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ANALYSIS OF 1992 DALL SHEEP AND MOUNTAIN GOAT SURVEY DATA KENAI NATIONAL WILDLIFE REFUGE

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Abstract: The Alaska Department of Fish and Game (ADFG) and the U.S. Fish and Wildlife Service (FWS) cooperated in evaluating alternative methods of estimation of Dall sheep (*Ovis dalli*) and Rocky Mountain goat (*Oreamnos americanus*)numbers on the 800,000 hectare (1.97 million-acre) Kenai National Wildlife Refuge (KNWR) during the summer of 1992. The techniques included double sampling to correct for visibility bias. We compared the accuracy of population estimates obtained by the standard census, by a double sampling and logistic regression approach and by estimates obtained using the Gasaway ratio technique. Our study illustrated that the standard, and even very intense aerial surveys may miss sheep. Group size emerged as a significant variable explaining visibility bias. The ratio and product estimator appeared to be a biased under-estimator of size. The variance estimator for the logistic estimator appeared more appropriate. Simulations using logistic regression and ratio estimation provided an indication of the effect of sample size on survey results.

Dall sheep and Rocky Mountain goat surveys by the Alaska Department of Fish and Game (ADFG) are typically conducted using Piper PA-18 aircraft flown at low altitudes with intensive circling of sheep or goat groups. No attempt is made to correct for animals or groups of animals missed using this technique, since sightability of sheep and goats is generally assumed to be high (Loranger and Spraker 1992). Unfortunately, surveys designed to count all the animals present in an area often underestimate animal abundance (Caughley 1977) and generally lack information necessary to estimate the accuracy and precision of the counts. A major reason for inaccuracies in aerial surveys is the lack of an estimate of the number of animals missed or visibility bias (Caughley 1974, 1977).

In an evaluation of the effects of several factors on the accuracy of aerial surveys, Caughley et al. (1976) found speed, height above ground, the width of survey strips, and observers had significant effects on survey results. Samuel et al. (1987) found that visibility of elk in northcentral Idaho was significantly influenced by group size and vegetation cover. Other studies of visibility bias in aerial surveys have reported affects from species (Broome 1985), season of the year (Gasaway et al. 1985), sex, terrain, past experience with aircraft (Singer and Mullen 1981), and age specific behavior (Miller and Gunn 1977).

Adjustments of aerial survey data for visibility bias can be made. Samuel et al. (1987) offered a sightability model for predicting the probability of observing elk groups during winter aerial counts. Eberhardt and Simmons (1987) suggested "double sampling" as a way to calibrate aerial observations. McDonald et at. (1990a) in the Arctic National Wildlife Refuge (ANWR) and McDonald et al. (1990b, 1991) in the Wrangell-St. Elias National Park (WRST) found a significant relationship between group size and the ability of a low intensity fixed-wing survey to detect Dall sheep.

This study was conducted by the ADFG and FWS to compare three methods of estimating Dall sheep and Rocky Mountain goat numbers on the 800,000 hectare (1.97 million-acre) Kenai National Wildlife Refuge (KNWR) during the summer of 1992. The study also compared estimates obtained using counts from all survey units with estimates made from a simulated probability sample of a subset of sample units. The specific objectives of this study included:

1. compare estimates of the abundance of Dall sheep and Rocky Mountain goats within defined

habitat in the KNWR obtained by the double sampling and logistic regression approach (McDonald et al. 1990a), the Gasaway ratio technique (Gasaway et al. 1986), and the ADFG standard aerial survey; and,

2. to simulate the results of a sample survey using stratified subsampling of the KNWR.

METHODS

Survey Procedures

We conducted aerial counts in late June and early July 1992 of Dall sheep and Rocky Mountain goats on specified habitats on and immediately adjacent to the KNWR. We subdivided existing Dall sheep and Rocky Mountain goat count areas used by the ADFG for annual population trend and composition surveys into 27 survey units totaling 1732.1 km^2 (668.8 mi^2). Boundaries of survey units consisted of physiographic features which we assumed severely limited movement among units between repeat surveys.

