Brian A. Gilbert[1], Gilbert Environmental, 4230 South Evergreen Road, Veradale, Washington 99037

and

Barbara J. Moeller, Wildlife Program, Puyallup Tribe of Indians, 3009 East Portland Avenue, Tacoma, Washington 98404

Modeling Elk Sightability Bias of Aerial Surveys During Winter in the Central Cascades

Abstract

Aerial surveys of elk have generally not been used to estimate elk abundance in western Washington primarily due to concerns over the highly variable detectability of elk in forested vegetation. The purpose of our study was to investigate the development and application of aerial sightability models to survey elk in forested habitats of the west-central Cascades. Survey units were delineated and surveyed from a helicopter. We used radio-tagged elk and logistic regression to model the influence of vegetation cover characteristics, elk group size, and activity on sightability of elk. Models were assessed using Akaike Information Criteria. The best model included elk group size and percentage of vegetative cover. These results indicate that when corrected for sightability, aerial surveys for elk may be a reasonable alternative for assessing elk abundance in wintering elk herds of the central Cascades.

Introduction

Elk (*Cervus elaphus*) population abundances in western Washington are difficult to assess primarily due to the visibility bias resulting from the variable effects of screening vegetation in dense coniferous forests. Elk abundance in Washington State has been variously estimated by reconstruction with harvest data, mark-recapture, aerial sightability, and minimum count estimators (Bender and Spencer 1999). In addition, sightability modeling has likely been limited by the considerable logistic difficulty, and consequently expense, in establishing conditions that allow for the development of sightability models (Bender and Spencer 1999).

Sightability models have rarely been explored for estimating elk population sizes in western Washington. However, sightability corrected aerial surveys for large ungulates have been developed (Samuel et al. 1987, Leptich and Zager 1992, Otten et al. 1993, Anderson et al. 1998, McCorquodale 2001) and used extensively for population assessment (Samuel et al. 1987) in heavily forested ecosystems. Houston et al. (1987) investigated the use of sightability adjusted aerial surveys of Roosevelt elk (*Cervus elaphus roosevelti*) in Olympic National Park. They found an average sightability of 74% of radio tagged elk and suggested that the concentration of elk in more open valley floors in winter facilitated censusing the elk population (Houston et al. 1987). They did not pursue refining the sightability relationship due to logistic constraints related to concerns over the costs and level of disturbance required for the effort inside the park (Houston et al. 1987). Elk sightability models have been developed (Samuel et al. 1987) and extensively utilized in very similar habitat conditions in northern Idaho. Sightability adjusted elk surveys are conducted in forested areas in winter when a large portion of the elk are concentrated on more open valley floor wintering habitats (P. Zager, Idaho Fish and Game, unpublished data).

Elk have been important to the Puyallup Tribe for subsistence and cultural reasons since recorded time. This importance has led the Puyallup Tribe to actively conduct elk research within the Medicine Creek Treaty protected area (MCTPA), including development of effective population assessment approaches. As part of these efforts, the Puyallup Tribe investigated the feasibility of using sightability corrected aerial survey estimates of wintering elk in the southern portion of the MCTPA.

We utilized software developed in Idaho (Unsworth et al. 1999) and radiocollared elk from existing research projects to develop a sightability model to estimate elk abundance in

[1]Author to whom correspondence should be addressed. E-mail: bgilbert3@mindspring.com.

© 2008 by the Northwest Scientific Association. All rights reserved.

the west-central Cascades. Our specific objective was to investigate relationships between common sightability factors and elk sightability in an area representative of lower elevation wintering areas for elk in the west-central Cascades. Our secondary objective was to apply the sightability model to aerial survey data in the Cowlitz river drainage in order to estimate the surveyed population size.

Methods

Study Area

The study was conducted in the southern portion of the MCTPA, within the elk wintering area of the upper Cowlitz River drainage near the town of Packwood, Washington (Figure 1). The area is dominated by dense coniferous forests of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) in the uplands, open agricultural and rangelands in the valley bottom, and open hardwood galleries dominated by black cottonwood (*Populus balsamifera ssp. trichocarpa*) and red alder (*Alnus rubra*) along the river floodplain. Topography was flat to rolling in the river bottom but increased steeply in the uplands. Elevation ranged from 450 m to 1500 m and snow accumulations were generally limited to the higher elevations.

