WHY ARE CARIBOU ON PIC ISLAND?

by

Steven H. Ferguson

A thesis
presented to the University of Victoria
in partial fulfillment of the
requirements for the degree of
Master of Science
in
Biology

We accept this thesis as conforming
to the required standard

[redacted]

Dr. E.M. Hagmeier

[redacted]

Dr. P.T. Gregory

[redacted]

Dr. C.W. Tolman

[redacted]

Dr. M. Edgell

[redacted]

Dr. A.T. Bergerud

ABSTRACT

Supervisor: Dr. E.M. Hagmeier

The population dynamics of a small relic caribou herd on Pic Island, Ontario (10 km^2) was studied (1977-81) to determine the factors regulating numbers and limiting population growth. Four alternative hypotheses were tested to determine why caribou have survived on Pic Island and disappeared on the adjacent mainland: (1) food resources were inadequate on the mainland, (2) the mainland caribou contacted disease which Pic Island caribou did not, (3) the mainland caribou were more susceptible to predators than Pic Island caribou, (4) the mainland population dispersed, whereas the Pic population was undisturbed.

The population on Pic Island was estimated at 42 in 1977, 49 in 1978, 54 in 1979, 39 in 1980 and 28 in 1981. Calf production was consistent at 20.0 percent of the population in 1978, 23.3 percent in 1979, 24.2 percent in 1980, 22.0 percent in 1981. At least 78 percent of the females, two years and older, gave birth. The sex ratio was equal. Winter calf mortality was the mechanism of decreased recruitment and relative population stability. A die-off during the 1976-77 winter, caused by nutritional stress and

wolf predation, eliminated 47 percent of the fall population. Emigration was assumed to have occured off the island during the 1979-80 and 1980-81 winters.

Seasonal food preferences were determined and estimates of the availability of these plants were used to compare Pic Island against the adjacent mainland. The mainland was found to provide a greater abundance of preferred food plants. The bulk of the evidence, although mostly circumstantial and therefore not conclusive, suggests that predation has limited and eliminated the caribou which have resided on the adjacent mainland and it is the lack of predators and the presence of escape habitat that has allowed the caribou to survive on the island.

Examiners: [redacted]

Dr. E.M. Hagmeier

[redacted]

Dr. C.W. Tolman

[redacted]

Dr. P.T. Gregory

[redacted]

Dr. A.T. Bergerud

[redacted]

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure No. | Number | Page

ACKNOWLEDGEMENTS

"See that knoll up there with the good view? Why if I were a wolf that's where I'd shit." Barry Snider, Terrace Bay District Biologist. This thesis is dedicated to my good friend who taught me how to put myself in the place of the animal being studied and thereby think like one. Biology could never have been so exciting without 'reverse anthropo-morphizing'.

I want to acknowledge the great help my brother Rodger gave during the last two years of the island study. Other people who helped with the study efforts included the rest of my family, Bruce McLean, Jill Bangman, Ludvik Krysl, Bruce Swift, and the staff of Neys Provincial Park over the four years.

Tom Bergerud's involvement in this study goes beyond the monetary and logistic support he contributed. In the *science* of wildlife biology his ideas will continue to survive in many forms, including the publication of this thesis.

Chapter I

INTRODUCTION

Management of caribou (*Rangifer tarandus*) has historically relied upon assessment of carrying capacity through food habits and range productivity studies (Leopold and Darling 1953, Edwards 1954, Cringan 1957, Scotter 1964, Ahti and Hepburn 1962, Klein 1968, Miller 1974 and Kelsall and Klein 1979). This approach has been criticised by Bergerud (1974, 1978, 1980) and has proved to be an inadequate approach (Parker 1972, Haber *et al.* 1976, Davis 1977, Gross 1978, and Walters et al. 1978). A more productive approach has been to look at population composition, natality, recruitment rates and mortality rates as indicators of population relationships with the environment. These primary indicators or numerical responses (*sensu* Solomon 1949, Holling 1966) in effect summarize the manifestations of nutritional, behavioral, environmental and genetic forces acting upon a population.

The complexity of this ecological relationship impedes attempts to determine how environment affects population dynamics and thereby limits the usefulness of carrying capacity and range productivity studies in management. The basic tenet of many caribou biologists is that food limits caribou populations. Bergerud (1974) argued that predation is a more important limiting factor than food and described a test to discriminate between these opposing views. This study was initiated in response to these conflicting hypotheses.

Romesburg (1981) suggests the use of the hypothetico-deductive method (Popper 1962, Harvey 1969, Platt 1964) as a means for testing research hypotheses in wildlife research. This method starts with a research hypothesis (a theory that is intended for experimental test), usually obtained by retroduction, from which predictions are made that should be true if the research hypothesis is actually true. To the extent that experiment confirms or rejects the predicted facts, the hypothesis is confirmed or rejected. Alternative test consequences or a null hypothesis are needed to test a research hypothesis.

Bergerud (1974) hypothesized that the decline of caribou in North America started with settlement which increased hunting and in some areas more natural predation losses and possibly also increased disease. This increased mortality was sufficient to start a decline because of the close balance between reproduction and natural mortality in undisturbed populations. Bergerud also suggested a test of his hypothesis by predicting that relic caribou populations living in habitats where deer (Odocoileus virginianus), moose (Alces alces), and wolf (Canis lupis) populations exist should have some escape habitat advantage from wolves which adjacent populations that disappeared did not (ie., calving on islands).

Pic Island lent itself to this experimental situation which allowed the testing of Bergerud's hypothesis. The island has supported a population of about 50 ± 30 caribou (Rangifer tarandus caribou, Banfield) for at least the last 30 years. On the adjacent mainland (Coldwell Peninsula) caribou have been occassionally seen during the past 30 years but none were observed on the peninsula for three years prior to my vegetation study in 1980. The peninsula has supported a small resident moose and deer population since about 1960.

Platt (1964) suggested the use of multiple hypotheses to remove the bias of possessiveness. Four alternative hypotheses were postulated which could explain the survival of caribou on Pic Island in comparison to their decline on the adjoining mainland:

Hypothesis 1: Resource limitation (food)

The population on the mainland declined because of a shortage of food resulting from habitat changes. Such habitat fluctuations could have resulted from climatic changes (Benson and Dodds 1977) or man's alteration of the habitat (Cringan 1957). In contrast, Pic Island has maintained an abundance of nutritious foods thereby permitting continued survival.

Hypothesis 2: Mortality through disease.

The population on the mainland declined because white-tailed deer transmitted disease (meningeal worm, Parelaphostrongylus tenuis) to caribou (Anderson 1972). Caribou on Pic Island survived because the island provided refuge from deer.

Hypothesis 3: Increased predation.

The caribou declined on the mainland because of density- dependent mortality resultant from increased predation. Moose and deer populations increased during the past century thereby supporting a higher wolf population which also preyed on caribou. The caribou on Pic Island have avoided excessive predation because of the islands biogeography (water barrier and rugged topography).

Hypothesis 4: Dispersal

The caribou on the mainland disappeared due to dispersal. The caribou on the island are isolated from the mainland preventing its recolonization.

1.1 Study Areas:

Pic Island (1038 ha) is located in Lake Superior (48°40' longitude, 86°35' latitude), 1-2 km offshore from the Coldwell Peninsula (3260 ha, Neys Provincial Park) in northern Ontario (Fig. 1). A second study area was Otter Island (212 ha) located 0.5 km from the north shore of Lake

Superior (Fig. 2). It is part of Pukaskwa National Park. Otter Island, like Pic Island, has supported caribou during all seasons of the year since observations started with Park development in the 1970's.

The three study areas Pic Island, Coldwell Peninsula and Otter Island are situated within the Superior Climate Region classified as moderate continental (Chapman and Thomas 1968). Proximity to the lake results in cooler summers, milder winters, and generally a higher incidence of wind and moisture than are characteristic of the inland areas. Topography (Fig. 3) is characteristic of the Precambrian rock formations with Pic Island being particularly rugged, displaying a 230 m relief.

Coldwell Peninsula, Otter Island and Pic Island are located in the southern extremity of the Boreal Forest's Superior Section as described by Rowe (1972). The forests of this area are typified by the prominence of black spruce (*Picea mariana*) with white spruce (*Picea glauca*) and tamarack (*Larix laricina*) forming the forests on wetter sites and jack pine (*Pinus banksiana*) usually present on dry sites. Inextricably woven into the patterns are the effects of fire, which favor black spruce, paper birch (*Betula papyrifera*), poplar (*Populus tremuloides*), and jack pine over balsam fir (*Abies balsamia*).

Figure 1. Location of Pic Island.

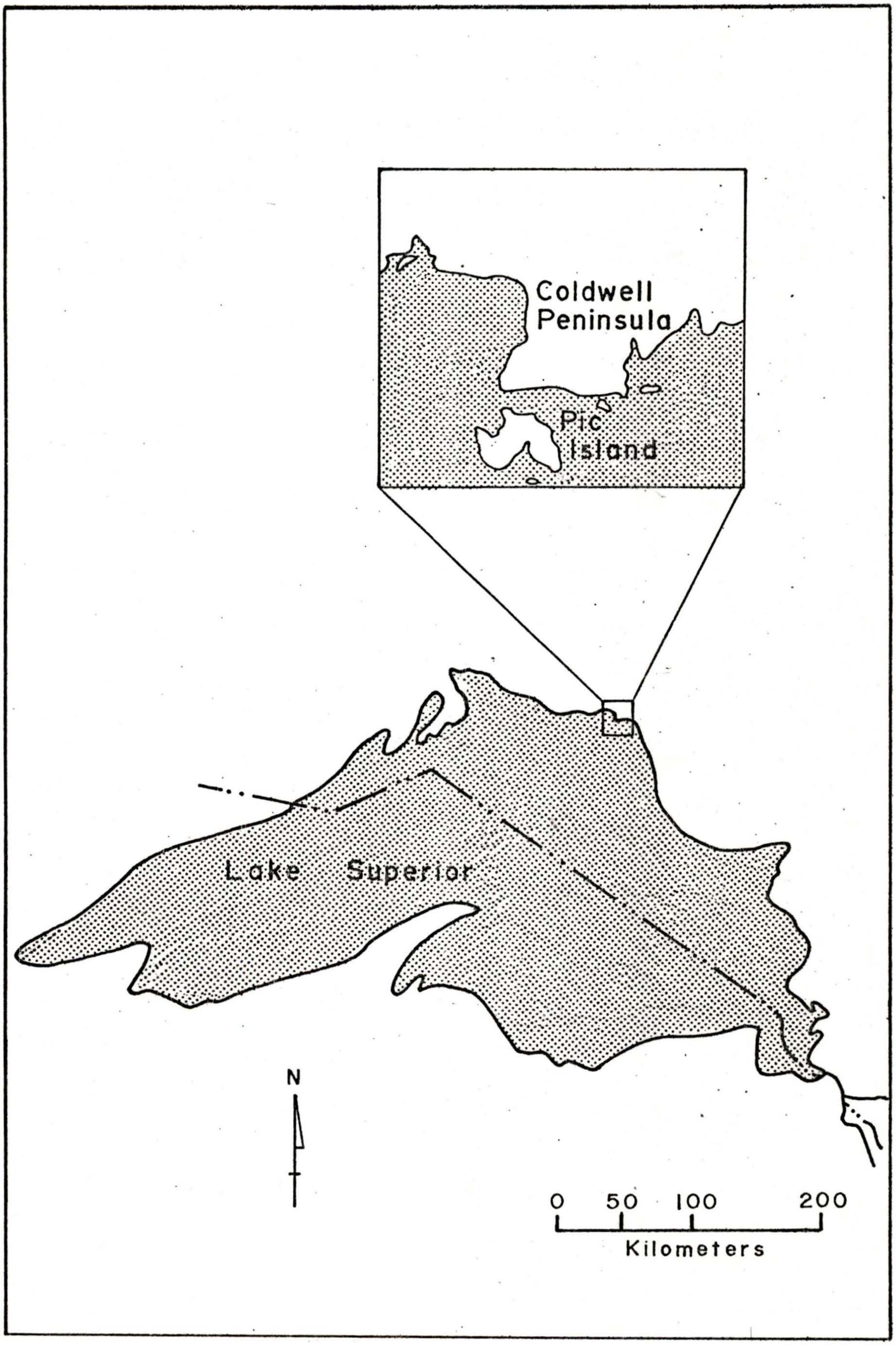

Coldwell
Peninsula
Pic
Island
Lake Superior
N
0 50 100 200
Kilometers

Figure 2. Otter Island (15 m contours).

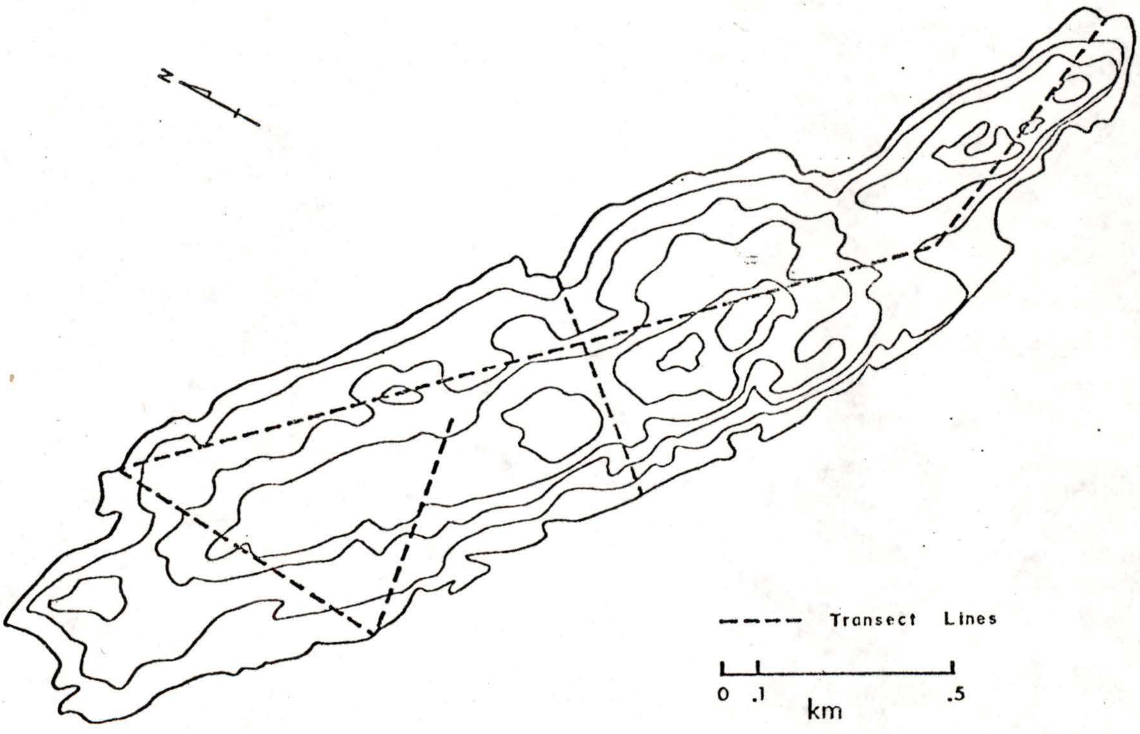
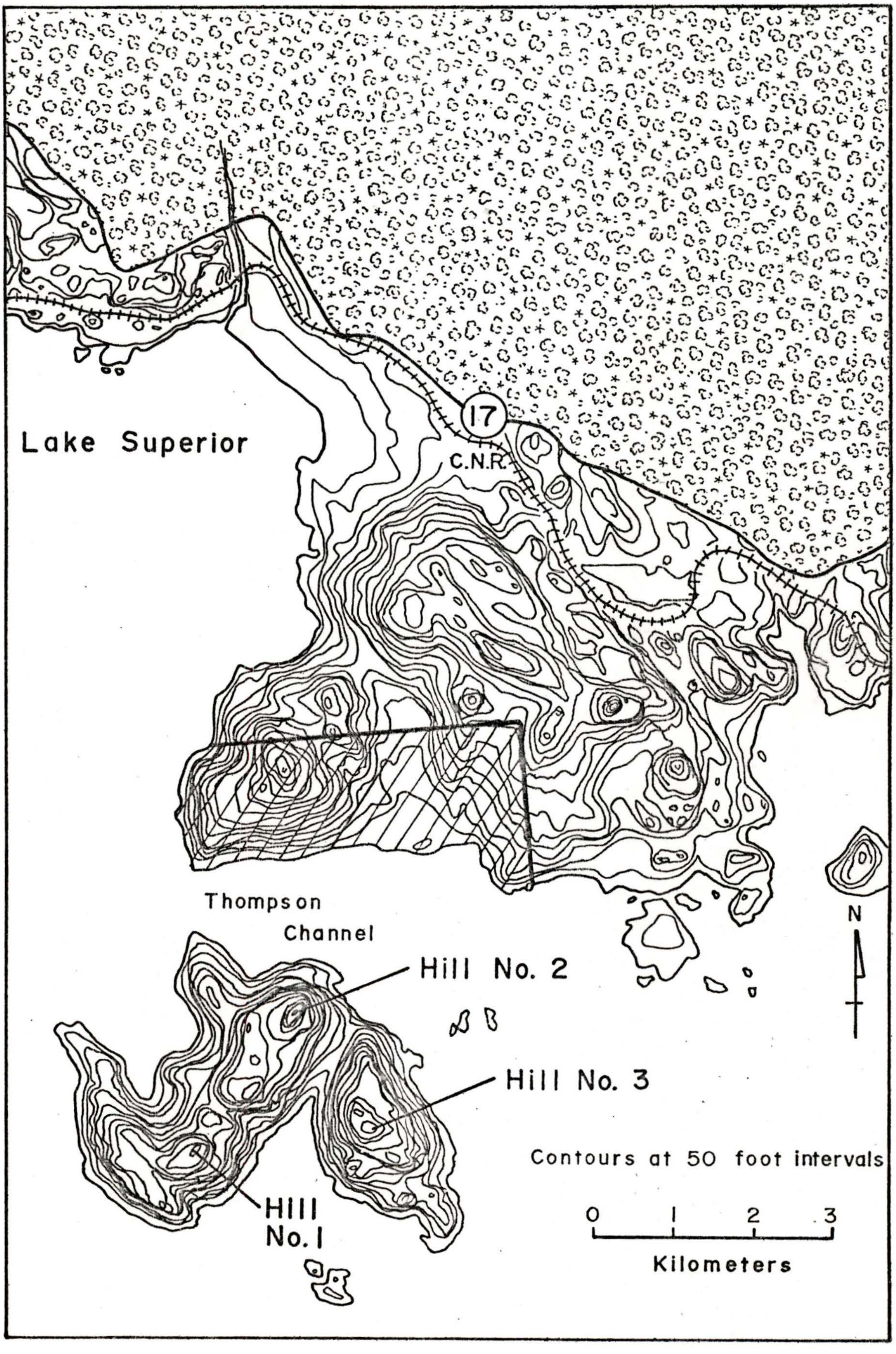

N
Transect Lines
0
.1
.5
km

Figure 3. Topography of the Neys area. Hatched area denotes that portion of Coldwell Peninsula used in the vegetation comparison. Elevation at lake level is 183 meters.


Lake Superior
17
C.N.R.
Thompson
Channel
Hill No. 2
Hill No. 3
Hill
No. 1
N
Contours at 50 foot intervals
0 1 2 3
Kilometers

2.0 METHODS

2.1 DEMOGRAPHIC CENSUSING:

Measurements of composition, natality, recruitment rates and mortality are considered better indicators of population quality than a total population count (Gross 1978, Caughley 1978). Methods of total count censusing were employed in this study because they allowed indirect measures of calf production and survival and estimates of mortality. The census methods chosen proved, in retrospect, to be sensitive enough to describe dramatic changes in the population over time, a more important characteristic than their accuracy or precision (Caughley and Goddard 1972). To test the reliability of census results, Caughley (1978) suggested using more than two independent methods of estimating relative abundance. The three estimates chosen for this study are line transect censusing, pellet census and a Petersen Index on marked animals. These three estimates described similar changes in population size and are considered to give a reasonable account of demographic changes on the island over the four years.

2.11 Line transect censusing:

In the line transect method, observers walked census lines of distance l_i (i = 1, 2, ...m) across the island (total distance for census period; $L = \sum_{i=0}^{m} l_i$) counting n, the number of animals sighted, and recording at the times of first flushing: a) radial distance r from observer to animal, b) right-angle distance y from the caribou flushed to the path of the observer, and c) angles of sighting θ from the observer's path to the point at which the animal was initially observed. The relationship among the three measurements is $y = r \sin(\theta)$. This technique is useful when the animals once disturbed respond with a noticeable flush (Seber 1973) as observed for caribou.

The basic idea underlying such a general model is that the probability of detecting an animal decreases as its distance from the line increases. Any estimator of the density (D) of animals is expressed as:

$$D = \frac{n}{2Lw} \qquad (1.1)$$

or

$$D = \frac{nf(0)}{2L} \qquad (1.2)$$

where w is usually referred to as half the estimated width of the strip and f(x) is the unknown probability density function (pdf) of perpendicular distances. For statistical reasons, it is advantageous to estimate $f(0) = (1/w)$ rather than w directly (Burnham <u>et</u> <u>al</u>. 1980). The initial assumption is that animals on the line are detected with certainty f(0) = 1, where f(x) defines the detection probability of the points as a function of their distance from the line (pdf). The most useful general equation is (1.2).

The basic assumptions underlying the various line transect models are:

1. Animals directly on the line will never be missed.
2. Animals do not move before being detected and none are counted twice on the same line.
3. Distances and angles are measured exactly.
4. Sightings are independent events.

Anderson *et al.* (1976) considered it essential that straight lines be used, and that the observer is able to detect all animals on the centre of the line and be able to determine the centre line of the transect accurately once an animal is flushed. They also suggest the analysis rest on a sample of animals that is reasonably large (n > 25) and that only interested, competent and trained personnel should be employed to conduct transect surveys.

For the 1980 and 1981 censusing, 10 straight transect lines were selected which covered all habitat types and from these, lines were chosen randomly. Although it has been stated that randomness is necessary (Gates *et al.* 1968, Seber 1973), that assumption is unnecessary if the line itself is randomly located (Eberhardt 1978). Previous to 1980, lines were not straight and were selected without random sampling. Censusing occurred before and after calving

(June 1st) during the 1978-1981 spring and summer work and also during September 1980. Caribou observations were used to calculate density and also allowed for estimation of other population parameters (productivity, age, sex and antler ratios, and calf survival). Dead caribou and parts, antlers, grouse (Bonasa umbellus), hares (Lepus americanus), bush-thrashed trees and caribou beds were also censused. Flushing behavior, escape strategies, cow-calf behavior, feeding and habitat use, moult and antler growth were described for each caribou observation.

All caribou observations were recorded detailing a description of the caribou, its behavior and the habitat used (Appendix 5.1: caribou observation card). Sex of caribou was determined by the presence or absence of a vulva patch (Bergerud 1961). In order to estimate productivity, it was necessary to determine which of the caribou observed after June 1st were calves and which were females with a calf (or a female which had a calf elsewhere). Caribou which were not initially visible were tested by observing their reaction to an imitated calf call if the animal was considered to be a female, and a cow grunt if the animal was considered to be a calf. Reproductive females approached calf calls while calves reacted by approaching imitated cow grunts. On closer inspection reproductive females which did not have their calves present could be distinguished by the presence of an udder (Bergerud 1964).

Burnham *et al*. (1980) recommended that density estimation be based on perpendicular (y) rather than sighting angles and sighting distances. The Fourier series (FS) method (Crain *et al*. 1978) which allows valid inferences to be based solely on perpendicular distances was chosen for this study because it is a nonparametric procedure that is model robust, pooling robust, meets the shape criterion f(0) = 0; it is easy to compute and its estimation efficiency for small samples is quite good (Burnham *et al*. 1980). The FS estimate seems to perform well, often even with samples as small as 30-40 and it does not require any assumptions about the nature of the detection process.

2.12 Pellet census:

This procedure was used as a method of estimating actual numbers of caribou by fecal pellet-group counts. It provided an objective measure of substantial population fluctuations and delineated preferred winter habitat types. A pellet census was carried out on the island every May for three years (1979-81). The count each spring used the same four continuous plot transect lines which started and ended on opposite shores of Lake Superior and described a cross section of the islands heterogeneous habitat. Since many small sampling units are more efficient than fewer larger units, and long narrow plots are superior to shorter wider plots of the same area (Robinette *et al*. 1958), 30 by 2 meter continuous plots (approximately 290 plots) were counted each spring. A preliminary pellet survey in late June, 1978, consisted of three lines totalling 2.6 km which were not divided into individual plots.

The time of leaf fall determined the start of the period of winter pellets and was determined by the first -5°C ambient temperature recorded in the fall from the Marathon weather station. Thirty or more pellets within the plot were considered to constitute a pellet group, approximately one half of the observed average pellet group size (66.1 ± 6.55 (s.e.), n = 16). For each plot the habitat was described (Appendix 5.1). Age of pellet groups were determined subjectively using leaf litter, texture, shape, color, mold, dryness and other characteristics.

Using Neff's (1968) review of the pellet-group count techniques and suggestions by Smith (1964:442) and Rogers *et al.* (1958), I assumed that caribou defecate 13 groups per day. This conversion factor agreed with averages for moose, black-tailed deer (*Odocoileus hemionus columbianus*), mule deer (*O. hemionus*), elk (*Cervus canadensis*), domestic sheep, Barbary sheep (*Ammotragus lervia*), and cattle listed in Neff's (1968) review.

The estimated number of caribou and standard deviation was calculated using the following formulas:

$$N = \frac{Ai \times d \times w}{Ap \times n} \qquad (2.1)$$

$$S.D. = \sqrt{\frac{\Sigma n^2 - (\Sigma n)^2 / n}{n - 1}} \qquad (2.2)$$

where Ai = area of island (1038 ha)
Ap = area of plot (60 m^2)
d = defecation rate (13.0 pellet groups/day)
n = number of plots
w = number of defecation days

2.13 Petersen Index:

The "Petersen's estimate" (Caughley 1978, Overton 1969) is applicable to this study, assuming the probability of re-sighting marked and unmarked caribou is equal; no immigration occurred; marked and unmarked caribou emigrate or die at the same rate; and no marks are lost. The intuitively reasonable relationship is then:

$$N = \frac{M\,n}{m} \qquad (3.1)$$

where M animals are marked in a population of size N (N being unknown) and m marked animals are resighted in subsequent sampling of n animals. Because equation 3.1 results in a positively biased estimate, Bailey (1951, 1952) suggested that when the number of marked individuals to be re-sighted is not decided prior to resighting a more satisfactory estimate is:

$$N = \frac{M(n + 1)}{m + 1} \qquad (3.2)$$

with standard error of approximately:

$$S.E. = \sqrt{\frac{M^2\,(n + 1)\,(n - m)}{(m + 1)^2 (m + 2)}} \qquad (3.3)$$

From the six marked caribou which included five with transmitters on the island in 1980, a Petersen's estimate was calculated from spring and fall observations. Two more marked caribou were added in 1981 and a Petersen's estimate was calculated from summer observations.

These small sample sizes created two problems. First, different sex and age classes were considered to be equally observable when they should be stratified (Downing *et al*. 1977). Second, Strandgaard (1972, cited by Downing *et al*. 1977) after detailed analysis of the effect of behavior, habitat and stratification on Lincoln Index estimates, concluded that acceptable precise estimates of roe deer (*Capreolus capreolus*) populations required that two-thirds of the total population be marked.