Survey units were placed into one of three strata based on sheep density: 1) high; 2) medium; and 3) low. The high density stratum contained 8 units totaling 478.9 km^2 (184 mi^2); the medium density stratum contained 6 units totaling 448.3 km^2 (173.1 mi^2); and, the low density stratum contained 13 units totaling 804.7 km^2 (310.7 mi^2). We based the stratification on available historical data from ADFG surveys and/or an overflight of the survey areas. All survey units were digitized on the KNWR's Geographical Information System. Our study utilized 3 aerial surveys, each using a two-person (pilot/ observer) crew in a Piper PA-18 fixed-wing aircraft. The first survey was a comparatively extensive, "stand-off" survey (0.38 min/km^2 (1 min/mi^2)) designed to avoid disturbance to animals and provide more safe operating conditions for the fixed-wing aircraft. The second survey was a relatively intensive, "standard" survey (1.2 min/km^2 (3 min/mi^2)) flown at low altitudes with intensive circling typical of surveys employed by the ADFG. The second survey utilized a different survey crew from the stand-off survey. A third, "intensive" survey (2.3 min/km^2 (6 min/mi^2)) was conducted in a randomly selected sample of units. The third survey was conducted immediately following the second survey using the same pilot-observer team.

We recorded the total number of sheep or goats in each group and plotted their location on 1:63,360 USGS topographic maps of the survey units. We determined the age and sex composition of each group as closely as possible. The elapsed time between surveys was $\leq$ 2 hours and we assumed that animals did not cross unit boundaries between any of the surveys.

The survey crews flying the stand-off and standard surveys compared mapped locations and descriptions of groups immediately following survey flights. The survey crews used proximity of map locations and age and sex composition of sheep or goats to identify unique groups observed by one or both surveys. Groups seen by the standard survey were considered "marked", and these groups were either seen or missed by the stand-off survey. Decisions regarding pooling of original groups recorded and marked on maps to account for movement, aggregation, and segregation between surveys were based on deductive judgement of the survey crews. When in doubt, crews used a conservative approach (i.e. they assumed groups were seen by both surveys) in determining if groups were seen by both surveys. Thus, it was unlikely that incidental movement of sheep between surveys resulted in sheep recorded as seen by the intensive and not the less intensive surveys. This approach yielded a conservative estimate of the population size as it likely overestimated the probability that a given group was detected during the less intensive survey.

Population Estimates Using Logistic Regression

We assumed the standard survey detected a random sample of sheep and goat groups present, "marked" their location, and gave an exact count of numbers present in detected groups. The stand-off survey either detected or did not detect the marked groups. We used logistic regression to estimate visibility bias inherent in the less intensive, standoff survey (Eberhardt and Simmons 1987, Samuel et al. 1987). The logistic model considered only the variable group size (McDonald et al. 1990b, 1991) with a significance level of $p = 0.05$. The standard survey missed some groups seen by the stand-off survey, but those groups did not enter the calculation of visibility bias in any way. Standard errors and sampling distributions of density estimates were calculated using the Jackknifing procedure (Manly 1991).

To complete the Jackknife procedure we let n denote the number of primary units in the sample and fit one logistic model using data from all survey units in a stratum. We then calculated the visibility bias, adjusted all stand-off survey counts and estimated the density of Dall sheep. The calculations were repeated n times dropping each unit from the logistic regression one-at-a-time. These n+1 estimates of density were then used in the Jackknife procedure to compute n pseudo-estimates of density:

$$D_{pk}=n^*D_t-(n-1)^*D_{tk}$$

where D_{pk} was the pseudo-estimate of the population size with one unit dropped, D_t was the estimated population size with all units present, D_{tk} was the estimate of population size with the kth unit dropped.

Finally, we completed the Jackknife procedure by averaging these n pseudo-estimates to arrive at a single estimate of density. The standard error of estimated density was computed from the variation in the n pseudo-estimates. The total number of sheep or goats in the survey area was computed by multiplying the Jackknifed estimate of density by the total area. McDonald et al. (1991) described the above Jackknife procedures in detail. Confidence intervals based on the Jackknife procedure were computed as if the n pseudo-values are a simple random sample of size n using the standard t-distribution with n - 1 degrees of freedom.

Logistic regressions were run on PC-SAS (SAS Institute, Inc. 1985) using the CATMOD procedure, VMS SAS (SAS Institute, Inc. 1986) using the LOGIST procedure, and SOLO (BMDP Statistical Software, Inc. 1988) using logistic regression. All programs gave comparable results.