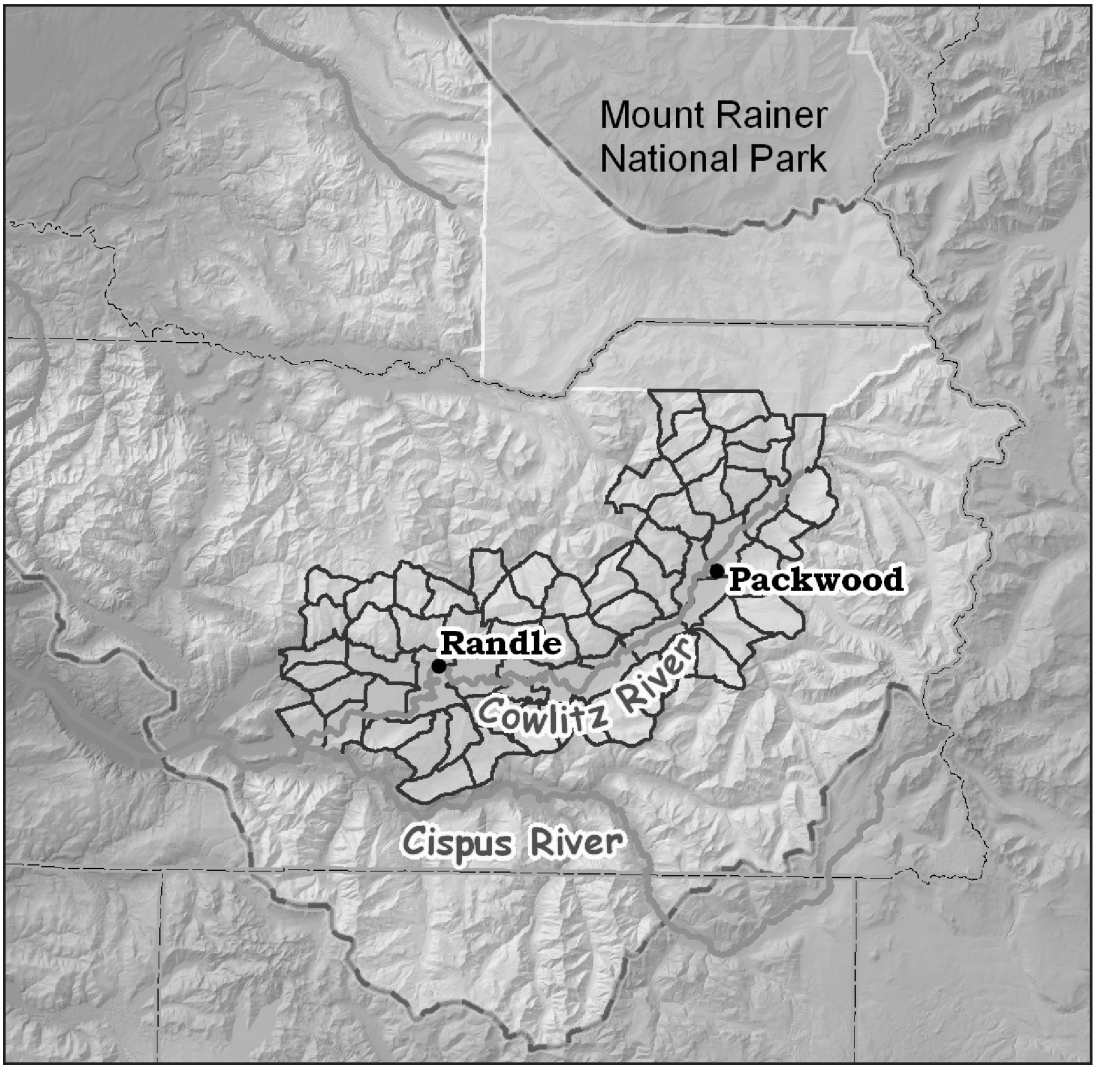

Figure 1. Map of the study area including aerial survey subunits. Dashed line represents the boundary of the Medicine Creek Treaty Protected Area.

