CARIBOU PROJECT SUMMARY AND REVIEW: February 1990

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GENERAL INTRODUCTION

In the fall of 1988 most caribou herds in the NWT were large and healthy (Williams and Heard 1986, Heard and Jackson 1989, Heard et al. 1989) and some major research projects had just ended (Don Thomas', Mark Williams', McLean and Heard, and Heard and Stenhouse). In fiscal 1989/90 most field projects were suspended so that the results of past work could be examined and a course for the 1990's could be charted.

This review centres on the work done out of Yellowknife, but also examines some of the work done by regional and CWS biologists.

The caribou program's ultimate goal was to provide sound and convincing management recommendations. In this review, we will attempt to decide if we were doing "the right things right" to meet that goal.

1. Logic: Were our objectives reasonable? (i.e., were the data collected to meet those objectives able to be interpreted as expected - do cow:calf ratios in March indicate over winter survival of calves and provide an index of recruitment - and is that a useful thing to know?)

2. Precision and accuracy: Were the data adequate with respect to accuracy, precision, and cost effectiveness? How

precise do the data (e.g., population estimates) need to be? 3. Frequency: How frequently are the data required (e.g., what is the best survey interval)?

4. Location: Were the right populations surveyed? and

5. Use: Were the results translated into management action or used as a basis for some other decision?

Caribou project activities were divided into 4 areas;

a) developing and improving techniques (e.g., aerial photography as a census technique, composition sampling techniques, urea N as a condition indicator),

b) monitoring caribou herd status (e.g., periodic census and recruitment surveys), and

c) increasing our fundamental understanding of caribou and wolf ecology and behaviour.

d) communicating results, concepts and management recommendations to the public and the scientific/management community.

Most of our time and money has been spent monitoring the status of the Bluenose, Bathurst, Beverly, and Kaminuriak herds (primarily through periodic census surveys and annual composition surveys) and attempting to improve monitoring techniques. Therefore the first part of this review will cover caribou composition surveys and the second will deal with census surveys. The final section, to be sent later, will cover our suggestions for future work.

COMPOSITION SURVEYS

Composition surveys have been done at 3 times of year. In spring, March and April, we estimate the calf:cow ratio (CCR); the ratio of calves to one year old and older females. In June, on the calving grounds, we estimate the proportion of parturient cows (pregnant and post-partum females) to other one year old and older caribou. During the rut we estimate the sex ratio in the herd.

1. Logic: We think that spring CCRs and the proportion of parturient cows on the calving ground are worth estimating but that fall sex ratios are not usually worth the effort.

Because pregnancy rates are relatively constant in caribou, recruitment to the population (as indexed by the spring CCR) is a measure of the survival from birth to age one year. First year survival is probably the key factor determining the abundance in caribou. Recent increases in the size of the Kaminuriak, Beverly, Bathurst, and Bluenose herds can all be related at least in part to increases in first year survival. Caughley correctly pointed out that age ratios can not be interpreted because ratios could change if either (in our case) the number of calves or the number of cows changed. In caribou, it is hard to believe that cow survival could change enough to account for the wide range of CCRs we observe, because if that were the case, we would not get a relationship between herd growth and CCR. The most likely way to get high cow mortality and low calf mortality (at least for a while) is through very high hunting. Hopefully, we would know about extraordinarily heavy kills as part of our day to day activities.

The best way to track herd trend is by censusing herd size, but if census surveys are done only every 3 or 4 years it could take 12 years to detect a trend change. Annual estimates of CCR are relatively cheap (1/4 the price of a census) and provide an index of trend for the intervening years. Census surveys cost about $80,000/yr while spring composition surveys cost between $15,000 and $30,000/yr. If you accept all of this stuff, then it seems to us that spring CCRs are well worth collecting.

We know that the proportion of parturient cows on the calving ground varies considerably among years, depending on caribou behaviour. If we estimate this parameter then we can eliminate a considerable amount of noise surrounding the calving ground population estimates. The question is, are calving ground classifications worth the cost? We think they are.

The estimation of total population size from calving ground estimates requires an estimate of the sex ratio in the total herd and the proportion of all females that are pregnant. Because we do not estimate the proportion of all females that are pregnant, it is not worth a lot of effort to estimate the sex ratio. Assuming an average sex ratio is probably pretty safe because they vary little. One situation where the sex ratio was considerably different from the mean was in the Kaminuriak herd in the early 1980's when survival was very high. It is worth estimating sex ratio there now, to see if it has returned to a level more typical of the mean.

2. Precision and accuracy: Recently, Davis and Adams have shown calf mortality does not differ from that of adults after fall. Their data reduces my concern that differential mortality may occur after our surveys in late March. Late winter survival may be different in the NWT but determining that for our herds is well beyond the scope of our resources for now. Accuracy of CCR's was brought into question when McLean and Heard found significant differences between groups selected arbitrarily and groups selected based on the location of radio collared cows both years the comparison was done (see attached report; Spring composition summaries for the Kaminuriak, Beverly, Bathurst and Bluenose caribou herds, 1986-89). The direction of the difference was different between years i.e., the CCR from arbitrarily selected groups was higher one year and lower the next.

Spring Classification Surveys

The results of 1986-1989 composition surveys indicate what we feel were the strengths and weaknesses of our methods of collecting spring CCR's. Nineteen spring composition surveys were conducted on the four mainland herds of barren-ground caribou between 1986 and 1989 (Appendix 1). Caribou were classified either from the ground after observers were placed near caribou using a fixed wing aircraft, helicopter, or snowmachine or from a flying helicopter. The Kaminuriak surveys consistently employed observers who used snowmachines to place themselves near caribou that were migrating past Eskimo Point. On the other herds, most samples were taken before caribou had left the forest.

Most sample units were selected arbitrarily but some Bluenose and Kaminuriak sampling sites were based on the presence of radio-collared cows. The mean CCR and its standard deviation were originally estimated using Cochran's ratio estimator, but to avoid assumptions about normality of the data, we switched to using the Jackknife technique. When the number of sample units was over 20, the mean was the same using both methods and the Jackknife provided only a slightly higher estimate of the standard deviation.