Population Estimates Using The Ratio Estimation Procedure

We used the intensive and standard surveys and standoff and standard surveys to construct a ratio estimate of the total sheep and goats (Gasaway et al. 1986). The following formulas (Cochran 1977, Reed et al. 1989) were used to compute the ratio estimators.

$Y_{i,h}$ and $X_{i,h}$ represented the number of sheep observed in unit i of strata h by the intensive and standard flights respectively. R_h was defined as:

$$\hat{R}_h = \frac{\sum Y_{i,h}}{\sum X_{i,h}}$$

$X_{2,h}$ represented the number of sheep observed by the standard flights in strata h including those units which were not double sampled.

The ratio estimator of the total for strata h, was:

$$\hat{Y}_{R,h} = \hat{R}_h \times \hat{X}_{2,h}$$

The variance of the ratio and ratio estimator were then used to arrive at an estimate of the standard error for each stratum. The estimates of the total and standard error were then computed using the standard formulas for stratified random sampling from Cochran (1977).

Sampling Simulations Using Logistic Regression

We simulated estimates of population size and generated 80% confidence intervals, from a stratified random sample of the low, medium, and high density strata using standoff and standard survey counts. We drew a random sample of n_1 units from 13 units in the low density stratum, n_2 units from 6 units in the medium density stratum, and n_3 units from 8 units in the high density stratum. We then corrected for visibility bias using logistic regression to estimate the number of sheep in each stratum and the total survey area. We drew another sample of the same size in each strata and repeated the process 1000 times. The standard deviation of the 1000 estimates of total sheep was used to compute the "simulated" 80% confidence interval based on the given sample size. Sample sizes were then allowed to vary within each stratum from a minimum of 2 to a maximum of 1 less than the number of units in that stratum. This generated 264 simulations for sheep and 264 simulations for goats.

Sampling Simulations Using Ratio Estimates

We used simulated double sampling to generate ratio estimates (Cochran 1977) of the total number of sheep in the KNWR for different sampling intensities. We generated ratio estimates for standoff versus standard and standard versus intense surveys. All high and medium density units and 5 of 13 low density units were double sampled in the standard and intense surveys. Simulated stratified random samples of sizes 3 through 8, 3 through 6, and 4 through 5 were drawn from the high, medium and low density strata respectively. The low density stratum had 3 empty units, prohibiting computation of the ratio of standard and

Table 1. The total area (km^2) of strata and estimated number and density of Dall sheep by stratum from counts made during standoff surveys, corrected for visibility bias using counts from standard surveys made in the Kenai National Wildlife Refuge, 1992.

Density strata	No. of units	Total area	Density	Total sheep
High	8	478.9	1.6860	807
Medium	16	448.3	0.5083	228
Low	13	804.7	0.1062	85
Total		1731.9	0.6472	1120[a]
Jackknifed estimate			0.6432	1114[b]

[a] Corrected for visibility bias but not Jackknifed.

[b] Corrected for visibility bias and mathematical bias by the Jackknife procedure resulting in a standard error for density of 0.09758 and total sheep of 169.

intensive counts for some samples of size 3. Therefore, the minimum sample size used in that stratum was 4. From each sample drawn, a subsample of 3 units in each stratum was selected at random for double sampling. This procedure was repeated 1000 times for each combination of strata sample sizes. The standard deviation of the 1000 estimates of total sheep was used to compute the "simulated" 80% confidence interval for the given sample size for each pair of surveys. We did not complete ratio simulations for goat surveys because of the large number of units without observations.

RESULTS

The standoff and standard surveys covered the same 27 units with an area totaling 1768.7 km^2 (683.1 mi^2). During the standoff survey the observation crew counted 850 sheep in 109 groups and 410 goats in 72 groups. During the standard survey the observation crew counted 1032 sheep in 149 groups and 456 goats in 84 groups. The standoff survey crew missed 57 sheep groups and 33 goat groups seen by the standard survey crew. However, the standard survey missed 17 sheep groups and 23 goat groups seen by the standoff survey crew. During the intense survey the observation crew counted 1056 sheep and 264 goats in 19 units totaling 1242 km^2 (479.7 mi^2). The ratio of sheep and goats seen during the standoff versus standard surveys was 0.82 and 0.9 respectively and standoff versus intensive was 0.91 and 0.77 respectively. The ratio of sheep and goats seen during the standard versus intensive surveys was 0.93 and 0.98 respectively.

