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ALASKA DEPARTMENT OF FISH AND GAME

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REFINEMENT OF THE AERIAL PHOTO-DIRECT COUNT-EXTRAPOLATION CARIBOU CENSUS TECHNIQUE

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State: Alaska

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SUMMARY

Four assumptions are implicit in the Aerial Photo-Direct Count-Extrapolation (APDCE) caribou census technique: 1) all of the adult females present in the herd are present in post-calving aggregations, 2) the adult females are randomly distributed throughout the post-calving aggregations, 3) the age and sex cohorts are randomly distributed throughout the herd during fall and 4) mortality of adult females from the time of the post-calving aggregation in midsummer to the time of the composition count in fall is zero. We tested the first three of these assumptions using the 1978 APDCE census of the Western Arctic Caribou Herd (WAH), and found assumptions 1 and 2 to be true. Variability of the fall composition counts led to extremely wide confidence intervals for all segments of the population. Obtaining accurate fall composition data is difficult and remains a major problem with the technique. It may be more accurate and economical to conduct a thorough, range-wide sampling scheme during the photocensus than to conduct and rely on traditional composition surveys during the rut.

We also investigated the accuracy of photo interpretation by having a second observer recount selected photographs. Counts of caribou from the same photograph by the two observers varied between 0 and 34 percent from the high to the low, but the difference between the first and second counts for all photographs was only 4.6 percent. This problem may be more serious than previously believed, and we recommend that it be considered by others using the APDCE technique.

A probable minimum of 93,931 and a maximum of 102,500 caribou were counted on the aerial photographs. The areas surveyed by transect and quadrat methods contained an extrapolated total of 8,333 additional caribou. Calculations of population size using the traditional APDCE census resulted in an estimate of 106,635 for the WAH population in July 1978. The July population size calculated from a visual census of cows on the calving ground was 93,802.

CONTENTS

BACKGROUND

Since studies of North American caribou (*Rangifer tarandus*) began, investigators have been developing and improving censusing procedures. Perhaps the first major achievement came in the late 1940's when aircraft were first utilized (Scott et al. 1950, Banfield 1954). A multitude of different aerial censusing procedures for wildlife have evolved and Parker (1972) has classified these into six general categories: 1) linear strip transect survey, 2) stratified random sampling survey, 3) total count census, 4) aerial photography, 5) infra-red and heat-sensitive photography and 6) habitat sampling survey. Techniques representative of these categories have been applied to caribou with variable success. No single census technique has proven perfect because the problems encountered are many and varied, and these problems frequently apply only to specific herds and situations.

The recent trend among Alaskan caribou biologists has been toward reliance on aerial photography techniques. Lent (1966) utilized aerial photography of post-calving groups in 1961 as a basis to census the Western Arctic Caribou Herd (WAH). Hemming and Glenn (1968) developed an "Aerial Photo-Direct Count-Extrapolation" (APDCE) technique in the late 1960's, and first used it successfully on the Nelchina Herd in 1967. Hemming refined and tested the technique on the WAH in 1970 (Pegau and Hemming 1972). Since then the APDCE or modifications of this technique have been used with variable success on several Alaskan caribou populations (Bos 1973, 1975; McIlroy 1975; LeResche 1975; Irvine 1976; Bente and Roseneau 1978; Davis and Valkenburg 1978; Davis et al. 1978; ADF&G files).

Because of increasing reliance upon the APDCE technique for censusing caribou and the identification of apparent shortcomings in the technique (Bente and Roseneau 1978; Doerr 1979; S. Harbo, pers. comm.), we held a

1-day workshop to discuss it. The meeting was held in Fairbanks in early 1978 and was attended by most people who have used or are using the APDCE technique (see Appendix I for list of attendees). The consensus of the meeting attendees was that, as presently used, the technique has significant shortcomings. Although most workers in the past concluded that the technique produced a valid minimum population estimate, it was emphasized that this was not necessarily true and either over- or under-estimation can occur.

The discussion identified four major assumptions implicit in the technique, as follow: 1) all adult females in the herd are counted in the post-calving aggregations, 2) adult females are randomly distributed throughout the post-calving aggregations, 3) age and sex cohorts are randomly distributed throughout the herd during fall and 4) mortality of adult females from the time of the post-calving aggregation in midsummer to the time of the composition count in fall is zero. Participants at the workshop agreed that the first three assumptions may contribute to considerable error in population estimates, and that improvements in the technique may be possible. Although supportive data are not available, it was agreed that the fourth assumption was probably not contributing appreciably to error.