2.14 Dead caribou:

For estimating inanimate objects which do not flush such as dead caribou, caribou beds, antlers or bush-thrashed trees, it is advisable to use the right-angle distances from line transects since such methods are relatively insensitive to the actual form of the frequency distribution (Robinette *et al*. 1958). Eberhardt (1968) gave theoretical reasons why the model:

$$D = \frac{n}{2Ly} \qquad (4.1)$$

would be appropriate when detection depends on visibility rather than on the behavior of animals and Caughley (1978) suggested it may be a good estimate for mortality surveys. From test estimates of inanimate objects on Pic Island, this model was considered positively biased and tended to overestimate. A strip census model (Eberhardt 1978) was chosen instead:

$$D = \frac{n*}{2Lb} \qquad (4.2)$$

where b is the strip half width chosen, L is the total length of all individual lines, and n* is the number of observed objects within the strip. A strip width of 6.6 m (b=3.3m) was used which assumed that all dead caribou within the area were detected.

2.2 EFFECTS OF NUTRITION:

To determine the effects of poor nutrition on the high density caribou population, morphological measurements were taken from captured caribou and cast antlers were collected and measured. Also blood samples were extracted for conditional analysis. I determined length of growing season for each year. This provides a measure of winter negative energy balance and the corresponding length of summer food availability.

2.21 Measurement of growth:

Each captured caribou was weighed to the nearest pound by suspending it from a spring scale with a capacity of 400 lbs. Weights were later converted to kilograms. Caribou weights not actually weighed were regressed from a relationship with heart girth. A series of external body measurements was taken with a flexible tape as the caribou lay on its side with the four legs tied together. Body measurements were made to the nearest 5 mm. Total length was measured along the dorso-medial line from the tip of the nose to the last tail vertebra following the animals contours. Heart (chest) girth was measured around the animal immediatedly posterior to the fore limb and the posterior edge of the scapula. Shoulder height was measured along the radial surface of the right foreleg and flank from the base of the radial dew hoof to the dorsal edge of the scapula.

2.22 Growing season:

Stewart et al. (1976) calculated growing season as the length (days) of the green period (between leaf flush and leaf abscission) each year. Meteorological records from the Marathon meteorological station were used to determine the dates for initiation of leaf growth and termination of the green period. Larcher (1973) considered -5°C the temperature required to cause cellular destruction (lysis in woody leaves). The concept of growing degree day postulates that a base or threshold temperature exists below which plants will not develop. Stewart et al. (1976) used maximum daily temperature (h) greater than 12.2°C to calculate a mean level of 75 degree days ($\sum (h-12.2)/2 = 32.8$) which they suggest as the level of heat units initiating leaf flush and resulting in a positive energy balance in moose. The termination date of positive energy balance was chosen to be that date when ambient temperatures of -5°C were reached. The number of days from the initial spring accumulation of 75 heat units to the first fall minimum temperatures of -5°C was accepted as the period of positive energy balance (growing season) for caribou.

2.3 TELEMETRY:

Caribou were radio tagged in the spring of 1981 primarily to test between the predation and disease hypotheses. Three radio tagged caribou were released on the mainland to see if they would contact disease or be predated. Seven radio-collared caribou were monitered on the island to determine behavioral strategies during calving, fall breeding and while escaping predators (flush from observer and/or dog). Telemetry also described activity and movement patterns both temporally (daily and seasonally) and spatially (home range sizes), and changes in these patterns due to differences among caribou (age, sex and reproductive status).

All movements and locations were marked on a 1:25,000 topographic map with a grid of 0.11 km^2 overlying the island. This relatively large grid size, relative to the study area, was used because of errors in telemetry readings due to observational inaccuracies, caribou movement, the heterogeneous and rugged topography, and its conifer cover.

Points were located on the map by triangulation using usually two or more bearings (directions). Aggregate and seasonal ranges were determined by plotting all observations acquired on each marked individual during the study and connecting the outermost observation points with boundary lines. This minimum area method (Dalke 1942, Mohr 1947), calculated using a planimeter, determined the area of each range.

2.31 Capture:

Caribou were captured in 4X6 m log traps, baited with ground lichen and block salt. A trip thread released a plywood door barricading the entrance. Standard samples (blood for condition analyses was undertaken by P. Karns at the Forest Research center, Grand Rapids, Minnesota; an incisor was pulled for aging; feces were examined for parasites by M.W. Lankester at the Lakehead University), and measurements of general morphology and weight were taken. Two caribou were captured in 1979, nine in 1980 and five in 1981 on the island. During the springs of 1980 and 1981 nine of these caribou were collared with radio transmitters designed by Cedar Creek, Bethel, Minnesota, and released.

2.32 Equipment:

Three towers were built on the three tallest hills on the island (Fig. 3) so as to describe caribou positions by triangulation. Two of the towers were constructed of two 3.5 m TV tower sections which supported two parallel four element yagi antennae secured to a center pole; the center pole swivelled at the base around a rosette. Three and four element yagi antennae were used for ground work. Two AVM LA-12 receivers were used interchangeably to monitor the 151 mhz signals. Two Rustrak strip chart recorders monitored caribou activity from the hill tops.

2.33 Field methods:

Caribou observations by telemetry were based on three techniques : actual location of animals from the ground; triangulation using two simultaneous tower readings; triangulation using a number of readings from ground and/or boat and/or tower. Escape behavior was initiated using a dog collared with a transmitter and released on the scent of a collared caribou allowing both animals to be tracked. Caribou were tracked using a hand-held antennae so as to observe their flushing behavior. Three times during 1980 (May 18-19, June 30-July 1, July 14-15) continuous readings were taken on caribou movement and activity every 15 minutes, for an average of 24 hours, from two hill (#1 and #2) towers, by two observers simultaneously.

2.4 Hypothesis 1: Food

To test whether caribou were on the island and not the adjacent mainland due to forage conditions, seasonal food preferences were determined and estimates of the availability of these plants for Pic Island versus Coldwell Peninsula were used to compare the two habitats.

2.41 Seasonal food preferences:

Food preference was measured in eight 33 X 1 m browse plots. These plots were selected on the island for their accessibility and for the occurrence of species shown to be preferred by caribou (Ferguson and Ferguson 1981). A unit of measurement, usually a leaf, for each plant (up to 35 species) was chosen to represent one bite. The number of bites available and the number eaten were counted within the different lines towards the end of each month (April to November 1981). Five hundred bites of each species were picked each month (or until no changes in weight of bites occurred) and oven dried at 110°C for 12 hours, to determine average dried weights (biomass) and track the changes in weight over the growing season.

Palatability of food species was calculated from estimates of availability and utilization:

Palatability = relative utilization/relative availability
relative availability = amount available for species (dry wt. in g) X 100 / total amount for all species
relative utilization = amount eaten for species X 100/ total amount eaten for all species

2.42 Estimating availability:

Forage availability was measured (July 2 - Aug. 12, 1980) in 219 plots on Pic Island and 238 plots placed in a 788 ha. section of the adjacent mainland (Fig. 2). Three types of plant classification were delineated: forbs, shrubs and lichens.

Statistical analysis included the t-test for two-group comparisons (Pic Island versus mainland) and the analysis of variance for multiple group comparisons (mainland, Pic and Otter Island). Significant differences between groups were identified by the use of Duncans Multiple Comparison test. Dependent variables were the basal area for individual plant species, distance, dbh (diameter at breast height), number of stems, bites eaten and bites available for mountain ash, maple, willow, alder, pin cherry, serviceberry, squashberry, dogwood, poplar, larch and elderberry, percent overstory for individual species, percent understory for individual species, percent cover of species in 4 m^2 plots, number of bites eaten and available for forb species (up to 100 forb species), ground lichen volume, slope, blowdown index, visibility index, aspect, and amount of arboreal lichen (tree species, distance, and number of bites). The minimum level of significance accepted was $P < 0.05$. Data in the text, tables and figures are given as means ± standard error of the mean unless otherwise stated. Common names of plants are used in the text while scientific and common names are listed in Tables 7 and 8.

Food preference was expressed by using Ivlev's (1961) Electivity Coefficient, $E=(r - p)/(r + p)$, where E equals the coefficient of electivity or preferece index, r equals the proportion of the variable which was utilized and p equals the proportion of the variable occuring within the environment or study area. Preference values indicate only the relative value of a plant species in comparison to others (ie. ranking). Absolute statements about preference and avoidance were avoided since these conclusions depend markedly upon the array of components deemed by the investigator to by available to the animal (Johnson 1980).

2.421 Shrubs:

Two people walked transect lines, following a compass bearing. Sampling was completed at regular intervals of 100 m (50 m on Pic Island) along each transect. At each regular interval a stake was placed on the ground to denote the quarter point and describe the boundaries of the 4 m^2 plot. The distance to the closest tree, sapling or shrub (referred to as shrubs) of each species considered to be potential caribou food (diameter at breast (dbh) greater than 0.5 cm or taller than 1 m) was measured and recorded. The dbh of each shoot considered to arise from a common root system was also recorded. The number of bites (usually a leaf or compound leaf was considered a bite and was determined by caribou feeding observations) left and eaten on the shoots of the shrub and on its branches were recorded separately (exceptions: for alder only recent leaf growth low to the ground; for dogwood only the number of stalks; and for larch only the height of the tree was recorded).

Distance for trees and saplings is to the center of the trunk and with shrubs, to the center in the clump. For shrubs and trees less than 5 cm dbh the dbh was measured 10 cm from the ground. Any species occurring greater than 50 m from the stake were excluded.

2.422 Forbs:

A 4 m^2 plot was marked out in each upper right hand quarter from the stake which was placed along the direction of the transect line. A bite, an arbitrary unit of measurement, represented the observed unit of plant, usually a leaf which the caribou removed with each bite. The number of bites left and remaining were recorded for forb species which were judged to be preferred from general observations. For other plant species in the 4 m^2 plots which were considered potential caribou food, the percent cover was recorded.

Dry weights were obtained by oven drying 500 bites of each species at 110°C for 12 hours or more. For each plot the habitat was evaluated subjectively within a 30 m radius area (Appendix 5.1). Three layers were described: overstory, understory and ground cover.

2.423 Lichens:

A visual estimation method (after Stevenson 1979) was used to determine subjectively the amount of arboreal lichen available to caribou. A small bag of lichen (2 grams dry weight) was carried in the field and used to estimate by visual comparison the number of such units on the tree below a 2 m height. The distance to the nearest trees and the species type were recorded for each plot. A minimum amount of lichen (1/2 unit) on a tree was necessary to include the tree's estimate. Unit weights of lichen which approximated visually the original 2 g bags were picked during the course of the lichen study. Later these units were dried and weighed and the average weight of all the units (2.113 ± 0.235, n = 22) was used in the biomass calculations.

2.5 Hypothesis 2: Disease

Deer, caribou and moose on the north shore of Lake Superior harbour protostrongylid nematode worms, as evidenced from spined larvae in their faeces (Lankester _et al_. 1976). Deer populations on the Rossport Islands have a high prevelance of meningeal worm (Lankester pers. commun.) in their faeces and it is expected that most deer populations in the area host this nematode.

All deer and caribou pellet groups found on the mainland and deer pellets on Pic Island were collected. Dr. M.W. Lankester (Lakehead University) examined the samples by the Baermann technique, to distinguish the presence of first-stage protostrongylid larvae (spined larvae) in faeces. The location and movements of the deer in the area were monitored and survival and behavior of moose living in close proximity to the deer population was watched.

2.6 Hypothesis 3: Predation

Movements of two wolf packs (Pic River and Mink Creek) in the area were monitored by observing tracks.

Twenty-six wolf scats from the Neys area, collected in 1978, were examined to determine composition. The hair impression technique employed was similar to that described by Williamson (1951). The hair was placed on a gelva-coated microscope slide and pressure was applied to a second slide placed over the first. The negative impression of the cuticular surface of a hair on the lower imprinted slide was then removed from the press and placed under a microscope for inspection and determined to species using Adorjan and Kolenosky's (1969) manual.

Three caribou were translocated to the mainland and their survival monitored by telemetry.

2.7 Hypothesis 4: Dispersal

To test whether the island caribou crossed Thompson Channel to the mainland during the spring and summer months, the Coldwell Peninsula beaches were checked intermittently for caribou tracks. Also sand was spread in suitable positions and thread strung across Moss Point (closest swimming distance = 0.4 km), to detect movement to and from the island. Tracks in the sand helped determine direction and species. A salt lick was set up on the Coldwell Peninsula in 1978 to attract cervids. This lick, as well as the beaches along the Peninsula were checked at least monthly to identify cervid tracks.

3.0 RESULTS

3.1 DEMOGRAPHY (1976-81):

The estimated population on Pic Island for 1978 was 49 caribou, 54 caribou in 1979, 39 in 1980 and 28 in 1981. The three census estimates (line-transect, pellet censusing, Petersen Index (n=44 1980, n=33 1981)) were in close agreement (Table 1, Table 2, Fig. 4). The decrease in population for 1980 and 1981 was likely due to emigration off Pic Island.

The average parturition rate over five years (1977-81) was 78.4 percent. The percentage of females (2 years and older) that gave birth to a calf was calculated from the estimated number of calves, yearlings and adults in the population, assuming an equal adult sex ratio (Fig. 5):

Percentage parous females = number of calves born/
number of adult caribou (2 years and older)/2

For years for which no census estimates of calves and yearlings were obtained, 22.0 percent calf production and 100 percent calf survival was assumed.

Productivity (defined as the addition of calves to the summer population) averaged 21.9 percent and was consistent over the four years sampled (Table 3). Low calf survival or recruitment (defined as the addition of 1-year-old individuals to the population) was detected only in 1978 (Table 3). I found six dead calves which represented calf mortality during the winter period (1977-81). Four died in the winter of 1978, one in 1979 and one in the winter of 1980. I found no dead calves after the winters of 1977 or 1981. The extensive winter mortality in 1977 was verified by a low percentage of yearlings the next spring (Table 3).

Sex ratio of adults on Pic Island appear to be about equal in all four years (Table 3). However there was a tendency for males to be captured in traps. Seven adult males, three adult females and five male calves were caught.

Table 1. Line-transect censusing information.

year	number lines	mean length km	total length km	number caribou seen	estimated number caribou
1978	35	4.30	150.7	30	53.7 ± 13.8
1979	47	4.18	197.0	38	53.2 ± 17.8
1980 summer	41	3.45	141.5	24	41.5 ± 20.7
1980 fall	28	4.77	133.6	17	
1981	61	5.01	305.8	37	31.1 ± 1.6

Table 2. Pellet census 1978-81.

	number of plots (2X30m)	pellet groups per plot X ± s.e.	mid-day census	leaf fall (-5°c)	total days	estimated number caribou
1978	72	0.514	June 27	Oct. 16	254	39.7
1979	290	0.483 ± 0.063	May 29	Oct. 15	226	46.3 ± 6.63
1980	279	0.545 ± 0.052	May 13	Oct. 9	215	54.9 ± 5.51
1981	185	0.341 ± 0.044	May 4	Oct. 20	196	37.6 ± 4.59

Table 3. Demographic data for Pic Island caribou population from line-transect observations (1978-81, Table 1).

year	number males seen	number females seen	calf recruitment		percent yearlings	
1978	7	7	20.0	(15)[1]	8.7	(25)[2]
1979	12	11	23.3	(30)	17.4	(27)
1980	14	14	24.2	(66)	20.0	(48)
1981	8	7	22.0	(15)	15.6	(32)
total	41	39	21.9	(126)		

[1] sample size of caribou which could be determined as:
a) female with calf
b) female without calf (non-parous)
c) female without calf but parous (calf elsewhere)
d) calf alone
e) none of the above

[2] sample size of caribou observations which could be determined as:
a) calves
b) yearlings
c) adult

Figure 4. Absolute number estimates of the caribou population on Pic Island (X ± s.e.).

* estimated from dead caribou censusing (1978-81).

** 1978 line transect census estimate before calving, assuming no emigration, immigration or mortality.

\+ estimated eight caribou died during the previous winter

ǂ emigration from the island during the previous winter.

++ emigration during the previous winter.

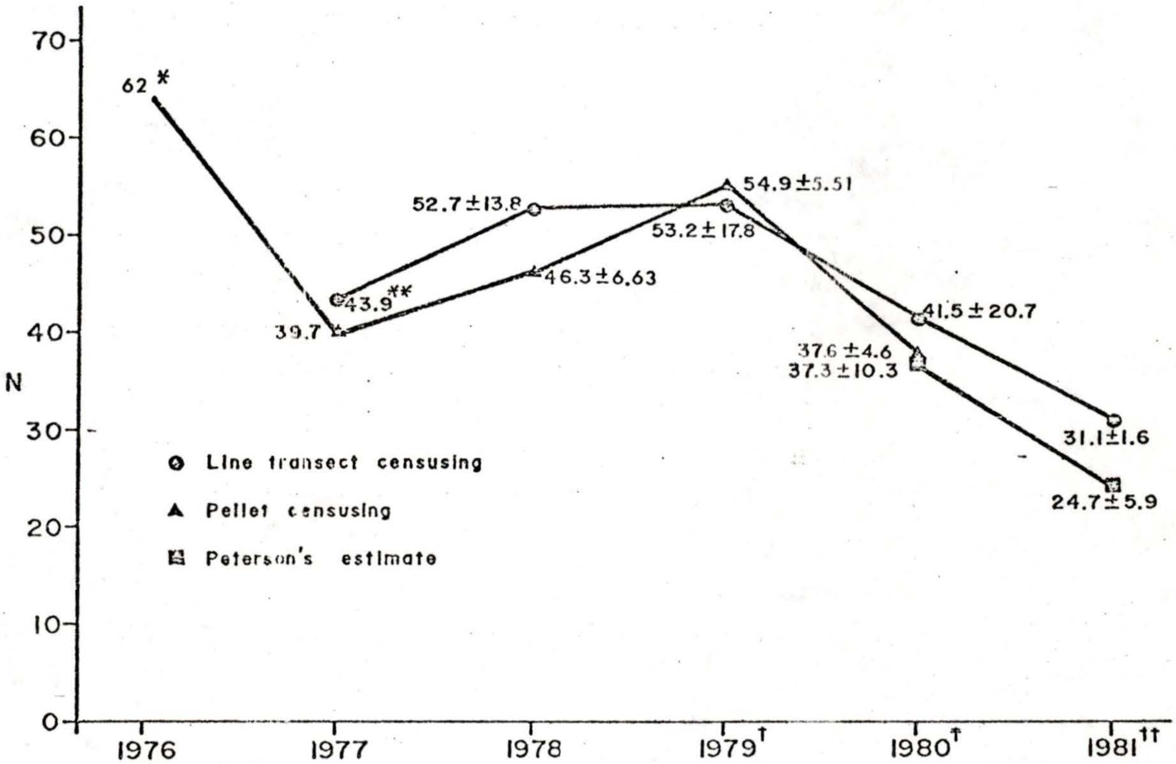
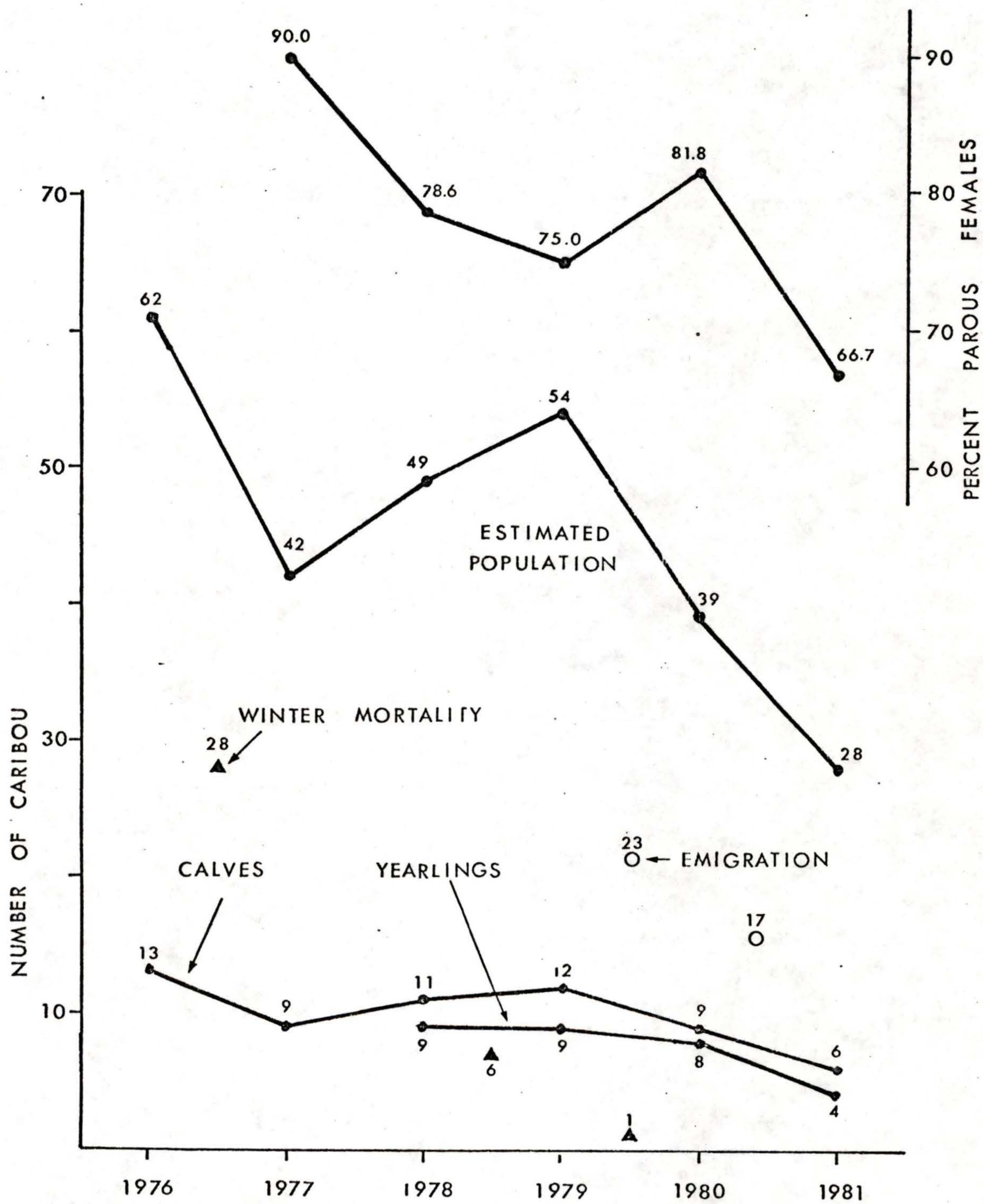

70
60
50
40
30
20
10
0
N
62 *
52.7 ± 13.8
54.9 ± 5.51
53.2 ± 17.8
43.9**
46.3 ± 6.63
39.7
41.5 ± 20.7
37.6 ± 4.6
37.3 ± 10.3
31.1 ± 1.6
24.7 ± 5.9
Line transect censusing
Pellet censusing
Peterson's estimate
1976
1977
1978
1979†
1980†
1981††

Figure 5. Demography of Pic Island caribou population (1976-81).


90.0
78.6
75.0
81.8
66.7
90
80
70
60
PERCENT PAROUS FEMALES
70
50
30
10
NUMBER OF CARIBOU
62
42
49
54
39
28
ESTIMATED POPULATION
WINTER MORTALITY
28
23
EMIGRATION
17
CALVES
YEARLINGS
13
9
11
12
9
6
9
9
8
4
6
1
1976
1977
1978
1979
1980
1981

Caribou remains located while censusing were identified to have died during the 1976-77 (n=9), 1978-79 (n=2), and 1979-80 (n=1) winters. Not all of the caribou remains were found because of scavenging and scattering by foxes, ravens, and wolves, as well as deterioration with age. During 470 km of transect lines walked over 1978-80, nine dead caribou were found at an average perpendicular distance of 2.25 ± 0.89 m (n=12, nine of 12 parts were distinguished as being from different animals). I chose a strip width of 3.0 m which included eight of the nine sightings. Substituting into Eq. 3.2, an estimated 29 caribou died during the 1976-77 winter. If there were 42 caribou on the island during the summer of 1977 (Fig. 4) which included nine calves (42 X 0.219 calf production) then before the winter die-off, an estimated 62 caribou (including 13 calves) were on Pic Island in 1976. Therefore the loss of 29 caribou represents a substantial die-off, accounting for 47 percent of the fall population.

To estimate the number of caribou that died during the 1978-79 winter, the ratio of number found to estimated dead for the 1976-77 winter (9:29) was used. From this calculation six caribou were assumed to have died over the 1978-79 winter. In 1980, during extensive censusing (L=275.3 km), only a calf jaw was located and it was assumed that this was the only caribou to have died the previous winter.

Census estimates suggest 23 and 17 caribou emigrated off Pic Island during the two winters of 1979-80 and 1980-81. In 1979 there were 54 animals, one died over the 1979-80 winter; in 1980 there were 39 animals of which nine were calves. Therefore there are 23 animals unaccounted for (54 - 1 - 30 = 23). In 1980 there were 39 animals, none died over winter; in 1981 there were 22 yearlings and adults (6 calves). Therefore 17 animals are unaccounted for (39 - 0 - 22 = 17) and are assumed to have left the island by ice during the winter. For the first time in five years caribou were observed on Coldwell Peninsula during the 1980-81 winter. From 1978 to 1981 productivity remained consistent (Table 3) and only one dead caribou caribou was found after 1979. Since no other mortality on the island was discovered I believe caribou left during the two winters.

3.2 Effects of Nutrition:

Seventy four percent of the males (n=38) and 25 percent of the females (n=16) observed after June 1st (pooled years) possessed antlers. Only one of the 12 male caribou captured had antler growth while both females captured were bald. Average cast antler size on the island was small (656.8 ± 121.8 g, n=18).

Weights and body measurements of 15 caribou captured from July 1979 to May 1981 are shown in Table 4. Weights of calves and yearlings caught in 1980 and 1981 which were born in 1979 revealed lower weights and reduced growth rates than

Table 4. Capture information for 15 caribou from Pic Island.

Date Captured	Name	Sex	Age (yr)	Weight (kg)	Ant	TL	SH (cm)	HG
1979, July 26	Rang	F	1.2	67.7	N	160	89	91
1979, Aug. 11	Fu	M	>3.0	149.2	Y	178	89	127
1980, April 23	Ian	M	1.0	44.7	Y	157	85	91
1980, April 26	Ma	F	>4.0	150.1*	N	140	102	132
1980, April 27	Rang	F	2.0	80.8	N	170	98	102
1980, April 29	If	M	3.0	111.9	Y	185	107	122
1980, May 4	DM	M	1.0	55.9	Y	152	91	99
1980, May 5	Tu	M	>4.0	104.6*	N	183	93	114
1980, June 19	Bo	M	>3.0	124.8*	Y	208	107	122
1980, June 26	Fre	M	1.1	51.0	Y	161	88	103
1981, April 30	Ian	M	2.0	105.7	Y	180	103	116
1981, May 2	Fa	M	1.0	80.8	Y	87	92	102
1981, May 13	Nob	M	1.0	85.8	Y	165	89	107
1981, May 15	If	M	>3.0	124.8*	Y	205	106	124
1981, May 20	Red	M	>3.0	140.5	Y	209	106	124

* weight estimated from regression of heart girth on weight of other caribou weighed ($y = 2.52x + -183.4$; $r = 0.925$)

Ant = antlered (Yes or No); TL = total length; SH = shoulder height; HG = heart girth.

calves born in 1980 (Table 5). The best recorded growing season over the study period (1978-81) was in 1980 while the shortest season occured the previous year in 1979 (Fig. 6).

