

DONALD C. THOMAS

Population estimates of barren-ground caribou March to May, 1967

 CANADIAN WILDLIFE SERVICE REPORT SERIES—NUMBER 9



**Population estimates and distribution of barren-ground caribou
in Mackenzie District, N.W.T., Saskatchewan, and Alberta—
March to May, 1967**

by Donald C. Thomas



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**Department of
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Abstract

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An aerial survey of barren-ground caribou in the Mackenzie District and adjacent portions of Alberta and Saskatchewan was conducted in 1967. It had four objectives:

- 1 To determine late winter distribution of caribou herds and their spring migration routes to the tundra;
- 2 To census all major herds;
- 3 To determine numbers of young in relation to older animals;
- 4 To assess human use of caribou on their winter range.

Surveys were flown for a total of 270 hours in March, April, and May 1967. Four populations of caribou were described, on the basis of their distribution and calving areas. Estimates of herd sizes for three of the populations were obtained from combinations of total counts, strip censuses, photographic counts, and a ratio method.

In March the main components of each population were distributed in the taiga near tree line. The late winter distribution of the herds and the timing of spring migration appeared to be related to snow conditions, although this observation requires further confirmation.

A total population of 322,500 animals is estimated in the area censused. This is considered a minimum estimate because the uncensused herds relatively deep in the forested zone were assumed to be composed entirely of adult bulls, and the ratio method was used to estimate their numbers. The total would be increased if small herds containing cows, calves, and young bulls were also in this zone. The final estimate of caribou in the three populations censused is 320,000 to 330,000.

Aerial photographs were used to obtain the number of calves of the year in the major herds of caribou. Where adequate samples were obtained, the percentage of calves in the herds varied from 11.2 to 15.0. The over-all average recruitment rate for the three populations in the survey region was 11.0 per cent.

Caribou hunting is still a way of life for Eskimos and Indians in parts of northern Canada, but they no longer depend so heavily on the animal. It appears that there has been a substantial reduction of the harvest.

Top left cover photo and black-and-white photos by Don Thomas. Other cover photos by Gerald Parker.

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Introduction

In February 1967, the writer contracted with the Canadian Wildlife Service to conduct an aerial survey of barren-ground caribou in the Mackenzie District, Northwest Territories, and adjacent portions of Alberta and Saskatchewan. The objectives of the survey were as follows:

- 1 to determine the late winter distribution of caribou herds and their spring migration routes to the tundra;
- 2 to census all major herds;
- 3 to determine recruitment for all major herds;
- 4 to assess human utilization of caribou on their winter range.

The contract period was three months, and a specific sum was available for the charter of aircraft. Accordingly, it was necessary to plan the survey carefully.

It was necessary to locate all major herds of caribou before formulating census plans. In March we flew transects spaced 20 miles apart to determine the preliminary distribution of caribou. Most were located in the forested portion of the range. The exact distribution and movements of each major herd were carefully noted on subsequent flights, so that the herds could be censused at a time when they were outside tree cover and clearly visible.

Census flights were carried out between April 8 and May 20. Herd estimates were obtained by the strip-census method, from photographs, from total counts, from herd composition counts, or from combinations of the four methods. Aerial photographs were taken at low altitude to obtain counts of calves born the previous June. Estimates of hunter kill were obtained from regional wildlife officers of the Territorial Game Section and the Saskatchewan Department of Natural Resources.

This survey was confined to caribou range west of 102 degrees longitude. This longitude forms the boundary between the districts of Mackenzie and Keewatin and between the provinces of Manitoba and Saskatchewan. The normal range of the barren-ground caribou on the mainland of Canada west of 102 degrees longitude contains about 370,000 square miles, of which 223,000 are within the forested zone (Kelsall map in Symington, 1965).

Acknowledgements

I wish to acknowledge the assistance of Dr. J. P. Kelsall, then Acting Superintendent, Western Region, Canadian Wildlife Service, Edmonton, who provided excellent administrative support and technical direction.

Superintendent of Game of the Northwest Territories, Mr. P. Kwaterowski, provided competent observers in officers Terry Lines and Archie Manderville. Mr. Lines assisted with the census of three herds of caribou, and Mr. Manderville helped enumerate one herd. Special thanks must go to pilot Clem Bekar, who did an excellent job of flying most of the survey, and to pilot Bill Hetrick, who flew one census.

The information on human utilization was obtained from Territorial Game Section wildlife officers T. Lines and R. Mercredi; Saskatchewan Department of Natural Resources conservation officers F. W. Terry and T. Jonasson; Corporal B. Braun of the Royal Canadian Mounted Police; and Mr. A. G. Gordon, Area Administrator of the Cambridge Bay area for the Department of Indian Affairs and Northern Development.

My wife, Alice, converted my scrawl into typescript for the rough draft of this report.

Mr. D. A. Benson, head of the Biometrics Section of the Canadian Wildlife Service, reviewed the section on the use of the strip census.

Itinerary

The first few days of March were spent in Winnipeg at a meeting of the Technical Committee on Barren-ground Caribou Preservation. After obtaining equipment from the Canadian Wildlife Service offices in Edmonton and Fort Smith, survey flights were initiated on March 8.

The first week of flying was devoted to locating herds in northern Saskatchewan and the territory

between Lake Athabaska and Great Slave Lake. For the following two and one-half weeks Yellowknife was used as a base of operations to survey the range from Great Slave Lake to the Arctic coast. Census flights were started April 8 and continued until May 20.

A summary of aircraft usage and the itinerary are presented in Table 1.

Table 1 Aircraft employment and itinerary

Date	Flt. no.	Aircraft	Flt. time hours & min.	Miles	General location	Purpose of flight
Mar. 8	1	180	4:55	490	NWT/Sask.	Plot distr.
9	2	Beech	8:15	1393	NWT/Sask.	Plot distr.
10	3	180	8:00	1035	N. Sask.	Plot distr.
11	4	180	5:20	700	E. Gr. Slave L.	Plot distr.
12	5	180	4:30	580	Black L.	Distr./photos
13	6	180	4:30	575	Nonacho L.	Distr./photos
14	7	206	5:10	645	Nonacho L.	Aerial photos
16	8	Aztec	7:45	1300	N. Yellowknife	Plot distr.
18	9	Aztec	6:30	1097	Gr. Bear L.	Plot distr.
19	10	Aztec	3:50	656	N. Gr. Slave L.	Plot distr.
22	11	180	6:30	736	Ft. Reliance	Plot distr.
25	12	Aztec	6:30	1100	N. Gr. Bear L.	Plot distr.
26	13	Aztec	5:15	888	N. Gr. Bear L.	Plot distr.
27	14	Aztec	6:30	1110	N. Gr. Bear L.	Plot distr.
29	15	Aztec	5:50	1000	Bathurst Inlet	Plot distr.
30	16	Aztec	3:30	504	Bathurst Inlet	Plot distr.
Apr. 8	17	180	7:05	3000	E. Gr. Bear L.	Pre-census distr.
9	18	180	8:20		E. Gr. Bear L.	Census
10	19	180	8:30		E. Gr. Bear L.	Photos
14	20	Az/180	14:30	1913	NWT/Sask.	Distr.
15	21	180			NWT/Sask.	Distr./photos
17	22	180	15:20	1875	Hepburn R.	Pre-census distr.
18	23	180			Hepburn R.	Census
23	24	180	6:10	2340	Nonacho L.	Distr./photos
25	25	180	5:15		E. Coppermine R.	Photo count
26	26	180	8:05		Horton L.	Pre-census distr.
27	27	180	10:05	2580	Horton L.	Census/photo count
28	28	180	5:50		E. Gr. Bear L.	Distr./photo count
30	29	180	5:35		Bathurst Inlet	Distr.
May 1	30	180	5:05	2490	Bathurst Inlet	Pre-census distr.
2	31	180	9:15		Bathurst Inlet	Census/photos
4	32	180	6:25		Bathurst Inlet	Distr.
5	33	180	7:00	2040	Nonacho L./Selwyn L.	Distr.
6	34	180	7:25		Selwyn L./Black L.	Distr./photos
7	35	180	2:40		Uran C./Yk.	Return to base
10	36	180	1:30	2520	Yk./Ft. Reliance	Ferry
11	37	180	2:05		E. Reliance	Pre-census distr.
12	38	180	5:15		E. Reliance	Pre-census distr.
13	39	180	12:00	1440	E. Reliance	Census
15	40	180	1:30		E. Reliance	Ferry
19	41	180	11:40		E. Reliance	Census
20	42	180	10:55	2880	E. Ft. Reliance/ Ennadai	Census/distr.
TOTAL			270:20	36,887		

Note: Yk. = Yellowknife, 180 = Cessna 180, Beech = Beechcraft, 206 = Cessna 206.

Late winter distribution and spring migration routes

Introduction

Before the search for the herds was started, a form letter was sent to all aircraft charter companies asking them to record sightings of caribou. Although the information obtained from pilots was scanty, their observations for the Bathurst Inlet region were of value.

To determine the March distribution of caribou, the entire forested winter range was surveyed using transects spaced at 20-mile intervals (Fig. 1). A fast twin-engine Aztec was used on some of the early flights, and it proved to be a good aircraft for covering large areas in a short time. A maximum of about 800 miles was flown between refueling stops, but the aircraft was limited to established landing strips. The Cessna 180, a lighter and slower aircraft, was found suitable for shorter trips closer to base.

At the outset, labels should be assigned to caribou occupying various geographic areas. Past use of herd names to identify aggregations of caribou has caused some confusion, because herds are continually changing in size, number, and geographic location.

Bergerud (1963) defined a caribou herd as "a temporarily discrete population of at least 100 animals and composed of individual aggregations distributed within a restricted geographic area". Banfield (1954) applied geographic names to 19 herds of caribou on the mainland of Canada.

Caribou-tagging studies (Miller and Robertson, 1967) and field observations indicate that in recent years certain calving grounds have been used year after year by caribou, although winter ranges may vary considerably. Therefore it would seem appropriate to identify several populations of caribou on the basis of where they commonly produce young. It is assumed in this report that four populations of caribou were present in the survey region. These are listed below with the herd names previously used (Banfield, 1954).

Population	Previous herd names
1 Bluenose	Great Bear Lake, Colville Lake
2 Bathurst	Radium, Rae, Yellowknife
3 Beverly	Saskatchewan, Athabaska, Hanbury
4 Kaminuriak	Brochet, Duck Lake, Churchill (Manitoba)

Although there is known to be temporary seasonal overlap of ranges of at least two of the populations and some interchange of numbers, it ap-

pears that the majority of animals belonging to one population remain faithful to that population for many seasons. In March 1967, several wintering herds constituted the above populations. These will simply be numbered as follows:

Population	Herd	March location
1 Bluenose	Bluenose	NW. Great Bear Lake
2 Bathurst	Bathurst 1	E. Great Bear Lake
	" 2	NE. Great Bear Lake
	" 3	SE. Great Bear Lake
	" 4	S. Coronation Gulf
3 Beverly	" 5	E. Bathurst Inlet
	Beverly 1	E. Great Slave Lake
	" 2	N. Lake Athabaska
4 Kaminuriak	" 3	SE. Black Lake
	Kaminuriak	N.W.T. border, E. Selwyn Lake

The location in March of these herds is given in Figure 2, and their subsequent migration routes are shown in Figure 3. Separation of populations into herds was somewhat subjective since there was not always a distinct demarcation between the herds. In fact, the first three herds of the Bathurst population could be called one herd and the same applies to the three herds of the Beverly population, except that at times there were differences in density, movement, and composition sufficient to separate the herds into those listed above. Moreover, the numbering of herds is convenient for discussion. More detailed accounts of the distribution and movements of these herds will be presented below.