We have encountered serious logistics problems in photocensusing the large Arctic herds (i.e. the WAH and Porcupine Herd) in the past. Many of these problems were directly or indirectly associated with the photo planes used. These planes were contracted from private industry or furnished by the Bureau of Land Management (BLM) on cooperative census efforts and all have been light, twin-engine models. Often they could not land at unimproved, but strategically located, airfields where the census operations were based, where fuel was closest and where all census efforts could be coordinated. Also, prohibitively expensive standby rates have prevented us from having these aircraft present while awaiting optimal photo conditions. On several occasions when optimum light conditions and caribou aggregations were present, poor communication prevented us from contacting the photo plane at another airport. Ready availability of a suitable aerial camera in a high-wing "bush" type aircraft throughout the census is requisite to relying on the APDCE technique for censusing many Alaska caribou herds.

OBJECTIVES

To test the validity of assumptions implicit in the APDCE caribou census technique; to identify sources of error inherent in the technique and, where possible, to calculate the confidence interval of each sample.

To refine the APDCE caribou census technique; to provide greater accuracy and precision in population estimates.

PROCEDURES

The objectives were addressed by conducting a modified APDCE census of the WAH during 1978. We modified slightly the basic APDCE technique procedure that Hemming and Glenn (1968) first described and

LeResche (1975) and Bente and Roseneau (1978) further discussed. The basic technique includes precensus reconnaissance, aerial photography of post-calving aggregations (and enumeration or estimation of peripheral animals), classification of animals in the post-calving concentration and classification of animals during rut. From these data a final estimate of caribou numbers is calculated.

Precensus Reconnaissance

This reconnaissance occurred in two phases. We conducted a calving ground census in mid-June which also served as a precensus reconnaissance. Further, occasional reconnaissance flights from Driftwood airstrip field camp during late June preceded the field work for the APDCE census which began on 4 July 1978. Using two Piper Super Cubs, a Bellanca Scout, a Piper Super Cruiser (PA-12) and a DeHavilland Beaver, we thoroughly searched a large area of the northern foothills of the western Brooks Range likely to contain post-calving aggregations. From 4 through 6 July about 25 hours of reconnaissance flights were flown.

Aerial Photography

On 6 July the caribou were suitably aggregated and photography began. Two of the fixed-wing aircraft directed the camera-equipped Beaver to nine groups of caribou which were photographed with a Fairchild T-11 9x9-inch aerial camera (courtesy of Naval Arctic Research Laboratory, Barrow, Alaska). One additional group was photographed with a hand-held 35-mm camera; another small group, not photographed, was counted directly from a Super Cub.

Analysis and counting of the 304 black and white 9x9-inch aerial photographs and the 20, 35-mm color slides began 5 September and took approximately 3 weeks to complete. An additional 2 weeks were spent cross checking the aerial photographs and calculating estimates of herd size. Scale of the 9x9-inch photographs ranged from 1:3000 to 1:6000, and all photographs were of adequate quality to permit counting. Counting was done by group; all the photographs of a group were laid out on a flat surface, and overlap lines were drawn on the transects that were used for counting. Only about two-thirds of the photographs were actually counted because sidelap was extensive, and because many photographs at the end of the transect runs contained no caribou. After all photographs were counted once, a sample was selected from each group and recounted by a second observer. The second observer also rechecked the overlap lines on photographs and checked for caribou that had moved from one transect to another during the photo runs. The 35-mm color slides were projected onto white paper on which a 3.0-inch grid had been drawn. Caribou within squares of the grid were individually counted, and, if the density of caribou in each square were high, a 0.4-inch grid of clear acetate plastic was taped to the larger grid to aid in counting.

Estimation of Caribou Not Present in Post-Calving Aggregations

We attempted to determine the number of adult females in the herd that were not in the post-calving aggregations (i.e. test assumption 1,

see Background) by sampling the entire range of the herd (see Davis and Valkenburg 1978). This would improve the accuracy of the census by providing an estimate of the number of caribou (particularly adult females) outside the post-calving aggregations.

