

EARLY CARIBOU CALF MORTALITY IN NORTHWESTERN  
BRITISH COLUMBIA

by

RICHARD EDWARD PAGE

B. Sc., University of Guelph, 1976

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF


MASTER OF SCIENCE

in the Department


of


Biology

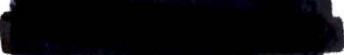
We accept this thesis as conforming  
to the required standard

  
Dr. Edwin M. Hagmeier

  
Dr. A. Thompson Bergerud

  
Dr. John E. McInerney

  
Dr. Frank P. Robinson

  
Dr. Carl J. Walters

  
Dr. Donald S. Eastman

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UNIVERSITY OF VICTORIA

December 1985

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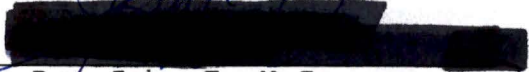



Supervisor Edwin M. Hagmeier

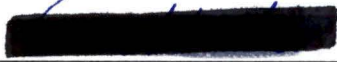
Thirty four newborn caribou calves were collared with mortality sensing radios in two study areas in Northwestern British Columbia. In 1979, calves suffered 60% mortality in the first month and 80% to 4 months. In 1980, mortality rates were 20% in the first month and 50% to 4 months. Wolf and grizzly bear predation were the primary mortality factors. The difference between years was hypothesized to be due to snow melt patterns that restricted the distribution of calving females in 1979 and increased predation rates. A minimum of 35% survival to the fall is necessary to balance adult mortality. Survey data indicated that excess predation on calves has been frequent over the last decade, leading to a decline in total number of caribou in the region.

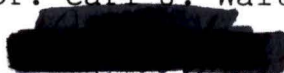
  
\_\_\_\_\_  
Dr. Edwin M. Hagmeier

  
\_\_\_\_\_  
Dr. (A. Thompson) Bergerud

  
\_\_\_\_\_  
Dr. John E. McInerney

  
\_\_\_\_\_  
Dr. Frank P. Robinson

  
\_\_\_\_\_  
Dr. Carl J. Walters

  
\_\_\_\_\_  
Dr. Donald S. Eastman

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## Acknowledgements

The outstanding contribution to this work came from Tom Bergerud. His dedication to caribou forced the initiation of this project. His ideas will be with me forever. In my short stay at UBC, Tom and Carl Walters re-awakened my awareness of the beauty of science.

To follow the caribou we need wings and I thank the twenty two helicopter and fixed-wing pilots who constantly gave their best. Especially Ed Williams, Emil Messic and Mel Mellison who gave their lives, to fly in the mountains of British Columbia.

Dave Hatler and Monte Bassett provided constant assistance, as did the Collingwood brothers, Ray and Reg, who have endured a lot of grief to preserve a way of life. Don Eastman pulled me out when funds were short.

This work was supported by grants from the Natural Science and Engineering Research Council, the Western Guides and Outfitters Association, the Stikine Foundation for Wilderness Studies of Smithers, B.C., the B.C. Fish and Wildlife Branch, the B.C. Parks Branch and the University of Victoria. My gratitude is extended to the many members of these organizations who contributed to the field work for little or no compensation.

Finally, my family becomes more supportive every year,  
and to them I dedicate this work.

## Introduction

Paul Errington in 1946 said that "It is upon the young, that the impact of predation can be expected to be felt". Yet when Tom Bergerud expressed the opinion that the decline of Woodland Caribou (*Rangifer tarandus caribou*) in Northwestern British Columbia in 1977 was due to excess predation on calves, his views were met with general disbelief. A technique had only recently been developed that used collars containing a radio transmitter and a motion sensitive switch to immediately determine whether a tagged animal was still alive. The animal could then be located soon after death and the cause of death identified. It was decided that this method provided the best means to test Bergerud's hypothesis.

Bergerud surveyed most of the caribou in the province in 1977-78 and identified areas of low recruitment and declining caribou numbers (Bergerud 1978). Field work on the Fire Flats of Spatsizi Provincial Park in summer 1977 suggested that heavy calf losses to an array of predators was the cause of recruitment failure (Bergerud and Butler 1978). I undertook intensive radio-collaring of caribou calves on the Fire Flats in 1979 because of the continued decline of this herd (Figure 1) but moved to Level Mt. in 1980 to increase sample size (Figure 2). Spatsizi remained as the primary study area and the focus of interest. This

study was initiated to quantify the causes of mortality of newborn caribou calves identified by Bergerud as being responsible for the caribou decline. The B.C. Fish and Wildlife Branch conducted a more extensive experiment concurrently on Level Mt. and the Horseranch Range to determine the magnitude of the patterns of loss identified by my intensive collaring effort (Elliott et al. 1984, Bergerud and Elliott in press).

The vocal and financial interest of the professional guiding and hunting industry in the fate of the caribou resource was instrumental in the recognition of the problem. Interest in Spatsizi caribou and the importance of timber wolf (*Canis lupus*) predation to the herd became a provincial issue through the efforts of the Sierra Club of Western Canada by 1978, but then came to national attention through the media motivated efforts of Greenpeace Canada.

A single major hypothesis was investigated to clarify the effects of predation on caribou calves in British Columbia.

Hypothesis: Sufficient calves are recruited to balance adult mortality.

This hypothesis and the associated alternate possibilities, provided the focus for the investigation, and for this thesis.

## Hypothesis

The method of strong inference is the most rigorous approach to science usually available to ecologists (Platt 1964, Quinn and Dunham 1983). Since hypotheses can never be proven, only disproven, an hypothesis testing approach will be taken to attempt to determine if recruitment failure has occurred in Northwestern B. C., and if lack of recruitment is identified, which of the possible reasons is responsible for the lack of calves. Recruitment is properly defined as the number of young surviving to join the adult population, but to avoid problems from variation in the onset of sexual maturity, recruitment will be treated in this discussion as number of caribou calves alive at one year of age as a proportion of the adult population. It was expected that excess predation of calves was responsible for the decline of caribou in Northwestern B. C. The converse of this idea was specified as the major hypothesis.

Hypothesis: Sufficient calves are recruited to balance adult mortality.

This hypothesis could be rejected if insufficient calves were born to the population due to infertility from disease, malnutrition, or severely skewed sex ratios.

If enough calves were born, too few might survive to recruitment age because of a variety of mortality factors. Loss to predation, accident, disease, and weather were

explicitly studied. Some information on dispersal rates was obtained. No other factors appeared likely to be important (Figure 3).

## Study Area

Spatsizi Provincial Park encompasses 6783 km<sup>2</sup> of the Spatsizi Plateau and the Skeena Mountains, 300 km north of Smithers, B.C. and an equivalent distance south of the Yukon border (Figure 4). The Spatsizi Plateau is an uplifted sedimentary plain heavily dissected by the Stikine River and substantially shaped and rounded by Pleistocene glaciation producing calcareous soils (Holland 1964). In the north, valleys are within the boreal forest zone, dominated by white spruce (*Picea glauca*), but vegetation tends increasingly toward subalpine associations in the south, with subalpine fir (*Abies lasiocarpa*) most common (Krajina 1964). Many valley bottoms above 1000 m (3500') in the southern half of the park are treeless with treed fringes, due to moisture stress and cold air drainage, creating extensive valley grasslands (Photo 1). Large areas of little relief lie above treeline between 1500 m (5000') and 2100 m (7000'). The resulting rolling alpine tundra has many arctic associations (Pojar 1976, Osmond-Jones et al. 1977, Bergerud and Butler 1978).

Level Mountain, 200 km to the northwest of Spatsizi (Figure 5), is wholly volcanic, being formed as a tuya during a series of eruptions during pre-Pleistocene glaciation. The resulting central cone reaches 2200 m (7200') but has been extensively altered by fluvio-glacial

and periglacial activity. The cone remnants are surrounded by a virtually flat, treeless, 1500 km<sup>2</sup> plateau between 1400 m (4500') and 1800 m (6000') with numerous post-glacial basaltic vents. Alkalic basalts predominate in the basement rock producing a soil of high pH (Hamilton and Scarfe 1977). Vegetation in the Level Mt. study area is all within the subalpine and alpine zones, similar to the upland areas of Spatsizi (Krajina 1964). The vegetation of Level Mt. and the nearby Horseranch Range was typed and mapped for caribou habitat value in conjunction with Ministry of Environment Resource Analysis Branch for Fish and Wildlife Branch for their wolf control and caribou recruitment project (Fenger et al. in press).

## Methods

### Surveying

Population estimates were necessary to document the direction of change of the herd, population parameters and relative predator densities. These data were primarily obtained by aerial survey. Winter surveys in 1979 were conducted from an Aeronca Champ aircraft operating from Hyland Post, April 14-16. The work was terminated prematurely by mechanical failure before Bergerud's 1978 wolf survey (Bergerud and Butler 1978) could be repeated. A Cessna 185 from Iskut was used to complete a comparable wolf survey February 23-25, 1980 by flying all watercourses in and adjacent to Spatsizi Park and counting tracks. Caribou and moose (*Alces alces*) were opportunistically counted. Dave Hatler also flew similar surveys to determine wolf numbers on Level Mt., and conducted a stratified block survey for moose (Elliott et al. 1985).

Spring surveys were flown in May and June from a variety of fixed-wing aircraft and helicopters, with one or two observers looking primarily for calving caribou, but incidentally noting adult caribou and predators. Groups of caribou were sexed and aged, and udder size was determined for females. Females with large udders that were not pregnant were considered to have already lost calves if no calf was present (Bergerud 1964a).

Summer monitoring flights were made by a PA-12 in 1979 and in 1980 by Hiller 12E or Bell 206 helicopters and Cessna 185s. Caribou were also incidentally noted during other work, or located due to the presence of a radio-collared calf within the group. Locations were plotted immediately on 1:250,000 topographic map sheets.

Fall rut surveys were flown in conjunction with Fish and Wildlife Branch or Parks Branch by helicopter. Known or suspected alpine rutting grounds were systematically searched by two or three observers. Groups of caribou were sexed by genitalia, and also aged by physical characteristics, from the air, but large groups were classified through spotting scopes from the ground (Elliott et al. 1984).

#### Capturing Caribou

The original scenario in 1979 called for newborn calves above tree-line to be located from a fixed-wing aircraft. The capture crew in a helicopter would be directed to the site by radio. If the calf was less than a day old, the helicopter could land nearby and the capture crew could run down the weak calf. In many cases, the calf would not move and could be approached at a walk. A contingency against the aircraft being unable to fly due to bad weather was provided by locating four camps on the mountains, close to where females were expected to give birth. The ground crews

were to attempt to locate and capture caribou on foot. With deep snow and limited manoeuverability, the ground crews only succeeded in capturing one calf. Through 1979 the technique was refined.

We became quite successful in 1980 and were able to catch calves up to one week old. A helicopter operating alone with a two-man capture crew plus pilot would search likely areas for pregnant females or calves. When a female with calf was sighted, the crew disembarked above the pair. The caribou usually ran downhill and the helicopter chased them back up to the waiting men. Running downhill and using terrain for concealment, it was possible to surprise a calf, outrun it and leap upon it (Photo 2).

Once the calf was captured, or occasionally before, the mother was darted with a small plastic dart (Pneu-dart) fired from a carbon dioxide powered Cap Chur pistol. The dart contained 12 mg of the neuromuscular blocking agent, succinyl choline chloride (Anectine), which rendered the caribou immobile. The mother usually approached closely to investigate the fate of her calf in Spatsizi, but Level Mt. females rarely approached within the 30 m range of the guns.

Extensive attempts were made in 1979 to capture adults without calves. Both sexes were darted from the helicopter with Pneu darts fired from pistols and by driving caribou with the helicopter toward men concealed on the ground

(Photo 3). Some adults were ambushed at salt-licks or stalked on foot during June 22-30, 1979 when we were without aerial support (Page and Bergerud 1979).

#### Collaring

Adult females were tagged only with visual collars and ear tags in colour combinations that allowed later visual identification of individuals. Ear tags and neck collars were made of double layers of polyvinyl chloride (PVC) plastic in bright blue, orange, yellow, and red and fitted with brass grommets. Ear tags were 5 x 15 cm and attached with #2 Ketchum Kurl-lock ear clips, while 15 X 45 cm neck collars were fitted to individual neck sizes with 2 sets of hardware links.

All caribou calves were collared with radio transmitters, providing a rapid method of locating dead calves and monitoring the location of live calves. A specially designed collar was used for calves to prevent injury as the neck grew. The black plastic collar was capable of expansion from 19 cm circumference to about 50 cm (Photo 4). To maintain a snug fit around the neck as the calf grew, the collar contained internally pleated elastic sewn with cotton thread that broke apart under strain. The two plastic halves of the collar were also sewn together at the top with cotton thread designed to rot and break off within 3-6 months to ensure that no calves were harmed by a collar that was too tight after the study ended. An

additional piece of elastic was sewn across the diameter of the collar to fit the smallest calves. Collars were sterilized with alcohol, air-dried and sealed individually in plastic bags to eliminate human odor.

A radio transmitter operating in the 148 MHz band was sealed in the underside of all calf collars, with a ribbon antenna within each collar half. The transmitter was wrapped with yellow tape to increase visibility of the black collar after death. Transmitters were supplied by Telonics Telemetry of Mesa, Arizona and fabricated into collars by M. Schlegel of Kamiah, Oregon according to the design developed by Schlegel (1976) for elk calves and extensively utilized on moose in Alaska (Ballard et. al. 1979, 1981, Franzmann et. al. 1980). The transmitter incorporated a mercury switch with a 1 hour time delay as a mortality sensor. If the collar was not moved for one hour, the pulse rate of the transmitted signal doubled, indicating a dead calf.

Initially, we feared that contaminating the calves with human scent would disrupt the reformation of the pair bond after release of the calf. It became apparent that visual and auditory clues were most important to the bond and we ceased to worry about scent (Photo 5).

After processing, calves were returned to the site where they were first located before any chase, not necessarily the capture site. The crew returned quietly to

the helicopter and left immediately. The mothers had little or no difficulty in finding their calves and often returned before we departed.

#### Measuring and Sampling

Body measurements of adults followed Bergerud and Butler (1978). Calves were similarly measured for total length, shoulder height, neck and heart girth, length of head, ear, tail and hind foot. Hair length at shoulder, extent of rump patch and body colour were noted. Calves were suspended by a doubled rope or cloth around the thorax from a 15 kg spring scale for weighing. Adults were lifted in a cargo net by the helicopter.

Blood was obtained from the radial vein using B & D Vacutainers, with 22 gauge needles for calves, and 18 gauge for adults. Serum was separated and frozen at camp after settling without centrifugation (Karns and Crighton 1978). The veins of newborn calves were so fragile and difficult to locate that we obtained few blood samples.

Anal swabs were taken from calves for bacteriology in both years, and also virology in 1980. A tuft of hair was removed from between the scapulae, and also from the lateral area of the hip in adults, for mineral analysis. An incisor was extracted with dental elevators and forceps for aging of adults (Bergerud 1964b). Fecal samples were frozen in plastic bags for parasitological examination.