The cumulative mean calf cow ratio was within 10% of the final estimate after 21 groups of caribou had been classified in 17 of the 19 surveys (Figure 1 in Appendix 1). The cumulative coefficient of variation (cv) was below 10% (considered to be our acceptable level of precision) in 15 of 16 surveys when at least 26 groups of caribou were sampled (Figure 2 in Appendix 1). A cv of less than 10% was not attained in only three surveys (Kam 87, Bev 89 and Bat 88) in which 30, 23 and 13 groups were sampled respectively. Of the 16 surveys in which a cv of < 10% was attained, only 5 (Bev 89, Kam 86S1, Kam 86S2, Kam 87 and Kam 88) did not reach the 10% cv level after 20 groups.

We conclude that the methods used to estimate calf:cow ratios between 1986 and 1989 usually resulted in an acceptable level of precision because relatively few groups were sampled in those surveys where the 10% cv level was not reached. Therefore it appears as though a cv of 10% can be consistently attained given a sufficient number of samples, using the survey techniques employed. However, the fact that 4 of the 5 surveys that did not attain a cv of 10% were conducted on the Kaminuriak herd, suggests that more samples are required when sampling migrating caribou on the tundra as opposed to sampling prior to the start of migration while the caribou are still on winter ranges. The Beverly 1989 survey provided a similar situation. The migration started during the sampling period, and the cv, which had dropped below .1 after 7 groups, jumped to .2 and then declined slowly. More samples are required to obtain precise estimates after the start of migration because age and sex classes appear to segregate immediately prior to and during migration. Therefore it is not surprising that the variability in calf:cow ratios is higher initially, and remains higher despite increasing sample sizes, as the composition of groups migrating past a fixed point will continue to change as different herd components move out of winter range in the trees.

It is difficult to establish specific guidelines for obtaining accurate and precise estimates of calf:cow ratios from spring composition surveys as each situation will differ. However, the easiest way to ensure a cv of 10% is reached is to take a programmable calculator into the field and enter the data from each group. One note of caution, is that the cv was observed to jump up after having dropped below 10% in 5 of 19 surveys. Therefore, several groups should be sampled after the level drops below 10% to ensure a precise estimate.

If a calculator is not available in the field, results from analyzing the 19 surveys conducted indicate that the cumulative mean calf:cow ratio, on average, is within 10% of the final estimate after 18 groups (Figure 1 in Appendix 1), and in 14 of 19 surveys, the cumulative cv was below 10% after 21 groups sampled. Therefore it appears that it is necessary to sample a minimum of about 20 groups in each area to ensure that precise estimates are attained. Our previous recommended minimum was 30 groups.

In several instances the cv jumped after the investigators sampled in different areas of the caribou distribution, suggesting that there may be significant differences in calf:cow ratios in segments of a population wintering in different areas. It follows, then, that it is not only important to obtain a precise estimate in a single area, it is also important to sample from all segments of a population in order to ensure that the estimated calf:cow ratio is accurate (is close to the calf:cow ratio in the total population).

In theory, sampling effort should be distributed according to the proportion of caribou in each area, which requires estimates of the numbers (density) of caribou in all areas occupied by caribou from the study herd. However, obtaining estimates of numbers of caribou in winter, especially in the forest, is difficult and expensive, requiring resource expenditures well beyond those available for spring composition surveys. To date, most sampling efforts have been allocated according to a gut feeling of the relative numbers of caribou in different areas and to logistical constraints (eg. finding and landing beside groups of caribou on the barrens). We would appreciate receiving input as to methods to deal with the problem of allocating sampling effort without accurate estimates of caribou densities in all areas of winter range occupied by a herd.

We concluded: 1. A level of precision of cv = 10% is consistently attainable using the methods employed between 1986 and 1989 if enough groups are sampled. 2. The variability in calf:cow ratio increases as caribou age and sex classes segregate immediately prior to and during migration. Therefore spring composition counts should be conducted prior to spring migration, in the trees, rather than during migration on the tundra. This suggestion involves major changes only on the Kaminuriak range. 3. Investigators should carry a programmable calculator with them to determine when they have sampled enough groups to attain a cv of 10% or less. Several additional groups should then be sampled to ensure that the CCR does not change and that the cv does not jump back up over 10%. 4. If a calculator is not available, at least 20 groups should be sampled. 5. Sample effort should be distributed according to density. The more information you can get on relative densities, the better. However, it is not worth attempting quantitative density estimates.

If one wanted to investigate the accuracy of CCR estimates further we suggest attempting to select sample sites more objectively. One way to do that would be to carry out spring composition work like it is done on the calving ground. That is, fly predetermined transects and classify animals near the flight lines so that the sample size is proportional to density. That would require a helicopter. It would involve many hours of flying over empty country and for the same cost would result in many fewer animals being classified. The binomial formula could be used to calculate the CCR and its standard deviation, which would give a precise result. The question remains of how to evaluate its accuracy.

To determine the effect of segregation during spring migration on the CCR estimate one could sample throughout the winter, sample at one point over the time that the migration is passing or, in April, sample along the length of the migration. As we have been recommending for 3 years, it is important to record the sex of calves. Do you think these studies are necessary?

<u>Calving Ground Classification Surveys</u>

Analyzing calving ground classification data with the Jackknife method did not result in sufficiently precise estimates of the proportion of parturient cows on the calving ground (see Appendices 3, 4, and 5). Because we know the density of animals within each stratum, we sampled so that sample size was proportional to density. We believe that helicopter flight lines resulted in sampling effort being distributed so that all animals had an equal probability of being sampled. Therefore the binomial formula (sd=FPC*(pq/n)^0.5) should an appropriate way to estimate the mean and standard deviation of the proportion of parturient cows on the calving ground. Using the binomial formula, rather than the jackknife method would result in negligible differences in the estimate of the proportion of parturient cows, but the binomial would produce much smaller standard errors. For example the proportion of parturient females in stratum 1 on the Beverly herd's calving ground in 1988 was 0.911 ± 0.2513 using the Jackknife estimate and 0.916 ± 0.00574 using the binomial formula. Using the binomial formula would allow for substantial savings in survey cost, because if we stick with the Jackknife we must increase our sample size to obtain an acceptable level at precision, but if we go with the binomial we could decrease sampling effort. (see Czaplewski, Crowe and McDonald.1983. Sample sizes and confidence intervals for wildlife population ratios. Wildlife Society Bulletin 11: 121-128.) Comments?

3. Frequency: We have recommended composition be done annually as an index of trend in the years between surveys. If it is not done annually it's usefulness as a trend index declines considerably and therefore may not be worth doing at all.

