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ESTIMATION OF DALL SHEEP NUMBERS IN THE WRANGELL-ST. ELIAS NATIONAL PARK AND PRESERVE

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Abstract: Aerial sample surveys of Dall (*Ovis dalli dalli*) sheep were conducted in Wrangell-St. Elias National Park, Alaska, in July 1990 and 1991. The sample surveys included a 2-stage stratified random sampling procedure combined with double sampling. Observers in a fixed-wing aircraft completed an aerial survey on a random sample of count units in high, medium, and low density sheep regions in the entire survey area (fixed-wing survey). The double sampling consisted of a more intensive survey by observers in a helicopter on a subsample of these units (helicopter survey). The helicopter survey provided groups of sheep known to exist in the count units which were either detected or missed during the fixed-wing survey. The probability of detection of a given size group during the fixed-wing survey was then estimated using logistic regression. The 2-stage sample combined with double sampling allowed extrapolation of sheep counts, corrected for visibility bias, to the entire survey area. The 2 years of survey allowed a comparison of independent estimates of Dall sheep density using nearly identical methodology.

Aerial surveys designed to count all the animals present in an area generally lack information necessary to estimate the accuracy and precision of the counts. Unfortunately these surveys often underestimate animal abundance (Caughley 1977). A major reason for inaccuracies in aerial surveys is the lack of an estimate of the number of animals not counted due to 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 that speed, height above ground, 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 (Gasaway et al. 1985), sex, terrain, past experience with aircraft (Singer and Mullen 1981), and age-specific behavior (Miller and Gunn 1977).

Several methods of adjusting aerial survey data for visibility bias have been described. Samuel et al. (1987) described sightability models 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 al. (1990) estimated visibility bias associated with aerial surveys of Dall sheep in the Arctic National Wildlife Refuge (ANWR), Alaska, using logistic regression to estimate visibility as a function of measurable explanatory variables.

Because of the size of the parks in Alaska, conventional surveys can cover only a small portion of sheep range. Wrangell-St. Elias National Park and Preserve (WRST) was last surveyed by the National Park Service (NPS) and the Alaska Department of Fish and Game (ADF&G) during a 4-year period from 1981 through 1984. These and previous sample surveys of WRST were an attempt to count all the sheep in the areas surveyed using a variety of aircraft and personnel. Past surveys provided valuable information necessary for the management of sheep in the Park and Preserve. However, the survey design, potential visibility bias, and extended survey period made interpretation of sample survey data difficult. In addition, the extensive flying necessary for a total count, much of the time in fixed-winged aircraft, made surveys expensive and dangerous.

An aerial sample survey of Dall sheep was conducted in late June - early July of 1990 and 1991 in WRST. WRST is a 53,418 square kilometer (20,625 mi^2) national park in southcentral Alaska. The sample surveys were conducted in the Wrangell Mountains and the adjacent portion of the Chugach Mountains in the park. The surveys used a stratified random sample with double sampling for correction of visibility bias. Sheep abundance was estimated by counting sheep from a fixed-wing aircraft in a random sample of count units stratified by sheep density. Counts made during the fixed-wing flight were corrected for visibility bias by comparison with a double sample from a helicopter on a subset of units, and used in a 2-stage sampling plan to estimate the abundance of sheep in the entire WRST.

This project is part of a regional effort to improve sample surveys of Dall sheep in National Parks of Alaska. The specific objectives of the sample surveys were:

1. to estimate abundance of Dall sheep in the Wrangell and Chugach mountains within WRST with known accuracy and precision;

2. to develop and test a sampling design that is more cost effective than those used in past surveys and can be completed easily in 1 season; and

3. to develop and test a sampling design that is safer than those used in past surveys.

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METHODS

Surveys were conducted during the last week in June and first week in July both years. The surveys utilized a 2-stage random sampling procedure with stratification combined with double sampling. The double sampling method involved conducting a comparatively extensive survey of Dall sheep from a fixed-wing aircraft in a stratified random sample of survey units, followed immediately by a comparatively intensive survey from a helicopter on a subsample of these units. We assumed that the intensive helicopter survey detected a random sample of sheep groups present, "marked" their location, and gave an exact count of sheep numbers present in detected groups. The fixed-wing survey either detected or did not detect the marked groups. Double sampling with helicopter and fixed-wing surveys allowed the use of logistic regression for estimation of visibility bias inherent in the extensive fixed-wing survey (Eberhardt and Simmons 1987, Samuel et al. 1987). We used the results of the relatively large sample size of the fixed-wing survey, corrected for visibility bias, to extrapolate a density estimate to all units in the stratum.

WRST, was divided into 31 primary sampling units (Fig. 1) grouped into high, medium, and low-density strata according to procedures described in Taylor et al. (1989). Previous surveys (Singer 1982, Mullen and Cella 1984) established the primary sampling units, that ranged in size from 96 to 2002 km^2 (37 to 773 mi^2) (Table 1). We selected a random sample of primary units from each density stratum for conducting fixed-wing surveys. The number of units selected in each stratum was proportional to expected sheep density. Each of these primary sampling units was further divided into subunits ranging in size from 132 to 471 km^2 (49 to 182 mi^2) (Table 2). The subunits were small enough that they could be sampled in 1 flight by the helicopter in the same amount of time required to fly the entire primary unit in the fixed-wing and large enough so that movement between subunits was minimized. The large size of some primary sampling units presented logistical problems for counting sheep from a fixed-wing aircraft within the time frame of the survey. Therefore, in larger primary units, a random sample of subunits was counted in the fixed-wing survey rather than the entire primary unit. In those cases, the helicopter survey counted sheep in a random sample of the subunits included in the fixed-wing survey.

Table 1. Area in square kilometers of the primary units in the Dall sheep survey at Wrangell-St.Elias National Park and Preserve, July 1990 and 1991.