The Veterinary Laboratory of the Ministry of Agriculture at Abbotsford, B.C. tested sera for the diseases brucellosis, and leptospirosis, and analyzed the fecal swabs. Pat Karns at the Forest Wildlife Research Laboratory in Minnesota analyzed blood constituents and aged teeth (Karns and Crighton 1978). Fecal parasites were determined from floatation of eggs by Murray Lankester at Lakehead University, Thunder Bay.

#### Weather

Weather stations were established to monitor climatic stress on calves. Stevenson screens containing hygrothermographs, or maximum and minimum thermometers, were placed atop 0.75 m high rock cairns (Photo 6). Totalizing anemometers were nearby. The two stations at 1676 m (5500') were placed at known calving sites and were checked frequently, averaging every 4 days. The two base camp stations at Kluayaz and Hatin Lakes were monitored daily (Table 1, Figures 4 and 5). Phenological progress of vegetation, migratory birds sighted and elevation of snowline were recorded.

#### Scat Collection

Wolf and bear scats were found opportunistically and incidental to other work or travel. The Level Mt. scats in 1979 were obtained from a wolf den site. A portion of the

scat containing all food items was carefully sealed in a plastic bag and frozen. Scats were autoclaved at 120° C for 3-5 hours to eliminate transmission of parasites. Hair was identified under a microscope on the basis of gross morphological characteristics using reference samples (Scott 1979) and the Ontario hair analysis manual (Adorjan and Kolenosky 1969). Age classes follow Bergerud and Butler (1978). There was less ground work and thus a small scat collection in 1980.

#### Insect Abundance

Behaviour of caribou in summer and their ability to aggregate is affected by the annoyance of insects. An attempt was made to quantify insect abundance by sweeping with a net while walking transects (Bergerud and Butler 1978), but the technique badly under-represented biting insects. Subjective estimates of insect annoyance were more valuable.

#### Monitoring

Collared calves and mortality signals from dead calves were located from aircraft. When fixed wings were used, H-shaped antennae were taped to the struts on each side with leads running to the programmable scanning receiver inside. A switching-box allowed the observer to listen to the signal from either or both antennae and quickly circle to the

collar location (Page 1982). Maximum distance of reception at the usual flight altitude of 2100 m (7000') was 25 km.

An antenna hand-held inside the plastic bubble of a Bell-47 was sufficient to receive a signal from 2 km. A 3 m wooden stick was strapped to the leg struts of other helicopters, with a single antenna bolted 1 m in front of the aircraft. The helicopter could be rotated to block the signal and roughly determine direction. Monitoring flights were flown daily if weather permitted (max. 4 days) in early June, decreasing to every 2-3 weeks in July and August.

When a dead calf was located from fixed wing, the exact location was noted until a helicopter flight could be made to investigate the site. In June, this was only a matter of days, but later in the summer it was sometimes weeks before a helicopter was available. The helicopter would land close to the suspected mortality site and the collar would be tracked on foot with a hand-held antenna. Once the collar was found, we walked circles of increasing diameter around the collar to locate any calf remains or predator sign, and collected hair found on twigs and scats (Photo 7).

Determination of the cause of death was often a matter of inference from available evidence. Carcasses were always consumed by predators with only hair, blood and bone chips remaining and the predators had left the kill site in all but two cases. If the time since location of the calf

remains was a few days, a predator chase could be reconstructed from tracks in snow and mud. Scats, hair and tracks of predators attested to their presence. If only one cause of death was possible, the cause was considered definite. If other mortality factors were conceivable, the primary cause was qualified as probable, while if a week or more had elapsed since death or little evidence for a mortality agent could be located, cause was qualified as probable. All causes were assumed correct for analyses since categorization of causes did not change any conclusions.

#### Statistical Tests

Statistical tests of significance were performed with the Statistical Analysis System Release 82.3 (SAS 1982) at the University of Victoria. Standard F-tests and t-tests were used and samples were pooled between years unless noted.

## Results

In 1979, 10 caribou calves were radio-collared and one was found dead at the birth site, for a total sample of 11 (Figure 6). In 1980, 23 calves were collared, and one was found dead at the birth site but not included in the sample, for a combined total in two years of 34 calves (Figure 7). In addition, 7 adult females were captured and released. Mechanical failures of the helicopter, lack of fixed-wing support, our inexperience in developing the capture methodology, and a much lower density of calving caribou than expected, contributed to the low success in Spatsizi in 1979 despite a high level of effort. An efficient, experienced crew of 3 combined with more caribou and perfect flying weather, resulted in the large number of calves collared on Level Mt. in 1980.

### Birth Sites

Nineteen birth sites were located (Figures 9 and 10). All were above treeline at an average elevation of 1820 m (Table 2). Most females moved upslope as parturition approached, until they reached a ridge top or a barrier of snow. The actual place of birth was usually free of shrubs and snow, and as level as possible. Precipitous slopes were almost always nearby to provide escape terrain (Photo 8) (Bergerud and Butler 1978). In 1980, some calves were born

on small snow patches as temperatures neared 20° C, probably to reduce thermal stress. The birth sites recorded were a biased sample of total calving females as females calving below treeline were almost impossible to detect. Even in the shrub zone, the birth sites of captured calves were difficult to find, resulting in the differences in elevations between recorded birth sites and capture sites in 1980 (means 1841 m versus 1660 m). Undoubtedly calving occurred below treeline, as in the Burwash herd to the north (Oosenbrug and Theberge 1980), but subsequent radio-collaring of adult females has shown that the vast majority of calving is in the alpine in Spatsizi (Hatler 1983). Contrary to Bergerud's suggestion (Bergerud 1978, Bergerud et al. 1984), there was no indication that aspect of birth site was influenced by wind direction nor that south slopes were preferred (Figure 8).

#### Captured Calves

There were no differences in calves between years ( $p < 0.05$ ) unless noted. Sex ratios were equal at birth. Calves were very large (Table 3). The largest calf weighed 10.6 kg at birth, while the smallest calf, 02-79, at 5.0 kg was the weight of the mean for newborn calves found in the Kaminuriak (Miller and Broughton 1974). Weight of day-old males was insignificantly greater than females, but as Dauphine (1976) found for yearlings, total length of males

was greater than the length of females ( $df=8$ ,  $t=1.87$ ,  $p=.10$ ). These calves are at the size limit that the females can conceive. One 10.3 kg male calf (01-79) suffered a broken back during the struggles of a difficult and protracted labour (see Appendix).

Blood was successfully drawn from only 2 calves; live calf 12-79 and 01-79 which was found dead of a broken back (cardiac puncture used). Given this small sample, blood parameters were considered normal (Pat Karns, pers. comm.). Fecal swabs revealed a very low diversity of microbial activity (Table 4). Of the 28 samples that resulted in bacterial growth, most showed only heavy *Escheria coli* but, *Pseudomonas sp.*, *Bacillus sp.*, *Enterobacter sp.*, *Klebsiella sp.*, *Staphylococcus albus* and *Staphylococcus aureus* were present. Two calves were positive for bovine corona virus.

#### Calf Mortality

By mid-August, only 15 of the original 34 calves were alive, for an average survival rate of 44% to 2 months of age. Causes of death varied from wolf and grizzly bear (*Ursus arctos*) predation to accidental loss in avalanches (Table 5 and 6; see Appendix for some specific cases). The mortality factors were proportionally the same in the two years but the rate of loss differed (Figure 11), so for some analyses of mortality the two years were pooled. Monthly survival rates were 62% in 1979, but 85% in 1980 (Figure

12). Within years, survival rates were extremely consistent from calving to mid-August, but the rates between years were significantly different ( $df=1,6$ ,  $F=80.9$ ,  $p=.0001$ ). A marked increase in survival through the fall occurred in both years. Elevation of mortality sites was also less than that of capture sites ( $df=23$ ,  $t=3.57$ ,  $p=.002$ ) and closer to valley bottoms.

Predation accounted for over half of the dead calves with three quarters of this loss due to wolves. Carcasses were totally consumed, leaving no indication of the condition of the calf before death. In the case of 06-80, though, wolves consumed the calf then buried the intact head with the collar still around the neck. Wolves frequently carried the collar away from the kill site, or chewed it heavily and used it in play behaviour (see 02-79, Appendix). A strong signal was still received even when the ribbon antennae were chewed from the transmitter. In 6 cases, wolves carried the collar a sufficient distance that the kill site could not be definitively located. One collar was located from a fixed wing aircraft August 10, but by the time we returned August 19, the collar had been moved over 150 m to the west, probably by wolves. Since there were usually few signs of the calf remaining at the sites of wolf kills, the information that could be retrieved from these kills was minimal. The collars always had wolf teeth

imprints and frequently were bloody with fragments of calf hair attached. A 5 cm section of the molars of the lower jaw sometimes remained at wolf kills. Two such sections from previous years were found incidentally.

The 3 grizzly kills were identical in pattern and were easily identified from other mortalities. The calf was completely consumed, but bone chips remained, particularly of the skull (Photo 9). The collar was within a few meters of the kill site. The surface vegetation or soil was disturbed, and in one case where the calf bled heavily, the grizzly excavated 1.5 m<sup>3</sup> of soil in a long trough.

When kills were made in the shrub zone, hairs of the predator were always found on twigs. Wolves always left scats at the kill, and grizzlies frequently did.

Two collars on Level Mt. were buried under the cryptogam, but not in the soil. I attributed this behaviour to red foxes (*Vulpes fulva*), but alternate explanations are possible. The collars were not retrieved until weeks after the kill.

Five deaths were classified as accidental. Calf 01-79 died of haemorrhage due to a broken back suffered during birth. Calf 13-79 was killed in an avalanche in which its mother probably perished also. This carcass was 90% consumed by a single golden eagle (*Aquila chrysaetos*) within 24 hours (Photo 10). Calf 09-79 died of starvation from separation

from his dam after a wolf pack attacked the group of caribou before the maternal bond had reformed after collaring. This was the only time we simultaneously collared more than one calf where the females might have difficulty locating their own offspring, confusion in reuniting the pair bond did occur. Both mothers apparently tried to bond with, and ran off, with the other collared calf (07-79) which was subsequently killed by the wolves. This death was classified as accidental.

Calf 05-80 was found dead with no apparent trauma, 3 days after collaring. We had observed this calf to have rejoined his mother. Autopsy revealed a collapsed lobe of the lung and a quantity of blood in the thoracic cavity. No pathogens, other than *E. coli*, were isolated from tissue samples and there was no indication of inflammation or edema. Temperatures reached 20° C that day and may possibly have caused excessive thermal stress.

Calf 17-80 was never seen after collaring, but the intact collar was found on a branch under water in a swollen mountain stream 200 m below where an adult caribou had crossed the stream. The stream was high and fast from runoff and the calf was presumed drowned.

One collar late in each year, after the major study period, ceased to be received due to radio failure or due to the location of the mortality collar on the ground in a

shielded area. There were strong magnetic anomalies in the region.

On June 14, 1980, the rear legs of a caribou calf were seen in a golden eagle nest on a cliff of Matsatu Creek. The nest was not closely inspected, except from the helicopter. The calf could have been scavenged.

One still-born calf was found on June 10 on a north-facing snow patch with the placental membrane still attached to the lower surface. The upper surface was clean, indicating normal maternal behaviour. The calf was very thin, weighing less than 5 kg, and the lungs had not filled. This was the only case of pre-parturent mortality identified. The calf was located after the period of parturition and was not included in the sample.

If caribou are choosing rugged terrain in which to calve to reduce predation, they are then exposing their calves to increased risk of accidents. Bergerud and Butler (1978) noted 2 out of 14 calves with broken legs in 1977. One calf had a completely fractured left femur on Tahltan Ridge on June 7, 1980. We attempted to capture it but were unsuccessful. Despite the leg pinwheeling over its back, held only by tissue, it ran uphill as quickly as the other two calves accompanying it. This calf survived at least one week. The right meta-carpal joint of calf 22-80 was dislocated during capture but the calf ran normally for at

least one month. Though subsequently the calf was killed by wolves, I believe that it recovered from its injury and would have survived had it not left the herd ( see Appendix).

#### Movements

Calves and their mothers remained in the area of the birth site, with daily movements averaging substantially less than one half of a km in the first two weeks. No collared calves joined the post-calving aggregation on the Fire Flats in 1979. In 1980, however, 2 large aggregations had formed by June 22, and 14 out of 16 collared calves were in a single aggregation by July 10. The aggregation remained cohesive through August.

Additional radio locations were obtained after the summer study period was over. On October 6, 1979, calves 06-79 and 60-79 were located alive 20 km south of Hyland Post, 5 km west of the Ross River. No visual confirmation was made. Calf 60-79 was located by radio and visually February 27, 1980 with 6 adult caribou at 1700 m (5700'), 15 km NW of Hyland Post.

Intermittent relocations of the collared calves from Level Mt. were made by Dave Hatler throughout the winter 1980-81 (Hatler 1981). At least 6 calves were still alive and in the rutting group on the northeast side of Level Mt. on September 27 (2-, 4-, 10-, 16-, 20-80). On January 16,

02-80 was contacted in the mortality phase at the head of Teh Creek, 130 km north of the study area and only 30 km south of the Alaska Highway. Calf 10-80 was alive near the Teslin River and 100 km north of the capture site. One month later, on February 16, 20-80 was found alive NE of Mt. Charlie Cole, 125 km from Level Mt. A dead signal was heard near the Kedahda River (16-80).

By June 10, one year after collaring, all collars should have been shed, but 10-80 was found in the company of another yearling on the NW plateau of Level Mt. with a functioning collar. Four other shed collars were found on this flight, in the Nahlin Valley (1-80, 25-80) and on the plateau (3-80, 11-80). These collars were likely carried back from the wintering area and dropped at Level Mt. (Hatler 1981, Elliott et al. 1984).

#### Weather and Insects

Weather was fairly mild during calving in both years. Temperatures in 1979 were normal but 1980 was exceptionally warm (Figure 15). The worst day was June 5, 1979 coinciding with the peak of calving. Winds reached 70 km/hr during heavy snowfall and low temperatures of  $-3^{\circ}\text{C}$ . Calf 04-79 was born in the early morning and collared at 1500 hr. It was warm, dry and healthy. Microhabitat reduced the severity of the weather. In this case, the calf used the downwind side of the bedded female for shelter.

Temperatures at calving elevations were moderated, showing lower maximums and higher minimums than the valley floor. Rain-equivalent precipitation totalling 2.49 cm in 1979 and 0.4 cm in 1980 were recorded at calving elevations during the 2 weeks of calving. Cumulative wind speeds were also lower at the calving site in 1979, but the opposite was found in 1980 (Figure 16 ).

In 1979, the snowline was still at 1341 m on June 6 and did not reach 1600 m until mid-June. Depth of snow exceeded one meter preventing movement of caribou. In contrast, the snowline in 1980 on Level Mt. was at 1676 m when we arrived May 27. By June 5, there were still extensive snowfields between 1500 m and 1700 m but the snowline was above 1800 m and there was no effective snow barrier to caribou movements.

Biting insects were light until June 25 in 1979, then reached levels of annoyance within 2 days. Mosquitoes were sufficiently abundant to force caribou to snowfields by the first of July, and disrupt any large aggregations. In 1980, with the mild, dry conditions, mosquitoes were common by May 30 and a nuisance by June 7. However, near drought conditions later in June did not allow a buildup in mosquito numbers, so caribou never utilized snowfields for insect avoidance and remained in large aggregations through the summer of 1980.

