense monitoring.

At this point, very little data exist to use in forming strata, so we will rely on biologists' knowledge of the local population, but geographic stratification is always an easily

implemented option. We note that part of an effective monitoring program is to make the program easy to implement so that new personnel can easily continue the program

Sampling Units

Each stratum must be subdivided into sampling units. At LACL, subunits are based on natural boundaries and range in size from 14 to 42 km^2 (5 to 15 square miles). The number of subunits per stratum at LACL varies from 4 to 19.

Because moose appear to use riparian areas heavily during winter we recommend that riparian zones not be used as boundaries. This would increase variability due to the random event of moose being on one side or the other of the riparian zone. Animals must be within a selected sampling unit, not close to it, to be counted as part of the survey.

Alternatively a grid system can be projected onto the study area to produce regularly sized sampling units. In a grid system, endpoints of flight transects can be programmed into onboard GPS units to ensure that survey effort is uniform and that the entire sampling unit is surveyed. If a grid system is used transects should be offset 0.21 km (1/8 mile) from the sampling unit boundaries to avoid edge effects. (NOTE: 0.42 km (1/4 mile) transect spacing is recommended when conducting the survey, hence the 0.21 km offset.) The size of the sampling units can vary but transects should not exceed 17 km (10 miles) in length to avoid observer fatigue.

Ideally once the sampling units are formed and numbered, a GIS layer displaying the sampling units should be produced to aid in planning the survey. This will also provide documentation when personnel changes occur.

Sampling Frequency and Replication

Aside from budgetary issues, the primary determinant of sampling frequency appears to be the availability of aircraft and pilots. Because some parks experience unreported harvests, which increases the need for abundance estimates, we recommend that parks or at least areas within parks be ranked in order of importance. In the few published reports of moose abundance estimates, aside from Isle Royal National Park, moose population sizes appear to change slowly, so a survey at each park every three years may be adequate.

This aspect of the SWAN monitoring program requires further discussion as we determine what resources are available for the conduct of moose surveys and areas are prioritized.

Trend Detection and Sample Size

The primary objective of any monitoring program is to detect changes in abundance that are biologically meaningful. Population levels will naturally fluctuate, and the addition

of sampling variance to this natural variability makes abundance changes even more difficult to detect. Thompson et al. (1998) discuss a components of variance analysis that can be used to estimate temporal variability when the data contain a sampling variance component. This temporal variance estimate can be used to establish bounds used to determine when a meaningful statistical change has occurred, but that does not necessarily mean that the change is biologically significant. As with all hypothesis tests, determination of a statistically significant difference does not necessarily imply a biologically meaningful difference. Ver Hoef and Frost (2003) discussed a Bayesian method that can be used to estimate the trajectory of a population; increasing, decreasing, or stable, in the presence of sampling variability. This type of analysis is useful only after multiple years of abundance estimates have been obtained.

In the absence of any long-term moose abundance data, and only two years of data from LACL, we focus on hypothesis tests and confidence intervals for abundance changes between two survey periods. A confidence interval for the change in population change can be obtained from the two abundance estimates A_1 and A_2 and their variances $VAR(A_1)$ and $VAR(A_2)$. A 95% confidence interval can be obtained from $(A_1 - A_2) \pm 1.96\sqrt{VAR(A_1)+VAR(A_2)}$.

A simple test for a statistically significant change in abundance between two surveys can be conducted using the test statistic

$$Z = \frac{A_1 - A_2}{\sqrt{VAR(A_1)+VAR(A_2)}}.$$

The value of this test statistic can be compared to a selected percentile from the standard normal distribution. For example, if the biologist is testing for a change, either increasing or decreasing, and uses a 5% level of significance, then a finding of a statistically significant change occurs if the test statistic is < -1.96 or > 1.96.