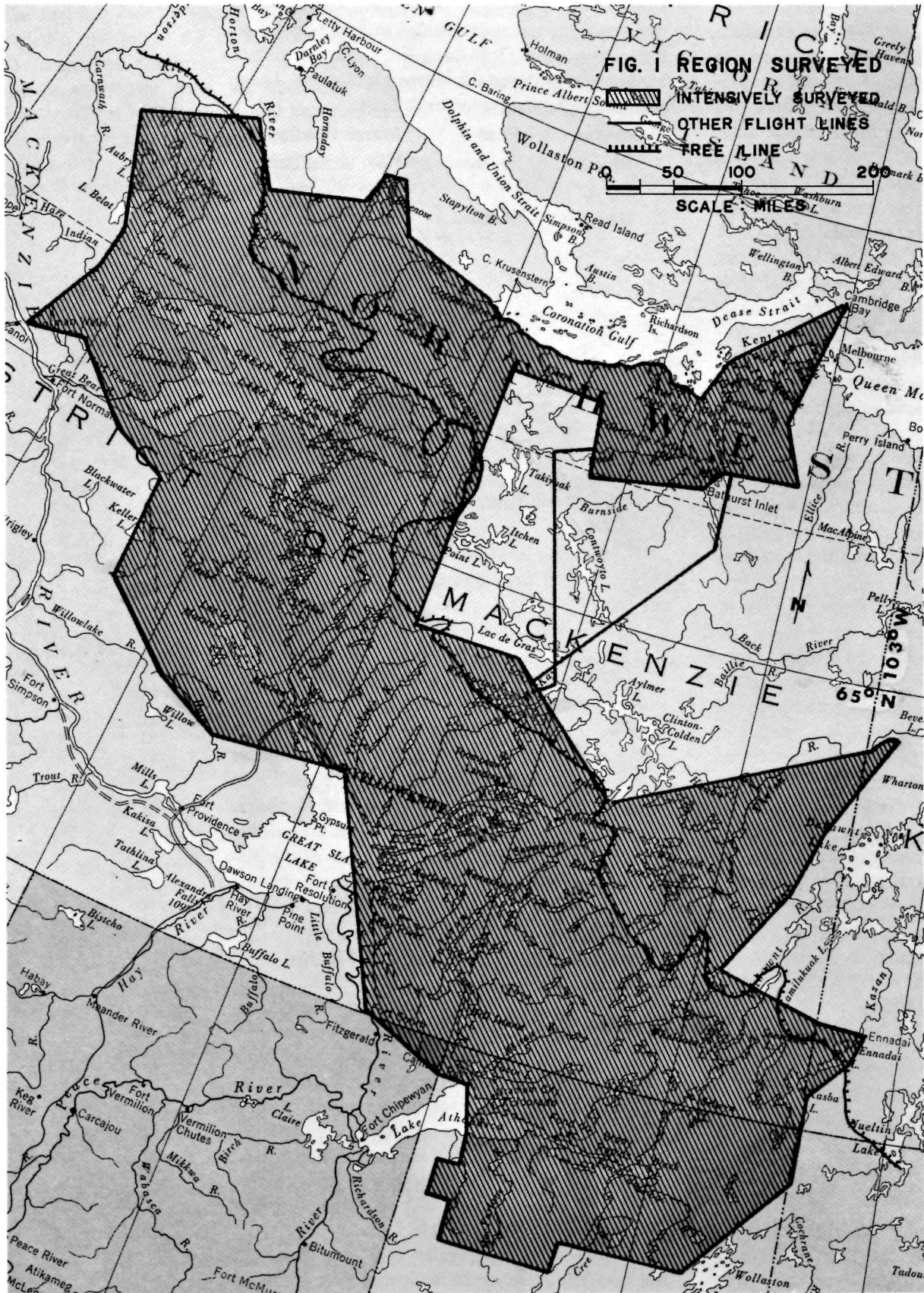
Distribution and movements of herds

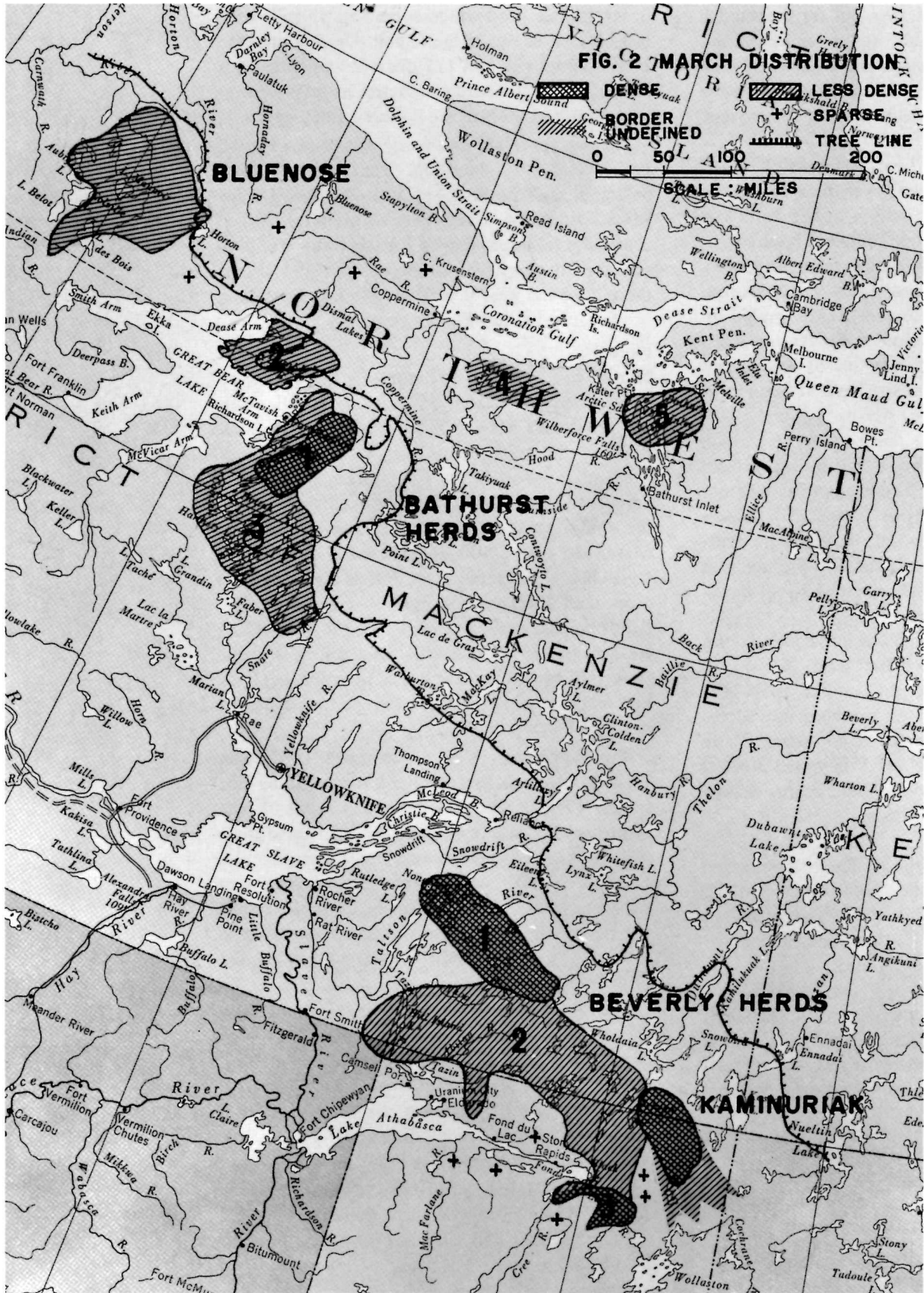
1 Bluenose population

Coverage of the area north of Great Bear Lake was less than desired because of poor weather, the remoteness of the area, and limitations of time and funds. The coastal region southwest of Dolphin and Union Strait was not surveyed because caribou have seldom been reported there in winter (Kelsall, 1968; Kelsall and Hawley, 1966).

First contact with the Bluenose population was on March 25 to 27. Figure 2 shows the distribution observed on those flights.

Caribou were congregated into large bands at the tree line, and trails indicated that some of





these bands had made forays out on the tundra north of Horton Lake but had returned to the trees. Trails in the Ewariege and Maunoir Lakes region indicated that caribou were moving toward the bands concentrated at the edge of the barrens near Horton Lake.

Next contact with the herd was April 26 when a pre-census flight was made over the area and the herd located. Exact distribution of the herd was found the next day and is presented in Figure 4.

During the four-week period between observations the herd moved out from the trees onto the tundra. On March 26 the herd occupied an area of about 9000 square miles, whereas on April 27 it was distributed over an area of 750 square miles, with 90 per cent of the herd in an area of only 200 square miles.

On April 26 only one small group of caribou was sighted within the forest, and it was moving east toward the tundra. The main herd was not moving appreciably on April 26 and 27. Animals in the northern part of the distribution were drifting south or southeast, while those in the southern portion of the distribution were shifting south-southwest.

No further information was obtained on the migration path of this herd after April 27.

It is believed that the shift to the south was temporary and that in May the herd moved toward Bluenose Lake and the Arctic coast. There is a possibility that the herd migrated toward Bathurst Inlet and, if so, it should be considered part of the Bathurst population.

2 Bathurst population

Preliminary mapping of the Bathurst herds began on March 16 and continued until March 30. The distribution and movements of the five herds are given in Figures 2 and 3. More detailed information will be given for each herd.

Herd 1

This large herd became more concentrated as it approached the tundra, and on April 25 it was at the limit of trees and probably reached its greatest concentration. The area covered by the herd contracted as follows (Fig. 5):

March 18	1990 square miles
April 9	1120 square miles
April 18	125 square miles
April 25	40 square miles

Unfortunately we could not follow this herd after April 25. On May 4 we attempted to plot its

progress, but head-winds averaging 45 miles per hour forced us out of the region. On that date the herd had not reached 111 degrees longitude. It is assumed that the herd continued its migration to the calving grounds in the Bathurst Inlet region.

We can speculate on the movement of the herd before March 16. Pronounced trails in the snow indicated that the herd had been in the Hepburn River – Rocknest Lake area and had travelled southwest to either side of Bishop Lake and then into the Wopmay and Grant Lakes region. From there it turned west toward Hottah Lake and then northeast to its mid-March location.

Herd 2

Herd 2 was traversed by flight 9 on March 17 and subsequently on March 25 to 29, April 10, April 26 to 28, and May 4. From March 16 to about April 20 the herd occupied the forested region of Caribou Point in Great Bear Lake. During that period, bands, often large, made excursions out on the tundra north of Hornby Bay. For example, on March 26 about 500 animals were observed in three bands near the East River. On April 10 more than 1200 caribou were observed in several bands on the tundra north of Hornby Bay. One band contained 675 animals. Distinct trails in the snow indicated that these bands were shifting back and forth between the trees and the barren region north of Hornby Bay.

From observations on flights made April 26 to 28 it was obvious that the herd had migrated east to the Coppermine River region. Trails in the snow could be seen for miles. Many of these trails were followed until the band was encountered. Bands at the northern edge of the movement were travelling almost east, whereas bands in the southern portion of the movement turned southeast to follow the route of herd 1, located east of the Coppermine River.

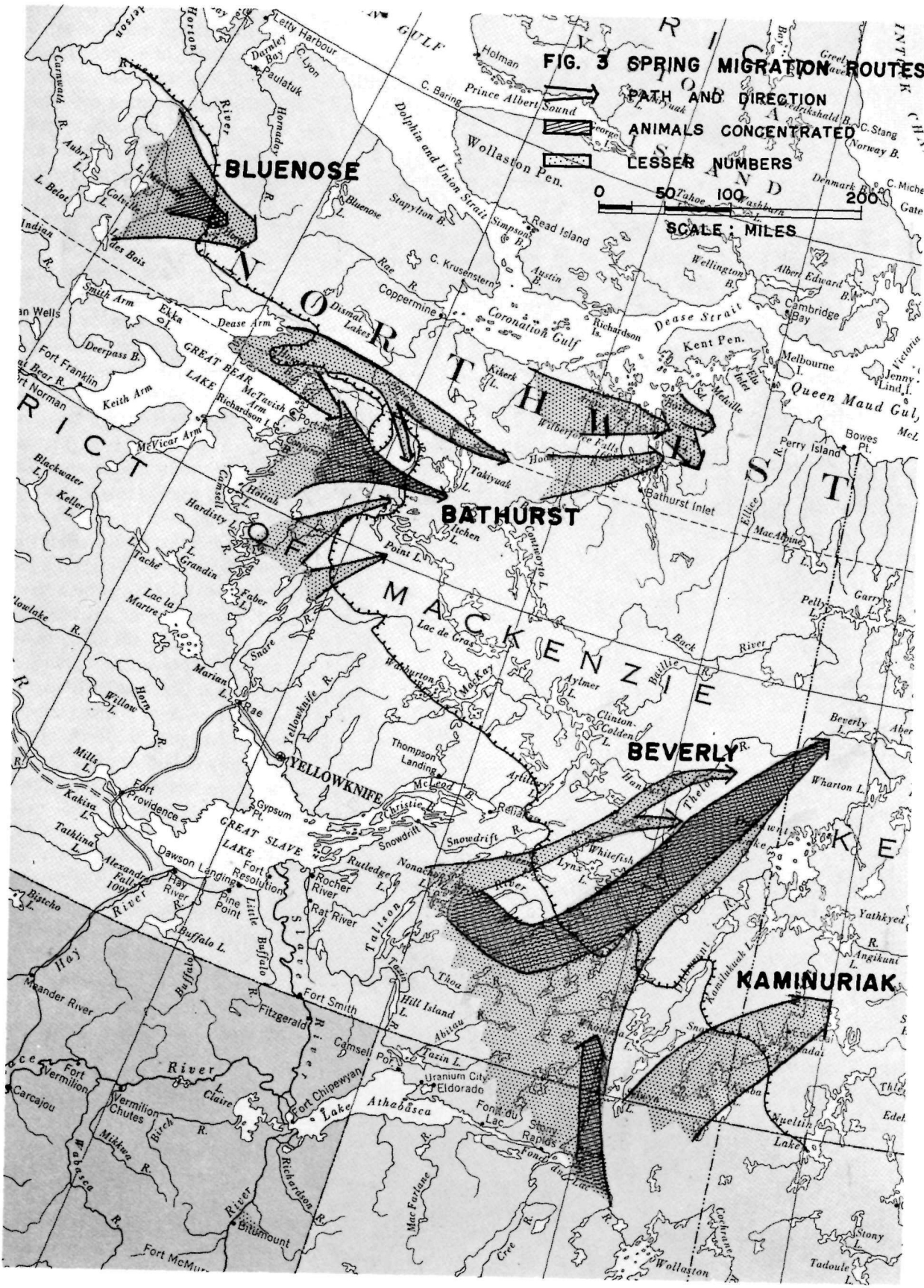
The largest aggregation, 5400 animals, was the result of several smaller bands coalescing as they started the long journey over the tundra. Such a large aggregation was unexpected and probably indicated that snow cover on the barrens made walking and feeding difficult.

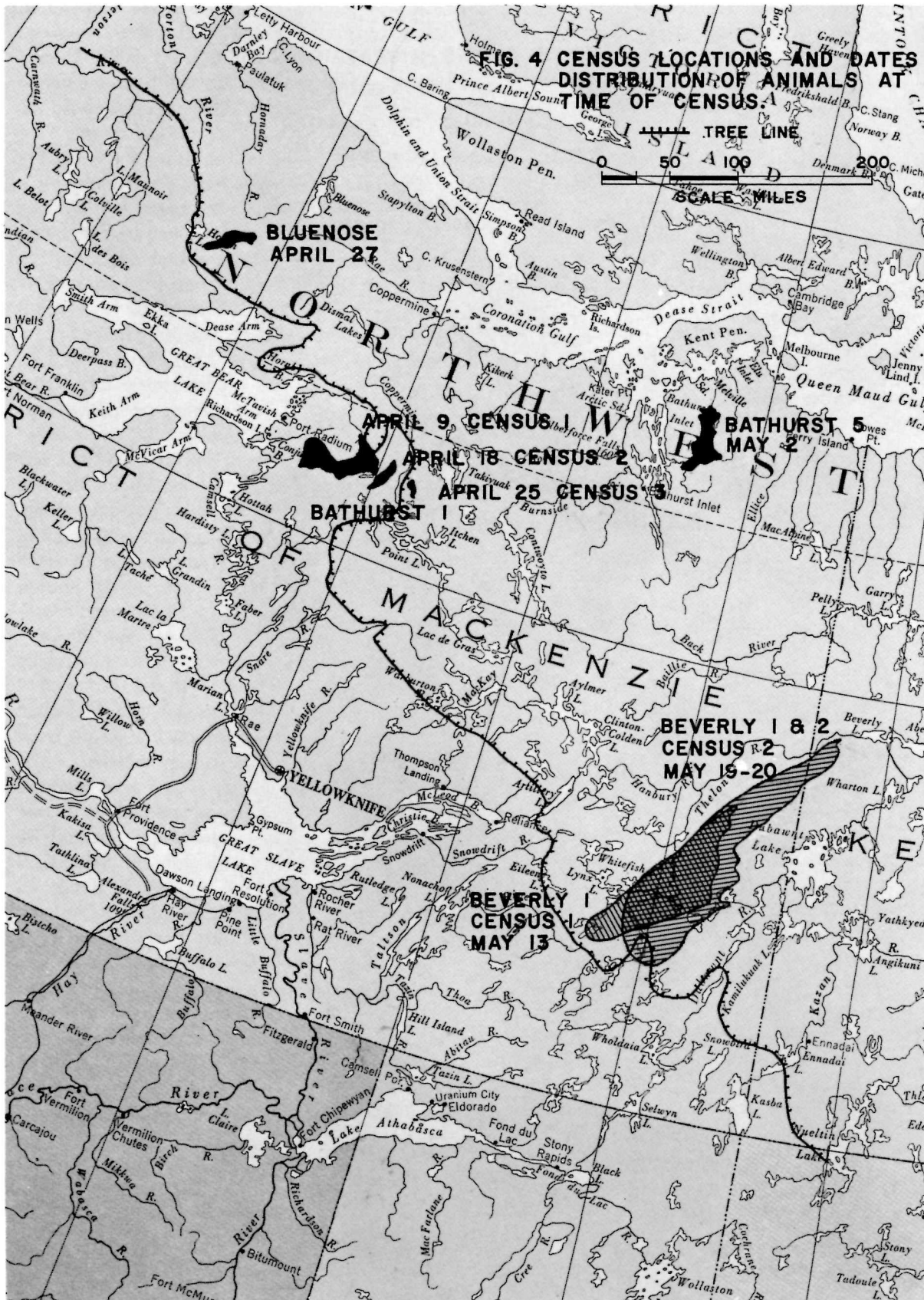
On May 4 caribou and their trails were observed from Bathurst Inlet to the Hood River at 111°45'W. longitude. Some of these were probably caribou that had wintered on the barrens inland from the coast, but many were thought to be animals belonging to Bathurst 2.

FIG. 3 SPRING MIGRATION ROUTES

PATH AND DIRECTION
ANIMALS CONCENTRATED
LESSER NUMBERS

SCALE: MILES
0 50 100 200





Herd 3

Bathurst 3 was continuous with Bathurst 1 in its distribution on March 16, but early in April it was distinct from that herd. The southern limit of the herd was approximately Ghost Lake. Animals in that region were mostly adult bulls. Bathurst 3 was of very low density with animals occurring in pockets of good timber in an area which has been extensively burned.

Migration routes of the herd are shown, in part, by arrows in Figure 3. These arrows indicate migration trails noted on two flights. A pattern of migration similar to that of herd 2 was found. Those animals within about 50 miles of herd 1 headed toward it, while those farther away headed directly toward Bathurst Inlet. The migration had started by mid-April, and most animals had reached the tundra by the end of the month.

Herd 4

Little is known about the size or movements of herd 4. It was learned in Coppermine that in February Eskimos were hunting caribou about 30 to 40 miles southeast of that settlement. On March 29 a flight was made from a point 25 miles inland from Coppermine to Arctic Sound. Visibility was reduced by ice fog, and only two caribou were spotted on the flight. Several small bands were sighted on the peninsula east of Arctic Sound and on Banks Peninsula. Yellowknife pilots had reported caribou in those regions earlier in March.

On April 30 a zig-zag pattern was flown from Kikerk Lake to Bathurst Inlet. Trails of migrating caribou were first encountered four miles east of Tree River, and others were seen as far east as Bathurst Inlet. Migration was in progress and several bands of caribou were counted, including a large one of 289 animals photographed at Wilberforce Falls on the Hood River.

Caribou movements in the Bathurst Inlet, James River, and Hood River region were recorded on flights May 1, 2, and 4. It is not definitely known to which herds all of the trails and caribou can be attributed. It is certain that animals north of the James River and in the Hood River drainage near Bathurst Inlet were coastal animals, but the demarcation between Bathurst 2 animals and Bathurst 4 animals in the upper Hood River system was uncertain if indeed one existed. On May 4 there was a space of about 46 miles in which no animals were sighted along the flight path, and this break was assumed to be the division between the two herds. Based on the migration rate of Beverly

1, which was 15.8 miles per day, forerunners of the Bathurst 2 herd would have travelled, in seven days, from their April 28 position near the Coppermine River to a position 110 miles to the east. If the above assumption is valid, then all animals east of that region on May 4 may be assigned to herd 4.

