by F. L. Miller and E. Broug

Calf mortality on the calving ground of Kaminuriak caribou

Canadian Wildlife Service Report Series Number 26

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Perspective
Barren-ground caribou numbers in northern Canada were estimated at three million up to the 19th century. The introduction of firearms to Indians and Eskimos, the arrival of whalers in the mid 19th century, and the demand for northern furs in the early 20th century were followed by a rapid increase in the annual kill of caribou. Reductions probably did not occur on the range as a whole before 1900, but were reported locally as early as the mid 1800's. The caribou range in northern Canada was first surveyed from the air in 1948–49 and an alarmingly low estimate of 670,000 caribou was made. Various studies throughout the 1950's and early 1960's indicated a decline in numbers which reached an all-time low about 1955. This decline apparently ended in that year and the population has since undergone little change.

The early studies are now regarded as pioneers in caribou research. They successfully monitored the trend in total numbers and identified many factors responsible for the decline in caribou populations. They contributed a great deal to knowledge of caribou ecology but were inconclusive, because of time limitations and the size of the areas covered.

In the early 1960's many conservation agencies recognized the need for intensive study of a particular barren-ground caribou population to provide information on population dynamics, human utilization and range condition. The Canadian Wildlife Service began such a study, lasting 2½ years, in spring 1966. It chose the Kaminuriak population mainly because it was accessible and its range limits were relatively confined. One biologist was responsible for each segment of the study; total numbers, mortality, recruitment and seasonal distribution; sex and age composition; seasonal physical and reproductive condition; winter range evaluation. The study was designed and carried out by the CWS, but the game agencies of Manitoba, Saskatchewan, Alberta and the Northwest Territories all contributed personnel at various stages.

The results of the research program indicated that the current principal limiting factor is the low rate of annual increment, as a result of high losses in the calf crops during the first month of life. On the basis of these findings, a 1-year study of calf mortality on the calving ground of the Kaminuriak population was carried out during the 1970 calving and post-calving periods.

Abstract
The causes of mortality among new-born calves from the Kaminuriak population of barren-ground caribou (*Rangifer tarandus groenlandicus*) were investigated between June 1 and July 29, 1970. The Kaminuriak caribou calve on the open tundra in central Keewatin, Northwest Territories. In 1970 most of them calved between latitudes 63°00′ and 63°40′ and longitudes 93°20′ and 95°00′. We spent 180 hours searching for dead calves by low level (30–100 m) flights in a Hiller 12-E helicopter. Necropsies on 57 calves and 8 adult female caribou revealed the causes of mortality to newborn calves, in descending order of frequency of occurrence, as follows: predation by wolves (*Canis lupus*), abandonment by maternal cows, still births, physiological or pathological disorders (nonspecific), pneumonia, malnutrition and injuries. Caribou responded to heavy rainfall by moving above the 122-m (400-ft) contour and remaining there through 3 or 4 dry days. Newborn calves with respiratory problems were associated with the wettest period during the calving season. Foraging by caribou followed the phenology of the new vegetation. Most calving took place between June 4 and 10. If harassment by aircraft takes place during the peak of calving a considerable loss of new-born calves could occur. Large post-calving groups of several thousand caribou had formed by June 12. The post-calving migratory period began on June 28 and most subsequent mortality was attributed to predation by wolves. The principal cause of calf mortality during the calving and post-calving periods in 1970 was predation by wolves. Much of the wolf predation was excessive to the wolves' needs. Pressures of wolf predation on the young of the Kaminuriak population may be a principal factor limiting the population's total growth. The importance of wolf predation on the young of caribou has not been fully realized. Predation by wolves is the most readily manageable cause of caribou deaths. An increased human harvest of caribou is expected, therefore, the understanding of the predator-prey relationship between wolves and caribou is a high priority for management.

Résumé
Les causes de la mortalité chez les nouveaunés de la population de caribous des toundras (*Rangifer tarandus groenlandicus*) ont fait l'objet d'une étude, entre le 1er juin et le 29 juillet 1970. La femelle du caribou de Kaminuriak met bas dans les toundras à découvert de la partie centrale du district de Keewatin (Territoires du Nord-Ouest). En 1970, la mise bas se fait en grande partie entre les latitudes 63°00′ et 63°40′ et les longitudes 93°20′ et 95°00′. Nous avons consacré 180 heures à chercher des cadavres de petits caribous en volant à faible altitude (30 à 100 m) à bord d'un hélicoptère *Hiller 12-E*. L'autopsie de 57 petits et de 8 femelles adultes a révélé les causes de la mortalité chez les nouveau-nés, en ordre décroissant de fréquence, comme étant les suivantes: attaque par les loups (*Canis lupus*), abandon par la mère, mise au monde de mort-nés, troubles physiologiques ou pathologiques (non précisés), pneumonie, malnutrition et blessures. Les caribous ont réagi contre les fortes pluies en se déplaçant au-dessus de la ligne de 122 m (400 pi) et en demeurant à l'abri pendant trois ou quatre jours. La naissance de petits atteints de troubles respiratoires a coïncidé avec la période la plus arrosée de la saison de mise bas. L'approvisionnement chez les caribous a suivi le renouveau de la végétation. La plupart des naissances ont eu lieu entre le 4 et le 10 juin. Si les caribous sont dérangés par des aéronefs pendant la période de pointe de la mise bas, il peut se produire une perte considérable parmi les nouveaunés. Vers le 12 juin, il s'est formé d'importants groupes comprenant plusieurs milliers de caribous. La migration post-natale a débuté le 28 juin, et la plupart des morts survenues par la suite ont été attribuées aux loups, dont l'attaque a été, dans beaucoup de cas, excessive par rapport à leurs besoins. Il est possible que les pressions exercées par les loups prédateurs sur les jeunes de la population de Kaminuriak soient un des principaux facteurs de la limitation de la croissance chez cette population, facteur dont on n'a pas encore pris conscience de toute l'importance. La prédation des loups est la cause la plus contrôlable de mortalité chez les caribous. Comme on s'attend à une augmentation de la chasse au caribou par l'homme, la compréhension du rapport de prédateur à proie qui existe entre le loup et le caribou revêt une grande importance dans le domaine de la gestion.

АБСТРАКТ
Причины смертности среди новорожденных телят у каминуриакской популяции, населяющих бесплодные земли карибу (Rangifer tarandus groenlandicus), подвергались исследованию в период с 1 июня по 29 июля 1970 г. Карибу популяции Каминуриак телятся в открытой тундре в Центральном Киватине, Северозападные Территории. В 1970 г. большинство из них телилось между 63°00' и 63°40' широты и 93°20' и 95°00' долготы. Мы провели 180 часов в поисках мертвых телят на низком полете (30 - 100 м) на борту вертолета Хиллер 12-Е. Вскрытие 57 телят и 8 взрослых коров карибу выявило следующие причины смертности новорожденных телят, приводимых ниже в последовательности уменьшения частоты появления: истребление волками (Canis lupus), телята, покинутые матками, рождение мертвого плода, физиологические или патологические нарушения (неспецифические), воспаление легких, недоедание и увечья. Вследствие сильных дождей карибу передвинулись выше контура 122 м (400 футов) и оставались там в течение 3-4 дней. Новорожденные карибу с осложнениями дыхательной системы появлялись в период наибольшей влажности в течение отеления. В поисках пищи карибу следовали за фенологией новой растительности. В большинстве случаев карибу телились в течение периода с 4 по 10 июня. Если в разгар периода отеления карибу обеспокоены низко летающими самолетами, то можно ожидать значительные потери новорожденных. К 12 июня после окончания периода отеления сформировались крупные группы карибу численностью в несколько тысяч. Послеотельный период миграции начался 28 июня и последующая смертность была вызвана преимущественно в результате нападений волков. Истребление волками являлось основной причиной смертности в течение периода отеления и после рождения карибу в 1970 г. Большинство жертв волчьего нападения превосходило потребность волков. Интенсивное истребление телят карибу популяции Каминуриак волками очевидно является основным фактором, тормозящим общий рост их популяции, важность которого не была полностью осознана. Истребление волками является одной из наиболее легко объяснимых причин смертности карибу. В будущем можно ожидать повышение улова карибу для нужд человека и поэтому понимание отношения хищник-жертва между волками и карибу является особо важным для умелого подхода.

Introduction

Changing land uses on the range of the Kaminuriak population of barren-ground caribou (*Rangifer tarandus groenlandicus*) and current trends towards liberalization of harvest restrictions have prompted further evaluation of the population dynamics of these caribou. The Technical Committee for Caribou Preservation is seeking to determine the maximum allowable harvest of caribou on a sustained basis that will allow for an increase in total numbers. The results of the CWS's 3-year intensive study of the Kaminuriak caribou suggest the following:

1. That the current density of caribou is well below the carrying capacity of the winter range (D. R. Miller, in prep.).
2. That the sex and age composition of the population indicates a young population with the potential for rapid increase in total numbers (F. L. Miller, in prep.).
3. That the female segment of the population has a good reproductive rate and that neither males nor females show signs of serious physical or nutritional deficiencies (Dauphiné, in prep.).
4. That hunting, believed to be the major cause of adult mortality, removes annually only about 5 per cent of the caribou over 1 year of age (Parker, 1972).
5. That in the absence of calf mortality, the 90 per cent rate of fecundity (Dauphiné, in prep.) would result in a population increase of over 25 per cent annually. Therefore, the principal factor limiting growth is the low annual increment, a result of high losses in the calf crops during the first month of life (Parker, 1972).

On the basis of these findings, CWS carried out a 1-year study of calf mortality on the calving ground of the Kaminuriak population during the 1970 calving and post-calving periods.

Study area

Geographically, Robinson (1968) divided the summer area (Fig. 1) into the coastal plain, extending inland about 137 km (85 miles) from the west side of Hudson Bay, and the interior plateau, west of the lowlands, grading into the hill and mountain region. The lowlands are characterized by numerous elongated drumlins and eskers. Drainage is poor, and many streams meander from one depression to the next. Many long narrow lakes have formed where rock ridges or moraines block their outlets (Robinson, 1968). The interior plateau is generally under 150-m (500-ft) elevation, but rock outcrops are more common than on the lowlands. It is also characterized by drumlins, eskers and numerous lakes (Robinson, 1968).