The probability that the standoff survey crew would see a group of sheep increased considerably ($p = 0.0001$) as group size increased. We used this relationship to adjust the number of Dall sheep counted during the standoff survey for visibility bias, resulting in an estimate of 1114 $\pm$ 222 (80% C.I.) total sheep in the survey area (Table 1). The probability that the standoff survey crew would see a group of goats also increased ($p = 0.0166$) as group size increased. Using this relationship to adjust the number of goats counted during the standoff survey for visibility bias, we estimated 541 $\pm$ 190 (80% C.I.) total goats in the surveyed area (Table 2).

The survey crew conducting the standard survey conducted the intensive survey in 19 survey units. The intensive survey counted slightly more sheep and goats (1056 and 264) than the standard survey (984 and 260). Nevertheless, during the intensive survey the survey crew failed to detect some sheep and goats seen during the standard survey in some units. The medium density stratum had 3 out of 6 units with standard counts greater than intense survey counts. Using the ratio of Dall sheep and Rocky Mountain goats seen during standard to intense surveys, we estimated 1114 $\pm$ 218 (80% C.I.) sheep and 464 $\pm$ 152 (80% C.I.) goats, respectively. Using the ratio of Dall sheep and Rocky Mountain goats seen during standoff and standard survey, we estimated 1042 $\pm$ 204 (80% C.I.) sheep and 471 $\pm$ 156 (80% C.I.) goats,

Table 2. The total area (km²) of strata and estimated number and density of Rocky Mountain goats by stratum from counts made during standoff surveys, corrected for visibility bias using counts from standard surveys made in Kenai National Wildlife Refuge, 1992.

Density strata	Area	Density	Total goats
High	478.9	0.2090	100
Medium	448.3	0.1768	79
Low	804.7	0.4599	370
Total	1731.9	0.3173	549[a]
Jackknifed Estimate		0.3124	541[b]

[a] Corrected for visibility bias but not Jackknifed.
[b] Corrected for visibility bias and mathematical bias by the Jackknife procedure resulting in a standard error for density of 0.0837 and total goats of 145.

Table 3. Selected examples of simulated standard error and 80% confidence intervals for estimation of animal numbers using the logistic model and the standard survey to calibrate a stratified random sample of units included the standoff survey in the Kenai National Wildlife Refuge in 1992.

Sample size by stratum			Sheep simulated				Goats simulated			
L[1]	M[2]	H[3]	CI			SE	CI			SE
2	2	2	1028	+/-	447	303	421	+/-	485	328
2	2	8	1119	+/-	197	144	504	+/-	411	301
2	6	2	1051	+/-	395	286	400	+/-	434	314
7	3	2	1030	+/-	382	280	423	+/-	229	168
7	3	3	1103	+/-	254	187	499	+/-	175	129
7	3	4	1107	+/-	206	153	511	+/-	168	124
7	3	5	1114	+/-	176	131	510	+/-	165	123
7	3	6	1103	+/-	142	106	515	+/-	166	124
7	3	7	1108	+/-	122	91	509	+/-	159	119
7	3	8	1110	+/-	100	75	512	+/-	156	117
13	6	8	1114	+/-	0	0	514	+/-	0	0

[1] L = low
[2] M = medium
[3] H = high

Table 4. Selected examples of simulated and 80% confidence intervals for ratio estimation of animal numbers using a stratified random sample of units included in all surveys and using more intensive surveys to calibrate the less intensive surveys and the corresponding logistic estimation for Dall sheep in the Kenai National Wildlife Refuge in 1992.

Sample size by stratum			Standard vs standoff simulated			Intensive vs standard simulated			Logistic simulated		
L[1]	M[2]	H[3]	80% CI			80% CI			80% CI		
4	3	3	1047	+/-	246	1118	+/-	253	1103	+/-	270
4	3	8	1044	+/-	128	1113	+/-	125	1104	+/-	126
4	6	3	1048	+/-	237	1115	+/-	232	1113	+/-	250
5	3	3	1044	+/-	238	1113	+/-	248	1095	+/-	272
5	3	4	1042	+/-	198	1112	+/-	206	1110	+/-	218
5	3	5	1042	+/-	172	1113	+/-	175	1111	+/-	180
5	3	6	1052	+/-	150	1121	+/-	154	1104	+/-	154
5	3	7	1046	+/-	141	1117	+/-	135	1115	+/-	133
5	3	8	1042	+/-	119	1113	+/-	118	1112	+/-	108
5	6	8	1052	+/-	104	1117	+/-	62	1116	+/-	67

[1] L = low
[2] M = medium
[3] H = high

respectively. The point estimates and precision of the logistic model procedure (1114 ± 222) and ratio procedure using standard and intensive counts (1114 ± 218) were essentially identical. Both estimates were higher than the ratio estimate using standoff and standard survey counts (1042 ± 204).