4. Location: If populations are not surveyed periodically then composition work is not going to provide useful monitoring information and is worth doing only under specific circumstances depending on the objectives. We feel that annual composition surveys should be continued on the Bluenose, Bathurst, Beverly and Kaminuriak herds and begun on Banks Island.

5. Use: Commercial caribou quotas were increased on the Kaminuriak and Bathurst herds because we believed those herds were (and still are) large and healthy. CCRs were definitely a factor supporting the census results and justifying those increases.

CENSUS SURVEYS

1. Logic: The census component of caribou population monitoring may be designed to provide information on both population size and population trend. However the emphasis varies. The primary objective of Bathurst, Beverly and Kaminuriak herd calving ground surveys was herd trend and the secondary objective was herd size. Almost everywhere else, the primary objective was herd size and the secondary objective was herd trend.

Those priorities may change. The Bathurst management plan calls for decisions to be made on the basis of total herd size. It says nothing about trend. Is trend worth estimating? What we need to know is if herd size is between certain limits. But trend is also important because it may foretell when herd size will pass a critical boundary. If our management decisions were made immediately after each new estimate of population size were obtained, and if those management decisions controlled subsequent changes in herd size (e.g., determined herd trend) then herd trend would be meaningless. But we know that neither of those conditions apply. We are not so much managing herd size as monitoring what nature gives us and trying to take maximum advantage when times are good and minimize adverse impacts when times are bad. Put another way, because we know population size will fluctuate regardless of what we do, a worthy management objective would be to reduce the amplitude of those fluctuations so that even the minimum herd size will be high enough to meet people's needs. To do those things we need to know herd trend.

If we always use the same formula to extrapolate numbers of parturient females to total herd size then there is no need to measure the required variables unless we have reason to think they have changed drastically (see Composition Section).

2a. Precision: A CV of less than or equal to 0.1 for all surveys has been our objective for years, and we think that remains an obtainable and worthwhile objective. It is probably never worth the effort to try to get the CV below 0.05.

The elimination of the stratified visual strip transect survey during calving ground surveys means that composition can be determined concurrent with the photography (thus increasing accuracy), and more time could be spent collecting composition data (thus improving precision). There has not always been sufficient time available to sample as intensively as we would have desired.

2b. Accuracy: Every study of aerial survey techniques has demonstrated that visual counts are inaccurate. Sightability bias, the difference between the observed and the true counts, can be corrected for if there is a consistent and known relationship between variables that affect visibility (e.g., strip width, flying hight, airspeed, per cent tree cover etc.). The problem we face is that aerial photography has demonstrated that sightability bias of caribou on calving grounds is highly variable (Appendix 4), suggesting that it is not possible to correct for sightability bias under those conditions. What other ways are there to deal with survey inaccuracies resulting from sightability bias?

Four survey designs are being used to census caribou in the NWT. On mainland calving grounds, density is estimated by counts of caribou on aerial photographs. On Banks Island and in the central and high arctic, caribou are counted visually on belt transects from either fixed wing aircraft (where the transect boundaries are delimited by wing strut markers) or from a helicopter, where a clinometer is used to measure the distance of animals from the aircraft. On Southampton Island we used Gasaway's moose survey technique; counting caribou from a helicopter within randomly selected blocks. We attempted to measure caribou sightability. Total counts of caribou on photographs of Bluenose post-calving aggregations has been successful on two occasions.

Sightability bias is still a factor in counts from both calving ground and post-calving aerial photographs. We have not been able to measure how many animals we are missing, but counting accuracy appears to be much higher (and therefore must be less variable) than visual counts of transect strips.

On Southampton Island, our attempt to measure visibility bias failed because caribou moved too far during the interval between our initial survey and the high intensity recount. That occurred even though the recount was carried out immediately after the completion of the block count. There appears to be no way around this problem unless caribou can be counted when they are less reactive and therefore less likely to move (e.g., in very cold weather, during the rut, etc).

We have spent 10 years and over a half million dollars in survey costs demonstrating the inaccuracies of visual transect strip surveys. However that technique is still being used and results are interpreted as if they are accurate or consistent underestimates. Why are Gasaway's moose survey procedures followed to the letter but his procedures to determine sightability bias ignored? We suggest that resistance to change is strong because:

1) In spite of overwhelming evidence otherwise, we cannot believe sightability is a problem. We may be willing to base management decisions on survey data knowing that we must be underestimating population size because our errors favour conservation.

2) Accurate techniques are so much more expensive.

3) Accurate surveys are difficult to design and we are too rushed (hopefully not too lazy) to spend the time required..

4) Research on survey methods is not very glamorous.

5) Inaccurate surveys are easy to pass off to non-technical people as good stuff.

We can deal with high costs if we want to, by doing fewer surveys or by taking money from other projects. Alternatively we can give up and use the money that would have been spent on a poor census for something we can do well.

Because we were unable to measure sightability on Southampton Island, we would like to try Mercer's spray dye mark-recapture technique in 1991. Obviously one of the big hurdles will be getting community approval but there is no reason not to try.

We are still trying to assess biases of counts of calving ground photographs, possibly by using concurrent video subsampling.

The biggest question, which we have found difficult to evaluate, concerns the pros and cons of post-calving vs calving ground census methods. We do not believe you can determine the accuracy of the post-calving technique unless a relatively high portion of animals of both sexes are radio-collared. That excludes the Bathurst herd as a candidate for that technique because political considerations do not allow us to collar animals. The Kaminuriak herd does not appear to aggregate sufficiently to obtain a total count most years. A post-calving estimate was obtained in 1987 but it required some assumptions and was not a total count. Thomas insists that the Beverly herd can be censused using post-calving photography but he has failed every time he has tried it. Bruce has had apparent success with post-calving counts in that he is able to find most of the radios and photograph the groups, but he has not been able to assess how many bulls he is missing. At this time we think Bruce should continue with post-calving photography and the other herds should be counted on their calving grounds.

3. Frequency: The most cost efficient survey interval can be determined using the methods described by Tim Gerrodette (1987. A power analysis for detecting trends. Ecology 68: 1364-1372). To determine the optimum survey frequency we need to know 1) what precision we can expect from the survey design, 2)

acceptable level of risk of making type one and type two errors and 3) the likely rate of change in the size of the study population. The optimum survey interval was considered to be the longest survey interval (and therefore the fewest total surveys and lowest total cost) to detect a trend over the shortest possible time.