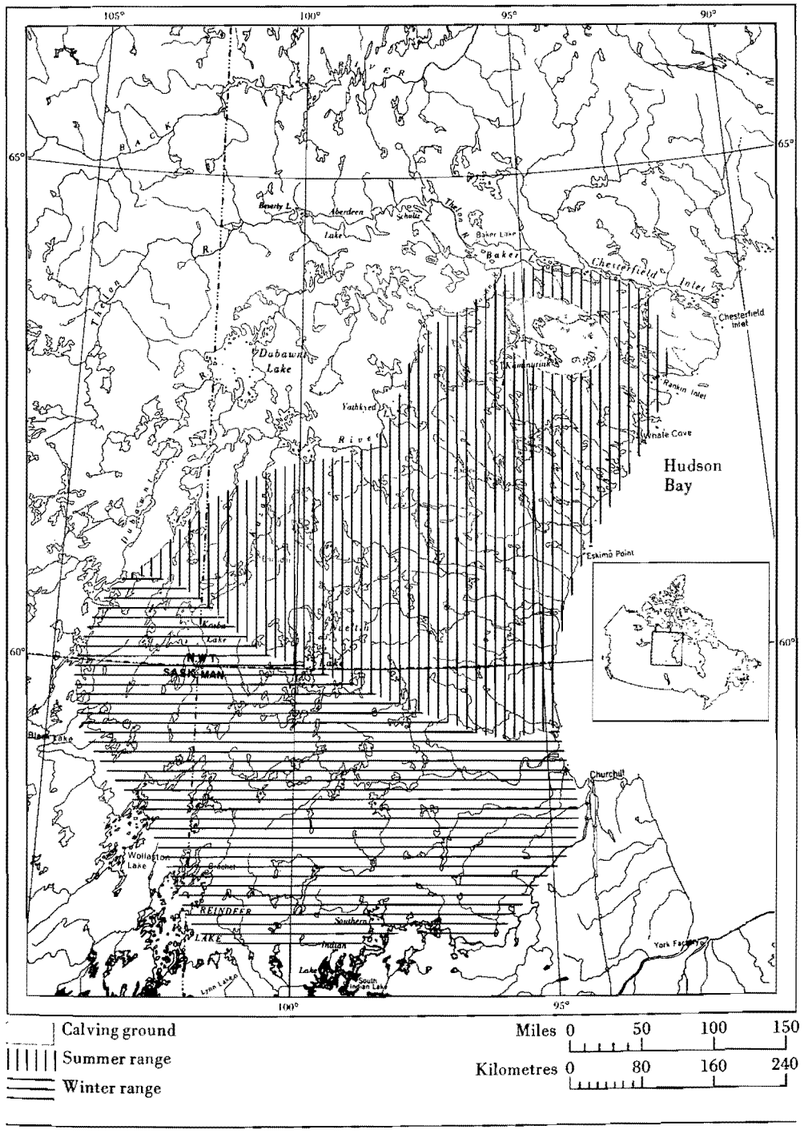
Wright (1955) described the geology of the summer area. Pleistocene features on the calving ground indicate that the glacial ice movement was in a south-easterly direction (Wright, 1955). This resulted in the formation of most drumlinoid ridges and furrows with their primary axes orientated in a northwest-southeast direction. Granite, granodiorite and allied rocks with many bands of partly assimilated schist, gneiss and amphibolite underlie most of the calving ground. The camp site at Calf Lake was on a rather unique mantle of diorite and gabbro with some syenitic intrusive rocks and minor amounts of serpentinite. Outcroppings of intermediate to basic volcanic rocks which included much schistose greywacke (Lower Thelon River belt) and undifferentiated basic intrusives dominated relatively dry, higher sites north of Calf, MacQuoid and Parker lakes.

Floristically, Rowe (1959) divided the summer range into the Tundra and Forest-Tundra. The Forest-Tundra section is referred to generally as the taiga (Kelsall, 1968). The term *tundra* is synonymous with barren-ground. The forested portion of the study area is sparsely vegetated by dwarfed members of the open boreal forest; black spruce (*Picea marina*), tamarack (*Larix laricina*), birches (*Betula* sp.) willows (*Salix* spp.) occur in varying frequencies, sometimes dominating local sites. On the tundra, vegetation is scanty on the drier sites which support *Empetrum nigrum*, *Vaccinium vitis-idaea*, *V. uliginosum*, *Ledum* sp., mosses and lichens. The vegetation is relatively lush on the poorly drained sedge (*Carex*) meadows and tussock muskegs which are dominated by species of *Carex*, *Eriophorum* and mosses intermixed with *Betula glandulosa*, *Salix* spp., *Ledum decumbens* and *L. groenlandicum*. Water covers up to 25, and in places 50, per cent of the land mass.

Cool wet springs and relatively dry moderate summers characterize the study area. Kendrew and Currie (1955) give the maximum temperature as 27°C (80°F). Kelsall (1968) gives mean annual precipitation for the summer range as 15 to 30 cm (6 to 12 inches). Maximum precipitation occurs in July and August (Kendrew and Currie, 1955).

Figure 1. Summer and winter ranges (1966 to 1968) and calving ground (1970) of barren-ground caribou of the Kaminuriak population.

Figure 1



Methods

To facilitate our search for caribou on the calving ground, Miller, Brehend and Tessier (1971) live-captured barren-ground caribou in tangle nets in northern Manitoba in April 1970. We located groups of animals on frozen lakes by aerial reconnaissance, set nets on their back trails in the adjacent forest and then herded the caribou into the nets using taxiing aircraft. We captured 80 caribou in 7 days and equipped 27 with radio transmitters.

During June and July, on the calving and post-calving areas we flew a total of 437 hours: 248 in the Hiller 12-E helicopter, 174 in a Cessna 180 and 15 hours in an Islander. We used 126 hours (29 per cent) of the total flying time establishing gas caches, relocating camps, moving personnel and obtaining supplies, and we devoted 71 per cent (311 hours) of the total flying to search and survey work.

The cost of aircraft charter did not allow us to search systematically for dead calves. We used both the Cessna 180 and Hiller 12-E to locate and follow post-calving groups of caribou, doing most flying at about 150 to 300 metres (500 to 1,000 feet). Only the helicopter was feasible for searching for dead calves because of its slow speed, 60 to 110 kilometres per hour (40 to 70 miles per hour), and good maneuverability at low levels, 30 to 75 m (100 to 250 ft).

Most often we searched for dead calves from 35 to 55 m (120 to 180 ft) above the ground at an average rate of 95 kmph (60 mph). The pilot operated the aircraft from a center seat position and scanned the terrain directly ahead, while an observer on each side of him scanned ahead and to his respective side. By this method we effectively searched a strip of ground 0.10 km (0.06 miles) wide, at a rate of 9.5 square kilometres (3.5 square miles) per hour. During the study we searched about 1,800 km² (700 sq miles) of the summer range with an estimated 10 to 20 per cent overlap.

We made extensive non-random searches for post-calving aggregations and dead calves throughout June and July. We returned as often as possible to the areas where caribou had been located and followed their fresh trails to their new locations when possible. We recorded all wolves sighted by colour phase and pack size.

When we located a dead calf, we landed the helicopter and performed a post-mortem examination. We searched on foot for other dead animals in the immediate area. When we located large post-calving groups we searched the periphery of the concentration intensively from the helicopter. If the caribou moved off the area, we often landed and searched the area on foot, after making several low level, 15- to 30-m (50- to 100-ft), passes over it. We estimated the ages of new-born calves from general body characteristics: weight, colour of pelage, absence or degree of wear on hooves, presence of umbilical cord or state of deterioration of umbilical remnants. The absence of tartar stain lines and of particles of vegetation compacted in the infundibula of the molariform teeth indicated an age less than 1 week (Miller, 1972a).

On June 2 and 4, T. C. Dauphiné, CWS, and E. M. Land, N.W.T. Game Management Service, carried out a general survey of caribou on the areas adjacent to Calf, Kaminak, Kaminuriak and MacQuoid lakes (Miller and Broughton, 1972: Appendix II). T. C. Dauphiné and D. B. M. Lamperd, CWS, delineated the calving area on June 9. The transect lines used on June 9 were the east-west military grid lines, spaced 10.06 km (6.25 miles) apart, beginning in the north with line no. 7,080,000 and proceeding line by line to the south, finishing with line no. 6,970,000 (Miller and Broughton, 1972: Appendix II). The aircraft flew along these transects at an altitude of approximately 180 m (600 feet) (Miller and Broughton, 1972: Appendix II). We carried out a systematic survey of caribou numbers on the calving ground on June 10 and 11. We divided the area occupied by the parturient females into 137 squares, each 23.5 km² (9 sq miles) in area (4.8 km by 4.8 km or 3 miles by 3 miles); for the survey, we chose 34 of the squares at random by drawing numbers from a hat. These comprised 24.8 per cent of the calving ground (Miller and Broughton, 1972: Appendix II). We counted all the female caribou 2 years or older within the boundaries, using Parker's (1970) method of counting the caribou within a 0.4-km (one-quarter-mile) wide strip on each side of the aircraft. Marks on the windows and wing struts enabled each observer to project an angle of 72° to the ground from an altitude of 150 m (500 ft). Six flight passes were required to survey each square. On June 18 through 21, T. C. Dauphiné and D. B. M. Lamperd flew an extensive survey in an Islander aircraft to determine if there were any isolated concentrations of female caribou that we had not previously detected on the calving ground (Miller and Broughton, 1972: Appendix II). The flights were made at about 150-m (500-ft) elevation.

We did all aerial photography with a 2¼-square SLR Kowa/six. We took overall group pictures at 250- to 300-m (800- to 1000-ft) elevation and obtained compositional pictures at 120 to 185 m (400 to 600 ft).

We made continuous recordings of temperature and relative humidity with Lambrecht Thermohydrographs. The CWS Eastern Region laboratory at Ottawa pre-checked and standardized all thermohydrographs with a standard sling psychrometer and rechecked them at the end of the field season. Miller and Broughton (1972: Table 2) give the location of each of 13 weather stations used in this study and its duration of operation. We used two maximum-minimum thermometers at each base camp to record daily highs and lows. At each base camp we recorded daily precipitation with a Glaisher's 20.3-centimetre (8-inch) bucket type rain gauge. We recorded twice daily at about 0800 and 2000 hours the following weather elements.

1. Wind speed with a Deuta-werke portable hand-held anemometer;
2. Wind direction with a homemade wind sock;
3. Visual estimates of the percentage of cloud cover; and,
4. The types of cloud cover present as determined with a Canadian Department of Transport Cloud Identification Chart.

After considerable discussion with several entomologists who are experienced in arctic work, we decided to keep only subjective records of insect activity. We recorded the dates for first emergence of flies and mosquitoes and days when mosquito activity reached a subjective "human discomfort" level.

Results and discussion

Type cases for calf mortality

The individual case histories not included in this section are reported in Appendix 1. The following type cases illustrate the various causes of calf mortality in descending order of importance.

1. Wolf predation. We found a female calf, CM61, on July 8, 1970. It had been dead about one day. It weighed 12.7 kilograms (27.9 pounds) and we estimated it was 4 weeks of age. Necropsy revealed that the wolf had killed the calf by crushing the skull. Tooth punctures in the abdominal area had penetrated the liver and right kidney resulting in extensive hemorrhage. The left thoracic area and left rump had been lacerated. There was a large volume of milk curds in the abomasum and some vegetation in the rumen. The wolf had not eaten any of the tissues of the calf.

On June 28, 1970, we found CM48, an adult cow. The cow was 8–10 years old based on the wear of the mandibular teeth. The appearance of the carcass suggested the animal had been killed in late May or early June. The wolf had apparently brought the caribou down by the neck. There was massive hemorrhaging on the neck, and the wolf had ripped open the throat. The energy reserves of the cow were high for the season of the year. Necropsy revealed that the cow was carrying an almost full-term female fetus. The wolf had eaten only the tongue and some cheek meat.

2. Abandonment. A male calf, CM29, was found on June 21, 1970. The calf weighed 4.5 kg (9.9 lb.). The calf was only hours old when it died but the cow had removed all afterbirth remnants from it. Examination of the calf revealed that the lungs were normal and had been functional. The stomach was devoid of any milk curds but did contain a few pieces of lichen. Possibly the cow was a young animal, calving for the first time. Calving did not lead to any social bond between herself and her calf. Her previous social ties with her group were retained and the calf abandoned.

3. Still births. On June 21, 1970, we found a male calf, CM27, weighing 7.2 kg (15.8 lb.). The majority of the placental membranes were still adhering to the calf. The umbilical cord was still moist and the hooves showed no evidence of wear. Examination of the carcass revealed that there were hemorrhages on the pericardium and the lungs were physiologically non-functional, resembling fetal lung.

