A SIGHTABILITY MODEL FOR MOOSE IN UPPER MICHIGAN

Thomas D. Drummer[1] **and Robert W. Aho**[2]

[1]Department of Mathematical Sciences, Michigan Technological University, Houghton, MI, 49931; [2]Michigan Department of Natural Resources, Wildlife Division, Baraga, MI 49908

ABSTRACT: We constructed a sightability model for a fixed wing aerial survey of moose in Michigan's Upper Peninsula. The probability of sighting decreased if the animal was bedded, in heavy cover, or in a group of size <3. Presence or absence of calves did not affect sightability, although presence/absence of calves data were not consistently collected. There was some evidence of differences in sightability between observers.

ALCES VOL. 34(1): 15-19 (1998)

Key words: Aerial census, sightability, visibility bias

Aerial surveys of biological populations underestimate population sizes due to visibility bias (Caughley 1974). Observed counts should be adjusted by taking into account the proportion of animals actually seen. Gasaway *et al.* (1986) recommended a double sampling procedure for moose (*Alces alces*) that partially accounts for visibility bias. In that procedure portions of the study area are sampled at low and high intensities and a visibility correction factor calculated from the ratio of those counts. Other approaches to account for visibility bias include line transect sampling (Buckland *et al.* 1993), mark re-sight methods (Rice and Harder 1977), and sightability models (Steinhorst and Samuel 1989). Sightability models relate the probability of sighting an animal or group of animals to attributes such as group size, habitat type, and activity. The basic population size estimator is

$$\sum_{k=1}^{L} \frac{1}{P_k} \sum_{i=1}^{n_k} \frac{m_{ik}}{\pi_{ik}},$$

where P_k is the probability the kth land unit (k = 1,2, ...L) is included in the sample, and π_{ik} is the sighting probability for the ith observed group (i = 1,2, ..n$_k$), which is of size m_{ik}. The π_{ik} are estimated by conducting relocation trials in an area with a known number of animals. Anderson and Lindzey (1996) built a sightability model for a helicopter survey of moose in Wyoming. In this study we constructed a sightability model to estimate the sighting probabilities for a forthcoming moose census in Michigan's Upper Peninsula.

STUDY AREA

The Michigan moose herd was reintroduced in 1985 when 31 animals were transplanted from Algonquin Provincial Park, Ontario, to a location in Marquette County, Michigan (Schmitt and Aho 1988). Sightability data were collected over a roughly 4000 km^2 area that included parts of Baraga and Marquette counties. The study area is more fully described in Schmitt and Aho (1988).

METHODS

Data were collected during the winter months from December 1993 through March 1996. Sightability trials were conducted no later than 13 March, with 75% of the trials conducted in January and February and 6% in December. In mid to late morning, a pilot and crew member located one or more radio-collared animals in the study area and recorded the animals' latitude and longitude with a Loran-C unit. Boundaries for a 3.22 x 3.22 km (2 miles x 2 miles) plot were constructed by adding and subtracting randomly generated numbers to the target animal's coordinates. In this way the target moose could have been placed anywhere in the plot. North-south flight lines 0.405 km (0.25 miles) apart were established and keyed into the Loran-C unit of the aircraft. The pilot and crew then returned to the base to pick up the observers. Two observers, one on each side of the aircraft, were then flown to the plot which was systematically surveyed using the programmed flight lines. Observers did not use moose tracks directly except to alert them to the possibility that an animal was in the area. The aircraft only left the flight line to verify a sighting. Surveys were conducted in a Cessna 206 fixed wing aircraft at an altitude of 150 m with a ground speed of 130 km/hr. The observers knew that a collared animal was on the plot but did not know its whereabouts. Other moose would appear on the plot but those were ignored in the sightability trials. The observers surveyed the plot until the target moose was either sighted or it was clear to the pilot that the observers had not sighted the moose. In either case, the observers determined the activity of the moose (bedded vs. non-bedded), density of cover in which the moose was located (0-33%, 34-66% and 67-100%), group size, and, whenever possible, the age and sex of the animals. In instances when the observers did not sight the target moose, we assumed that these attributes did not change from the time the observers passed over the moose until they returned to it. In general the target moose were doing the same thing in the same spot from the time the pilot and crew first saw them until the observers collected the data. If we did not believe that to be the case, that trial was excluded from analysis.

A moose group was classified as bedded only if all group members were bedded. If ≥ 1 animals were standing or running, then the group was classified as non-bedded. Only twice was a target moose observed running.

We assigned a cover class based on the proportion of the ground not visible in an area of about 10 m radius around the target moose. Observers used a crown closure dot diagram (Husch *et al.* 1993) as an aid. Group size was the number of animals in the group associated with the target animal and included all ages and sexes of animals.

Eight observers were used in the sightability trials. One observer had considerable experience in aerial searches for moose and all of the observers had some experience with aerial surveys, but not necessarily for moose. Two observers had previous aerial censusing experience on Isle Royale National Park, Michigan, but were used only once as substitutes. These two and one other observer who participated just twice will not be involved with future censusing efforts. The other 5 observers are considered the primary observers.