We can expect the precision of surveys to average cv = 0.15 with improvements to calving ground composition techniques as discussed under Composition Surveys above. We suggest that we adopt the same significance standards as have been accepted for moose surveys. In all calculations we have assumed that two-tailed tests would be done and that we want to be 90% sure of not making a Type 2 error (i.e., concluding no trend when in fact there was one).

It is difficult to know what rate of change to use as a basis for calculating survey intervals. Smaller rates of change are more efficiently detected by longer survey intervals (Figure 3) because greater absolute changes in numbers occur over longer intervals.

Optimum survey interval	Fractional rate of decline per year
2	>.240
3	.164 - .240
4	.125 - .164
5	.102 - .125
6	.085 - .102
7	.075 - .085
8	.070 - .075
etc...	

Short survey intervals will not detect small rates of change as efficiently as longer ones. All survey intervals will detect large rates of change, but with longer survey intervals, the population will have declined further before detection. Regardless of the survey interval, with a CV of 0.15, the population has to decline by about half in order to get a significant difference between any two surveys. Two surveys 3 years apart would detect a decline of at least 53% whereas two surveys 6 years apart would detect a decline of at least 57%. Thus the absolute difference in the percent change in herd size before detection is not great.

If you can predict the rate of change then the above table gives you the optimum survey interval. But the average rate of change is not easy to predict. If one wants to err on the side of reduced efficiency rather than having a decline go undetected longer than necessary, the maximum expected decline rate should be used to choose the optimum survey interval. The Kaminuriak herd declined at only about 3%/yr. The greatest decline rate we know of occurred on Banks Island at about 15%/yr. Thus a four year survey interval would be most efficient at detecting the 15%/yr decline, our worst case scenario.

Because there are no other examples of consistently high rates of decline that we know of (excluding St. Mathew Island), it seems unlikely that caribou would decline at such a consistently high rate. Assuming that a more plausible long-term average rate of decline is 10%/yr (or less), then, a 6 year survey interval would be sensitive and efficient. Therefore we think serious consideration must be given to 4, 5, and 6 year survey intervals.

The biggest risk of long survey intervals is, if we ever had rapid declines, that the population would decline further before detection than if survey intervals were shorter. Therein lies the value of annual recruitment estimates. If we suspect a decline within a given herd for any reason (near significant trend, poor recruitment, high level of hunter kills, etc), we could survey that herd ahead of schedule to confirm the trend and reduce absolute declines in herd size. A six year survey interval would permit that kind of flexibility.

In conclusion, therefore, we recommend that the caribou survey intervals be increased from once every 2 to 3 years to once every 6 years.

Where a herd is threatened with extinction (e.g., Banks Island) and if more data will aid conservation efforts (i.e., the cost of ignorance is high), then the survey interval could be reduced.

4. Location: Southern Ellesmere is the only place we know of where caribou were, or are declining and the decline went undetected longer than necessary. This resulted because it was considered a low priority area and was not surveyed. However, there may be undetected declines occuring in other unsurveyed areas (e.g., parts of Baffin Island). A six year survey interval would free up money to survey other areas.

5. Use: Survey results are relied on heavily for management decisions. The Kaminuriak decline was real and led to the formation of the Beverly/Kaminuriak Cariobu Management Board and its actions. Documentation of herd size increases has led to increased GHL, commercial, resident, and non-resident quotas when and where appropriate.

Appendices

1. Spring composition summaries for the Kaminuriak, Beverly, Bathurst, and Bluenose caribou herds, 1986-89

2. Bathurst calving ground survey June 1986 (to follow later)

3. Beverly calving ground survey 2 - 14 June 1987

4. Beverly calving ground survey 2 - 14 June 1988

5. Kaminuriak calving ground survey 5 - 17 June 1988

Figure 3. Relationship between the rate of population decline and the number of surveys required to detect a trend. Curved lines represent 3, 4, 5 and 6 year survey intervals. Survey precision was assumed to be cv = 0.15. Although the relationship between the number of surveys and the rate of decline is plotted as a curve, it is impossible to do a fraction of a survey so the number of surveys declines in steps e.g., if 2.3 surveys are required to detect a trend then 3 surveys must be done. Heavy curved lines indicate the otimum survey intervals for decline rates exceeding 0.085. All survey intervals would detect a decline after two surveys when the rate of decline exceeds 0.164 but a 3 year interval is the most efficient because only the decline will be detected after only 3 years. At rates between 0.085 and 0.164, a three year interval is less efficient because more surveys are required (3 or 4 vs 2) which usually means more total time is required and therefore a greater total decline before detection. For example, at a decline rate of 10%/yr the decline would be detected after 2 surveys 6 years apart for a total time of 6 years and a total decline of 47%, after 3 surveys 5 years apart for a total time of 10 years and a total decline of 65%, after 3 surveys 4 years apart for a total time of 8 years and a total decline of 57%, and after 3 surveys 3 years apart for a total time of 6 years and a total decline of 47%. Although the 3 and 6 year survey intervals give results over the same, the 6 year survey interval was more efficient because only 2 rather than 3 surveys were required.

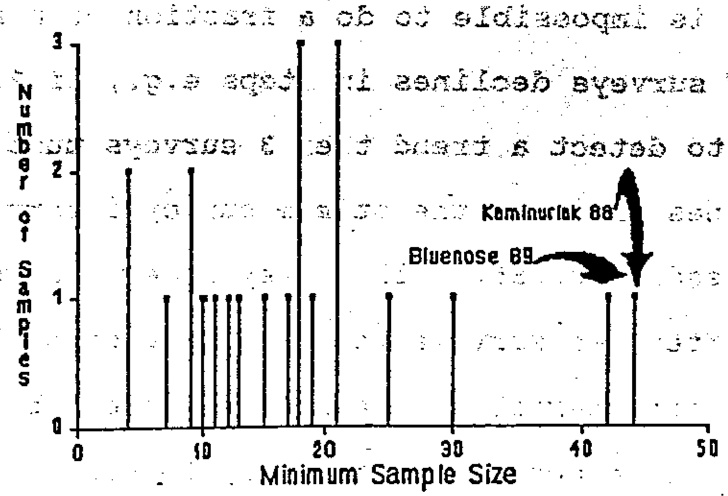


Figure 1. Frequency distribution of the minimum number of samples required to attain a calf:cow ratio estimate that was within 10% of the final estimate.