We estimated a minimum number of sheep and goats by combining counts of independent animals from the standoff and standard surveys. The standard survey crew counted 1032 sheep and 456 goats and missed 65 sheep (17 groups) and 49 goats (23 groups) observed by the standoff crew. Based on these counts we concluded that a minimum of 1097 sheep and 505 goats existed in the surveyed area at the time of the standoff survey.

The standoff and standard surveys included an inventory of all units within the study area. By drawing a large number of stratified random samples of counts made during these two surveys, we simulated estimates of sheep and goats which could be expected using the logistic model if the surveys sampled only a portion of the units. Table 3 provides an example of the results of these simulations.

The broadest confidence interval was obtained with the minimum sample size in each stratum (i.e. n_1, n_2, and n_3 = 2). The narrowest confidence interval was obtained with the maximum sample size in each stratum (i.e. $n_1 = 12$, $n_2 = 5$, and $n_3 = 7$). Point estimates both increased and decreased when sample sizes increased. Increasing the sample in any stratum improved the precision of the estimate. The simulated confidence intervals may be used to compare the expected precision as a function of the corresponding sample sizes. This may help in choosing a sampling strategy for future studies.

An example of population estimates and confidence intervals obtained by simulating double sampling and ratio estimates are contained in Table 4. We used simulations to correct the standard survey counts using the intensive survey counts and standoff survey counts using the standard survey counts. These estimates were compared to estimates and confidence intervals generated using the logistic model for estimating the visibility correction factor generated in simulations. A total of 48 combinations of strata sample sizes was possible. With small sample sizes the ratio estimate, regardless of surveys compared, appeared more precise than the logistic model estimate. However, as sample size increased, the precision of the logistic model estimate improved to the point of exceeding the apparent precision of the ratio estimators. In all cases the logistic model estimate of sheep and goat numbers exceeded the estimate derived from the ratio estimator.

DISCUSSION

The intensity of the KNWR standoff (fixed-wing) survey (0.38 min/km^2; 1 min/mi^2) was greater than the standoff (fixed-wing) survey in the WRST surveys (0.21 min/km^2; 0.54 min/mi^2) reducing the likelihood that sheep and goats would be missed by the KNWR standoff survey. Nevertheless, the standoff and even the much more intense standard and intense surveys conducted during our study missed sheep and goats. Our results illustrate that sheep and goat estimates based on the relatively intense standard survey used by the ADFG, and even very intense aerial surveys may be improved by adjustments for visibility bias.

As in the other aerial surveys of Dall sheep using double sampling and logistic regression (McDonald et al. 1991 and McDonald et al. 1990a) group size emerged as a significant variable explaining visibility bias for both sheep and goats. Corrections for visibility bias using the logistic regression model and the ratio estimation procedure resulted in essentially identical point estimates and precision for sheep and goats when using standard and intensive survey counts. However, this is not surprising since these 2 surveys missed few sheep and the data are likely biased because the same crew conducted both surveys.

When comparing the 2 methods, it seems more appropriate to compare estimates made from the surveys using the independent standoff and standard surveys. The point estimate obtained with the ratio of standoff and standard counts is lower than the minimum number of sheep known to be in the study area. The point estimate obtained with the logistic estimator is slightly higher than the minimum estimate and likely more realistic. The ratio and product estimator appears to be a biased underestimate of size, as could be expected since ratio estimators typically contain some mathematical bias.