High density strata:		Medium density strata:		Low density strata:	
Unit	Area km^2	Unit	Area km^2	Unit	Area km^2
1	1185.76	10	1199.83	25	1258.54
2	1361.36	13	535.76	26	1158.41
3	2002.15	15	507.90	27	469.17
4	1037.93	16	513.33	28	901.63
5	652.65	17	363.04	29	748.26
6	793.39	18	894.65	30	1323.90
7	999.99	19	1161.15	31	1199.82
8	733.47	20	550.54		
9	734.63	22	916.50		
11	337.54	23	716.14		
12	610.33	24	475.49		
14	96.00				
21	213.32				
Total	10758.52		7834.01		7059.74

While the same basic sampling procedures were used in both years, survey methodology was changed slightly in 1991 as a result of experience gained in 1990. To the extent possible, the same sample units randomly selected for the 1990 survey were also sampled in 1991 to permit comparisons between years. Counting procedures from the fixed-wing aircraft were modified slightly in 1991 so comparisons with 1990 counts (unadjusted for visibility bias) were limited to counts from the helicopter survey. Additional primary units and subunits were randomly selected from the low, medium, and high density strata in 1991 to provide additional units and subunits for both the fixed-wing and helicopter surveys in the event that larger sample sizes were possible.

Experienced pilots and observers conducted both the fixed-wing and helicopter surveys. Data collected during surveys included the number of groups of sheep detected, number of sheep counted in each group, and habitat characteristics at the location of the group. All observed sheep were classified to the extent possible as lambs, rams (>1 year old), and ewe-like (ewes plus

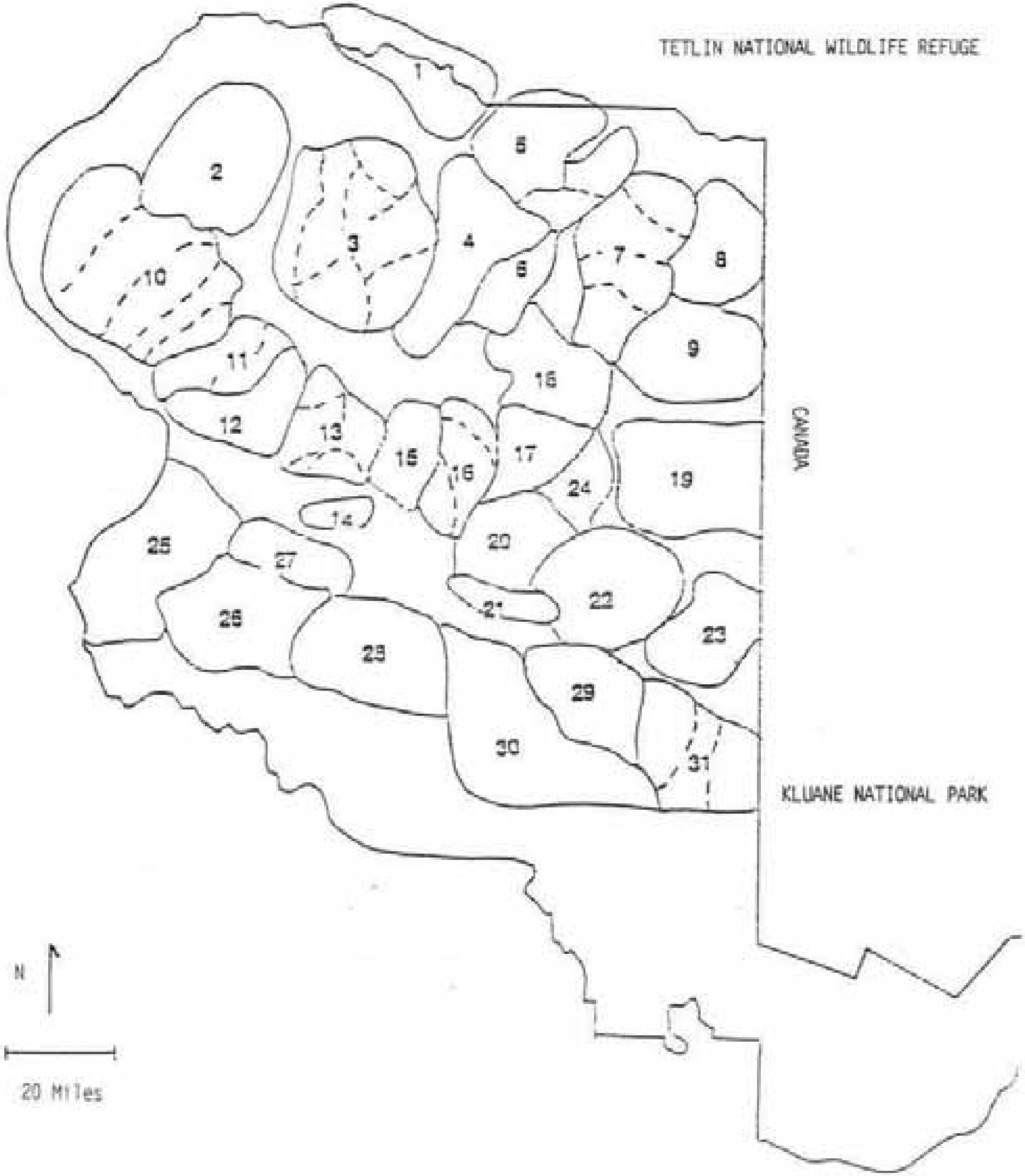

Fig. 1. Map of the Wrangell-St. Elias National Park and Preserve showing 31 primary sampling units. Dashed lines divide units into subunits.

subadult rams). Observers recorded habitat variables including substrate (vegetation or rock color), terrain, and percent slope. Locations of groups were marked on U.S.G.S. 1:250,000 scale quadrangle maps with a contour interval of 61 m (200 feet). Groups were considered distinct if they appeared to consist of a unique group of individuals based on location and sex and age composition.