Had we been able to survey the area around Takiyuak Lake on May 4 as planned, the above speculation would not have arisen, but in the North plans are subject to the vagaries of the weather.

Herd 5

In late March, a series of flights was planned for the barrens around Bathurst Inlet and west to the Coppermine River. A flight on March 29 was not productive because of severe ice fog in the Bathurst Inlet region. Next day, one flight was made over a herd located east of the Inlet. Its presence was known from pilot reports and the observations of the Area Administrator at Cambridge Bay. Fifteen bands totalling 223 animals were counted on the one flight line.

In the rugged country near the coast, the animals were difficult to see, as they were interspersed among rock rubble on the hill tops. It was decided to wait for the herd's movement to a terrain more suitable for strip census.

On May 1 the herd was located 20 to 40 miles east of the Inlet and its precise distribution was found next day when census transects were flown (Fig. 4). Some animals were moving southwest and some northwest on May 2.

3 Beverly population

The Beverly population has been separated into three herds. Preliminary distribution maps were drawn in the second week of March from the information obtained on flights 1 - 7 (Fig. 2).

Herd 1

The distribution of this large herd changed little from March 11 to about April 30, when the herd started to migrate northeast. However, there were always movements within the distribution boundaries. In March the direction of movement was westerly, whereas in mid-April it was east-south-east.

Migration pattern of the herd is given in Figure 6.

Spring migration began about May 1 in the Manchester Lake area. For two or three weeks before that date there was an easterly flow of animals from Nonacho Lake to Manchester Lake.

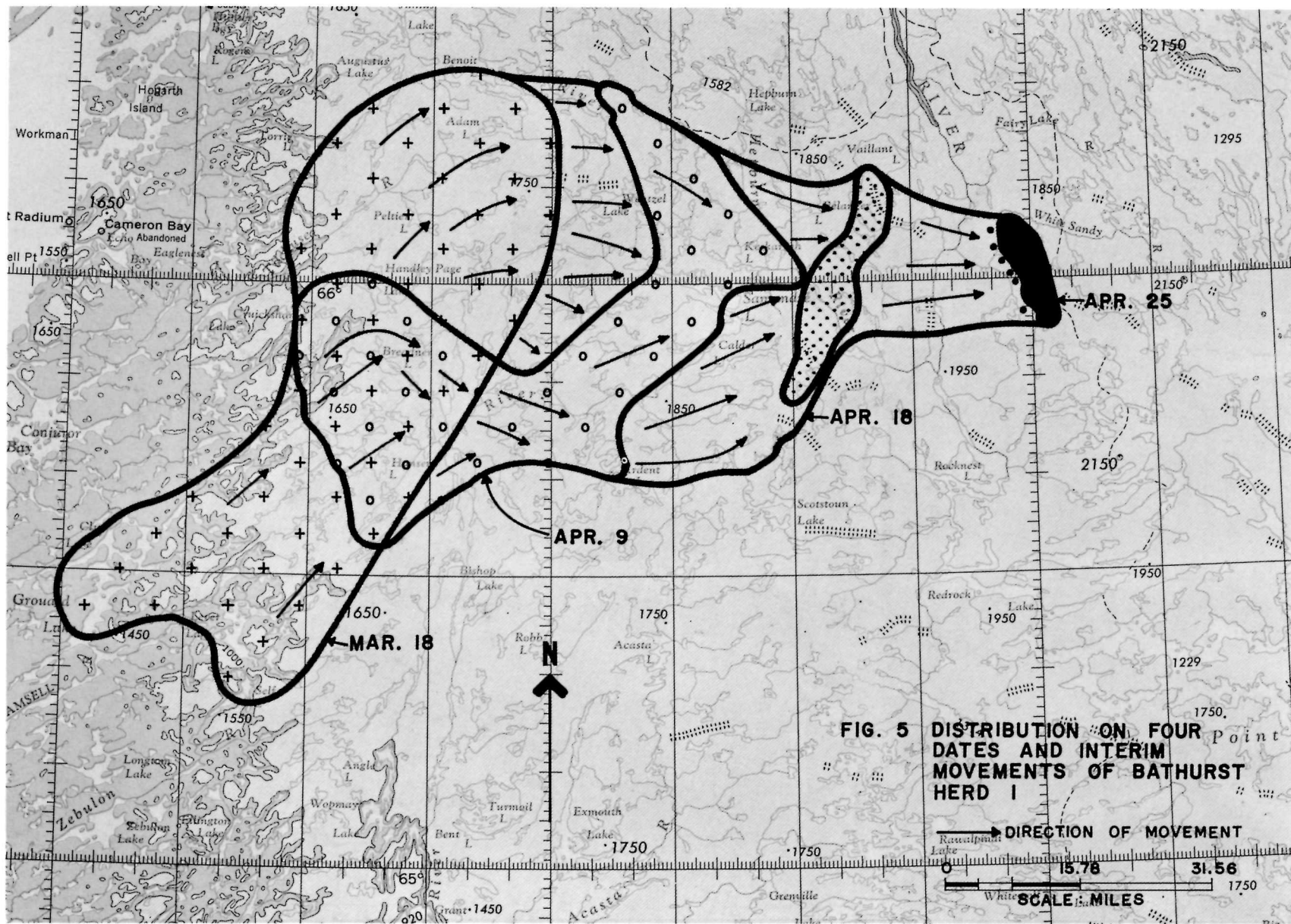
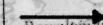
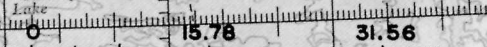


FIG. 5 DISTRIBUTION ON FOUR DATES AND INTERIM MOVEMENTS OF BATHURST HERD I

 DIRECTION OF MOVEMENT

 SCALE MILES

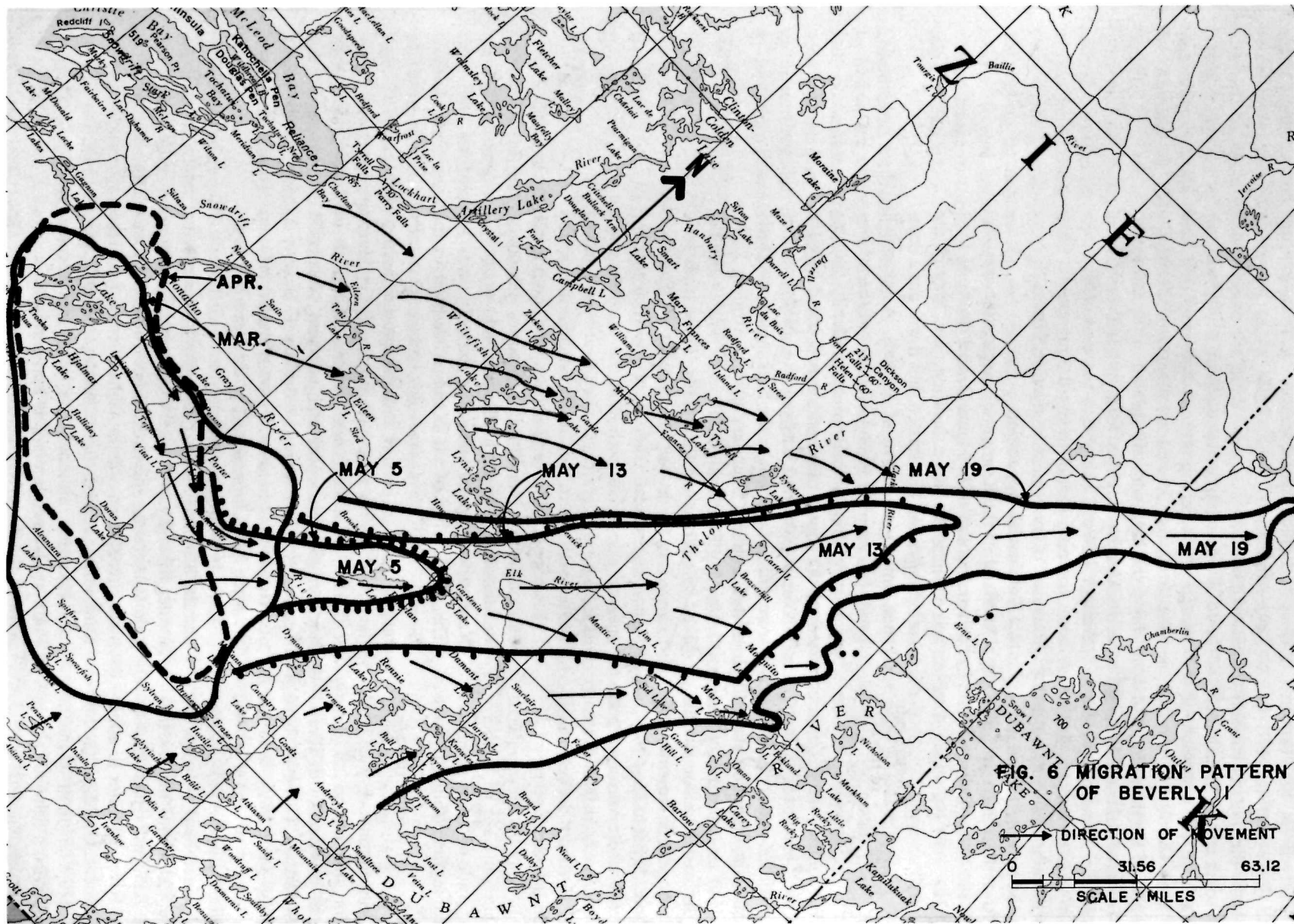


FIG. 6 MIGRATION PATTERN OF BEVERLY I

→ DIRECTION OF MOVEMENT
 0 31.56 63.12
 SCALE: MILES

Well-used trails were observed on the Taltson River between Nonacho Lake and the end of Gray Lake. From Gray Lake the trails of caribou were directed toward the south end of Manchester Lake where there was a large concentration of animals.

On May 5 the forerunners of the migration had reached Gardenia Lake. Hundreds of caribou used the same trail which began on Manchester Lake and passed near the east edge of Penylan Lake. On May 13 the front of the migration was north-east of the Clarke River and on May 19 had nearly reached the Thelon River near Beverly Lake. Rate of migration across the barrens was as follows:

Dates	No. of days	Miles travelled	Average rate of travel, miles per day
May 5-12	8	134	16.7
May 13-19	6	87	14.3
May 5-19	14	221	15.8

As previously mentioned, the migration started on a very narrow front, but as it progressed the movement widened to the east. Caribou on the western limit of the main migration remained static for the two-week period May 5 to May 19.

As indicated in Figure 3, there was a second small migration from Nonacho Lake past Eileen, Whitefish, Tyrrell, and Eyeberry Lakes which joined the main migration between Eyeberry Lake and the Clarke River. On May 12 these animals were scattered from Whitefish Lake to Eyeberry Lake. On May 18 to 20 trails of a few stragglers heading east were noted in the Whitefish Lake region.

Herd 2

In early March herd 2 was continuous with herd 1 and with herd 3. For this reason all three herds could be considered one herd with several foci of densely populated caribou. However, herd 2 was made up largely of adult bulls, whereas herd 1 was composed largely of cows, calves, yearlings, and young bulls. By mid-April the majority of adult bulls had joined herd 1 except for those around Black Lake. On May 5 the few that wintered south of Lake Athabaska had recently crossed the Fond du Lac River 20 miles to either side of Fond du Lac settlement. On May 20 adult bulls with antlers in velvet to a length of 10 inches were migrating in the timber from Selwyn Lake to Porter Lake. Some of those belonged to herd 3,

some to herd 2, while some came from south of Lake Athabaska.

Herd 3

Herd 3 was composed largely of adult bulls, although precise composition counts were not possible from the 35-mm. photographs taken. On May 5 the herd was still located in the same area as in March. On May 20 adult bulls migrating through Selwyn Lake and to the west of that lake were no doubt part of the herd 3 migration. Their direction of movement is given in Figure 3.

4 Kaminuriak population

On March 9 the Kaminuriak population was distributed as shown in Figure 2, and on April 15 it was still in the same location. On May 5 the spring migration had started, but it was not a compact, unified movement of animals. A few small bands had reached Ennadai Lake, but the majority of migrating animals were gradually filtering out of the winter range and were located between Wholdaia Lake and Kasba Lake. Many animals were still as far south as the Saskatchewan-Northwest Territories boundary east of Striding Lake.

On May 20 the migration route was clearly defined by caribou and their trails. These trails were followed as far as the Department of Transport Station at Ennadai, where it was learned that the main migration had passed in the previous seven days. Several migrating bands of caribou, totalling 205 animals, were still in the Ennadai and Kasba Lakes region, and stragglers extended south to the Saskatchewan-Northwest Territories boundary.

Relationship between the Beverly and Kaminuriak populations

The relationship of the Kaminuriak herd to the Beverly herds was one of overlapping winter ranges. Loss of part of the Kaminuriak herd to the Beverly herds may have occurred. On March 9 there were three concentrations of caribou in northern Saskatchewan and adjacent Northwest Territories. These were the Beverly 1, Beverly 3, and Kaminuriak herds. Caribou scattered between the three herds formed part of the Beverly 2 herd.

Early in March the animals between Beverly 1 and the Kaminuriak herd were moving toward the former herd. By mid-April there were virtually no animals between the two herds. Whether the animals involved in the movement were from the Kaminuriak herd or from the Beverly population is not known, although the latter is suspected. From trails encountered, it appeared that a segment of the Beverly 1 herd had spent part of the

winter southeast and east of Black Lake and had, in February, moved northwest to its March location. If so, the animals between the herds were simply stragglers of the Beverly 1 herd. If not, then animals from either the Beverly 3 herd or the Kaminuriak herd joined Beverly 1 during March.

In mid-April there were scattered groups of animals between the Kaminuriak herd and the Beverly 3 herd. Because the distribution of the two populations overlapped, it was difficult to draw distribution boundaries for the respective populations. It was impossible to determine if there was exchange or transfer of animals between the two populations.

Discussion and conclusions

In March the majority of caribou in each of the four populations was located in forested terrain near the tree line. During this period those herds in the northwestern part of the range were closer to the tundra than those farther south.

Herd	Miles from tree line	Degrees of latitude
Bluenose	0	68
Bathurst 2	0	67
Bathurst 1	10-20	66
Beverly 1	40	62
Kaminuriak	80	60

This distribution phenomenon is not caused by latitude *per se*, but is probably a function of climatic conditions, the most obvious of which are depth and hardness of snow. During our plane landings, we observed that snow was deeper in the southeast portion of the range than in the northwest. Deep snow in the southeast portion of the winter range appeared very white in the aerial photographs. Caribou dislike hard, deep snow, and it appears that distribution and eventual migration of the caribou were a response to snow depth and density, as observed earlier by Pruitt (1959).

It is postulated that the distribution of the major herds in winter was dictated by the above climatic conditions and by fire damage to the forested portions of the range. It was noted that the best caribou range was in a belt within 100 miles of the tree line. Forest fires have devastated a large proportion of the range at distances greater than 100 miles from the tree line. It is unlikely that a large herd, such as Bathurst 1 or Beverly 1,

could winter deep in the forested zone, because only a few pockets of mature timber remain, thus decreasing the amount of suitable ground and arboreal lichens available for food.

The only good caribou range of any extent in Saskatchewan was occupied by the Kaminuriak and Beverly 3 herds. It was alarming to see the destruction caused by forest fires in Saskatchewan to the north and south of the Lake Athabaska water-way, and to a lesser extent in the Northwest Territories between Great Slave Lake and Great Bear Lake.

Prior to or during early spring migration, spectacular concentrations of caribou occurred near tree line in the northern herds, but were less evident in the southern herds. It appears that formation of very large aggregations may be a mass response to a favourable environment which spatially is very restricted. If this supposition is correct, the territories occupied by the northern herds (Bluenose, Bathurst 1 and 2) may have been less favourable to caribou than the range occupied by the southern herds (Beverly 1-3 and Kaminuriak) at the time the census was made.

Timing of spring migration to the tundra was related to latitude in a manner similar to that noted for distribution. Caribou in the northwest sector left the forested areas about mid-April, whereas those in the southeast portion of the range left the trees a month later.