The power of a hypothesis test is the probability of detecting a change when a change has occurred. Generally speaking, we want the power of the test to be high. The power depends on the actual level of change and the variance of the abundance estimate. The variance of the abundance estimate cannot be totally controlled, but can be affected by the sample size used to produce the abundance estimate. Sample size here refers to the number of subunits assessed in the survey rather than the fraction of the study area surveyed. The precision of the estimator and the ability to detect changes in population size are dependent to a large extent on the number of subunits surveyed.

We used data from LACL to examine the effect of sample size on precision of abundance estimates and trend detection. We used existing survey data to conduct a simulation study to estimate the probability of detecting changes of given size in the currently estimated population size. The LACL study area consists of three primary units, each of which has been surveyed once. The population estimates were obtained using the methods proposed in this document.

Each unit consists of at least four strata, with estimated moose densities similar for all four strata. Due to the similar densities, we concluded that the strata structure could, for now, be ignored. This could change as additional data becomes available.

For each simulation study, we simulated a number of moose groups per subunit. For each simulated moose group, we simulated group size, snow cover, and ground cover. The distribution of the number of groups per plot was estimated using the existing survey data. We did not assume any particular probability model for the number of groups per plot, but estimated the proportion of sampling units containing zero groups, one group, two groups, etc. Initially, roughly 25% of the plots in all studies were estimated to have zero groups. Because group size, snow cover, and ground cover have been shown to affect the probability of detection, the distributions for these covariates were estimated from the LACL sightability study. In the sightability study the covariate values were recorded for all moose groups whether or not they were sighted, so any source of bias was eliminated. If we used the covariate distributions obtained from the actual survey, those distributions would be biased. For example, smaller group sizes, less likely to be sighted than large groups, would be under-represented in the survey data. Still, the reader should note that the distribution of the number of groups per subunit was obtained from only one survey. In all simulation studies, a target value of 80% of the observations generated had high snow cover and 20% had low snow cover, which was the snow cover breakdown in the sightability study. The target ground cover distribution was 55% low, 35% medium and 10% heavy ground cover. The target group size distribution was 40 % group size 1, 25% group size 2, 20 % group size 3, 9% group size 4, and 2% for each of group sizes 5, 6 and 7. From simulation to simulation, these percentages varied due to random fluctuation in the simulation process.

We considered a population decline of 30% over a 10 year period to be biologically significant. This corresponds, roughly, to a 10% decline over 3 years, which we assume to be the survey frequency. Thus we simulated population level representing 10%, 20%, 30%, 40% and 50% declines in abundance from the baseline value estimated in the survey. This was done by changing the distribution of the number of groups per subunit, primarily by increasing the fraction of plots with zero groups.

The simulation study was conducted as follows. First, the population was generated, with the size approximately equal to the current abundance estimate. Each data point consisted of a subunit number, a group size, a snow cover value and a ground cover value. Then a random sample of n subunits was selected and the sightability model applied to the simulated moose groups in the selected subunits. The sample sizes varied depending on the number of subunits in the unit. For each sample size, 1,000 simulations were conducted, each simulation yielding an abundance estimate and the variance of the abundance estimate. This process was repeated for populations with abundances representing abundance declines of 10%, 20%, 30%, 40%, and 50%.

We estimated the sampling variance of the abundance estimator using the observed sampling variance rather than the theoretical variance. We used the test statistic

previously described and conducted a one-sided hypothesis test, testing for a statistically significant abundance decrease. We used 10% and 5% levels of significance, corresponding to critical values of 1.645 and 1.28, respectively. That is, if the test statistic was greater than 1.645 (or 1.28) the null hypothesis of no change was rejected. We recommend using a 10% level of significance, which increases the power of the analysis. The power of the test is estimated by the probability of the test statistic exceeding the critical value. In the simulations, abundance estimates were well modeled by a normal distribution and so a normal distribution was assumed for the test statistic. The reader should note that these are estimates of power and are heavily dependent on only one year of survey data.

The weakness of this approach is that if abundance declines (or increases) slowly, and the test is performed to compare estimates in successive years, then the test may not detect a series of small changes.