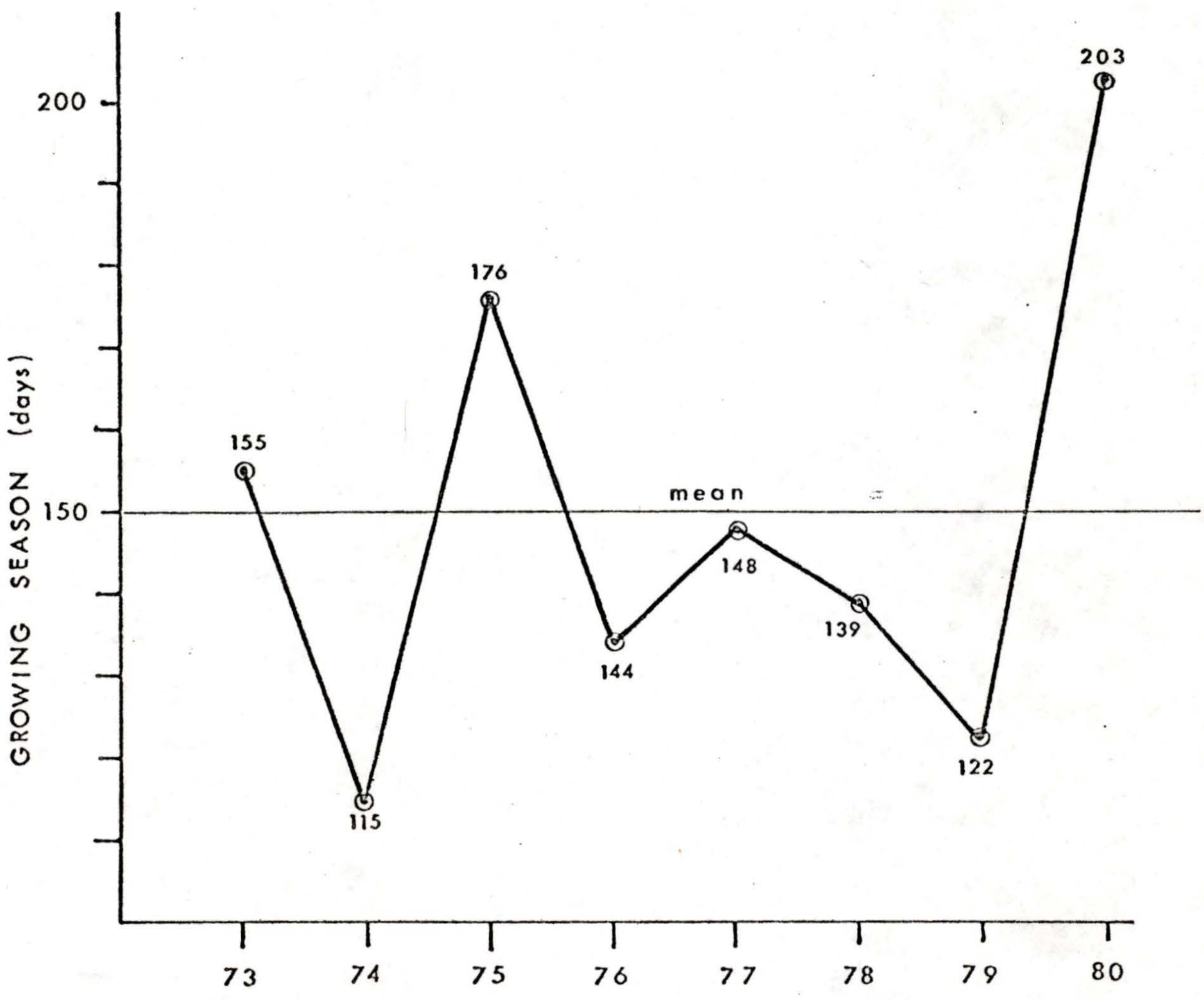
Blood characteristics of Pic Island caribou did not show significant differences between years (Appendix 5.5).

Table 5. Spring weights (April 23 - May 13) of short yearlings campared between cohorts and as 2-year-olds.

year calves born in	spring weights (kg)		weight recaptured as 2-year-old (kg)
1978	67.7[1]	-------------------	80.8
1979	55.9		
	51.0[2]		
	44.7	-------------------	105.7
1980	80.8		
	85.8		

[1] captured July 26
[2] captured June 26

Figure 6. Length of growing seasons for the Marathon area (1973-80).


GROWING SEASON (days)
200
150
mean
155
115
176
144
148
139
122
203
73
74
75
76
77
78
79
80

3.3 Hypothesis 1: Food

3.31 Seasonal food preferences:

Selection of food varies seasonally depending on the needs of the animal, the phenological condition of plant species, and their availability. For example, although caribou rely on lichens (ground and arboreal) in the winter, these plants are selected only because snow conditions have reduced the availability of alternative food sources. Figure 7 portrays the changes in relative importance of plant foods to the island caribou as suggested by field observations. Figures 8 and 9 are specific examples of how different plant species become available as caribou food, depending on their phenological condition.

During the month of April alder and maple stems were highly selected while currant, raspberry, serviceberry, mountain ash and birch were sometimes browsed (Figs. 10,11,12). Arboreal lichen, Labrador tea and Canada yew formed the major portion of the caribou's diet during this late winter period. In May, Dryopteris ferns supplied the caribou with the greatest volume of food and were preferred while leafing raspberry, currants and maple contributed to

Figure 7. Schematic representation of energetic periods and their relationship to the seasonal selection of food by caribou on Pic Island.

(Bw = birch, Ac = maple, So = mountain ash, Al = alder)

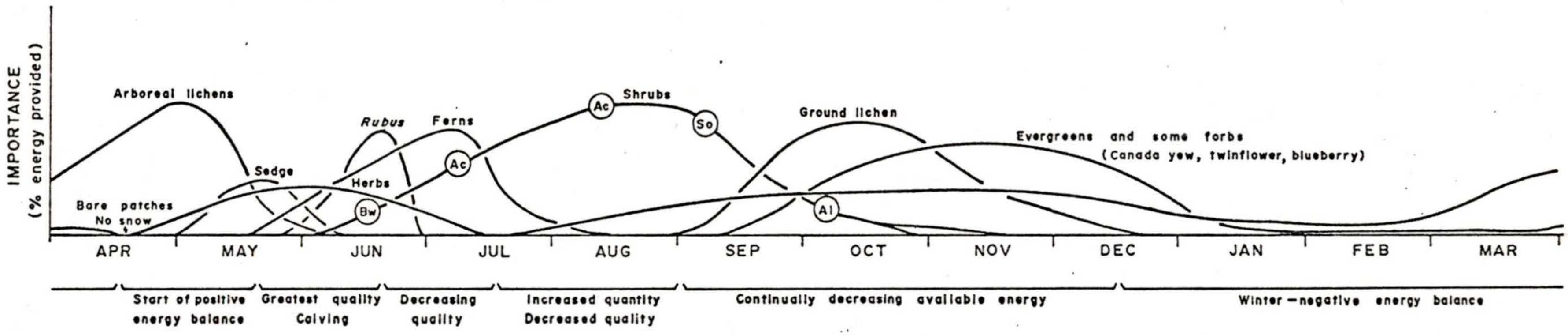

IMPORTANCE
(% energy provided)
Arboreal lichens
Sedge
Bare patches
No snow
Rubus
Ferns
Herbs
Bw
Ac
Shrubs
So
Ground lichen
Evergreens and some forbs
(Canada yew, twinflower, blueberry)
Al
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
Start of positive energy balance
Greatest quality Calving
Decreasing quality
Increased quantity Decreased quality
Continually decreasing available energy
Winter – negative energy balance

Figure 8. Leaf emergence dates for six species of trees and shrubs (1981).

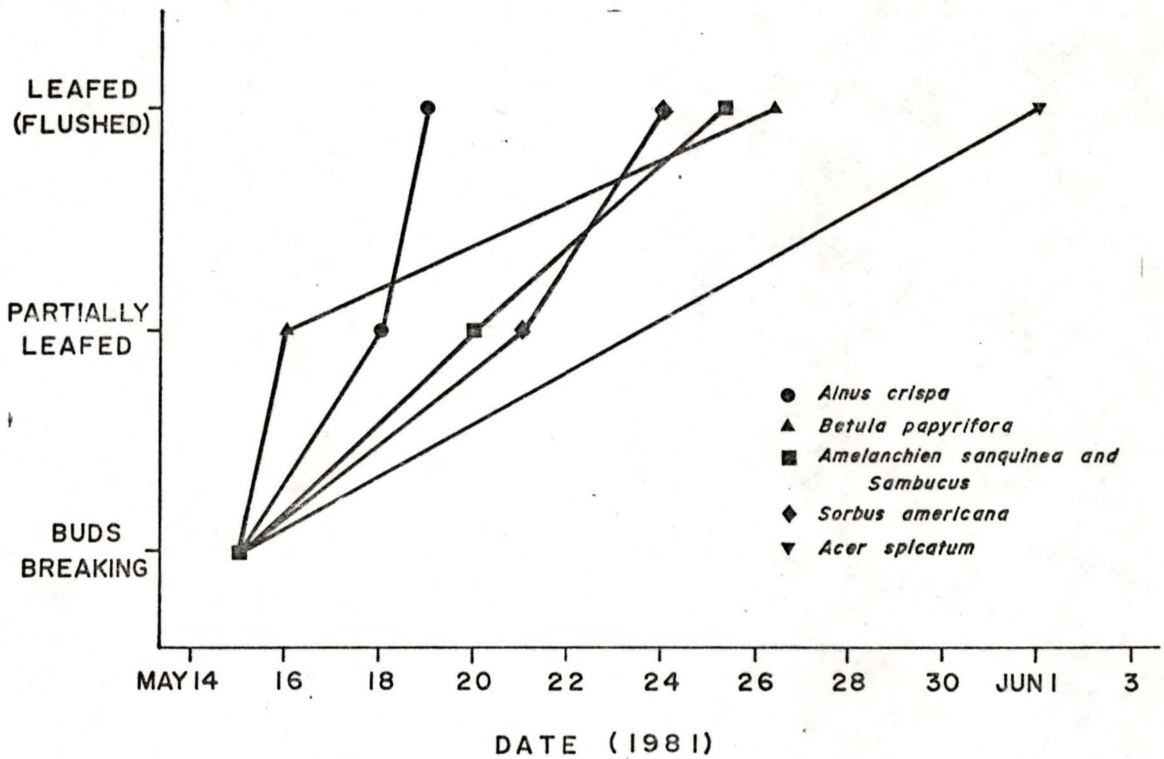
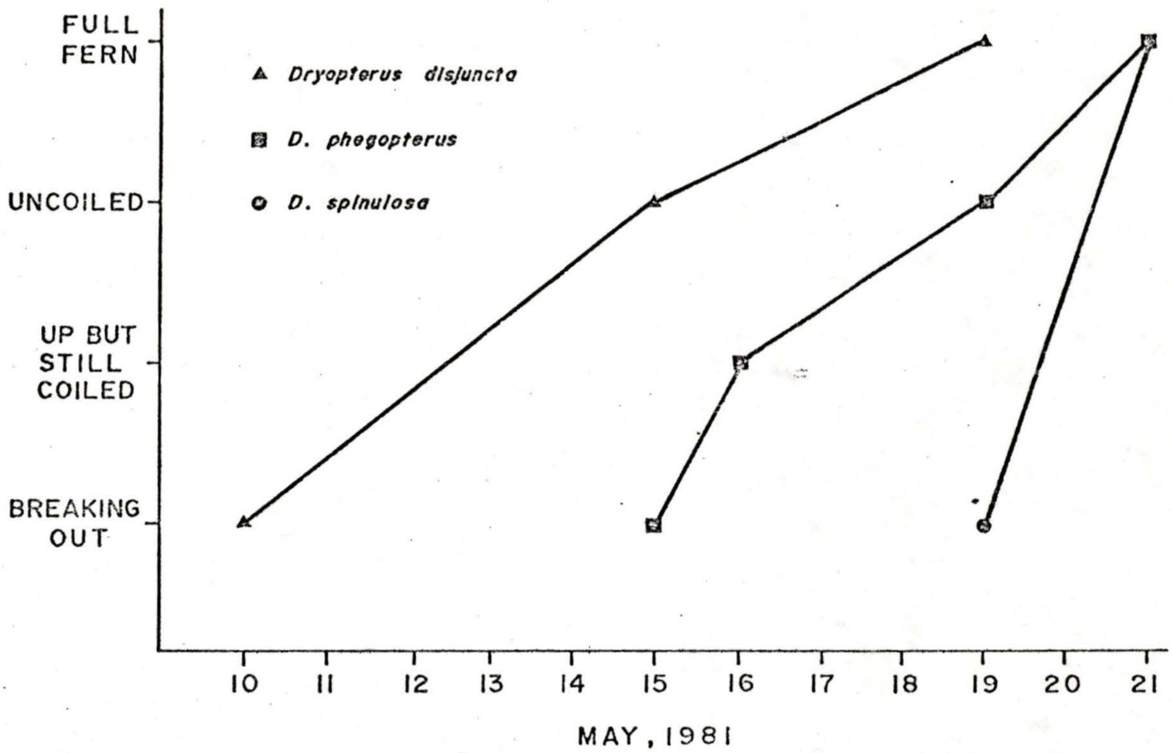

LEAFED
(FLUSHED)
PARTIALLY
LEAFED
BUDS
BREAKING
Alnus crispa
Betula papyrifora
Amelanchien sanquinea and
Sambucus
Sorbus americana
Acer spicatum
MAY 14
16
18
20
22
24
26
28
30
JUN 1
3
DATE (1981)

Figure 9. Timing of eruption of three important fern species (1981).


FULL FERN
UNCOILED
UP BUT STILL COILED
BREAKING OUT
Dryopterus disjuncta
D. phegopterus
D. spinulosa
10
11
12
13
14
15
16
17
18
19
20
21
MAY, 1981

the diet. In June there was an explosion in both the number of plants species eaten and the amount. Because of the limited nutritious growth on the island, fresh winter type caribou feces (hard pellets) could be found all year. The soft paddies associated with succulent spring and summer forage were formed primarily in the hardwood valleys during June and July. During June and July the ferns continued to be highly selected while the shrub species, primarily mountain ash and maple, became more important in the diet. Forb species that were important foods included raspberry, currants, horsetail, bunchberry, Clintonia, rose-twisted stalk and sarsaparilla.

With the colder weather during the fall, forb species were destroyed by frost, leaving only the shrub species and lichen as potential caribou foods. During early summer, maple was the preferred shrub (palatability index), being replaced by mountain ash in the late summer and early fall. Alder and other shrub species, including raspberry, also became more important as caribou foods during this late summer to fall period.

Figure 10. Seasonal changes in palatability of three fern species eaten by caribou over the spring to fall pericd.

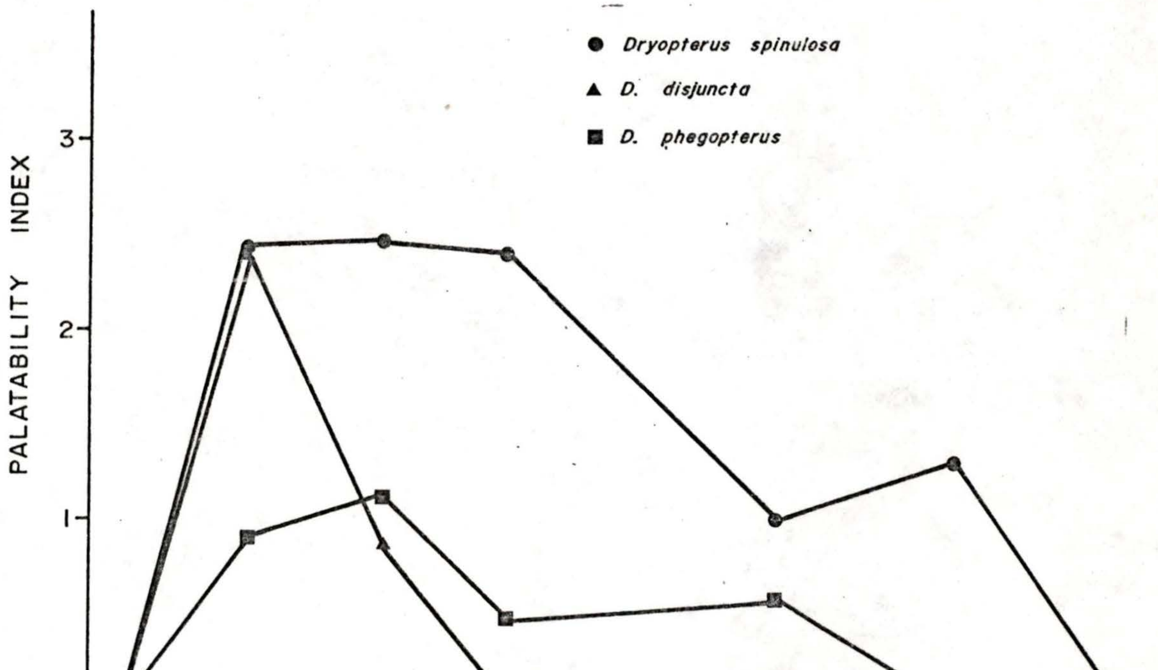

Dryopterus spinulosa
D. disjuncta
D. phegopterus
PALATABILITY INDEX
0
1
2
3
MAY 3
MAY 26
JUN 18
JUL 22
SEP 7
OCT 10
NOV 8

Figure 11. Seasonal changes in palatability of shrub species eaten by caribou over the spring to fall period.

other shrubs = birch, alder, saskatoon, dogwood

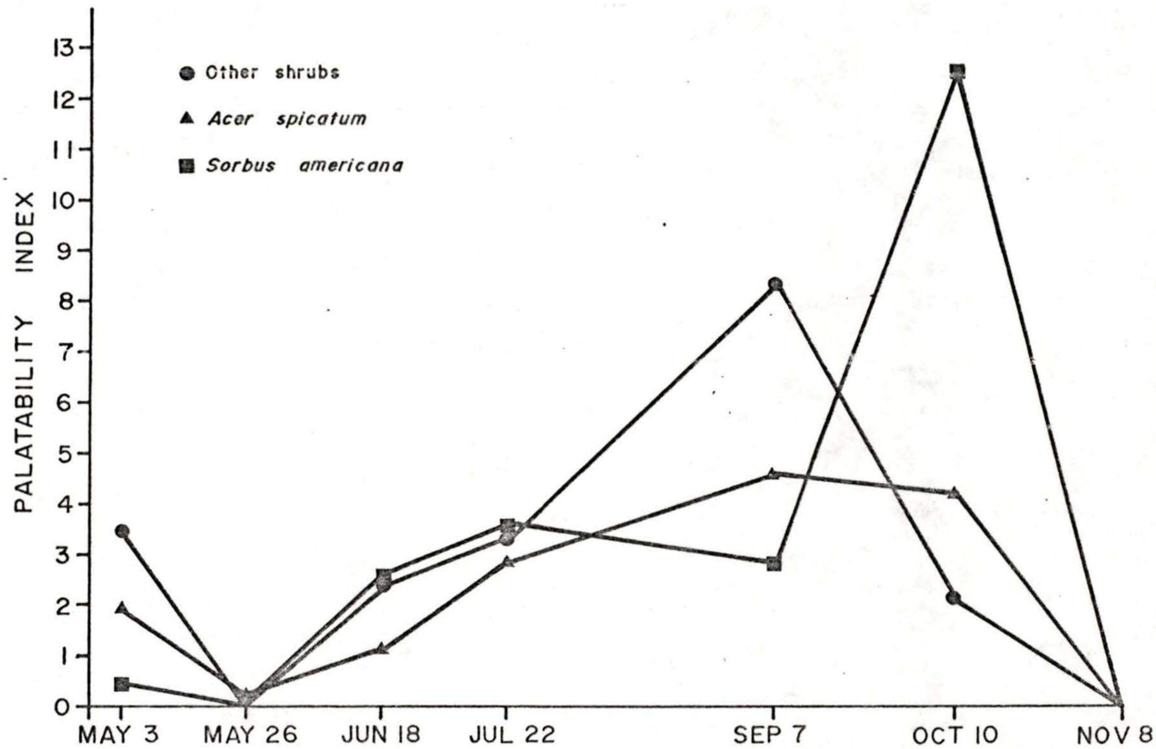
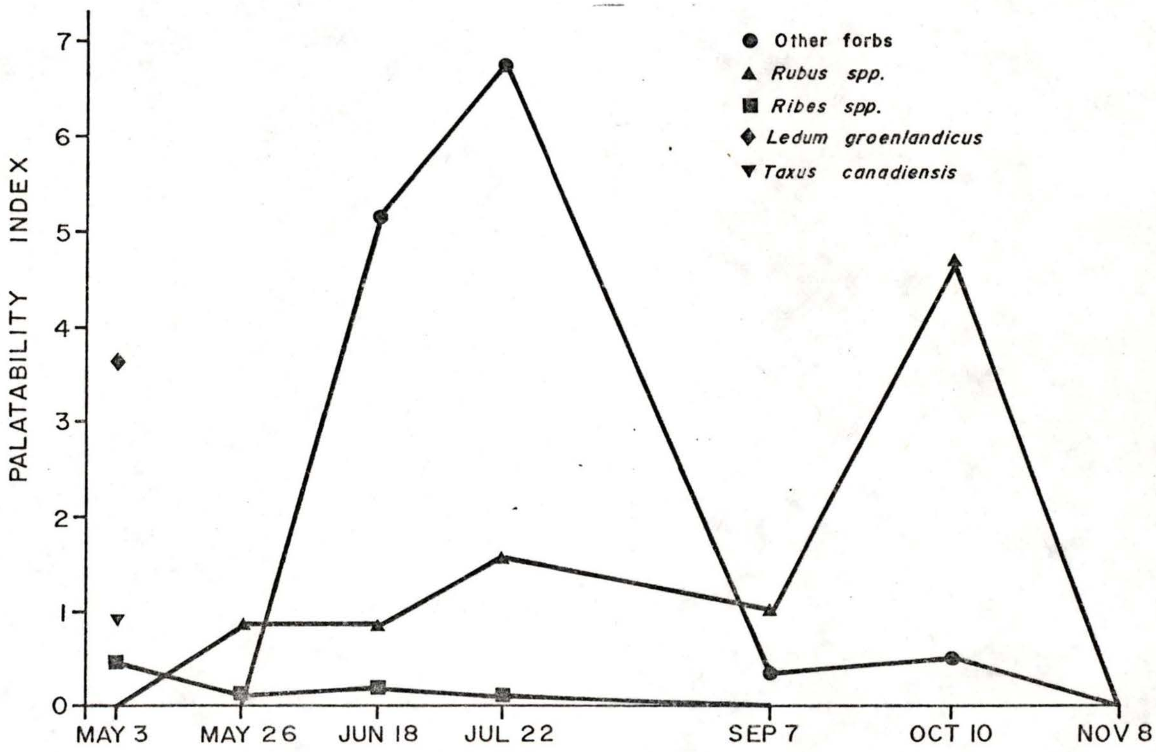

Other shrubs
Acer spicatum
Sorbus americana
PALATABILITY INDEX
0
1
2
3
4
5
6
7
8
9
10
11
12
13
MAY 3
MAY 26
JUN 18
JUL 22
SEP 7
OCT 10
NOV 8

Figure 12. Seasonal changes in palatability of forb species eaten by caribou over the spring to fall period.

other forbs = sweet-petasites, bunchberry, horsetail, starflower, clintonia, sarsaparilla, blueberry, enchanters nightshade, cow wheat, rose-twisted stalk.



Other forbs
Rubus spp.
Ribes spp.
Ledum groenlandicus
Taxus canadiensis
PALATABILITY INDEX
0
1
2
3
4
5
6
7
MAY 3
MAY 26
JUN 18
JUL 22
SEP 7
OCT 10
NOV 8

3.32 Availability of Preferred Plants:

On the mainland there was a significantly greater abundance of all preferred shrub species than on Pic Island during the period from leaf emergence in the spring to August 12, 1981 (Table 6). Of the 56 forb species considered potential caribou food, 14 were shown to be more abundant on the mainland whereas four were more abundant on the island (Table 7 and 8). The mainland had a greater variety of species (potential caribou food per 4 m^2 plot) than the island (9.00 ± 0.226; n = 220 versus 3.99 ± 0.219; n = 202) and a greater total number of species present (53 versus 42).

Conifer cover (spruce-balsam fir) on the island constituted 58.6 percent of the overstory, while the major canopy cover on the mainland was hardwoods, comprising 59.4 percent of the total overstory (Table 9). Although both areas had similar percentages of food shrubs composing the understory (Table 9), alder made up the greatest percentage of cover on the island while the mainland offered a greater variety of other food species (willow, serviceberry, cherry, poplar, dogwood and squashberry). The island, because of the shallow soil surface, supported smaller trees (dbh) but with a greater density or basal area (Table 10).

Table 6. Comparing abundance (weight in grams of leaves available per hectare) and preference (P) between Pic Island and the adjacent mainland shrub species as spring and summer caribou foods.

Species	P	Pic Island	Mainland	sig.
<u>Populus tremuloides</u>	+0.9775	0.397 ± 0.206	11.00 ± 3.12	**
<u>Salix</u> spp	+0.7960	8.702 ± 3.202	12.76 ± 3.48	*
<u>Acer spicatum</u>	+0.7029	25.64 ± 6.751	2774.0 ± 263.9	**
<u>Amelanchier</u>	+0.5480	7.482 ± 2.732	599.4 ± 57.99	**
<u>Prunus virginiana</u>	+0.5118	6.618 ± 1.976	87.58 ± 13.77	**
<u>Sorbus americana</u>	+0.1138	173.3 ± 32.79	1151.0 ± 90.46	**
<u>Alnus crispa</u>	-0.5939	408.6 ± 68.02	1072.0 ± 176.9	**

P = preference index = $\frac{A - B}{A + B}$; where A = proportion of food type eaten/amount available, B = proportion of food type in habitat = species density/total density; +1 most preferred, -1 least preferred

* 0.05 significance, ** 0.01 significance.

Example: For Acer spicatum a = eaten/available (from Table 9)
= 5.97/25.64 = 0.2328 g/m
b = available/total available = 25.64/630.7
= 0.04065 g/m

$$P = \frac{a - b}{a + b} = \frac{0.2735}{0.1922} = 0.7029$$

Table 7. Comparing abundance (g/4 m²) of spring and summer forb species ranked in order of preference between the Pic Island and the adjacent mainland (P as in Table 9).