Elk Surveys and Data Collection

We delineated survey units over the study area using topographic breaks (e.g., ridges, rivers, major creeks) that would be easily identified by observers during aerial surveys of the study area (Steinhorst and Samuel 1989). Survey units were 8-16 km^2 and required approximately 1 hour to survey by helicopter. Survey units occurred on the north and south side of the Cowlitz River and generally spanned the river valley up to the extent of the drainage basin. These units represented the core range of elk during late winter in the Packwood area. Areas outside of the core range with lower concentrations of elk within the upper reaches of the Cowlitz drainage and major tributaries were not surveyed. Survey units within the core range were stratified into high or low concentration areas of elk use during winter. Although some locations from radio-telemetry data were available, stratification of survey units was based on a general understanding of the distribution of wintering elk in this area. Survey units classified as "High" density were identified in the valley bottom and areas with gentler topography immediately adjacent to the valley while survey units classified as "Low" density were at upper elevations and on steeper terrain.

Surveys were conducted using a Bell 206 BIII (Jet Ranger) helicopter with a pilot and 3 observers. Average survey speed was approximately 95 km hr^{-1} and flown at approximately 122 m above ground level. Sampled survey units were randomly selected within strata. Each subunit was surveyed systematically to insure it was searched entirely. Areas with minimal topographic relief were flown with strip transects using the LORAN-C navigation unit in the helicopter to insure minimal overlap, whereas areas with greater topographic relief were surveyed along elevation contours with intervals of approximately 100 m. When an elk was detected by an observer, the pilot diverted from the transect to the area of the sighted elk group. Group size and composition were recorded, elk were classified as cows, calves, spike bulls, raghorns (bulls generally without brow tines and/or less than full antler development), adult bulls, or unclassifiable. Data recorded for each sighted group included: activity when sighted (categorical variable: bedded, standing, or moving based on the most active elk in the group when first sighted), percent vegetation cover as a continuous variable, vegetation class (categorical variable: conifer, hardwood, or mixed), and percent snow cover. Percent vegetation cover was determined by estimating the percentage of the group obstructed by vegetation in an area including all elk in a group with an additional 10 m buffer margin.

A total of 19 and 32 radiocollared animals during 2004 and 2006 respectively were available for detection during the surveys. Radiocollared animals were marked with cryptically colored collars that did not increase their sightability. Collared animals were distributed across the study area and were located in a range of vegetation types. During surveys, all groups were checked for radio signals from radiocollar transmitters. If a group contained a collared elk, that animal's frequency was removed from the list of available frequencies. Once the visual survey of a unit was completed, the unit was reflown in an attempt to relocate the remaining animals on the frequency list. No previous knowledge of the location of collared animals existed for the surveyors and they searched all frequencies in each unit surveyed. If an animal was relocated within the boundary of the just completed unit, data were recorded as described above for sighted groups and that group was recorded as a "missed" group.

Surveys were conducted in late winter (February–March) of 2004 and 2006. In 2004, all surveys were conducted in similar weather conditions (mostly cloudy, light winds, temperature near 4-5 °C, no precipitation). Initial surveys in 2006 were conducted with no snow cover whereas later surveys were conducted after a major snowfall event which resulted in moderate to high snow cover over most of the study area.

Data Analysis/Model Development

Binomial sighted/missed data from elk groups with at least one radiocollared animal during aerial surveys were used in a logistic regression to estimate the probability that a group of elk would be sighted. The logistic regression model used was:

$$\pi = e^u / 1 + e^u$$

where π was equal to the probability of sighting elk groups from a helicopter and $u = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$ is the linear regression of k independent variables affecting sightability. The covariates used as potential predictors of sightability in the

logistic regression were selected based on factors known to influence elk sightability (Samuel et al. 1987, Otten et al. 1991). Variables included in the analysis were group size, vegetation cover, vegetation class, and activity. Snow cover was positively correlated with vegetation cover (correlation coefficient of 0.59) and was encountered in only a portion of surveys in 2006. Therefore, snow cover was not considered in the model selection process. Vegetation cover and vegetation class were weakly correlated (correlation coefficient of 0.18) and so both were included in model selection. Logistic regressions were run for each of the 15 potential models.

Second order Akaike Information Criteria (AICc) (Burnham and Anderson 1998) was used since the number of observations was not at least 40 times the number of variables (Anderson et al. 2001). The best model was determined by the highest AICc weights, which represented the weight of evidence in support of the model, and the lowest AICc difference, which indicated the most plausible model (Burnham and Anderson 1998). The c-statistic was used to assess the predictive capability of the model. Models with an AICc difference of ≤ 2 were considered for further inference as they are considered to have substantial support as the best model (Burnham and Anderson 1998). Model fit and correlation between covariates for the best model were assessed using established model fit statistics and correlation matrices.