In order to make this determination, we divided the Arctic Coastal Plain north of 69°30'N into 46,800 transect lines, each being 1 second of longitude, and used a random number table to select 15 of these for sampling. These 15 transects (Fig. 1) were flown between 3 and 15 July, and all caribou within a half mile on either side of the aircraft were counted and classified by age and sex from the aircraft (see Davis and Valkenburg 1978 for additional detail). We assumed a 100 percent sightability of caribou in the transects.

The area south of 69°30'N was divided into quadrats, each being 1 degree of longitude by 30 minutes of latitude (Fig. 1). The size of each quadrat varied slightly (922 mi^2 to 1,044 mi^2) because lines of longitude converge toward the poles. This created 122 possible quadrats which we subdivided into two strata. The northern stratum (Brooks Range North) was considered more likely to have female caribou and was therefore sampled more intensively. Seven of 41 possible Brooks Range North quadrats were selected for sampling. Of the remaining 81 possible quadrats in the southern stratum (Brooks Range South), 6 were selected for sampling. Most quadrats were searched by observers in fixed-wing aircraft between 3 and 15 July, but one quadrat in the southern stratum was not searched until 4 August and another was not searched until 20 August because of poor weather and logistical problems. We assumed that little movement to or from the areas occurred during July and August. The variance and confidence limits of the estimate of caribou numbers within the transects and quadrats were calculated using standard statistical procedures (Student's-t distribution) and assuming 100 percent sightability of caribou present.

Sex and Age Composition of Caribou in Post-Calving Aggregations

We conducted composition counts of each group as soon as practical after photography to test assumption 2 (see Background) and to ascertain the variance of sex and age composition within and among post-calving groups. All counts were done from the ground using spotting scopes and a helicopter was used to place observers in strategic positions in front of moving caribou. These counts were conducted on 6 and 7 July. We summarized and recorded the data from each group at 10-minute intervals. Within- and among-group means and variance were then calculated.

Sex and Age Composition during Rut

We conducted fall composition counts from 12 to 20 October. All counts were done from a helicopter because caribou were aggregated in small groups. For the first time, we obtained composition counts from groups north of the Brooks Range. To test assumption 3 (see Background) and to determine the variance of sex and age composition within and among rutting assemblages, we sampled the composition of each major rutting assemblage which was located, and recorded the data at 10-minute intervals.