Table 2. Actual survey time spent by the fixed-wing aircraft and the helicopter during the survey of Dall sheep at Wrangell-St.Elias National Park and Preserve, July 1990, 1991.

	1990			1991		
Unit	Time min.	Area km^2	Min. per km^2	Time min.	Area km^2	Min. per km^2
Fixed-wing flights:						
3A	N.S.[a]	N.S.	N.S.	70	277.81	0.29
3B	N.S.	N.S.	N.S.	78	343.15	0.23
3D	50	131.91	0.38	36	131.91	0.27
3G	70	313.78	0.22	58	313.77	0.18
6AB	N.S.	N.S.	N.S.	83	397.59	0.21
7A	179	471.72	0.38	N.S.	N.S.	N.S.
7B	N.S.	N.S.	N.S.	101	278.64	0.36
7C	N.S.	N.S.	N.S.	49	236.00	0.21
11AB	66	337.53	0.20	76	337.54	0.23
14	22	95.99	0.23	26	95.99	0.27
10A	45	353.79	0.33	N.S.	N.S.	N.S.
10DE	76	291.17	0.26	60	291.17	0.21
13ABCD	117	535.77	0.22	76	535.77	0.15
16ABC	93	513.34	0.18	118	513.34	0.23
27ABC	85	469.18	0.18	98	469.18	0.21
31ABC	109	1199.8	0.09	83	1199.7	0.07
Helicopter flights:						
3A	N.S.	N.S.	N.S.	89	277.81	0.32
3D	66	131.91	0.50	91	131.91	0.69
6B	76	205.72	0.37	N.S.	N.S.	N.S.
7A	106	471.72	0.22	N.S.	N.S.	N.S.
7B	N.S.	N.S.	N.S.	155	278.63	0.56
11A	55	164.13	0.24	36	153.15	0.24
14	30	95.99	0.31	43	95.99	0.45
10E	40	164.13	0.24	72	164.13	0.44
13D	39	152.89	0.26	58	152.89	0.38
16A	N.S.	N.S.	N.S.	40	116.99	0.34
27BC	N.S.	N.S.	N.S.	66	473.97	0.14
31C	N.S.	N.S.	N.S.	43	473.02	0.09

[a]N.S. = No survey conducted.

Fixed-wing flights were made in a Piper PA-18 Super Cub or an Arctic Tern over the entire primary unit or subunit. Fixed-wing flights used the same aerial survey procedures as the helicopter flights, but at a greater distance from the sheep, with less circling, and with less time used. The fixed-wing flights in both years were conducted at a speed of approximately 0.19 min/km^2 (0.3 min/mi^2); but the 1991 survey flew farther from the mountain slopes and with less circling than the 1990 survey. Helicopter surveys were conducted from a Bell Jet Ranger

II in 1990 and a Hughes 500D in 1991. Helicopter flights occurred at the rate of approximately 0.3 min/km^2 (0.48 min/mi^2).

In 1990 either the fixed-wing or the helicopter survey may have been conducted first in a subunit. However, in 1991 the fixed-wing flight was conducted first to minimize disturbance potentially caused by the helicopter survey. For safety, the helicopter survey usually began when informed the fixed-wing aircraft was leaving a count unit. Generally only 1-3 hours elapsed between surveys and never more than 6 hours. Data were not used if more than 6 hours passed between the 2 surveys flights. Both surveys were conducted so that there was a minimum of disturbance to sheep (ie. minimal circling and avoiding flying directly toward sheep).

Each day, immediately following survey flights, helicopter and fixed-wing crews compared mapped locations and descriptions of sheep groups. Criteria used to decide if groups were observed by both survey crews included proximity of recorded locations and age and sex composition of observed groups. Reconciled groups were used to show which groups "marked" by the helicopter survey were missed by the fixed-wing survey and which were sighted. Often, groups recorded and marked in close proximity were pooled to account for movement, aggregation, and segregation between surveys based on deductive judgement of the survey crews. Crews used a conservative approach so that it was unlikely that incidental movement of sheep between surveys resulted in sheep recorded as seen by the helicopter and not the fixed-wing surveys. This approach yielded a conservative estimate of the population size because it tended to overestimate the probability that a given group will be detected during the fixed-wing survey.

We estimated visibility bias with logistic regression (Samuel et al. 1987) and standard errors and sampling distributions of sheep density using the Jackknifing procedure (Manly 1991). The visibility bias of a sheep group during the fixed-wing survey within a given density stratum was estimated using a logistic regression model that was a function of the explanatory

variables group size and habitat. We also examined helicopter and fixed-wing survey counts of sheep in groups sighted by both surveys to decide if the helicopter survey but detected by the fixed-wing survey did not enter the calculation of visibility bias in any way.

<u>The jackknife method</u>.--The jackknife method (Manly 1991), is a repeated sampling procedure which allows the calculation of confidence intervals when no better methods are available. In our case, the method was used to estimate a mean and standard error of population density.

We first fit 1 logistic model using data from all primary units, calculated the visibility bias, adjusted all fixed-wing surveys and estimated the density of sheep using the appropriate formula for 2-stage stratified random sampling. These calculations were then repeated n times dropping each primary 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 density with 1 primary unit dropped, n was the number of primary units in the sample, D_t was the estimated density with all units present, and D_{tk} was the estimate of density with the k<u>th</u> primary unit dropped.

Finally, the jackknife procedure was completed 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 in WRST was computed by multiplying the jackknifed estimate of density by the total area of all primary units. The stratified random sampling formula and Jackknife procedures are described in more detail in McDonald et al. (1990). Confidence intervals based on the jackknife procedure were computed as if the n pseudo-values represented a simple random sample of size n using the standard t-distribution.