Population Estimates

A data file with the survey results listing each group sighted and data for each covariate were entered into Program Aerial Survey (Leban and Garton 2000). Regression coefficients and variable covariances from the "best" model were used to adjust sightability of groups. Each sighted group was corrected by multiplying the size of the group by the inverse of the probability that they would have been seen (Unsworth et al. 1999). Estimates within surveyed units were then extrapolated to the unsurveyed units within the study area to estimate population size.

Results

A total of 37 subunits were surveyed using a stratified random sample including 21 high density units and 16 low density units. A total of 370 elk in 26 groups with at least one radiocollared animal were recorded during surveys while 124 elk in 31 groups were missed during surveys and relocated using radio-telemetry resulting in a detection rate of 46%.

The best model, as determined by AICc included group size and vegetation cover (Table 1). Vegetation cover and group size were the most predictive variables, and were included in all of the models accounting for 90% of the summed AICc weights. Only the best model was determined to have, "substantial support" as the next best model had an AICc difference of > 2 (Burnham and Anderson 1998). The AICc weight of the best model was 0.759, which was over 6.7 times greater than the second best model (Table 1).

Table 2 reports the regression coefficients and variable standard errors from the models included in the 90% model set. The coefficients and covariances were used to parameterize the sightability model in Program Aerial Survey (Leban and Garton 2000). Population estimates were calculated in two ways (Table 3). During surveys, some units classified as High density had no sighted groups. This indicated a serious problem with population estimation since including a survey in a High density unit with no elk detections indicates incorrect strata classification. Hence, to investigate the effect of stratification "error" we calculated population estimates first with the original classification and then with the High units with no elk detected in them reclassified as "Low" units. As would be expected, incorrect stratification had a dramatic effect on population estimates (Table 3). When High subunits where no elk were sighted were included in the estimation process as High density units, the estimated population size was 662 elk. However, when they were adjusted to be classified as Low density units, the estimated number of elk was 968 or an increase of 46% over the low estimate. Actual bias in our population estimates was not possible to discern since comparable estimates for state management units for 2006 were not available for this elk population.

Discussion

The primary concerns over elk sightability in dense coniferous forests are 1) habitats where elk have zero probability of being sighted from the air, and 2) undercounting bias when groups are sighted. In our study, we had no situations

TABLE 1. Complete model set including c-statistic, AICc, AICc difference, AICc weights for logistic regression models of elk sightability in the Packwood Area in the Cowlitz River drainage, Washington. Response variable was probability of sighting an elk group. All models based on a sample size of 57 elk groups.

Model	C	AICc	AICc Diff	AICc Wts	Sum of Wts
Group size, vegetation cover	0.908	49.905	0.000	0.759	0.759
Group size, vegetation cover, vegetation class	0.904	53.704	3.799	0.114	0.873
Group size, vegetation cover, activity	0.908	54.178	4.273	0.090	0.962
Vegetation cover	0.847	57.940	8.035	0.014	0.976
Group size, vegetation cover, vegetation class, activity	0.904	58.062	8.157	0.013	0.989
Group size	0.814	60.240	10.335	0.004	0.993
Vegetation cover, activity	0.855	61.149	11.244	0.003	0.996
Vegetation cover, vegetation class	0.848	61.566	11.661	0.002	0.999
Group size, activity	0.818	63.550	13.645	0.001	1.000
Group size, vegetation class	0.812	64.499	14.594	0.001	1.000
Vegetation cover, vegetation class, activity	0.855	65.059	15.154	0.000	1.000
Group size, vegetation class, activity	0.814	67.952	18.047	0.000	1.000
Vegetation class	0.591	83.172	33.267	0.000	1.000
Activity	0.527	83.393	33.488	0.000	1.000
Vegetation class, activity	0.617	85.490	35.585	0.000	1.000

TABLE 2. Summary of results of logistic regressions investigating the probability of sighting elk groups from a helicopter in aerial surveys in the Packwood Area of the Cowlitz River drainage in west-central Washington in 2004 and 2006. Included models are from the 90% confidence set as established by AICc model selection.