## Adult Females

The first adult drugged in 1979 died, because we failed to reach her until 10 minutes after darting and she had aspirated regurgitant (101-79). We darted and tagged four females with calves and one without a calf in Spatsizi in 1979. Two females with calves were captured at Level Mt. in 1980. An additional 12 females and 4 males were captured and collared in Spatsizi in fall of 1980. Measurements are listed in Table 7 . There were no differences in the size of females captured between the two areas and three times. Males averaged only 10% larger than females in body measurements ( $p>0.1$ ) but the largest male weighed 80% more than the only female weighed (263 versus 145 kg).

Blood sera from five females with calves were negative for brucellosis and leptospirosis consistent with the negative findings for moose from a nearby area (Hudson et al. 1978). Results of blood and hair analyses will appear in Butler (in prep). The fecal samples did not contain any dorsal-spined eggs indicative of nematode infection. A cursory examination of 101-79 did not reveal any major parasites, though a single *Dictocaulus* was found in the right lung. No rumen flukes were found.

Collared adult females were still reported in Spatsizi 3 years later, up to 100 km from the original collaring locations.

## Predators

Only in winter when tracks could be seen could wolf numbers be reliably estimated. There were 6 wolf packs in Spatsizi totalling an estimated 70 wolves in late winter 1977-78 (Bergerud and Butler 1978) and 42 in 1979-80 (Figure 17. Haber (1978) though, estimated up to 100 wolves in 4 packs based largely on hearsay evidence . Dave Hatler (Elliott et al. 1984) estimated 5 packs on Level Mt. totalling about 37 wolves in late winter 1979-80 and 40 in 1980-81 based upon intense aerial survey (Figure 18, Table 8). Wolf densities were approximately 1 wolf/100 kkm<sup>2</sup> in both study years.

Wolves were rarely seen. There were 2 observations of single wolves in Spatsizi in summer and 4 observations totalling 10 wolves in Spatsizi in winter. Fourteen wolves identified by 19 track sightings were in the study area and able to predate calves in 1979. Only 5 track observations representing 6 individuals were seen in 1980 on Level Mt. Yet, the densities of wolves in both areas were essentially the same and do not account for this difference in caribou hunting intensity by wolves. Scat analysis indicated similar reliance on caribou calves in both areas in 1979 (Table 10).

There were 19 sightings of grizzly bears representing 13 bears in 1979 and 13 sightings of 9 bears in 1980. One wolverine (*Gulo luscious*) was seen in the alpine actively

hunting caribou in each year. Eleven sightings of black bears (*Ursus americanus*) were made in 1979 but none in 1980. There were at least 8 golden eagles in Spatsizi, and over 20 sightings of at least 10 golden eagles on Level Mt. Two eagle eyries and 2 gyrfalcon (*Falco rusticolus*) eyries were located on Level Mt., each of which fledged two young.

#### Population Parameters

The Fire Flats aggregation continued its decline in 1979 (Figure 1). 236 caribou were present in 1977 but only 110 aggregated in 1979. Compare the number of calves in Figure 9 from 1979 with Figure 3, p. 144 of Bergerud and Butler (1978) for 1977. There were one-third fewer calves in the later year. Only sparse numbers of caribou were seen during frequent overflights in 1980 by a local pilot (Carl Simmons pers. comm.). The Spatsizi area population as determined by rut surveys probably continued to decline through 1983 or may have become stable (Table 12), (Bergerud and Elliott in press).

Fecundity of adult females determined by udder counts was 77% in 1979 compared to 82% in 1977 (Bergerud and Butler 1978). On June 10, 1980, 86% of the females on Level Mt. had visible udders and 82% the year previous (Table 9). Pregnancy rates of caribou are essentially constant (Bergerud 1980). Males were sufficiently abundant representing 42% of all adults sighted in 1979 and 40% in 1980 (Table 11).

## Discussion

In the first year at least, very few of the collared calves survived the summer study period. Collaring itself did not appear to produce the pattern of mortality observed. There was no abandonment by females in either year, despite contamination by human scent in 1980. Mothers seemed to identify their calves first aurally, then visually, and only then by smell. If human scent reduced predation, lower rates of predation would have been expected in the first few days after collaring. Finally, and conclusively, survival of collared calves was the same as uncollared calves, as evidenced by fall rut surveys. In 1979, 9% calves was expected from the collared sample and 9% was found in the fall survey. On Level Mt. in 1980, 19% were expected and 16% were surveyed (Figure 11 and Table 12). The collared calves were an unbiased sample.

Our focal point is the hypothesis that sufficient calves are recruited to balance adult mortality. Adult mortality rates in this study were not measured and other attempts at life table analysis have been unsuccessful (Miller 1974, Doerr 1980). However, Bergerud (1980) estimated the natural mortality of adult caribou in North America to vary from 7 to 13 percent with a mean of 10 percent. There is an inverse correlation between adult mortality rates and percent calves in the population due to shifts in predation

(Bergerud 1982). The estimated natural mortality of adult caribou in NW British Columbia during the years studied was at least 12% with an additional 2 - 3% hunting mortality (Bergerud and Elliott in press). Current work indicates that adult mortality could possibly be closer to 20% (Hatler unpubl., Edmonds and Bloomfield 1984, Fuller and Keith 1980), but results are preliminary. Only one mother of a collared calf was known to have died, and that was in an avalanche. Adult mortality did not appear to be excessively high during the summer study period. To be conservative, a minimum of 15% calf recruitment would be necessary to maintain population levels (Bergerud 1978).

Recruitment is defined to be the number of animals at one year of age, but we only obtained data until 5 months. After the summer study period, calf survival increased dramatically, (Figure 12) more closely approximating adult survival rates. Bergerud (1980, 1982) estimated overwinter calf mortality to be twice that of adults. This estimate agrees with a sample of the Delta herd in Alaska where overwinter survival was 80 - 92% (Davis et al. 1980). Spring yearling counts were consistently higher than fall calf crops (Hatler 1981), probably due to differential movements of the herd in spring, so could not reliably indicate recruitment rates. Still, recruitment was less than 8% in 1979 and less than 15% in 1980. In these two

years, recruitment was insufficient to balance adult mortality. The hypothesis is rejected.

The alternate explanations to the hypothesis are limited. Calves might not be born, yet spring udder counts indicate that 86% of the females gave birth (Table 9). Pregnancy rates of caribou are essentially constant (Bergerud 1980) in all but cases of extreme and chronic food shortages (Thomas 1982). Caribou do not have twins (McDonald and Martell 1981, Mc Ewan 1971). The calves could conceivably die after birth from malnutrition. Rather than being malnourished however, all captured calves were large and vigorous. In fact, the smallest newborn calf in this study at 5.0 kg was the mean weight for the Kaminuriak herd (Miller and Broughton 1974). Large birth weight is indicative of good maternal nutrition during pregnancy and is correlated with high survival (Haukoija and Jalovaara 1978, Verme 1963, Verme 1977). Heart girth of females was similar in spring and fall indicating that fat reserves were not totally depleted overwinter (Table 7). Low fertility is rejected as an explanation for poor recruitment.

There was also no sign of the diseases mastitis or besnoitosis in adults that could have reduced milk production leading to starvation of calves. Calves vigorous at birth could later succumb to disease, but cultures from newborn calves, and the few carcasses that could be

recovered, indicated no disease organisms present in unusual abundance, with the exception of the ubiquitous *E. coli*. One calf (05-80) may have suffered from heavy *E. coli* O-group infection as reported to have caused death in West Greenland reindeer calves (Claussen et al. 1980). In reported cases though, death required at least 8 days and disease symptoms were obvious, both pre- and postmortem. This calf died in 3 days and showed no indications of disease on gross examination and necropsy, and leucocyte counts were not elevated. Death due to a massive infection of *E. coli* is unlikely to have been the cause. No disease agent appears to be implicated in the decline.

Calves did not disperse. All collared calves remained in the study area for the summer. Indications were that after migration to wintering areas, they returned to the mountains of their birth. Females in Spatsizi show strong fidelity to a specific calving mountain (Hatler unpubl.).

Other studies have suggested from circumstantial evidence, that calves may die in inclement weather, even though cold cannot kill adults (Kelsall 1968, Kudryashova 1980). No collared calves in this study died due to weather stress. The worst day of weather in the two years was June 5, 1979 coincident with the peak of calving. Though wind gusts reached 70 km/hr, average cumulative wind speed for the day was only 7.0 km/hr/hr at a low temperature of  $-4^{\circ}$  C,

insufficient to cause death. Death from windchill has been suggested to have killed caribou calves in the Arctic (Kelsall 1968), but wet coats, high winds and freezing temperatures for prolonged periods were required. These conditions do not exist in British Columbia. If calves are able to use microclimate, or bed to avoid the wind, no mortality occurs at temperatures of  $-5^{\circ}$  C and winds of 56 km/hr (Hart et al. 1961). Calves in Spatsizi bedded against the downwind side of the female to maintain homeostasis and birth sites were generally in favourable microclimates. They also have the option of making altitudinal shifts up or down to avoid freezing rain conditions. Weather for the previous ten years should not have killed calves in Northwestern British Columbia, especially since calves should always be able to escape death from windchill by seeking shelter (Henshaw 1968).

The difference in calf survival between years was negatively correlated with spring snow depths. Fall calf crops were significantly lower after late springs with deep snow (Figure 19;  $df=1,6$ ,  $r=.78$ ,  $F=11.6$ ,  $p=.01$ ). With high pregnancy rates and no evidence of disease, malnutrition or intrinsically weak newborn calves, the potential adverse effects of deep snow on overwinter productivity and condition of females can be eliminated from consideration (Peterson and Allen 1974).

There was a fairly high loss of calves to accidental sources. Some loss to avalanches, birth anomalies and drowning might be expected, but the 15% loss experienced by these animals appears excessive. No individual accident occurred in the sample more than once, suggesting that the losses were random, but accidents such as avalanches and broken legs are peculiar to high elevation calving, and should be low in the forested areas.

Some females in these populations do calve in the shrub and forest zones, which appear to be the preferred calving areas for other populations (Fuller and Keith 1980, Oosenbrug and Theberge 1980). Apparent selection in those studies may be a lack of choice. Alpine areas are not available to Alberta caribou and the Burwash herd in the Yukon, 300 km north of Level Mt., may be excluded from calving in the alpine by spring snow cover. Strong pressures must be operating to force the females in this study to calve at extreme elevations.

The obvious selection pressure for alpine calving is predation (Bergerud et al. 1984). At least 50% of the deaths of calves was due to predation by grizzly bears or wolves (Figure 20). In 1979 in Spatsizi, predators moved in from surrounding areas and scoured every mountain in the calving area. Grizzlies, in particular, intensively searched the alpine area.

There was little or no alternate prey for predators in these high alpine areas. Grizzlies never hunted marmots and were observed to traverse marmot colonies without pausing. Green vegetation for grizzlies was only available at lower elevations, yet they forsook this abundant and nutritionally adequate food source (C. Jonkel, pers. comm.) to hunt high alpine for caribou calves. It appeared on Level Mt. that grizzlies were also in the alpine to find mates and so remained at high elevations despite low hunting success. Wolves were primarily dependent on moose, which are only found below treeline. Both grizzlies and wolves had to choose to leave other food sources and rely exclusively on their ability to hunt caribou calves.

Female caribou are not able to defend their young against predators as large as wolves and bears, so are choosing to distance themselves from these threats to their offspring in favourable escape terrain (Bergerud et al. 1984). As calving approaches, female caribou move toward high elevation alpine areas and disperse from each other, to minimize encounter rates with predators. The array of predators (wolves, grizzlies, wolverines and golden eagles) must search much greater areas in years of no snow, than if females are concentrated by snow or are in calving herds. Predators must expend greater energy hunting mountains than valleys, and may not detect calving females above them due

to rising air currents. The strategy of alpine calving is a good one, given the alternatives.

The ultimate cause of the decline of the caribou of Northwestern B. C., that began in the early 1970's may not ever be known (Bloomfield 1979). By the end of the decade, when this study began, the overwhelmingly significant factor responsible for continued loss of herds and the decline of populations was excessive levels of predation, primarily on calves in the first three months of birth. Many other studies have documented population declines or limitation from heavy neonatal predation, for caribou (Bergerud 1971), moose (Franzmann et al. 1980, Ballard et al. 1981) and deer (Carswell and Brown 1977, Cook et al. 1971, Smith and Lecount 1979, Hatter 1984). The magnitude of predation losses in Northwestern British Columbia during this study was sufficient that if all other calf mortality factors were controlled, and hunting was halted, the populations would continue to decline.

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Table 1. Weather station operation - including presence of Stevenson Screen, hygrometer, thermograph, anemometer, rain gauge and maximum and minimum thermometers.

Area	Elev (m)	Hygrom Screen	Anemom Thermog	Precip	Thermom Max	Thermom Min	Dates of Operation
Spatsizi-1979							
Thule Mt.	1676	X	X	X	X	X	25/05-14/06
Fire Flats	1311	X	X	X	X	X	25/05-14/06
Kluayaz L.	975			X	X	X	25/05-30/06
Level Mt-1980							
Kakachuya	1676	X	X	X	X	X	02/06-04/08
Hatin L.	945			X	X		31/05-14/06

Table 2. Birth site characteristics.

## Table Headings

Date of Birth  
 Elev - Elevation in m  
 Asp - Aspect of site  
 Slp - Slope in degrees  
 Top - Distance to top of slope in m  
 Snow - Snow Code  
     1 site bare, no snow within 50m  
     2 site bare, patches of snow within 50m  
     3 site bare, deep snow within 50m  
     4 snow at site  
     5 fresh snow at site  
 Veg - Vegetation Code  
     1 bare  
     2 lichen and grass only within 50m  
     3 shrubs within 50m  
     4 shrubs at site, open canopy  
     5 <10% canopy  
 Cloud- Cloud cover in %  
 Prec - Precipitation -lt rn -light rain  
 Dir - Direction of Wind  
 Speed- Wind Speed  
     light <15 kmh  
     mod 16-49 kmh  
     strong >50 kmh

#	Date	Elev	Asp	Slp	Top	Sno	Veg	Cloud	Prec	Wind	
										Dir	Speed
1979											
01	June 3	1830	SW	5	200	3	2	100	lt rn	S	light
02	June 2	1770	SSE	50	300	2	2	20	none	SE	light
03	June 4	1705	E	40	100	3	1	50	lt rn	-	0
04	June 5	1675	E	20	500	3	3	100	snow	SW	strong
05	June 2	1920	EW	0	200	2	2	80	none	S	mod
06	June 7	1675	N	5	300	1	3	100	snow	N	mod
07	June 7	1830	E	5	300	2	3	100	snow	S	mod
08	June 7	1890	NE	5	150	3	2				
	Mean	1786		16	256	2.4	2.2	81			
1980											
01	June 2	1660	W	20	100	3	2	100	lt rn	NW	mod
02	June 4	1890	EW	0	0	3	2	90	none	N	strong
03	June 5	1890	N	10	600	2	2	10	none	N	mod
04	June 4	1670	S	60	200	1	1	10	none	NW	mod
05	June 6	1920	W	5	0	3	2	0	none	-	0
06	June 7	1700	N	30	100	4	2	0	none	-	0
07	June 7	1675	S	50	200	2	2	0	none	NW	light
08	June 7	1890	NW	40	50	4	1	0	none	NW	light
09	June 10	2010	NS	0	0	4	1	0	none	NW	light
10	June 10	1930	W	10	100	3	2	0	none	NW	light
11	June 9	1930	N	20	200	4	2	0	none	NW	light
	Mean	1840		22	140	3.1	1.7	19			
Overall Mean		1820		19.6	189						

Table 3. Calf Physical Characteristics.