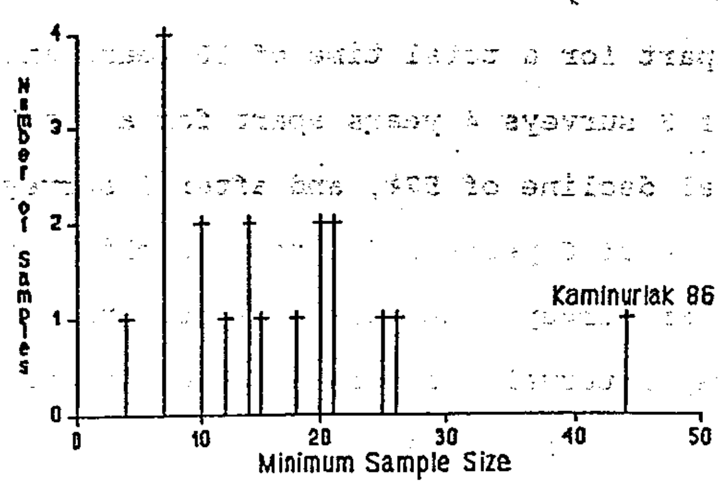
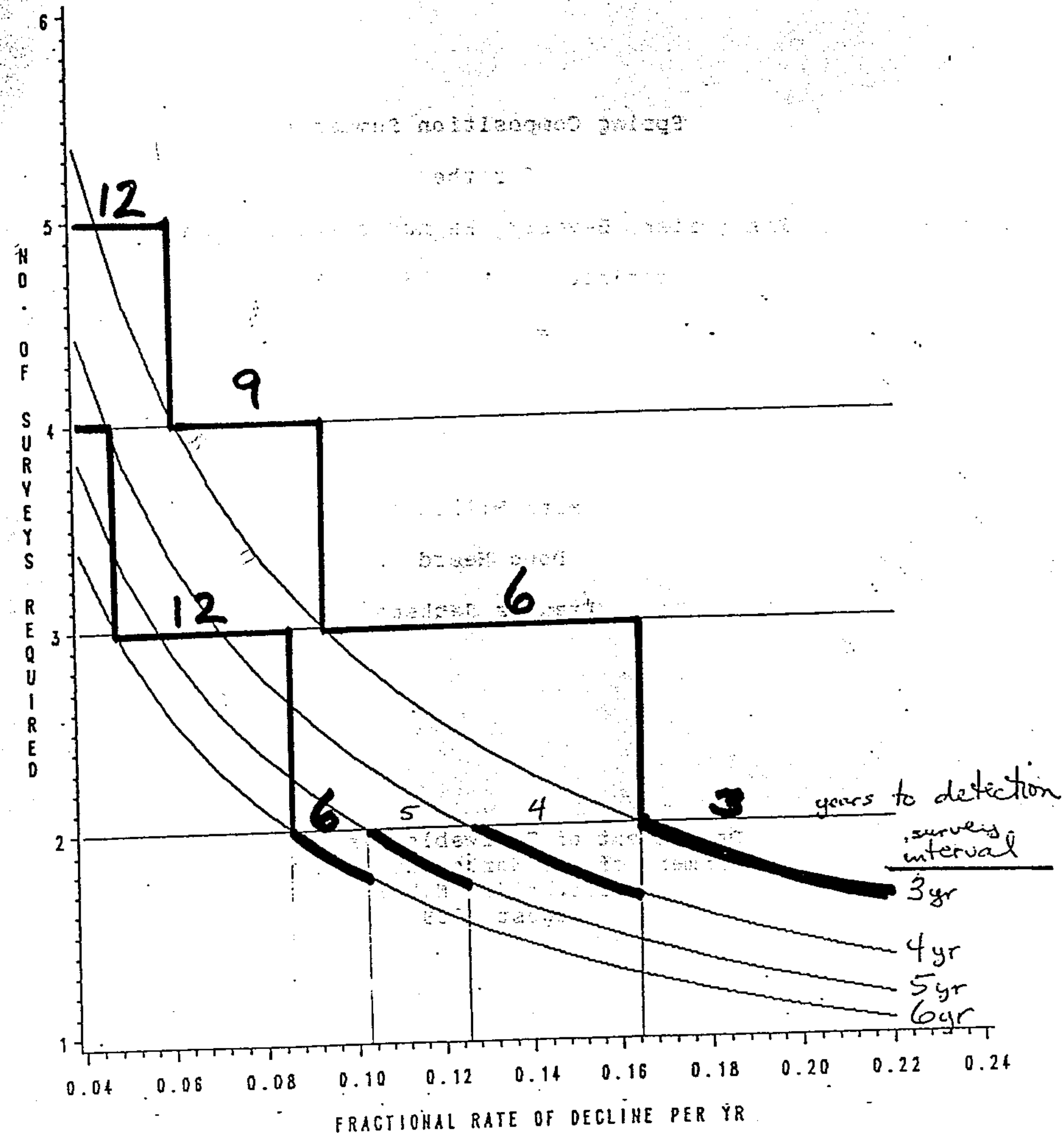


Figure 2. Frequency distribution of the minimum number of samples required to attain a coeffficient of variation less than of 10%.

Figure 3.

DETECTING TRENDS



cv = 0.15
CURVES represents different survey intervals
YEARS TO DETECTION = SURVEY INTERVAL x (no. surveys - 1)
TOTAL DECLINE = $[(1 - \text{FRACTIONAL RATE})^{\text{years}}] - 1$

Spring Composition Summaries

for the

Kaminuriak, Beverly, Bathurst and Bluenose

caribou herds, 1986 - 89

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August 1989

1986 Kaminuriak, Beverly, Bathurst and Bluenose Caribou Herd Spring Classification Statistics.

Survey	No. of groups classified[8]	CCR[1]	s[9]	CV	% calves in sample	Estimate of % calves in herd[2]	Sex ratio in sample[3]	Minimum sample size based on the CCR[5]	Minimum sample size based on the CV[4]	Wolves seen: 100 hr flying
Kaminuriak 1	27	48	4.14	.09	31	21–22	8	18	21	–
Kaminuriak 2	56	69	5.84	.08	32	27–29	45	30	44	–
Kaminuriak 1&2 (combined)	83	55	3.64	.07	31	23–25	20	25	21	–
Beverly	30	45	2.91	.06	25	21	35	7	14	130
Bathurst 1	15	60	4.88	.08	29	27	50	4	10	–
Bathurst 2	21	48	3.99	.08	22	22	67	9	15	–
Bathurst 1&2 (combined)	36	58	3.64	.06	27	26	54	9	10	–
Bluenose 1[6]	29	52	2.97	.06	29	24	26	10	12	–
Bluenose 2[7]	29	64	4.98	.08	32	28	35	18	26	–
Bluenose 1&2 (combined)	58	58	3.10	.05	31	26	31	30	26	24