Model		Group Size			Vegetation Cover			Vegetation Class		
Rank	Constant	β	SE	P	β	SE	P	β	SE	P
1	0.835	0.217	0.096	0.025	-0.047	0.015	0.002			
2	0.893	0.227	0.101	0.026	-0.050	0.016	0.002	0.442[c]	0.600	0.462
								-0.256[h]	0.757	0.735

c = conifer cover class, h = hardwood cover class

TABLE 3. Summary of aerial survey results for the Packwood area of the Cowlitz River drainage in west-central Washington during late winter (early 2006).

	Original Unit designations		Adjusted Unit designations	
	Estimate	90% CI Bound	Estimate	90% CI Bound
Total elk	662	81	968	229
Cows	409	50	607	143
Bulls	67	11	88	19
Branched antler bulls	24	9	27	11
Calves	178	25	262	74
Spikes	43	7	61	15
Raghorns	19	7	21	10
Adult bulls	5	2	6	3
Bulls:100 cows	16	8	15	3
Calves:100 cows	43	1	43	12
Spikes:100 bulls	63	18	69	46
Raghorns:100 bulls	28	35	24	32
Adult bulls:100 bulls	8	4	7	3
Branched bulls:100 bulls	36	52	31	35

where radiocollared elk were not detectable from the air. When groups of elk were sighted, even in dense timber, we were always able to identify the individual with the radiocollar. Although our data are admittedly sparse, being from one area and over two years, this would indicate that situations where animals are not detectable are rare.

Our overall detection rate (46%) was intermediate when compared with other sightability efforts on elk in forested habitats. Leptich and Zager (1992) reported detecting 42% of radiocollared groups in dense forests of north-central Idaho, McCorquodale (2001) reported detecting 50% in the more open forests of the eastern Cascades, and Samuel et al. (1987) reported a relatively high rate of 58% in north-central Idaho. This suggests that elk use habitats during the winter in western Washington forests have reasonable detection rates during aerial surveys for elk, at least in our study area.

The modeling results identified covariates important to sighting elk groups and parameter values comparable to other models developed for elk sightability in western forested habitats (Samuel et al. 1987, McCorquodale 2001). In addition, the clear differentiation of the best model, significance of the model parameters, and the apparent predictive capability of the best model suggests that the relationship between our model covariates and the probability of sighting elk groups was strong.

Only 23% of sighted or missed elk groups contained bulls and only 4% of the total elk counted were bulls. This paucity of bulls could be seen as a concern over the application of the sightability function. However, McCorquodale (2001) found that the functional relationship between variables affecting sightability and the probability of sighting elk groups was the same for males and females, which suggests that models such as ours that do not differentiate sightability according to gender are likely to adequately correct helicopter survey data.

The distribution of elk in late winter in the Cowlitz drainage facilitates aerial surveying since most elk are found in relatively open valley bottom habitats. Houston et al. (1987) conducted their work in areas with very similar topography and vegetative characteristics to our study area. As in our study, they found that in early spring the valley bottoms contained a, "very high proportion" of elk during their survey period and that adult males, "appeared to be well represented" (Houston et al. 1987, pg. 224). However, within our study, the proportion of the elk population that continued to utilize densely forested mountain terrain adjacent to the valley bottom was unknown. Houston et al. (1987) identified this concern as a primary reason for caution in using elk density estimates from aerial surveys. If a considerable proportion of the elk population did occur in these areas, then the estimates of abundance would be biased low. Bull elk, especially adults, have been found to have a higher probability of wintering at higher elevation (Irwin 2002) and adult male elk were found to occur at higher elevation and in deeper snow than females in winter range in Idaho (Unsworth et al. 1998). Concern arises when considering McCorquodale's (2001) finding that lone males in units with low density were repeatedly missed by surveyors. This suggests that the spatial distribution of males and females on winter range may substantially bias population estimates when adequate care is not taken in sample unit design. If bulls were geographically separated from cows in our study area, then estimates could be biased. However, surveys in the valley units did show a small number of bulls and estimated bull to cow ratios from Program Aerial Survey output were comparable to past population estimates. In addition, surveys were not restricted to the valley bottoms as adjacent forested upland units (which may have contained bulls) were also surveyed.