Species	P	Pic Island	Mainland	sig.
Cornus stolinifera (dogwood)	+0.9965	0.0056±0.0056	0.0873±0.0392	*
Epilobium angustifolium (fireweed)	+0.9932	0.0133±0.0133	0.257 ±0.257	
Prunus virginiana (cherry)	+0.9893	0.0205±0.0205	0.0668±0.0282	
Salix spp. (willow)	+0.9873	0.0275±0.0143	0.0546±0.0442	
Galium triflorum (starflower)	+0.9780	0.0019±0.0019	0.0137±0.0090	**
Aralia nudicaulis (sarsaparilla)	+0.9453	0.1106±0.0960	8.235 ±1.7640	**
Sorbus americana (mountain ash)	+0.9405	0.0914±0.0238	0.1434±0.0368	
Acer spicatum (maple)	+0.9220	0.1461±0.0474	3.6759±0.7582	**
Alnus crispa (alder)	+0.9077	0.1453±0.0441	0.4011±0.1234	
other ferns	+0.8484	0.0295±0.0220	1.9860±0.1384	**
Populus tremuloides (poplar)	+0.8149	0.1778±0.0896	0.1224±0.0868	
Ribes glandulosum (skunk current)	+0.7389	0.5650±0.3403	0.0204±0.1511	
Rubus pubescens (dwarf raspberry)	+0.7207	0.2494±0.0834	0.502 ±0.269	*
Rubus strigosus (red raspberry)	+0.6899	0.4628±0.2170	1.085 ±0.356	*
Dryopteris phegopteris (beech-fern)	+0.6551	0.4217±0.1393	0.3996±0.1181	
D. spinulosa (wood-fern)	+0.5870	0.9066±0.2020	1.352 ±0.1974	
D. disjuncta (oak-fern)	+0.0806	1.2416±0.2831	0.5180±0.1022	*
Cornus canadensis (bunchberry)	-0.1811	0.3093±0.0626	1.5347±0.1773	**
Betula papyrifera (birch)	-0.3427	1.0740±0.2056	0.0638±0.0179	**
Ledum groenlandica (labrador tea)	-0.8250	1.832 ±0.517	1.658 ±0.466	
Vaccinium spp. (blueberry)	-0.8546	3.221 ±0.516	2.310 ±0.535	
Ribes americanum (American current)	-1.0000	0.0	0.0126±0.0126	
Fragaria vesca (strawberry)	-1.0000	0.0	0.0274±0.0114	*
Rubus parviflorus (thimbleberry)	-1.0000	0.0	0.1704±0.1613	
Actaea rubra (baneberry)	-1.0000	0.0073±0.0073	0.0828±0.0512	
Rosa sp (rose)	-1.0000	0.0	0.0604±0.0294	*
Aster macrophylus (big-leaf aster)	-1.0000	0.0	0.1554±0.0311	
Diervilla lonicera (bush honeysuckle)	-1.0000	0.0194±0.0194	0.3971±0.3971	*
Amelanchier sanguinea (saskatoon)	-1.0000	0.0090±0.0074	0.1707±0.0400	**

Table 8. Twenty-seven forb species (potential caribou food) comparing abundance (average percent cover of species/4 m^2 plots) between Pic Island and adjacent mainland.

Species	Pic Island (219)	Mainland (240)	sig.
Carex spp. (grass)	1.598±0.658	2.660±0.640	
Gaultheria hispidula (snowberry)	1.05 ±0.62	2.29 ±0.74	
Viola spp. (violet)	0.882±0.467	0.613±0.202	
Cyperaceae spp. (sedge)	0.753±0.44	1.508±0.652	
Taxus canadensis (Canada yew)	0.489±0.209	0.0	
Oxalis montana (wood sorel)	0.480±0.329	0.0	
Vaccinium oxycoccos (small craneberry)	0.457±0.372	0.367±0.334	
Juniperus communis (juniper)	0.411±0.306	1.104±0.561	*
Trientalis borealis (starflower)	0.365±0.0098	0.146±0.054	*
Coptis trifolia (goldthread)	0.251±0.229	0.042±0.024	
Circaea alpina (enchanters nightshade)	0.228±0.106	0.392±0.315	
Mitella nuda (naked mitterwort)	0.228±0.150	0.029±0.022	
Lineaus borealis (twinflower)	2.080±0.510	0.192±0.079	**
Mianthimum canadensis (mianthimum)	0.137±0.059	3.475±0.480	**
Kalma angustifolia (sheep-laurel)	0.137±0.137	0.0	
Clintonia borealis (clintonia)	0.046±0.046	4.604±0.653	**
Potentilla tridentata (cinquifoil)	0.023±0.023	0.046±0.030	
(rose-twisted stalk)	0.023±0.023	0.046±0.025	
Chamaedaphne calyclata (leatherleaf)	0.0	0.317±0.170	
Vaccinium Vitis-Idaea (cowberry)	0.0	0.292±0.292	
Equisetum spp. (horsetail)	0.0	0.196±0.099	
Andromeda glaucophylla (bog rosemary)	0.0	0.167±0.167	
Melampyrum lineare (cow wheat)	0.0	0.067±0.063	
Petasites spp. (sweet-petasites)	0.0	0.054±0.039	
Solidago spp. (goldthread)	0.0	0.021±0.021	
Geranium sp (geranium)	0.0	0.021±0.021	
Anaphalis margaritacea (pearly-everlasting)	0.0	0.008±0.008	

Table 9. Overstory and Understory percent cover compared between Pic Island and the adjacent mainland.

	Mainland	Pic Island	
OVERSTORY			
total	51.05 ± 1.56 (237)	59.72 ± 1.57 (194)	
<u>Abies balsamia</u>	10.53 ± 1.12 (124)	10.05 ± 1.37 (52)	
<u>Betula papyrifera</u>	26.56 ± 1.60 (192)	23.74 ± 1.62 (134)	
<u>Picea glauca</u>	8.72 ± 1.19 (81)	22.55 ± 1.71 (120)	**
<u>Picea mariana</u>	1.48 ± 0.44 (26)	1.20 ± 0.46 (8)	
<u>Sorbus americana</u>	2.78 ± 0.50 (54)	0.93 ± 0.35 (12)	**
other species	2.04 ± 0.56 (34)	1.06 ± 0.46 (7)	
UNDERSTORY			
total	41.61 ± 1.85 (236)	44.97 ± 1.58 (167)	
<u>Abies balsamia</u>	7.89 ± 0.93 (113)	19.80 ± 1.93 (85)	**
<u>Acer spicatum</u>	0.44 ± 0.12 (21)	1.32 ± 0.50 (85)	
<u>Alnus crispa</u>	0.83 ± 0.19 (34)	12.45 ± 1.32 (72)	**
<u>Picea glauca</u>	17.31 ± 1.69 (110)	3.10 ± 0.78 (19)	**
<u>Sorbus americana</u>	9.80 ± 1.58 (89)	7.31 ± 1.03 (50)	
other species	7.54 ± 1.21 (87)	1.64 ± 0.48 (14)	**

Table 10. Basal area (basal area factor = 2.00, k value = 35.35).

species	Mainland (240)	Pic Island (219)	
<u>Abies balsamia</u>	1.57 ± 0.134 (139)	3.73 ± 0.360 (123)	**
<u>Betula papyrifera</u>	3.18 ± 0.227 (159)	5.09 ± 0.354 (167)	**
<u>Picea glauca</u>	0.95 ± 0.145 (58)	5.50 ± 0.482 (139)	**
<u>Picea mariana</u>	0.30 ± 0.055 (44)	0.38 ± 0.115 (25)	
other species	0.56 ± 0.086 (58)	0.70 ± 0.093 (68)	
total	6.54 ± 0.271	15.41 ± 0.657	**

Although there was no significant difference in the amount of ground lichen (*Cladonia spp.*) between the island ($3.0 \times 10^{-6} \pm 0.10 \times 10^{-6}$ m^3 of lichen per m^2) and mainland ($3.25 \times 10^{-6} \pm 1.50 \times 10^{-6}$ m^3 per m^2), there were areas on the mainland which supported large flats of ground lichen which were not censused in the initial 1980 vegetation survey. The island had none of these distinct areas which were easily recognized from aerial photographs. A greater volume of ground lichen (36.29 ± 32.96 m^3) was estimated from seven areas of ground lichen - spruce flats on the mainland (0.1846 ha.) than for all of the island (31.08 ± 10.36 m^3 ; 1036 ha.).

The island had a greater density of arboreal lichen below the 2 m height of trees (0.2298 ± 0.01680 g/m^2) than the mainland (0.01131 ± 0.001668 g/m^2). This supply of lichen on the island was of a more uniform density and most had been previously browsed. In contrast the mainland, although it contained a younger forest, offered areas of high density lichen which were easily available and revealed no visible browse line.

For maple and mountain ash, the effect of browsing pressure by caribou on the island over time has resulted in a decrease in the number of stems (Table 11). Probably due to this decrease in the number of competing shoots, there has been a corresponding increase in the size of the main stem. For serviceberry, willow and pin cherry there was an increase in both the number and the size of stems which was also attributed to the browsing pressure.

Table 11. Comparison of the number of stems in a clump of trees and the average dbh (in cm) of the main or largest stem, between Pic Island which is heavilly browsed by caribou and the adjacent mainland with minimal browsing pressure.

Species	Mainland	(mean ± s.e.	(n))	Pic Island		sig.
Acer spicatum	stems	2.28±0.05	(166)	1.40±0.13	(43)	**
	dbh	3.06±0.18	(166)	4.87±0.38	(43)	**
Sorbus sp	stems	1.98±0.09	(206)	1.56±0.09	(129)	*
	dbh	6.70±0.44	(205)	10.51±0.58	(129)	*
Alnus crispa	stems	3.63±0.21	(188)	3.98±0.29	(141)	
	dbh	3.19±0.12	(188)	4.64±0.15	(141)	**
Amelanchier sp	stems	1.56±0.08	(144)	2.42±0.34	(19)	**
	dbh	1.66±0.12	(143)	2.79±0.30	(20)	**
Salix spp	stems	1.71±0.17	(70)	2.32±0.35	(28)	**
	dbh	2.88±0.26	(70)	4.41±0.48	(28)	**
Prunus sp	stems	1.17±0.06	(58)	1.72±0.24	(18)	**
	dbh	2.20±0.19	(58)	3.12±0.76	(18)	*

3.4 Hypothesis 2: Disease

During the springs of 1978, 1979, 1980 deer sign was observed in #4 Valley, including the use of a salt lick. On May 7, 14, 26 (1979) an individual deer was seen in this Valley. There was no indication that the deer utilized any other part of the island or that it remained longer than the early spring period from April-May. Deer feces collected on the island (1978, n=8; 1979, n=3) and mainland (1978, n=2) contained no spined larvae. It is possible that the deer was using the island as a fawning area.

A small population of moose existed on the mainland. I estimated a moose density of 0.3 moose/km^2 from 249 4 m^2 plots censused for winter pellet groups during the summer of 1980. This population remained viable during the 1976-81 period in the presence of deer. I observed no evidence of moose becoming inflicted with neurological disease transmitted from white-tailed deer (ie. paraplegia, circling, or loss of fear).

During the course of the summer study I checked three beaches on Coldwell Peninsula about three times per week, from early May to the end of August (120 days). I estimated that approximately 120 moose and 20 deer visited the beaches each of the summers. This ratio of moose to deer visits did not vary over the years from 1978-81. Age ratios, estimated from tracks indicated good productivity for the moose (May to July 1979: 14 adults, 7 calves, 4 yearlings) and deer (1979: 4 adults, 1 fawn) populations.

3.5 Hypothesis 3: Predation

The black bear (*Ursus americanus*) is a potential predator; recent studies have shown consistent black bear predation on moose calves in Alaska (Franzmann and Schwartz 1979) and on elk calves in Idaho (Schlegel 1976).

A bear lived on the island during the summer in 1978 and in 1979 and may have been present in previous years. The bear left the island during mid-summer 1979. Signs of the bear indicated that it roamed over most of the island but concentrated its activity on the south side. Bear sign during May of both years included: fresh scats which contained ants and sedge, digs in fern areas, stripping of the bark off elderberry, over-turned rocks, and old trees and roots which were pawed out. In May of 1979 a dead caribou was found near a bear den. The adult male caribou had supplied the bear with food over the late winter and early spring. The left humerus was cracked longitudinally with sign of haemorrhage, suggesting the caribou suffered a fall off a 4 m ledge nearby. Caribou droppings at this site indicated that the caribou remained below the cliff for a period of time before dying, and was then dragged 5 m to the entrance of the bear den.

No other sign of bear predation on caribou was observed on either the mainland (214 spring scats examined) or the island (23 scats examined). Black bear predation has not been documented for eastern cervid populations and was considered unimportant as a predation factor in this study.

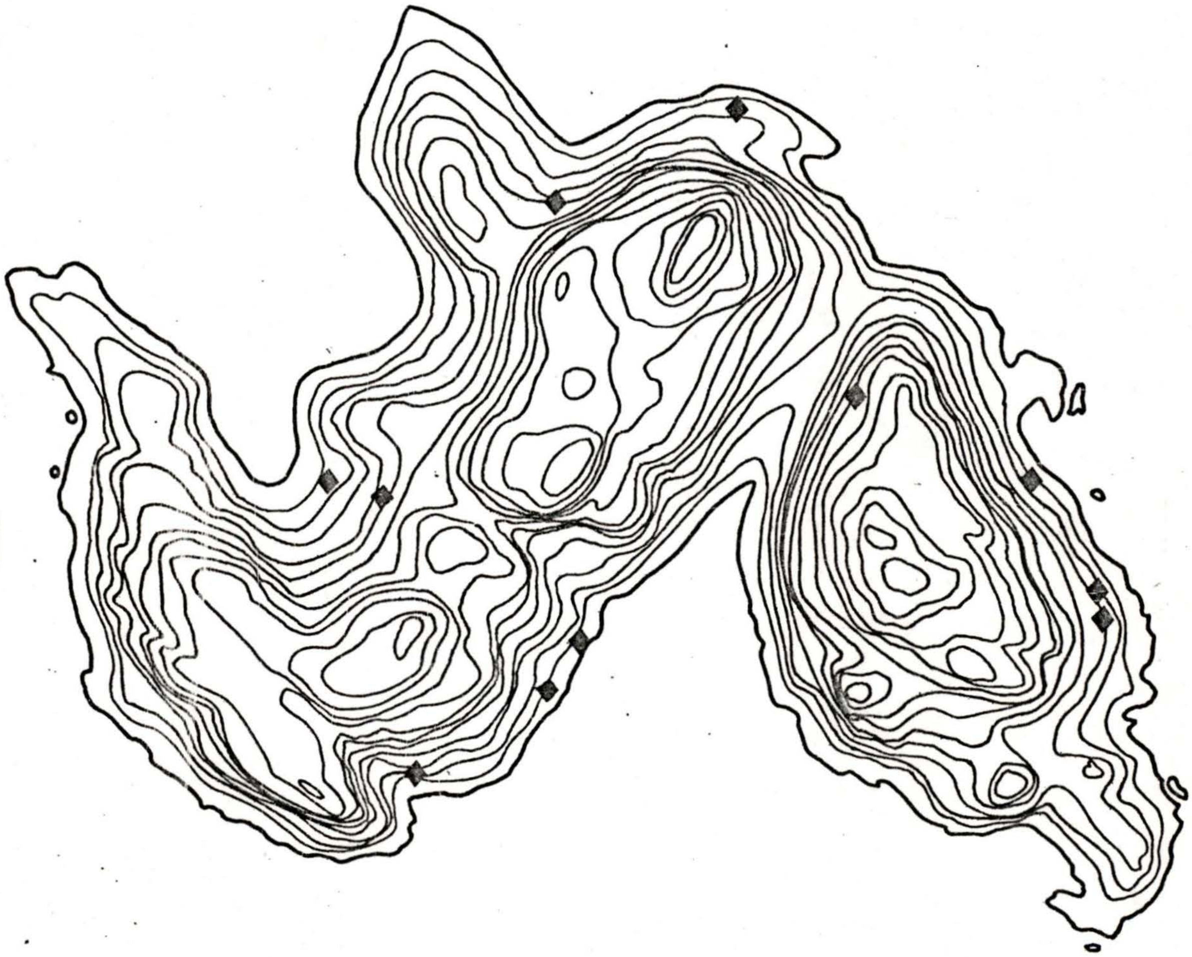
Lynx (*Lynx canadensis*) sign was not observed on either the island or the adjacent mainland, although during the high in the hare cycle, lynx sign was observed at the mouth of Pic River within the Neys area. There is no evidence of lynx predation on calves outside of Newfoundland (Bergerud 1971) and it was considered unimportant as a predator factor in this study.

Wolf predation has been a pervasive influence on the evolutionary development of caribou. Caribou abundance has traditionally been limited by predation and their k-selected life-history strategy is a result of this selective pressure in an open habitat of relative faunal simplicity, found in the barren north. Of 26 wolf scats collected in 1978 from the Coldwell Peninsula and Neys Park area, 14 were judged to contain adult cervid remains by hair impression techniques (Adorjan and Kolenosky 1969). Using Floyd *et al.*'s (1978) technique for determining relative amounts, caribou (108 kg) made up 59 percent of the cervids eaten, moose (270 kg) 32 percent and white-tailed deer (70 kg) 9 percent. Of the eight wolf scats collected, which were estimated to have been formed by wolves during the August 1977 to April 1978 period, four were identified as containing caribou, three had moose remains and one contained deer hair. Again, caribou under the foregoing assumptions supplied the wolves with the greater percentage of food (53%). It was during this period, 1977-78 that the small herd of caribou occupying the Coldwell Peninsula and the Little Pic River Valley disappeared.

Wolf predation on Pic Island during the late winter of 1976-77 was partly responsible for the decline which reduced the island population by almost a half. A major die-off occured during the 1976-77 winter on Slate Islands, located 23 km southwest of Pic Island in Lake Superior. I estimated approximately one third of the Slate Island caribou died of starvation during the course of that winter (pers. files). Dead caribou remains located on Pic Island (Fig. 13) were found to be near Lake Superior and major valleys, the two routes wolves would be expected to use in chasing caribou (Bergerud and Wyett 1976). Caribou were found to respond to predators by running uphill in predator avoidance studies on the island (Appendix 5.10: Escape Behavior). Because of scavenging and the length of time taken to locate them, only two of the remains could be distinguished as having been eaten by wolves. Sign of wolves and their activity in the Neys area during this study was restricted to the 1977 die-off and tracks of a pack of five wolves which were on the Coldwell Peninsula in December of 1977. No more wolf sign was seen on the island or the Peninsula area up to January 1982 when observations stopped.

I released a caribou on the mainland in June of 1980 to determine how it would fare in the presence of wolves. The radio collared caribou continued to give an active signal up

Figure 13. Locations of dead caribcu remains from the 1976-77 winter die-off which included animals which died from malnutrition and/or wolf predation.



until November of 1981, when it either left or the radio-collar stopped transmitting.

3.6 Hypothesis 4: Dispersal

Tracks of only one caribou were observed crossing the sand and thread markers placed on Moss Point, Pic Island. This animal walked out to the rocky point before returning to the island forest. No other summer movements to and from the island were detected by this method. In spring of 1981 a captured caribou released on the mainland swam back to the island within two weeks of its release. No caribou tracks during the summer were observed on the Coldwell Peninsula beaches up until the release of a captured caribou in 1980.

The tracks of one caribou were observed near the Park in May and June of 1979 (Table 12). Not until the winter of 1980-81 were caribou again observed on the peninsula. During the summer study from early May to the end of August (120 days) of 1978 and 1979 approximately 110 moose visits, 20 deer visits and no caribou visits were recorded on the sand of three major Coldwell Peninsula beaches. During the 1980-81 winter and the following 1981-82 winter a group of caribou occupied the Peninsula. I estimated that 23 and 17 caribou were missed from census estimates in 1980 and 1981. I assumed that these caribou crossed the Thompson Channel over ice formed during the previous winters.

Table 12. Estimates of caribou numbers on Coldwell Peninsula.

year	season	number	observations
1970-74	winter	10	OMNR Ontario Ministry Of Natural Resources personnel observed caribou tracks crossing highway 17 by tracks in snow (two major crossings)
1975	winter	10	OMNR observations and National Park helicopter saw two caribou near Premier mountain
1976	summer	5-10	Estimated by B. Snider (Dist. Biologist) from beaches and walking
1977	winter&summer	0	No caribou observations
1978	winter&summer	0	Extensive walking by author
1979	winter	0	Snowshoed Coldwell Peninsula
	summer	1	Extensive walking by author (one caribou crossed from the north of highway 17 in May into C.P. and left the area in June).
1980	summer	1	One caribou released on mainland.
	winter	1	Active signal from released caribou.
1981	winter	3-10	OMNR plane saw cow and calf, author observed tracks and sign by walking. Two caribou released on mainland during summer.
1982	winter	5-15	Observations by OMNR personnel and R. Ferguson (research assistant).

4.0 DISCUSSICN

4.1 DEMOGRAPHY (1976-1981):

Pic Island supported a population of approximately 60 caribou in 1976 and during the summer and winter of that year, caribou also resided on the adjacent mainland. The winter of 1976-77 resulted in a major die-off on the island which can be attributed to wolf predation and/or a difficult winter because of the high density of animals competing for a limited food resource. The mainland caribou population disappeared by 1977 during heavy wolf predation and did not reappear until 1981. The island population rebuilt over the three years following the 1976-77 die-off (constant productivity of 21.9 percent of the summer population consisting of calves) from about 30 to 50 caribou in 1979 (Fig. 4).

Estimates based on island censusing for 1980 and 1981 suggest an emigration of caribou off the island during the previous winters for both years. No evidence of dead caribou on the island were collected during these years and observations from the winter of 1981 and 1982 revealed a small herd of caribou occupying the Coldwell Peninsula, including calves. No caribou movements were detected during the spring-summer months and it is hypothesized that the caribou left the island during the winter, across the ice.

4.2 Effects of Nutrition:

Caribou, when they were more numerous in this area, migrated north and south annually. The Pic Island - Coldwell Peninsula and most of the north shore and its associated islands were wintering areas for the migratory caribou herds. With the decrease in caribou numbers, fewer caribou reached Pic Island and fewer migrated. Some became localized on the island and by avoiding wolf predation, became limited by nutrition. Changes in the factors controlling the population resulted in changes in the population. Some of the effects of high density were:

1. environment: most palatable plants are heavily grazed and some have almost disappeared (eg. Canada yew, honeysuckle, sarsaparilla); the use of stuffer foods increases (eg. blueberry and labrador tea); browse lines appear (eg. a 2 m line for arboreal lichen).
2. reproduction: the reproductive rate decreases; calf mortality due to causes other than predation increases.
3. morphology: there was a decline in size and weight of mature animals; antler size decreased.
4. physiology: the population was in poor physiological condition (more susceptible to disease and insects).

4.21 Reproduction:

Changes in productivity as a result of nutrition can be manifested as:

1. decreased conception due to failure of ovulating females to copulate, or copulation without fertilization, or conception with an early death of zygote, blastocyst or early embryo (Dauphine 1976).
2. in utero mortality (absorption of later fetus). Dauphine (1976) considered embryonic or fetal mortality in caribou to be rare and therefore prenatal mortality not to be significant. Two female caribou remains were found on Pic Island with fetus bones in their pelvis, indicating that the female died either while giving birth to a calf or due to poor nutrition in the later stages of pregnancy.
3. calf mortality due to post-natal nutritive failure or environmental conditions (eg. wind-chill). Most calf loses occur during the first 48 hours after birth and in deer (Verme 1962) are usually the result of one or more of the following: poor condition of calf; calf too small to reach teats; cow does not permit calf to suckle; delayed or no lactation. On the Slate Islands I found four dead calf remains during the spring of 1977. Low calf production in 1977 on Pic Island was indicated by few yearlings (8.7% of the spring population, Table 3) in 1978.

4. winter calf mortality due to poor condition, small size (Moen 1973), and/or social dominance (intra-specific competition for good quality foods in limited supply).

Winter calf mortality appears to be the causual link between poor nutrition and decreased recruitment for Pic Island caribou. Of all dead caribou found on the island (n=21) 43 percent were identified as being calves. Because of smaller size and softer bones, the remains of dead calves were more difficult to locate on censusing than adult animals. Only two of the dead caribou which were estimated to have died prior to 1976 (n=8) were calves. Of 13 dead caribou remains to have died since 1976, 54 percent were calves. Calf mortality is the major mortality factor on Pic Island and is the mechanism of decreased recruitment and relative population stability.

Estimates of calf production and survival (Table 3) indicated an increasing caribou population on Pic Island over the study period (1978-81). Calf recruitment was relatively consistent with 21.9 percent of the summer population consisting of calves. Free-ranging caribou populations without any mortality, potentially can increase by 30 percent every year (Bergerud 1978). The lowered recruitment observed on the island can be explained satisfactorilly by the balanced sex ratio (extrapolation from Fig. 5). A ratio favoring females is expected (Bergerud 1980) and a rmax = 0.30 is based on a sex ratio of 1:2 (males:females).

The number of adult females giving birth to calves does not seem to be limiting calf production. Density-dependent effects of nutrition could conceivably cause an older age of sexual maturation of females (Dauphine 1976). The 2-year-old females which were included in the calculation of parturition rate (78.4 percent) rarely become pregnant (Bergerud 1980). Assuming the average percent 2-year-old is similar to the percent yearlings in the population (15.4 percent, Table 3) then almost all adult females 3-years and older were pregnant (93.8 percent). Reproductive rates for different female age classes on the island did not appear to be lower than expected (Bergerud 1980).

4.22 Morphology:

Body weight is one of the more universally used criteria for reflecting growth rate and nutritive status. Pic Island caribou, because of the limited nutrition available to them, are smaller (average adult male weight = 91.7 ± 18.8 kg, n=5) than most woodland caribou (Bergerud 1980). Growth rate and a decrease in ultimate body size is related to the quality of the spring and summer forage, which corresponds with the period of most active growth of caribou, rather than with the quality of winter forage. Caribou, like all cervid species occupying northern range have developed mechanisms to reduce the importance of winter foods as the main factor influencing winter survival:

1. body fat stored over the growing season supplies 20-30 percent of the energy required during the winter by catabolism of fat (Mautz 1978);
2. a lowered metabolic rate (approximately one third of an energy reduction is required by deer to meet basal life functions (Holter et al. 1977));
3. their insulative coat is better than deer or moose (Kelsall 1968);
4. behavioral adaptations (winter telemetry work suggested that the caribou remain bedded for long periods during severe weather).

Short yearlings (11 months old) captured in the spring of 1981 were larger than 1979 or 1980 (Table 5). This difference in growth likely occured in the summer of 1980, when the growing season was 53 days longer than the mean (Fig. 6). Further evidence to support that the longer growing season resulted in increased nutrition was that 1980 calves had antlers (n=8) and some with spikes, where as in 1978 and 1979 none of the observed calves had antlers (n=3 and n=2 respectively).

Antlers have a lower priority for growth than most other body tissues (Cowan and Long 1962; example of priority sequence: body fat, muscle, hair, antlers). Caribou without antlers were more prevelant than in any other caribou population studied. These changes have occurred slowly over the generations and can be described by changes in the weights of discarded antlers (Table 13). Recently (1976-1979) cast Pic Island antlers were significantly smaller than old Pic Island antlers (1975 and earlier) and all Pic Island antlers were much smaller than antlers found on the adjoining mainland (Coldwell Peninsula). This suggests that the factors operating to decrease body and antler size on the island are not present on the mainland. The same decreases in antler size with time was observed on the Slate Islands (Bergerud and Butler 1974; Table 13). But the recent decrease in antler size on Pic Island was greater than the decrease for the Slate Island antlers (Table 13, $P<0.05$). The largest antlers collected from this area came from the Slate Islands in 1949 and in 1947-48. Caribou initially colonizing the Slate Islands could maximize energy intake in the absence of wolves and the need to migrate. This likely resulted in an increase in body and antler size.

Table 13. Weights of caribou antlers collected from various locations along the north shore of Lake Superior.