We examined the initial stratification of primary units based on the number of sheep seen by the 1990 and 1991 surveys. A primary unit was placed into a different density stratum if the analysis suggested the unit was misclassified. Following post-stratification we repeated the estimation procedures described above and obtained additional estimates of sheep density for the purpose of evaluating the effectiveness of the initial stratification.

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.

RESULTS

The 1991 fixed-wing and helicopter surveys covered more area (8191 km^2; 3124 mi^2) than the 1990 surveys (6089 km^2; 2351 mi^2) and resulted in a larger sample of sheep groups. The 1990 helicopter survey covered all or a portion of 7 primary units including 6 subunits, an area of 1357 km^2 (531 mi^2). The 1990 fixed-wing survey covered all or a portion of 9 primary units including 21 subunits, an area of 4713 km^2 (1820 mi^2) (Table 2). In 1991 the helicopter survey covered all or a portion of 9 primary units including 10 subunits, an area of 2318 km^2 (895 mi^2), while the fixed-wing survey covered 10 units including 25 subunits, an area of 5773 km^2 (2229 mi^2) (Table 2). The fixed-wing survey took less time in both years (0.19 min/km^2; 0.5 min/mi^2) than the helicopter survey (0.30 min/km^2; 0.78 min/mi^2).

A total of 2,486 individual sheep were seen in 1990 and 3,518 individual sheep in 1991. The 1990 survey detected 348 separate groups and the 1991 survey detected 624 separate groups (Tables 3 and 4). The helicopter crew saw 15 more groups than the fixed-wing survey in double sampled units in 1990, and 89 more groups in 1991. However, the helicopter survey missed 21 groups seen by the fixed-wing survey in 1990 and 30 groups in 1991 indicating both surveys are subject to visibility bias. The logistic regression model used only the groups of sheep seen by the helicopter survey as the test set of groups of sheep known to be present in the survey area (75 in 1990 and 218 in 1991).

The relationship of sightability, group size, and substrate was evaluated by logistic regression (Fig. 2). Only group size had a significant affect on sightability in 1990 ($\underline{P}$ = 0.0009) and 1991 ($\underline{P}$ = 0.0039). The fixed-wing survey detected approximately 1 out of every 3 solitary sheep both years (35 % in 1990 and 38 % in 1991). As group size increased to 40 the probability of detection increased to approximately 90%.

The estimate for the average density of sheep for the study area in 1990, when counts are expanded without correction for visibility bias, was 0.64/km^2 (1.65/mi^2) (Table 5). This resulted in an estimate of 16,313 sheep. The jackknifed estimate, corrected for visibility bias in the fixed-wing survey, was 1.01/km^2 (2.62/mi^2). The jackknifed standard error of density was 0.12 with a CV = 11.8%. The approximate 95% confidence interval on the total number of sheep