Herd	Approx. date one-half the herd had reached the tundra	Approx. degrees of latitude
Bluenose	April 10	68
Bathurst 2	April 25	67
Bathurst 1	April 25	66
Beverly 1	May 9	62
Kaminuriak	May 15	60

Depth and hardness of snow were probably the chief factors which controlled time of migration. Unfavourable snow conditions can impede movement and affect food availability.

The northern edge of the Beverly 1 distribution did not change from March 15 to April 15. Unfavourable snow conditions farther north may have prevented this herd from utilizing what appeared to be equally good range.

Caribou in the northwest part of the winter range fed on the edge of the tundra during late winter, although most of them were within tree line in March. They migrated in April.

Population estimates

It is to be hoped that there will never be so few caribou that it will be possible to count them. (Clarke, 1940)

Introduction

A prerequisite to effective management of a wild-life species is knowledge of the population dynamics of that species. Population parameters of most value in studies of population dynamics are total numbers, composition, recruitment, and mortality. In practice, a sampling procedure is usually required to obtain estimates of actual parameters. One of the most difficult statistics to obtain for large mammal populations is a reliable estimate of population size.

Former estimates of the number of barren-ground caribou on the central mainland of Canada are given in Table 2.

When a population estimate is given for caribou it should be qualified by the time of year, because the July 1 population may be 30 to 35 per cent greater than the May 31 population of the same year. This is because of the addition to the herds of new calves. At the time of the 1967 census the herds were near the low point in the yearly cycle of numbers.

Estimation of caribou numbers is difficult for several reasons. Their pattern of distribution, which is constantly changing, is not a good enough fit to any of the usually employed formal statistical distributions (normal, Poisson, etc.) to permit the use of extremely refined methods of statistical sampling. Caribou are commonly aggregated to such an extent that it is difficult to count them physically, even in a narrow transect. Caribou periodically migrate rapidly so that an aerial census must be completed in one day. They occur in a region where the climate is often inhospitable, and facilities for the census crews such as gasoline and lodging are difficult to obtain, thus making prolonged contact with a specific herd almost impossible.

On the other hand, caribou spend part of the year on the tundra where they are not shielded from view by trees. The amount of effort required

to make an accurate census of caribou in thick tree cover is so great that it was outside the scope of this survey. Because of the restriction on time and funds, it was decided to enumerate the herds after they had left the thick forest and were out on the tundra or in open stands of small trees near the tree line.

In this study four methods were used to obtain estimates of the major herds:

- i) a total count of animals in a given area,
- ii) a strip-census method,
- iii) aerial photography,
- iv) a ratio method.

Each of these is discussed below.

Methods

1 Total count

All non-photographic methods of census rely on the skill of the observers. If the animals are thinly distributed, they can be counted individually. Large aggregations must be counted by the smallest convenient units. During the present survey, units of 1, 2, 5, 10, 20, 50, and 100 were used. Experience in counting by units is vital to the accuracy of such a method. Accuracy is attained by constantly practising the method on survey flights and comparing results with photographs where the actual number of animals in the band is known or can be determined. The shape of the aggregation affects the counting accuracy, because linear groups are more easily counted than non-linear groups.

During total counts air speed was reduced and passes repeated until a satisfactory count was achieved. The area was systematically covered by flying closely spaced transects or by flying a zig-zag pattern. The method is suitable only for the counting of relatively small numbers of animals in a small area.

2 Strip census

A strip census is often used to estimate the size of an aggregation of caribou. The method assumes a random normal distribution of caribou on the ground. Since that assumption is seldom or never completely met, it is necessary to realize the inherent weaknesses of the technique, and to reduce such weaknesses to a minimum by traversing the area occupied by the animals on systematically spaced transects. Spacing of transects (sampling intensity) depends upon the distribution and density of caribou and time-cost limitations. Sampling intensity must be increased as the distribu-

Table 2 Number of barren-ground caribou on the central mainland of Canada

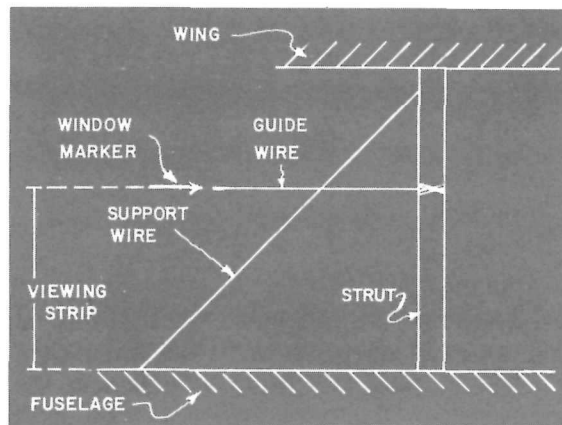
Source	Year	Method	Population
Clarke (1940)	1937	Range capacity	3,000,000
Banfield (1954)	1949	Aerial census	670,000
Kelsall and Loughrey (1955)	1955	Aerial census	277,000
Kelsall (1960)	1958	Census and calculations	200,000

tion departs from randomness. The degree of non-randomness of caribou is often related directly to density, so that density is usually the best guide for the allocation of sampling intensity.

Stratification of a distribution into zones which are sampled at differing intensities will usually produce estimates of most confidence. If the degree of non-randomness varies over the census region then stratification is desirable. The purpose of stratifying is to reduce the variance of the overall population estimate. This is achieved by partitioning the total variation so that much of it is assigned to differences among strata. In this way variation within strata is kept small (p. 417, Steel and Torrie, 1960). Each stratum is sampled at an intensity proportional to the degree of non-randomness. Allocation of sampling effort should be proportional to stratum variances, but since these cannot be calculated in advance, it is assumed that they will vary with density. It is also important to sample more heavily the densely populated strata. By doing so, a greater return is obtained from any given expenditure of time and effort. Siniff and Skoog (1964) used the estimated population of each stratum as a basis for allocation of sampling effort.

In this paper variances and confidence limits were not calculated. They would be theoretically invalid because the sampling was systematic rather than random. Also since the actual distribution of animals could not be recorded and fitted to the random normal distribution, variances so calculated would tend to be too large and limits too wide by an unmeasurable amount. The method used is based on an assumption of a normal random distribution in full realization of its weaknesses, and with stratification and other measures employed to minimize those weaknesses. Although the strip census method has its limitations, it was considered to be the most efficient method available for censusing caribou under many of the field conditions encountered.

When the strip census method was employed, certain procedures were followed. If time permitted, the distribution and relative densities of the herd were determined on the day previous to the census. Line transects were drawn on 1:250,000 maps at right angles to the main axis of the herd and extended past the known or presumed distribution borders. The area was then stratified on the basis of caribou density.



7 Apparatus used on left side of aircraft to mark strip width, as viewed from back seat.

Prior to take-off, the aircraft altimeter was adjusted for pressure changes and the strip widths appropriate for the census conditions were determined. The first observer sat beside the pilot on the right side of the aircraft. Markers on the strut and the window gave the angles which produced various strip widths. A wire device (Fig. 7) was constructed on the left side of the aircraft to mark the outer border of the strip censused by the second observer (seated in the rear of the aircraft). Angles of observation were checked in flight before each census.

Strip widths are calculated from the observation angle readings taken on the Brunton compass. In a right-angled triangle the tangent of an angle is equal to the opposite side divided by the adjacent side. A table of natural tangents will give figures necessary for the calculations. Allowance must be made for the blind spot under the aircraft.

The surveys were flown at 600 or 800 feet, depending on conditions. The rule was to fly as high as possible to increase coverage, but not so high that animals were difficult to see. Flying at lower altitudes tends to increase the error caused by variations in relief and makes map reading difficult. Map reading was done exclusively by the pilot on census flights. He was instructed to follow the flight line religiously and definitely not to steer toward caribou. Animals sighted off the strip were recorded in a notebook, when it was obvious no animals on the strip would be missed meanwhile. Binoculars were often used to scan any patch of ground on which it would be difficult to see animals. When large numbers of animals were encountered the pilot slowed the aircraft to about 70 miles per hour. Transects were terminated when it was certain that the outside edges of the herd had been passed. The pilot marked the transect entry and exit points.

The strip census method is not suitable for areas where elevation varies greatly, although it may be argued that the variations in strip width caused by the relief will tend to cancel out, provided the aircraft is maintained at a given altitude

above the average relief. Some of the errors inherent in the strip-census method are given in Banfield *et al.* (1955).

3 Aerial photography

Aerial photography can be employed to obtain a very accurate count of large aggregations, or an entire herd of caribou if they are concentrated in a small area. An aerial camera was used to obtain accurate counts of three herds, and a 35-mm. reflex camera was used to record the size of one large aggregation and several smaller ones. Overlapping photographs were taken of aggregations too large to encompass in one photograph. If caribou are on a contrasting background they can be counted on photographs taken at long range.

In the laboratory, prints were viewed at a magnification of 6× or 12× with a binocular dissecting microscope using reflected light, and individual caribou were marked with India ink as they were counted.

4 Ratio

The ratio method is ideally suited to the estimation of numbers when a certain identifiable class of known frequency in a population is absent or partly absent from a censused population. If fully grown bull caribou, which we shall define as those four years of age or older at the time of census, are known to constitute 20 per cent of a population but are absent from the censused portion of the population, then the estimated size of the population censused must be increased by a factor of 1.25 to account for the bulls. If the bulls are known to constitute a herd elsewhere, then the size of that herd is evident.

Estimates of the caribou herds relatively deep in the forest, which were known to be mostly fully grown bulls, were made by the above method. It was necessary to determine the percentage of adult bulls in the herds censused to apply the method. This was obtained from aerial photographs.

Results of herd estimates

1 Bluenose population

An estimate of the Bluenose herd was obtained on April 27. On the previous day, a search flight was conducted to determine the location of the herd and a gas cache placed in the centre of the herd. About 90 per cent of the herd was located in an area of about 200 square miles (Fig. 2).

In preparation for a strip census, lines were drawn on 1:250,000 maps (one inch = 3.95 miles)

at 0.25-inch intervals to cut across the distribution pattern at right angles to the long axis.

Because the ground was covered with recent snow and it was sunny, caribou could be seen for long distances. Accordingly, starting at transect 3 every second line was flown at an altitude of about 1000 feet.

On the flat terrain it was possible to see caribou beyond one mile, so a total count was attempted. When isolated large aggregations suitable for photographing were encountered, it was decided to totally count the northwest portion of the area occupied by caribou, using the transects, and then photograph and totally count the large aggregations in the remainder of the distribution.

Odd-numbered transects 3 to 25 were flown, and a total count was obtained for that portion of the herd. The remaining aggregations of the herd were photographed if they were large, or counted if they were small or in a long file. The whole area occupied by the main herd was systematically searched and all bands recorded.

The number of caribou in each aggregation photographed was estimated at a glance, usually to the nearest 50, in case the photographs proved to be defective. This was not the case, and caribou were easily counted on the printed photographs. A stereoscope was used at a magnification of 6×, and individual animals were marked with India ink as they were tallied. The results of this count are presented in Table 3.

The total number of caribou counted in 148 small bands between the larger photographed aggregations was 7094, an average of 48 per band.

Total count on transects 3 to 25:

Observer 1	383
Observer 2	456
Both	<u>839</u>

Summary of results:

Photographed	9,557
Counted between photographs	7,094
Counted on transects	839
Total	<u>17,490</u>
Estimated number missed or outside area censused	1,500
Total for herd	19,000

The events leading to the estimate of this herd illustrate how versatile the estimator must be to

achieve the best results. He must choose the type of census best suited to the conditions that he encounters.

The method of census was changed from a limited strip census to a total count using systematic transects, to a photographic and total count. A recent undrifted snowfall of about three inches caused the caribou to congregate into large bands which were generally well separated from other bands.

The disparity between the photographic and the estimated counts (Table 3) is not large when it is realized that band size was usually estimated at a glance and not by the individual animal or unit counting method. The first few aggregations were counted with more care, which is reflected in the accuracy of the first 11 counts:

Estimated number	2705
Actual number	2692

On April 26, bands numbering 12, 13, 14, and 15 animals were found in an area of 1500 square miles outside the census area. About 170 square miles were sampled, to yield a figure of about 600 animals in the area. Probably another 900 animals were missed in the region north and east of the main distribution, and in the forested region to the west. These two estimates were added to the census total to produce the final estimate of 19,000 for the herd. No adjustment for mature bulls has to be made to the herd estimate, because the full complement of bulls was present in the censused herd.

2 Bathurst population

Herd 1

Census 1

On April 8 the location and relative density of herd 1 were determined. Because most of the herd was in a relatively small area (1120 square miles), and future movements of the herd were uncertain, it was decided to census them even though part of the herd was in rugged, forested terrain. It was also desirable to introduce the pilot and second observer to the strip-census method and to experiment with strip widths under different ground conditions including forest cover.

Lines were drawn on 1:250,000 maps (1 inch = 3.95 miles) at one-quarter inch intervals to cut across the narrow part of the distribution. The area was stratified into three zones and it was planned to survey zone A on transects at one-mile intervals and zones B and C at two-mile intervals.

Table 3 Number of caribou estimated compared to a photographic count of aggregations north of Great Bear Lake

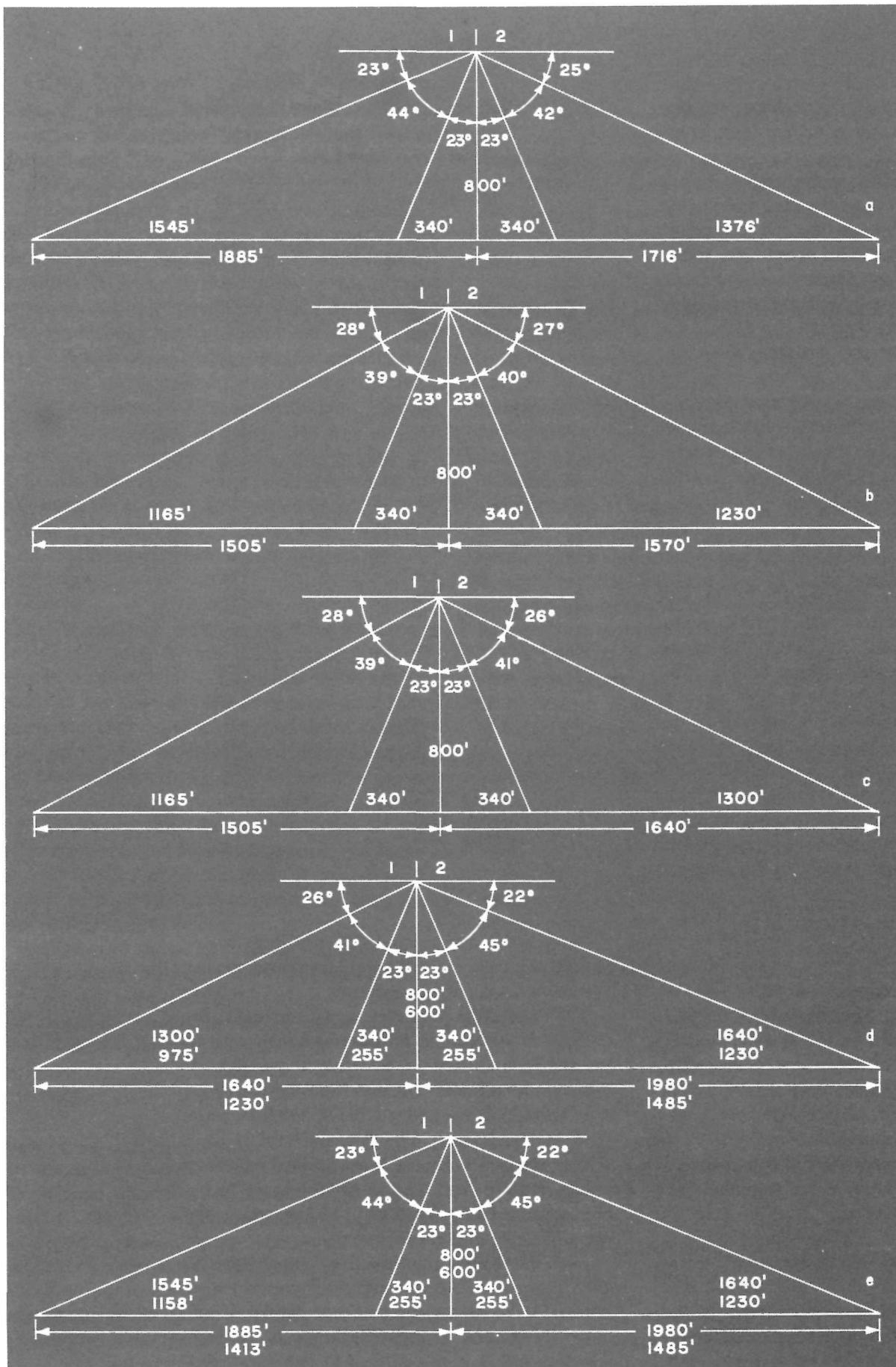
Frame no.	Estimated number	Number photographed
pre- 1	280	(no photo) (280)
1	150	177
2	200	175
3	200	190
4	250	287
5	250	280
6 } 7 } 9 }	500	396
10	300	272
11	105	114
12	400	408
13	150	192
14	250	396
15	500	558
16	200	414
18 } 19 }	400	705
21	450	796
22	400	530
23	270	308
24	200	285
25	250	363
26	170	200
27	150	246
28	250	388
29	650	598
30	150	174
31	200	416
32	100	228
	Total 7575	Total 9557
	Difference 1982	
	% Difference 20.7	

Zone A had a dense population and large aggregations, whereas zones B and C contained smaller and more scattered aggregations.