4. Pathophysiological. We located a 9- to 10-year-old cow, CM19, and her male calf, CM18, on June 20, 1970. The calf had great difficulty in getting to its feet and was uncoordinated when it attempted to walk. The calf's anal area was caked with fecal material. We killed the calf and examined it because of its extremely weak condition. The calf weighed 8.6 kg (18.9 lb.) and we estimated he was 10 to 14 days old. Examination of the calf failed to reveal any abnormalities. The stomach contained primarily vegetation and a small amount of milk curds.

The cow had remained in the vicinity so we killed and examined her to determine, if possible, why the calf failed to nurse successfully. Necropsy revealed necrotic vulvitis and inflammation of the vagina and uterus. There were some placental remnants present in the uterus. The udder was swollen but the milk appeared normal in colour and consistency. Bacteriological examination of a milk sample yielded a hemolytic *Escherichia coli*. This organism is a common cause of mastitis in cows. The metritis and vaginitis may have caused the cow to go off milk production. When the cow came back into milk production, the calf was too weak to nurse, or possibly because of the *E. coli* mastitis did not like the flavour of the milk and refused to nurse. The failure of the calf to nurse and its inability to utilize lichens resulted in the severely weakened condition. The animal would have undoubtedly subsequently died of malnutrition.

5. Pneumonia. A female calf, CM15, 3 to 7 days of age, found on June 19, 1970, weighed 4.5 kg (9.9 lb.) and had been dead 1 to 2 days. Examination of the calf revealed extensive pneumonic involvement

of all lobes of the lungs. There was no milk in the stomach, only lichen, which suggests that the calf may have been abandoned by her dam. The pneumonia could have developed as a result of exposure to the heavy rain and freezing temperatures of June 16, 1970 (Miller and Broughton, 1972).

6. *Malnutrition*. On June 21, 1970, we found a male calf, CM34: the calf weighed 7.2 kg (15.8 lb.) and was 10 to 12 days old. Examination of the calf revealed a few pneumonic patches on the diaphragmatic lobes of the lungs. There was vegetation in the stomach but no milk curds. The calf was probably separated from his dam too early to be able to utilize only vegetation and survive. Separation could have resulted from the death of the dam or the dam's abandonment of the calf.

7. *Trauma*. CM43, a female calf, estimated to be 2 to 4 days old when found on June 24, 1970, weighed 8.3 kg (18.3 lb.) and had been dead for 2 or 3 days. The umbilical cord remnant was dried up and the hooves showed slight wear. Further examination revealed a massive abdominal hemorrhage, from a ruptured liver. The right diaphragmatic lobe of the lung had also been ruptured. There were extensive bruises over the right shoulder, in the middle of the back and extending to the lumbar area. The critical injuries were probably caused by aggressive action of a single cow as a result of CM43 venturing too close to her calf or by flight behaviour by a group of caribou.

Table 1
Detected calf mortality, by sex and age, during June and July 1970, on the calving ground of the Kaminuriak caribou, District of Keewatin, N.W.T.

Cause of death	Sex			Age in days						
	♀	♂	?	0–½	1–7	8–14	15	21	28	35
Wolf-killed	8	6	4		2/2*(2)†	2/1(2)	2/0	1/1	1/1	0/1
Abandoned by maternal cow	4	8		3/6	0/1	1/1				
Still births		5	1							
Physiological or pathological	3	2		1/1	1/0	0/1	1/0			
Pneumonia	4				3/0	1/0				
Malnutrition	2	2			1/0	1/1		0/1		
Injuries	3				2/0	1/0				
Natural causes undetected	4	1			1/0	0/1	1/0	1/0		1/0
Totals	28	24	5	4/7	10/3(2)	6/5(2)	4/0	2/2	1/1	1/1

* Females/males.
† (Sex unknown).

Table 2
Utilization of caribou calves killed by wolves during June and July 1970, District of Keewatin, N.W.T.

Wolf-killed caribou calves	Utilization
CM32	None
CM55	None
CM60	None
CM61	None
CM64	None
CM67	None
CM65	Abomasum only
CM1	Viscera only partial
CM31	Viscera only partial
CM38	Viscera
CM44	Viscera
CM51	Viscera
CM53	Viscera
CM56	35%, viscera, meat from both sides of withers and left front shoulder
CM52	45%, viscera, meat from right hindquarter
CM50	50%, viscera, meat from hindquarters and back along flank to middle of rib cage
CM59	80%, all but head and lower portions of legs
CM16	90%, all but lower portions of the four legs

Summary of barren-ground caribou calf mortality

Of the 57 dead calves that we found, wolves killed 18 (Table 1). Eleven (61 per cent) of the wolf-killed calves were less than 2 weeks old and the remaining seven ranged between 2 and 6 weeks of age. The most interesting aspect of the wolf killing was the slight utilization of most of the calf carcasses (Table 2). A third of the calves were apparently killed for practice or play, or in the "heat of the chase" and then left with no part of the carcass being eaten. Wolves had taken only a part or all of the viscera of seven calves and had utilized 35, 45, 50, 80 and 90 per cent of the carcasses of the remaining five. We probably missed the remains of most calves that had been consumed in excess of 80 per cent.

Table 3
A comparison by colour phase of wolves sighted on the summer range of the Kaminuriak caribou during June and July 1970, with wolves collected in 1956 as part of the wolf control project at Eskimo Point, N.W.T.

Colour phase	Novakowski (1956)		Miller and Broughton (1970)	
	Number	%	Number	%
Grey	35	65	20	63
White	9	17	5	16
Grey-Brown	6	11	4*	12
Black	4	7	3	9

* Includes the two calico wolves of Table 5 (Miller and Broughton, 1972).

No wolf dens were found on the calving ground from 1966 through 1970. In 1970 no active wolf dens were found north of the south end of Kaminak Lake (62°05′ N, 95°00′ W), only two old dens.

The hemorrhagic condition of all carcasses fed upon or mauled indicated that all of the calves were alive when attacked by wolves. As there were no active wolf dens on the calving ground, it is unlikely that wolves returned to kills. We found no evidence of wolves feeding on carrion on the calving area during June. Therefore, wolves on the calving area would have to be continuously moving along with the caribou, because of the clumping and moving of caribou groups after the peak of calving.

We believe that most, if not all, of the wolves that prey on caribou calves from the Kaminuriak population during June and July are from the nonbreeding segment of the wolf population. Kuyt (1972) also thought that most wolves on the caribou calving ground of the Beverly Lake population and those following the post-calving groups in July were nonbreeding wolves. Kelsall (1960) indicated that wolves select caribou calves during the calving period. Parker (1972) stated that in 1967 and 1968 wolves on the northern section of the Kaminuriak caribou range during June and July preyed mainly on calves but wolf numbers appeared very low. Murie (1944) suggested that wolves limited caribou numbers in an Alaskan population by predation on the calves. Pimlott *et al.* (1969) found that in Ontario white-tailed deer (*Odocoileus virginianus*) fawn hair comprised 71 per cent of the summer occurrences in the wolf scats that contained deer hair, and moose (*Alces alces*) calf hair 88 per cent in those that contained moose hair during the summer period.

We made 32 sightings of wolves during the study period: 19 in June and 13 in July. Location and dates of wolf sightings by colour phase are given in Miller and Broughton (1972: Table 5). The frequency of wolves by colour phase during 1970 can be compared with the frequency by colour phase of 54 wolves killed in winter near Eskimo Point, N. W. T. (Novakowski, 1956). The percentages of wolves by colour phase in the two samples (Table 3) is very similar, which suggests that we saw most of the wolves on the calving area. The wolves were segregated geographically by colour phase. We observed only grey and calico (grey-brown) wolves on the calving ground in June 1970. The white phase wolves were between Yathkyed Lake and South Henik Lake and the black, grey and grey-brown phases of wolves were on the open tundra south of Ferguson Lake and between South Henik and Maguse lakes.

All wolf kills found after July 1 were in association with dense stands of willows or birches suggesting that wolves had ambushed moving caribou. On one occasion a single wolf had apparently killed three calves: two within 3 m (10 feet) of each other and a third about 35 m (120 feet) away. Henshaw (1970) observed that herding greatly intensified breeding in reindeer and caribou in Alaska, but the sexual activity was interrupted when the caribou passed through belts of riparian willows. Henshaw (1968; 1970) noted that caribou were hesitant to cross through vegetation and that some animals showed signs of alarm and attributed the behavioural responses to adaptation to the pressures and methods of wolf and bear (*Ursus arctos horribilis*) predation.

Before the total impact of wolf predation on caribou during June and July can be evaluated we must learn whether the wolves are from the tundra wolf population or from the taiga wolf population or both. Parker (1972) has estimated the wolf population on the home range of the Kaminuriak caribou at 500 to 600. He considered that the estimate was conservative, as do we. Fuller and Novakowski (1955) found that the age ratio was three young to 10 adults for 13 wolves representing three entire packs. If nonbreeding wolves on the calving grounds are from both the taiga and tundra groups there could be 125 to 150 wolves present, (25 per cent juveniles). If they are from the coastal tundra wolf group they might number from 25 to 50. At least 25 of 32 wolves seen on the summer range were different individuals.

We attributed approximately one-third of the calf deaths (Table 1) to predation by wolves. There is no way of estimating the number of additional calves that were killed and entirely eaten by wolves. We have produced, however, a conservative estimate of wolf predation on caribou calves to illustrate the possible impact of only 25 wolves on the calf crop. The estimate was based on the degree of calf utilization by wolves (Table 2) and the minimal number of individual wolves observed.

Estimate

1. If there were 25 wolves on the calving ground.
2. And 24,000 parturient caribou produced 19,200 calves in 1970.
3. And each wolf killed one calf per day to meet its energy demands, because it did not return to its kills, did not feed on carrion and was experiencing a high rate of hunting activity in its pursuit of caribou groups and the stalking and ambushing of moving prey.
4. And 33 per cent of the wolf kills were not fed upon.
5. And an additional 40 per cent of the wolf-killed calves were so slighty utilized that the users made a second kill per day at least 50 per cent of the time.
6. And 15 per cent of the kills were utilized to a degree that allowed the wolves to go 2 days without *having* to kill other calves.
7. From 4, 5, and 6 it may be assumed that 62 per cent of the wolf kills were usable. Thus in order to obtain 25 "usable" ones, 40 calves must be killed per day.
8. Therefore, 25 wolves killed:

Date	Days	Calves	Per cent calf crop
June 2–30	28	1,120	6
June 2–July 14	42	1,680	9
June 2–July 28	56	2,240	12

Even if the rate of killing of calves without utilization (33 per cent) and with minimal use (37 per cent) was much lower than in our sample, we judge that each wolf probably killed on the average at least one calf per day from June until about the end of July. All the nonbreeding wolves on the

Kaminuriak caribou range could take 20 to 30 per cent of the new-born calves, if both taiga and tundra wolves are present on the summer range and kill at the estimated rates.

We found two adult cows that had been killed by wolves. CM48 was apparently killed in late May or early June. The wolf had ripped open the throat and removed the tongue and some of the flesh from the left side of the face. Some meat was also taken from the right rump and along the right side of the mid-dorsal line (only about 5 per cent utilization). The fetus was a near-term female still in the amniotic sack. The cow appeared to have been in good condition for the breeding season. CM58 was also a radio-equipped animal. She had been killed prior to our first radio detection of her on June 8. She had calved before being killed and about 20 per cent of her carcass had been utilized.