Unit 3 South was surveyed in 2003 using proposed methods, yielding a population estimate of 220 moose. This unit contains 40 subunits (sampling units) in five strata and encompasses an area of 1200 km^2 (432 square miles), yielding an estimated density of 1.4 moose per km^2 (0.51 moose per square mile). To interpret the power analysis (**Table 1**), for example, a sample size of 20 subunits using a 10% level of significance yields a 57% chance of rejecting the null hypothesis of no change and thereby detecting a 30% abundance decline. This assumes that 20 subunits were sampled in each survey. The same sample size of $n = 20$ subunits yields an 86% chance of detecting a 50% decline. As sample size increases, the cost of the survey increases and the ability to detect change increases. It is important for the biologists responsible for conducting the monitoring program to make some decisions about sample size. A starting point is to determine what level of decline is biologically meaningful. This is difficult because there is at most one year of data available for some study areas, and the natural variation in abundance levels is unknown. If resources are available we therefore recommend, initially, a conservative approach. We recommend using the maximum possible sample size to obtain precise baseline estimates of abundance and to observe as large a fraction of the study area as possible.

From **Table 1**, for mid-level sample sizes, the power does not exceed 50% unless the population decline is 30%, and even the largest sample size has only a 26% probability of detecting a 50% decline. There is not a great deal of difference in power for the 5% and 10% level of significance so we used 10% in the remaining simulations.

Table 1. **Probability of detecting given % change in population size for varying sample sizes for LACL Unit 3 South. Total number of subunits = 40.**

Using 10% Level of Significance					
	Amount of Change				
Sample Size	**10%**	**20%**	**30%**	**40%**	**50%**
10	**0.15**	**0.22**	**0.33**	**0.47**	**0.56**
15	**0.17**	**0.28**	**0.44**	**0.62**	**0.73**
20	**0.19**	**0.34**	**0.57**	**0.76**	**0.86**

25	**0.22**	**0.42**	**0.69**	**0.89**	**0.94**
30	**0.26**	**0.53**	**0.83**	**0.96**	**0.99**
Using a 5% Level of Significance					
10	**0.08**	**0.13**	**0.22**	**0.33**	**0.41**
15	**0.09**	**0.17**	**0.31**	**0.50**	**0.60**
20	**0.11**	**0.22**	**0.43**	**0.64**	**0.77**
25	**0.13**	**0.29**	**0.55**	**0.81**	**0.89**
30	**0.16**	**0.39**	**0.73**	**0.92**	**0.97**

Unit One was surveyed in 2004 yielding an abundance estimate of 200 moose. Unit One consists of 25 subunits and 794 km^2 (286 square miles), with an estimated density of 1.9 moose per km^2 (0.70 moose per square mile). We used the same simulation process for estimating the power to detect changes in abundance representing 10%, 20%, 30%, 40% and 50% declines (**Table 2**). Sample sizes were n = 5, 10, 15, and 20. As with previous power analysis, the power is low for declines of 20% or less.

Table 2. **Probability of detecting given % change in population size for varying sample sizes for LACL Unit One. Total number of subunits = 25.**

Using 10% Level of Significance					
	Amount of Change				
Sample Size	**10%**	**20%**	**30%**	**40%**	**50%**
5	**0.14**	**0.19**	**0.25**	**0.29**	**0.41**
10	**0.17**	**0.25**	**0.39**	**0.47**	**0.67**
15	**0.20**	**0.35**	**0.55**	**0.67**	**0.88**
20	**0.25**	**0.51**	**0.76**	**0.88**	**0.98**

Units 2 and 3 North (**Table 3**) consist jointly of 69 subunits covering 2,197 km^2 (791 square miles). The 2005 abundance estimate was roughly 400 moose, the base value used in the simulations. Estimated density is 1.4 moose per km^2 (0.51 moose per square mile)

Table 3. **Probability of detecting given % change in population size for varying sample sizes for LACL Units 2 and 3 North. Total number of subunits = 69.**