## Table headings

Age - Days- or -Hours  
WT - Weight in kg  
EA - Ear length in cm  
HE - Length of head in cm  
NE - Neck circumference in cm  
SH - Shoulder height in cm  
HG - Heart girth in cm  
LN - Total length in cm  
TA - Tail length in cm (excluding hair)  
FT - Length of hind foot in cm  
HL - Length of shoulder hair in cm

#	Date	Sex	Age	WT	EA	HE	NE	SH	HG	LN	TA	FT	HL
1979													
01	June 3	M	-4	10.3	8	21	20	68	46	90	10	38	-
02	June 4	F	-8	5.0	8	-	18	53	33	71	8	-	-
03	June 5	M	-12	8.25	7	-	20	61	44	84	10	-	2
06	June 6	M	2-	11.2	9	21	23	-	49	94	12	39	2
07	June 7	M	-12	8.0	8	21	18	61	44	78	7	45	1
09	June 7	M	-18	9.0	9	23	21	70	47	97	8	38	2
10	June 7	F	2-	10.2	8	23	42	69	47	84	9	37	2
11	June 7	F	-5	5.7	8	19	18	62	42	70	7	35	1
12	June 8	M	2-	13.0	8	23	25	74	55	94	7	38	2
13	June 8	F	2-	8.0	7	20	18	56	43	83	10	35	1
60	June 2	F	-6	9.8	10	-	25	-	50	-	8	-	-
102	May 27	M	Fetus	8.0	9	-	20	60	42	81	9	34	2
1980													
01	June 2	F	-18	10.0	7	22	25	71	56	85	9	38	3.5
02	June 2	F	-18	10.0	9	21	24	70	49	92	8	37	3
03	June 4	F	2-	11.3	8	24	25	69	50	94	9	37	3
04	June 4	F	2-	12.6	8	22	23	71	53	100	9	39	4
05	June 4	M	-12	10.0	8	22	24	63	48	95	8	37	3
06	June 4	F	1-	11.0	9	23	23	62	51	95	9	37	3
07	June 4	F	3-	15.0	9	26	30	70	62	140	8	39	3
08	June 5	M	2-	12.8	9	22	26	72	54	94	10	39	3
09	June 5	M	-18	10.2	8	24	17	73	53	92	9	38	3
10	June 5	M	-18	10.6	9	25	27	58	54	98	9	40	3
11	June 5	M	2-	14.0	9	23	26	77	56	106	10	42	3
13	June 5	F	3-	115.0	9	25	27	80	63	110	9	38	4
14	June 5	F	1-	11.0	9	22	22	67	57	92	10	37	3.5
16	June 5	F	-12	7.3	6	21	20	61	48	77	9	34	2.5
16	June 6	M	2-	12.5	9	24	28	69	55	87	10	38	3
17	June 6	F	-18	6.8	7	22	22	60	42	80	7	34	2.5
18	June 6	M	2-	10.5	8	22	27	70	54	92	9	38	3
19	June 7	F	-8	7.5	7	21	20	62	55	84	8	35	3
20	June 7	F	2-	11.5	9	21	26	73	55	94	8	41	2.5
21	June 8	F	2-	13.0	9	25	26	63	61	102	10	40	4
22	June 8	F	2-	10.2	9	23	26	65	48	94	9	37	3
24	June 10	M	3-	10.8	9	26	26	73	53	97	8	39	3
25	June 10	M	1-	8.0	8	22	21	54	43	86	8	37	3
Means		M	N=7	9.5	8	23	21	65	48	91	9	39	2.3
(<1 day)		F	N=8	7.8	8	21	22	63	47	80	8	36	2.6

Table 4. Bacteriology and virology of fecal swabs from calves.

abbreviations - hemolytic or non-hemolytic

*Escheria, Staphylococcus*

Bovine corona virus -

virology is positive (+) or negative (-)

Calf No.	Bacteriology	Virology
01-79	no growth	
02-79	no growth	
03-79	non-hemo E. coli	
06-79	no swab	
07-79	Pseudomonas sp.	
09-79	negative	
10-79	heavy coliform	
11-79	negative	
12-79	hemo and non-hemo E. coli	
13-79	hemo and non-hemo E. coli, Enterobacter	
60-79	no swab	
102-79	fetus, no swab	
01-80	heavy non-hemolytic E. coli, Klebsiella	-
02-80	heavy hemo and non-hemo E. coli	-
03-80	heavy non-hemo E. coli	-
04-80	heavy non-hemo E. coli	-
05-80	heavy non-hemo E. coli	-
05-80	dead - same from oral and anal swabs, lungs, kidney, and liver	-
06-80	heavy non-hemo E. coli	-
07-80	heavy hemo E. coli	-
08-80	heavy non-hemo E. coli	-
09-80	Staph. albus, Bacillus sp.	-
10-80	Heavy non-hemo E. coli, Enterobacter sp.	-
11-80	heavy non-hemo E. coli	-
13-80	heavy non-hemo E. coli	-
14-80	heavy hemo and non-hemo E. coli	-
15-80	scant Staph. albus	-
16-80	heavy non-hemo E. coli	-
17-80	heavy non-hemo E. coli	-
18-80	heavy non-hemo E. coli	-
19-80	heavy Staph. aureus	-
20-80	heavy non-hemo E. coli	-
21-80	heavy non-hemo E. coli	+ corona
22-80	heavy non-hemo E. coli	+ corona
24-80	no growth	
25-80	no growth	

Table 5. Mortality of radio-collared calves.

## Table Headings

Time - Days-hours since death  
Age - Of calf in days  
Wt - Weight of carcass in kg  
Cons - % of carcass consumed  
Dis - Distance from capture site in km  
Elev - Elevation in m  
Veg - Dominant vegetation at kill site  
Cause  
Def - Cause of death certain  
Prob - Highly probable cause of death  
Poss - Most likely cause of death, though evidence indirect

#	Sex	Date	Time	Age	Wt	Cons	Dis	Elev	Veg	Cause of Death
1979										
01	M	June 3	-6	2	10.3	0	0	1770	bare	Def-Back broken
10	F	June 8	-18	2	-	-	1	1770	fir	Prob-Wolf
09	M	June 8	-1	1	8.9	0	.3	1615	fir	Def-Study starvation
13	F	June 10	1-	3	3.5	90	.15	1675	snow	Def-Avalanche
07	M	June 14	1-	6	0	100	.5	1580	fir	Def-Grizzly
02	F	June 18	3-	12	0	100	1	1830	snow	Def-Wolf
12	M	July 16	>14	26	0	100	9	1280	birch	Def-Wolf
03	M	July 15	-	-	-	-	6	>1980		Unknown
06	M	July 15	-	-	-	-	-	-		Unknown
		Mean	8				2.5	1707		
1980										
05	M	June 7	-12	3	9.0	5	.4	1800	bare	Prob-Aneurism
14	F	June 8	2-	4	-	-	0.4	1280	-	Prob-Drowning
07	F	June 16	2-	14	0	100	1	1470	willow	Def-Grizzly
13	F	June 16	4-	12		0100	4.5	1220	aspen	Def-Wolf
06	F	June 16	4-	10	2.25	80	4	1450	fir	Prob-Wolf
22	F	July 29	>19	30	-	-	1.5	1525	willow	Poss-Wolf
17	F	Aug 19	39-	30	-	-	2.5	1675	bare	Poss-Grizzly
08	M	Aug 19	<30-	50	-	-	1	1370	willow	Poss-Wolf
18	M	Aug 19	<30-	50	-	-	25	1525	willow	Poss-Wolf
15	F	Aug 19	<30-	50	0	100	2.5	1585	willow	Def-Grizzly
24	M	Sept 27	-	-	-	-	20	1525	willow	Poss-Wolf
		Mean	16	24			5.7	1500		

Table 6. Summary of calf mortality to August 15.

Most Likely Cause of Death	1979	1980	Total
Predation Wolf	3	5	8-
Grizzly	1	3	4
Accidental	3	2	5
Unknown	2	1	3
Total Deaths	9	11	20
Total Collared	11	23	34

Table 7. Adult Physical Characteristics.

Table headings follow Table 3. plus

Calf - Present(Y) (calf number if captured), or Absent(N)  
LXWXD - Length, Width, Depth of Udder

#	Date	Calf	WT	EA	HE	NE	SH	HG	LN	TA	FT	Udder LXWXD		
Spatsizi - Spring 1979														
Females														
04	June 5	03		11	41	65	137	142	216	18	-	17	10	10
05	June 6	Y		13	46	50	132	134	218	19	61	15	13	10
08	June 7	07		18	38	45	122	118	193	15	57	12	10	10
14	June 8	13		15	45	58	117	132	182	21	58	12	10	10
15	June 25	N		14	41	41	122	117	199	10	57	none		
101	May 27	102	148	15	43	46	118	121	200	17	59	10	10	2
Level Mt. - Spring 1980														
Females														
12	June 5	11		16	32	51	127	127	222	20	61	18	12	9
23	June 8	22		15	44	48	108	130	210	17	61	18	10	7
Spatsizi - Fall 1980														
Females														
00	Oct 21	Y	145	15	48	62	112	137	204	20	57	16	9	10
01	Oct 22	N		17	43	56	105	136	193	17	59	none		
02	Oct 23	N		13	44	58	117	136	197	11	56	none		
03	Oct 23	N		15	42	53	121	127	191	18	56	none		
04	Oct 24		no data											
05	Oct 24	Y		13	44	50	118	123	212	19	59	16	9	6
06	Oct 25	N		16	48	63	118	136	217	16	66	none		
07	Oct 26	Y		13	45	54	124	129	206	15	57	small		
08	Oct 27	N		13	44	62	122	141	203	16	55	none		
09	Oct 28	N		15	42	61	117	134	211	15	61	none		
10	Oct 23		no data											
11	Oct 28	N		15	41	63	124	136	201	13	60	none		
Males														
13	Oct 23			16	44	74	125	142	214	16	60			
14	Oct 24		188	14	46	67	113	137	221	19	62			
15	Oct 25		263	15	52	78	142	144	228	20	63			
16	Oct 27			16	47	80	140	138	220	19	64			
Females - means			146	15	43				204					
Males - means			226	15	47				220					

Table 8. Wolf pack estimates.

## Spatsizi

Pack	1977-78	1979-80
Spatsizi	12	8
Marion	7	6
Kehlechoa	5	6
Coldfish	20	7
Eaglenest	8	7
Stikine	20	8
Total	72	42

## Level Mt.

Pack	1979-80	1980-81
Granite	4	4
Nahlin	12	12
Kakachuya	5	5
Sheslay	5-8	4-5
Beatty	2	7
Tahltnan	5-6	6-8
Total	33-37	38-41

Table 9. Productivity of female caribou from spring aerial surveys.

	Date	Total Females	Udders No	Yes	Calves	% Parous
1979						
Mountains	3-12 June	40	3	37	34	92
	14 June	13	2	11	6	85
	15 June	12	8	4	1	33
	18 June	10	2	8	3	80
Fire Flats	19 June	12	3	9	0	75
	21 June	2	1	1	0	50
	22 June	5	2	3	0	60
	23 June	1	0	1	0	-
	24 June	42	8	34	2	81
	25 June	5	1	4	0	80
	26 June	19	8	11	1	58
	28 June	1	0	1	0	-
Total		162	38	124	47	77
1980						
	2 June	15	3	12	6	80
	4 June	34	9	25	11	74
	5 June	35	7	28	14	80
	6 June	17	2	15	13	88
	7 June	17	0	17	15	100
	8 June	13	0	13	13	100
	10 June	42	6	36	29	86
Total		173	27	146	101	84

Table 10. Food habits of wolf and bear from analysis of scats. Only primary item in each scat recorded.

		Wolf			Spatsizi	
		Level Mountain			All	%
		Pup	Adult	%		
Caribou	Adult	1	6	18	4	12
	Calf	2	7	24	8	24
	Unknown	2	2	11		
	Total			53		35
Moose	Adult		1	3	3	9
	Calf		6	16		
	Unknown	1		3	1	3
	Total			21		12
Goat					3	9
Deer		1		3		
Sm. Mammal	Beaver		6	16	3	9
	Hare		3	8	1	3
	Marmot		1	3	1	3
	Gr. Squirrel				1	3
Other	Wolverine	4		11		
	Ptarmigan	1		3	1	3
	Unknown		1	3	2	6
Total		11	34/45		28	

	Spatsizi Bear	
	Grizzly	Black
Caribou Calf	2	
Moose Calf		1
Grnd. Squirrel	1	1
Lemming		1
Vegetation	3	4
Total	6	7

Table 11. Sex and age composition of caribou sighted during spring aerial survey.

	Males	Females	Yglngs	Calves	Total
1979 June 3-28	127	172	26	52	377
1980 June 2-10	128	190	49	101	468

Table 12. Fall aerial surveys in Spatsizi Park (from Parks Branch files).

Year	% Calves	Total Classified
1976	7	660
1977	5	1544
1978	13	510
1979	9	576
1980	12	895
1981	9	296
1982	9	914
1983	15	232

Figure 1. Decline of the Fire Flats post-calving aggregation.

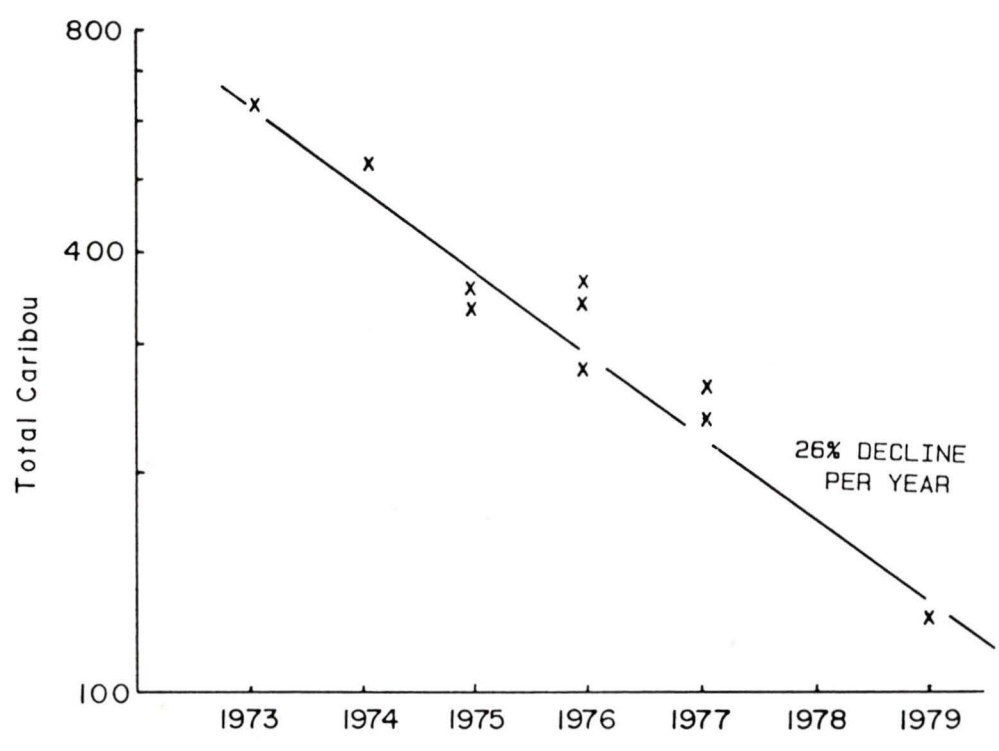


Figure 2. Study areas.