Wolves remain one of the most manageable causes of mortality of Kaminuriak caribou and the least understood in terms of the predator-prey relationship. We suggest, as did Pimlott (1967), that energy requirements of wolves make it very unlikely that they regularly subsist on small animals during the summer. We believe, as did Murie (1944), that most of the breeding wolves obtain caribou during early summer from the late northward movement of males and stragglers left behind the main movement. We suggest that the many crippled caribou seen during June and July become the staple diet of wolves in August, September and October. This explains the absence of cripples on the wintering grounds. Pimlott's (1967) supposition that more than one wolf per 100 white-tailed deer surpasses the point of equilibrium in the wolf-deer relationship may be approximately true for the wolf-caribou situation. Parker (1972) has calculated that the Kaminuriak caribou (1:114) are approaching this ratio. Therefore, the pressures of wolf predation on the Kaminuriak population may be a principal factor limiting the population's total growth. We agree with Pimlott (1967) that the importance of wolf predation on the young of cervids, in this case of caribou, has not been generally recognized and the following from Pimlott (1967) best summarizes this section:

> If a considerable portion of this predation is non-compensatory, a population of wolves of high density would exercise a considerable influence on ungulate populations. Allee, Emerson, Park, Park and Schmidt (1949) listed a series of principles that arose from their review of predation. The third is of particular interest to this discussion: "predation is frequently directed against the immature stages of the prey and as such may constitute an effective limiting factor." (p. 374)

Twelve calves died apparently because they were abandoned by their maternal cows (Table 1). Nine of the calves were only a few hours old when they died, one was less than 1 week and two less than 2 weeks old at death. Only one of the nine calves that had died during their first hours of life was completely cleaned of afterbirth. Remnants of placental tissue remained on all the others and CM41 was almost totally encased in placental tissue. Likely, all nine calves were born after the peak of calving (June 11).

Abandonment of new-born calves by their maternal cows was the second most common cause of mortality. This seemingly abnormal behaviour of the maternal cows could be explained by the following suppositions.

1. It was the first time that they calved. They were probably 2- or 3-year-olds that were not truly aware of, or adjusted to, the state of parturition, therefore, they left the calves and did not nurse them. Young cows calving for the first time, especially after the peak of calving when the caribou are in large groups, may retain strong social ties with the group and fail to establish bonds with their newly dropped calves. During the last 2 weeks of June we observed that many of the small peripheral groups were composed of maternal cows and new-born calves that were only hours or a few days old. The groups were usually several miles from large post-calving groups. The cows in the small groups had apparently left the large groups to drop their calves and in so doing established a strong mother-young bond which is essential for successful rearing of the calves. Any cow, especially one calving for the first time, that stayed in the large moving groups and dropped her calf, would, however, probably retain an affinity to the group and desert her calf on the migrational path.
2. The cows may have had some physiological or pathological problems that resulted in irritation during the birth processes and desertion of the calves when they were dropped. If they cleaned the calves and stayed with them, they may have later suffered from some condition such as mastitis which caused them to desert their young. The second supposition would be extremely hard to defend and prove. In our limited collection one cow with metritis, mastitis and so on stayed with her calf even though it was unable to nurse. Another cow with a distended udder, suggestive of mastitis did not desert her calf.
3. The three older calves that were classified as abandoned could have become separated from their maternal cows when the group was disturbed by hunting wolves or low-flying aircraft, especially our helicopter. Helicopters create a much higher level of disturbance than fixed-wing aircraft. Ground observations during the study showed that caribou were alerted to an approaching helicopter at three to five times the distances at which they responded to an approaching fixed-wing aircraft. Cows who were unable to nurse their calves because of udder inflamations would be least likely to seek out their calves after being separated in this way.

We could not determine any of the causes of still births. It is likely, however, that many of the still births are attributable to the youngest segment of the breeding females. The young parturient females probably were less well nourished and suffered more from the stresses of carrying the fetuses to termination than older females. Both Michurin (1967) and Skoog (1968) believed that early breeding by young female caribou and reindeer was not desirable as it could jeopardize the survival of the young cows and their offspring. If the young females are the greatest contributors to both still births and abandonment of offspring these two causes of calf mortality should overlap somewhat and have less impact.

Five calves suffered physiological or pathological problems: three (CM5, 18 and 54), we found alive and killed. CM5 and CM18 were on migrational paths but were too weak to move with their post-calving group. Autopsies revealed no pathological entities and we attributed their conditions to fatigue. CM35, female, and CM39, male, had both died shortly after birth. Their lungs appeared partially non-functional. CM54 was a female calf over 15 days of age when we found it, too weak to stand. The maternal cow was standing over it. The calf had a massive abscess in association with its liver, only about one-third of which was functional. The calf's weakness was probably due to its failure to nurse and the dissemination of toxins from the abscess. A low incidence of these physiological or pathological maladies is to be expected in the new-born of any cervid population.

Four calves had died from pneumonia. All had died after the 2.18 cm rainfall of June 16, which was associated with freezing temperatures. Although pneumonia did not appear critical as a mortality factor of new-born caribou during the 1970 calving period, we believe that in some years it could be one of the principle causes of deaths. We base this belief on the observed movements of the caribou groups in response to the wetness of that period. Also, the weather during the 1970 calving period appeared mostly favourable to calf survival. It would be necessary to have much more sophisticated climatic monitoring equipment than that used in the current study to evaluate the impact of climatic elements on the survival of new-born calves. Table 4 gives the results of our various manipulations of the *degree day* concept (Baskerville and Emin, 1969) for evaluating the impact of weather on an organism. In the table:

Table 4
An evaluation of the climatic elements recorded during June 1970 on the calving ground of the Kaminuriak caribou, District of Keewatin, N.W.T.

June 1970	Gross degree day C°	Wind (kmph)	Adjusted degree day C°	Rain (mm)	Net degree day C°
3	9	32	−23	2.8	−51
4	6	24	−18		−18
5	8	9	−1	6.8	−69
6	−1	72	−73	6.1	−134
7	−2	48	−50		−50
8	1	40	−39		−39
9	3	6	−3		−3
10	6	5	1		1
11	7	8	−1		−1
12	7	32	−25		−25
13	6	24	−18		−18
14	5	24	−19	0.3	−22
15	4	13	−9	0.3	−12
16	2	22	−20	21.8	−238
17	4	10	−6		−6
18	6	13	−7		−7
19	5	19	−14		−14
20	5	13	−8		−8
21	4	6	−2		−2
22	6	16	−10		−10
23	7	10	−3		−3
24	6	10	−4	0.3	−7
25	8	5	3		3
26	9	10	−1		−1
27	10	5	5		5
28	7	19	−12	4.5	−57
29	9	2	7	0.3	4
30	11	8	3		3
Totals	158		−347		−779

Gross degree day (GDD) = Aver. daily temp. − A threshold of 0°C
Adjusted degree day (ADD) = GDD − (1°/km per hour wind)
Net degree day (NDD) = ADD − (1°/0.1 mm precipitation)

The GDD is the average daily temperature with a threshold of 0°C. The ADD considers the influence of wind, based on average daily wind velocity. A further adjustment for each 0.1 mm of precipitation gives the NDD. A consideration of any combination of additional weather elements might help to refine the evaluation as might different manipulations of the elements. A rapid estimation of heat accumulation from maximum and minimum temperatures is discussed by Baskerville and Emin (1969). From Table 4 it can be seen that the accumulated heat values for the ADD

decreased 3.2 times from the GDD and the NDD is 5.9 times lower than the GDD. We believe that the NDD gives a better measure of the impact of prevailing weather on new-born caribou. The fact that the NDD in 1970 was negative reflects more the use of the metric system in calculations than the minimal adverse influence of weather during the 1970 calving period. A negative value of several thousand would, however, suggest that the weather was unfavourable for the new-born young. In years of high negative values pneumonia could be expected to be a leading cause of mortality of caribou calves.

Both Zhigunov (1961) and Parker (1972) believed that precipitation and winds governed the caribou's choice of calving areas. Kelsall (1960:51–63 and 1968: 238–241) summarizes his observations and the findings of many other field workers who observed caribou calf mortality during periods of adverse weather. There is total agreement on the detrimental effects of wind chill on new-born caribou and that the combination of strong winds, low temperatures and precipitation is the most lethal. Lentz and Hart (1960) found by studies of fur patches from caribou calves that air speed and direction and wetness of the fur affect heat loss. They (Lentz and Hart, 1960) stated that "The combined effect of these factors may increase the rate of heat loss by a factor of four to six." Hart *et al.* (1961), working with live calves from the Beverly population, found that at a wind chill value of about 1000, calves with wet fur had a significantly greater metabolic rate than dry calves. They also found that calves died when wind chill values exceeded 1100 or when the metabolic rate approached 25 Cal/hour/kg^{¾} for long duration. Kelsall (1960:54–55), however, notes that there are many climatic factors that wind chill measurements do not take into account and which may be of importance to calf survival. Pruitt (1960) reported "M. V. Nazarov (Reindeer Husbandry, 1926) observed that in cold springs, if freezing temperatures and winds coincided at the time of fawning, the entire fawn crop was often annihilated."

Of the four calves that suffered from starvation, two died after their dams, we found a third, female, alive by the side of its dead mother and a fourth separated from its dam and post-calving group. One of the maternal cows (CM8) died from an abdominal hemorrhage as a result of a ruptured uterus. The second maternal cow (CM26) was too decomposed for a detailed examination. The placenta, however, had not been expelled indicating the animal had died 1 or 2 days after calving. The third maternal cow (CM46) died from extensive peritonitis and was also infected with besnoitiosis. The loss of calves due to the deaths of their dams as a result of some disease or disorder associated with parturition appears to be rare and has little impact on the total calf crop.

Two adult females were shot because they had great difficulty in walking. CM2 was lactating but had not nursed and was without a calf. There were areas of erosion on the articular surface of the distal ends of her right femur and humerus and she had arthritis of the right stifle joint. This animal also had besnoitiosis. CM6 was a nonbreeder. Her lameness was the result of erosion of the surfaces of the stifle joint. This animal reacted positively to a test for brucellosis. We killed a third adult cow (CM19) because her calf was too weak to walk. The maternal cow had metritis, hemorrhagic vaginitis and a swollen udder. Bacteriological culture of her milk yielded a hemolytic *E. coli*. Another maternal cow standing over her dead calf was not collected but from the appearance of her distended udder it is most likely that she was also suffering from mastitis.

We found three calves that had died from injuries apparently caused by adult caribou. The calves were probably trampled by other caribou while in flight from wolves or aircraft or by single antagonistic cows when they ventured too close to their calves. One calf died from a ruptured kidney, another from ruptured lungs and liver and the last from blows to the neck. DeVos (1960) found five caribou calves that had been trampled and punctured with antlers. He believed that the deaths resulted from adult females attacking strange calves that had strayed too close. This type of mortality is currently within acceptable limits. If harassment by aircraft is, in fact, one cause of such injuries to calves, the incidences will increase with the increasing aircraft exploration on the calving grounds.

The possible impact of aircraft harassment on new-born calves by causing abandonment, separation and injuries can be illustrated by a simple mathematical approach.

1. If there are 24,000 cows on the calving ground;
2. And 80 per cent of them produce young;
3. And 80 per cent of the young are produced during 5 days of peak production, and we assume that production is random;
4. We have: 24,000 x 80% = 19,200 calves
   19,200 x 80% = 15,360 calves
5. Then: 15,360 ÷ 5 = 3,072 calves/day
6. And: 3,072 ÷ 24 = 128 calves/hour
7. Therefore: Aircraft harassment during the peak of calving could possibly indirectly result in a considerable loss of new-born calves.