Using 10% Level of Significance					
	Amount of Change				
Sample Size	**10%**	**20%**	**30%**	**40%**	**50%**
15	**0.17**	**0.26**	**0.39**	**0.52**	**0.73**
25	**0.32**	**0.35**	**0.55**	**0.73**	**0..92**
35	**0.25**	**0.45**	**0.71**	**0.87**	**0.98**
45	**0.30**	**0.58**	**0.86**	**0.97**	**0.99**

II. Field Methods

Survey Preparations and Setup

It is critical to arrange hiring of pilots and aircraft well before the survey takes place, as early as late summer. The sightability model was constructed with data collected from multiple pilots flying Piper Supercubs, so Supercubs or similar aircraft with the ability to fly "low and slow" and offering good visibility should be used in all surveys. Observers should be scheduled as early as possible as well. One observer is required for each aircraft, and each observer should be equipped with a map of the study area and several data sheets. Observer training is discussed in **section IV**.

Some pre-flights may be needed to assess snow cover. **We recommend > 50% snow cover for surveys.** Although the sightability model contains a snow cover variable, the number of observations collected under light snow conditions was relatively small, so estimates produced from heavier snow cover are more reliable.

Selection of Sampling Units

Ideally, sampling units within each stratum should be selected at random to provide a valid estimate of abundance for each stratum. **A minimum of two (2) sampling units per stratum is required to produce a valid estimate of sampling variance for a stratum**, which is required to produce a variance estimate for the entire study area. We note that a sample size of n = 2 is not likely to produce a stratum abundance estimator of useful precision. Sample sizes are always affected by weather, so we recommend a tiered system of sample selection. That is, plan for bad weather (small sample size), average weather (medium sample size), and good weather (large sample size). Select the units for the small sample size first. Then select additional units to increase the sample size. For example, suppose that a study area consists of N = 30 sampling units. In the worst weather, unless the entire survey is cancelled, you estimate that you can survey 5 sampling units. Then $n = 5$ is your worst case scenario. Select 5 units at random from the 30 units. Under average weather you estimate that you can survey 10 sampling units. From the 25 units not selected, select 5 more units, and so on.

There are other options for determining which sampling units are surveyed. For example, suppose a study area consists of 30 sampling units, but biologists believe that a large part of the moose population resides in, say, 6 of these units. As a fallback plan, one could plan to survey at least those 6 units and expand the survey when weather and resources permit. Also, it is possible to rotate sampling units in and out of a monitoring plan (Urquhart and Kincaid, 1999) in a rotating panel survey. There are some advantages in detecting change in this type of plan. To our knowledge, however, this type of plan has not been applied to moose or any game species, and the analysis of data from such plans is complex. Given the lack of data on moose abundance, it is impossible to determine if this type of plan should even be considered. For now we recommend the use of a geographically widespread survey with random selection of sampling units.

In the Michigan surveys (Drummer and Aho, 1998) a spatial checkerboard pattern of sampling units was used in the first several surveys. This is essentially a systematic sample that provides good spatial coverage. Although technically not a random sample, for practical purposes it would be treated as such.

Conducting the Survey

• Select the sampling units to be surveyed, using the tiered approach previously described. Determine flight patterns for each sampling unit.

• It is important to maintain constant flight intensity of surveyed sampling units. Flight intensity is a function of aircraft speed, elevation, and transect spacing. The sightability model was constructed using 0.41 km (¼ mile) transect spacing, flying at an altitude of 65 m (200 feet). If sampling units contain elevation changes then transects can be laid out along elevation contours. If transects are spaced further apart it decreases the probability of detection and the abundance estimators will be biased. **It is therefore important that pilots and observers have a plan as to how to survey each subunit prior to the conduct of the survey.**

• To avoid double counting of animals, which can move from sampling unit to sampling unit, it is best to survey spatially close sampling units on the same day if possible.

• To be counted as a sighting, moose groups must be inside the surveyed subunits. Moose groups close to but outside the selected subunits are not counted.

• To double check ground and snow cover classifications it is recommended to take a picture of each sighting. A space is provided on the data sheet for recording a photo number. It is best to go with the observer's first impression of ground and snow cover, but occasionally changes need to be made, as well as correcting data recording errors.