1 Calf-cow ratio; calves:100 one year old and older females (cows); jackknife mean.
2 Assuming herd sex ratio of 66 males:100 females (mean of 6 NWT fall composition surveys – Parker 1972, Brackett et. al. 1982, Williams et al in prep) except for the Kaminuriak herd in 1986 when percent calves was calculated based on 66 and 83 males:100 females (Heard and Calef 1986).
3 One year old and older males:100 one year old and older females.
4 Minimum sample size above which CV remained below 0.10.
5 Minimum sample size above which CCR remained within 10% of the final estimate.
6 Group selection based on the location of radiocollared caribou.
7 Group selection was arbitrary.
8 Excluding groups which were made up of bulls only.
9 Standard deviation based on jackknife technique.

1987 Kaminuriak, Beverly, Bathurst and Bluenose Caribou Herd Spring Classification Statistics.

Survey	No. of groups classified[8]	CCR[1]	s[9]	CV	% calves in sample	Estimate of % calves in herd[2]	Sex ratio in sample[3]	Minimum sample size based on the CCR[5]	Minimum sample size based on the CV[4]	Wolves seen: 100 hr flying
Kaminuriak	30	35	4.00	.11	22	17	24	21	N/A	0
Beverly	20	34	3.53	.10	21	17	30	18	20	143
Bathurst	30	37	2.60	.07	21	18	40	21	7	94
Bluenose 1[6]	30	55	4.94	.09	26	25	57	21	14	–
Bluenose 2[7]	24	41	3.09	.07	21	20	55	19	20	–
Bluenose 1&2	54	47	3.08	.07	23	22	56	48	14	–

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9 Standard deviation based on jackknife technique.

1988 Kaminuriak, Beverly, Bathurst and Bluenose Caribou Herd Spring Classification Statistics.

Survey	No. of groups classified[8]	CCR[1]	s[9]	CV	% calves in sample	Estimate of % calves in herd[2]	Sex ratio in sample[3]	Minimum sample size based on the CCR[5]	Minimum sample size based on the CV[4]	Wolves seen: 100 hr flying
Kaminuriak	52	31	2.65	.09	21	16	14	44	25	0
Beverly	17	50	3.75	.08	24	23	54	15	7	17
Bathurst	13	58	14.09	.24	24	26	92	12	N/A	17
Bluenose	29	46	3.28	.07	24	22	48	17	7	45

1 Calf-cow ratio; calves:100 one year old and older females (cows); jackknife mean.
2 Assuming herd sex ratio of 66 males:100 females (mean of 6 NWT fall composition surveys - Parker 1972, Brackett et. al. 1982, Williams et al prep) except for the Kaminuriak herd in 1986 when percent calves was calculated based on 66 and 83 males:100 females (Heard and Calef 1986).
3 One year old and older males:100 one year old and older females.
4 Minimum sample size above which CV remained below 0.10.
5 Minimum sample size above which CCR remained within 10% of the final estimate.
6 Excluding groups which were made up of bulls only.
7 Standard deviation based on jackknife technique.

1989 Kaminuriak, Beverly, Bathurst and Bluenose Caribou Herd Spring Classification Statistics.

Survey	No. of groups classified[6]	CCR[1]	s[7]	CV	% calves in sample	Estimate of % calves in herd[2]	Sex ratio in sample[3]	Minimum sample size based on the CCR[5]	Minimum sample size based on the CV[4]	Wolves seen: 100 hr flying
Kaminuriak	38	44	1.75	.04	27	21	19	11	7	–
Beverly	23	36	4.48	.12	22	18	32	13	N/A	0
Bathurst	16	36	1.98	.05	21	18	32	4	4	46
Bluenose	56	45	3.04	.07	25	21	38	42	18	0

1 Calf-cow ratio; calves:100 one year old and older females (cows); jackknife mean.
2 Assuming herd sex ratio of 66 males:100 females (mean of 6 NWT fall composition surveys – Parker 1972, Brackett et. al. 1982, Williams et al in prep) except for the Kaminuriak herd in 1986 when percent calves was calculated based on 66 and 83 males:100 females (Heard and Calef 1986).
3 One year old and older males:100 one year old and older females.
4 Minimum sample size above which CV remained below 0.10.
5 Minimum sample size above which CCR remained within 10% of the final estimate.
6 Excluding groups which were made up of bulls only.
7 Standard deviation based on jackknife technique.