We could not determine the causes of deaths for five calves. Three of these calves were too decomposed for detailed examination. The fourth one (CM14) still had the maternal cow standing by and the cow appeared to be suffering from mastitis. The calf had been dead for only several hours, but we could not detect the cause of death. The fifth calf (CM68) was found on a caribou trail in a dense stand of birches. Its pelage was very wet and the calf appeared to have been harassed, but the cause of death could not be determined.

We found no caribou that had drowned during the current study. An Eskimo from Baker Lake known as "Scotty" gave us the mandibles from a new-born calf that he collected in late July, 1968. He had watched through a spotting scope as the calf was being born. The mother then left the calf and crossed a body of water to rejoin a post-calving migration. The calf attempted to follow its mother and drowned in doing so. Kelsall (1968:261–263) reported isolated cases of caribou drownings. On August 11, 1951, an estimated 450 dead caribou (53.3 per cent calves) were found scattered along 16 km (10 miles) of the north shore of Aberdeen Lake (Kelsall, 1957: 40–41).

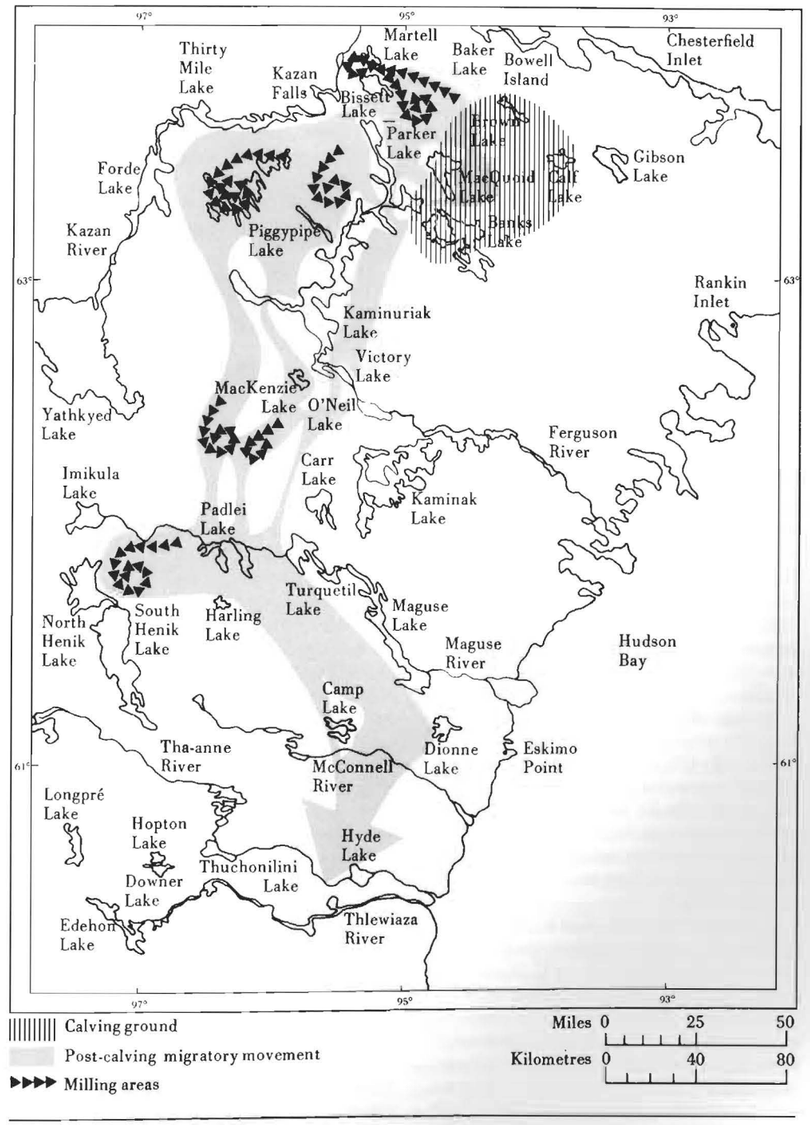
In some years the retention of ice shelves along the edges of water courses could cause many caribou to remain in the water for prolonged periods of time and subsequently drown when weakened by exposure. The loss of caribou due to drowning during the post-calving period is probably greatest among the calves, especially late born calves. In 1970 the ice was gone before the caribou began their post-calving movements and migrations. Caribou of the Kaminuriak population do not have to make dangerous water crossings such as those made by caribou of the Beverly population.

Distribution and movements

In 1970 caribou of the Kaminuriak population began their northward spring migration in April, with groups of caribou changing directions several times during the first 2 weeks of that month. By May, however, the caribou were well into the tundra and arrived on the calving ground by late May. Most calving took place between June 5 and 11, 1970, and large post-calving groups began to form by June 12, 1970. The caribou meandered over the tundra for most of June, then many of them began their midsummer migration southward to the taiga on June 28, 1970. Overall distribution and movements during June and July 1970 are given in figure 2. Our field work was terminated on July 29, 1970, as some of the caribou began to penetrate the taiga south of the McConnell River. Miller *et al.* (in prep.) obtained data on distribution, movements and social cohesion by radio tracking Kaminuriak caribou on the calving and post-calving areas. The distribution and movements of these caribou, determined by

Figure 2. Distribution and movements of barren-ground caribou of the Kaminuriak population, June and July 1970.

Figure 2



aerial search and survey in 1970, are given in Miller (1972b).

Environmental elements

Temperatures ranged from −3.4°C (26°F) to 16.1°C (61°F) in June and 2.8°C (37°F) to 23.9°C (75°F) in July (Miller and Broughton, 1972: Appendix IV). During the peak of calving (June 5–11) temperatures ranged from −3.4°C to 11.1°C (52°F). The longest period of freezing temperatures (0°C or below) during the peak week of calving was 38 hours (26.8 per cent). Only 6 hours of freezing temperatures occurred after June 10, 1970.

The weather on the calving ground after the peak of calving was quite moderate and favourable for calf survival with the exception of June 16 when 2.18 cm (0.86 inch) of rain fell, followed by a night of below-freezing temperatures. Temperatures over 10°C (50°F) first occurred on June 10, 1970. Temperatures exceeded 10°C for a total of 400 hours or 29.7 per cent of the time: 95 hours (7.0 per cent) in June and 305 hours (22.7 per cent) in July. The longest durations of temperatures in excess of 10°C were 15 hours in June and 90 hours in July. Only twice in July did temperatures in excess of 10°C persist for more than 30 hours (July 11–12, July 19–22).

A range of 14–100 per cent relative humidity was experienced during the study period: 29–100 per cent in June and 14–100 per cent in July (Miller and Broughton, 1972: Appendix V). Relative humidity exceeded 90 per cent for 319 hours or 23.7 per cent of the study period: 167 hours (12.4 per cent) in June and 152 hours (11.3 per cent) in July.

We recorded a total of 10.67 cm (4.19 inches) of rainfall at our base camps during June and July 1970: 4.33 cm (1.70 inches) in June and 6.34 cm (2.49 inches) in July (Appendix 2). Relatively little precipitation occurred during the peak calving period. Periods of rainy and overcast weather varied from several hours to 8 days. The greatest accumulation of rain was 4.43 cm (1.74 inches) during the 8-day period from July 20 to 27, 1970.

Wind direction and velocity were recorded on 125 occasions (Appendices 3 and 4). The prevailing wind was from the north-west (25 per cent of the recordings). A total of 64 per cent of the recorded winds came from the northern quadrants: 45 per cent from the north-west quadrant and 19 per cent from the north-east quadrant. The percentage of recorded winds from the various points of the compass are given in Appendix 3.

We recorded wind speeds of 0–112+ kmph (0–70+ mph). On June 6 and 7 the force of the wind pegged the anemometer at 112 kmph. On those dates wind velocities in excess of 160 kmph (100 mph) were recorded at Baker Lake, Rankin Inlet, Chesterfield Inlet and Eskimo Point settlements. Wind speeds exceeded 32 kmph (20 mph) on 56 occasions or for 44.8 per cent of the recordings (Appendix 4). The strongest winds came from the north, followed by winds from the north-west (Appendix 3). Winds from the southern quadrants never exceeded 48 kmph (30 mph) (Appendix 3).

Because of the reasons listed by Kelsall (1960: 62–63), the discontinuity of records for measured climatic elements and because the weather conditions were relatively moderate during the 1970 calving period we will not attempt to evaluate the stress wind chill causes new-born calves. The behavioural responses of calves under unfavorable wind and temperature regimes are not known and would greatly increase the usefulness of such climatic data.

We experienced few days when the potential (over 22 hours at our base camp during June) for unobstructed sunlight was realized. Appendix 5 gives an estimation of daily hours of sunshine during the calving period. The sun shone an average of 9.4 hours per day between June 1 and 27. This was about 42 per cent of the total potential direct radiation for that time period. We did not attempt any evaluation of daily or accumulative solar radiation.

Cloud cover varied daily and sometimes hourly throughout the study period (Miller and Broughton, 1972: Appendix VI). No correlation was attempted between cloud cover and other weather elements. Cloud forms by percentages on 123 occasions during June and July 1970 are given in appendix 6.

The first flies and mosquitoes were detected during the last days of June. Mosquitoes did not reach levels of human intolerance until the first of July. High levels of mosquito activity usually began by mid morning and continued until early evening. High humidity and cool temperatures throughout most of July kept mosquito harassment at a low level as compared to some years. We observed caribou grouping and running in response to insect activity. Although the caribou would have accumulated greater fat reserves, or done so more rapidly, had there been no blood sucking insects, their harassment seldom caused the caribou to restrict their forage intake for prolonged periods.

During the first 2 weeks of June the vegetation responded to the prevailing moderate weather. Sedges, grasses and grass-like plants grew rapidly. The lichens on the wet meadows freshened, while those lichens on the higher drier sites remained desiccated and crumbled when handled. The small pothole lakes were free of most of their ice and rivers were overflowing the ground ice.

Phenological changes took place in some vegetation that markedly altered the appearance of surrounding landscapes. Cotton-grasses (*Eriophorum* spp.) were the first sedges that showed some greening of blades. After the 0.54-cm (0.25-inch) rainfall on June 5 lichen clumps on drier sites freshened immediately, but due to the drying effect of the winds during the next 2 to 3 days they became desiccated again. When the lichens had lost their freshness the caribou resumed foraging on sedges on the wet sites. Physiological dehydration may reduce palatability of lichens. By June 11 cranberries (*Vaccinium* spp.) had shown considerable greening of the leaves as did Labrador tea (*Ledum* spp.). Cotton-grasses and other sedges (*Carex* spp.) of the surrounding moist areas appeared to be growing rapidly. The leaf buds had not burst on the willows or birches.

The new growth of sedges, grasses and periodically freshened lichens was readily available to the caribou from the period of peak calving. By the last days of June birches and, within the following week, willows were in full leaf. Grasses and sedges had greened and many were in flower. The Labrador tea was in full bloom, but *Empetrum nigrum* was still in the process of greening. Lichens freshened at night even with the minimum of 0.25 mm (0.01 inches) of rainfall, but with the rising sun and desiccating winds they dried within a few hours. Aquatic and wetland grasses were lush and tall covering the edges of small bays, stream sides and the edges of smaller pools. The sedge meadows were green, whereas a week before they had appeared yellow from the air.

During July the caribou stripped the leaves of willows and birches and fed on the new growth of sedges, grasses and freshened lichens. Forage was abundant throughout the area.

Only traces of the deepest snowbanks persisted by late June along margins of larger lakes and deep rock outcrops. Ice remaining on larger lakes was melting rapidly and there was much open water around the islands and along the shorelines. By mid July even the largest lakes were virtually free of ice and all the rivers were free flowing.