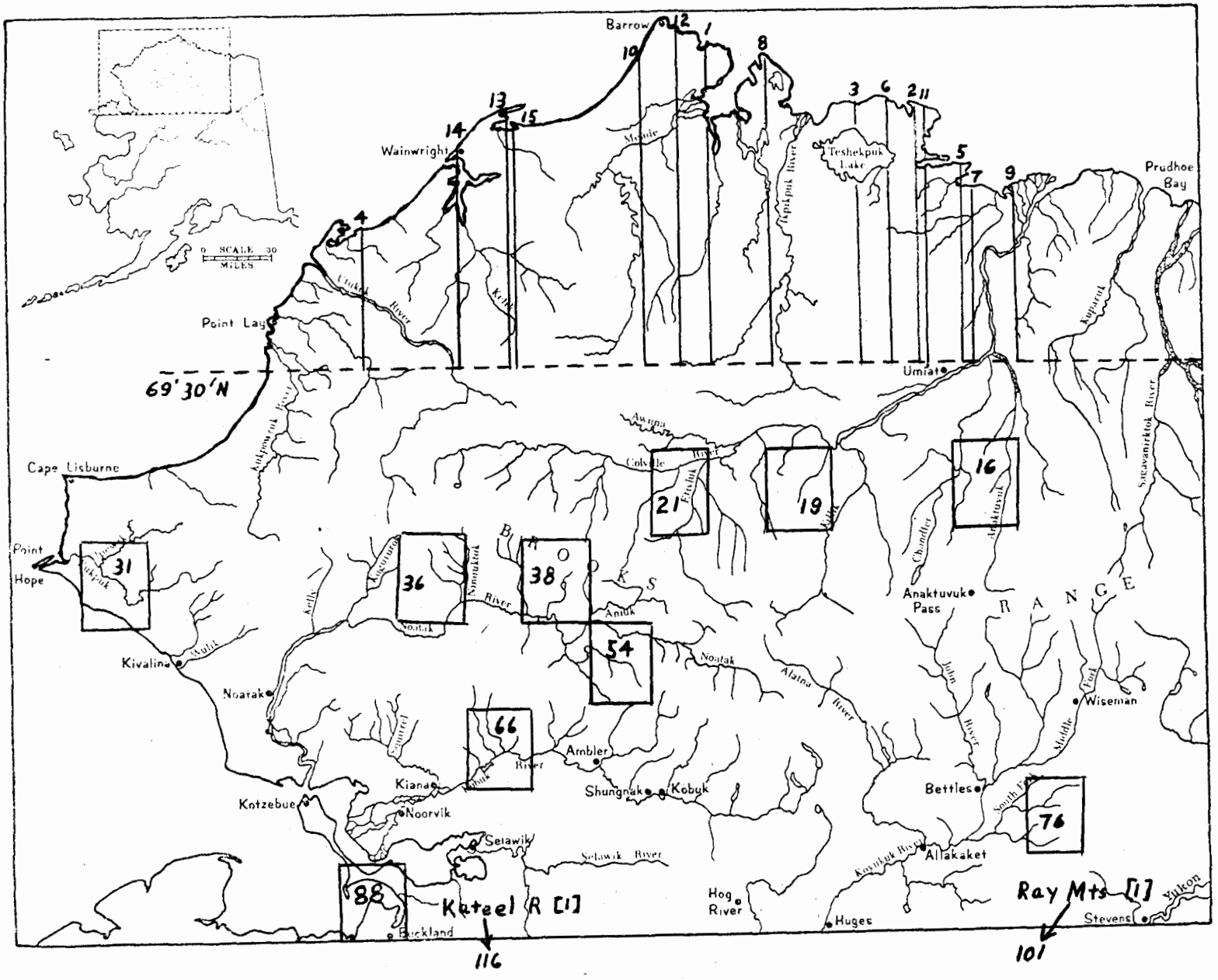

Figure 1. Location of transects and quadrats flown during July 1978 to determine the number of WAH caribou not present in post-calving aggregations.

RESULTS

Photocensus

During the reconnaissance conducted on 5 through 7 July, 11 post-calving groups were located and 10 of these were photographed. Locations and results of the analysis and counting of these groups are presented in Table 1.

We recounted selected photographs to determine the precision of the photo analysis (Table 2). Although the difference in the number of caribou counted on each photograph by the two observers varied between 0.0 and 24.1 percent from the high to low count, the overall difference between the first and second count totals was 4.6 percent (30,780 vs. 32,169). Time limitations precluded repeated counts which could have been used to calculate variance and confidence limits.

Differences in counts between observers on sample photographs (see Table 2) within each group were used to generate high and low estimates of group size (Table 3). The low estimate was also the complete count in seven of the nine groups in which recounting was done. This occurred because extrapolations from recounts lowered the estimated number of caribou in only two groups and raised the number in seven groups. The extrapolated total of 99,329 compares to the actual (i.e. first observer's) total count of 95,656. The arithmetic mean of the two is 97,492.5.

Composition Counts

Results of the July composition counts are presented in Tables 4 and 5. Percent cows in the herd was consistently the least variable statistic both within and among groups. There was no significant difference ($P > .05$) in percent cows among the three groups, and the within-group standard error of the mean ranged from 3.72 to 1.09. Further analysis of these composition counts is in progress and will be reported upon further in a manuscript for publication.

Fall composition counts were analyzed in much the same way as the July counts (Tables 6 and 7). Both the within- and among-group variance of the ratio of bulls, yearlings and calves per 100 cows in fall composition were rather large. Also, according to the counts, the numbers of bulls, yearlings and calves, respectively, per 100 cows on the Arctic Slope were much lower than on the south side of the Brooks Range. The significance of these differences is unknown because of the variability of the sample. Further analysis of these results is in progress.

Results of the transect and quadrat sampling are presented in Tables 8 and 9. We calculated that 1,996 cows were present outside the post-calving aggregations or about 5 percent of the total cows in the range of the WAH. The majority of these cows were found on the Arctic Coastal Plain, including the Teshekpuk Lake area. Although they are within the range of the WAH, most caribou in the vicinity of Teshekpuk Lake appear to be sedentary and probably comprise a discrete herd (Davis and Valkenburg 1978). If cows counted on all transects within the probable range of the Teshekpuk Lake were not considered to be members of the

Table 1. Summary of information gathered from post-calving groups photographed during the 1978 WAH APDCE census.