The aircraft's altimeter was corrected for changes in barometric pressure and then used to maintain an altitude of 800 feet above ground. Ground altitude was obtained from the numerous spot elevations marked on the 1:250,000 maps used for navigation. The first observer, having several markers to choose from, decided on a strip width of 1376 feet. The second observer had a predetermined strip width of 1545 feet, which was not adjustable in flight (Fig. 8a).

Even-numbered transects 2 to 28 of zone C were flown first. After a refueling stop north of Wentzel Lake we decided that time did not permit us to fly zone A at one-mile intervals, so both zones A and B were censused at two-mile inter-

8 Observation angles and strip widths: (a) Bathurst herd 1, census 1; (b) Bathurst herd 1, census 2; (c) Bathurst herd 5; (d) Beverly herd 1, census 1; (e) Beverly herd 1, census 2.



vals, before refueling and returning to Port Radium. Transect totals are given in Table 4.

The greatest source of error in the census was the inability to see caribou in the timber of zones B and C. The second observer stated that most caribou he counted were on the inner portions of the strip, suggesting that most caribou at the outer reaches of the strip were missed, except those on lakes. I estimated that only about 80 per cent of the strip was effectively counted.

Most of the disparity between the two observers is attributed not to chance or distributional differences, but to the excessive strip width of observer 2 and his inexperience in enumerating caribou from an aircraft. An experienced observer will see more animals than an inexperienced ob-

server. It has been demonstrated that where it is possible to look ahead observers in the front seat miss fewer caribou than those in the rear seat, who can see to the side only (Bergerud, 1963).

Another reason why the counts of zone B varied was that an unexpected mass of caribou was encountered at the south end of transects 30, 32, and 34. Our transects, by chance, did not pass over many of the caribou in that region, but most of those tallied were recorded by the first observer. The region of high density should have been stratified and flown at mile intervals, but light conditions and fuel supply were not adequate to extend coverage of the region.

Adjustments to the estimate (Table 5) obtained by the strip-census method are subject to criticism.

Table 4 Results of census 1, Bathurst 1

Zone C			Zone A			Zone B		
Trans. no.	Caribou counted		Trans. no.	Caribou counted		Trans. no.	Caribou counted	
	Obs. 1	Obs. 2		Obs. 1	Obs. 2		Obs. 1	Obs. 2
2	21	0	2	15	0	30	319	241
4	15	9	4	0	0	32	753	140
6	64	33	6	60	25	34	181	50
8	171	92	8	0	60	36	125	24
10	302	170	10	20	0	38	157	1
12	62	70	12	83	42	40	40	252
14	255	135	14	534	290	42	47	88
16	134	359	16	11	400	44	45	5
18	335	200	18	185	160	46	113	40
20	295	710	20	210	30	48	105	27
22	137	210	22	0	0	50	240	301
24	108	65	24	0	78			
26	69	63	26	473	202			
28	237	44	28	180	320			
			30	15	0			
			32	15	0			
			34	0	2			
			36	20	0			
Total	2205	2160		1821	1609		2125	1169
Observer	Strip width		Percentage coverage		Caribou counted			
1	1376 ft.		13.03		6151			
2	1545 ft.		14.63		4938			
Both	2921 ft.		27.66		11089			

Note: Spacing of transects = 10,560 ft.

Table 5 Estimate of numbers, Bathurst 1, census 1

Observer	Zone C	Zone A	Zone B	All zones	Adjust. 1	Adjust. 2	Adjust. 3
1	16,922	13,975	16,308	47,205	59,006	73,757	82,000
2	14,963	10,997	7,990	33,750	42,187	52,734	58,500
Both	15,780	12,400	11,908	40,088	50,110	62,637	69,500

Adjustment 1 – Estimated 20 per cent of caribou missed in that part of strip in which animals were generally visible.

Adjustment 2– Estimated 20 per cent of strip not counted because it was too wide.

Adjustment 3 – Estimated 10 per cent of herd was outside area censused.

Note: In this table and subsequent tables of estimates the estimate of numbers for observer 1 is calculated from a ratio formula.

$$\frac{\text{Area of transect strips of observer 1}}{\text{Total area occupied by caribou}} = \frac{\text{Caribou counted on strips by observer 1}}{\text{Total caribou in area surveyed.}}$$

The resulting estimate (for a zone, herd, etc.) would be used if only observer 1 was conducting the census. Estimates for observer 2 are calculated in a like manner. Estimates for both observers are obtained by the same ratio method. Area covered by the strips of both observers and total animals seen by both observers are substituted into the formula. The resulting estimate is not an average of the individual estimates when the observation angles of the two observers differ.

Adjustment 1 is reasonable because of the tree cover. Several other workers have found, by experimental methods, that about 20 per cent of the caribou are missed under similar conditions of visibility (Banfield *et al.*, 1955; Watson and Scott, 1956; Bergerud, 1963). It is obvious that the exact figure missed will vary with the particular census conditions. Twenty per cent is probably a reasonable correction factor.

Adjustment 2 was necessary because the strips were too wide to see all animals in the tree cover at the outer portion of the strip. This was especially true for the strip counted by the second observer.

Adjustment 3 was necessary because an estimated 10 per cent of the herd was outside the region censused.

Census 2

On April 17 Bathurst herd 1 was concentrated in the Hepburn River region (Fig. 9). Probably 90 to 95 per cent of the herd was in a 125-square-mile area, with the remainder of the herd migrating toward that region from the west.

The terrain occupied by the herd had little relief except for hills about 300 feet high west of the Hepburn River. Except for the hill tops, which were barren, the region was characterized by open areas interspersed with patchy areas of small trees. The open stands of small trees did not appreciably obscure animals.

In preparation for a strip census, transects equivalent to one-mile ground intervals were prepared on 1:250,000 maps. The area was stratified into two zones, one to be intensively surveyed at one-mile intervals and the other to be surveyed at two- or four-mile intervals depending on time available.

Next morning plans had to be changed because Samandre Lake and the area to the east were in ice fog. None of the transects could be flown until the fog burned off. On the flight to Samandre Lake, 414 caribou were sighted, a surprisingly high number, so transects at four-mile intervals were flown in a new zone C.

After a refueling stop, zone A was censused at one-mile intervals. After another refueling stop, light conditions were not adequate to census zone B.

All transects were flown at an average altitude of 800 feet above ground. Observation angles and strip widths are shown in Figure 8b. When large aggregations were encountered the pilot lowered flaps and reduced speed to about 70 miles per hour to facilitate counting.

Results are given in Tables 6 to 10.

The largest source of error in this census is attributed to the difficulty of accurately counting large aggregations. Much of the error that could have arisen because of the non-randomness of distribution was overcome by the intensity of sampling.

Table 6 Results of census 2, Bathurst 1, zone A

Transect no.	Caribou counted		
	Obs. 1	Obs. 2	Both
2	0	0	0
3	0	0	0
4	0	0	0
5	0	12	12
6	235	610	845
7	275	570	845
8	930	900	1,830
9	260	185	445
10	645	400	1,045
11	2,900	1,440	4,340
12	330	375	705
13	75	521	596
14	450	220	670
15	1,400	800	2,200
16	400	130	530
17	2,350	981	3,331
18	3,276	885	4,161
19	2,780	1,570	4,350
20	265	207	472
21	1,650	90	1,740
22	50	110	160
23	354	8	362
24	700	140	840
25	45	67	112
26	650	900	1,550
27	0	0	0
28	0	14	14
29	60	200	260
30	4	75	79
31	320	210	530
32	110	33	143
33	120	110	230
Total	20,634	11,763	32,397

Disparity between observers in numbers counted was attributed in part to caribou distribution and in part to differences in experience of observers. Distribution characteristics and the chance location of transects produced a high count for the first observer on transects 11, 18, 19, and 21. A large part of the difference in totals was accounted for on transects 18 and 19 when a concentration of animals occurred between the transects and was tallied largely by the first observer.

Census 3

On April 25 the herd was located at the limit of trees east of the Coppermine River. It was estimated that 90 per cent of the herd was in an area of 40 square miles (Fig. 4). It was an excellent opportunity to obtain a photographic count of the herd using the K20 aerial camera.

The herd was systematically photographed, starting at the south end. Large aggregations were photographed with several overlapping frames.

Table 7 Calculation of numbers, census 2, Bathurst 1, zone A

Observer	Strip width, ft.	Percentage coverage	Caribou counted	Estimate of numbers
1	1230	23.3	20,634	88,575
2	1165	22.1	11,763	53,312
Both	2395	45.4	32,397	71,422

Table 8 Results of census 2, Bathurst 1, zone C

Transect no.	Caribou counted			Tallied outside strips
	Obs. 1	Obs. 2	Both	
A	3	12	15	263
B	0	20	20	0
C	0	0	0	0
D	0	0	0	0
E	0	0	0	120
F	0	0	0	0
G	0	0	0	0
H	0	35	35	0
I	0	0	0	80
J	0	0	0	0
Total	3	67	70	463

Note: Interval between transects = 21,120 ft.

Table 9 Calculation of numbers, Bathurst 1, census 2, zone C

Observer	Strip width, ft.	Percentage coverage	Caribou counted	Weighted estimate of numbers
1	1230	5.8	03	52
2	1165	5.5	67	1215
Both	2395	11.3	70	617

Table 10 Estimate of numbers, Bathurst 1, census 2, all zones

Observer	Zone A	Zone C	Zones A, C	Adjusted*
1	88,575	52	88,627	93,291
2	53,312	1,215	54,527	57,397
Both	71,422	617	72,039	75,830

*Estimated 5 per cent of herd outside census areas.

Small bands were not photographed because of insufficient film, but many of these were counted and recorded by observer 2.

Ninety pictures taken at altitudes up to 1000 feet were required to photograph all large aggregations. After coverage of the herd was complete, 13 photographs of the region of highest density

were taken at 2000 feet above ground. These frames were taken to see if caribou could be counted on photographs taken at high altitude and to aid in the photographic reconstruction of the area at the time caribou on the photographs taken at low level were being counted.

When the 4 × 5 inch prints were received they were viewed under a stereoscope at 6× or 12× magnification. Overlapping photographs were delineated so that no animals would be counted twice, and individual animals or groups of ten were marked with India ink as they were tallied.

Table 11 Results of census 3, Bathurst 1

Film No. 6				Film No. 7			
Frame no.	Caribou	Frame no.	Caribou	Frame no.	Caribou	Frame no.	Caribou
1	240	29	1739	1	369	Duplications at high altitude	
2	345	30	1319	2	424		
3	462	31	994	3	580		
4	918	32	396	4	335	35	5307
5	334	33	2600	5	234	36	2524
6	262	34	2500	6	305	37	8200
7	197	35	5320	7	69	38	3500
8	169	36	6200	8	162	39	4350
9	344	37	2600	9	290	40	3340
10	324	38	1280	10	485	41	2480
11	67	39	1180	11	256	42	3200
12	535	40	990	12	1645	43	2100
13	370	41	343	13	919	44	735
14	226	42	160	14	660	45	2200
15	excluded	43	1960	15	2200	46	1450
16	720	44	excluded	16	407	47	600
17	3690	45	840	17	1950	Total	39986
18	500	46	475	18	1650		
19	1430	47	1270	19	140		
20	883	48	1532	20	excluded		
21	193	49	122	21	excluded		
22	1250	50	981	22	891		
23	1033	51	699	23	excluded		
24	476	52	1600	24	2125		
25	213	53	437	25	752		
26	310	54	440	26	508		
27	960	55	240	27	excluded		
28	2440	56	200	28	244		
			57308	29	1205		
				30	1220		
				31	850		
				32	850		
				33	1900		
				34	657		
				Total	24282		

Results are shown in Table 11.

Total of photographic count (84 photos)	Film 6 – 57,308 Film 7 – 24,282
	81,590
Counted and not photographed	2,355
Total	83,945
Herd size:	
Total photographed and counted	83,945
Estimate after adjustment 1*	88,360
Estimate after adjustment 2†	93,000

The estimate of the Bathurst 1 herd from aerial photographs is considered to be the most accurate

*Adjustment 1 – Estimated 5 per cent of caribou missed in region surveyed.

†Adjustment 2 – Estimated 5 per cent of caribou outside of area surveyed.

ever achieved on a herd of that magnitude. Accuracy could have approached 100 per cent if an automatic aerial camera mounted on the bottom of the aircraft fuselage had been used.

Most of the caribou in the photographs taken at 2000 feet could be counted because they contrasted with the white background. The photographic count in census 3 produced estimates which are probably within five per cent of the true herd size. Results of the other two censuses can be analysed in terms of the census 3 result (Table 12).

Table 12 Summary of Bathurst 1 estimates

Observer	Census 1	Census 2	Census 3
1	82,000	93,000	—
2	58,500	57,500	—
Both	69,500	76,000	93,000



9 Bathurst herd 1 approaching the limit of trees early in spring migration, near Hepburn River, 60 miles east of Great Bear Lake, April 17, 1967. Altitude of aircraft approximately 200 feet.



10 Migrating caribou near the Big Bend of the Coppermine River, April 28, 1967. There are about 1260 animals in the photograph. Altitude of aircraft approximately 500 feet.

Compared to the census 3 total, the adjusted estimates of observer 1 are 10 per cent low in census 1 and equal in census 2. Assuming that the estimate of the number outside the census areas is correct and that no errors were caused by the non-randomness of distribution or other weaknesses inherent in the strip-census method, then about 43 per cent of the animals were missed or undercounted by observer 1 in the first census. Since aggregations were not large over most of the census region, animals missed because of trees were the cause of the estimate error. Estimates of observer 1 in the second census, where no adjustment was necessary because animals were exposed to view, were quite accurate.

Adjusted estimates of the second observer are about 36 per cent low in censuses 1 and 2. Excluding other sources of error, in census 1 he missed or undercounted about 58 per cent of the animals and in census 2, 38 per cent of the animals. In census 1 the error was largely due to missed animals, while in census 2 it was due to an underestimation of very large aggregations.

Herd 2

A partial census of herd 2 was conducted on April 28. By that date all but a few stragglers had left the winter range and were in the Coppermine

River region (Fig. 10). All large trails were followed until the aggregation was found and counted or photographed. One very large aggregation was photographed with three frames on the aerial camera and partially photographed with 18 overlapping frames on the 35-mm. camera. After 18 frames the film ran out, and the remaining animals in the large aggregation were counted.

The large aggregation was counted in units of 100 by observer 1. The tally was 5,000 animals. Observer 2 counted it twice and estimated 4,500 and 4,300 caribou. The two photographic counts were not in complete agreement. Five thousand two hundred animals were counted on the three photographs taken with the aerial camera. Those in the background of the third frame were obscure because of the long range. A count of the 18 Kodachrome transparencies gave a total of 4490 caribou. In addition 1150 animals were counted after the film ran out, giving a total of 5640. These two counts were averaged to arrive at the total of 5400 for the aggregation. The result indicates that total counts of very large aggregations can be reasonably accurate, if the observer is experienced.

One other large aggregation of animals near the Big Bend of the Coppermine River was photo-

graphed. It contained 1323 animals. Smaller aggregations, totalling 890, were counted without aid of the camera. Most of these were in an area south of the Big Bend of the Coppermine River.