Aerial photography

We began the aerial photography of caribou on the calving ground in early June. The low level, 100- to 165-m (300- to 500-ft) flying that was necessary for good compositional photography of mixed groups was a serious form of harassment to the caribou. As our primary objective was to determine the causes of mortality to new-born calves we decided not to introduce possible additional mortality by aircraft harassment. Therefore, we carried out most of the photography for determining composition of caribou groups at heights above 200 m (600 ft). Thus, the photography was mostly unsatisfactory for compositional counts by current techniques and knowledge of resultant imagery.

As the principal value of aerial photography is its objectivity, we decided to examine the calf/cow relationship only in groups of caribou that could be totally segregated by sex. The approach greatly reduced the amount of usable photography but eliminated subjective compilation of data.

We photographed 52 groups comprising a total of 9,519 cows and calves (Table 5). The photography was done during four major stages of their calving and post-calving activities: end of peak calving, 5 days before and right after initiation of the post-calving migratory period and when the impetus of the migration began to wane as the caribou were nearing the tree line.

The unequal sample sizes during the four periods greatly reduces the value of overall quantitative analysis of the data. An estimation of the mortality on a chronological basis is, however, justifiable. Although, the sample sizes for the four periods vary considerably, the average number of caribou per group photographed (90, 142, 311 and 281) suggests that the estimations of mortality for the first two periods should be comparable as should those for the last two. Average group size (Table 5) weakly reflects the progressive gregariousness of the caribou throughout the summer. The decrease in average group sizes during late July was probably caused by the fragmentation of many large migratory groups as the migration waned.

Table 5 shows that although the overall percentage of cows with calves for each of the four periods appears to follow a logical pattern, the percentage of cows with calves

Table 5
Calf/cow and calf/group statistics obtained by aerial photography between June 12 and July 29, 1970 on the calving ground and summer range of barren-ground caribou of the Kaminuriak population.

Date	No. groups photographed	Average group size	Combined group size	Range of group sizes	Range of calf/cow ratios (%) by groups	Overall calf/cow ratio (%)	Estimated mortality*
End of peak calving							
12/6	10	58	592	26–196	48–95	76	16
13/6	13	114	1,477	57–179	54–93	81	10
Five days before post-calving migratory period							
23/6	8	142	1,136	32–353	78–92	83	8
After post-calving migratory period had begun							
30/6	7	135	948	50–249	38–87	60	33
3/7	7	486	3,402	140–985	16–75	34	62
Caribou nearing tree line							
22/7	2	172	343	62–79	62–79	66	27
23/7	1	429	429			59	35
24/7	3	333	998	120–577	54–69	56	38
29/7	1	194	194			66	27

* 90% is rate of fecundity of Kaminuriak females, which have spent 3 years on the calving ground (Dauphiné, in prep.).
$100-\left(\frac{\text{Overall calf/cow ratio, \%}}{\text{Expected calf/cow ratio, 90\%}} \times 100\right)$.

for any period varies greatly among groups. Even at the end of the peak of calving, some groups of cows and calves had only about 50 per cent of the expected calf/cow ratio. At the same time, however, other groups of cows and calves exceeded the expected calf/cow ratio by about 5 per cent. The reasons for such variations are unknown. If they do not reflect variation in birth rates among in-group females, they might lie with social affinities and the levels of intolerance expressed by individual females.

We estimated calf mortality from aerial photographs. Mortality to calves appeared to range from 8 to 16 per cent and averaged 11 per cent during the premigratory period. Calf mortality ranged between 27 and 62 per cent and averaged 37 per cent during the post-calving migratory period. We believe, however, that these data are possibly complicated by changing group composition throughout the calving and post-calving periods.

Several assumptions must be made in order to evaluate the mortality of calves as estimated from aerial photography. We must assume that yearlings could be distinguished and that no 2-year-olds were present in the photographed groups used for ratio counts. These assumptions are supported in part by our knowledge of segregation within and among post-calving groups of Kaminuriak caribou (F. L. Miller, in prep.). Also, we must assume that only one-half of the nonbreeding 3-year-olds were in the photographed groups. Therefore, we assumed that the expected ratio of calves to cows in the photographed groups should be 90/100. The assumptions are arbitrary, but they are based on what factual data are available. It is unlikely that the true number of calves to cows could be lower. The reader can re-evaluate the average percentage of mortality for calves at any date by dividing the overall percentage of calves seen by any expected calf ratio, and subtracting this from 100 per cent.

To attempt to explain the observed values for the calf/cow ratios and estimated mortality of calves, one must speculate about the synchrony of parturition and behaviour of the caribou during calving and post-calving periods. Although the time of parturition is well synchronized in barren-ground caribou as evidenced by the short span of peak calving, our observations during late June and early July led us to believe that possibly as much as 5 per cent of the calf crop was born after the peak of calving in 1970. We think that it is most likely that this percentage of late births occurs in most, if not all, years.

A minor element of the reproducing segment of the population being out of synchrony may help the species survive in years when the synchronized calf crop fails. The observed higher ratio of cows to calves on June 23 was probably influenced by late births and masking of calf mortality by calfless cows leaving the cow/calf groups to join peripheral groups of nonbreeders and juveniles. Our observations of group cohesion and sex and age class segregation suggested that the peripheral groups grew mainly by the influx of what appeared to be adult females after mid June until the migrations began. It is most likely that the maternal cows became more intolerant of calfless cows as the dams' maternal-filial bonds grew stronger as their calves aged. Calfless and barren cows could have been harassed sufficiently to cause them to temporarily break their ties with their groups and move to peripheral groups until the migration began. The post-calving migratory period began on June 28, and with the drive to migrate came a much greater tolerance of all other caribou by maternal cows. Possibly the estimated high mortality of calves calculated from the July 3 photography 5 days after the migrations had begun reflects the relative desegregation of the migratory groups. The great influx of juveniles, young bulls and barren or calfless cows into the maternal groups would greatly increase the adult/calf ratio and thus exaggerate calf mortality. After the calving ground animals had joined the bulls and remaining juveniles on the summer range, the groups began a reshuffling and segregation process that seemingly continued for several weeks. The resultant segregation partially explains the reduction in estimated calf mortality during late July.

We cannot recommend the use of aerial photography until the technique can be used more objectively. The lack of understanding of group cohesion and dynamics of group structuring negate most aerial photography unless total coverage is obtained or the representation of the population in the sample is understood.

From the data obtained by aerial photography and our subjective impressions of the fate of the calf crop from June through July we can only conclude the following: that the 62 per cent mortality value of July 3 is an over estimate, that the average estimated mortality value of 37 per cent approximated the true loss of calves during the first 2 months of life in 1970, and that calf mortality most likely varies from year to year depending upon the impact of one or several decimating factors in any one year.

Conclusions and recommendations

The principal cause of observed calf mortality during the calving and post-calving periods in 1970 was predation by wolves. Much of the killing of the new-born calves was done without subsequent utilization. This suggested that many of the wolves that killed calves were stimulated by drives associated with learning in young, predatory animals. Necropsies of all calves which we have reported as being killed by wolves revealed that the calves were alive when taken by wolves. None of the calves that had died from causes other than predation were fed upon by wolves. This, plus the killing of calves without utilization, suggests that carrion was not important to the wolves on the calving ground.

The second major cause of calf mortality was the abandonment of new-born young by the maternal cows. We believe this seemingly abnormal behaviour was restricted to young females producing calves for the first time, and especially to those which produced calves during post-calving movements. The rate of such abandonment of new-born young might be directly associated with the physical condition of the maternal cows and one would expect that the youngest parturient females in the population would be in poorest physical condition during any given calving period.

Ten per cent of the dead calves were still births, and, we believe, most of these were dropped by cows producing young for the first time or by very old and weakened females. About 30 per cent of the dead calves found during 1970 had died from physiological or pathological disorders, pneumonia, malnutrition and injuries. None of these factors contributed substantially to the reduction of the current calf crop, and all seemed well within acceptable limits for healthy cervid populations.

The weather during the 1970 calving period was favourable for calf survival with the exception of the one heavy rainfall of 2.18 cm (0.86 inch) on June 16 followed by freezing temperatures at night. However, in some years unfavourable weather conditions would indirectly account for most of the deaths of new-born calves, by causing pneumonia or other respiratory diseases.

If harassment by aircraft does result in injuries in new-born caribou the incidence will probably increase with the increasing aircraft exploration on the calving grounds and post-calving areas. If harassment by aircraft takes place during the peak of calving a considerable loss of new-born calves could occur.

The most questionable part of the evaluation of the total impact of wolf predation on caribou during June and July was the number of calves killed and totally eaten by wolves. Whether or not the wolves were from the tundra wolf population or from the taiga wolf population or both is another primary consideration. Also of importance is what segments of the wolf population and what percentages of those segments were preying on the new-born caribou. It was most likely that during June most of the predation on new-born calves was by nonbreeding wolves. During July, however, caribou migrated into the wolf denning areas and both nonbreeding and breeding wolves had opportunity to prey on them.

Wolves remain the most readily manageable of mortality factors in the life equation of the Kaminuriak caribou and possibly the least understood in their impact on the caribou population. Pressures of wolf predation on the Kaminuriak population may be a principal factor limiting the population's growth. The importance of wolf predation on the young of caribou has not been fully realized.

We may expect mortality in new-born caribou to vary from year to year depending on prevailing weather conditions during the calving period, the degree of predation, the age span of breeding females in any particular year and the possible outbreaks in some years of disease or physiological maladies. The high loss of new-born calves continues to be the principal factor limiting the population's growth.

We think that our results and the findings of other investigators satisfactorily document, on a qualitative basis, the general causes of mortality to new-born caribou. Therefore, we suggest that as the high loss of new-born calves to wolves could be a major factor limiting the population's growth, the desirability of reducing predation on calves by wolves should be considered by management agencies.

To manage this problem, it will be necessary for us to develop a better understanding of predator-prey associations, that is, the wolf-caribou relationship. This can best be done on a limited basis by initiating a study of wolf-caribou relationships from the premigratory period in March to the calving period in June. We currently have telemetry systems which could greatly refine the results that could be obtained from such a study. It is likely that we could continue to catch caribou and radio equip them with minimum cost and effort. The problem of capturing wolves, however, is a new one to us and there may be additional problems. We believe that the use of helicopters is necessary to ensure the capture of wolves during late March and early April.

Currently proposed resettlement programs would put several hundred Indians back on the land and surely result in a much higher human harvest of caribou. Therefore, the understanding of the predator-prey relationship between wolves and caribou is the first priority in management of these caribou.

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Appendices

Appendix 1
Case histories for Kaminuriak caribou examined on the calving area, District of Keewatin, N.W.T., June to July 1970

The following records are for 50 calves and six adult female caribou on which autopsies were performed during the study. Included also are records for two adults (CM10 and CM62) and one yearling (CM49) male caribou that died on the calving ground but were not directly related to the consideration of calf mortality. Specimens CM15, 18, 19, 27, 29, 34, 43, 48 and 61 reported under "Type cases for calf mortality," are not included. Details for each case history appear as follows: specimen, cause of death, sex, age, body weight and remarks. Dates, locations and additional statistics for each specimen are given in Miller and Broughton (1972).