Area and Time Period		Mean ± Standard Error (g)
Pic Island:	1976-1979	372.7 ± 107.7 (7)
	<1975	934.9 ± 151.8 (9)
	combined	656.8 ± 121.8 (18)
Coldwell Peninsula		1256.7 ± 168.7 (8)
Slate Islands:		
	collected in 1949	1881.0 ± 239.1 (18)
	collected in 1974 [1]	885 (10)
		1045 (10)
		1200 (10)
		1492 (10)
		2332 (10)
St. Ignace and Rossport Islands collected in 1947-1948		1500.0 ± 226.2 (12)

Antlers found on the Lake Superior mainland were significatly larger than island antlers, and on both Pic and Slate Islands the decrease in antler size with time was significant.

[1] five classes from most recent to oldest (Bergerud and Butler 1974)

4.3 Why Pic Island?

To test whether caribou were on the island and not the mainland due to forage conditions, seasonal food preferences were determined and estimates of the availability of these plants were used to compare the island and the adjacent mainland. This method ignores consideration of spatial variation and quality. Still the results were distinct: the mainland had more food but the caribou chose (no conscious decision necessary) Pic Island. I conclude that the caribou are on the island not because of the amount of preferred foods.

No wolves entered the Coldwell Peninsula area between 1979-81. No evidence of disease from deer having affected the local caribou and moose populations was found. Dispersal was not restricted and those animals on the mainland previous to 1977 declined while residing there. Caribou transplanted on the mainland and those that are assumed to have emigrated off the island, survived and reproduced. The final test of the predation hypothesis will be the survival of the caribou on the mainland once the resident wolf packs discover them. The predation hypothesis predicts better survival on the island.

The evidence suggests that predation has limited and eliminated the caribou which have resided on the adjacent mainland and it is the lack of predators and the presence of escape habitat that has allowed the caribou to survive on the island.

4.4 Distribution and Abundance

The basic question in ecology is to determine the factors that relate to distribution and abundance of animals (Andrewartha and Birch 1954). The caribou along the north shore of Lake Superior occur on the most southerly border of their present distribution, making this an ideal locale to study factors limiting caribou distribution. How do these caribou survive so far south and why only on Pic Island and a few scattered locations along the north shore of Lake Superior?

During the early 1800's caribou migrations north of Lake Superior followed a pattern which brought caribou herds to the islands and the Lake Superior shoreline during the winter. Blair (1911, cited in Cringan 1957) documents a slaughter of 2400 caribou on Michipicoten Island in one winter during the 1800's. In the 1960's caribou still migrated between Pic Island and the mainland (Table 14), and I suggest that it was during this period that a group of caribou began to use the island continually, resulting in the present population which is relatively sedentary. A non-nomadic caribou population of high density resulted in overbrowsing of the island and led to the morphological changes observed in this population.

Table 14. Faunal history of the Neys area.

Date	Observations
1940 e	Caribou on Pic Island (hunted from Marathon)
1945-1955 b,c,e	Approximately 20 caribou used Neys beach.
1955-1965 b	Caribou swam between Pic Island and the Coldwell Peninsula across the Thompson Channel. Caribou continued to use the Neys area beaches.
1964-65 b	A large herd of caribou (approximately 100) crossed over the ice on Thompson Channel in small groups.
1960-1970 a,b,c	Caribou continued their use of the Neys beach area.
1965 a	Deer sign first appeared on the Coldwell Peninsula and the small population has continued its existence there up until 1981. Moose sign was always present since 1940. Three beaches on Coldwell Peninsula were checked three times per week from early May to the end of August (1978 and 1979). From these checks it was estimated that over the 120 day period there were 110 moose visits and 20 deer visits.
1971, 1977, 1979, 1980 a	One to two caribou were seen in the McKeller area (5 km from Neys)
1965-1973, 1975, 1976 f	Small groups of caribou crossed the trans-canada highway during the winter at two crossings.
1976-77 g	The winter die-off on Pic Island and wolf kills were found on the Coldwell Peninsula and island.
1977, 1978, 1981 g	Some scattered caribou observations on Coldwell Peninsula.

Observers:
- a Phil Bridson
- b Oliver LeBar
- c Clem Downing
- d Colin MacMillan
- e William Hienrick
- f OMNR personnel
- g author

The past 100 years have brought significant changes to the caribou's environment which has resulted in a marked reduction in the Ontario population. Presently, only small pockets of caribou, totalling approximately 300 animals occupy range along the north shore of Lake Superior, including Pic Island. There are now only a few caribou on the Neys mainland, in contrast to the 40 ± 20 that have resided on the island for over 20 years.

Why then, have caribou declined in northern Ontario during the last century, and what do Pic Island and other areas along the north shore of Lake Superior have to offer caribou which would allow these populations to persist? My thesis is that predation can be used to describe the process which has resulted in the changes in caribou distribution. Human or unnatural predation can be easily linked to the caribou decline. Up until the 20th century much of northern Ontario was caribou range (deVos and Peterson 1951) and these migratory herds were regulated by their obligate hunter, the wolf, with some Indian hunting exerting its predatory influence. Human predation methods became more sophisticated during the 1800's, with increased settlement by white man, and these methods were easily employed against the highly susceptible herds of gregarious and tradition-bound caribou.

Second, and probably more importantly, during the last century natural or wolf predation on caribou has increased.

This increased wolf pressure has been made possible by the recent influx of moose and deer populations into this area. Deer and moose live at higher densities and reproduce faster than caribou, making them less susceptible to the greater predator pressure from wolves and man. The greater prey biomass which now includes deer and moose, has allowed the wolf population to increase, and concurrently resulted in a decrease in caribou (Bergerud 1974).

A decisive requirement of this description of changes in predatory pressure is an explanation for the changes in distribution of moose and deer. There are two factors which were instrumental in allowing the northward expansion of moose and deer range. First, was the settlement of the north which resulted in an increase in early successional forest habitat. The new and highly nutritious growth which follows after fires and disturbances, such as logging, is an advantage to most boreal species. But moose and deer are better adapted to take advantage of these variations in the environment (Geist 1971) than caribou.

Moose and deer within the boreal forest live in short-lived subclimax plant communities generally created after forest fires or logging practices. This transient deciduous tree and shrub community is irregular with expansion and slow contraction. Moose and deer range also expands repeatedly into the fresh transient habitat and retreats slowly into small patches of permanent habitat which form nuclei for future expanding populations (Geist 1971).

Characteristics of r-selection are the ability to discover the habitat quickly, reproduce rapidly to use up the resource and disperse in search of other new habitats (Wilson 1975). Among cervids it is possible to describe an ascending gradient of K-selection, demographic traits and population stability from deer and moose to caribou and elk. An expanding population can be expected to minimize the age of maturation of individuals, concentrate reproductive effort early in life and increase brood size, all of which are characteristic of moose and deer relative to caribou and elk (Ferguson unpublished).

Therefore the use of transient environment after burns has selected for a higher rmax in moose and deer. Expanding and contracting population phases for moose and deer create conflicting selection pressure for single or multiple births and have produced a mechanism that ties ovulation rate to the nutritional regime of the female (Geist 1975). There is no evidence that natality rates of free ranging caribou are affected by nutrition (Bergerud 1980).

The second factor which allowed the expansion of moose and deer range was climate. Peterson (1959) first suggested that changes in the climate during the past century can be correlated with changes in the distribution of cervids in North America. A world-wide warming trend from 1880-1945 (Thomas 1959, Flint 1971, Matthews 1976, Benson and Dodds 1977) made northern Ontario more congenial to moose and deer, both of which are not as well adapted to severe winter conditions as caribou (Telfer and Kelsall 1979).

The bulk of the evidence, although mostly circumstantial and therefore not conclusive, suggests that these changes have resulted in the decline of caribou in northern Ontario and are responsible for the precarious situation in which we now find the remaining small pockets of caribou which range along the north shore of Lake Superior.

REFERENCES

Adorjan, A.S. and G.B. Kolenosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Research Report (Wildlife) No. 90. Ontario Dept. of Lands and Forests. 64 pp.

Agassiz, L. and J.E. Cabot. 1850. Lake Superior. Boston: Gould, Kendall and Lincoln. 428 pp.

Ahti, T. and R.L. Hepburn. 1962. Preliminary studies of woodland caribou range, especially lichen stands in Ontario. Ont. Dept. of Lands and Forest., Res. Rep. (Wildl.) No. 74. 135 pp.

Altmann, M. 1963. Naturalistic studies of maternal care in moose and elk, p. 233-253. In Rheingold, Harriet L. (ed.). Maternal behavior in mammals, Wiley and Sons, New York.

Anderson, D.R., J.L.Laake, B.R. Crain, and K.P. Burnham. 1976. Guidelines for line treatment sampling of biological populations. J. Wildl. Manage. 43(1): 70-78.

Anderson, R.C. 1972. The ecological relationships of meningeal worm and native cervids in North America. J. Wildl. Dis. 7: 304-309.

Andrewartha, H.G., and Birch, L.C. 1954. The distribution and abundance of animals. University of Chicago Press, Chicago.

Baccus, R., N. Ryman, M.H. Smith, C. Reuterwall and D. Cameron. 1979. Genetic variability and differentiation of large grazing species of mammals. In press.

Bailey, N.T.J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38: 293-306.

Bailey, N.T.J. 1952. Improvements in the interpretation of recapture data. J. Animal Ecol. 21: 120-127.

Baskin, L.M. 1970. Reindeer, ecology and behavior [in Russian]. Nanka AS USSR, Moscow. 151 pp.

Benson, D.W. and G.D. Dodds. 1977. Deer of Nova Scotia. Dept. of Lands and Forests, Nova Scotia.

Bergerud, A.T. 1961. Sex determination of caribou calves. J. Wildl. Manage. 25:205

Bergerud, A.T. 1964. A field method to determine annual parturition rates for Newfoundland caribou. J. Wildl. Mgmt. 28: 477-480.

Bergerud, A.T. 1971. The population dynamics of Newfoundland caribou. Wildl. Monogr. 25. 55 pp.

Bergerud, A.T. 1974. The decline of caribou in North America following settlement. J. Wildl. Mgmt. 38: 757-770.

Bergerud, A.T. 1975. The reproductive season of Newfoundland caribou. Can. J. Zool. 53:1213-1221.

Bergerud, A.T. 1978. Caribou - Pp. 83-101 in J. Schmidt and Gilbert eds. Big Game of North America. Stackpole Books.

Bergerud, A.T. 1980.A review of the population dynamics of caribou in North America. Reimer,E., Gaare,E. and Skenneberb,S. (eds.) Proc. 2nd Int. Reindeer/Caribou Symp.,Rorcs,Norway,1979.

Bergerud, A.T. and H.E. Butler. 1974. Wildlife investigations on the Slate Islands. 46 pp.

Bergerud, A.T. and W.R. Wyett. 1976. Faunal investigations in the proposed Pukaskwa National Park. pp 63. Can Nat. Parks No. G-289.

Blair, E.H. 1911. The Indian tribes of the upper Mississippi Valley and region of the Great Lakes is described by Nichclas Perrot. Clark, Cleveland, Vol. 1 pp. 1-372. Vol. 1 pp. 1-372.

Braend, M. 1964. Genetic studies of serum transferrins in reindeer. Hereditas 52: 181-188.

Burnham, K.P., D.R. Anderson and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildl. Mono. No. 72.

Carter, C. 1979. A trip to lonely Caribou Island cutpose of the lakes. Inland Seas 35 (2): 98-103.

Caughley, G. 1978. Analysis of vertebrate populations. John Wiley and Son, London.

Caughley, G. and J. Goddard. 1972. Improving the estimates from inaccurate censuses. J. Wildl. M anage. 36: 135-140.

Cavalli-Sforza, L.L., and W.F. Bodmer. 1971. The genetics of human populations. W.H. Freeman and Co., San Francisco. 965 pp.

Chapman, L.J. and M.C. Thomas. 1968. The climate of Northern Ontario. Climatological Studies, No. 6, Dept. of Transport, Meteorological Branch.

Cowan, I. McT. 1956. What and where are the black-tailed deer? In Taylor, W.P. (ed.). The deer of North America. The Stackpole Co., Harrisburg, Pennsylvania.

Cowan, R.L. and T.L. Long. 1962. Studies on antler growth and nutrition of white-tailed deer. Proc. Nat. White-tailed Deer Symposium. 1: 54-60.

Crain, B.R., K.P. Burnham, D.R. Anderson, and J.I. Laake. 1978. A Fourier series estimator of population-density for line transect sampling. Utah St. Univ. Press, Logan, Utah. 25 pp.

Cringan, A.T. 1957. History, food habits and range requirements of the woodland caribou of continental North America. Trans. N. Amer. Wildl. Conf. 22: 485-500.

Dalke, P.D. 1942. The cotton tail rabbit in Connecticut. State Geol. Nat. Hist. Survey Bull. 65: 1-97.

Dauphine, T.C. 1976. Growth, reproduction, and energy reserves. Pt. 4. Biology of the Kaminiurak population of barren-ground caribou. Can. Wildl. Ser. Rep. Ser., No. 38, 77 pp.

Davis, J. 1977. Status of Alaskan caribou herd. Paper read at Symposium on Parameters of Caribou Population Ecology in Alaska, Nov. 16-19, Fairbanks, Alaska.

deVos, A., P. Brokx and V. Geist. 1967. A review of social behavior of the North American cervids during the reproduction period. Amer. Mid. Natur. 77: 390-417.

deVos, A. and R.L. Peterson. 1951. A review of the status of woodland caribou Rangifer tarandus in Ontario. J. Mammal. 32: 329-337.

Downing, R.L., H.D. Michael and R.J. Poux. 1977. Accuracy of sex and age ratio counts of white-tailed deer. J. Wildl. Manage. 41(4): 709-714.

Eberhardt, L.L. 1968. A preliminary appraisal of line transects. J. Wildl. Manage. 32: 82-88.

Eberhardt, L.L. 1978. Transect methods for population studies. J. Wildl. Manage. 42: 1-31.

Edwards, R.Y. 1954. Fire and the decline of a mountain caribou herd. J. Wildl. Manage. 18: 521-526.

Ferguson S.H. and R.S. Ferguson. 1980. Investigations of caribou foods on Otter Island (July 26-28, 1980). 16 pp. typed report for Parks Canada. Pukaskwa Nat. Park.

Ferguson, S.H. and R.S. Ferguson. 1980 On the presence and uniqueness of Pic Island caribou. Unpublished typed report, 23 pp., Ministry of Nat. Res.

Ferguson S.H. and R.S. Ferguson. 1981. The Island caribou. 23 pp. Unpublished typed report Ont. Min. of Nat. Res.

Flint, R.F. 1971. Glacial and Quaternary geology. John Wiley and Son, 892 pp.

Floyd, T.J., L.D. Mech and P.A. Jordan. 1978. Relating wolf scat content to prey consumed. J. Wildl. Mgmt. 42: 528-532.

Franzmann, A.W. 1972. Environmental sources of bighorn sheep physiologic values. J. Wildl. Manage. 36: 924-932.

Franzmann, A.W., A. Flynn, and P.D. Arneson. 1975. Serum corticoid levels relative to handling stress in Alaskan moose. Can. J. Zool. 53: 1424-1426.

Gahne, B. and J. Rendel. 1961. Blood and serum groups in reindeer compared with those in cattle. Nature 192: 529-530.

Gates, C.E., W.H. Marshall, and D.P. Olsen. 1968. Line transect methods of estimating grouse population densities. Biometrics 24(1): 135-145.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. Univ. Chicago Press, 383 pp.

Geist, V. 1975. On the relationships of social evolution and ecology in ungulates. Amer. Zool. 32: 205-220.

Gottleib, L.D. 1971. Gel electrophoresis: new approach to the study of evolution. Bio. Science 21: 939-944.

Gross, J.E. 1978. Competition and carrying capacity measurements: A credibility gap? Colorado Cooperative Wildlife Research Publ.

Haber, G.C., C.I. Walters and I. McT.-Cowan. 1976. Stability properties of a wolf-ungulate system in Alaska and management implications. Dept. of Zool. U.B.C. Unpublished Research Rept.

Hardin, J.W., N.J. Silvy and W.D. Klimstra. 1976. Group size and composition of the Florida Key Deer. J. Wildl. Manage. 40: 454-463.

Harestad, A.S. 1981. Computer analysis of home range data. Fish and Wildlife Branch Bulletin No. B-11. pp. 25

Harris, H. 1966. Enzyme polymorphisms in man. Proc. Roy. Soc. London 164B: 298.

Harvey, D. 1969. Explanation in geography. Edward Arnold, London, U.K. 521 pp.

Holling, C.S. 1966. The functional response of invertebrate predators to prey density. Mem. Entomol. Soc. Canada. 48: 1-86.

Holter, J.B., W.E. Urban, and H.H. Hayes. 1977. Nutrition of northern white-tailed deer throughout the year. J. Anim. Sci. 45 (2): 365-376.

Ivlev, V.S. 1961. Experimental ecology of the feeding fishes. Yale Univ. Press. New Haven, Conneticut, USA. 302pp.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Karns, P.D. and V.F.J. Crichton. 1978. Effects of handling and physical restraint on blood parameters in woodland caribou. J. Wildl. Manage. 42: 904-908.

Kelsall, J.P. 1968. The migratory barren-ground caribou in Canada. Can. Wildl. Ser. Monograph No. 3 Queens Printer, Ottawa. 340 pp.

Kelsall, J.P. and D.R. Klein. 1979. The state of knowledge of the Porcupine Caribou Herd. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 44.

Klein, D.R. 1968. The introduction, increase and crash of deer on St. Matthew Island. J. Wildl. Manage. 32: 350-367.

Lankester, M.W., V.J .Crichton, and H.R. Timmerman. 1976. A protostrongylid nematode (Strongylida: Protostrongylidae) in woodland caribou (Rangifer tarandus caribou) Can. J. Zool. 54: 680=684.

Larcher, W. 1973. Limiting temperatures for life functions: gradual progress of damage due to temperature stress. Pages 195-231 in Temperature and life. Springer-Verlag, New York.

Lavigne, D.M., J.P. Bogart, R.G.H. Downer, R. Danzman, W.W. Barchard, and M. Earle. 1979. Genetic Variability in Northwest Atlantic harp Seals. In press.

Lent, P.C. 1974. Mother-infant relationships in ungulates. Pages 14-53 in V. Geist and F. Walther, eds. The behavior of ungulates and its relation to management. IUCN New Ser. Publ. 24, Morges, Switzerland.

Leopold, A.S. and Darling. 1953. Wildlife in Alaska. The Ronald Press Co., New York, 129 pp.

Franzmann, A.W., and C.C. Schwartz. 1979. Kenai Peninsula moose calf mortality study. Alaska Dept. Fish and Game Fed. Aid in Wildl. Rest. Final Rep. W-17-10.

LeResche, R.E., U.S. Seal, P.D. Karns, and A.W. Franzmann. 1974. A review of blood chemistry of moose and other cervidae, with emphasis on nutritional assessment. Nat. Can. Ottawa. 101: 263-290.

Lewontin, R.C. and J.L. Hubby. 1966. A molecular approach to the study of genetic heterzygosity in natural populations. II Amount of variation and degree of heterozygosity in natural populations of Drosophila pseudoobscura. Genetics 54: 595-609.

Linsdale, J.M. and P.Q. Tomich. 1953. A herd of mule deer. Univ. of California Press, Berkeley. 567 pp.

Markgren, G. 1969. Reproduction of moose in Sweden. Viltrevy 6: 129-299.

Matthews, S.W. 1976. What's happening to our climate? Nat. Geog. 150: 576-615.

Mautz, W.W. 1978. Nutrition and carrying capacity. Pages 321-348 in Schmidt, J.L. and D.L. Gilbert, eds. Big Game of North America, Stackpole Books.

Miller, D.R. 1974. Biology of the Kaminuriak population of barren-ground caribou Part 3: Taiga winter range relationships and diet. Can. Wildl. Ser. Rep. Series No.

36. p 42. of 5;Moen, A.N.I. 1973. Wildlife ecolcgy. W.H. Freeman and Company, San Francisco. 458 pp.

Moen, A.N. 1973. Wildlife ecolcgy. Freeman and Company, San Francisco, 458 pp.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. Am. Midland Nat. 37: 223-249.

Nadler, C.F., C.E. Hughes, K.E. Harris and N.W. Nadler. 1967. Electrophoresis of the serum proteins and transferrus of Alces alces (elk), Rangifer tarandus (reindeer), and Ovis dalli (dall sheep) from North America. Comp. Biochem. Physiol. 23: 149-157.

Neff, D.J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. J. Wildl. Mgmt. 32(3): 597-614.

Nevo, E. 1978. Genetic variation in natural populations: patterns and theory. Theor. Pop. Biol. 13: 121-177.

Overton, W.S. 1969. Estimating the numbers of animals in wildlife populations in Wildlife Management Techniques 3rd Edition, Ed. R.H. Giles. p. 433.

Parker, G.R. 1972. Biology of the Kaminuriak population of barren-ground caribou. Part 1. Can. Wildl. Serv. Rep. Ser. 20, Information Canada, Ottawa. 93 pp.

Peterson, R.L. 1959. Changes in the mammalian fauna of Ontario; in Changes in the fauna of Ontario. Ed. F.A. Urquhart. p. 43-58. University of Toronto Press. 75 pp.

Platt, J.R. 1964. Strong inference. Science 146: 347-353.

Popper, K.R. 1959. The logic of scientific discovery. Basic Books, New York.

Popper, K.R. 1962. Conjectures and refutations. Basic Books, New York, N.Y. 412 pp.

Ralls, K., K. Brugger, and J. Ballou. 1979. Inbreeding and juvenile mortality in small populations of ungulates. Science 206: 1101-1103. involved in the use of deer pellet group counts. Trans. N. Am. Wildl. Conf. 23: 411-425.

Robinette, W.L., R.B. Ferguson, and J.S. Gashwiler. 1958. Problems involved in the use of deer pellet group counts. Trans. N. Am. Wildl. Conf. 23411-425.

Rogers, G.O., Julander, and W.L. Robinette. 1958. Pellet-group counts for deer census and range-use index. J. Wildl. Mgmt. 22(2): 193-199.

Romesburg, H.C. 1981. Wildlife Science: gaining reliable knowledge. J. Wildl. Manage. 45: 293-313.

Rowe, J.S. 1972. Forest regions of Canada. Canadian Forest Service, Dept. of the Environment, Ottawa.

Schlegel M. 1976. Factors affecting calf survival in north central Idaho. Proc. West Assoc. Fish and Game Commissionerss Annu. Meeting 56:342-355.

Schweder, T. 1977. Point process models for line transect experiments. pp. 221-242. In J.R. Barbra, F. Brodeau, G. Romier, and B. van Cutsem (Eds.) Recent Developments in Statistics. North-Holland Publ. Co., New York, N.Y.

Scotter, G.W. 1967. Effects of fire on barren-ground caribou and their forest habitat in northern Canada. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 32: 246-259.

Seal, U.S. 1978. Assessment of habitat conditions by measurement of biochemical and endurance indicators of the nutritional, reproductive and disease status of free-ranging animal populations. Proc. Symp. on Classification, Inventory and Analysis of Fish and Wildlife Habitat, Off. Biol. Serv., U.S. Fish and Wildlife Serv.

Seal, U.S., L.J. Verme, J.J. Ozoga and A.W. Erickson. 1972. Nutritional effects on thyroid activity and blood of white-tailed deer. J. Wildl. Manage. 36: 1041-1052.

Seber, G.A.F. 1973. The estimation of animal abundance. Hafner Publ. Co., Inc., New York, N.Y. 506 pp.

Selander, R.K. 1976. Genic variation in natural populations. In Molecular Evolution. Edited by F.J. Ayala. Sinauer Associates, Sunderland, Mass.

Selander, R.K. M.H. Smith, Y. Yang,U.E. Johnson, and J.B. Gentry. 1971. Biochemical polymorphism and systematics of the genus Peromyscus I. Variation in the old-field mouse (Peromyscus polionotus), Studies in Genetic VI. Uni. Texas Publ. 7103: 49-90.

Selander, R.K., D.W. Kaukman, R.J. Baker and S.L. Williams. 1974. Genic and chromosomal differentiation in pocket gophers and the Geomys bursarius group. Evolution 28: 557-564.

Shelton, P.C. 1979. Population studies of beavers in Isle Royale National Park, Michigan. pp. 353-356 in Linn, R.M. (ed.) Proc. 1st Conf. Res. Natl. Parks, Natl. Park Service Trans. and Proc. Ser. No. 5.

Smith, A.D. 1964. Defecation rates of mule deer. J. Wildl. Mgmt. 28(30: 435-444.

Solomon, M.E. 1949. The natural control of animal populations. J. Anim. Ecol. 18: 1-35.

Stewart, R.R., R.R. MacLennan, and J.D. Kinnear. 1976. Annual variation of plant phenological events and its theoretical relationship to energy balance in moose. North American Moose Conference and Workshop 12: 1-30.

Stevenson, S.K. 1979. Effects of selective logging on Arboreal lichen on Selkirk caribou. Min. of Envir. Fish & Wildl. report No. R-2 ISSN 0701-581X.

Strangaard, H. 1972. The roe deer (Capreolus capreolus) population at Kalo and the factors regulating its size. Danish Rev. Game Biology 7: 205 pp.

Telfer, E.S. and J.P. Kelsall. 1979. Studies of morphological parameters affecting ungulate locomotion in snow. Can. J. Zool. 57: 2153-2159.

Thomas, M.K. 1959. Changes in the climate of Ontario. In Changes in the fauna of Ontario. Ed. F.A. Urquhart. pp. 59-75. University of Toronto Press.

Verme, L.J. 1962. Mortality of white-tailed deer fawn in relation to nutrition. Proc. Nat. White-tailed Deer Disease Symp. I, 15-38.

Walters, C.J., R. Hilborn, R. Peterman, M. Jones and B. Everitt. 1978. Porcupine caribou workshop, draft report on submodels and scenarios. Unpubl. Report, Institute of Animal Resource Ecology, Univ. of B.C., Vancouver. 42 pp.

Williamson, V.H.H. 1951. Determination of hairs by impression. J. Mamm. 32: 80-84.

Wilson, E.O. 1975. Sociobiology: the new synthesis. Harvard. Univ. Press, Cambridge. 697 pp.

Woolf, A. 1978. Pathology and necropsy techniques. Pages 425-436 in Schmidt, J.L. and D.L. Gilbert, eds. Big Game of North America, Stackpole Books.

Wright, S. 1969. Evolution and the genetics of populations. Vol. 2. The theory of gene frequencies. Univ. Chicago Press. 511 pp.

5.0 APPENDIX

5.1 Observation Cards

Figure 14. Vegetation card used for recording habitat information which was necessary to calculate estimates of caribou food availability and use.

Site__________
Location______________

Date________________
Observers______________
Page No________

SAR VEGETATION METHOD

Transect No.________ Direction________________
Stand No.__________ Plot No.____________

Habitat Description:

Basal Area Sp	No. Trees	Overstory Sp	% Cover

Understory Sp	% Cover	Ground Cover Sp	% Cover

Slope________ Aspect______________
Visibility______________ Blowdowns__________

4 m² Sp	Left	Eaten	Sp	% Cover

Units________

Lichen	Sp	Distance	No. Bites
1			
2			
3			
4			

Shrubs

Sp	Distance	No. Stems	DBH Max.	Bites Air	Ground	Eaten Air	Ground
Ac							
So							
Al							
Am							
Sa							
Po							
Pr							
Vib							
Co							
La							
Samb							

Explanation of Habitat Description used in both SAR Vegetation Method (Fig. 14) and Caribou Observation Card (Fig. 15).