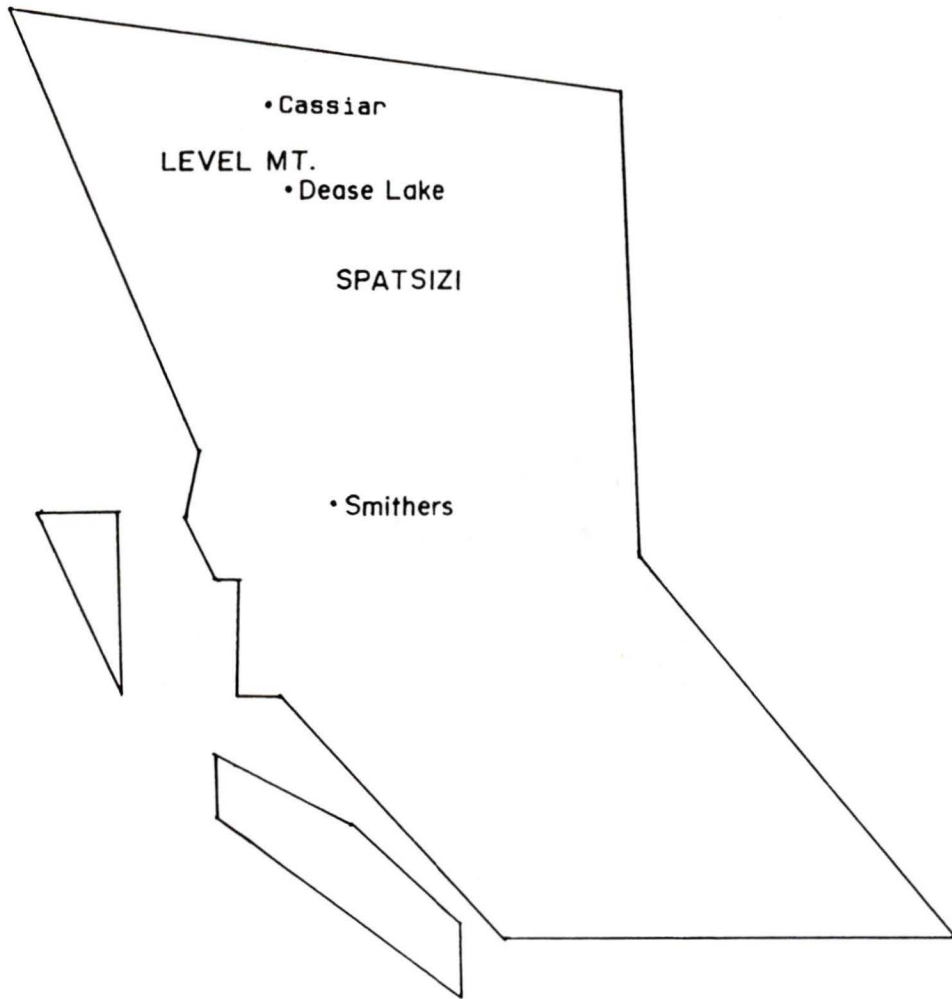


Figure 3. Hypothesis.



## HYPOTHESIS

Ho: Sufficient calves are recruited to  
balance adult mortality.

H1: Insufficient calves are recruited.

Reasons for insufficiency:

Infertility

Loss to: Accidents Disease

Predators Weather

Figure 4. Spatsizi study area showing location of camps ( ) and weather stations (Wx) (redrawn from 1:250,000 map sheet 104H).



Figure 5. Level Mt. study area showing location of camps ( ) and weather stations (Wx) (redrawn from 1:250,000 map sheet 104J).



Figure 6. Calf capture sites in 1979. Locations of calves seen but not captured indicated (x).



Figure 7. Calf capture sites in 1980.

6

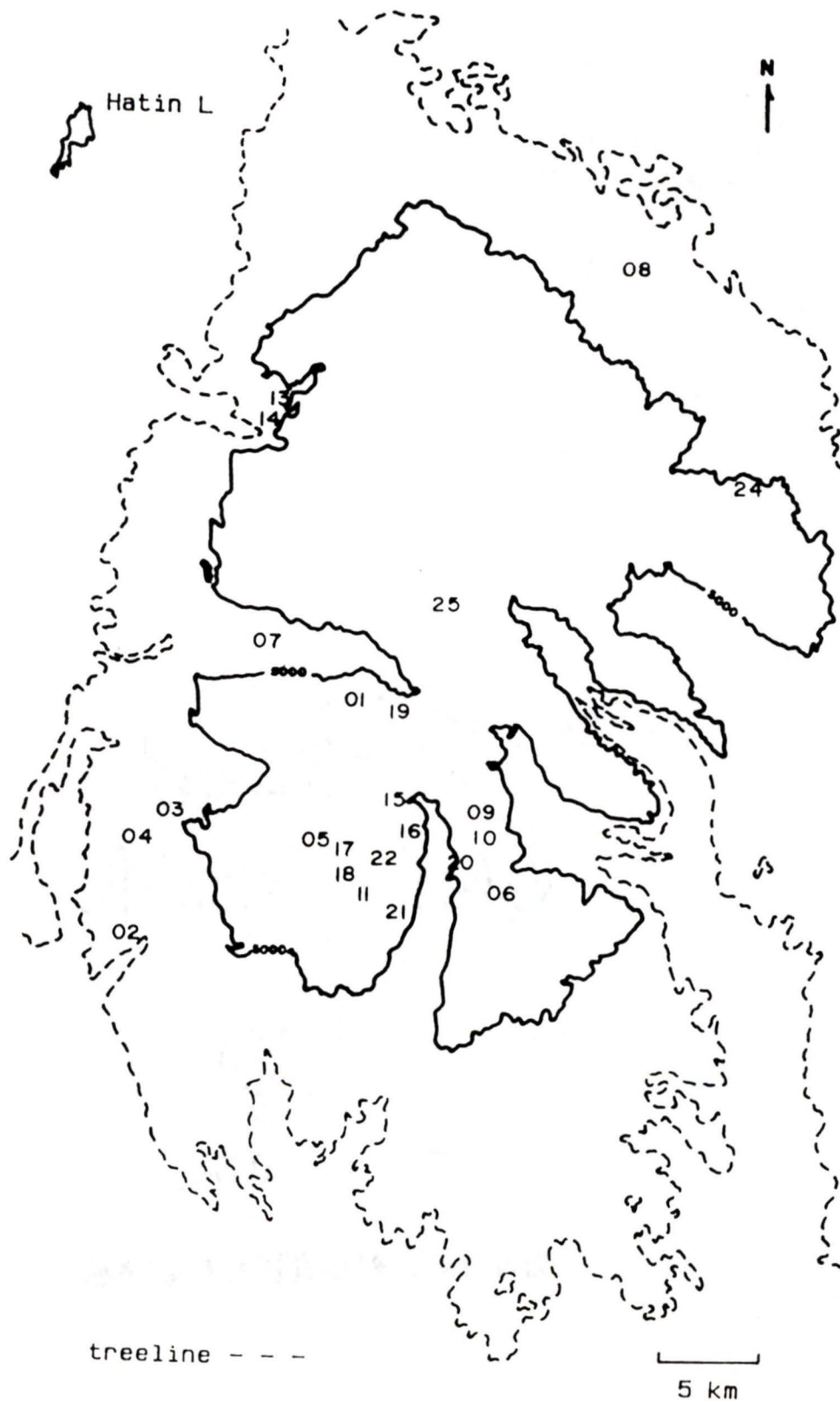
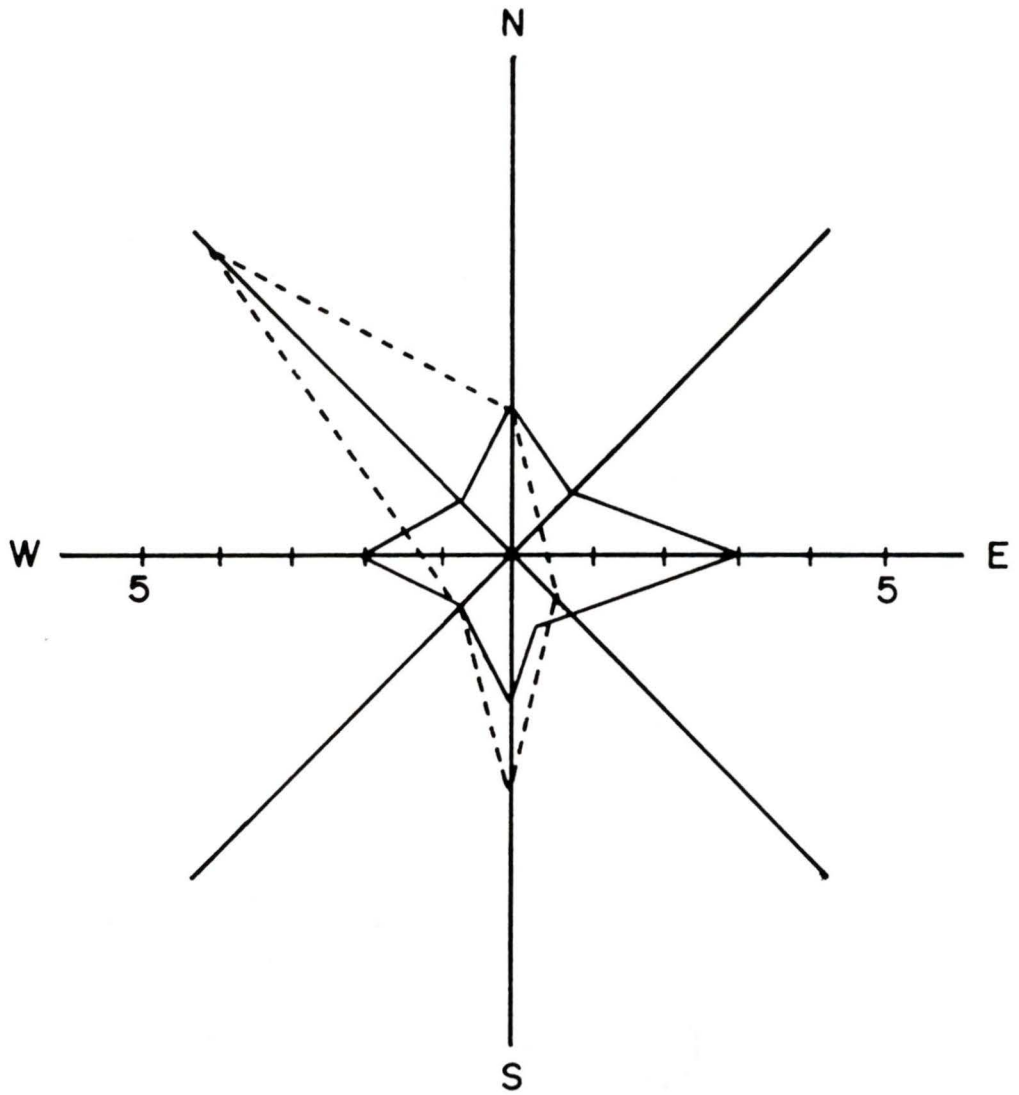


Figure 8. Relation of wind direction to aspect of birth site. Axes are number of sites located.

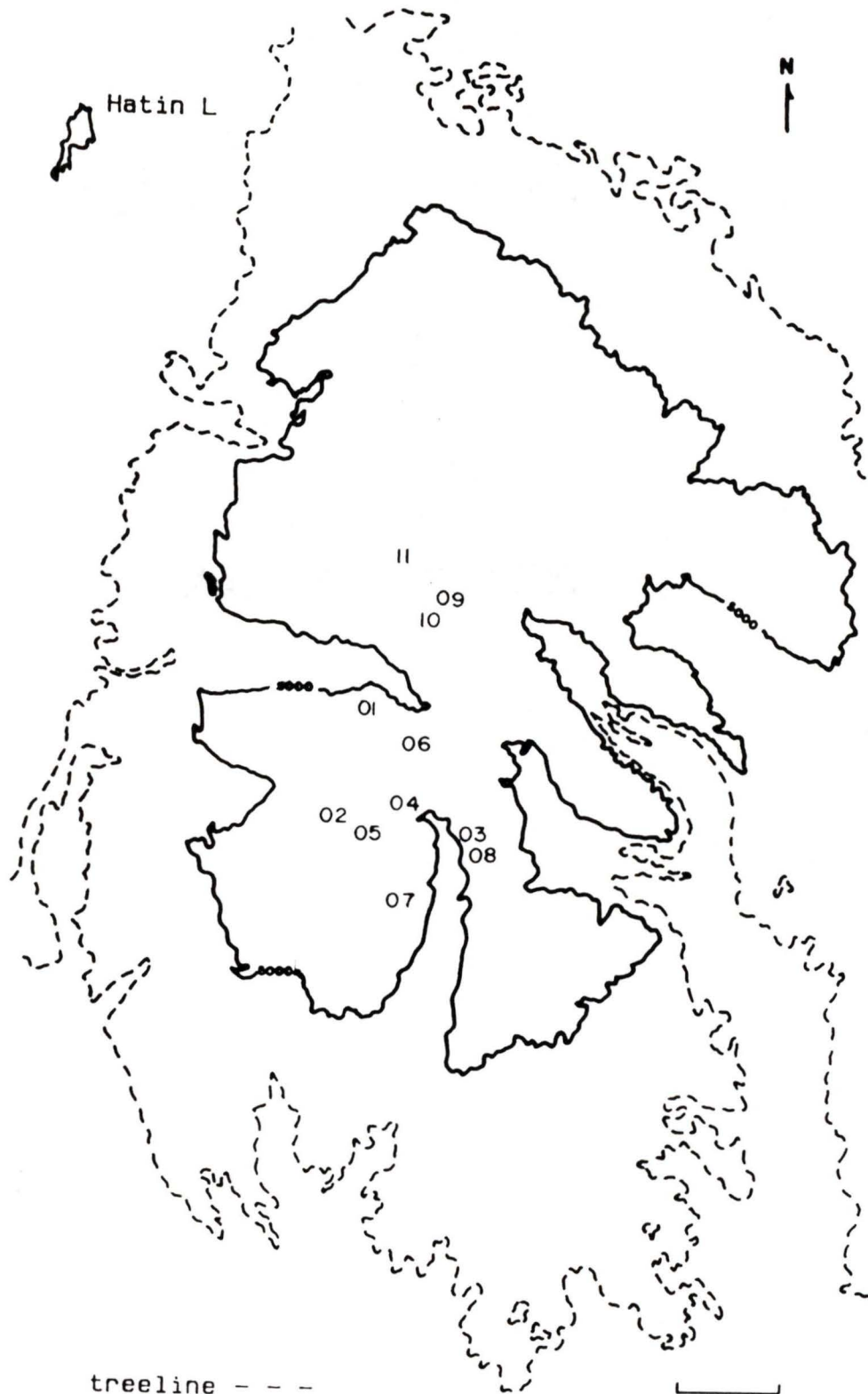


Wind Direction -- and Aspect of Birthsite —

Figure 9. Location of birth sites found in 1979.