Sequence of Events

• In late summer, make arrangements for aircraft and pilots
• Secure observer crews
• Conduct training flights for observers as needed
• Train observers in snow cover and ground cover measurement
• Make copies of maps and data sheets
• Randomly select sample units; use layered approach with increasing sample sizes.
  Consult previous power analysis to determine sample size requirements
• Determine flight patterns for selected subunits
• Conduct Survey

III. Data Analysis and Reporting

Data Sheets

Copies of the data sheet are in **Appendix Two**. Required fields at the top of the sheet are:
1) Pilot name

2) Observer name
3) Name of unit or stratum
4) Date.

For each sighting, record:
1) Sampling unit
2) Ground cover (1 = < 33%, 2 = 34-66%, 3= > 66%)
3) Snow cover (1 = < 66%, 2 = > 66%)
4) Number of cows in group
5) Number of calves in group
6) Number of bulls in group
7) Photo number
8) Field notes - anything of interest.

If no sightings were made in a sampling unit, enter zeroes in all fields. It is important to include the zero sightings sampling units so that variance calculations are correct.

Spreadsheet Program

An EXCEL spreadsheet program that computes abundance estimates and confidence intervals has been developed for LACL and is currently specific to that park. Once the study areas and sampling units have been defined, a similar program will be developed for each park. A copy of the LACL program will be supplied to each park. Readers should view that program and familiarize themselves with the format. Make suggestions for improvements if needed. The abundance estimator used at LACL is detailed in **Appendix One.**

Tests for Changes in Abundance

For the first few surveys we advise using the simple Z-test to test for changes in abundance. The Z-test statistic is of the form

$$Z = \frac{A_1 - A_2}{\sqrt{VAR(A_1) + VAR(A_2)}},$$

where A_1 and A_2 are the abundance estimates and $VAR(A_1)$ and $VAR(A_2)$ are the estimates of the sampling variance. As data are collected over time, other methods to test for trend may be used. The power of the Z-test has been investigated for various sample sizes using LACL data, but this may not be applicable for other parks.

See the section **Trend Detection and Sample Size** for additional comments.

IV. Personnel Requirements and Training

Roles and Responsibilities

In addition to safe flying, pilots are a part of the survey team and are responsible for sighting animals. In addition to sighting animals, observers are required to record the data and, if possible, take pictures of sighted animals so that ground cover and snow cover classifications can be reviewed.

Qualifications and Training

Pilots should be experienced at aerial surveys because they are likely to see the majority of animals. Ideally observers should be experienced at aerial surveys. Data from Michigan (Drummer, unpublished data) indicate that sightability increases with survey experience. Inexperienced observers should make at least two practice flights prior to the surveys. It is advisable to pair the most inexperienced observers with the most experienced pilots.

All observers should be trained in measuring snow cover, ground cover, and group size, the three covariates used in the sightability model. Group size is relatively easy to determine, but problems can occur when an animal or group of animals is sighted, and after circling the initially sighted animals, additional animals are sighted. The observer must determine if the animals are all part of one group or if separate groups were sighted. This can be problematical. If a cow is sighted, and after some circling the observer detects a calf with the cow, the calf should be included in the group. In other cases the animals may be spread out. In these cases we recommend that the observer use their first impression.

Observers are required to provide a measure of ground cover (< 33%, 34-66%, and > 66%). The ground cover pertains to a roughly 10m diameter circle surrounding the group. All observers should view photographs of sightings taken at LACL and note the ground cover class used for each sighting so that they are consistent. Heavy cover (> 66%) has been rare at LACL. Snow cover is measured on a two point scale: < 66% and > 66%. Nearly all sightings at LACL have occurred in heavy snow cover so photographs of those sightings may not be of much help.

We recommend that new observers participate, if possible, in training flights with experienced observers to learn ground cover and snow cover classification. These flights would have to be conducted in aircraft capable of holding at least two observers and may not be suitable for the survey, but they are suitable for learning ground and snow cover classification.