The habitat was described for an area 30 m in radius. The percentage cover of the total overstory and of each major tree species (greater than 5 percent of the overstory) ws estimated for summer leaf conditions. Trees were defined as being greater than 5 cm in dbh and taller than 3 m. The understory percent cover was estimated for trees, sapling and shrubs greater than 10 percent of the total canopy, less than 5 cm in dbh and less than 3 m tall, in the same 30 m radius area. The herb layer or the ground cover was estimated in a 15 m radius area by describing percent cover for each major (greater than 10 percent cover) forb, herb, sapling and shrub which was less than 1 m in height. Browsing sign was recorded. The slope and aspect was estimated using a compass. A subjective estimate of blowdown severity was measured according to four classes: 1) none, 2) some present, 3) would cause the caribou some difficulty in moving, and 4) would be almost impossible for the caribou to walk. Visibility was an estimated maximum distance at which a caribou would be able to detect another caribou or a wolf.

Figure 15. Caribou Observation Card.

CARIBOU OBSERVATION CARD

Date________ Obs______ No______ Time_______ to_______ View_____________

Tags Y N CND describe________________________________ Con ______

Sex M F RV or Con_______ Calf Test Y N Con_____ Mother Test Y N Con______

Age A 2 1 C CND Con______ Color_________ Neck Mane________________

Antlers Y N CND V Diagram___________________________ Ht.____________ Pts.____________

Udder Y N CND Pregnant Y N CND Con_____ Moult Y N CND %__________

Activity_________________________ F B W R

Census Str.________ Perp.________ θ________ Run______ Walk_____ Circle_____

Senses 1: Alert_______ Flush_______ 2: Alert_______ Flush_______

Vocals Response______________________________ Stimulus___________________

Habitat Before: Overstory_____________________ Understory___________________________

Forbs_______________________________ Bl____ Vis_____ Slo_____ Asp_____

After: Overstory_____________________ Understory___________________________

Forbs_______________________________ Bl____ Vis_____ Slo_____ Asp_____

Environment: Sky___________ Wind____________ Temp________ Insect________ Ground__________

Escape Behavior: ____

____

Other Observations (Behavior):

Explanations for Caribou Observation Card

Obs.: observers initials

Time: first heard to last heard

View: left or right side, rear or complete

describe: colors of ear tags and neck collar (radio)

Con: confidence in description (100% = complete confidence)

Sex: male, female by vulva patch (RV = rear view) or by subjective inference (confidence)

Calf Test: response of animal to cow grunt

Mother Test: response of animal to calf grunt

Age: A = adult, 1 = one year old, 2 = two year old, CND = could not determine

Neck Mane: length and color

Antlers: V = velvet, and diagram R (right) and L (left) antlers with estimated height and number of points

Moult: Y = yes, N = no, and percent of animal which has lost old winter hair

Activity: before flush occured: F = feeding, B = bedded, W = walking, R = running

Census: see line transect methodology; distance ran, walked, and circled (in degrees)

Senses: used on first and second flush; sight, sound, scent

Vocals: cow grunt, stag pant, calf grunt, wheezy snort

Habitat: see apendix above

Environment: sky - percent cloud; wind - N(none), L(light), M(moderate), S(strong), G(gale); Temp. (relative seasonal temperature) - C(cool), W(warm), H(hot); Insect - N(none), B(bad), T(terrible); Ground - quiet (wet) or noisy (dry).

Escape Behavior: did the caribou use trails, run up or down hill, use specific habitat etc.?

Other Behavior: eg. feeding, reproductive, dominance hierarchies interaction

5.2 Pic Island Vegetation Stands

Thirteen stands (Fig. 16) on Pic Island were described by the Ontario Ministry of Natural Resources, during a preliminary forest research inventory of tree types and their harvestability. The stands revealed variation in nearly all vegetative parameters measured in my study (Table 15,16,17,18). From field reconnaissance and aerial photographs, the stands appeared to characterize geographic units within the islands temporal and spatial variations in physical conditions (water availability, thermal environment, solar energy).

Figure 16. Vegetation stands on Pic Island. Numbers in circles correspondes to stand numbers used in Table 15, 16, 17, 18.

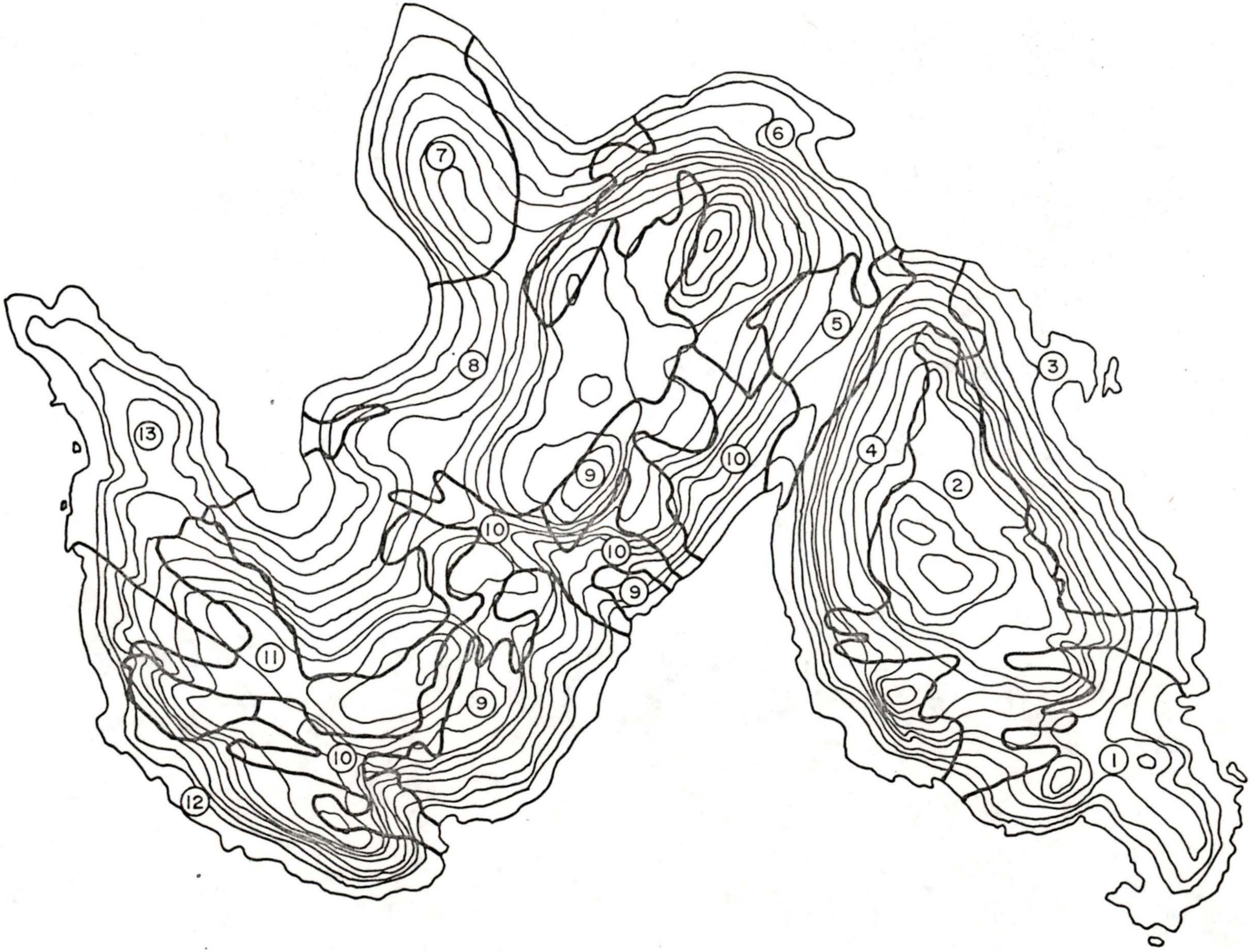

7
6
5
8
3
13
4
10
9
2
10
10
9
11
9
10
12
1

Table 15. Characteristics of 13 stands on Pic Island.

S	n	Area(ha)	Visitility	Slope (in degrees)	Mnt. Ash density (shrubs/ha)	Alder density (shrubs/ha)	Maple density (shrubs/ha)
1	17	72.0	28.82±3.28	15.71±5.00	7.39±3.56	7.80±3.29	3.58±0.39
1	15	108.4	30.67±3.34	24.00±7.18	16.01±3.91	40.58±8.21	3.21±0.02
3	13	59.5	32.22±3.24	38.50±6.75	4.55±0.76	104.76±32.7	5.61±2.20
4	15	84.6	31.07±3.06	36.78±6.08	6.30±2.45	51.05±15.1	3.18±0.00
5	20	30.6	48.75±99.67	5.00±5.00	21.91±4.37	77.04±2.53	17.21±8.39
6	15	99.1	50.00±6.31	16.67±3.22	15.24±5.50	88.46±52.3	7.36±3.37
7	15	56.0	41.20±7.20	12.33±3.27	8.76±3.42	68.09±13.8	3.18±0.00
8	28	189.5	44.00±4.67	12.50±2.25	15.49±5.82	69.37±23.3	25.83±16.2
9	12	67.0	50.50±9.32	16.11±3.09	47.76±32.2	56.50±19.9	3.18±0.00
10	20	95.4		9.00±1.63	57.57±25.4	15.66±8.45	72.53±38.8
11	20	46.7	33.50±3.10	17.50±4.73	16.53±3.32	69.53±39.2	3.18±0.00
12	16	66.8	27.50±3.34	52.27±9.89	25.01±4.76	48.51±10.8	6.30±3.11
13	13	69.8	32.92±5.09	12.00±2.44	5.07±0.96	35.49±14.4	3.80±0.69
total	219	1059.2		20.64±1.65	26.36±7.86	49.86±6.73	14.43±4.32
Analysis of variance between stands (S) (* = 0.05, ** = 0.01)				**			*

Table 16. Basal area for 13 stands on Pic Island.

Stand	Total	Balsam Fir	Birch	Black Spruce	White Spruce	Other Trees
1	15.05±2.40	2.88 1.40	2.76±0.87	9.06±2.38±	0.18±0.13	0.18±0.18
2	22.86±2.34	11.07±1.83	7.27±1.04	4.33±0.80	0.0	0.20±0.11
3	10.70±2.62	3.54±1.24	3.31±0.87	3.15±0.85	0.31±0.24	0.38±0.27
4	17.67±2.19	5.73±1.44	3.67±0.64	8.13±1.54	0.0	0.13±0.09
5	8.05±2.19	3.05±1.32	2.75±1.04	0.0	1.55±1.00	0.70±0.29
6	16.47±2.45	2.27±0.78	4.07±1.24	9.20±2.40	0.20±0.14	0.73±0.36
7	19.80±1.94	1.13±0.55	1.60±0.45	15.07±2.47	0.0	2.00±0.77
8	20.36±1.72	6.18±1.02	8.00±1.19	4.32±1.09	1.00±0.39	0.86±0.20
9	8.00±2.00	0.50±0.34	3.17±1.12	4.00±1.62	0.0	0.33±0.19
10	14.90±1.79	3.20±0.90	9.30±1.30	0.45±0.22	0.35±0.30	1.60±0.37
11	17.40±1.91	3.35±1.00	8.85±1.48	4.35±0.93	0.35±0.35	0.50±0.19
12	8.38±1.88	0.50±0.27	3.56±0.80	3.50±1.18	0.0	0.81±0.43
13	16.85±2.40	3.08±1.64	3.08±0.98	10.54±2.28	0.08±0.08	0.08±0.08
	15.40±0.66	3.73±0.36	5.10±0.35	5.49±0.48	1.68±0.11	1.38±0.09
sig.	**	**	**	**		**

Table 17. Abundance ($g/4m^2$) of forbs for 13 stands on Pic Island.

Stand	Bunchberry	Raspberry	Currant	*D.spinulosa*	*D.disjuncta*	*D.phegopterus*
1	0.0	0.0	0.0	1.24±1.24	4.24±4.24	5.65±5.65
2	0.0	0.0	0.0	0.0	0.0	0.0
3	2.46±2.46	0.0	0.0	2.92±2.92	9.15±7.92	0.0
4	0.20±0.20	0.0	0.0	0.0	0.0	0.0
5	12.70±5.28	60.2±44.6	8.90±6.40	11.4±2.63	41.1±11.6	7.65±6.80
6	2.60±1.46	5.87±5.87	0.67±0.67	7.13±5.86	8.20±5.90	6.13±5.16
7	1.0 ±1.0	0.0	0.0	0.0	0.0	0.0
8	5.93±2.35	0.0	2.64±2.01	1.25±0.64	9.98±7.54	2.79±1.94
9	1.0 ±1.0	0.0	0.0	0.0	0.0	0.0
10	8.75±4.04	72.9±68.8	38.1±30.9	11.50±4.33	14.1±4.36	10.25±3.55
11	6.70±2.04	0.0	2.0 ±1.38	1.40±0.78	1.30±0.92	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0
	3.79±0.77	12.55±4.61	4.86±2.93	3.14±0.69	7.86±1.79	2.85±0.94
	**	*		**	**	

Table 18. Abundance (g/4m) of forbs for 13 stands on Pic Island.

S	willow	alder	maple	ash	birch	No. forb species per 4 m²
1	0.0	0.0	0.0	0.0	10.24±6.68	2.76±0.30
2	0.0	0.0	0.33±0.23	0.27±0.27	18.27±9.08	1.80±0.26
3	0.0	3.77±2.40	0.0	0.0	45.54±30.9	2.00±0.41
4	0.0	4.07±3.03	0.0	0.0	7.27±2.97	1.87±0.24
5	0.15±0.15	0.0	4.80±2.41	4.20±2.43	84.55±31.6	8.15±0.65
6	3.93±3.93	3.60±2.91	1.07±1.07	2.20±1.93	30.53±14.2	3.53±0.89
7	0.0	0.0	0.0	0.0	1.93±0.89	3.00±0.31
8	1.79±1.79	3.86±2.18	1.50±1.10	1.61±0.64	5.00±2.18	3.36±0.60
9	0.0	4.17±4.17	0.0	0.92±0.92	2.17±2.17	2.42±0.58
10	0.0	0.0	13.9±5.86	2.45±1.49	23.35±17.7	6.95±0.88
11	2.60±1.81	5.75±4.37	0.0	0.70±0.33	5.55±2.94	5.10±0.66
12	0.0	1.13±1.13	0.0	3.00±1.88	74.94±30.7	1.88±0.38
13	0.0	0.0	0.0	0.0	37.15±24.1	1.77±0.30
	0.75±0.39	2.08±0.63	1.99±0.65	1.32±0.34	26.27±5.03	3.68±0.21
			**		**	**

5.3 Otter Island vegetation compared to Pic Island

Two areas of relatively high densities of caribou, Pic Island and Otter Island, were used to descripe caribou feeding preferences during the period from leaf emergence in the spring to July 28 (1980). Fifty vegetation plots on the 212.0 ha. Otter Island were compared against a sample of 219 plots on the 788 ha. Pic Island.

Caribou remain on Pic Island the year round, yet there is more abundant food 1 km swimming distance away on the mainland. Browsing pressure is significant, since approximately 40 caribou have occupied the 10 km^2 island for at least 10 years. On the other hand, Otter Island (2.5 km^2) supported only two caribou (Ferguson and Ferguson 1980) during the period of the vegetation study and probably a similar number of caribou resided here during the spring and summer leaf growing season.

The preferece of shrub species by caribou on Pic Island was less variable than caribou preferences on Otter Island (Table 19). This likely resulted because browsing pressure on Pic Island had reduced species which were highly preferred. On Otter Island the preferred forb species were: rose, squashberry, mountain ash, ferns, and poplar seedlings. Sarsaparilla accounted for 90 percent of the forb biomass eaten and aster accounted for 80.2 percent of the forb biomass available (Table 20). Of the Otter Island shrubs, mountain ash, squashberry, dogwood and poplar scored highest on the preference index (Table 19), while mountain ash accounted for 41.1 percent of the shrub biomass eaten compared to alder which accounted for 54 percent of the shrub biomass available.

Table 19. Shrub biomass available and utilized by caribou compared between Pic Island and Otter Island.

species	Pic Island			(weight in grams) Otter Island		
	available	eaten	P	available	eaten	Preference Index
Populus tremuloides	0.397	0.022	+0.977	20.88**	12.58**	+0.408
Salix spp.	8.702	1.057	+0.796	125.0**	11.25**	-0.018
Acer spicatum	25.64	5.974	+0.703	286.6**	26.11**	-0.176
Amelanchier sanguinea	7.482	0.304	+0.548	7.640	0.159	0.000
Prunus spp	6.618	0.215	+0.512	34.42*	0.0	-0.377
Sorbus americanus	173.3	59.85	+0.114	133.6	58.56	+0.675
Alnus crispa	408.6	67.44	-0.594	433.1	7.264**	-0.953
Viburnum edule	0.001	0.0	-1.000	2.229	0.0	+0.580
Cornus stolenifera	0.0	0.0	?	14.91	3.143	+0.574
total		630.70	134.80	1058.25	107.74	

Table 20. Comparison of forb biomass between two islands of high density and the mainland with low moose, deer and caribou densities.

Species	weight (g) per bite	multiple range test	density low (0.4/km²) Mainland	high (10/km²) Bic[1] (g/4 m²)	medium (1.0/km²) Otter[2]
Betula papyrifera	0.0409	available**	0.2356a	1.0740**b	0.2356**a
		eaten **	0.0638a	0.0479**b	0.0 **a
Sorbus americana	0.0695	available	0.1434	0.0914	0.0473
		eaten	0.0092	0.0231	0.0320
Acer spicatum	0.0734	available**	3.6760b	0.1461**b	0.3112a
		eaten	0.0178	0.0446	0.0088
Alnus crispa	0.0699	available	3.6760	0.1461**	0.3112
		eaten *	0.0178	0.0446	0.0088
Amelanchier	0.0336	available**	0.1707a	0.0090**b	0.0235b
		eaten	0.0028	0.0	0.0
Salix spp.	0.0367	available	0.0546	0.0275	0.0
		eaten	0.0028	0.0	0.0
Populus tremulodies	0.1109	available	0.1224	0.1778	0.4369
		eaten *	0.0	0.0263	0.0998
Prunus virginiana	0.0467	available	0.0668	0.0205	0.0
		eaten	0.0	0.0066	0.0
Cornus stolenifera	0.0816	available	0.0873	0.0056	0.0
		eaten	0.0	0.0015	0.0
Vibernum edule	0.1080	available *	0.9913a	0.0*b	0.0086**ab
		eaten	0.0414	0.0	0.0043
D. phegopterus	0.148	available	0.3996	0.4217	0.0533
		eaten	0.0006	0.0724*	0.0059
D. disjuncta	0.158	available**	0.5180a	1.2416*b	0.111 **b
		eaten	0.0	0.1537	0.0
D. spinulosa	0.289	available**	1.352a	0.0906b	0.0116**b
		eaten **	0.0181	0.2679**	0.0
other ferns	0.431	available**	1.9860a	0.0295b	0.0431b
		eaten	0.0392	0.0009	0.0
Ribes glandulosa	0.1163	available	0.0204	0.5650	0.0
		eaten	0.0	0.0250	0.0
Ribes americana	0.1163	available*	0.0126a	0.0 a	0.349 *b
		eaten	0.00145	0.0	0.0
Fragara vesca	0.0285	available*	0.0274a	0.0 *b	0.0017 *b
		eaten	0.0006	0.0	0.0
Rubus sp	0.0563	available**	1.587a	0.7065**b	0.0090**c
		eaten	0.0014	0.1296	0.0
Rubus pubescens	0.0546	available	-	0.2494	-
		eaten	-	0.0325	-
Rubus strigosus	0.0580	available	-	0.4628	-
		eaten	-	0.0990	-
Rubus parviflorus	1.136	available	0.1704	0.0.	0.0
		eaten	0.0	0.0	0.0
Epilobium sp	0.323	available	0.257	0.0133	0.0
		eaten	0.0132	0.0044	0.0

Aralia nudicaulis	1.153	available**	8.235b	C.1106**a	0.996ab
		eaten **	0.1057a	0.0369a	2.883b
Cornus canadensis	0.0816	available**	1.5347a	0.3093**b	0.4912b
		eaten **	0.0 a	0.0443**b	0.0571b
Actae rubra	0.0817	available	0.0828	C.0	0.0
		eaten	0.0	C.0	0.0
Gallium triflcrum	0.0297	available	0.0137	0.0019	0.0
		eaten	0.0	0.0003	0.0
Diervilla lonicera	1.059	available**	0.3971a	0.C194**b	0.0424b
		eaten	0.044	C.0	0.0
Aster macrophylus	1.243	available**	0.1554a	0.0 a	32.716**b
		eaten **	0.0a	0.0a	0.0249 *b
Rosa sp	0.196	available*	0.0604ab	0.0 *a	0.1333**b
		eaten **	0.0a	0.0a	0.0510*b
Vaccinium spp	-	available	2.310	3.221	2.290
		eaten	0.0	0.069	0.0
Ledum groenlandicus	-	available	1.658	1.832	5.118
		eaten	0.0	0.0	0.0
Total		available	26.555	11.788	48.294
		eaten	C.2965	1.1291	3.1668

Any two means standard error fcllcwed by a common letter belong to a subset, whose highest and lowest means dc not differ by more than the shortest significant range at the five percent level (** 1%).

[1] t-test for 2 group ccmparison between Pic Island and the adjacent mainland.

[2] 2 group comparison between Pic Island and Otter Island.

In comparing the two islands it appears that to compensate for the lack of sarsaparilla on Pic Island, caribou have switched to grazing on ferns and seedlings. Alder assumed a more important role on Pic Island once other preferred shrub species (Table 21) had been used. On Pic Island, very little dogwood, sarsaparilla, big-leaf aster and squashberry are present, all of which were important spring-summer foods for caribou on Otter Island. This can be attributed to the different habitat and/or to past grazing pressures.

Table 21. Biomass of forb species eaten by caribou on Pic and Otter Islands and by moose on the mainland.

Species	Mainland $g/4m^2$	Pic Island $g/4m^2$	Otter Island $g/4m^2$
deciduous suckers[1]	0.0712	0.1932	0.1449
ferns	0.0635	0.4946	0.0059
Ribes spp.	0.0015	0.0250	0.0
Rubus spp.	0.0014	0.2611	0.0
Cornus canadensis	0.0	0.0369	0.0571
Aralia nudiclaulis	0.1057	0.0440	2.883
other forbs[2]	0.0578	0.1707	0.0759
total	0.2970	1.1295	3.1672

[1] birch, mountain ash, maple, alder, saskatoon, willow, poplar, cherry, dogwood, squashberry.

[2] blueberry, strawberry, Rubus parviflorus, fireweed, three-flowe bedstraw, bush honeysuckle, rose, big-leaf aster.

The two islands showed no significant difference in the number of species per 4 m^2 plot (3.81 ± 0.341 (44) versus 3.99 ± 0.219 (202)), amounts of arboreal lichen (0.188 ± 0.0337 g/m^2 versus 0.230 ± 0.0168) or ground lichens (2.00 ± 0175 cm^3/m^2 versus 3.00 ± 0.01).

5.4 Population Genetics

5.41 Methods:

5.411 Field phase:

Blood and tissue samples were taken from trapped and immobilized caribou. For each animal one vial of blood was frozen (-40 °C) whole without heparinization. Another sample was centrifuged in the field within 5 hours and vials of serum and red blood cells frozen. C. Reuterwall (pers. comm., Department of Human Genetics, University of Arhus, Denmark) considered that whole blood samples withstand fairly rough treatment without hemolyzing as compared to moose, red deer (_Cervus elaphus_), or roe deer. A plug of muscle and ear tissue was taken with biopsy instruments and frozen with an equal volume of saline. These samples were kept in a deep freezer until time to transport them to a laboratory at the University of Guelph, when they were packed in dry ice and driven there.

5.412 Laboratory phase:

The electrophoretic technique is to allow protein to migrate in a slab of starch or acrylamide gel under the influence of an electric field. Different mobilities are due to different electrostatic charges. Specific histochemical stains are applied directly to the electrophoretic medium with bands of stain representing phenotype, enzyme activity protein concentration and electromorph.

Tissues were partially thawed and homogenized in an equal volume of deionized water. The homogenate was then frozen at -70°C, thawed and clarified by centrifugation at 14,500 G for 30-40 min. at 4°C. The supernatant was stored at -70°C.

Starch-gel electrophoresis was carried out at room temperature of about 22°C employing methods of Selander et al. (1971). A series of experimental trials were performed in order to determine the most favorable buffer system, tissue type, and running time which produced the best resolution of the following soluble enzymes: esterase, lactate dehydrogenase (LDH), transferrins and haemaglobin. Dr. J.P. Bogart at the University of Guelph carried out the electrophoreses.

5.42 Findings:

By the mid 1960's, electrophoretic techniques were sufficiently refined to be introduced to population genetics by Lewontin and Hubby (1966) in their analysis of natural populations of Drosophila, and by Harris (1966), in his studies on human populations. These multi-loci studies were the beginning of a new method of analysis of genetic variation and population structure (Gottleib, 1971).

Since we cannot directly measure genetic variation in DNA, estimates of genetic variation in populations are based on heterogeneity of structural gene products (enzymes and other proteins). These analyses use indirect measures of structural heterogeneity, since techniques of amino acid sequencing are too time consuming and expensive (Selander 1976). Electrophoretic mobility of protein provides indirect information about DNA thereby justifying the common practice of referring to segregating proteins as alleles (alternate forms of a gene).

Work on the blood protein of reindeer (Braend 1964, Gahne and Rendel 1961, Nadler et al. 1967) has reported great variation, with the transferrin genotype being especially variable. Recent literature comparing non-temperate cervids (Baccus et al. 1979) describe reindeer as having the lowest heterozygosity (H = 0.014) in comparison to white-tailed deer which showed significant differences in their heterozygosities. The range within this one deer species was almost as great as that across the other seven cervid species studied. Baccus et al. (1979) suggest that perhaps white-tailed deer are more of a habitat generalist on the average since there is a trend for habitat generalists to have higher heterozygosities (Nevo 1978). However, there is no obvious correlation between heterozygosity and the size of the species range which is the characteristic Nevo used to define habitat generalists. As additional data have accumulated, many of the earlier hypotheses about genetic variation have not been substantiated (eg, body size of mammals). Certainly the examination of cervid genetics has just begun and the importance of electrophoresis as a tool of observation is yet to be completely realized.

Once a population becomes partially or completely isolated we expect that this will be reflected in an alteration of the gene frequencies due to genetic drift, inbreeding, or founder effects. Therefore isolated or even partially isolated poulations should become genetically distinctive (Lavigne et al. 1979). The indication of high variability in gene frequencies for Pic Island caribou population suggests no founder effect has occurred.

Three of the four proteins analysed were shown to be heterozygous (LDH homozygous) in a sample of only five caribou. Transferrins revealed three loci, two with different alleles. It would be of interest to determine the origin of the north shore caribou by comparing genetic patterns. Whether they are remnants of the early 1900's Ontario population or predecessors of a group of six caribou which were released on Caribou Island, Lake Superior around 1903. Carter (1979) describes how several hundred of these Island caribou crossed the frozen ice to the mainland at about 1925. Also in 1934 the Ontario Ministry of Lands and Forest transported part of the herd to the mainland north of Lake Superior, while the last caribou on the Island was apparently shot about 1950.