Figure 10. Location of birth sites found in 1980.



Hatin L

N

tree line - - -

5 km

Figure 11. Survivorship curves of collared calves.

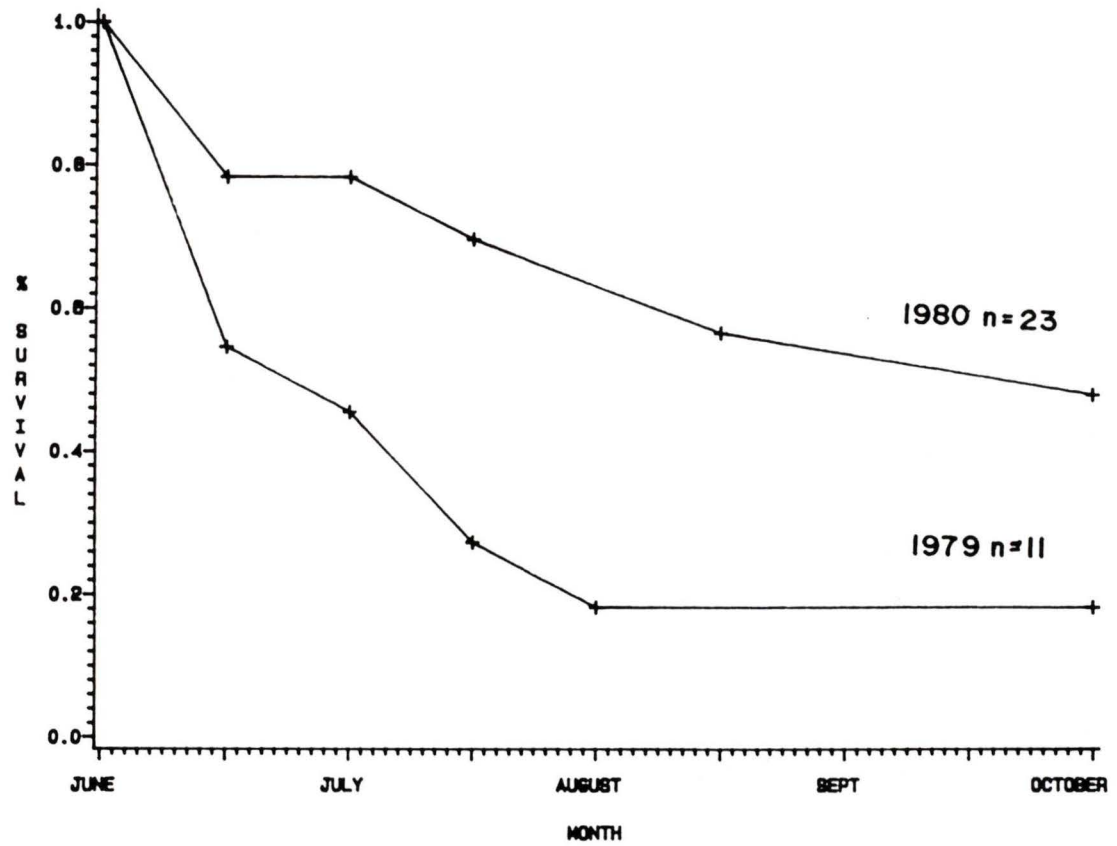


Figure 12. Logarithmic survivorship curves of collared calves.

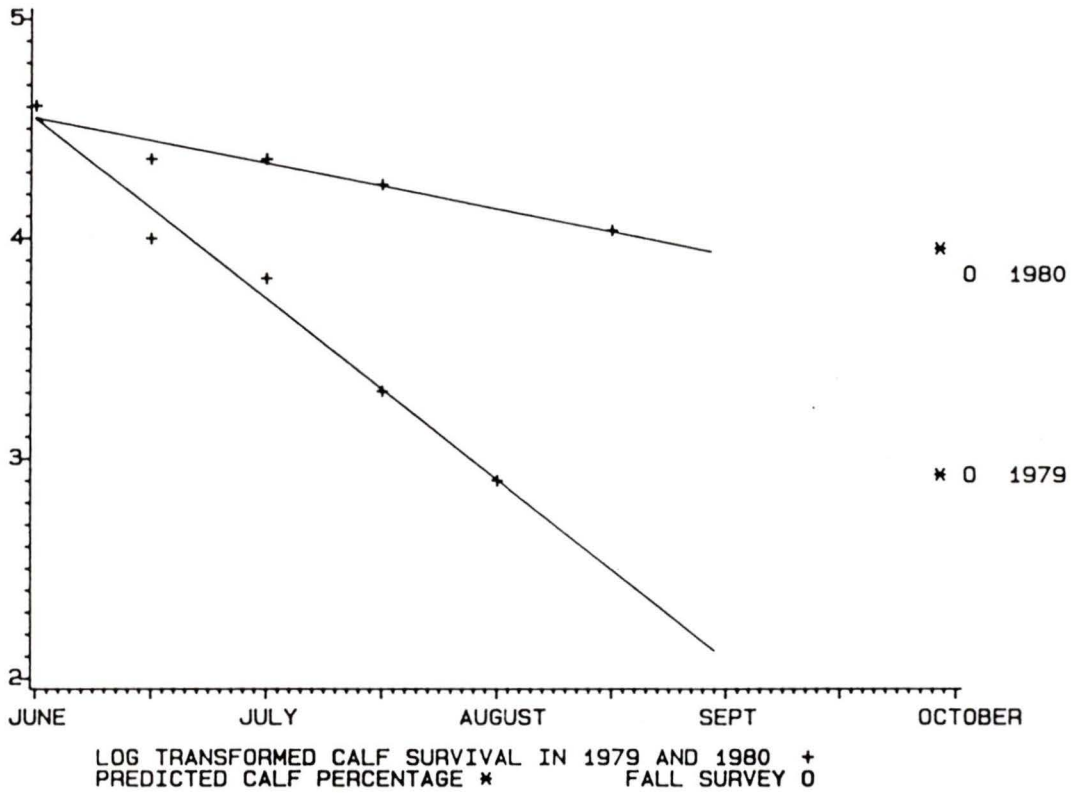
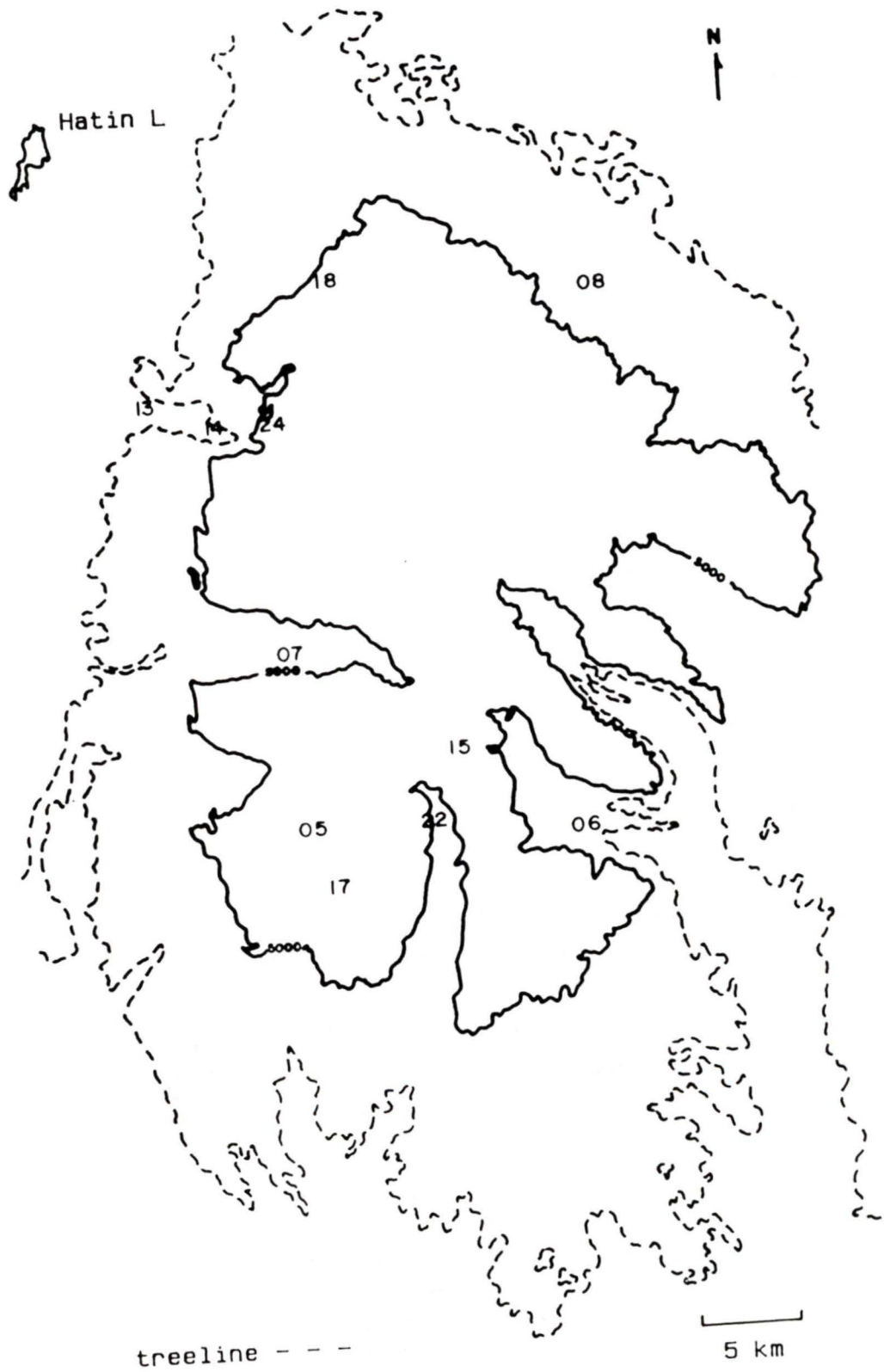


Figure 13. Calf mortality sites in 1979.



Figure 14. Calf mortality sites in 1980.



Hatin L



treeline - - -

5 km

Figure 15. Thermograph charts from weather stations. Temperature from calving elevation only in 1980. Chart interrupted from June 11 to June 16.

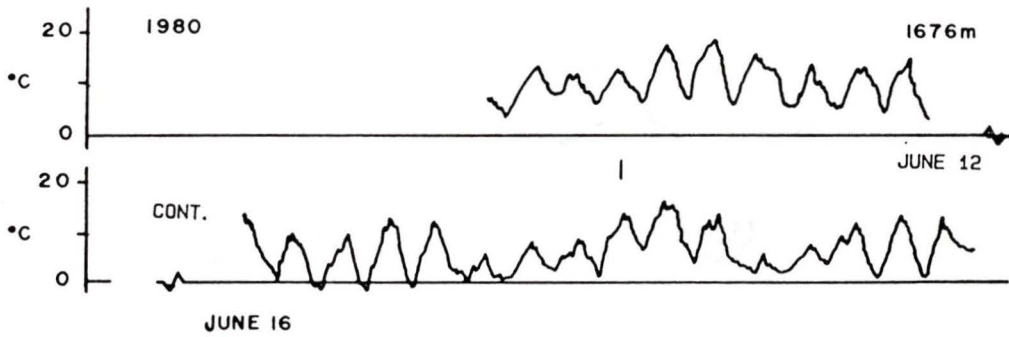
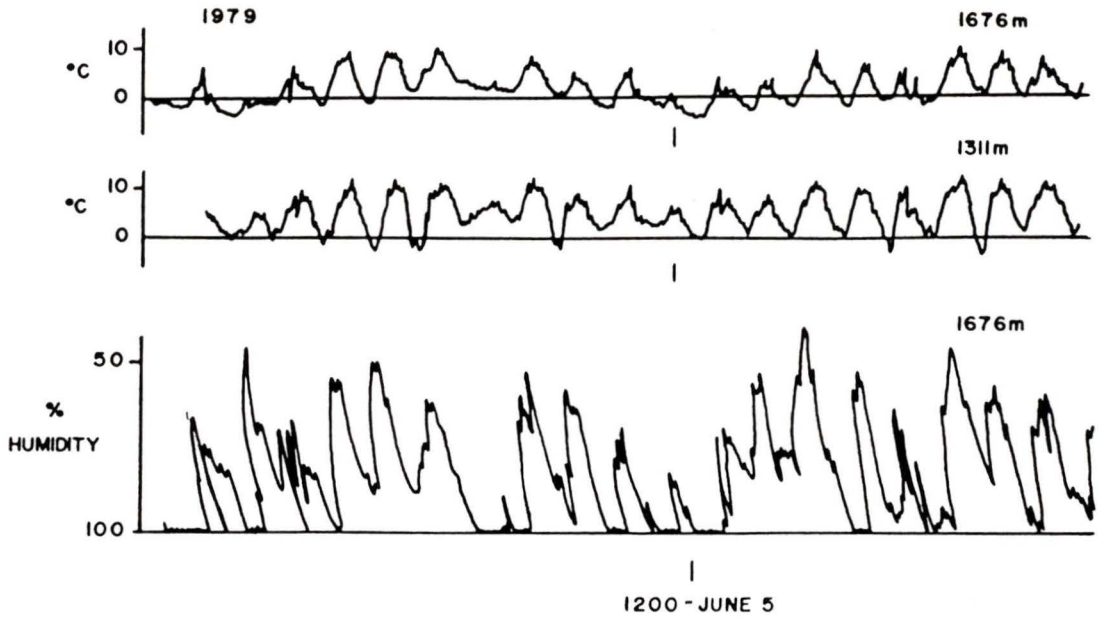


Figure 16. Cumulative wind speeds from weather stations.