Results:

Total photographed (two aggregations)	6,723
Total counted	890
Grand total	7,613
Adjusted total*	10,000

Herd 3

This herd was not censused because it was less important than the major herds and was widely scattered within the forest until about April 30. During March and April many bands of herd 3 joined herd 1 as the latter started to migrate toward the Coppermine River. For example, on April 17 a pronounced trail was followed from a point 32 miles south-southwest of Ardent Lake to that lake, at which point the trail was obliterated by other trails. Sixty animals were counted in one group along the trail. On April 25, when census 3 was conducted on herd 1, perhaps 20,000 animals were still south of herd 1.

The size of herd 3 may be deduced from ratios derived from composition counts. It is known that animals in the southern portion of herd 3 were adult bulls. It is assumed that they were all adult bulls belonging to herds 1 and 2.

A count of antlerless bulls in herd 1 was made. Only 1.9 per cent of the herd was composed of large bulls which had lost their antlers by April 17 (sample size = 1875). Many of those bulls with no antlers on April 17 were obviously young bulls two and three years old. The older, mature bulls were elsewhere.

On April 28, herd 2 was composed of 2.9 per cent antlerless bulls (sample size = 1702), but again many of these were young bulls.

Owing to segregation by age and sex, it is seldom possible to get herd composition counts of caribou that represent the over-all herd structure. Kelsall (1968), who compiled ratios of adult males to adult females from many sources, indicates that about 35 per cent of adult caribou are males. If adult bulls are considered to be those four years and older and if 60 per cent of the population is four years or older, then those bulls should represent about 21 per cent of the population. Since

*Adjustment: Estimated 75 per cent of total herd was photographed or counted.

the combined population of herds 1 and 2 is about 100,000, there are about 25,000 adult bulls to be accounted for and these must have comprised herd 3. It is estimated on the above calculations that herd 3 contained 25,000 to 30,000 animals.

Herd 4

Herd 4 was observed in migration on April 30 and May 4. Animals sighted and attributed to the herd totalled 1900. Some had crossed Bathurst Inlet on May 1, but most were still in the Hood River system on May 4. It was noted that some bands contained a large percentage of mature bulls.

From caribou sighted and trails observed, it is estimated that the herd contained 5,000 to 10,000 animals, with the former figure more likely.

Herd 5

Herd 5 was located east of Bathurst Inlet on May 1 and was stratified into two zones and censused next day. Zone A was flown at one-mile intervals, and zone B at two-mile intervals. The area occupied by the animals was excellent for strip census: flat and snow-covered.

Observation angles and strip widths are given in Figure 8c. The results of census 5 are given in Tables 13, 14, and 15.

Census results of Bathurst 5 are considered accurate because conditions were excellent for the strip method; animals were not highly aggregated so that most counts were exact; visibility was good and animals easy to see against the snow background; relief was slight over most of the census area. The above factors combined with intensive coverage produced little difference between the two observers' estimates.

3 Beverly population

Herd 1

Census 1

On May 5 Beverly 1 had started to migrate in the Manchester Lake region and caribou at the front of the movement had reached Gardenia Lake. It was necessary to wait until most of the herd had reached the tundra before attempting a census.

On May 12 the width of the migration in the Beaverhill-Mosquito Lakes region was determined and a census was planned for the following day. Lines were drawn on 1:250,000 maps at right angles to the direction of migration so that if high densities were encountered transects could be flown at one-mile intervals. The plan was to stratify the area covered by the herd as the transects were being flown.

Table 13 Results of Bathurst 5 census

Zone A			
Transect no.	Caribou counted		
	Obs. 1	Obs. 2	Both
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	14	15
8	110	45	155
9	103	70	173
10	165	281	446
11	385	520	905
12	375	125	500
13	03	15	18
14	250	70	320
15	165	70	235
16	90	156	246
17	59	112	171
18	22	28	50
19	0	36	36
20	0	34	34
21	0	2	2
22	0	0	0
23	0	58	58
24	46	45	91
25	25	0	25
26	200	30	230
27	110	75	185
28	11	78	89
29	17	8	25
30	0	29	29
31	110	0	110
32	24	40	64
33	83	0	83
34	50	91	141
35	13	0	13
36	0	0	0
Total	2416	2032	4449

Zone B			
Transect no.	Caribou counted		
	Obs. 1	Obs. 2	Both
38	20	74	94
40	15	25	40
42	21	54	75
44	0	0	0
46	0	0	0
Total	56	153	209

Table 14 Calculation of numbers, Bathurst 5, zone A

Observer	Strip width, ft.	Percentage coverage	Caribou seen	Herd estimate
1	1300	24.6	2416	9813
2	1165	22.1	2032	9209
Both	2465	46.7	4448	9527

Note: Interval between transects = 5,280 ft.

Table 15 Calculation of numbers, Bathurst 5 zone B

Observer	Strip width, ft.	Percentage coverage	Caribou seen	Herd estimate
1	1300	12.3	56	455
2	1165	11.0	153	1387
Both	2465	23.3	209	895

Note: Interval between transects = 10,560 ft.

Estimates of numbers, zones A and B:

Observer 1	10,268
Observer 2	10,596
Both	10,422

Estimated 10 per cent of herd outside census region.

Estimated population = 11,500

The census was started at 800-foot altitude on transect C7 (Fig. 11), which was expected to be near the front of the migration. Accordingly, the region between C7 and the Clarke River was flown at two-mile intervals. Because caribou were not encountered in large numbers, a change was made to four-mile transects. When large clumped aggregations were found at the front of the migration, the strip-census method was temporarily abandoned in favour of a total count.

After a refueling stop, transects were resumed at four-mile intervals beginning at C5. Starting at A28 the flight altitude was reduced from 800 feet to 600 feet because some caribou on open-ground patches were being missed. Observation angles and strip widths are shown in Figure 8d. In the early afternoon most of the animals were lying on patches of exposed ground and were difficult to see. Binoculars were used by observer 1 to scan patches where caribou blended well with the background.

After another refueling stop we censused south to transect B2 before light conditions caused a termination of the census even though caribou were still numerous.

Basic census results are presented in Table 16. The distribution was divided into four strata (Fig. 11), based on sampling intensity and caribou density. Post-census stratification does not alter the over-all results or the confidence of the results but it is convenient for analysis of data. Estimates of

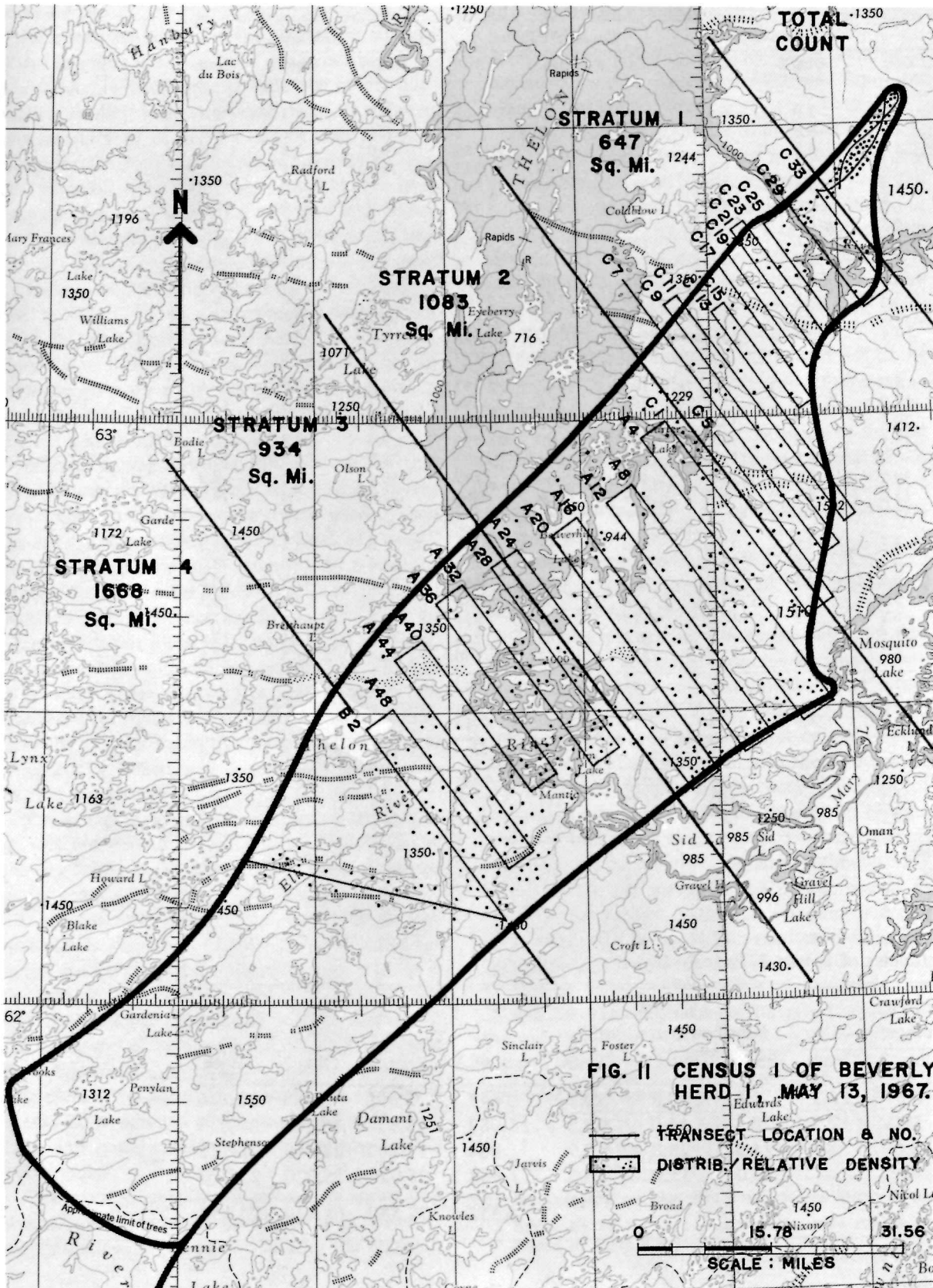


Table 16 Results of census 1, Beverly 1

Transect no.	Transect length*	Sq. mi. covered			Caribou counted			Density†		
		Obs. 1	Obs. 2	Both	Obs. 1	Obs. 2	Both	Obs. 1	Obs. 2	Both
Stratum 1										
C 33	11.8	3.7	2.9	6.6	36	27	63	9.7	9.3	9.5
C 29	13.0	4.0	3.2	7.2	02	0	2	0.5	0	0.3
C 25	15.8	4.9	3.9	8.8	50	15	65	10.0	3.8	7.4
C 23	16.4	5.1	4.0	9.1	85	130	215	16.7	32.5	23.6
C 21	17.0	5.3	4.2	9.5	41	39	70	7.7	6.9	7.4
C 19	16.3	5.1	4.0	9.1	83	104	187	16.3	26.0	20.5
C 17	19.7	6.1	4.9	11.0	78	77	155	12.8	15.7	14.1
C 15	14.6	4.5	3.6	8.1	117	161	278	26.0	44.7	34.3
C 13	20.7	6.4	5.1	11.5	43	11	54	6.7	2.2	4.7
C 11	27.6	8.6	6.8	15.4	59	29	88	6.9	4.3	5.7
C 9	37.9	11.8	9.3	21.1	86	58	144	7.3	6.2	6.8
C 7	37.5	11.6	9.2	20.8	56	50	106	4.8	5.4	5.1
C 5	22.9	7.1	5.6	12.7	8	30	38	1.1	5.4	3.0
Stratum 2										
C 1	28.8	8.9	7.1	16.0	185	62	247	20.8	8.7	15.4
A 4	38.5	12.0	9.5	21.5	368	126	494	30.7	13.3	23.0
A 8	32.6	10.1	8.0	18.1	253	232	485	25.0	29.0	26.8
A 12	32.6	10.1	8.0	18.1	97	99	196	9.6	24.4	10.8
A 16	34.6	10.7	8.5	19.2	309	174	483	28.9	20.5	25.2
A 20	34.0	10.5	8.4	18.9	109	60	169	10.4	7.1	8.9
A 24	35.5	11.0	8.7	19.7	298	64	362	27.1	7.4	18.4
Stratum 3										
A 28	26.6	6.2	4.9	11.1	130	61	191	21.0	12.4	17.2
A 32	26.6	6.2	4.9	11.1	165	90	255	26.6	18.4	23.0
A 32	25.3	5.9	4.7	10.6	208	225	433	35.2	47.9	40.8
A 40	22.5	5.2	4.1	9.3	120	31	151	23.1	7.6	16.2
A 44	28.6	6.7	5.3	12.0	129	325	454	19.2	61.3	37.8
A 48	23.7	5.5	4.4	9.9	216	62	278	39.8	14.1	28.1
B 2	28.0	6.5	5.2	12.7	238	112	350	36.6	21.5	27.5
B 10	30.0	7.0			143			20.4		
Total	719.1	206.7	158.4	359.1	3712	2454	6013			
Average								18.0	14.9	16.6
C33 to C5	271	84.2	66.7	150.9	744	731	1465	8.8	10.8	9.7
C1 to A24	237	73.3	58.2	131.5	1619	817	2436	22.1	14.0	18.5
A28 to B2	181	42.2	33.5	76.7	1206	906	2112	24.5	23.2	23.9

* Within distribution border.

† Caribou per square mile.

Table 17 Stratum estimates of census 1, Beverly 1

Stratum	Percentage coverage*			Density (Caribou per sq. mi.)			Area (sq. mi.)	Herd estimates		
	Obs. 1	Obs. 2	Both	Obs. 1	Obs. 2	Both		Obs. 1	Obs. 2	Both
1	13.0	10.3	23.3	8.8	10.8	9.7	647	5,693	6,988	6,276
2	6.8	5.4	12.2	22.1	14.0	18.5	1,083	23,934	15,162	20,035
3	4.5	3.6	8.1	24.5	23.2	23.9	934	22,883	21,669	22,323
4	—	—	—	15.0	15.0	15.0	1,668	25,020	25,020	25,020
Total							4,332	77,530	68,839	73,654

* Percentage coverage of area in stratum occupied by caribou.

Results of total count = 4,175.

the number of caribou in each stratum are given in Table 17.

Although the density of the animals in stratum 1 was less than in strata 2 and 3, the caribou were less randomly distributed as indicated by the fluctuating density values for each transect. This is contradictory to earlier statements that non-randomness increased with increasing density of caribou. Animals were highly aggregated in stratum 1 because the land was relatively flat and snow-covered, whereas in strata 2 and 3 the bands had spread out to occupy the numerous open hill tops.

Because of the widely scattered distribution of the animals (Fig. 4), the increased coverage of stratum 1 was justified to reduce estimate variation. When time is limited, it is better to get an accurate estimate of the majority of animals than to spend considerable time accurately estimating a small portion of the herd.

Stratum 2 was flown at 800 feet and at that altitude animals were difficult to see on snow-free patches of ground. Binoculars were used by one observer to scan patches of ground and, as a result, his density value for the stratum was 57.8 per cent higher than the other observer's. It is true that some of the difference could be attributed to chance, but not more than perhaps 20 per cent. When the flight altitude was reduced to 600 feet in stratum 3, the disparity in density values between the two observers was small. For these reasons the density value and estimated population recorded by observer 2 for stratum 2 are considered to be low.

The size of stratum 4, or density of animals in it, was not definitely known. On a survey flight the day before the census, animals were numerous as far south as Penylan Lake. On census 2, May 20, animals were numerous as far south as Damant Lake. Migration leaders moved 87 miles between censuses 1 and 2. Assuming that animals in the rear of the migration moved at a slower rate and at an oblique angle to the leaders, animals at the south end of Penylan Lake on May 13 would have been north of Damant Lake on May 20. Therefore it is logical to assume that stratum 4 should be terminated at the south end of Penylan Lake and would constitute an area of about 1668 square miles.

The over-all density of animals in stratum 4 was estimated to be 15 per square mile. Density was probably 20 per square mile in the northern

half of the stratum, and about 10 per square mile in the southern half of the stratum.

Census 2

After waiting several days for clear weather a second census of Beverly herd 1 was flown on May 19 and 20.

Preparations were similar to those for census 1. The area covered by caribou was stratified because animals were highly aggregated near the front of the migration. The region near the front of the migration was flown at four-mile intervals and the rest of the distribution at eight-mile intervals. Visibility was excellent because the entire area had received about four inches of fresh snow the previous day and it had not drifted.

Transects were flown from the north end of the migration toward the south end. Observation angles and resultant strip widths are given in Figure 8e. A stop for fuel was necessary at the end of transects A11 and C4. Transects north of C6 were flown at 800 feet above ground and those south of, and including, C6 were flown at 600 feet because of poorer visibility.