5.43 Inbreeding: Low levels of genetic variation are found in certain populations which are isolated on islands or found on refuges (Selander et al. 1971 and 1974). Genetic drift results in the fixation of alleles thereby reducing heterozygosity and genetic variation. Also because the population will remain small for several generations, genetic drift is further enhanced in populations with low rates of increase (Cavelli-Sforza and Bodmer 1971). The deviation between the observed and expected number of heterozygotes can be used to calculate an inbreeding coefficient (Wright 1969), from the data on the genotypic arrays for the variable loci collected from electrophoretic analysis. Inbreeding should result in a decrease in heterozygosisty and reduced genetic variability compared to that expected in a randomly breeding population. There is now good evidence (Ralls et al. 1979) that inbreeding in small populations of ungulates results in increased juvenile mortality.

5.5 Blood Characteristics of Pic Island Caribou

5.51 Methods:

Blood was sampled from the lateral saphenous vein, with some collected in EDTA for hematology and the remainder allowed to clot 2-4 hours and separated by centrifuge for preparation of serum. Serum and whole blood was frozen, and transported to the Forest Wildlife Research Laboratory at Grand Rapids, Minnesota for chemical analysis to determine 30 assays. Hematology and routine chemistry assays were described by Karns and Crichton (1978).

5.52 Findings:

Condition can be evaluated by making comparisons between different blood assays from populations in different habitats or the same population can be measured over more than one year (Seal *et al*. 1972). Assays reflecting metabolic differences have potential for interpretation as indicators of the status of animal populations and the condition of habitat. Le Resche *et al*. (1974) considered PCV (hematocrit) and BUN as good indicators of condition for moose and Seal (1978) considered RBC, BUN, PCV, cholesterol, LDH, and T-4 as reasonable indicators of condition for white-tailed deer. The three blood variables BUN, hematocrit, and glucose were found to vary between the three years of blood collection on the Slate Islands for caribou (Ferguson unpublished).

To determine whether any yearly differences might be significant, the effects of age, sex, seasons, and reproductive condition which have been democstrated for most big game species in North America (Franzmann 1972, Seal et al. 1972, Franzmann et al. 1975), must be first taken into consideration. The sample from the island (Table 22) is too small to detect any of these differences, and its usefullness is limited to describing Pic Island caribou population in a comparison study.

Table 22. Hematolcgy and blood chemistry of Eic Island caribcu (captured 1978-81).

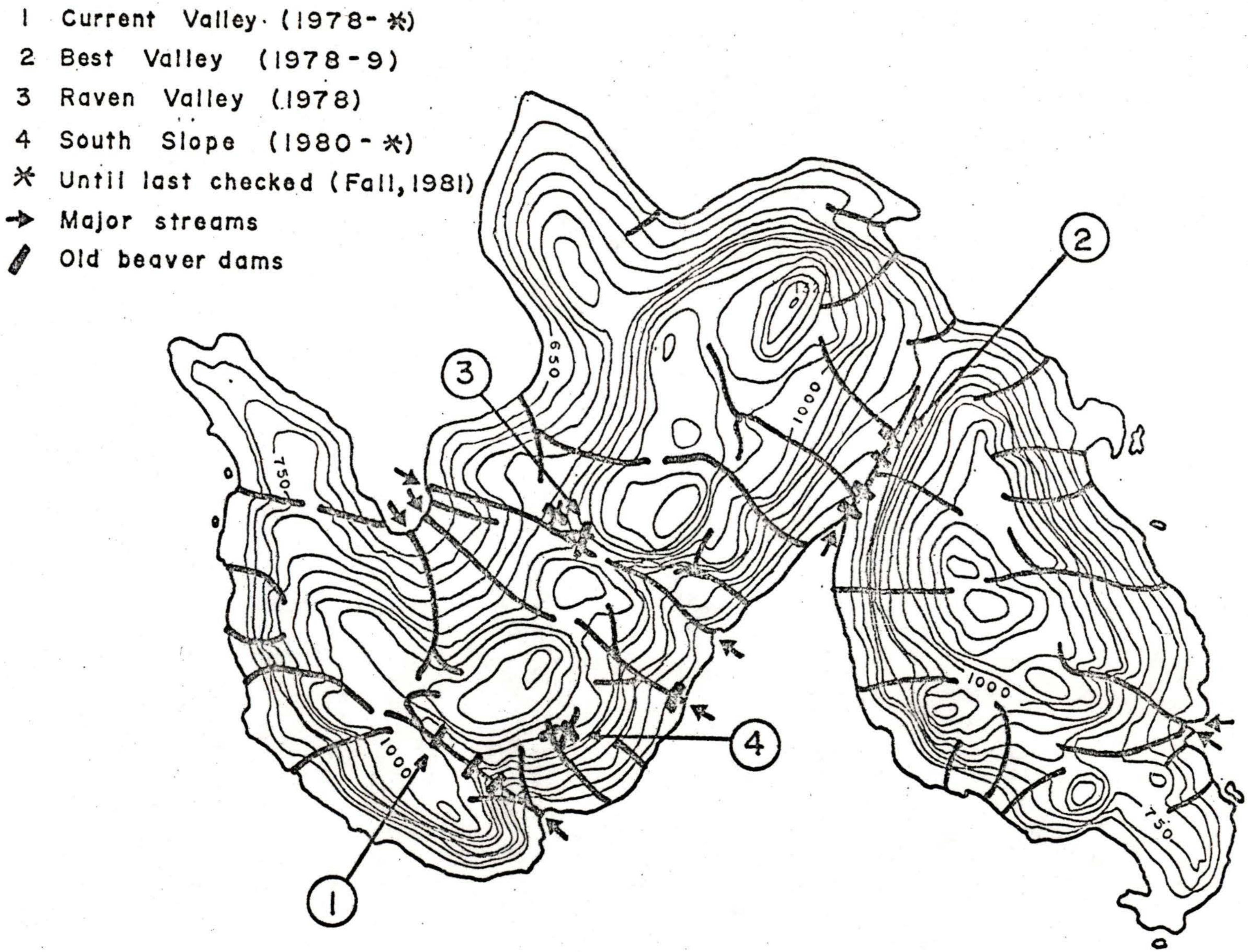
Date	sex	age	Hb	LDH	AlkP	Chol	Gluc	BUN	Creat	T.P.	Alb	Glob	Ca	Cu
1979														
7/26	f	yrl.	15.1	1060	8.9	77	20	25	1.5	4.9	4.10	0.80	9.9	-
8/11	m	ad.	-	784	8.2	89	161	24	1.7	5.0	3.70	1.30	9.8	-
1980														
4/23	m	calf	19.0	678	7.6	60	-	-	1.2	5.3	4.12	1.18	6.5	51
4/26	f	ad. P	17.4	360	5.9	51	-	-	2.1	5.1	3.93	1.17	9.0	46
4/27	f	2yr.NP	18.8	1102	11.5	57	166	16	2.5	4.6	3.97	0.63	9.5	127
4/29	m	2-3yr	18.1	869	8.7	53	181	22	2.4	4.6	4.04	0.56	8.9	32
5/4	m	calf	16.7	721	10.0	48	-	-	1.2	3.7	3.04	0.66	7.4	51
5/5	m	hummel	17.8	763	11.1	115	33	22	1.8	6.8	3.74	3.06	9.8	67
6/19	m	ad.	-	1100	9.5	80	281	35	1.0	6.4	4.28	2.12	9.5	70
6/26	m	yrl.	16.1											
1981														
4/30	m	2yr.	16.6	760	7.2	58	127	14	2.2	5.0	3.50	1.50	7.0	54
5/2	m	calf	16.7	640	13.2	63	10	1	1.7	5.0	3.73	1.27	9.1	46
5/13	m	calf	16.0	600	6.4	49	165	18	1.5	4.7	3.61	1.09	9.3	56
5/15	m	ad.	17.8	720	8.6	57	204	21	2.5	5.3	4.33	0.97	8.8	41
5/20	m	ad.	16.3	1160	11.5	68	66	68	2.0	5.1	3.81	1.29	6.1	44

Hb = hemaaglobin, IDH = lactic dehydrogenase, AlkP = alkaa line phosphatase, Chol = cholesterol, Gluc = glucose, BUN = blood urea nitrogen, Creat = creatine, T.P. = total protein, Alb = albumin, Glob = globulin, Ca = calcium, Cu = copper.

5.6 Status of Beaver on Pic Island

From the 1962 aerial photos eight active beaver colonies were located on most of the nine major water systems of the 10 km² island (Fig. 17). The 1974 aerial photos reveal no beaver activity as did ground observations in 1976 and 1977. South of highway 17, only one active beaver colony remained in the mid-1970's and that was a lodge built on a sunken dredger in Port Coldwell harbor. Recolonization of the Neys Lake water system draining into Port Coldwell harbor, occurred during the summer of 1978. Young beavers, probably from the Lake Superior lodge, were observed along the Coldwell Peninsula and Pic Island shoreline. By August of 1978 two other beaver colonies were established in this area: one on Neys Lake and one on the island (Currant Valley beaver meadow).

Figure 17. Drainage patterns and sites of recent (1976-1982) and old (1960's) beaver activity.


1 Current Valley (1978-*)
2 Best Valley (1978-9)
3 Raven Valley (1978)
4 South Slope (1980-*)
* Until last checked (Fall, 1981)
Major streams
Old beaver dams
650
750
1000
1000
1000
750
1
2
3
4

The main beaver colony on the island has persisted (1978-1981) despite difficulties in obtaining food in the overmature habitat; food trails during the first year of colonization were greater than 40m and included one trail up a 75° slope rising 15 m; by May of each spring (1979-1981) the winter food cache was completely depleted; all of the hardwood used in the dam and lodge was de-barked; the lodge was primarily constructed of mud; balsam fir trees were used in dam construction; and after their first year of residency only one beaver kit was born in 1979. During the summer of 1978 dams were started in NW Raven Valley and Best Valley, but only the latter persisted through the winter.

The island retained no consistent fresh water source, during the summer of 1979 which was the driest in the 1977-81 period. The best dam, built in Currant Valley was lowered to a 30 cm water depth and by August the entrance to the lodge was visible above the water line. The beavers resorted to constructing terraced dams beneath the major pond in an attempt to retain water. The Best Valley dam dried up and by July the beavers had left or died. A skull of a beaver, estimated to have died in 1978 was found in this valley during the summer of 1979.

The summer of 1980, although not reducing water levels to the low of 1979, was still a relatively dry year (the second lowest water levels recorded, 1977-1981). The dams in Currant Valley continued to be built upon but they remained weak and easily broken. Also, food trails increased in distance to 0.3 km. In 1980 a lodge and three ponds were built east of Currant Valley along the south shore, likely by the offspring of the former colony. All of the four beaver residences built during the study period were on previously occupied (1960's) dam sites. The beaver colony, on Neys Lake of the mainland, had expanded further inland during 1979 and 1980, as offspring of this lodge followed up the lakes waterways.

Food supplies for beavers on the island have been declining steadily for at least 35 years, as aspen and birch dating from the fire of 1847 (Agassiz and Cabot 1850) have been cut back farther and farther from water. Fluctuations in beaver numbers is more dramatic on islands, and for Isle Royale (Shelton, 1979) more dramatic inland than on its harbors. Shelton (1979) suggested tularemia caused the decline in beaver in the 1950's. Tularemia is easily spread among stream dwelling beavers, which suffer the annual changes in water level fluctuations, compared to those living on larger bodies of water.

Although the beavers on Pic Island are free from their major predator, the wolf, they have inherited other regulatory factors which may make recolonization of the island impossible. The forests are more mature compared to the last period of beaver colonization in the 1960's. Periodic and seasonal low water levels can create an ideal situation for disease, such as tularemia. This could explain the sudden disappearance of beaver from the Neys area during the late 1960's.

Beaver activity has a noticeable effect on the environment and these changes on the island can be related to the caribou's life history. Beaver dams create an edge effect which can increase the variety of foods available to caribou. Also, beaver cutting activities change the overstory canopy by removing hardwoods and creating blowdowns. Both results could be beneficial to the caribou's food source, depending on the kind of new growth which succeeds the mature habitat. Generally on Pic Island, the regrowth after disturbance is Balsam fir which is unpalatable to caribou. A major effect on the habitat occurs when a beaver dam becomes inactive and creates a beaver meadow. The dead trees provide arboreal lichens and the meadow vegetation is preferred by caribou during the spring (eg. horsetail, sedge and grasses). In some cases deciduous growth, usually in the form of suckers, increased in beaver meadows and in moist blowdown areas which provide prime summer foods for the caribou. Last, the open meadows and blowdown areas also provide an arena for the fall rutting displays of caribou.

5.7 Home Ranges of Caribou

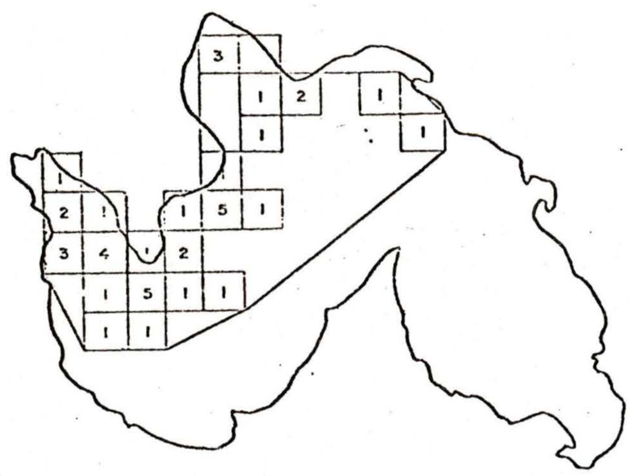
Home ranges are defined (Harestad 1981) as an integrated expression of an animal's locations and movements over a specific time interval. A regression of home range area on the number of fixes suggested that other factors, besides the number of times caribou were located by telemetry, were determining the variations in home range size observed in 1980 (Table 23). The difference between home range sizes between spring (April 26 - July 2) compared to fall (September 9 - October 2) for the five animals was significant. Smaller home ranges in the fall could be due to the shorter time period locations were taken and/or to the rutting activities of the associated animals. Variation in range sizes was significantly greater in the fall and is probably the result of the variation in activity of animals during the breeding period.

Table 23. Home ranges of individual radio-collared caribou during summer and fall, 1980.

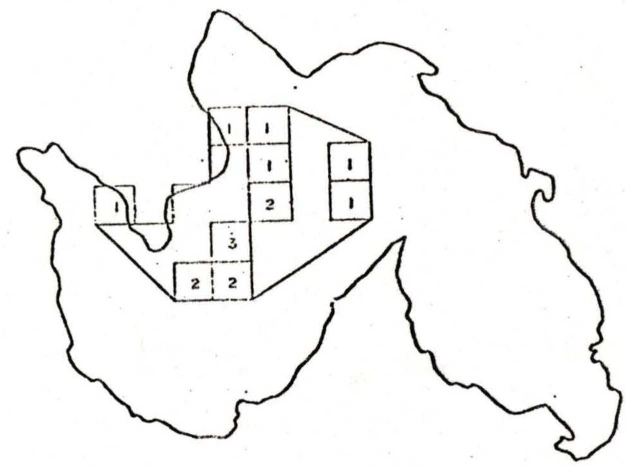
animal	April 26 - July 2		Sept. 9 - Oct. 2	
Ma	4.84 km^2	(n=35)	2.58 km^2	(n=15)
Rang	5.72	(36)	3.79	(14)
If	6.26	(31)	6.38	(17)
Tu	5.93	(24)	3.78	(18)
Bo			2.64	(11)
Total (mean±s.e.,n=5)	5.69±0.31		3.83±0.69	

Because the sample size was only five animals, comparisons with age, sex and reproductive classes was not possible, but it appeared that the younger animals displayed larger home ranges, fewer patterns or traditions in movements and were less predictable. An older female caribou (Ma, Table 4) who gave birth to a calf in 1980 and 1981, had the smallest home range size during the spring to fall period for both years (Fig. 18) and showed the greatest predictability in movement patterns. In 1980 (June 1 - July 2) after giving birth to a male calf during the first week of June, Ma and her calf remained in a small belt of area ranging from NE Point through Windy Bay to #4 Valley. In 1981 she remained in Maple Valley from May 16-26, then in the Windy Bay to #4 Valley area from May 28 - June 11, during which she likely gave birth to her female calf, and then moved back again to Maple Valley from June 12-23, after which she and her calf used most of the island.

Figure 18. Home ranges of four caribou during the summer (April 26 - July 2) and fall (Sept. 9 - Oct. 9). Numbers refer to the number of times the caribou was located in the 0.11 km^2 area.

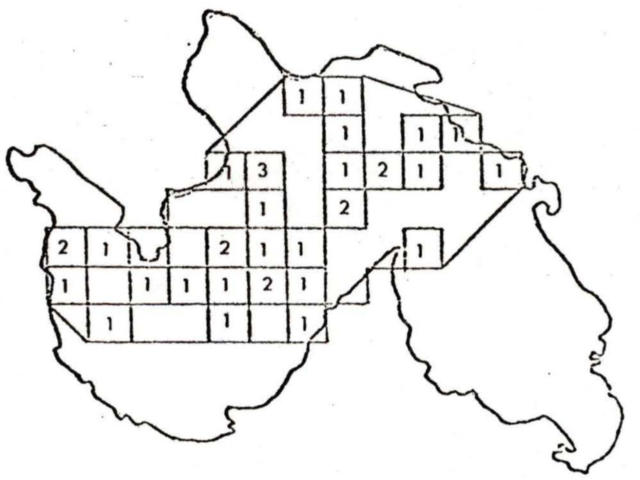


SUMMER

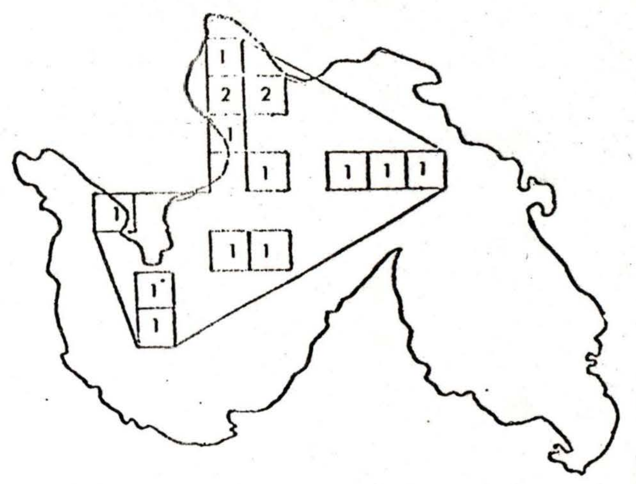


FALL

MA (>4 yr female) CALF

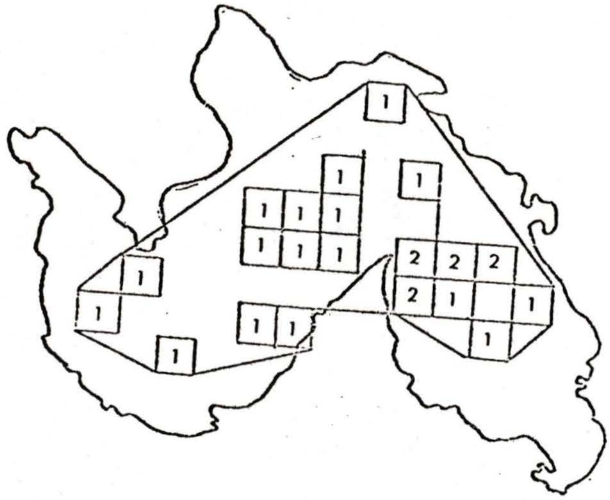


SUMMER

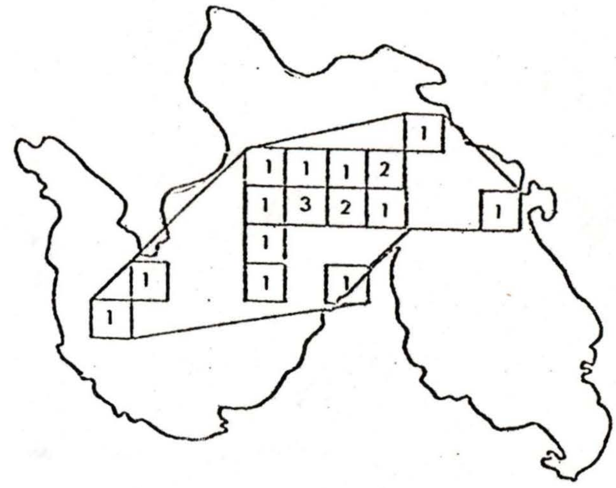


FALL

RANG (2.5 yr female)

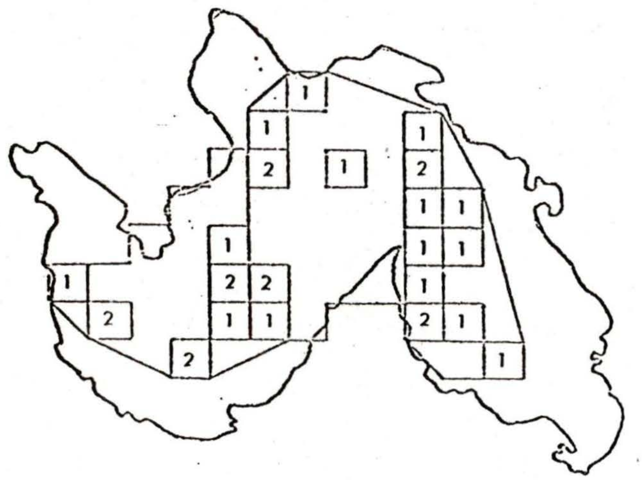


SUMMER

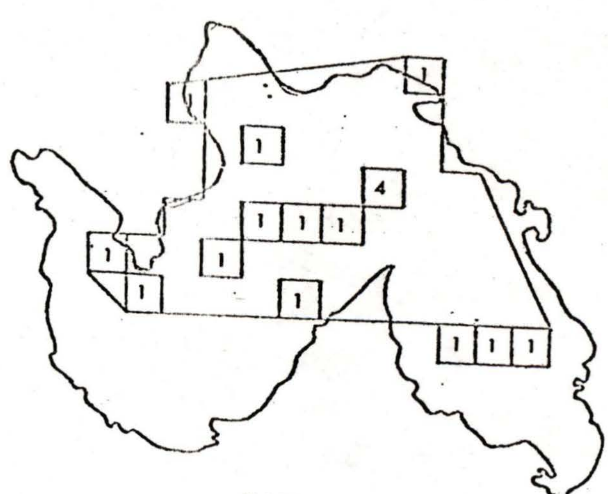


FALL

TU (>4 yr male hummel)



SUMMER



FALL

IF (3 yr male)

5.8 Caribou Aggregations

Group size varied seasonally (Table 24). Other than cow-calf combinations, caribou avoided each other and remained as singles once calving began in late May. Group size increased during the fall rutting period in September, with rutting groups of three-nine animals being observed. Aggregation groups of two-four caribou were not unusual during the winter and early spring (Table 24). Still the individual animal remained the most common social unit, other than cow-calf combinations, throughout the seasons.

Table 24. Seasonal changes in group size.

group size	April 14-May 20	May 21-June 31	July 1-Aug 31	Sept 1-Oct 17	Nov - April
one	44	39	29	25	3
two	6	9[1]	4[2]	1[3]	1
three	3		1	3	
four	2			1	
five				1	1
six				1	
seven					
eight					
nine				1	
no. obs.	55	48	34	33	5
total C	73	57	40	59	10
$\bar{X}\pm se$	1.33±0.10	1.99±0.06	1.18±0.13	1.79±0.30	2.00±0.96

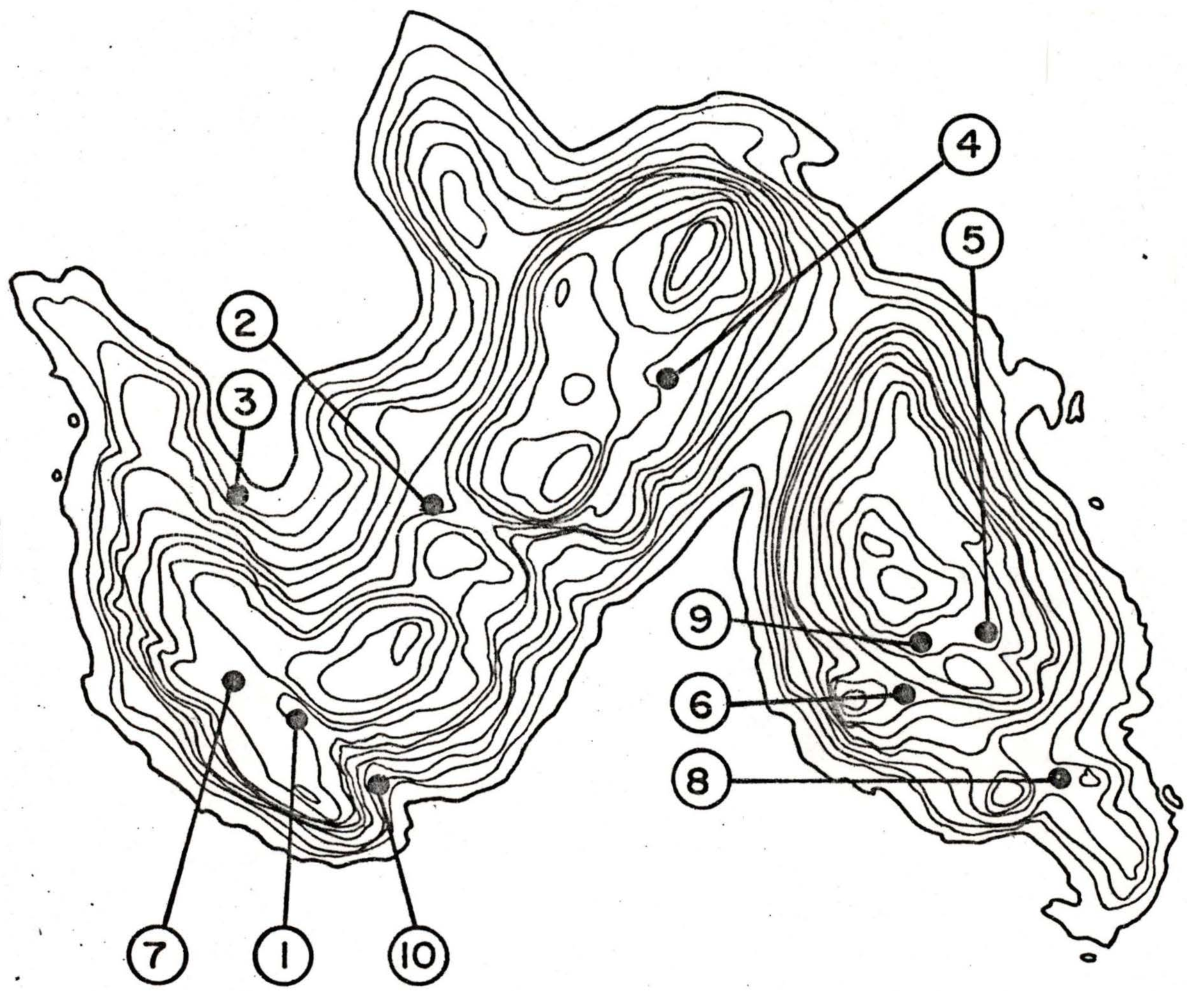
[1] Eight of the nine pairs of caribou were cows with their calves

[2] Two of four pairs were cows with their calves while six lone calves were observed

[3] Of 59 caribou observed in the fall of 1980, 34 were in groups associated with rutting activity (4.29±2.14, n=8)

To test whether caribou form post-calving aggregations, all calf tracks were recorded from June 16 to July 11, 1979 (Fig. 19). A 2-tailed Poisson variance test was used to show that the coefficient of dispersion of the points (C.D. = 1.54) described a random distribution ($P < 0.05$). The caribou did not form post-calving aggregations and did not have localized calving areas.