Perhaps the most challenging logistical aspect of this monitoring program will be to create and maintain experienced observer teams, particularly if survey frequency is only

once every several years. We ask participating parks to commit to observer training and to consider sharing observers with other parks.

V. Literature Cited

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Appendix One

Sightability Model and Abundance Estimator

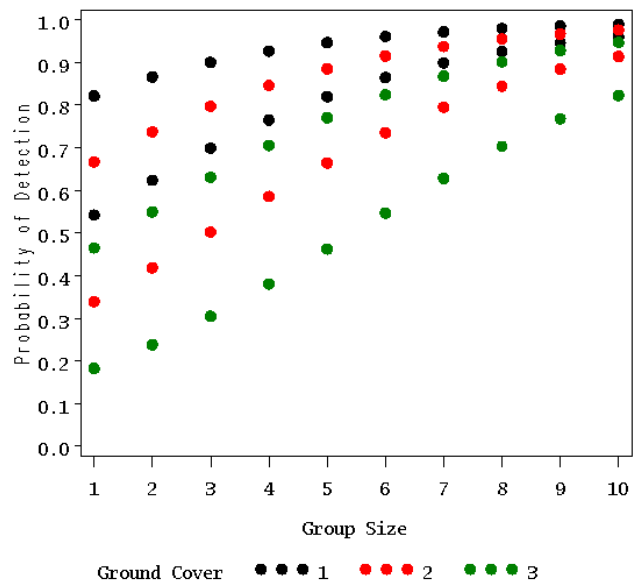
The sightability model is a logistic regression model that models the probability that a group is detected as a function of group size, ground cover, and snow cover. The regression model is

P(detection) =

$$\frac{\exp(0.67 + 0.33 \times GroupSize + 1.36 \times SnowCover - 0.83 \times GroundCover)}{1 + \exp(0.67 + 0.33 \times GroupSize + 1.36 \times SnowCover - 0.83 \times GroundCover)},$$

where *exp* denotes the base of the natural logarithms. Snow cover is a binary variable (0 : < 66%, 1 : > 66%) and ground cover is measured on a three point scale (1 : < 34%; 2 : 34 - 66%; 3 : > 66%). The ground cover variable is treated as if it were a continuous scale variable even though it could be argued it is categorical in nature. This was justified based on nonparametric logistic regression analysis and the fact that there were not many observations in high (> 66%) ground cover. The covariate values are inserted into this equation to produce an estimated detection probability. **Figure 1** indicates these probabilities for various group sizes.

Figure 1. Sighting probabilities based on sightability model developed for LACL survey. There are two plots for each color representing high and low snow cover conditions. **Ground cover = 1 corresponds to < 33%, etc.**



Once this probability, say Θ, is computed, it used to produce a weight for that observation. Let a stratum consist of N sampling units and let n denote the number of sampling units surveyed ($n \leq N$). Let GS_{ij} denote the group size for the ith sighting on the jth sampling unit. The abundance estimator is given by $\frac{N}{n}\sum_{j=1}^{n}\sum_{i=1}^{k}\frac{GS_{ij}}{\theta_{ij}}$ where the inner sum occurs over the k observations in a subunit and the outer sum is over the sampling units. This total is then inflated by the reciprocal of the fraction of sampling units surveyed. The estimates for the various strata are then summed to produce the estimate for the study area.

It may be the case that the number of animals on a subunit is correlated with the size of the subunit, which is currently under investigation at LACL. If that is the case, the sums will be inflated by the reciprocal of the land area surveyed rather than the number of sampling units surveyed.

Appendix II

SWAN Moose Survey Data Sheet

Date:_____ Pilot/Observer:_____ Study Area:_____

CODES: **Snow Cover: 1 for < 66%, 2 for > 66%**
Ground Cover: 1 for < 33%, 2 for 34-66%, 3 for > 66%

Observation Number	Stratum	Sampling Unit	# Cows	# Calves	# Bulls	Snow Cover 1 or 2	Ground Cover 1, 2, 3	Photo #	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									