CM1. Wolf-killed, male, 1 to 2 days, 4.5 kg (minus viscera).
Remarks: Ripped above shoulder and back of neck; brokeu vertebral column; occipital and right temporal areas punctured and fractured; two tooth marks and massive subcutaneous hemorrhage in left thoracic area; bruises on left and right hips in the vicinity of the femur; rib cage punctured several times; lungs and heart punctured; heel of ramus fractured.
CM2. Shot, animal had locomotor problems, female, 5–7 years (est. by mandibular teeth), 58.9 kg.
Remarks: Past-term; lactating, but had not nursed, plugs still present in teat canals; liver heavily infected with *Cysticerus;* gap between missing left first incisor and present right first incisor 8 mm at gingiva, 10 mm at the crown; limping badly; calfless; afterbirth protruding 250 mm from the vaginal orifice; eroded area on distal end of femur and distal end of right humerus; arthritic right stifle joint; 37 warble larvae; afterbirth in rumen; specimen infected with besnoitiosis.
CM3. Pneumonia, female, 1–3 days, 5.1 kg.
Remarks: Extensive pneumonia in right diaphragmatic lobe; apical lobes normal; left and right diaphragmatic lobes showing hepatization; much gas in intestinal track; scours staining hindquarters (almost identical to *E. coli*); fly larvae in mouth and stomach; very little milk in stomach; some lichen and other vegetation in rumen.
CM4. Ruptured left kidney — possibly resulted from approaching too closely to and being stepped on by maternal cow or another cow with a calf, female, 3–5 days, 5.6 kg.
Remarks: Scour material on inside of hind legs; lungs not indicative of pneumonia; some inflamation in stomach; ruptured left kidney in association with abraded skin patch on left rump.
CM5. Killed — found alive on migration path — — too weak to follow maternal cow, female, 1–2 days, (unbilical remnant still present), 5.4 kg.
Remarks: Although the hooves were not as well developed as other calves', cartilage and soft parts showed extensive wear; no curds in intestines; all organs appeared normal; perhaps just fatigued.
CM6. Shot — animal had locomotor problems, female, 7–9 years (est. by mandibular teeth), 68.0 kg.
Remarks: Heavy infection in liver of *Cysticercus tenuicollis;* 113 warble larvae; animal sighted running with bad limp; erosion in right stifle joint between the femur and tibia joints; positive brucellosis.
CM7. Still birth, male, not applicable, 5.4 kg.
Remarks: Placental membrane still on fetus; fetus had been on the ground for at least several hours and maternal cow was still standing guard over it; bond was broken when cow left fetus upon approach of the helicopter and rejoined the post-calving group.
CM8. Massive abdominal hemorrhage as a result of puncturing of the uterus during parturition — ruptured uterus, female, 8–10 years (est. by mandibular teeth), undetermined.
Remarks: Maternal cow dead with her new-born calf dead next to her.
CM9. Malnutrition — due to death of maternal cow, male, 7–12 days, undetermined.
Remarks: Specimen too decomposed to take measurements; stomach filled with vegetation, but no milk.
CM10. Undetermined — possibly due to old age, male, 15+ years (est. by mandibular teeth), undetermined.
Remarks: Animal found dead still retaining autumn rack of antlers; apparently died in autumn 1969 and remained fairly well intact under the snow cover; mandibular teeth indicated specimen was older than any other male that we had yet examined from the Kaminuriak population.
CM11. Undetermined, female, 8–12 days, 6.1 kg.
Remarks: Trace of pneumonia around apical lobe of lungs; only vegetation in rumen, no milk.
CM12. Pneumonia, female, 5–8 days, 4.8 kg — (maggots throughout body cavity).
Remarks: Pneumonia extensive in lungs; only dead about 2 days; could have resulted from heavy rainfall and freezing temperatures of June 16.
CM13. Abandoned by maternal cow, female, less than 1 day, 4.8 kg.
Remarks: Dead for several days; never nursed, stomach devoid of contents.
CM14. Undetermined, male, 10–14 days, 7.2 kg (dress weight, minus visera).
Remarks: Maternal cow probably had mastitis or a very large udder; three gulls destroyed most of the organs; maternal cow standing off 30 m; calf had been dead for only several hours and was not infested by fly larvae.
CM16. Wolf-killed, undetermined, undetermined, undetermined.
Remarks: Remains of new-born calf (size of legs indicates the calf would not be more than 1 week of age); two forelegs found 5 m from two hind legs; body and head missing; apparently wolves divided up the carcass; meat was fresh, indicating that the calf had been dead for only several hours; extensive hemorrhages on hind legs.
CM17. Abandoned by maternal cow, female, less than 1 day, undetermined.
Remarks: Measurements not taken, too much deterioration of the carcass; the hooves did not show any signs of wear, but lungs indicated that the calf was alive on delivery; did not nurse; no contents in stomach.
CM20. Undetermined, female, 4–7 days, 4.3 kg.
Remarks: Too much post-mortem change to determine the cause of death.
CM21. Still birth, male, n.a., 3.4 kg.
Remarks: Smallest caribou calf we have ever seen; too much post-mortem change for detailed examination.
CM22. Injury, female, 7–10 days, 4.6 kg.
Remarks: Extensive hemorrhages on left side of neck at the level of the thoracic inlet and on anterior cervical to the middle level of the throat; no evidence of predator attack; assumed cause of trauma a fall or violent contact with an adult caribou.
CM23. Still birth, male, n.a., 6.8 kg.
Remarks: Maternal cow may have had trouble passing the calf.
CM24. Abandoned by maternal cow, male, hours — had never nursed, 5.3 kg.
Remarks: Umbilical cord dried, but not completely; rigor mortis had come and gone.
CM25. Malnutrition — due to death of maternal cow, female, 1–2 days, 5.8 kg.
Remarks: Dead, curled up next to maternal cow (CM26); pneumonic patches in lungs; no food items in stomach.
CM26. Undetermined, female, 4 years(est. by mandibular teeth), undetermined.
Remarks: Maternal cow with new-born calf (CM25) dead together; placenta not expelled; probably died within 1 to 2 days after giving birth to the calf; the cow appeared in excellent condition for the breeding season; her mesenteric fat deposits were quite abundant; but she was too decomposed for detailed measurements; she was infected with besnoitiosis.
CM28. Abandoned by maternal cow, male, 2–5 days, 4.9 kg.
Remarks: Very little milk in stomach; too much post-mortem change for detailed examination.
CM30. Abandoned by maternal cow, male, hours — had not nursed, 5.3 kg.
Remarks: Yellow cartilage still attached to each of the hooves; born alive and cleaned off; apparently abandoned after cleaning.
CM31. Wolf-killed, male, 8–12 days, 6.5 kg.
Remarks: Massive subcutaneous hemorrhage posterior to right shoulder, extended caudad 10

cm; also massive subcutaneous hemorrhage posterior of sternum continuing posteriorly 13 cm; tooth marks right thigh and left cervical area below mandible; 13 cm of massive subcutaneous hemorrhages on chest; stomach and tract missing; the rest of the animal was left intact.

CM32. Wolf-killed, female, 5–7 days, 6.1 kg.
Remarks: Massive subcutaneous hemorrhage on both sides; ruptured liver with massive abdominal hemorrhage; wolf grabbed calf by middle of back and apparently shook it to death; no part of calf was consumed by wolf; calf had been nursing well, had large milk curd in stomach; lungs appeared normal.

CM33. Still birth, undetermined, n.a., 4.5 kg.
Remarks: Afterbirth remains on calf; too much post-mortem change for detailed examination.

CM35. Left lung not functional, female, hours, 6.1 kg.
Remarks: Heavily maggoted; too much post-mortem change for detailed examination; stomach full of milk curds. Only the cardiac lobe and two small areas of the right diaphragmatic lobe of the lungs were functional; the left diaphragmatic and most of the right diaphragmatic lobes were non-functional (embryonic-type) lungs. The calf had nursed, but the large amount of non-functional lung made it impossible for the calf to adequately oxygenize its blood. Possibly died from premature birth but this is questionable, since the calf was strong enough to nurse after being dropped. More likely, there was a physiological failure to convert from embryonic, fetal lnng to active lung at the time of birth.

CM36. Still birth, male, n.a., 5.2 kg.
Remarks: Anterior half still wrapped in afterbirth; large pile of droppings from the maternal cow was at the head of the new-born calf; too much post-mortem change for detailed examination.

CM37. Abandoned by maternal cow, male, hours — never nursed, 3.4 kg.
Remarks: Maggots throughout body cavity; too much post-mortem change for detailed examination; stomach empty, hooves showed no sign of wear.

CM38. Wolf-killed, female, 10–14 days, undetermined.
Remarks: Right temporal area punctured; marks through back above withers; wolf ate most of the heart and viscera, entering body cavity through right rib cage; rest of carcass intact.

CM39. Undetermined, male, hours, 6.7 kg.
Remarks: Hooves were still yellow tipped and showed no wear; calf had nursed, stomach was full of milk curds; appeared to be in good condition, but condition of its hooves suggested that it never got up from its bed after being dropped; lungs did not appear completely functional physiologically, they seemed too red and dark, not pink enough or full enough for truly functional lungs, however, there was too much post-mortem change for detailed examination.

CM40. Abandoned hy maternal cow, male, hours, 4.3 kg.
Remarks: Body cavity full of maggots; too much post-mortem change for detailed examination; no milk in stomach; prohably dead for more than a week; never nursed.

CM41. Abandoned by maternal cow, male, hours — never nursed, 4.1 kg.
Remarks: Body cavity heavily infected with maggots; too much post-mortem change for detailed examination; afterbirth attached along mid-dorsal line and right side of calf; hooves all dried up, but showed no wear; maternal cow apparently deserted the calf before she had finished cleaning him off.

CM42. Abandoned by maternal cow, female, 10–12 days, 7.3 kg.
Remarks: Hooves showed considerable wear; heavily infected with maggots; too much post-mortem change for detailed examination; only vegetation found in stomach, no milk curds.

CM44. Wolf-killed, male, 1–3 days, 4.7 kg.
Remarks: Tooth marks around umbilical area; hemorrhage on left stifle joint and on the cervical area of the neck mid-way between the thorax and the mandibular process; massive hemorrhage in the occipital area of the skull; punctures on parietal and frontal bones; hemorrhage on the left side of the rib cage and also posterior to the rib cage; punctures along the small of the back; the wolf ate the viscera, but did not consume any meat.

CM45. Still birth or abandoned — questionable — too much post-mortem change for detailed examination, female, hours, 4.7 kg. (completely eviscerated and dehydrated).
Remarks: All organs and viscera missing; hooves showed no wear and were badly dried up; probably never moved; dead for 8 to 12 days or more.

CM46. Peritonitis, female, 5–6 years (est. by mandihular teeth), undetermined.
Remarks: Dead cow with live calf (CM47); blood in milk; extensive bruises and hemorrhages along mid-dorsal line left side of back, possibly the result of several strikes from other cow's hooves; animal dead less than 24 hours; antlers skinned-over, pedicles non-functional; animal had besnoitiosis; in the abdominal cavity there was intensive peritonitis; fibrin tags involving most of the intestinal tract, bladder, liver and omentum; multiple necrotic foci on surface of and throughout liver; adhesion of the rumen to the abdominal wall on the left side; hemorrhages on the left rump extending paravertebrally forward to the withers area involving the last six ribs, also sternum posterior to humerus; the uterus was fully involuted; hladder was normal; the spleen was enlarged, but this may be the result of post-mortem changes; increased amount of fluid in thoracic cavity, udder showed little activity; wounds may have been caused by a fall, but are so extensive likely to have been caused by another animal; there were adhesions to the abdominal wall but no rupture of the rumen and no fistulous tracts indicating penetration of the skin; a fulminating type of infection with rapid dissemination of organisms throughout the liver; liver tissues preserved in 10 per cent Formalin for histological examination.