Caribou Group No.	Location	Scale of Photographs	Readability of Photographs	Caribou Counted on Photos	Remarks
1	Noluck Lake	1:4000	good	21,295	
2	Upper Colville River	1:4400	fair	8,699	steep slopes, dense clumps
3	Kidney Creek	1:4400	poor	9,645	steep slopes, dense clumps
4	E. Fork Kidney Creek	1:6000	poor	1,452	small scale, dense clumps, poor light
5	Upper Driftwood Creek	1:6000	very poor	4,777	small scale, dense clumps, poor light
6	Upper Kukpowruk River	1:3000	good	3,560	
7	Upper Iligluruk Creek	1:3500	good	2,316	
8	Nilik Creek	1:4000	good	10,570	
9	Lisburne Hills	1:4000	good	25,309	
10	Elbow Creek	variable[1]	very poor	7,533	difficult to delineate overlap
11	Mount Kelly	visually enumerated		500	
			Total	95,656	

[1] 35-mm photographs

Table 2. Results of counts and recounts of individual aerial photographs of WAH aggregations, July 1978.

Caribou Group Number	Photograph Number	Initial Count (Valkenburg)	Recount (O'Connor)	Percent Difference from High to Low
1	17-20	0	--	
	21	434	--	
	22	1469	--	
	23	112	--	
	24	189	214	11.7
	25	121	--	
	26	35	--	
	27-32	0	--	
	Transect 1 Total	2360		
	33	0	--	
	34	610	--	
	35	1468	--	
	36	1952	2204	11.4
	37	2824	--	
	38	1419	--	
	39	832	--	
	40-43	0	--	
	Transect 2 Total	9105		
	40-46	0	--	
	47	975	953	2.3
	48	402	--	
	49	283	--	
	50-54	0	--	
	Transect 3 Total	1660		
	60-62	0	--	
	63	1154	1173	1.6
	64	2351	--	
	65	1545	--	
	66	507	--	
	67	274	333	17.7
	68-71	0	--	
	72	1233	--	
	73	1106	--	
	Transect 4 Total	8170		
2	83-87	0	--	
	88	1	--	
	89	0	--	
	90	1383	1222	11.6
	91	1152	--	
	92	1071	989	7.7

Table 2. Continued.

Caribou Group Number	Photograph Number	Initial Count (Valkenburg)	Recount (O'Connor)	Percent Difference from High to Low
2	93	242	--	
	94-97	0	--	
	98	1211	1596	24.1
	99	921	--	
	100	1341	1538	12.8
	101	477	508	6.1
	102	61	--	
	103-105	0	--	
	106	3	--	
	107	461	413	10.4
	108	94	--	
	109	38	--	
	110	149	--	
	111-116	0	--	
	117	94	--	
	118	0	--	
3	119	12	--	
	120-121	0	--	
	122	12	--	
	123	9	--	
	124	0	--	
	125	641	--	
	126	417	--	
	127	137	--	
	128	55	55	0.0
	129-132	0	--	
	133	17	--	
	134	69	--	
	135	132	--	
	136	113	108	4.4
	137	13	--	
	138	0	--	
	139	73	--	
	140	721	--	
	141	616	653	5.7
	142	384	--	
	143	181	--	
	144-151	0	--	
	152	11	--	
	153-155	0	--	
	156	16	--	
	157	22	22	0.0

Table 2. Continued.

Caribou Group Number	Photograph Number	Initial Count (Valkenburg)	Recount (O'Connor)	Percent Difference from High to Low
3	158	10	--	
	159-163	0	--	
	164	50	--	
	165-169	0	--	
	170	5934	6333	6.3
	171	0	--	
4	172-179	0	--	
	180	228	202	11.4
	181	9	--	
	182-185	0	--	
	186	141	--	
	187	362	373	2.9
	188-191	0	--	
	192	107	--	
	193	352	--	
	194	253	--	
	195	0	--	
5*	All odd-numbered photos were not counted, except for 197.			
	197	1228	1253	2.0
	198	681	--	
	200	552	--	
	202	732	--	
	204	743	815	8.8
	206	165	--	
	208	333	--	
	210	9	--	
	212-214	0	--	
	216	13	13	0.0
	218	321	--	
6	223-229	0	--	
	230	2095	2413	13.2
	231	1462	--	
	232	3	--	
7	233-234	0	--	
	235b	1907	2107	9.5
	235 Total	2316	--	
	236-240	0	--	

* Overlap of photo coverage was excessive, so all caribou appeared on the photos listed.

Table 2. Continued.