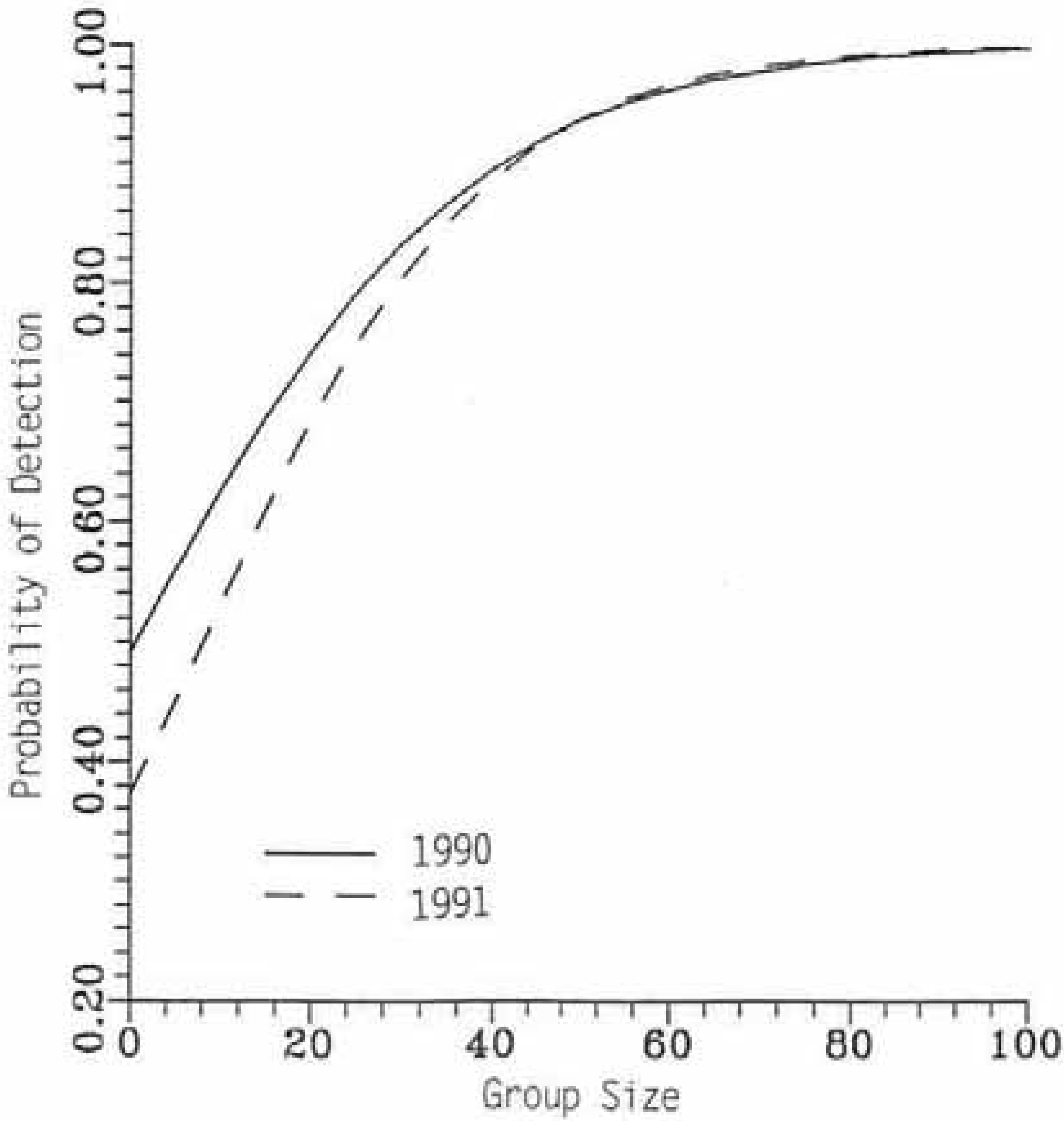

Fig. 2. Estimated probability of detection of Dall sheep for fixed-wing survey as a function of group size in Wrangell-St. Elias National Park and Preserve, 1990 and 1991.

Table 3. Number of Dall sheep counted by unit or subunit during fixed-wing and helicopter surveys at Wrangell-St.Elias National Park and Preserve, 1990.

Double sampling survey

Unit	Fixed-wing survey Sheep	Fixed-wing survey Groups	Helicopter survey Sheep	Helicopter survey Groups	Groups heli-copter missed	Groups fixed-wing missed
3D	220	24	276	33	6	15
7A	57	9	104	16	3	10
10E	11	2	26	1	2	1
11A	60	4	79	7	1	4
13D	167	8	127	7	3	2
14	134	13	124	11	6	4
Total	649	60	736	75	21	36

Complete fixed-wing survey

Unit	No. sheep 1990	No. groups 1990
3	571	76
7	523	66
10	147	15
11	219	12
13	355	28
14	149	19
16	185	18
27	75	14
31	16	3
Total	2240	251

was 25,972 ± 6,233 sheep (Table 6). The estimated density of sheep for the study area in 1991, when counts were expanded without correction for visibility bias, was 0.52/km^2 (1.347/mi^2) (Table 7). This resulted in an uncorrected estimate of 13,341 sheep. The jackknifed estimate of density, corrected for visibility bias in the fixed-wing survey, was 0.978/km^2 (2.533/mi^2) (SE = 0.46, CV = 18%). The approximate 95% confidence interval on the total number of sheep was 25,088 ± 10,598 sheep (Table 6).

A total of 10 subunits in 8 primary units and 1 entire primary unit was surveyed from a helicopter in 1991 compared to 5 subunits in 5 primary units and 1 entire unit in 1990 (Table 8). The 4 subunits and 1 primary unit surveyed both years provided some comparative data. Counts in 1991 exceeded 1990 counts in 2 subunits and the primary unit, but are lower than 1990 counts in 2 subunits. Both surveys provided complete coverage of the subunits and primary unit using similar techniques.

The range of estimated density of sheep in individual primary units in the high density stratum overlapped with estimates for units in the medium density stratum. Likewise, estimated density of sheep in individual primary units in the medium density stratum overlapped with estimates for units in the low density stratum (Table 9). During both years the density estimate for unit 11 in the high density stratum fell within the range of densities estimated for the medium density stratum. Units 11 and 12 in the high density stratum and 13, 15, and 16 in the medium density stratum are similar in vegetation and terrain. Additionally, the density estimated in 1991 for unit 10 in the medium density stratum was less than the estimated density in unit 27 within the low density stratum. Density estimates for units 10 and 27 were almost identical in 1990.

Table 4. Number of Dall sheep counted by unit or subunit during fixed-wing and helicopter surveys at Wrangell-St.Elias National Park and Preserve, 1991.

Double sampling survey	Fixed-wing survey		Helicopter survey			
Unit	Sheep	Groups	Sheep	Groups	Groups helicopter missed	Groups fixed-wing missed
3A	185	20	235	37	6	23
3D	140	30	234	50	4	24
7B	105	33	237	75	10	52
10E	19	5	34	6	0	1
11A	24	5	35	5	1	1
13D	151	13	162	17	2	6
16A	2	1	2	1	0	0
14	137	11	172	16	1	6
27BC	10	3	54	8	0	5
31C	27	8	16	3	6	1
Total	800	129	1181	218	30	119

Complete fixed-wing survey

Unit	No. sheep 1991	No. groups 1991
3	1354	213
6	352	83
7	437	93
10	47	18
11	130	18
13	277	29
14	137	12
16	161	19
27	73	12
31	27	8
Total	2995	505

This overlap in density of the 3 strata prompted us to investigate the potential effects of re-stratification of primary units (with a new stratified random sample in future years). Unit 10 was post-stratified into the low density stratum and units 11 and 12 were placed in the medium density stratum. Following post-stratification, the jackknifed estimate of density for 1991, corrected for visibility bias in the fixed-wing survey, was 1.08/km^2 (2.8/mi^2) (SE = 0.28, CV = 10%). The approximate 95% confidence interval on the total number of sheep was 27,796$\pm$ 6,448 (Table 10). Using the same post-stratification, the revised estimate of sheep using 1990 data was slightly higher (Table 10), but with a smaller variance (CV = 7%) than the original 1990 estimate (CV = 11.8%).

We examined the difference in counts of sheep within groups detected by both surveys in 1991 to find if a correction should be made for counting errors in the fixed-wing survey (Table 11). The fixed-wing survey counted 97% of the sheep counted by the helicopter survey suggesting counts by the fixed-wing survey slightly underestimated the number of sheep in a group (assuming counts from the helicopter were correct). However, we chose to be conservative and made no under-count correction to fixed-wing counts and raw data were used to correct for visibility bias.

Table 5. Estimated total number of Dall sheep by unit (uncorrected for visibility bias), estimated density by strata, and estimated stratified density in the Wrangell-St. Elias National Park and Preserve, July 1990.