A total of 39 radio-collared moose were used in the study. One moose was used as the target moose 9 times, but most animals were used 1 or 2 times. The minimum time between trials on the same animal was 2 days. However, this occurred only once and at least 10 days separated sightability trials on other animals.

We used logistic regression (Hosmer and Lemeshow 1989) to determine if group size, cover, activity, presence or absence of calves, and observer affected sightability. The dependent variable was zero or one depending on whether or not the target animal was sighted. We treated cover and group size as continuous rather than categorical variables. Activity was defined as = 0 if the target group was bedded and = 1 otherwise. To assess observer effects we defined indicator variables for the 5 primary observers to indicate their presence or absence on a trial. The 3 substitute observers were treated as one group and assigned a value of zero.

Model building strategy followed the process described in Hosmer and Lemeshow (1989). Empirical logit plots (Agresti 1990) were used to assess the effects of group size and cover. Variables were tested one at a time with univariate logistic regression. Potentially important variables were then submitted to a stepwise selection procedure using a 0.15 significance level as the criteria for entering the model. We then tested for pairwise interactions between the main-effects variables that were included as a result of the stepwise selection process.

RESULTS

We conducted 89 sightability trials. In one trial the target moose wandered off the plot and in 3 other trials the survey plane was off track, so those points were eliminated from the analysis. In the remaining 85 trials the target moose was sighted 33 times for overall sightability of 38.8%. In another trial the target animal could not be sighted and the values of the covariates could not be determined, yielding n=84 data points for the regression analysis.

In 68% of the trials target animals were found in mixed conifer-deciduous stands. Target animals were in pure conifer stands or pure hardwood stands 20% and 11% of the trials, respectively. Only once was a target animal located in an open area.

The empirical logit plot (Fig. 1) indicated that logit(sightability) decreased linearly with cover. Sightability was 50.0% (n = 46) for 0-33% cover, 29.2% (n = 24) for 34-66% cover, and 21.4% (n = 14) for 67-100% cover. Observed group sizes ranged from 1 to 3 ($\overline{X}$ = 1.64) with greatest sightability, 60.0% (n = 15), for groups of size 3. Sightability for group size = 1 was 37.8% (n = 45) compared to 29.2% (n = 24) for group size = 2. Based on the empirical logit plot of sightability vs. group size we used linear and quadratic terms in group size in the regression analysis.

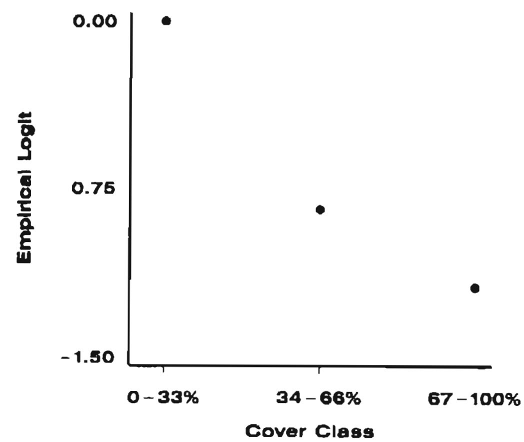

Fig. 1. Empirical logit plots of sightability rates of moose in different cover classes.

Activity (P = 0.0046) and cover (P = 0.0172) were significantly related to sightability. Bedded animals had lower sightability (23.8%, n = 42) than non-bedded animals (54.8%, n = 42). Presence or absence of calves (P = 0.4037) did not affect sightability, although there were only 13 instances in which calves were present. Group size (P = 0.1507) and the indicator variables for the 5 primary observers (P = 0.1619) were within the 0.25 significance level that Hosmer and Lemeshow (1989) recommend for inclusion in the stepwise regression analysis and were therefore included.

In the stepwise regression analysis, activity, cover, the quadratic group size term, and the indicator variable for the most experienced observer entered the model. When pairwise interactions between these terms were included in the stepwise selection process, activity, activity by cover interaction, cover by quadratic group size interaction, and the indicator variable for the most experienced observer entered the model.

We eliminated the observer variable from the model. We did pairwise comparisons of the most experienced observer's regression coefficient and those of the 4 other primary observers and found no significant differences (all $P > 0.1802$). Also, sightability rates were not significantly different across the 3 years of the study ($P = 0.377$) possibly indicating that inexperienced observers had learned observing skills quickly. When we excluded the observer variables from the stepwise analysis, cover, activity and the quadratic group size term entered the model. The resulting fitted model is

$$\pi(X) = \exp(-0.64 - 0.54 \times \text{cover} + 1.26 \times \text{activity} + 0.65 \times \text{size}^2) / (1 + \exp(-0.64 - 0.54 \times \text{cover} + 1.26 \times \text{activity} + 0.65 \times \text{size}^2)),$$

where $\pi(X)$ denotes the probability of sighting a moose group with characteristics X; activity is as previously defined; cover = 1, 2, or 3 for 0-33%, 34-66% and 67-100% cover, respectively; size = observed group size - the mean group size of 1.64.