CM47. Shot, female, 14–21 days, 11.2 kg.
Remarks: Healthy with well developed heart and lungs; only vegetation in the stomach; no signs of milk; possibly could have existed on vegetation alone if it had been able to join a gronp and leave its dead maternal cow; however, the calf's dextrostix was less than 45 mg per 100 ml of blood, a relatively low rating on a standard set for bovines.

CM49. Injury resulting in contusion and hroken neck, male, 1 year, undetermined.
Remarks: Left metacarpal bone broken at the medio position; had apparently tripped or stumbled while running at high speed; head struck a rock, the momentum carried his body forward, and he received a broken neck; there was massive hemorrhage along both sides of neck and the eyes had popped from their sockets from the impact.

CM50. Wolf-killed, undetermined, 10–14 days, remaining carcass 3.6 kg.
Remarks: Entire frontal area of skull crushed; temple area punctured; viscera consumed; hindquarter and back along the flank to middle of rib cage consumed.

CM51. Wolf-killed, female, 10–14 days, 8.1 kg.
Remarks: The wolf apparently grabbed the calf by the right hind leg; massive hemorrhage and bruises along right hind leg; skull punctured on parietal and frontal bones; hemorrhage and punctures on left shoulder posterior to withers; punctures on cervical area of neck; massive hemorrhage on right shoulder posteriad to hip; wolf consumed all viscera.

CM52. Wolf-killed, female, 5–7 days, 4.5 kg. (minus viscera and a portion of the right hindquarter).
Remarks: Punctured and fractured skull; lungs, heart still in carcass; wolf ate part of right hindquarter and all remaining viscera.

CM53. Wolf-killed, undetermined, 5–7 days, undetermined.
Remarks: Apparent wolf kill; too much post-mortem change for detailed examination; been dead for several days; viscera missing; no other causes of death evident.

CM54. Shot, female, over 15 days, 14.7 kg.
Remarks: Calf was found alive, but too weak to get off her side; the maternal cow was standing off about 6 m and moved off about 100 m upon our approach with the helicopter; dextrostix gave a reading of about 45 per cent; massive abscess in association with the liver; perforation of the abomasum with resulting abscess formation involving the left lobe in the liver, the margins of the liver were rounded; the abscess also involved the xyphoid cartilage in the sternal area and adjacent muscles; the abomasal folds in the area of the adhesion were highly inflamed; only ahout one-third of liver functional; hacterial products would cause a toxaemia and this no doubt would cause an anorexic condition and lead to rapid weakening of the animal.

CM55. Wolf-killed, female, over 15 days, 12.5 kg.
Remarks: Massive hemorrhages on right rump to withers and left hind leg; punctures over withers; massive hemorrhages on throat; wolf didn't eat any of the calf;abscess caused adhesion of the left diaphragmatic lobe of the lung to the diaphram; adhesions associated with abscesses in the liver; tissues taken for histological examination and impression smears for Gram stain.

CM56. Wolf-killed, female, over 15 days, 10.9 kg (meat missing from both sides of withers posteriad along the rib cage, and liver and lungs missing).
Remarks: Massive hemorrhage on right rump and middle of back; hemorrhage on left hind leg and left front shoulder; the wolf ate the missing meat.

CM57. Shot, calf found alive separated from post-calving group on migrational path — was close by wolf-killed calf (CM56), male, over 21 days, 15.9 kg.
Remarks: Dextro stix less than 45 per cent; animal appeared in excellent condition; no sign of milk in rumen; blood sample collected from this specimen and (CM54); possibly this calf could have survived without the maternal cow, if it had been able to join a post-calving group.

CM58. Wolf-killed, female, 4–5 years (est. by mandibular teeth), undetermined.
Remarks: From the advanced state of deterioration of the carcass we assumed that radio-collared animal no. 2 had been dead since before the first detection of her radio on June 8, 1970; viscera and liver were missing; too deteriorated to do an examination; left femur was broken; ribs chewed on; lumbar vertebrae were broken off at the ends; all of the organs were missing.

CM59. Wolf-killed (assumed), undetermined, undetermined, undetermined.
Remarks: All the head and legs had been consumed by wolves; wolf tracks were near carcass and hind legs were about 10 feet from rest of carcass.

CM60. Wolf-killed, female, over 21 days, 11.7 kg.
Remarks: Skin ripped from right rump, approximately 10 cm^2 left gluteal muscles punctured and ripped; skull punctured and fractured at parietal and occipital areas; massive hemorrhage on right cervical area below mandible; punctures and massive hemorrhaging along mid-dorsal line and shoulders; punctured right kidney resulted in abdominal hemorrhages; stomach full of milk curds; lungs normal; carcass still warm; maternal cow about 50 m to the east moving back and forth watching our activity.

CM62. Undetermined (possible wolf-kill), male, over 15 years (est. by mandibular teeth), undetermined.
Remarks: Probably died or was killed in November or December 1969; it had cast its antlers, but the pedicles were still soft and were scarred over; dead in water and could have been killed on ice; viscera, and meat from hindquarters and the middle back, were missing; several ribs broken off and chewed on; mandibular teeth the most worn of a male caribou that we have seen to date; surely the oldest hull we have collected to date from the Kaminuriak population.

CM63. Undetermined, female, over 21 days, 12.9 kg.
Remarks: Dead on migration path several days before it was found; too much post-mortem change for detailed examination; milk in its abomasum; rumen full of vegetation; some small bruises on the abdomen, could have resulted from kick by an adult animal; possibly some strange cow or its own maternal cow, since the maternal cow had stopped nursing for some reason.

CM64. Wolf-killed, male, over 23 days, 17.7 kg.
Remarks: Grabbed by the back of the neck just below occipital area; puncture on throat below mandible; hemorrhages on back of right shoulder and right lumbar area; punctures through skin back of rib cage, right side; abdominal hemorrhages; lungs in good condition; ruptured liver and right kidney; abomasum full of milk curds; cow with large udder moving swiftly along the trail 0.4 km south in direction of the calf.

CM65. Wolf-kiled, male, over 21 days, 12.5 kg (minus guts, lulngs, heart, liver, right rib cage and right flank).
Remarks: Severed backbone; abomasum missing; skull crushed (left frontal and occipital areas); hemorrhages and punctures on neck; hemorrhages over withers, right shoulder and right cervical area; hemorrhages on left rump; minor hemorrhages on right rump; dead only a few hours.

CM66. Undetermined, female, over 15 days, 9.5 kg.
Remarks: Too much post-morten change for detailed examination — no milk in her abomasum; little vegetation in rumen, mostly liquid and little sedge; seemingly not nursing or feeding very much; had been dead for 5 to 10 days.

CM67. Attacked by wolves, dicd of sustained injuries, ±35 days, undetermined.
Remarks: Picked up by members of the Arctic Lodge between North and South Henik lakes; was apparently from the post-calving group with radio-collared animal no. 6, just north of the Arctic Lodge; calf had been attacked by a wolf or wolves on July 18 or 19; the skin was ripped over the left shoulder; the calf had apparently been grahbed by the right hindleg at the hock and the medio-posteriad portion; skin was ripped in the middle of the back on right side; the posterior half of the left scapular muscles were ripped away; there were massive hemorrhages on the area surrounding the left scapular and left humerus; massive hemorrhages in the left and right lumbar regions; punctures along the mid-dorsal lumbar region and punctures on the right gluteal muscles; massive hemorrhage at the distal end of the right femur; two ribs of the left side broken and punctures at the mid-dorsal thoracic area; liver and kidney appeared in good shape as did the lungs and heart; no sign of milk in stomach, but a well developed rumen filled with vegetation, containing lichens sedges, willow, *Vaccinium vitis-idea*.

CM68. Undetermined, female, about 35 days, 19.3 kg.
Remarks: Calf fonnd dead in dense stand of birches on migrational path; animal appeared healthy; no milk in abomasum; vegetation in rumen; no fat deposits; pelage very wet.

Appendix 2
Precipitation on the summer range of the Kaminuriak population of barren-ground caribou, District of Keewatin, N.W.T., 1970.

Date		Precipitation mm	Precipitation inches
June	3	2.8	0.11
	5	6.8	0.27
	6	6.1	0.24
	14	0.3	0.01
	15	0.3	0.01
	16	21.8	0.86
	24	0.3	0.01
	28	4.6	0.18
	29	0.3	0.01
July	4	0.3	0.01
	6	0.8	0.03
	12	8.6	0.34
	13	5.1	0.20
	14	3.8	0.15
	15	0.5	0.02
	20	7.4	0.29
	21	17.3	0.68
	22	3.3	0.13
	23	8.9	0.35
	24	2.3	0.09
	25	3.3	0.13
	26	1.3	0.05
	27	0.5	0.02

Appendix 3
Directions and velocities of winds occurring during the June–July 1970 study period, District of Keewatin, N.W.T.

Maximum velocity of winds by direction				Percentage frequency of winds by direction	
kmph		mph			
112+	N	70+	N	10.8	N
40	NNE	25	NNE	5.0	NNE
24	NE	15	NE	2.5	NE
32	ENE	20	ENE	0.8	ENE
32	E	20	E	5.8	E
0	ESE	0	ESE	0.0	ESE
32	SE	20	SE	7.5	SE
16	SSE	10	SSE	0.8	SSE
48	S	30	S	6.7	S
8	SSW	5	SSW	0.8	SSW
40	SW	25	SW	10.0	SW
32	WSW	20	WSW	4.2	WSW
40	W	25	W	11.7	W
40	WNW	25	WNW	2.5	WNW
64	NW	40	NW	25.0	NW
48	NNW	30	NNW	5.8	NNW

Appendix 4
Frequencies by classes of winds occurring during the June–July 1970 study period, District of Keewatin, N.W.T.

Occasions	Class kmph	Class mph
9	0– 2	0– 1
24	3– 8	2– 5
36	9– 16	6–10
26	17– 24	11–15
10	25– 32	16–20
14	33– 40	21–25
2	41– 48	26–30
1	49– 56	31–35
1	57– 64	36–40
1	65– 72	41–45
1	73–112+	46–70+

Appendix 5
Estimated daily hours of sunshine during the calving period, base camp (63°28′N, 93°35′W), District of Keewatin, N.W.T.

June 1970	Daily hours of sunshine
1	10
2	10
3	0
4	0
5	6
6	2
7	1
8	9
9	22
10	22
11	22
12	9
13	7
14	5
15	6
16	0
17	8
18	18
19	22
20	13
21	8
22	4
23	2
24	4
25	22
26	17
27	4

Appendix 6
Daily observation of cloud forms by percentage on 123 occasions during June and July 1970.
Based on Canada Department of Transport, Meteorological Branch cloud chart (64-0071)

Cloud form	June No. obs.	June Monthly %	July No. obs.	July Monthly %	June–July No. obs.	June–July Period %
Stratus	20	20.4	19	25.0	39	22.4
Stratocumulus	15	15.3	20	26.4	35	20.1
Cirrus	17	17.3	8	10.5	25	14.4
Cirrostratus	16	16.3	6	7.9	22	12.6
Cumulus	8	8.2	14	18.4	22	12.6
Cumulonimbus	10	10.2	7	9.2	17	9.8
CAVU*	9	9.2	1	1.3	10	5.7
Cirrocumulus	2	2.1	0	0.0	2	1.2
Nimbostratus	1	1.0	1	1.3	2	1.2

* CAVU equals no cloud cover (clear all the way, visibility unlimited).

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