Unit	% Area surveyed	Total km^2	No. sheep observed	Estimated total sheep	Density sheep/km^2
High density strata:					
3	21.11	202.15	571	2705	
7	47.17	999.99	523	1109	
11	100.00	337.54	219	219	
14	100.00	96.00	149	149	
Total		3435.68	1462	4182	1.22
Medium density strata:					
10	53.77	1199.53	147	273	
13	100.00	535.76	355	355	
16	100.00	513.33	185	185	
Total		2248.62	687	813	0.36
Low density strata:					
27	100.00	469.17	75	75	
31	100.00	1199.82	16	16	
Total		1668.99	91	91	0.05

Table 6. The estimated number of Dall sheep and density, corrected for visibility bias, by stratum in Wrangell-St.Elias National Park and Preserve, July 1990 and 1991

		1990		1991	
Density of strata	Area[b] km^2	Density[b] per km^2	No. sheep	Density[b] per km^2	No. sheep
High[a]	10758.52	2.03	21849	1.811	19484
Medium[a]	7834.01	0.52	4083	0.398	3117
Low[a]	7059.74	0.11	763	0.116	819
Total	25652.27	1.04	26695[b]	0.913	23420[b]
Jackknifed estimates		1.01	25972[c]	0.978	25088[c]
SE		0.119	3060	0.179	4596

[a] Standard errors are not available because the sample size in each stratum is too small to use the jackknife procedure.
[b] Corrected for visibility bias but not jackknifed.
[c] Corrected for visibility bias and mathematical bias by the jackknife procedure.

Sheep observed during the helicopter surveys were classified by sex and age as completely as possible in 1991 (Table 12). These data were not corrected for differences in visibility. Ewe groups likely contained yearling and 2-year-old rams that were not easily classified. Thus, we categorized sheep as either mature ram, ewe-like, or lamb (Table 12). The ratio of lambs to ewe-like was

.17, the ratio of young to all adults was .12, and the ratio of rams to ewe-like was .42.

Table 7. Estimated total number of Dall sheep by unit (uncorrected for visibility bias), estimated density by strata, and estimated stratified density in the Wrangell-St. Elias National Park and Preserve, July 1991.

Unit	% Area surveyed	Total km^2	No. sheep observed	Estimated total sheep	Density[a] sheep/km^2
High density strata:					
3	53.27	2002.15	1354	2542	
6	50.11	793.40	352	702	
7	51.46	999.99	437	849	
11	100.00	337.54	130	130	
14	100.00	96.00	137	137	
Total		4229.08	2410	4360	1.03
Medium density strata:					
10	53.77	1199.53	47	87	
13	100.00	535.76	277	277	
16	100.00	513.33	161	161	
Total		2248.62	485	525	0.23
Low density strata:					
27	100.00	469.17	73	73	
31	100.00	1199.82	27	27	
Total		1668.99	100	100	0.06

[a] Stratified average density: 0.52 sheep per km^2

Table 8. Comparison of the number of sheep observed by helicopter surveys in 1990 and 1991 at Wrangell-St. Elias National Park and Preserve.

Unit	No. sheep 1990	No. sheep 1991
3A	N.S.[a]	235
3D	276	234
7A	104	N.S.
7B	N.S.	237
10E	26	34
11A	79	35
13D	153	162
16A	N.S.	2
14	124	172
27BC	N.S.	54
31C	N.S.	16
TOTAL	762	1181

[a] N.S. = No survey conducted.

Table 9. Stratification analysis by unit for the 1990 and 1991 surveys at Wrangell-St. Elias National Park and Preserve.

Strata	Unit	No. sheep 1990	Corrected density per km²	No. sheep 1991	Corrected density per km²
High	3	571	1.93	1354	2.27
High	6	N.S.	N.S.	352	1.81
High	7	523	1.65	437	1.69
High	11	219	0.76	130	0.68
High	14	149	2.34	137	2.30
Medium	10	147	0.34	47	0.17
Medium	13	355	0.86	277	0.85
Medium	16	185	0.45	161	0.47
Low	27	75	0.26	73	0.14
Low	31	16	0.022	27	0.05

[a] N.S. = No survey conducted.

Table 10. Post stratified estimated number of Dall sheep and density, corrected for visibility bias, by stratum in Wrangell-St. Elias National Park and Preserve, July 1991.

Density of strata	Area[b] km²	1990		1991	
		Density[b] per km²	No. sheep	Density[b] per km²	No. sheep
High[a]	9810.65	1.858	18216	2.033	19950
Medium[a]	7582.35	0.687	5211	0.667	5047
Low[a]	8259.27	0.193	1598	0.138	1141
Total	25652.27	0.976	25025[b]	1.019	26138[b]
Jackknifed estimate		1.025	26286[c]	1.083	27792[c]
SE		0.0678	1740	0.1090	2796

[a] Standard errors are not available because the sample size in each stratum is too small to use the jackknife procedure.
[b] Corrected for visibility bias but not jackknifed.
[c] Corrected for visibility bias and mathematical bias by the jackknife procedure.

DISCUSSION

The most recent attempt at sample survey of sheep in the WRST was during the period 1981-1984. Singer and Mullen (1981) reported covering 17 1/2 (73%) of the count units in a helicopter survey in 1981. Singer (1982) reported the results of the 1981 surveys as well as surveys of additional areas in 1982, and Mullen and Cella (1984) reported surveys of 5 additional count units in 1983 and 1984. No estimate of survey time was provided for the first 2 survey years. The 1983 and 1984 surveys took slightly over 16 hours of survey time. The 1981 and 1982 surveys covered a much larger area than the 1983 and 1984 surveys and probably required more than twice the time. It appears our surveys in both years were more cost effective. Also, our surveys were safer than previous surveys if it is accepted that more flight time with an objective of counting all sheep increases risk.