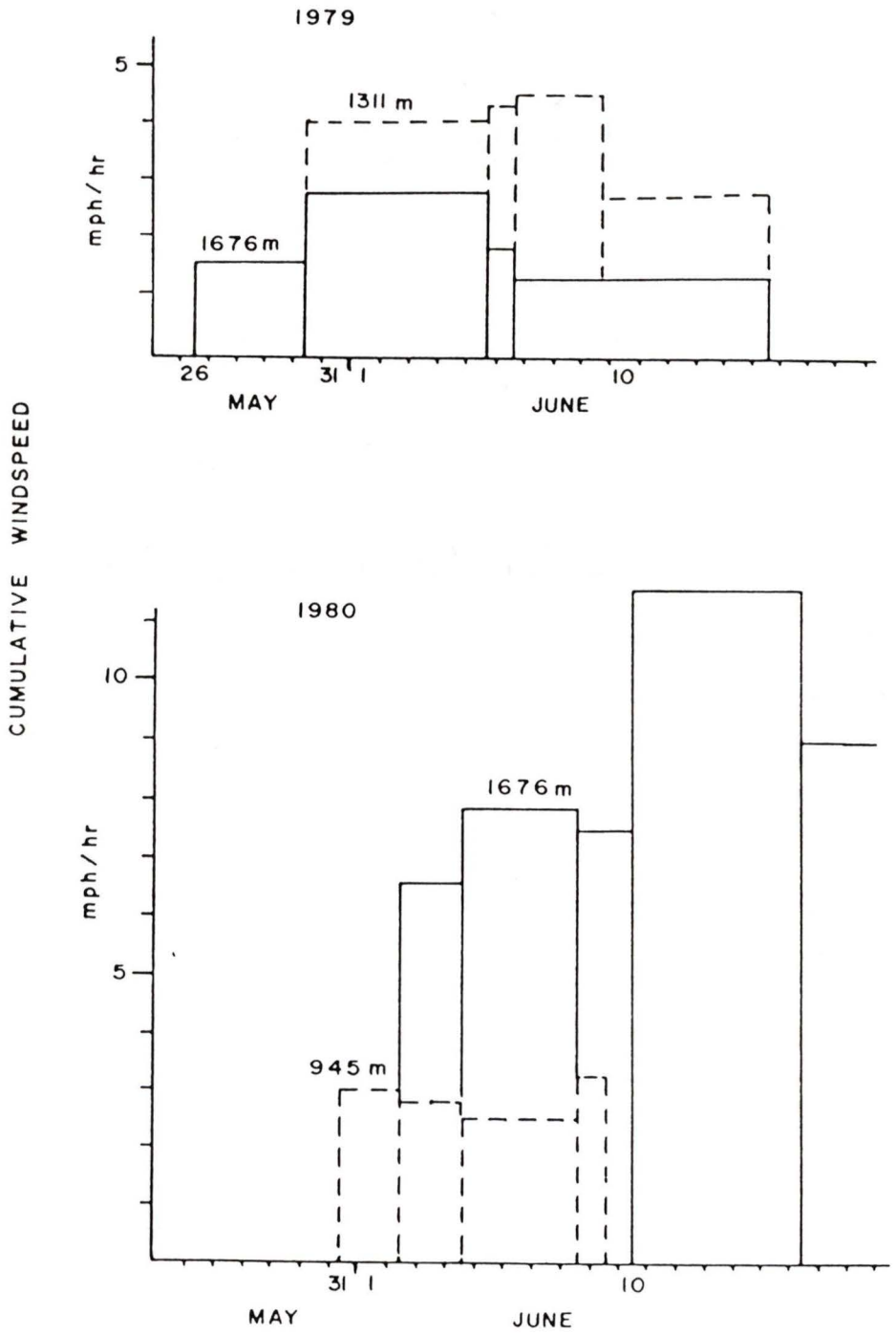


Figure 17. Location of wolf packs in Spatsizi (after Bergerud and Butler 1978).

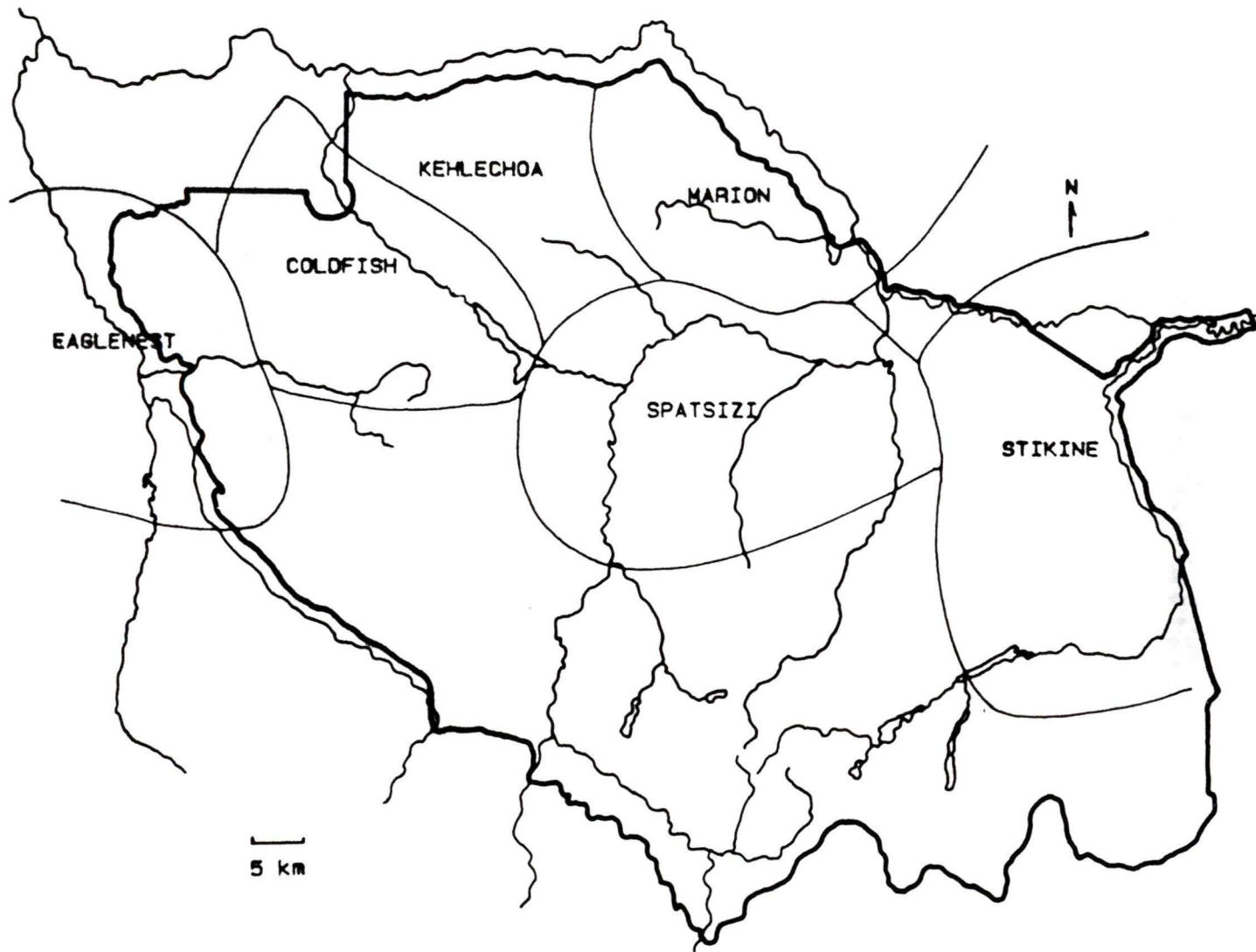


Figure 18. Location of wolf packs on Level Mt.

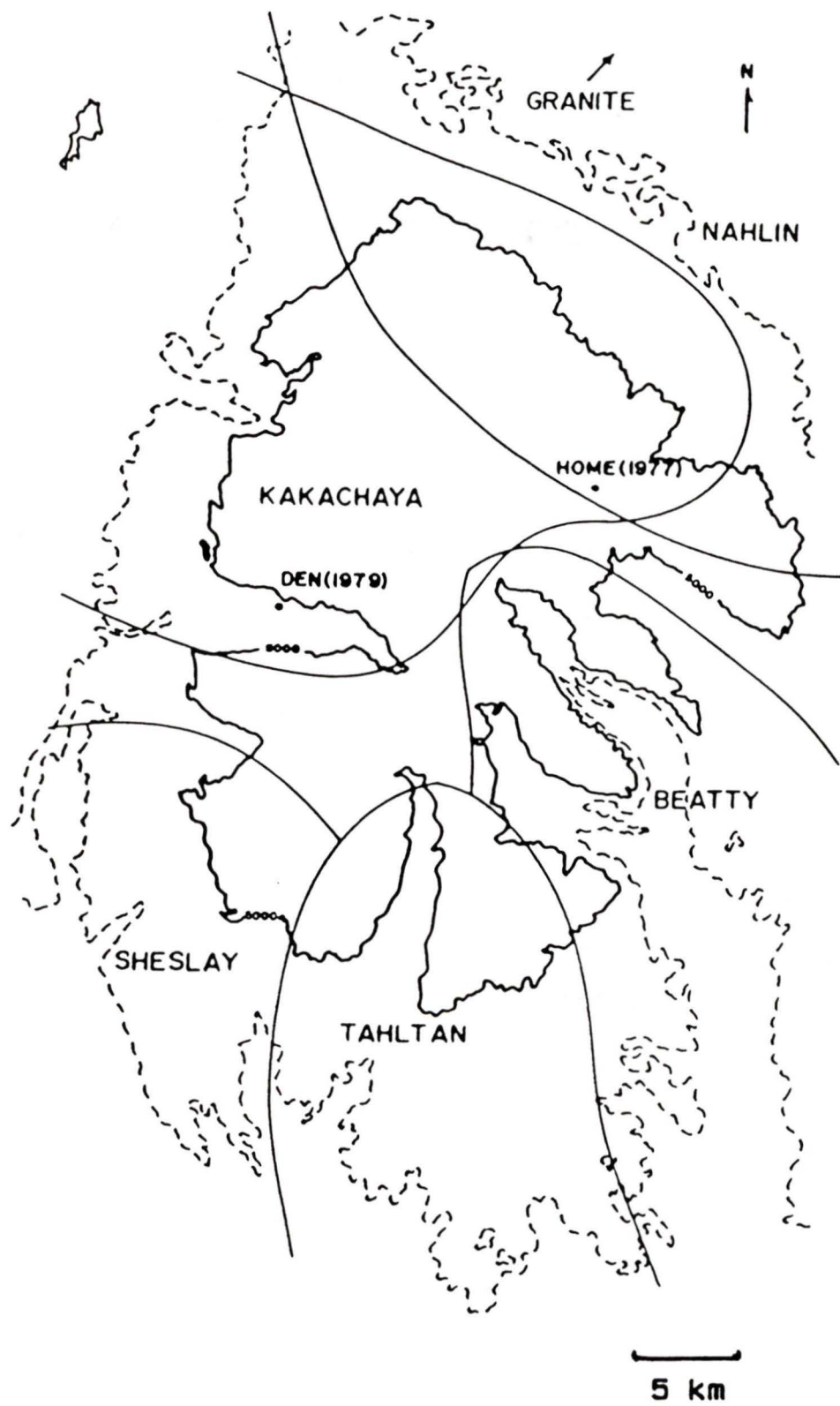


Figure 19. Correlation of Spatsizi fall calf numbers and spring snow depths.

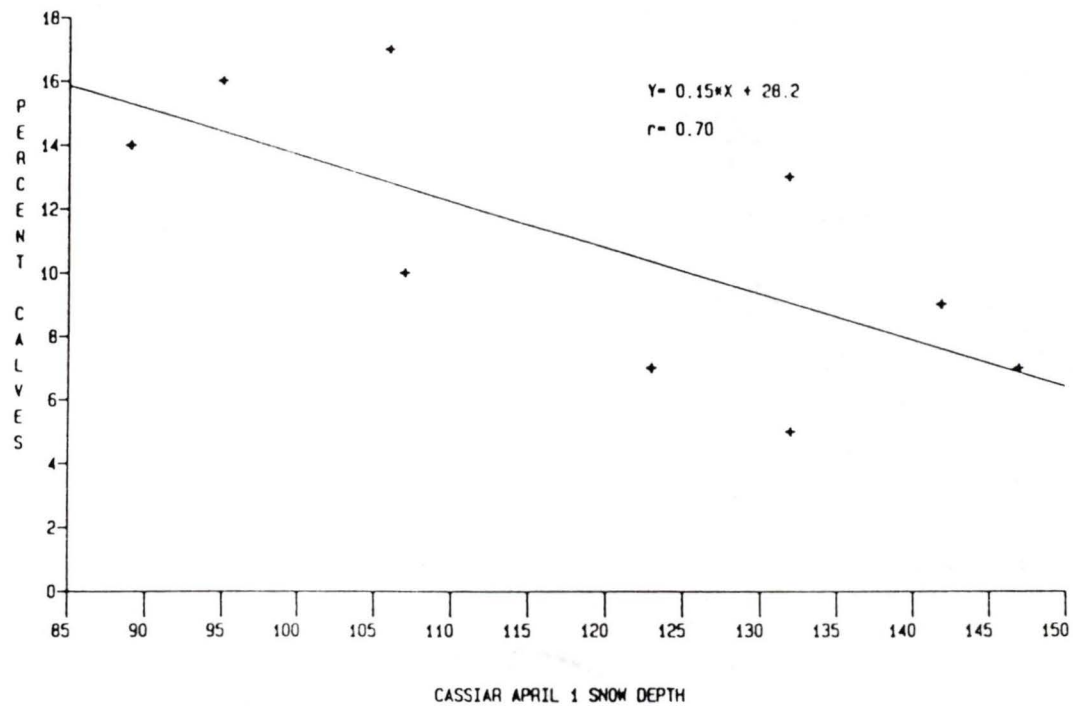
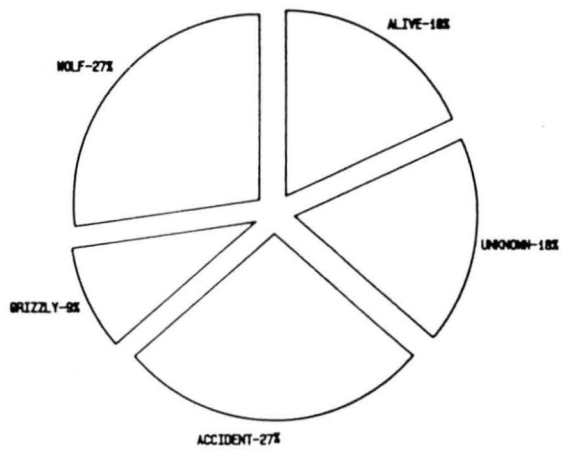


Figure 20. Fate of collared calves.

SPATSIZI-1979



LEVEL MT-1980

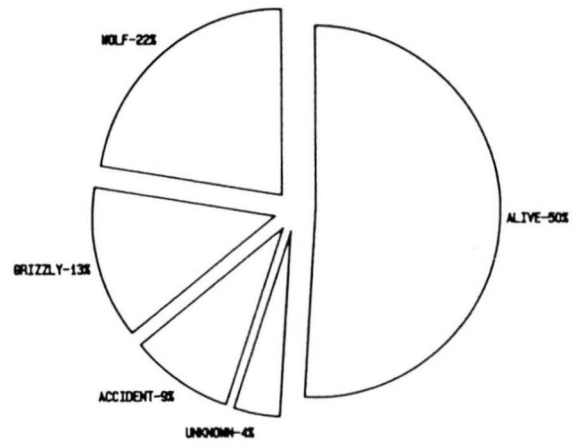


Photo 1. Fire Flats post-calving area in March.  
Note treeless grassland at high and low elevations,  
here covered by snow.