Caribou Group Number	Photograph Number	Initial Count (Valkenburg)	Recount (O'Connor)	Percent Difference from High to Low
8	2-4	0	--	
	5	2137	1671	21.8
	6	1060	--	
	7	0	--	
	8	2848	--	
	9	2976	--	
	10	953	--	
	11b	478	445	6.9
	11 Total	529	--	
	12	15	--	
	13	0	--	
	14-24	52	--	
9	29	84	--	
	30	1720	--	
	31	768	752	2.1
	32	1157	--	
	33	2378	--	
	34	745	720	3.4
	35	2238	--	
	36	481	--	
	37-39	0	--	
	40	23	--	
	41	173	--	
	42	541	--	
	43	920	--	
	44	1501	1765	15.0
	45	893	--	
	46	2580	--	
	47	781	--	
	48-50	0	--	
	51	798	--	
	52	1347	1326	1.6
	53-57	1155	--	
10 (35 mm)	4	986	--	
	8	517	--	
	10	598	--	
	12	265	--	
	13-14	1019	--	
	18-20	2954	--	
	23-24	256	--	
	25-26	50	--	
	28	50	--	
	29	200	--	
	30-31	500	--	

Table 3. Extrapolated number of caribou on census photos from 1978 WAH APDCE census.

Caribou Group No.[a]	Total Caribou Counted on Photos (Observer #1)	Total Caribou Extrapolated to be on Photos from Partial Recount of Photos (Observer #2)	Average No. Caribou Extrapolated from #1 and 2
1	21,295	24,426	22,860.5
2	8,699	9,170	8,934.5
3	9,645	10,252	9,948.5
4	1,452[b]	1,408[b]	1,430.0
5	4,777	5,011	4,894.0
6	3,560	4,100	3,830.0
7	2,316	2,559	2,437.5
8	10,570[b]	8,389[b]	9,479.5
9	25,309	26,481	25,895.0
10	7,533	7,533	7,533.0
Subtotal	95,156	99,329	97,242.5
11 (visual count)	500	500	500.0
Total	95,656	99,829	97,742.5

[a] See Table 1 for group identity.
[b] If these values are transposed, then a high and low photo count value can be calculated to be 102,500 and 93,931.

Table 4. Results of composition counts of post-calving aggregations of the WAH, 6-7 July 1978.

Date and Location	Total Bulls per 100 Cows	Yrlgs per 100 Cows	Calves per 100 Cows	Yrlg % in Herd	(Total Yrlg)	Calf % in Herd	(Total Calves)	Cow % in Herd	(Total Cows)	Bull % in Herd	(Total Bulls)	Sample Size
6 July 1978:												
Ipewik River	20.0	21.7	66.4	10.4	(542)	31.9	(1656)	48.0	(2494)	9.6	(500)	5192
Lisburne Hills	37.8	14.4	60.8	6.8	(100)	28.6	(422)	47.0	(694)	17.7	(262)	1478
7 July 1978:												
Anisak River	63.0	23.9	54.0	9.9	(660)	22.4	(1490)	41.5	(2760)	26.2	(1740)	6650
Chert Chip Creek	26.6	9.3	69.1	4.5	(333)	33.7	(2486)	48.8	(3596)	13.0	(955)	7370
Weighted Mean:	36.2	17.1	63.4	7.9	(1635)	29.3	(6054)	46.1	(9544)	16.7	(3547)	20,690

Table 5. Analysis of post-calving group composition of the WAH in 1978 by 10-minute interval.

	Bulls	Calves	Yearlings	Cows	Total
Anisak River, Chert Chip Creek:					
Sample Size	2695	3976	993	6356	14,020
Weighted Mean	42.4/100C	62.3/100C	15.6/100C	45.3(%)	
Standard Error of Mean ($\frac{s}{\sqrt{n}}$)	12.40	2.99	2.71	1.09	
Number of 10-Minute Intervals (n) = 40					
Nilik Creek:					
Sample Size	500	1656	542	2494	5.192
Weighted Mean	20.0/100C	66.4/100C	21.7/100C	48.0(%)	
Standard Error of Mean ($\frac{s}{\sqrt{n}}$)	2.90	4.53	4.77	1.91	
n = 26					
Lisburne Hills:					
Sample Size	262	422	100	699	1,478
Weighted Mean	37.8/100C	60.8/100C	14.4/100C	47.0(%)	
Standard Error of Mean ($\frac{s}{\sqrt{n}}$)	8.21	7.18	2.63	3.72	
n = 13					

Table 6. Results of fall composition counts of the WAH, 1978.