Table 11. Analysis of possible bias by group size during the survey of Dall sheep at Wrangell-St. Elias National Park and Preserve, July 1991.

Group size	No. sheep fixed-wing	No. sheep helicopter	Ratio fixed to helicopter	No. groups
1 to 5	134	146	0.92	60
6 to 10	131	131	1.00	18
11 to 15	157	184	0.85	14
16 to 20	18	16	1.13	1
21 to 25	41	46	0.89	2
26 to 30	23	30	0.77	1
31 to 35	57	34	1.68	1
36 to 40	44	38	1.16	1
41 to 45	0	0	0	0
46 to 50	0	0	0	0
51 to 55	53	52	1.02	1
Total	658	677	0.97[a]	

[a] Ratio of totals.

Table 12. Herd composition data for Dall sheep from helicopter flights at Wrangell-St. Elias National Park and Preserve, July 1991.

Unit	Rams	Ewe-like	Lambs	Unclas-sified	Ram: ewe-like	Lamb: ewe-like
3	105	310	55	15	0.339	0.177
7	69	106	20	42	0.651	0.189
11	2	33	0	0	0.610	0
14	38	48	5	81	0.792	0.104
10	8	26	0	0	0.308	0
13	41	102	19	0	0.402	0.186
16	0	2	0	0	0	0
27	10	12	6	26	0.833	0.50
Total	276	650	107	147	0.425	0.165

It can be argued that cost effectiveness is a function both of cost and accuracy of results. Our results provide an estimate of sheep abundance with a measure of accuracy and precision. Sample surveys during the 1981-1984 period were an effort to count all sheep present. Over this 4 year period, 10,496 sheep were counted in 25 of the 29 primary count units in the WRST. Singer (1982) estimated sheep numbers in uncounted units in the Wrangell's portion of the area and corrected the total using a factor of 1.25 to account for missed sheep. Singer's "corrected" estimate was 15,723 sheep. This estimate is only slightly below our estimates of sheep without correction for visibility bias. No measure of accuracy or precision was provided by Singer.

Both the 1990 and 1991 surveys resulted in substantially higher estimates of sheep in the WRST than the previous surveys. However, the densities reported by Singer (1982) in some high density units exceeded our overall estimate of density in this stratum. Singer (Undated) reported densities of 1.08/km^2 (2.8/mi^2) in the Preserve portion of WRST and 0.656/km^2 (1.7/mi^2) in the Park portion. In a survey of Dall sheep at the northwestern limit of their range in the Brooks Range of Alaska, Singer, et al. (1983) reported densities as high as 0.71/km^2 (1.85/mi^2) with an average of 0.162/km^2 (0.42/mi^2). Densities in other Alaska populations as reported by Singer (Undated) ranged from a low of 0.154/km^2 (0.4/mi^2) in Noatak to 0.81/km^2 (2.1/mi^2) in the Gates of the Arctic National Park. Densities from both the 1990 and 1991 surveys of WRST after correction for visibility were well within this range.

The estimate of 25,088 total sheep in 1991 based on the original stratification is very close to the estimate of 25,972 sheep obtained in 1990. But, the precision of the 1991 estimate is less than the 1990 estimate. The precision of the estimates made in our survey was a product of the jackknifing procedure and was sensitive to the variation in estimates of sheep density among individual units in each stratum included in the survey sample. The Jackknife procedure calculated pseudo-values for sheep density by dropping 1 surveyed unit at a time and then estimating total sheep for WRST. Dropping a misclassified unit from the calculation of density for a particular stratum effected the density estimate for that stratum far more than dropping a properly classified unit.

The original stratification used in this study was based on an extensive aerial reconnaissance of WRST (Taylor et al. 1989). However, the existing grouping of units resulted in overlap in densities between high and medium density strata and medium and low density strata. This greatly contributed to the width of confidence intervals in 1990 and 1991. While the overlap was greater in 1991 the relationship was consistent for both the 1990 and 1991 surveys suggesting a problem in the initial stratification. Following post-stratification, the estimate of sheep in WRST increased for both areas and the precision improved. It is possible that estimates of sheep numbers with the smaller standard errors following post-stratification were a better representation of sheep numbers in WRST at the time of the surveys. However, it is likely that a new stratified random sample from the re-stratified units for future survey will yield more precise results than the 1990 or 1991 surveys.

The logistic regression indicated that group size was the only significant explanatory variable in determining sightability from the fixed-wing. The logistic regression with substrate variables indicated that tundra, dark rock, light rock, and mixed substrate lacked significant influence on sightability. McDonald et al. (1990) also found that group size was the only significant variable affecting the probability of detecting Dall sheep in ANWR. When the roles of the fixed-wing and helicopter aircraft were reversed in the analysis of our data, this same relationship existed, although the helicopter was better able to detect single sheep and small groups. This suggests the helicopter is a better vehicle for observing sheep and confirms the important influence of group size on detection probabilities. Each variable recorded during aerial surveys increases the difficulty of the survey. Future surveys of Dall sheep in similar habitat could ignore substrate as a potential influence on sightability.

During both years of survey the fixed-wing and helicopter crews counted approximately the same number of sheep in groups seen by both. While a slight upward adjustment of less than 3% could have been made to the fixed-wing counts, in the interest of a conservative estimate, no correction was made. In future surveys, this relationship should continue to be monitored since different observers, and changes in habitat and counting conditions may affect fixed-wing counts.