Extension of the analysis to include pairwise interactions in the stepwise selection process yielded

$$\pi(X) = \exp(0.13 - 0.61 \times \text{cover} + 1.24 \times \text{activity} \times \text{size}^2) / (1 + \exp(0.13 - 0.614 \times \text{cover} + 1.24 \times \text{activity} \times \text{size}^2)).$$

This model indicates that sightability for bedded groups (activity = 0) is constant for all group sizes, which we do not believe to be the case, and therefore selected the prior model for use in the census.

If, for example, during the course of a census observers spotted a group of 2 moose bedded in 67-100% cover, the estimated probability of detection used in the Steinhorst and Samuel estimator would be computed as

$$\pi(X) = \exp(-0.64 - 0.54\text{x}3 + 1.26\text{x}0 + 0.65\text{x}(2-1.64)^2) / 1 + \exp(-0.64 - 0.54\text{x}3 + 1.26\text{x}0 + 0.65\text{x}(2-1.64)^2)$$

DISCUSSION

Conduct of the sightability trials must be realistic in that they resemble the actual censusing procedure and observation conditions, such as weather. In the census we will use the same protocol of 2 observers and 0.405 km (0.25 miles) transect spacing. Data collection over a 3 year period lessens the chance that the sightability data are collected only in unusual weather conditions.

We did not use dummy plots in which there were no collared animals, although that did happen once by chance. We assume that observers will view the census plots with the same intensity as was used in the sightability trials. We do not anticipate that double counting of animals will be a problem. Even with flight lines only 0.405 km apart, in only one instance was the same moose sighted from 2 different flight lines and this was immediately recognized.

There was some evidence of differences in sighting probability between observers, although this was not the case when considering only those observers to be used in the census. Data are insufficient to determine if variability between observers was constant over time. There were no significant differences in overall sighting rates between years, with sightability actually declining over time from 40% in year 1 to 30% in year 3 of the study. Even with considerable variability in aerial survey experience among the observers we therefore chose not to include observer variables in the sightability model. If additional sightability trials are conducted we will attempt to arrange observing crews to enhance comparison of observers, as this study was not designed for that purpose.

We could not determine why groups of size 1 had greater sightability than groups of size 2, although the difference is not statistically significant ($Z = 0.78$, $P = 0.4325$). All size 1 groups were adults whereas 44.4% of size 2 groups and 38.5% of size 3 groups had calves present. Presence or absence of calves did not affect sightability when only size 2 and size 3 groups were analyzed (P = 0.1371), although the total sample size was small (n = 32). In 7 cases presence or absence of calves was not recorded which may also have affected the analysis. Also, group size was not related to cover ($\chi^2_{(4)}$ = 3.990, P = 0.406) nor activity ($\chi^2_{(2)}$ = 3.480, P = 0.176).

Consistent assessment of cover class is crucial. We initially used a 4 point scale (0-25%, 26-50%, 51-75%, 76-100%). However, we had difficulty in assigning a cover class in some intermediate cover cases and so switched to a 3 point scale. To check our cover classifications we took a picture of the target animal with a 35 mm camera and will continue this practice in the census.

ACKNOWLEDGEMENTS

Thanks to pilot Steve Adkins and to Don Elsing for help with moose relocations. Thanks also to observers Tom Bach, Mary Hindelang, Brad Johnson, Jack Lewis, Terry Minzey, and Joanne Thurber. Funding was provided by the Michigan Department of Natural Resources and Federal Aid in Wildlife Restoration, Michigan Pittman Robertson project W-127-R.

REFERENCES

AGRESTI, A. 1990. Categorical data analysis. Wiley, New York, NY. 558 pp.

ANDERSON, C. A. and F. G. LINDZEY. 1996. Moose sightability model developed from helicopter surveys. Wildl. Soc. Bull. 24:247-259.

BUCKLAND, S. T., D. R. ANDERSON, K. P. BURNHAM, and J. L. LAAKE. 1993. Distance sampling. Chapman and Hall, New York, NY. 446 pp.

CAUGHLEY, G. 1974. Bias in aerial survey. J. Wildl. Manage. 38:921-933.

GASAWAY, W. C., S. D. DUBOIS, D. J. REED, and S. J. HARBO. 1986. Estimating moose population parameters from aerial surveys. Biol. Pap. Univ. Alaska, Fairbanks. No. 22. 108 pp.

HOSMER, D. W. and S. LEMESHOW. 1989. Applied logistic regression. Wiley, New York, NY. 307 pp.

HUSCH, B., C. I. MILLER, and T. W. BEERS. 1993. Forest mensuration. Third ed. Krieger Publishing Company. Malabar, FL. 401 pp.

RICE, W. R. and J. D. HARDER. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. J. Wildl. Manage. 41:197-206.

SCHMITT, S. M. and R. W. AHO. 1988. Reintroduction of moose from Ontario to Michigan. Pages 258-274 *in* L. Nielsen and R. D. Brown (eds.) Translocation of Wild Animals. Wisconsin Humane Soc., Milwaukee, and Caeser Kleberg Wildl. Res. Inst., Kingsville, TX.

STEINHORST, R. K. and M. D. SAMUEL. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415-425.