Date	Total Bulls per 100 Cows	Yrlgs per 100 Cows	Calves per 100 Cows	Yrlg % in Herd	(Total Yrlgs)	Calves % in Herd	(Total Calves)	Cows % in Herd	(Total Cows)	Bulls % in Herd	(Total Bulls)	Sample Size
10/14/78[a]	230	85	45	18	(17)	10	(9)	22	(20)	50	(46)	92
10/15/78[b]	43	13	38	7	(34)	20	(103)	52	(270)	22	(116)	523
10/15/78[b]	60	20	55	8	(74)	23	(205)	43	(373)	25	(222)	874
10/16/78[b]	21	16	43	9	(19)	24	(51)	55	(118)	12	(25)	213
10/17/78[b]	16	11	25	7	(79)	17	(175)	66	(694)	10	(110)	1058
10/19/78[c]	118	59	74	17	(147)	21	(185)	29	(251)	34	(297)	880
10/19/78[d]	53	37	67	14	(11)	26	(20)	39	(30)	21	(16)	77
10/20/78[e]	56	27	64	11	(209)	26	(492)	41	(772)	23	(430)	1903
Herd Mean	47.6[f]	20.6[f]	47.7[f]									

[a] Representative of 1,500 caribou south of the Colville River, between the Killik River and Gunsight Mountain.
[b] Representative of about 50,000 caribou (rough guess) wintering north of the Brooks Range. Mean, weighted by sample size, was used to calculate the herd mean.
[c] Representative of about 2,000 caribou in the Squirrel River valley.
[d] Representative of about 1,000 caribou in lower Salmon and Hunt River valleys.
[e] Representative of about 30,000 caribou (rough guess) in the Selawik Flats.
[f] These numbers are calculated by weighting the composition counts for a particular area by the number of caribou thought to be in the area.

Table 7. Analysis of fall composition counts of the WAH in 1978 by 10-minute interval.

Area	Sample Size	Number of 10-Minute Intervals	Bulls/100 Cows (s.e.)[a]	Yrlgs/100 Cows (s.e.)[a]	Calves/100 Cows (s.e.)[a]
South of Colville River	92	5	230 (53.0)	84 (87.3)	45 (12.8)
North of Umiat	874	19	60 (27.7)	20 (10.0)	55 (7.3)
Upper Colville River	213	5	21 (5.8)	16 (4.2)	43 (7.8)
Wainwright	1058	10	16 (2.2)	11 (2.9)	25 (2.0)
Total (North Slope)	2237	39	42.8[a]	18.0[a]	39.3[a]
Selawik area	1903	11	56 (4.6)	27 (1.2)	64 (1.5)
Squirrel River	880	5	118 (6.6)	59 (5.7)	74 (4.4)
Salmon River	77	2	53 (8.8)	37 (5.5)	67 (4.4)
Total (South Slope)	2860	18	74.0[a]	37.1[a]	67.2[a]

[a] These figures are weighted by sample size.

Table 8. Results of transect and quadrat surveys of the range of the WAH, July 1978.

Area	No. Transects or Quadrats	No. Cows Seen	No. Caribou Seen	Extrapolated Area Total (cows)(80%C.I.)	Extrapolated Area Total (Total caribou)(80%C.I.)	No. Mi^2 Surveyed	No. Mi^2 in Survey Area
Arctic Coastal Plain	15 transects	95	389	1810±1502	7413±3513	1312	25,000
North Brooks Range	7 quadrats	13	120	73±67	675±843	6542	36,825
South Brooks Range	6 quadrats	6	19	77±101	245±547	5965	77,042

Table 9. Density of caribou on transect lines and quadrats determined during distribution surveys of the WAH in 1978.