This study was not designed to evaluate the difference in sheep response to helicopter versus fixed-wing surveys. Nevertheless, no extraordinary avoidance behavior was noted during either survey in 1990 or in 1991. On 2 occasions during the 1990 helicopter survey, a large group of sheep seen in open flat terrain responded to the helicopter by grouping tightly together and running. However, these groups did not seek rough terrain or escape cover. There was some concern voiced by reviewers of the 1990 survey that the helicopter may disturb sheep and bias subsequent counts by the fixed-wing crew. To address this concern, 1991 helicopter flights occurred after fixed-wing flights in all double sample surveys. Disturbance of sheep was kept to a minimum in our surveys as neither survey flew close enough to obtain a complete classification of sex or age and repeated circling was avoided.

The design of our surveys did not provide accurate composition counts. But, the helicopter survey in 1991 attempted to classify all sheep as lamb, ewe-like, or ram. Identification of lambs in small groups of sheep was relatively easy while differentiating between yearling rams and ewes and classification of individuals in the larger groups of sheep was more difficult. Young rams and lambs were likely misclassified in the larger groups and some yearling rams were likely misclassified in all groups.

The ratio of rams to ewe-like in our study may be biased since classification of large ewe-lamb groups contained few yearling rams. The rams classified in the ewe-lamb groups contained some young rams, but we made no estimate of the bias associated with misclassifying rams in large groups. Nonetheless, our estimate of the ratio of rams to ewe-like was within the range of similar ratios recently reported for Dall sheep throughout Alaska (Singer et al. 1981, Singer et al. 1983, Ayres 1986, Heimer and Watson 1986, Ayres 1987, Taylor et al. 1987, Singer Undated). The 42 rams per 100 ewe-like in our study was identical with the ram:ewe ratio reported for WRST by Singer and Mullen (1981).

Singer (Undated) reported the proportion of lambs in the 1970's and 1980's within National Parks and Preserves in Alaska. Proportions ranged from 18% to 32% with WRST reported as 18% in the 1970's and 19% in the 1980's. Kellyhouse (Undated) surveyed a portion of WRST in 1981 and 1984 and reported 19% and 16% lambs, respectively. This is slightly higher than our estimate of 10% in 1991. The ratio of lambs to ewe-like in our sample was similar to the ratio reported by Garrett (1987) for Dall sheep in the Hulahula River and adjacent drainages of the ANWR, Alaska. However, the ratio in our study was lower than other lamb:ewe ratios recently reported for Dall sheep in Alaska (Singer et al. 1981, Singer et al. 1983, Ayres 1986, Heimer and Watson 1986, Ayres 1987, Taylor et al. 1987, Singer Undated). The ratio was much lower than the most recent lamb:ewe ratio reported for WRST (Singer and Mullen 1981). While likely an underestimate, the low ratio of lambs to ewe-like in our study and the declining lamb proportions reported by Kellyhouse (Undated) suggest the need for a survey designed to more accurately find the sex and age composition of Dall sheep in WRST.

RECOMMENDATIONS

1. Estimates of Dall sheep in the WRST from the 1990 and 1991 surveys are substantially higher than previous surveys and contain estimates of precision. Future surveys using the same methods would provide managers with a better measure of the trend in sheep numbers.

2. Future surveys using the double sampling strategy should attempt to increase the speed of the fixed-wing survey. This would allow more primary units to be surveyed and thus increase the confidence in expansions of density data to the entire area. Or, surveys of a fixed set of primary units could be done with less flying and thus result in a less costly and safer survey.

3. The 1991 survey attempted to classify sheep as to sex and age. Lamb:ewe ratios are minimum estimates due to the inclusion of young males as ewes. Future surveys combining helicopters with fixed-wing aircraft should include sex and age composition counts in the data collected by helicopter surveys. Classification of animals into age and sex categories should be done by a combination of observations from the helicopter and a sample of herds classified from the ground. Ground counts can be used to correct helicopter counts of young males and ewes. Observations from a fixed-wing aircraft should be used to expand estimates of abundance and age and sex ratios to the entire population based on double sampling procedures. A random survey would result in a less biased estimate of the ratios than provided by the more haphazard approach used in 1991.

4. Sex and age composition data are characteristics of populations. WRST is a large area containing several management units. If more than 1 population exists in WRST then classifications and population estimates should be made so they are relevant to individual populations.

5. Because the fixed-wing survey crew saw groups not seen by the helicopter crew, an alternative approach is suggested to population estimation when composition counts are considered unnecessary. A sample survey could employ 2 fixed-wing crews which could calibrate each other (i.e., develop sightability correction factors) by flying the same units prior to flying additional separate units. This method should be evaluated in the WRST or a similar area.

6. Planning for future surveys should attempt to reduce time lost in ferrying between fueling locations, the base of operations, and survey units.

7. The survey depends on the accurate location of sheep groups by fixed-wing and helicopter survey crews. Global Positioning System technology should be investigated for use in locating sheep groups by both surveys.

8. Some subunits in our surveys were too large for the helicopter survey and some boundaries were difficult to follow. Boundaries of all subunits should be evaluated before future surveys. Past sheep observations should be used to evaluate existing boundaries.

9. The 2-staged sampling plan used in 1990 and 1991 was necessitated by the NPS's desire to survey sheep within the existing sampling units. The variance of the jackknifed estimate of sheep density should decrease if more smaller units are used. An alternative to the present sampling strategy is to subdivide all primary units so that subunits are approximately the same size. A stratified random or systematic sample could then be taken of the subunits, treating them as primary units.

10. WRST should be re-stratified using the existing or smaller survey units. A few units appear misclassified in the original stratification based on both 1990 and 1991 survey results. Most of the subunits should be placed in the same stratum as the original primary unit. However, there may be enough variability in some of the larger units to warrant a change in the stratum for some smaller units. The original stratification was based on

an aerial stratification survey. Ideally, stratification surveys should be completed immediately prior to sample surveys. However, logistics and cost constraints may prevent stratification surveys prior to each sample survey. An alternative approach is to use the data from the 1990 and 1991 surveys along with data on habitat, precipitation, harvest, etc., and re-stratify without stratification surveys.

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