We also feel the variance estimator for the logistic estimator for both sheep and goat is more appropriate. Several factors associated with the 3 surveys may have contributed to the lower variance of the ratio estimator. First, the intensity of all 3 surveys resulted in relatively few sheep being missed. For example, the standoff survey, the least intensive effort, missed less than 20 percent of the sheep and 10 percent of goats of the total seen by the standard survey. This similarity in counts resulted in a ratio between any 2 survey counts (R^) approaching 1. Second, in the logistic procedure, area is used as an auxiliary variable while, for the ratio estimator, equal unit size is assumed, even though units are of different sizes. Third, the formulas for calculation of variance used with the ratio estimator assume independent counts, however the counts made in the double sampling design are dependent.

The standoff and standard surveys covered all units. However, it may be desirable to sample populations rather than survey all units. Simulations using logistic regression and ratio estimation provided an indication of the effect of sample size on survey results. While increasing the sample size in any stratum improved the precision of the estimate using both estimating procedures, increases in sample size within the medium and high density strata had the greatest effect on precision. As with the point estimates the ratio estimator appeared to have a lower variance. The above reasons offered for this reduced variance also apply to the simulations. In addition, in cases where the standoff survey actually counted more sheep and goats than the standard survey the point estimate and variance would be artificially reduced. Even with the bias likely in calculating the precision of the ratio estimate the logistical model provides a more precise estimate of animal numbers with larger sample sizes.

LITERATURE CITED

BMDP Statistical Software, Inc. 1988. SOLO Advanced Set 8/88. Version 2.0. Los Angeles, CA. 129pp.

Broome, L. S. 1985. Sightability as a factor in aerial survey or bird species and communities. Aust. Wildl. Res. 12:57-67.

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

_____. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, N.Y. 234pp.

____, R. Sinclair, and D. Scott-Kemmis. 1976. Experiments in aerial survey. J. Wildl. Manage.

40:290-300.

COCHRAN, W. G. 1977. Sampling techniques, 3rd ed. John Wiley and Sons, New York, N.Y. 428pp.

EBERHARDT, L. L. AND M. A. SIMMONS. 1987. Calibrating population indices by double sampling. J. Wildl. Manage. 51:665-675.

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

LORANGER, A. AND T. SPRAKER. 1992. 1992 Dall sheep and mountain goat surveys: Kenai National Wildlife Refuge. Management study proposal. U.S. Fish and Wildl. Service, Anchorage AK and Alaska Dept. of Fish and Game, Juneau. 12pp.

MANLY, B. F. J. 1991. Randomization and Monte Carlo methods in biology. Chapman and Hall, New York, N.Y. 281pp.

MCDONALD, L. L., H. B. HARVEY, F. J. MAUER, AND A. W. BRACKNEY. 1990a. Design of aerial surveys for Dall sheep in the Arctic National Wildlife Refuge, Alaska. Bienn. North. Wild Sheep and Goat Counc. 7:176-193.

____, D. STRICKLAND, D. TAYLOR, M. MULLEN, AND J. KERN. 1990b. Estimation of Dall sheep numbers in the Wrangell-St. Elias National Park July 1990. Unpublished technical report. National Park Service, Alaska Region. Anchorage, Alaska. 26pp.

____, D. STRICKLAND, D. TAYLOR, J. KERN, AND K. JENKINS. 1991. Estimation of Dall sheep numbers in Wrangell-St. Elias National Park and Preserve - July 1991. Unpublished technical report. National Park Service, Alaska Region. Anchorage, Alaska. 40pp.

MILLER, F. L. AND A. GUNN. 1977. Responses of Peary Caribou and muskoxen to helicopter harassment. Can. Wildl. Serv. Occas. Pap. No. 40. 90pp.

REED, D. J., L. L. MCDONALD, AND J.R. GILBERT. 1989. Variance of the product of estimates. Draft report. Alaska Department of Fish and Game, Fairbanks, AK.

SAMUEL, M. D., E. O. GARTON, M. W. SCHLEGEL, AND R. G. CARSON. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. J. Wildl. Manage. 51:622-630.

SINGER, F. AND K. MULLEN. 1981. Summer distribution and numbers of Dall sheep and mountain goats in Wrangell-St. Elias National Park and Preserve, progress report - 1981. NPS, Alaska Region, Natural Resources Survey and Inventory Report AR-81/02. 17pp.

SAS INSTITUTE INC. 1985. SAS User's Guide: Statistics, Version 5. Cary, N.C. 957pp.

_____. 1986. SUGI VMS SAS. Cary, North Carolina. 660pp.