Snow cover may create problems with elk sightability model selection in the study area as evidenced by the changes in sighting conditions in the 2006 surveys after a snowfall event. When snow was included in preliminary models, a negative regression coefficient suggested that snow cover reduced the sightability of elk groups. This seems counter-intuitive since elk should be more easily sighted with a white background. Although Samuel et al. (1987) found that snow cover was not an important predictor of sightability, Leptich and Zager (1992, 1993) found a positive relationship between snow cover and sightability. The negative effect we found may be explained by the fact that many of the sighted groups were detected in open areas where snow melt had resulted in limited snow cover and patchy conditions which likely complicated detection, while most missed groups were found in higher elevation or more densely forested areas with high snow cover. This effect was complicated by the small sample size of surveys conducted under snow conditions and is supported by the fact that snow cover and vegetation cover were positively correlated (correlation coefficient of 0.59). Although McCorquodale (2001) reported positive parameter estimates for snow cover overall, he found apparently similar results in that sightability was lower at high snow cover (44–46%) than at low snow cover (63–67%) and it was especially low when snow cover was between 40 and 59%.

Stratification can be difficult in the absence of data as evidenced by the lack of elk in survey units that a priori were classified as High density units based upon topographic location. Since survey units were developed with limited data on elk occurrence, it should be expected that some units may be classified as high density due to their topographic location, but may actually be low density units when actual elk distribution is considered. The presence of high density units with

no elk during surveys had considerable influence on our estimates of elk abundance (Table 3). This factor can also be dramatically affected by the size of the survey units, where larger units are less likely to result in non-detections and smaller units may have elk in the adjacent units that could have recently moved out of the unit boundary. In fact, groups of elk were sighted just outside of survey unit boundaries and hence were not recorded as a sighted group for that particular survey. This problem can likely be addressed over time as survey unit boundaries are adjusted and surveying effort allows for stratification based upon data.

Literature Cited

Anderson, D. R., W. A. Link, D. H. Johnson, and K. P. Burnham. 2001. Suggestions for presenting the results of data analyses. Journal of Wildlife Management 65:373-378.

Bender, L. C. and R. D. Spencer. 1999. Estimating elk population size by reconstruction from harvest data and herd ratios. Wildlife Society Bulletin 27:636-645.

Burnham, K. P. and D. R. Anderson. 1998. Model Selection and Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York.

Houston, D. B., B. B. Moorhead, and R. W. Olson. 1987. Roosevelt elk density in old-growth forests of Olympic National Park. Northwest Science 61:220-225.

Irwin, L. L. 2002. Migration. *In* D. E. Toweill and J. W. Thomas (editors). North American Elk: Ecology and Management. Smithsonian Institution Press, Washington, D.C., Pp. 493-514

Leban, F. A. and E. O. Garton. 2000. Program Aerial Survey 2000, Version 1.00, Beta 6.1.4, February 12, 2000.

Leptich, D. J. and P. Zager. 1992. Coeur d'Alene elk ecology project, study II: elk sightability models: elk sightability bias in relation to timbered cover types and bull elk. Job Completion Report W-160-R-20-1. Idaho Department of Fish and Game, Boise, Idaho, USA.

Received 6 June 2007
Accepted for publication 23 May 2008

Acknowledgment

This study was funded by the Puyallup Tribe of Indians, BIA Unresolved Hunting and Fishing Rights Grant, and a USFWS TWG grant. We thank the Puyallup Tribal Hunting Commission for support and participation in the project. P. Arnold provided GIS Analysis. We thank C. Madsen (NWIFC), L. Richardson, R. Woodin (WDFW), J. White, and J. Hagerman for his exceptional skill in conducting aerial surveys.

Leptich, D. J. and P. Zager. 1993. Coeur d'Alene elk ecology project, study II: elk sightability models: elk sightability model validation at the Starkey Experimental Forest and Range, Oregon. Job Completion Report W-160-R-23-1. Idaho Department of Fish and Game, Boise, Idaho, USA.

McCorquodale, S. M. 2001. Sex-specific bias in helicopter surveys of elk: sightability and dispersion effects. Journal of Wildlife Management 65:216-225.

Otten, M. R., J. B. Haufler, S. R. Winterstein, and L. C. Bender. 1993. An aerial censusing procedure for elk in Michigan. Wildlife Society Bulletin 21:73-80.

Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. Journal of Wildlife Management 51:622-630.

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

Unsworth, J. W., L. Kuck, E. O. Garton, and B. R. Butterfield. 1998. Elk habitat selection on the Clearwater National Forest, Idaho. Journal of Wildlife Management 62:1255-1263.

Unsworth, J. W., F. A. Leban, E. O. Garton, D. J. Leptich, and P. Zager. 1999. Aerial Survey: User's Manual. Idaho Department of Fish and Game, Boise, Idaho, USA.