Basic information for the computation of herd estimates is given in Table 18. Calculations of herd size are in Table 19.

The area of stratum 3 was increased by 380 square miles to compensate for caribou movements between the two census days. That is approximately the area of a strip 8 miles wide and 48 miles long. It is assumed that animals would have moved about eight miles in the 14-hour interval between census flights because the rate of migration was about 16 miles per day. By chance, the two individual estimates of the herd are almost the same. Individual stratum estimates vary considerably and point to the largest source of error in the census — the low sampling intensity combined with a highly non-random distribution of animals in strata 1 and 2.

Table 18 Herd estimate of Beverly 1, census 1

Observer	Estimate from strip census	Plus total count	Adjustment 1*	Adjustment 2†
1	77,530	81,705	102,131	127,664
2	68,839	73,014	91,268	114,085
Both	73,654	77,829	97,286	121,607

* Estimated 20 per cent of animals missed inside strips.

† Estimated 20 per cent of animals outside region included in Table 8 estimates.

Table 19 Results of census 2, Beverly 1

Transect no.	Transect length	Area covered (sq. mi.)			Caribou counted			Density (caribou/sq. mi.)*		
		Obs. 1	Obs. 2	Both	Obs. 1	Obs. 2	Both	Obs. 1	Obs. 2	Both
Stratum 1										
A 26	4.0	1.2	1.2	2.4	0	0	0	0	0	0
A 25	14.2	4.4	4.2	8.6	68	150	218	15.5	35.7	25.4
A 24	14.8	4.6	4.3	8.9	29	69	98	6.3	16.0	11.0
A 23	15.4	4.8	4.5	9.3	107	105	212	22.3	23.3	22.8
A 22	14.8	4.6	4.3	8.9	282	156	438	61.3	36.3	49.2
A 21	15.9	4.9	4.7	9.6	0	0	0	0	0	0
A 20	14.2	4.4	4.2	8.6	34	85	119	7.7	20.2	13.8
A 19	13.0	4.0	3.8	7.8	55	39	94	13.7	10.3	12.1
A 18	14.2	4.4	4.2	8.6	56	59	115	12.7	14.0	13.4
A 17	14.6	4.5	4.3	8.8	10	9	19	2.2	2.1	2.2
A 16	16.8	5.2	4.9	10.1	57	210	267	11.0	42.9	26.4
A 15	17.3	5.4	5.1	10.5	147	136	283	27.2	26.7	27.0
A 14	12.8	4.0	3.7	7.7	1	117	118	0.3	31.6	15.3
A 13	15.0	4.7	4.4	9.1	24	90	114	5.1	20.4	12.5
A 12	15.4	4.8	4.5	9.3	9	0	09	1.9	0	9.7
A 11	15.4	4.8	4.5	9.3	152	3	155	31.7	0.7	16.7
Stratum 2										
B 9	15.0	4.7	4.4	9.1	50	100	150	10.6	22.7	16.5
B 7	14.2	4.4	4.2	8.6	45	09	54	10.2	2.0	6.3
B 5	17.7	5.5	5.2	10.7	0	89	89	00	17.1	8.3
B 3	21.7	6.7	6.3	13.0	99	0	99	14.8	0	7.6
B 1	20.7	6.4	6.1	12.5	00	167	167	0	27.4	13.4
B 2	25.7	8.0	7.5	15.5	466	344	810	58.2	45.9	52.3
B 4	18.8	5.8	5.5	11.3	223	177	400	38.4	32.2	35.4
B 6	25.7	8.0	7.5	15.5	104	48	152	13.0	6.4	9.8
B 8	22.1	6.9	6.5	13.4	26	345	371	3.8	53.1	27.7
B 10	47.4	14.7	13.9	28.6	515	441	956	34.3	31.7	33.4
B 12	37.5	11.6	11.0	22.6	378	459	837	32.6	41.7	37.0
C 2	37.9	11.8	11.1	22.9	328	283	611	27.8	25.5	26.7
C 4	34.8	10.8	10.2	21.0	149	104	253	13.8	10.2	12.0
Stratum 3										
C 6	28.0	6.5	6.1	12.6	184	209	393	28.3	34.3	31.2
C 8	34.8	8.1	7.6	15.7	52	80	132	6.4	10.5	8.4
C 8	52.9	12.3	11.6	23.9	153	95	248	12.4	8.2	10.4
C 10	46.2	10.8	10.1	20.9	173	72	245	16.0	7.1	11.8
C 12	49.0	11.4	10.7	22.1	84	40	124	7.4	3.7	5.6
C 14	33.5	7.8	7.3	15.1	111	57	168	14.2	7.8	11.1
C 16	33.8	7.9	7.4	15.3	128	11	139	16.2	1.5	9.1
C 18	31.5	7.3	6.9	14.2	110	25	135	15.1	3.6	9.5
C 20	18.5	4.3	4.1	8.4	17	34	51	4.0	8.3	6.0
Total	891.6	252.4	238.0	490.4	4426	4417	8843			
Average								17.5	18.6	18.0
A26 – A11	224.2	70.7	66.8	137.5	1031	1228	2259	14.6	18.4	16.4
A9 – C4	339.2	105.3	99.4	204.7	2383	2566	4949	22.6	25.8	24.2
C6 – C20	328.2	76.4	71.8	148.2	1012	623	1635	13.2	8.7	11.0

*Within distribution of caribou.

Table 20 Calculation of numbers, Beverly 1, census 2

Stratum	Percentage cover			Density caribou/sq. mi.			Area (sq. mi.)	Herd estimates		
	Obs. 1	Obs. 2	Both	Obs. 1	Obs. 2	Both		Obs. 1	Obs. 2	Both
1	7.5	7.1	14.6	14.6	18.4	16.4	940	13,724	17,296	15,416
2	3.2	3.0	6.2	22.6	25.8	24.2	3320	75,032	85,656	80,344
3	2.7	2.5	5.2	13.2	8.7	11.0	2840	37,488	24,708	31,240
Total							7100	126,244	127,660	127,000

A recent four-inch snowfall had caused caribou in the two strata to mass into aggregations on the hills, where snow was shallower and food more easily obtained. Near the head of the movement the migrating caribou were in long columns at right angles to the transects, which is a suitable distribution for the strip-census method. The increased coverage of stratum 1 would result in fairly accurate estimates of numbers. Least confidence was in the estimates for stratum 2.

No adjustments are necessary to the strip-census estimates shown in Table 20 because the entire region occupied by caribou is included in the estimates, visibility was excellent, the aggregations were small so that individual caribou could be tallied, and caribou were easily seen against the snow.

In summary, neither census of Beverly 1 was considered adequate. In census 1, coverage was insufficient in relation to the distribution pattern of the animals; animals were difficult to see; and a large proportion of the animals was outside the area censused. Census 2 was weak because the sampling intensity was definitely inadequate for the form of caribou distribution in a large part of the census area. But the type of census conducted was the only possible means of obtaining an estimate of numbers.

On the strength of the two censuses, the final estimate of 127,000 is considered to be within 20 per cent of the actual number. Adjustments were necessary to census 1, but the magnitude of the adjustments was estimated on the basis of post-census results and experience. Adjustments were made after census 2 was conducted and the results of census 2 were used to make one of the census 1 adjustments. It may be argued that the adjustments to census 1 were calculated in retrospect to bring the census 1 estimate near that of census 2, but in fact the adjustments applied were based on known census conditions. By chance, the estimates of the two censuses are similar. An error of 20 per cent in individual census results could be expected.

Herds 2 and 3

Estimates for Beverly 2 and 3 are based on herd composition counts. It is assumed that all caribou in herds 2 and 3 were adult bulls, four years of age and older. The assumption is based on photographs of herd 3, aerial observations, and field reports from conservation officers in northern Saskatchewan.

The percentage of mature bulls in herd 1 was estimated from the photographs taken to determine calf recruitment. In a sample of 1,326 animals in March and April only 1.2 per cent were adult bulls.

At the time of the second Beverly 1 census most of the adult bulls were still south of the census region. It was noted that most of the animals near the tree line on May 20 were young members of both sexes. No mature bulls with antlers in velvet were seen on census transects, although a few were present in the rear of the migration.

If adult bulls four years and older comprise 21 per cent of the Beverly population and only 1 per cent of the bulls were in the censused portion of the population which numbered 127,000, then herds 2 and 3 contained 31,750 animals.

4 Kaminuriak population

An estimate of the number of caribou in the Kaminuriak population was not obtained. Instructions were to census the herd located on the Saskatchewan – Northwest Territories border if it migrated toward Beverly Lake, but it migrated toward Kaminuriak Lake instead. It was not feasible to census the herd before it reached the tundra.

Summary of herd estimates

A summary of herd estimates is given in Table 21 and Figure 12. The total of 322,500 is considered a minimum estimate because the uncensused herds relatively deep in the forested zone were assumed to be composed entirely of adult bulls, and the ratio method was used to estimate their numbers. A final estimate of caribou in the three populations censused is 320,000 to 330,000.

Table 21 A summary of herd estimates

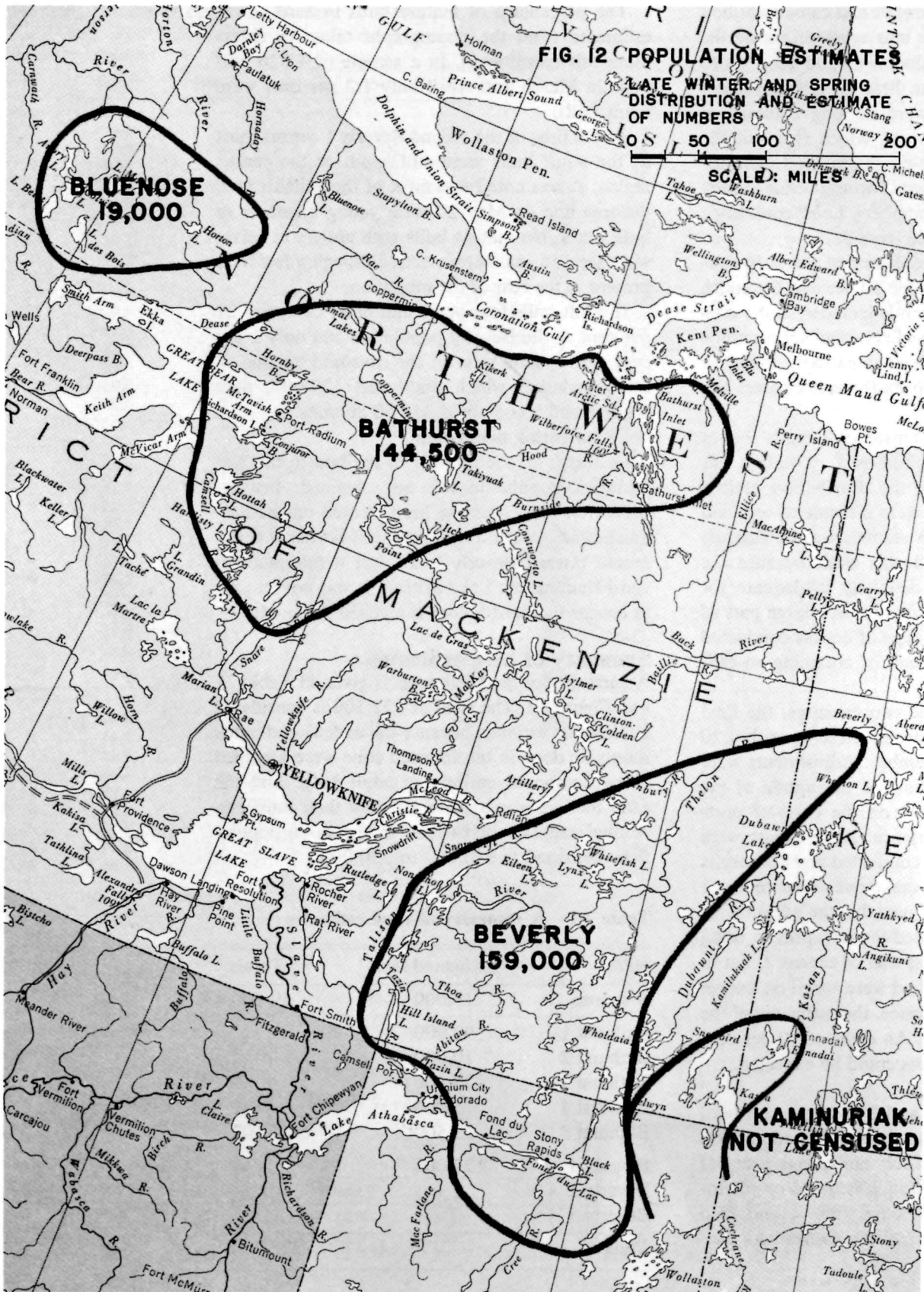
Herd	Estimated size	Totals
Bluenose	19,000	19,000
Bathurst 1	93,000	
Bathurst 2	10,000	
Bathurst 3	25,000	
Bathurst 4	5,000	
Bathurst 5	11,500	144,500
Beverly 1	127,000	
Beverly 2 } Beverly 3 }	32,000	159,000
Total		322,500

FIG. 12 POPULATION ESTIMATES

LATE WINTER AND SPRING
DISTRIBUTION AND ESTIMATE
OF NUMBERS

0 50 100 200

SCALE: MILES



Recruitment of caribou

The objective of this phase of the aerial survey was to obtain recruitment statistics for each of the major herds of caribou. Birth of caribou calves occurs each June, and by the end of that month calves usually constitute 30 to 35 per cent of the total caribou on the summer range. However the most important statistic in caribou population studies is recruitment, the number of calves surviving their first year.

Herd composition counts are of little value unless the population is sampled adequately. The animals sampled should be representative of the population as a whole, or if they are biased then the direction and degree of bias should be known. Caribou herds are difficult to sample because sex and age classes are segregated most of the year. Typically, in winter the bulls penetrate deeper into the forest than do the cows and calves. In spring migration the pregnant cows predominate near the front of the movement, yearlings and young bulls predominate farther back, and old bulls are the last to reach the summer range. These considerations must be kept in mind when herd composition counts are made. Statistics of calf frequency in the herds sampled are known to be biased

in favour of calves and the approximate degree of bias is known.

In the analysis to follow it is important to remember that calves censused in April and May are those 10 and 11 months old and are from the calf crop of 1966. Recruitment figures are most accurate at this time.

Aerial photographs were taken of caribou at low altitude with a Kodak aerial camera loaded with Kodak Super-XX aerographic film, A.S.A. 100 (Fig. 13). An attempt was made to sample animals throughout their distribution and to sample both small and large aggregations.

The $4 \times 5\frac{1}{4}$ inch prints were viewed at a magnification of 6 or $12\times$ using a stereoscopic microscope and reflected light. Some prints in which the animals could not be clearly distinguished were omitted. Calf counts are difficult in the spring. Some calves were obvious, but others were very similar to small yearlings. Characteristics used to identify calves were size, head shape, antler growth and appearance, length of neck, and colouration. Undoubtedly, some mistakes were made. Results are presented in Table 22.

13 Low-level aerial photographs were used to obtain estimates of herd composition. Cows and calves before spring migration, Hepburn River, April 17, 1967. Altitude of aircraft approximately 50 feet.



To obtain the average number of calves in all the major herds it is necessary to weight the calf estimates with respect to herd size. In Table 23 this is done for the Bathurst population. In Table

24 the same procedure is used for the three populations together. Therefore, the over-all complement of calves in the caribou of the survey region was about 11 per cent.

Table 22 Recruitment statistics of the major herds

Population	Herd	Date of census	Sample size	No. calves	Per cent calves	Adjusted per cent calves *
Bluenose		Apr. 27	526	74	14.1	14.1
Bathurst	1	Apr. 10	1197	155	12.9	
Bathurst	1	Apr. 17	1312	126	9.6	
Bathurst	1	Total	2509	281	11.2	9.0
Bathurst	2	Apr. 10	487	52	10.7	
Bathurst	2	Apr. 28	1142	167	14.6	
Bathurst	2	Apr. 28	838	100	11.9	
Bathurst	2	Total	2467	319	12.9	10.3
Bathurst	5	May 2	858	117	13.6	10.9
Bathurst total of 1, 2, and 5			5834	717	12.3	
Beverly	1	Mar. 14	1339	204	15.2	
Beverly	1	Apr. 23	110	14	12.7	
Beverly	1	Total	1449	218	15.0	12.0

*Adjusted for deficiency of adult bulls in sampled herds.