Survey Date and Area	Transect Line or Sector Number[a]	Caribou/mi^2
7-11 July 1978		
Arctic Coastal Plain - Transects	1	0.0085[b]
	2	0.5521
	3	0.2308
	4	1.9623
	5	0.0270
	6	0.3889
	7	0.0615
	8	0.2703
	9	0.1094
	10	0.1356
	11	0.9556
	12	0.0880
	13	0.2308
	14	0.0588
	15	0.0449
	Ave	0.2965 ± 0.1414[c]
5 July-9 August 1978		
Brooks Range North - Quadrats	16	0.0152
	19	0.0022
	21	0.0933
	31	0.0064
	36	0.0000
	38	0.0128
	Ave	0.0183 ± 0.229[c]
Brooks Range South - Quadrats	54	0.0000
	66	0.0000
	76	0.0053
	88	0.0000
	101	0.0137
	115	0.0000
	Ave	0.0032 ± 0.0071[c]

[a] Refer to Figure 1, in text.
[b] These figures are carried to four places to preclude listing zero caribou/mi^2 where some were observed.
[c] All figures for the 80% confidence level.

WAH, then more than 95 percent of the cows were present in post-calving aggregations.

Several population estimates of the WAH for 1978 are shown in Table 10. Three different methods (two of which are independent) were used to calculate population size. One estimate is based on a calving ground census and the other two are from photo counts of the post-calving aggregations. The high photo count and high APDCE estimates were derived by using the highest count from the photographs (Table 3). Likewise, the low counts were derived by using the low count from the photographs. The high and low APDCE estimates also include the high and low estimates, respectively, of percent cows determined from the July composition surveys. The "most probable" estimate was calculated from the unextrapolated count of photographs and the mean percent cows from the July composition count. Due to the variability of the fall composition counts, no attempt was made to generate estimates incorporating this variability. Rather, we assumed that the weighted mean composition was representative of the population.

DISCUSSION AND RECOMMENDATIONS

In past discussions of the APDCE technique (see Background), researchers have assumed either that there was no error involved in counting the photographs or that the error was minimal. Our preliminary results show that potentially serious differences between counts by different individuals exist. Differences in counts did not appear to be related to the scale of the photographs, but were correlated with a subjective evaluation of the readability of the photograph. Readability involved several variables, including density of the caribou, topographic relief, speed of movement of the animals and clarity of the photographs. Because we do not know the actual number of caribou on the photographs, it is difficult to draw conclusions about the differences between counts by different observers and the accuracy of the counting. Variability between repeat counts made by the same and independent observers may give some quantitative indication of the quality of the photographs, and therefore the reliability of a particular census. We recommend that this problem be considered by others using the APDCE technique.

Our preliminary attempts to attach confidence limits to fall composition counts yield confidence intervals that are too wide to be useful. Variability of the fall composition counts therefore remains a major problem.

We recommend that sampling from a herd's entire range be an integral part of any APDCE census. This will serve as a quantitative reconnaissance and will make estimates more accurate and add confidence to estimates of herd size. Although this sampling is time consuming and expensive, it may reduce the amount of necessary pre-photography reconnaissance and allow omission of expensive rut composition surveys.

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Table 10. Population estimates for the WAH, July 1978.[a]

Basis for Estimate	High Estimate	Most Probable Estimate	Low Estimate
Count of photos and extrapolated number from transects and quadrats	115,647[b]	104,950[c]	99,491[d]
APDCE	126,167[e]	106,635[f]	95,267[g]
Census of calving ground		93,802[h]	

[a] These estimates must be reduced to exclude Teshekpuk Lake Herd caribou and to allow for calf loss to October to allow direct comparison with past estimates of herd size.
[b] Based on high photo count and high estimates from transects and quadrats.
[c] Based on actual photo count (i.e. excludes extrapolation) and mid-point of 80% C.I. for transects and quadrats.
[d] Based on low photo count and low estimates from transects and quadrats.
[e] Same assumptions as footnote 2 and high estimate of cows in July composition and mean fall composition.
[f] Same assumptions as footnote 3 and mean July and fall composition values.
[g] Same assumptions as footnote 4 and low estimate of cows in July composition and mean fall composition.
[h] Based on best estimate of adult females on the calving ground and mean fall composition used for extrapolation.

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J. Rood, J. P. Jacobson and C. Lofstedt unbegrudgingly flew long and irregular hours as survey pilots and Maxson Aviation provided efficient logistics support.

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Appendix I. Attendees of a workshop to discuss the APDCE caribou census technique held in Fairbanks, 1978.

Name	Affiliation
P. Bente	Renewable Resources Consulting Services, Ltd.
G. Bos	Alaska Department of Fish and Game
R. Cameron	Alaska Department of Fish and Game
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P. Valkenburg	Alaska Department of Fish and Game
K. Whitten	Alaska Department of Fish and Game