Photo 2. Capturing calves.  
Photo by Dave Hatler.



Photo 3. Capturing adult caribou in October.

Photo 4. Collared calf 11-80.  
Photo by Dave Hatler.



Photo 5. Processing calf.  
Photo by Dave Hatler.

Photo 6. Weather station at calving site on Level Mt. in  
1980.  
Photo by Dave Hatler.



Photo 7. Searching for evidence at calf mortality site.

Photo 8. Calving site of 07-79 in Spatsizi.



Photo 9. Remains of calf 07-79 killed by grizzly.

Photo 10. Remains of calf 13-79 killed in avalanche and scavenged by golden eagle.



## Appendix 1

## Selected Case Studies of Calf Mortalities

01-79 - captured June 3  
- died June 3  
- recovered June 3

0600 - Female caribou seen pregnant the day previously at the birthsite standing over dead calf. As we landed, adult ran down mountain and did not present a shot. Calf laterally recumbent with mucus on underside. Cartilage balls on tips of hooves. Collected carcass for necropsy at base camp.

No external sign of trauma, no dermal punctures. All abdominal organs normal and healthy. Lungs had filled. Heart and aorta virtually empty of blood. Large haematoma in thoracic spinal area. Dislocation between 4 and 5 thoracic vertebrae and rupture of posterior intercostal artery. No pathogens isolated. Wt. = 10.3 kb.

Cause of Death - Haemorrhage due to broken back suffered during parturition.

- 02-79 - captured June 4
- died June 16
- recovered June 18

1245 - Picked up mortality signal from head of Happy Valley.  
1320 - Landed on knoll above collar. Collar and wolf tracks visible in snow below me. Found portion of lower molars from 1978 (probable wolf kill). Two wolf scats and 2 sets of tracks in snow by collar. Collar very heavily chewed. Teeth imprints in metal. Antennae chewed off. Found fresh section of molars identical to piece just found. Tracks indicate wolves had run across slope, parallel to each other, tossing collar between them and jumping around it. After leaving the collar in snow, they hunted the bare patches at the head of the valley then moved over the ridge to the SW. Began snowing heavily, so we abandoned search for kill site.

Cause of Death - Wolf predation. 2 wolves came over 2000 m ridge above female and calf at capture site. Caribou ran across slope for at least 2 km before calf was caught. Wolves apparently consumed carcass then ran off with collar for 1 km

03-79 - captured June 5  
- died June 20 - July 15  
- not recovered

July 15, 1600 - Mortality signal heard on top of Taylor Mt.  
(about 2000 m.) from PA-12.

July 18, 1700 - Flew into Buckinghorse Lake with fishermen  
but couldn't pick up signal from ground because of  
topography. Tried from both ends of lake and from part  
way up Buckinghorse Mt.

Cause of Death - Unknown.

07-79 - captured June 7  
- died June 13  
- recovered June 14

1330 - 3 year old grizzly on ridge 2 km to NE. Found intact collar in fir., 20 m downhill from kill site. 3 x 5 m trough dug in soil at 1585 m. Only 1 scrap of fur (3 x 10 cm) and 2 bone chips remained. 3 grizzly scats collected, one containing soil.  
Cause of Death - Grizzly predation.

- 09-79 - captured June 7
- died June 8
- recovered June 8

1500 - Normal signal from collar. We look for 10-79 who died on opposite side of hill.

1630 - Collar on fast mode. Found carcass laterally recumbent on left side in small patch of fir. Collected carcass for necropsy at base camp.

No signs of trauma. All organs normal. No pathogens isolated. No milk curds in stomach. Two *Abies* needles on tongue. Three *Abies* needles, 2 *Vaccinium*, 2 *Linnaeus* leaves undigested in stomach.

Cause of Death - Starvation due to project-caused abandonment. We simultaneously collared 09 and 10 within 200 m of each other and the two females began looking for their calves together. 10 was vocal while 09 was silent and both females approached 10. We recaptured 10 and flew her to the site of 09. Tracks in snow indicate both females were bonding to 10 while 09 was left behind. Before 09 began vocalizing, 8 wolves attacked the group and both females ran off with 10. Calf 10 was separated from her mother in the chase and killed. 09 would likely have rejoined her mother if the wolves had not arrived.

- 13-79 - captured June 8
- died June 9
- recovered June 9

1600 - Poor visibility, ceiling at 1524 m. Avalanche late yesterday on slope where calf was collared. No sign of collared female. Flushed mature golden eagle from avalanche slope. Carcass found at 1676 m at edge of avalanche path. Collar in perfect condition 150 m above carcass. Carcass weight = 3.5 kg. 95% consumed by eagle. Small avalanche came down across path we just walked. Passed within 50 m of helicopter. All bones present and intact but some dislocated. Chip out of left scapula.

Cause of Death - Avalanche. Calf (probably with female 12-79) crossing under snow cornice near capture site when avalanche began. Calf hit by snow at edge of slide but rolled downhill, losing collar and ending up on top of snow 300 m below point of initial impact. Carcass scavenged by single adult golden eagle. Mother probably also perished.

05-80 - captured June 4  
- died June 7  
- recovered June 7

1435 - Calf laterally recumbent 400 m from capture site. Eyes, tongue eaten. Anus pecked. 4 x 6 x 6 cm. hole in right hip. Carcass collected for necropsy.

Only other signs of trauma are 2 lacerations on ribs. All are post-mortem effects. All organs normal. Stomach contained grass, lichens and milk. 50 ml. of blood in thoracic cavity. Right cardiac lobe of lung collapsed and reddish. No blood in alveoli. No pathogens isolated from oral or anal cavity, kidney, liver or lungs. Brain not checked for edema. Weight = 9.0 kg.

Cause of Death - Indefinite. Possible pulmonary aneurism from associated heat stress. Slightly scavenged by ravens and mew gulls.

06-80 - captured June 4  
- died June 10-14  
- recovered June 16

1445 - Isolated signal to patch of dirt in 1.5 m tall willow on knoll at 1450 m. No signs in dirt but recently disturbed. Recent rain. Excavated intact head with collar still on neck in 50 x 50 x 30 cm. hole. Hole was deep and narrow with no debris raked over it. No other parts of carcass found. Wolf tracks nearby.  
Cause of Death - Probable wolf kill.

14-80 - captured June 5  
- died June 7  
- recovered June 8

1100 - Heard mortality signal June 7 but live signal June 8 because collar on branch in stream being moved by water. Collar under 10 cm. of water at 1311 m at junction of 2 tributaries of Matsatu Creek. Very strong current due to snow melt runoff. Collar intact, no sign of calf carcass. Adult caribou tracks at stream crossing upriver.

Cause of Death - Assumed drowned in fast water. Collar washed off by current.

18-80 - captured June 6  
- died July 11 - August 9  
- received August 19

1445 - located collar after 45 minutes searching, even though signal isolated within 30 m. Collar was buried under cryptogam covered by 10 cm. chunks of lichen and moss. Almost impossible to see. Soil was not disturbed. One drop of blood, wolf teeth imprints on collar. Small amount of calf hair on ground 30 m to the west. No other sign.

Cause of Death - Possible wolf kill with collar buried by red fox.

22-80 - captured June 8  
- died June 23 - July 9  
- recovered July 29

June 8, 1835 - 2 men hid in rocks at 1829 m while helicopter chased 8 caribou with 4 calves back. Darted female, then chased calf. Ground very rocky and broken so couldn't jump on calf. Helicopter came over from behind at 10 m and blew REP forward into rocks landing on calf. Right front knee of calf dislocated. Still walking on leg but limping. Calf weighed 10.25 kg.

June 10 - Calf with mother. Running well on all legs.

July 29, 1655 - Found collar in wet swale of braided creek channel. Not at kill site. Wolf tooth marks in collar. No other sign found. 4 men searched 15 minutes in 100 m radius and beyond this along trails.

Cause of Death - Probable wolf kill with accessory study-induced susceptibility to predation.

## Appendix 2

## Computer Printouts From Statistical Tests

Linear regression of logarithmic calf survival.

SAS

18:40 SATURDAY, NOVEMBER 2, 1985 1

OBS MONTH CALVES79 CALVES80

1	1	4.60517	4.60517
2	2	3.99903	4.36005
3	3	3.81671	4.36005
4	4	3.30589	4.24226
5	5	2.90042	.
6	6	.	4.03463
7	7	.	.
8	8	.	.
9	9	.	.

SAS

18:40 SATURDAY, NOVEMBER 2, 1985 3

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: CALVES79 LOG SURVIVAL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	1.68316826	1.68316826	164.91	0.0010	0.982133	2.7119
ERROR	3	0.03062065	0.01020688			ROOT MSE	CALVES79 MEAN
CORRECTED TOTAL	4	1.71378891				0.10102913	3.72544534

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
MONTH	1	1.68316826	164.91	0.0010	1	1.68316826	164.91	0.0010

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR >  T	STD ERROR OF ESTIMATE
INTERCEPT	4.95623835	46.77	0.0001	0.10596024
MONTH	-0.41026434	-12.84	0.0010	0.03194821

SAS

18:40 SATURDAY, NOVEMBER 2, 1985 4

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: CALVES80

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	1	0.16121837	0.16121837	44.82	0.0068	0.937260	1.3882
ERROR	3	0.01079186	0.00359729			ROOT MSE	CALVES80 MEAN
CORRECTED TOTAL	4	0.17201023				0.05997739	4.32043113

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
MONTH	1	0.16121837	44.82	0.0068	1	0.16121837	44.82	0.0068

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR >  T	STD ERROR OF ESTIMATE
INTERCEPT	4.65441569	82.17	0.0001	0.05664266
MONTH	-0.10437017	-6.69	0.0068	0.01559038

Comparison of logarithmic calf survival rates between years.

SAS

13:45 TUESDAY, NOVEMBER 13, 1984 1

OBS	YEAR	MONTH	CALVES
1	1	1	0.0000
2	1	2	-0.6061
3	1	3	-0.7885
4	1	4	-1.2993
5	1	5	-1.7047
6	1	6	.
7	2	1	0.0000
8	2	2	-0.2451
9	2	3	-0.2451
10	2	4	-0.3629
11	2	5	.
12	2	6	-0.5705

CALF MORTALITY IN 1979 AND 1980  
 THE INDEPENDENT VARIABLE (X) IS MONTH  
 THE DEPENDENT VARIABLE (Y) IS CALVES  
 THE CELL OR CLASS VARIABLE IS YEAR  
 SUMS OF SQUARES TABLE

13:45 TUESDAY, NOVEMBER 13, 1984 2

TYPE	SSX	SSXY	SSY	MX	MY	N	A	B	DF	RES_SS	F	PROB
CELL 1	10.0	-4.1026	1.71379	3.0	-0.87972	5	0.351068	-0.41026	3	0.03062	.	.
CELL 2	14.8	-1.5447	0.17201	3.2	-0.28474	5	0.049245	-0.10437	3	0.01079	.	.
-----												
POOLED	24.8	-5.6473	1.88580	.	.	10	.	.	6	0.04141	.	.
COMMON	24.8	-5.6473	1.88580	3.1	-0.58223	10	0.123683	-0.22771	7	0.59982	.	.
TOTAL	24.9	-5.3498	2.77082	3.1	-0.58223	10	0.083811	-0.21485	8	1.62139	.	.
-----												
F-TESTS:	DF:											
SLOPES	1, 6	.	.	.	.	.	.	.	.	.	80.9044	0.0001
ELEVATIONS	1, 7	.	.	.	.	.	.	.	.	.	11.9219	0.0107

Linear regression of percent fall calves and arcsin transformed percent fall calves on spring snow depth.

SAS

20:28 THURSDAY, NOVEMBER 14, 1985 1

OBS	YEAR	DEASE	CASS	ISKUT	PERCA	ARCCA1	TRACA
1	1976	58	147	56	0.07	15.34	0.0349604
2	1977	63	132	53	0.05	12.92	0.0295452
3	1978	38	89	13	0.14	21.97	0.0494515
4	1979	74	142	70	0.09	17.46	0.0396436
5	1980	63	132	53	0.13	16.43	0.0476513
6	1981	55	123	49	0.07	15.34	0.0349604
7	1982	55	107	68	0.10	18.43	0.0417893
8	1983	.	95	.	0.16	23.58	0.0528690

SAS

20:28 THURSDAY, NOVEMBER 14, 1985 2

DEP VARIABLE: PERCA PERCENT CALVES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	0.005180262	0.005180262	5.856	0.0519
ERROR	6	0.005307238	0.0008845397		
C TOTAL	7	0.010487			
ROOT MSE		0.029741	R-SQUARE	0.4939	
DEP MEAN		0.101250	ADJ R-SQ	0.4096	
C.V.		29.37404			

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB >  T	VARIABLE LABEL
INTERCEP	1	0.253648	0.063846	3.973	0.0073	INTERCEPT
CASS	1	-0.00126079	0.0005209845	-2.420	0.0519	CASSIAR SNOW DEPTH

SAS

20:28 THURSDAY, NOVEMBER 14, 1985 3

DEP VARIABLE: ARCCA1 ARCSIN PERCENT CALVES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	58.714042	58.714042	11.633	0.0143
ERROR	6	30.282145	5.047024		
C TOTAL	7	88.996187			
ROOT MSE		2.246558	R-SQUARE	0.6597	
DEP MEAN		17.683750	ADJ R-SQ	0.6030	
C.V.		12.70408			

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB >  T	VARIABLE LABEL
INTERCEP	1	33.908336	4.822716	7.031	0.0004	INTERCEPT
CASS	1	-0.134226	0.039354	-3.411	0.0143	CASSIAR SNOW DEPTH

VITA

Surname: PAGE Given Names: RICHARD EDWARD  
Place of Birth: ST. CATHARINES, ONT. Date of Birth: 9 SEPTEMBER, 1953

Educational Institutions Attended, with Dates of Entering and Leaving:

UNIVERSITY OF GUELPH, GUELPH	1972 to 1976
UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER	1979 to 1980
UNIVERSITY OF VICTORIA, VICTORIA	1980 to 1985
MICHIGAN TECHNOLOGICAL UNIVERSITY, HOUGHTON	1981 to present

Degrees, Diploma, Etc., Awarded, with Dates and Names of Institutions:

B. Sc. (Honours) 1976 University of Guelph, Guelph

Honors and Awards:

Ontario Scholarship, 1972

Employment:

Resource Technician, Ontario Ministry of Natural Resources, 1976 to 1978

Research Assistant, University of Victoria, 1979 to 1981

Research Assistant, Fish and Wildlife Branch, Victoria, 1980

Consultant, The Spatsizi Association for Biological Research, Vancouver, 1980

Research Assistant, Michigan Technological University, Houghton, 1981 to 1982

Wildlife Habitat Analyst, Research Branch, Ministry of Forests, Victoria, 1982 to present

Publications:

Page, R. E. in press. Integration of moose population dynamics for management - a review and synthesis of modelling approaches in North America. *Viltrevy*.

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EARLY CARIBOU CALF MORTALITY  
IN NORTHWESTERN BRITISH COLUMBIA

Author

  
Richard Edward Page

28 February, 1986