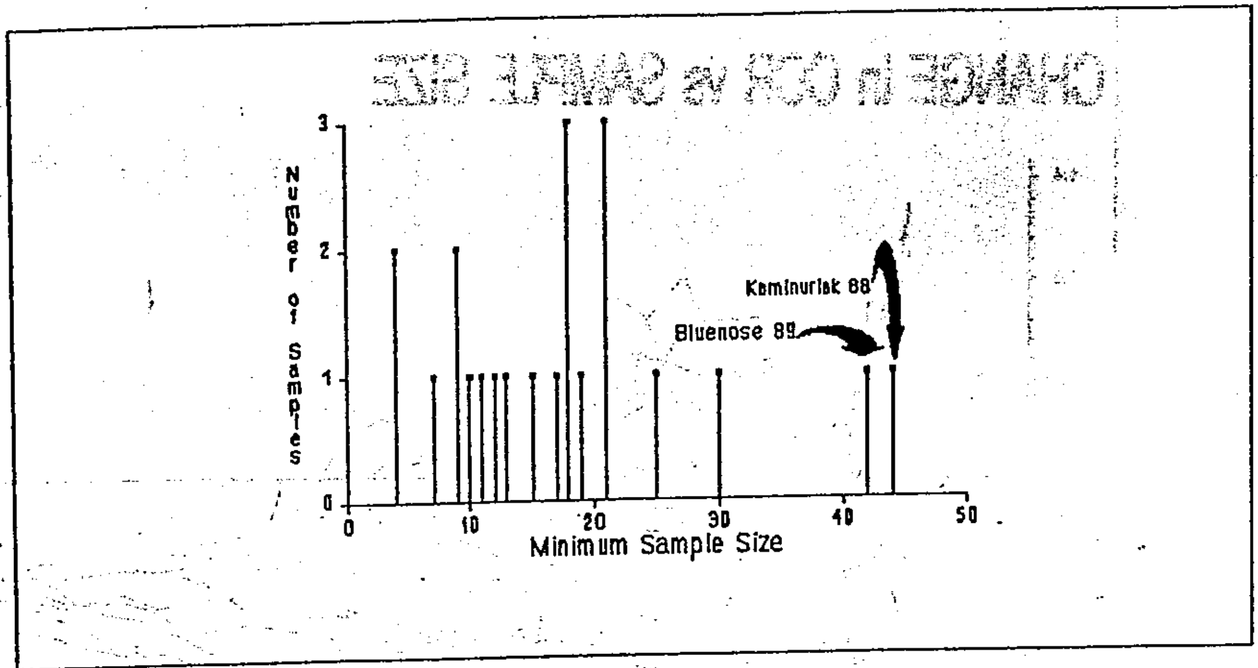


Figure 1. Frequency distribution of the minimum number of samples required to attain a calf:cow ratio estimate that was within 10% of the final estimate.

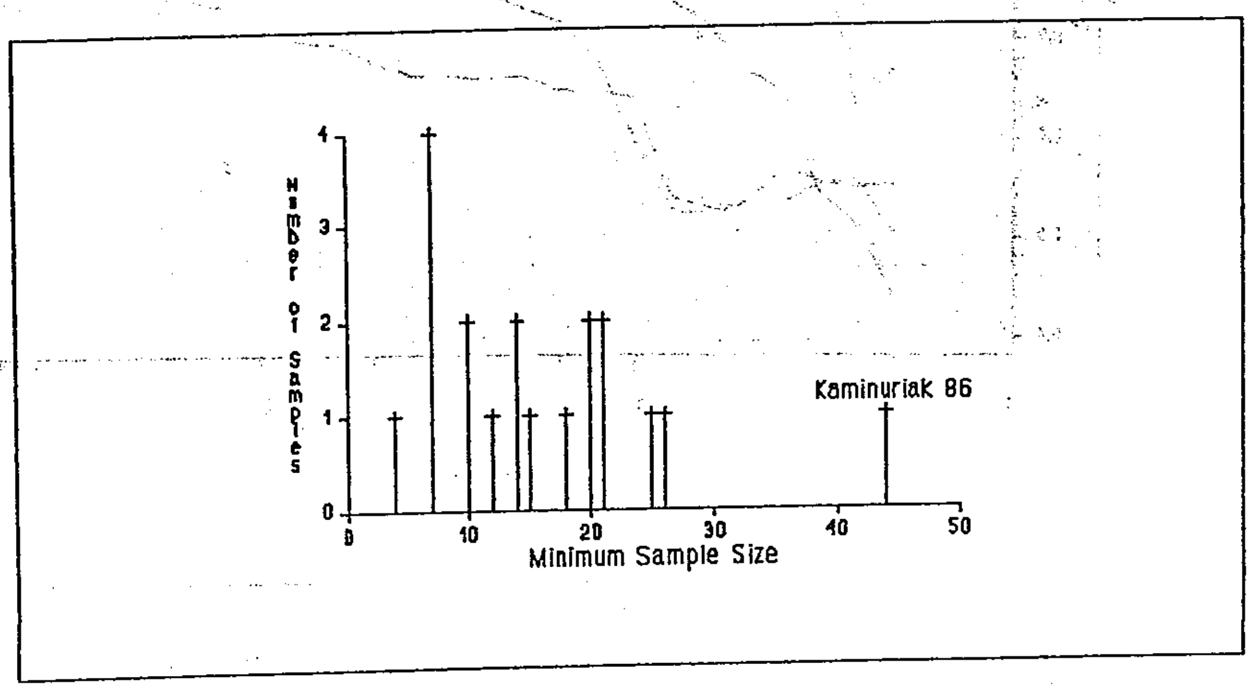
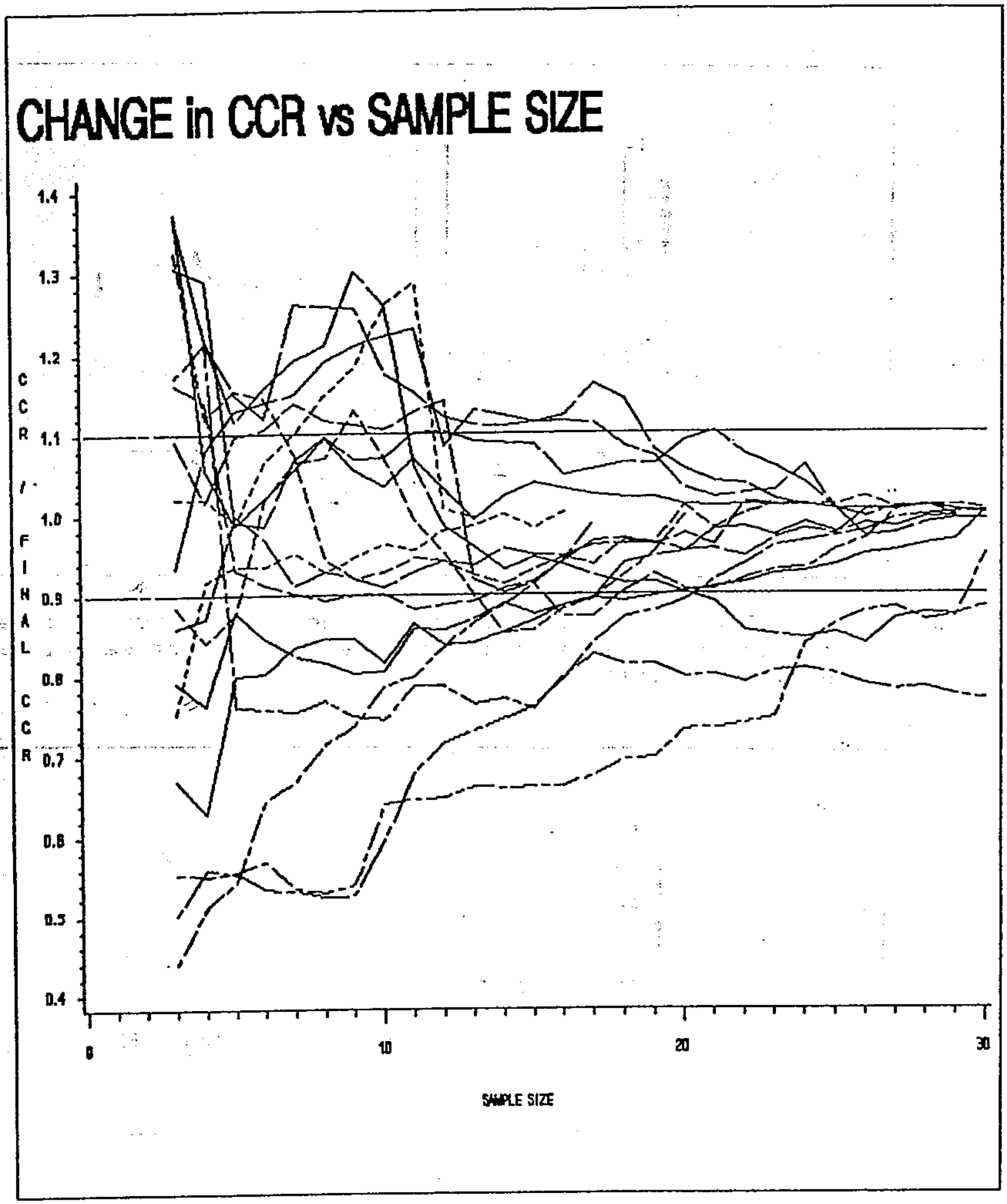
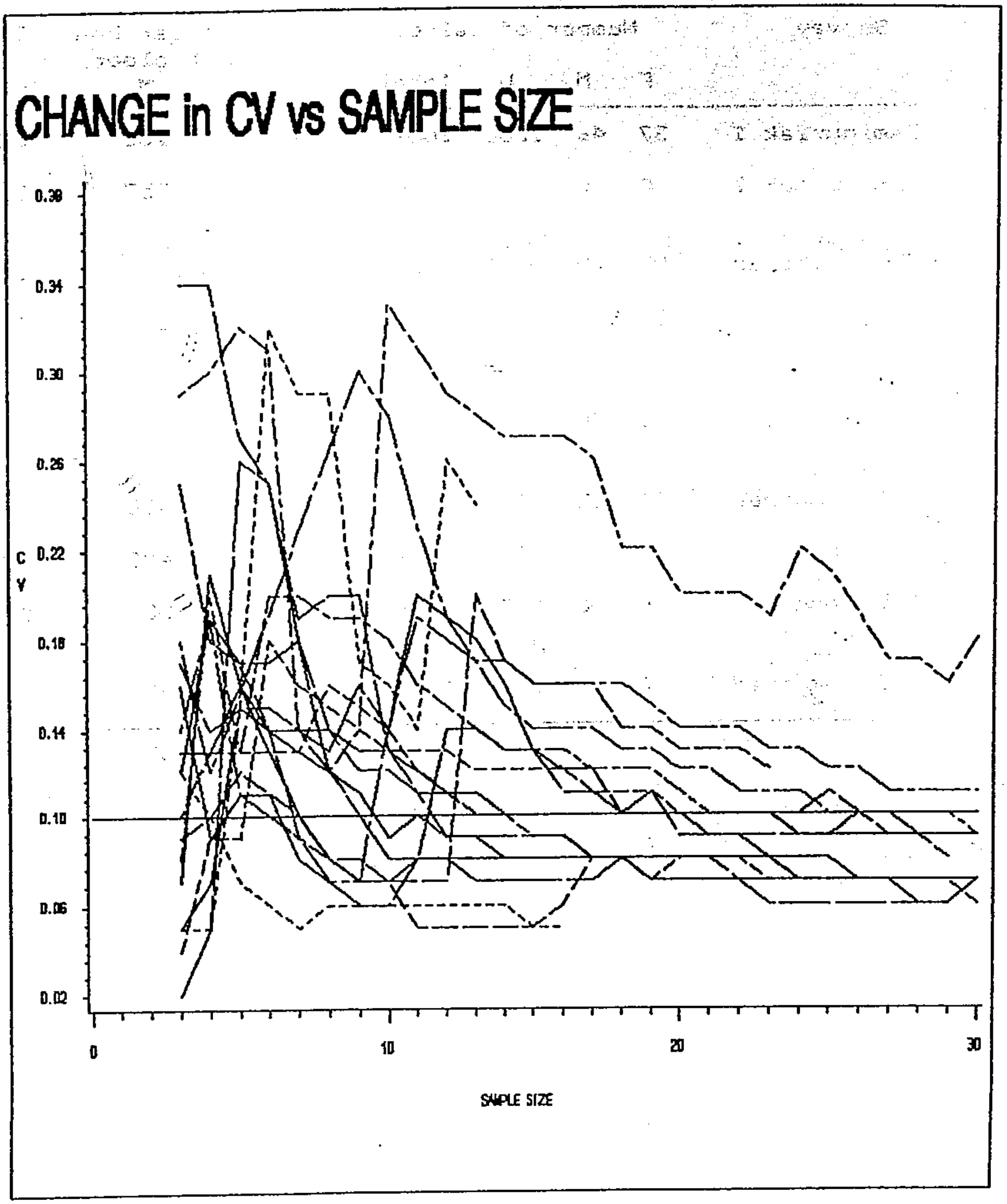


Figure 2. Frequency distribution of the minimum number of samples required to attain a coeffficient of variation less than of 10%.



The change in cow:calf ratios (CCRs), expressed as a proportion of the final CCR versus sample size. CCRs are usually within 10% of their final value after 20 samples.



The change in the CV of the estimated cow:calf ratio versus sample size.

1986 Kaminuriak, Beverly, Bathurst, and Bluenose caribou herd spring composition data (F = female, M = male, U = unknown sex)

Survey	Number of calves				Number of caribou 1 yr old & older		Totals
	F	M	U	Total	F	M	
Kaminuriak 1	37	49	1568	1654	3434	288	5376
Kaminuriak 2	0	0	0	1176	1693	757	3626
Kaminuriak 1 & 2 combined	37	49	1568	2830	5127	1045	9002
Beverly	933	804	232	1969	4339	1510	7818
Bathurst 1	86	73	721	880	1448	720	3048
Bathurst 2	71	50	101	222	461	308	991
Bathurst 1 & 2 combined	157	123	822	1102	1909	1028	4039
Bluenose 1	0	0	794	794	1533	403	2730
Bluenose 2	0	0	1076	1076	1674	581	3331
Bluenose 1 & 2 combined	0	0	1870	1870	3207	984	6061