Table 23 Weighted percentage of calves in three Bathurst herds

Herd	Herd size	Per cent calves*	Weighted per cent calves
Bathurst 1	93,000	9.0	7.3
2	10,000	10.3	0.9
5	11,500	10.9	1.1
Total	114,500		9.3

*Adjusted: see Table 22.

Table 24 Weighted percentage of calves in three populations

Population	Population size	Per cent calves *	Weighted per cent calves
Bluenose	19,000	14.1	0.8
Bathurst	144,500	9.3	4.2
Beverly	159,000	12.0	5.9
Total	322,500		10.9

*Adjusted: see Table 22.

Human utilization of caribou

Barren-ground caribou are still an important resource for native people living in caribou territory. Caribou hunting is a way of life for Eskimos and Indians in parts of northern Canada, but their existence no longer hinges on the availability of the animals, as it once did. Changing modes of winter transportation in the North make it easier to hunt a large area around each settlement. For example, motorized toboggans enabled the Eskimos at Coppermine to kill a fair number of caribou during the winter of 1966–67, although there were only scattered bands within 50 miles of the settlement.

In past years the numbers of barren-ground caribou have been affected considerably by the mortality inflicted by native hunters. In the 1940's Banfield (1954) estimated the annual kill to be 86,000 animals. In 1954 and 1955 the take was estimated at 66,000 and 73,000 respectively, but decreased to 12,000–15,000 by 1957–58 (Kelsall, 1960). Decreased availability of animals was judged to be the reason for the reduced kill. For

many years before 1959, human utilization alone closely approached or exceeded the annual increment of caribou (Kelsall, 1960). It is important, therefore, to obtain accurate figures on the number of caribou killed each year by hunters. If human utilization figures are available and natural mortality can be estimated, then the combined mortality can be weighed against increment statistics to obtain a net rate of population increase or decrease.

The number of caribou killed during the autumn and winter of 1966–67 was compiled from the estimates of officers responsible for wildlife in each region and is presented in Table 25.

It would be possible to estimate the autumn and winter kill of caribou by native hunters if the number of hunters, their mode of hunting, and the distribution of caribou were known. Utilization of caribou was not high in 1966–67 because the major herds were remote from most hunters. Accessibility of animals around each major settlement is briefly discussed below.

Table 25 Estimates of caribou killed during autumn and winter, 1966–67

Region	Estimator	Population affected	Kill estimate
Stony Rapids, Sask. (includes Wollaston Lake, Fond du Lac, and adjacent N.W.T. trappers)	Mr. F. W. Terry, Conservation Officer	Beverly	3,000
Uranium City, Sask. (includes Camsell Portage)	Mr. T. Jonasson, Conservation Officer	Beverly	375
Yellowknife (includes Reliance, Snowdrift, and Pellatt Lake)	Mr. T. Lines, Game Management Officer	Beverly/Bathurst	281
Rae (includes Hottah and Snare Lakes)	Mr. R. Mercredi, Game Management Officer	Bathurst	2,000
Coppermine	Cpl. B. Braun, R.C.M.P.	Bathurst	1,000
Bathurst Inlet (includes a few hunters from Cambridge Bay)	Mr. A. G. Gordon, Area Administrator Cambridge Bay	Bathurst	2,000
Total			8,656

1 *Wollaston Lake Post* — In March there was a herd of bulls at Waterfound River, 50 miles from Wollaston Lake Post. According to Mr. G. Parker of the Canadian Wildlife Service at Churchill (pers. comm.), trappers took some bulls when the herd passed within 30 miles of the post earlier in the winter.

2 *Stony Rapids* — There was only a light autumn and spring migration past Stony Rapids and Black Lake. Caribou were available during the winter at distances of 20 to 30 miles. Most of the animals taken were bulls.

3 *Fond du lac* — Animals were scarce within 50 miles of the settlement during the winter. A small migration of bulls passed the village in the spring. Evidence of a few kills was noted May 5 on a flight along the Fond du lac River.

4 *Uranium City* — Caribou were available in small numbers 30 miles to the northwest of Uranium City and within 20 miles of Camsell Portage. Trappers in the Northwest Territories north of Camsell Portage accounted for most of the caribou taken. Once again mostly bull caribou were available to the hunters.

5 *Snowdrift/Fort Reliance* — In the early winter there were a few trappers along the tree line and out on the tundra between Great Slave Lake and the Thelon River. Caribou were available to the hunters at that time. In March and April animals were not far from Fort Reliance, but were not hunted extensively because few trappers remained in the area after Christmas.

6 *Yellowknife*—Two Eskimo families at Pellatt Lake shot 153 caribou in the autumn but could obtain no more during the winter. Indians from Yellowknife killed a small wandering band of 10 caribou near Gordon Lake but otherwise had to drive the winter road to Hottah Lake to obtain animals.

7 *Rae* — Indians at Rae travelled north on the winter road to Port Radium and hunted caribou in the Hottah Lake region. Many of the animals killed were trucked back to Rae for consumption. Trappers at Snare Lake hunted caribou all winter.

8 *Coppermine* — In the early winter the Eskimos travelled southwest toward Dismal Lake to shoot caribou and in late winter travelled southeast about 40 miles to obtain animals. Bands of caribou periodically travelled through the Rae and Richardson Rivers region and some of these were taken by the Coppermine Eskimos. Extensive use of motorized toboggans made the moderate kill

possible. Each hunting family obtained an average of about 15 caribou.

10 *Bathurst Inlet* — Eskimos at Bathurst Inlet were able to shoot caribou from autumn 1966 to spring 1967. Hunters averaged 120 caribou per hunting family. Motor toboggans are not as yet used by Bathurst Inlet Eskimos. It is estimated that Eskimos from Cambridge Bay shot about 200 caribou on the mainland east of Bathurst Inlet. The herd they were hunting was composed largely of cows, calves, yearlings, and two-year-old animals.

It can be concluded that about 10,000 caribou were taken in the census region during the autumn and winter of 1966–67. Mature bulls made up a large proportion of the over-all take. This is 3.2 per cent of the estimated population of caribou in the region. Spring and summer hunting would probably account for another 2,500 animals, so that the yearly hunting mortality would be about 4 per cent of the entire population.

Predation by wolves

The location and number of all wolves sighted on survey and census flights were recorded on the maps or in a notebook. Presumed wolf kills were often recorded.

Bluenose population — On the April 27 census of the herd, seven wolves in one pack were twice seen pursuing caribou. Neither of the pursuits was successful. Two dead muskoxen or caribou were seen in the census region. A blood splash indicated that one was a wolf kill.

Bathurst herd 1 — Wolves were very numerous in the large herd and were frequently sighted. Probably the best indication of the number of wolves in the main herd was obtained April 18 on the second census of the herd. On that census 68 wolves were counted inside the census strips and 22 outside the strips. Because wolves tend to run away from the noise of the aircraft and because the transects were only a mile apart, a few wolves could have been counted twice. Since wolves are difficult to see unless they run, many were no doubt missed. Since 45.4 per cent of the area occupied by the caribou herd was sampled by the strip-census method, it is estimated that about 150 wolves were within the main caribou distribution. Large packs of as many as 12 wolves were commonly seen.

Some wolves tend to remain around old kills and are temporarily left behind a moving herd. It is reasonable to suggest that 200 to 300 wolves were associated with the Bathurst 1 herd in late winter 1967.

On April 25, when the herd was concentrated in about 40 square miles, caribou were periodically pursued by wolves. A fresh kill was examined. The animal was a female, judged by tooth wear to be about 10 years old. Two large packs of wolves were still on the Hepburn River when the main herd of caribou had advanced 25 to 30 miles to the east.

Bathurst herd 5 — Two wolves were seen on the census transects May 2, and one wolf was sighted about 20 miles northeast of Baychimo Harbour on May 1.

Beverly herd 1 — Wolves were occasionally seen on early flights over caribou concentrated in the Nonacho Lake region. The largest pack contained four wolves. Many kills were sighted. However the Beverly herd had remained in a relatively small area for at least three months. No wolves were seen within the range of the predator-control

camps on the Taltson River. Only one wolf was seen on the two censuses of the herd in May.

No wolves were sighted in herds 2, 3, and 4 of the Bathurst population nor in herds 2 and 3 of the Beverly population.

Conclusion — Wolves are difficult to see in the forested regions. A very small percentage of the total wolves are seen, so that it is impossible to estimate numbers of wolves on the basis of a few counts. Wolves can be seen on the tundra or in small-tree terrain, especially if they are in large packs.

The over-all impression was that wolves were not numerous in any of the herds except Bathurst 1. In late winter it was providing some food for at least 200 wolves.

If wolf control is considered necessary, it should be applied to wolves following the main Bathurst herd when it becomes concentrated on the winter range in March and April.

The 1955 population estimate (Kelsall and Loughrey, 1955) of 277,000 caribou indicated a sharp decline from Banfield's (1954) estimate of 670,000 caribou in 1949. Kelsall (1960) estimated that the population in 1957-58 was 200,000. However, his estimate was not based on a complete census of the range. If 65,000 animals can be attributed to the Kaminuriak population and other animals wintering east of 102 degrees longitude (Parker, pers. comm.), the increase has been from 200,000 in 1958 to 387,000 in 1967, an average annual population growth rate of 7.6 per cent. If the natural mortality rate of the animals older than calves was 5 per cent per year (Kelsall, 1968, p. 202) and hunting mortality was about 5 per cent per year, then a 17.6 per cent recruitment rate would be necessary to produce a 7.6 per cent yearly net increase in population. Recruitment in this discussion refers to the addition of calves that are almost one year old. A 17.6 per cent recruitment rate is well within the reproductive capacity of caribou but it is high compared to the estimate of 11 per cent recruitment for the 1966-67 reproductive year. Either recruitment has been high in the past few years or the 1958 population was larger than 200,000.

By the spring of 1967, on the basis of estimates of recruitment, hunting mortality, and natural mortality, the caribou in the survey region should have increased about 2 per cent over the spring 1966 population (recruitment rate, 11 per cent per year; hunting mortality, 4 per cent per year; natural mortality, 5 per cent per year). Confidence cannot be placed in the above estimates because the natural mortality estimate is probably inaccurate. Of the three rates necessary to calculate the annual rate of increase (or decrease) the most difficult to obtain is the annual rate of natural mortality. Accurate rates of natural mortality could be determined for a discrete herd if two or more accurate censuses were obtained as well as accurate hunting mortality statistics and recruitment rates.

1 A total of 270 hours was flown March to May 1967 to determine the numbers, distribution, and movements of barren-ground caribou west of 102 degrees longitude in northern Canada.

2 Four populations of caribou, the Bluenose, Bathurst, Beverly, and Kaminuriak, were described on the basis of their distribution and calving areas.

3 Two of the populations, the Bathurst and the Beverly, were divided into herds on the basis of density, composition, and movement.

4 Estimates of herd size were obtained from combinations of total counts, strip censuses, photographic counts, and a ratio method.

5 Excluding the Kaminuriak population the estimated number of caribou in the survey region was 322,000. This is considered a minimum estimate. The final estimate is 320,000 to 330,000.

6 In March the main component of each population was distributed in the taiga near tree line. The mature bull segment was located deeper in the forested zone.

7 In April herds were more highly concentrated in the northwest portion of the range (higher latitudes), compared to the southeast (lower latitudes). Herds at higher latitudes migrated to the calving grounds earlier than those farther south.

8 Forest fires have destroyed many areas of former caribou winter range. The best winter range is in the forested area within 100 miles of the tree line.

9 Aerial photographs were used to obtain the number of calves of the year in the major herds of caribou. Where adequate samples were obtained the percentage of calves in the herds varied from 11.2 to 15. After estimates were adjusted for the absence of adult bulls the estimates of calves varied from 9.0 to 14.1 per cent. The over-all average recruitment rate for the three populations in the survey region was 11.0 per cent.

10 Autumn and winter hunting mortality accounted for about 10,000 animals in the survey region.

11 Wolves and wolf kills were fairly numerous in only one large herd, Bathurst 1.

12 If past census estimates are reliable, barren-ground caribou on the mainland of Canada increased from 200,000 to 387,000 in the past nine years, an average of 7.6 per cent per year.

13 It is estimated from recruitment and mortality statistics that the caribou in the survey region increased about 2 per cent in 1966-67.

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En 1967, on a effectué un relevé aérien des populations de caribou de la toundra dans le district de Mackenzie et dans les régions voisines de l'Alberta et de la Saskatchewan en vue de:

- 1 Déterminer la répartition des hardes de caribous à la fin de l'hiver, ainsi que leurs routes de migration printanière vers la toundra;
- 2 Dénombrer toutes les hardes importantes;
- 3 Établir le nombre des petits par rapport à celui des adultes;
- 4 Évaluer l'intérêt que les caribous présentent pour l'homme dans leur habitat d'hiver.

Au cours des 270 heures de vol effectuées en mars, avril et mai 1967, l'équipe d'enquêteurs a étudié quatre hardes de caribous du point de vue de leur répartition et de leur aire de mise bas. L'importance numérique des hardes fut établie, dans le cas de trois hardes, en juxtaposant les chiffres obtenus à la suite du dénombrement global, des sondages détachés, des relevés photographiques et du calcul des moyennes proportionnelles.

Au cours du mois de mars, les principaux éléments de chaque harde se groupaient, dans la taïga, aux limites de la forêt subarctique. La répartition des troupeaux à la fin de l'hiver et la période de migration printanière semblent dépendre de l'état de la neige; toutefois, cette conclusion ne pourra être établie qu'après des observations complémentaires.

On a estimé à 322,500 animaux la population totale de l'aire recensée. Il faut voir là une estimation minimale, car on a supposé que les hardes non recensées, engagées plus avant dans la zone forestière, se composaient surtout d'adultes. Pour en déterminer le nombre, on s'est servi de la méthode de la moyenne proportionnelle. Le chiffre de la population totale serait plus élevé si cette zone renfermait aussi des hardes restreintes. Le dénombrement définitif des trois groupes recensés s'établit entre 320,000 et 330,000 caribous.

Grâce à la photographie aérienne, on a dénombré les petits nés au cours de l'année au sein des hardes importantes de caribous. Dans les endroits où l'on a pu pratiquer des sondages suffisants, l'importance numérique des petits variait de 11.2 à 15 p. 100. La moyenne générale de renouvellement serait de 11 p. 100 pour les trois hardes de la région étudiée.

Les Esquimaux et les Indiens du nord du Canada s'adonnent encore, en certains secteurs, à la chasse au caribou, mais ils comptent moins qu'au paravant sur cet animal pour leur subsistance.

В 1967 г. с воздуха изучали карibu (*Rangifer tarandus groenlandicus*) в районе Макензи и сопредельных участках Альберты и Саскачевана. Цель изучения сводилась к следующему:

- 1 установить позднезимний ареал стад карibu и пути их переходов в тундру;
- 2 взять на учет все большие стада;
- 3 определить количество молодняка по отношению ко взрослым животным;
- 4 установить число карibu, уничтоженных человеком для личного употребления, в их зимнем ареале.

На изучение карibu было израсходовано 270 летных часов в марте, апреле и мае 1967 г. Ареал и районы отела карibu послужили основанием для описания четырех популяций. Количество голов стад определялось путем комбинирования суммарных подсчетов, подсчетов на полосах, с фотоснимков, а также путем метода пропорций.

Большинство животных каждой отдельной популяции в марте месяце находилось в тайге вблизи зоны деревьев. Расположение стад поздней зимой и синхронность весенних переходов оказалось зависят от состояния снега, хотя это наблюдение нуждается в дальнейшей проверке.

Общая популяция исследованного района определяется количеством в 322.500 голов. Однако эта цифра считается заниженной, так как неучтенные стада, находящиеся сравнительно в глубине лесной зоны, были условно приняты как состоящие исключительно из взрослых быков; для их подсчета был использован метод пропорций. Абсолютное число животных было бы большим, если бы малые стада также находились в этой зоне. Конечная оценка карibu в трех изученных популяциях выражена суммой в пределах 320—330 тыс. голов.

Аэрофотосъемки были использованы для подсчета телят прошлогодного отела в больших стадах карibu. Где было получено достаточное количество образцов, процентное отношение телят в стаде колебалось в пределах 11,2 и 15. Общая средняя скорость пополнения для всех трех популяций в районе исследований составила 11%.

Охота на карibu все еще является главным занятием эскимосов и индейцев в северных районах Канады. Однако эти две народности теперь в меньшей мере зависят от этого животного, уничтожение которого человеком сейчас, кажется, значительно уменьшилось.



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