Figure 19. Location of caribou calf tracks (June 16 - July 11, 1979). Numbers indicate the earliest to latest dates located.


4
5
2
3
9
6
8
7
1
10

5.9 Cow-calf Behavior

Vocal sounds were used by caribou to communicate and communication is necessary for social interaction. Caribou were more vocal during early spring (April-May) and during the rut (September-October) than during the remainder of the year. Cow grunts to a calf were rare and only used by females trying to relocate calves in situations of potential danger. The calves were more vocal in trying to maintain close ties with their mother, but not as vocal as cow-calf combinations in open environments (Lent 1974). Later in the summer cow-calf bonds weakened and the sighting of lone calves was not unusual. During July 1 - August 31, only two of four pairs of caribou observed were cows with their calves (Table 24), while six lone calves and one lone female with an udder were seen. Calves were never observed hidden by their mothers as occurs in deer (deVos *et al*. 1967), but they did remain sedentary while the cow roamed to feed. The behavior of the cow-calf combinations on the island agreed with Hardin *et al*. 's (1976) hypothesis, that higher densities and the absence of predation, results in weaker social bonds and fawns (Key deer) behaving more independent at an earlier age. Observations of lone calves were not uncommon, although the mother's strategy of leaving the young while feeding is expected from forest dwelling cervids (black-tailed deer, Cowan 1956; mule deer, Linsdale and Tomich 1953; elk, Altmann 1963; and moose, Markgren 1969).

5.10 Escape Behavior

A flush was considered the initial reaction of a caribou to the approaching observer which resulted in a hard run away from the flushing stimulus.

A typical caribou encounter during the spring or summer was initiated by the animal alerting to the sound of the approaching observer (91% of the 83 observations) and flushing to sight of movement (48% ,n=79) or sound (41% ,n=79). The caribou then ran an average of 26.29 ± 3.98 m (n=70) before stopping. The total observation which included circling behavior and sometimes second and third flushes lasted an average of 3.91 ± 0.44 min. (n=70). During the fall rut period, caribou relied more on their sense of smell to flush (47% ,n=30) but still alerted primarily to sound (75%, n=12). While caribou ran further during the fall (48.65 ± 6.47 m, n=32, n=32), the length of observations was longer (5.96 ± 2.12 min., n=32). No significant stimulus was determined for the wheezy snort associated with some flushes (sight and movement 9/21, scent 4/21, sound 3/21).

Sighting distances varied with sex, age and reproductive status of the individual animals. Females may have initiated a flush at a greater distance from the observer (radial distance = r) than males, especially cow-calf combinations (Table 25). Lone calves waited until the observer was relatively close before reacting. The distance at which caribou flushed varied seasonally (Fig. 20). All animals flushed significantly further in the early spring than the summer. Possibly the density of vegetation affected detection.

Table 25. Sighting distances (meters from the observer to the caribou at the moment the flush was detected) from line transect census lines on Pic Island.

	sighting distance (meters) X ± s.e.	(n)
males	22.3 ± 1.4	(17)
females	24.3 ± 2.7	(12)
calves	19.3 ± 6.2	(3)
cow-calf	37.0 ± 11.8	(4)

Several characteristics of a flush became apparent from observations of caribou while I was walking transect lines, during predator simulation, and during telemetry observations (Table 26). If the animal anticipated a threat from the flushing stimulus it ran hard, zig-zagged if the predator was close, used the easiest and best caribou trails when available, and ran uphill if it was flushed in a valley initially. Only one observation of caribou using the water as an escape strategy was noted. A calf I chased, jumped into Lake Superior and followed the shoreline for 1 km, until it had successfully eluded me.

Figure 20. Average flushing distances (95% C.L.) for adult caribou observed on census lines.

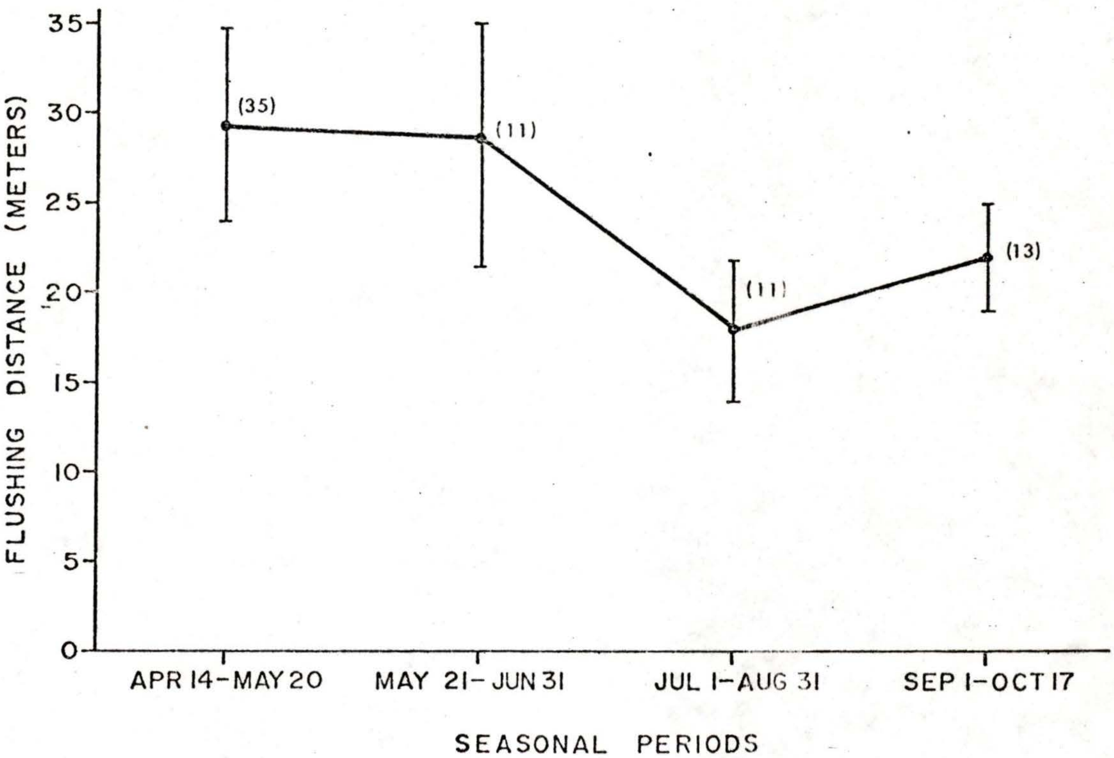

35
30
25
20
15
10
5
0
FLUSHING DISTANCE (METERS)
(35)
(11)
(11)
(13)
APR 14-MAY 20
MAY 21-JUN 31
JUL 1-AUG 31
SEP 1-OCT 17
SEASONAL PERIODS

Table 26. Movement behavior of radio-collared caribou when approached by ground using telemetry.

Animal	Date	Hours	Dist (km)	Time (minutes)	Speed	Habitat	Observations
Ma&c	April 28	1400-1545	0.69	10	4.14	13-8	Sh Tr
>4yrF	May 1	1400-1500	0.23	15	0.92	13-8	Sh Tr
			1.42	45	1.89		
	May 26	1915-1930	0.26			13	Sh Tr
			0.81	10	4.87		
	June 7	2130-2200				8-11	Up
	June 8	1940-2015	0.66	6	6.59	8	Sh Tr
	June 9	1522-1645	1.57	25	3.77	6-8-7-8	Sh Tr
	June 17	1830-2045	1.02	30	2.04	8	Va Tr
	July 2	1147-1300	0.76	38	1.20		Va Tr
Rang 2yrF	April 27	1030-1130	1.42	60	1.22	8-6	Up
Tu >4yrM	June 20	1400-1415	0.61	30	1.22	4-5	Sh Tr
Rang	June 20	1130-1415	1.10			4-5	Va Tr Ci Up

Up = ran uphill
Tr = used trails and easy running areas
Zz = zig-zagged
Ci = circled
Sh = followed shoreline (within 0.2 km)
Va = used valley

Hb = habitat used (- = ran to) see Fig. 16

Animal = description of caribou (age and sex), Hours = time of day, Dist = distance caribou ran, Time = length of time dog chased cario
Speed = Dist/Time

For the predator simulation (Table 27) a dog chased one of three caribou on five runs for a short distance (0.23 ± 0.14 km) lasting less than 10 minutes. The caribou responded by running 1.64 ± 0.42 km in 30.4 ± 8.4 minutes, averaging 3.24 ± 0.86 km/hr. The fastest initial rush was recorded by a female (Ma) when she averaged 12 km/hr for five minutes. This flushing speed appears quite slow, unless the density of the vegetation and the ruggedness of the terrain is taken into consideration. Compared to the adjacent mainland the island had a greater density of trees (Table 10) and a greater slope (*15.16 ± 1.37°, n = 156 versus 20.64 ± 1.65°, n = 155).

Table 27. Behavior of caribou chased by a dog simulating a predator (wolf). (Observation legend as in Table 26)

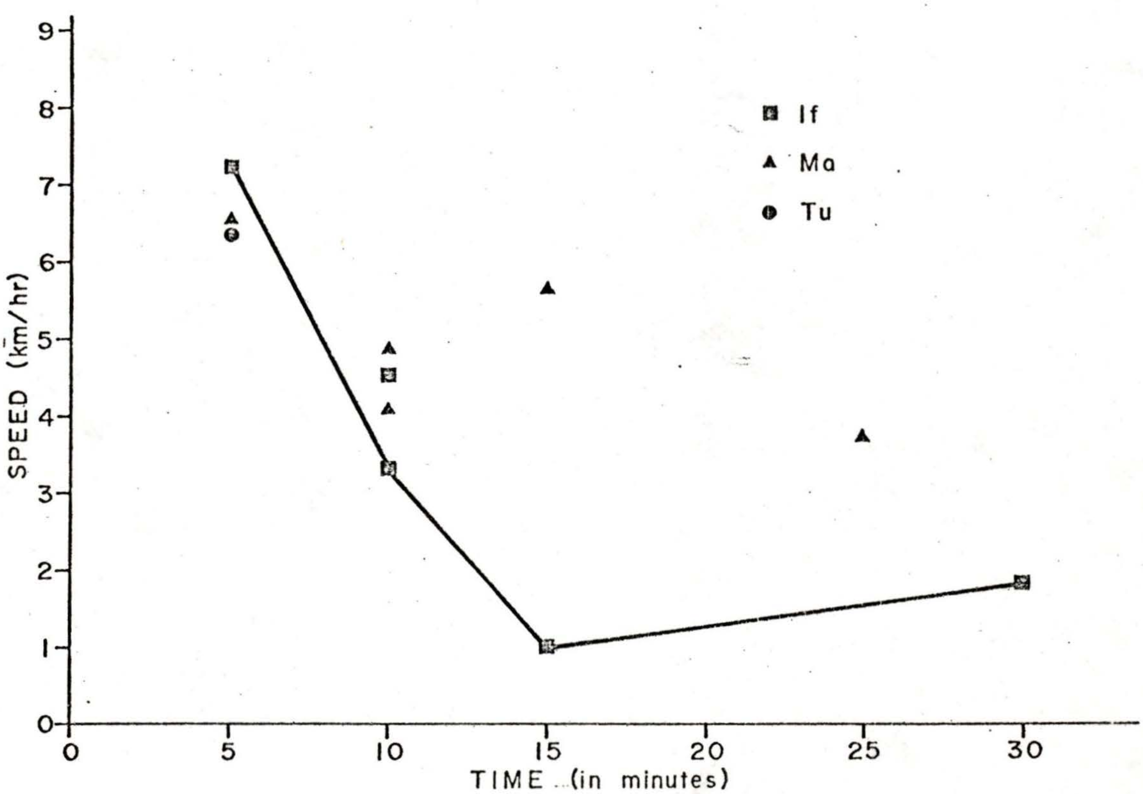
Name	Age	Sex	Date	Time	Pred	Ran	Dog	Habitat	Observations
Rang	2yr	F	June 10	1405-1450	E	1.22	0.43	5-6-7	Up Ci
?			June 10	1720-1750	E	>1.0	0.17	5-6	Up Zz
If	3yr	M	June 12	1330-1335	B	1.93	bark	9	Tr Sh Va
If	3yr	M	June 25	1600-1625	E	1.32	0.21	10	Up Tr Sh
Ma&c	>3yr	F	June 27	1123-1150	E	2.21	0.12	7-8	Tr Sh

Pred = dog simulating predator; E = elk hound, B = beagle
Ran = distance caribou ran (km)

There was a decrease in the speed at which caribou flushed with time (Fig. 21). One animal's run (If) was tracked for over 30 minutes (1330-1400) during which it ran 1.35 km and displayed an initial burst of speed, typical for all runs, of just under 10 km/hr for the first five minutes (Fig. 21). After 15 minutes of running the animal stopped to rest and/or slowed down once realizing the dog was no longer in pursuit. Twenty minutes after the initial encounter If resumed a walking pace (2 km/hr) away from the area which initiated the chase.

Figure 21. Rate of speed of caribou flushed by a dog simulating a predator (wolf) regressed against the length of encounter. The speed was calculated relative to the time when the chase was initiated.

Regression: $y = 7.09 - 0.16x$, $r = -0.856$


If
Ma
Tu
SPEED (km/hr)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25
30
TIME (in minutes)

5.11 Activity Patterns

An active signal was considered any noticeable change in an ampage reading (receiver), from a radioed caribou, over a 30 second interval. Any fast movement of the caribou's neck and its attached collar (feeding or walking) resulted in an active reading. Treating the active or not active determinations as a binomial population, allowed the testing of patterns using the Chi-squared test.

A comparison of frequency of activity readings for the four seasons indicated differences in activity between all seasons (Fig. 22).

No daily (dawn, mid-day, dusk) activity patterns were detected (Fig. 23) for spring (May 15-29, 1981), or the summer (June 1 - August 20, 1980 and 1981), or the fall (September 12 - October 19), or the combined results (May 15 - October 19, 1980 and 1981). During the spring and summer of 1980 (April 26 - July 3) eight collared caribou movements of greater than 2 km in less than 24 hours were detected by telemetry. Of these only two occurred during the mid-day. Of 16 movements detected (Table 28) during three periods of continuous telemetry readings (average 25 hours duration), none occured during the mid-day. For the May 18-19 telemetry readings, hot weather during the day appeared to restrict caribou movements to the night (Fig. 24). Caribou in the summer (June 30-July 1 and July 14-15), after moulting, still avoided long movements during the mid-day heat. Movements were restricted to the two crepuscular periods: dawn (just after daylight) and dusk (just before dark). This would suggest that the island caribou do not have crepuscular activity patterns but that major activity in the form of extensive movements seldom occurred during the mid-day.

Figure 22. Seasonal activity of caribou. Number of activity readings in brackets.

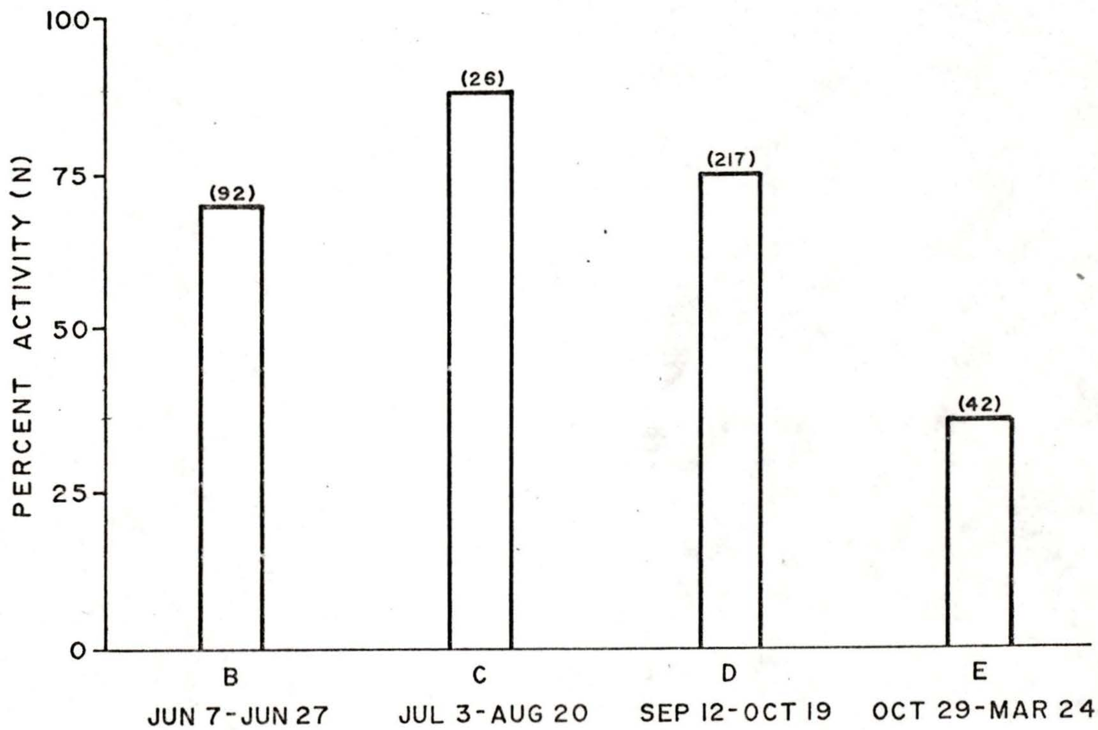

PERCENT ACTIVITY (N)
100
75
50
25
0
(92)
(26)
(217)
(42)
B
JUN 7-JUN 27
C
JUL 3-AUG 20
D
SEP 12-OCT 19
E
OCT 29-MAR 24

Figure 23. Daily activity patterns for the island caribou. Spring and summer (B - C) activity readings are grouped to compare daily activity patterns with fall (D) readings.

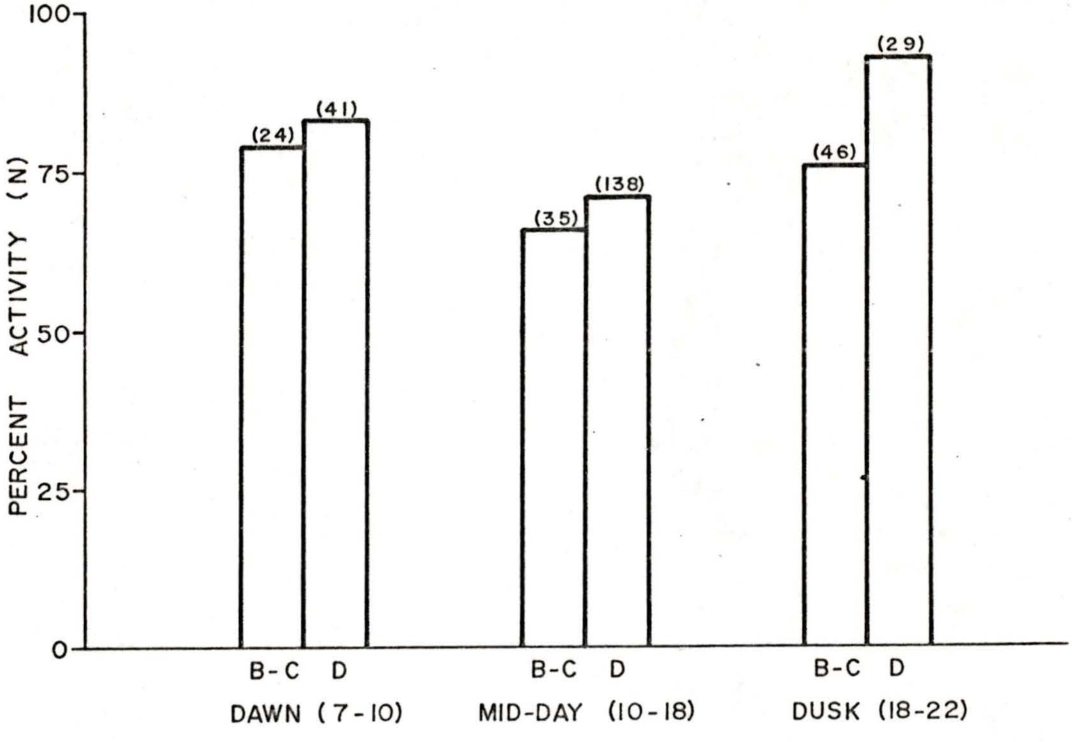

100
75
50
25
0
PERCENT ACTIVITY (N)
(24)
(41)
(35)
(138)
(46)
(29)
B-C D
B-C D
B-C D
DAWN (7-10)
MID-DAY (10-18)
DUSK (18-22)

Figure 24. Movement patterns (represented by solid lines, distance in km) over 24 hours of continuous telemetry readings for individual caribou.

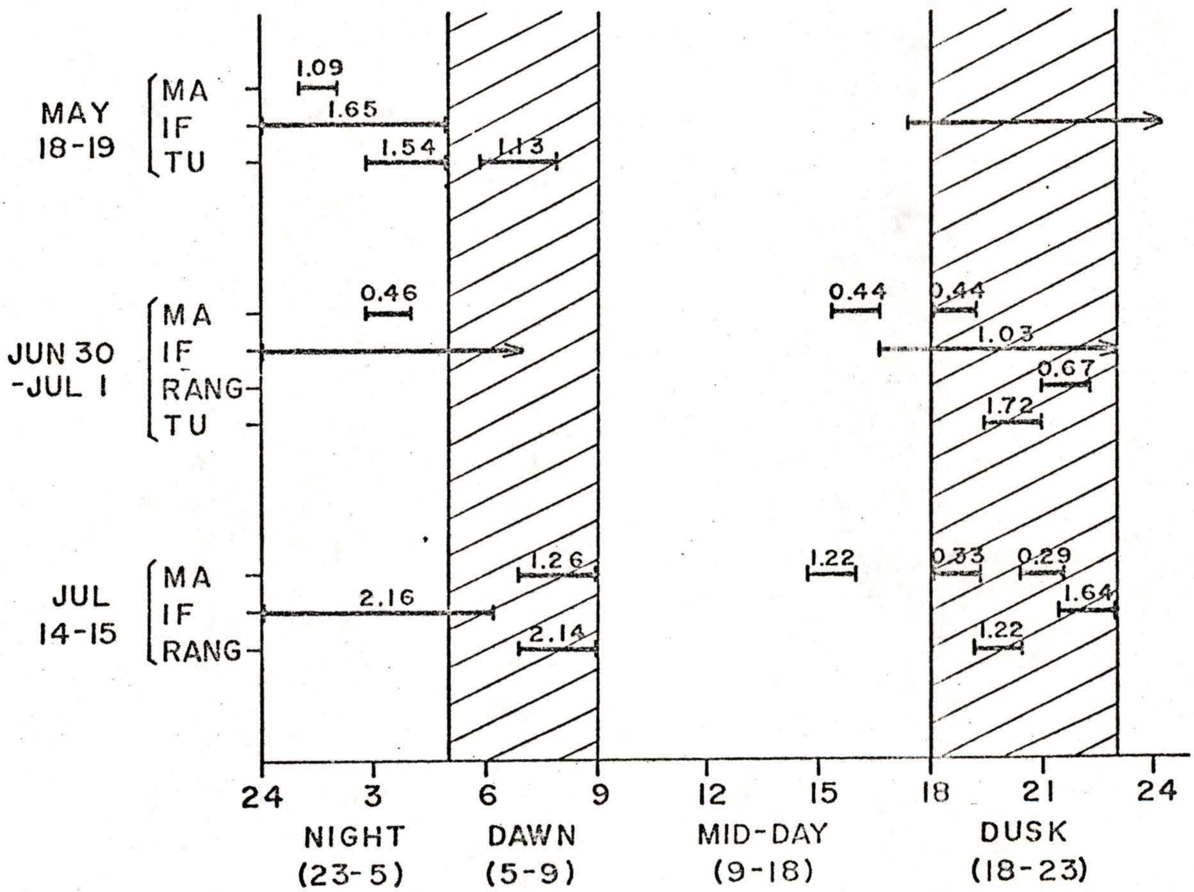

MAY
18-19
MA
IF
TU
1.09
1.65
1.54
1.13
JUN 30
-JUL 1
MA
IF
RANG
TU
0.46
0.44
0.44
1.03
0.67
1.72
JUL
14-15
MA
IF
RANG
1.26
2.16
2.14
1.22
0.33
0.29
1.64
1.22
24
3
6
9
12
15
18
21
24
NIGHT
(23-5)
DAWN
(5-9)
MID-DAY
(9-18)
DUSK
(18-23)

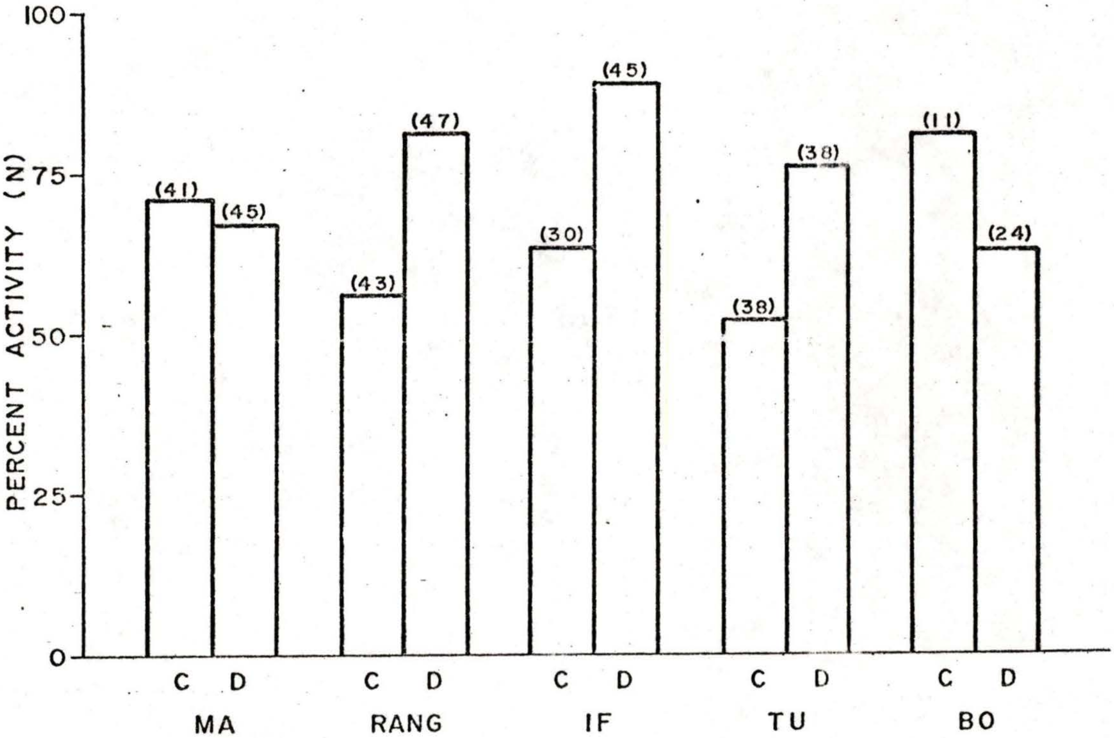
Table 28. Caribou movements during three periods of continuous telemetry readings.

	Date and Time		
	May 18-19 1300 - 2000	Jun 30-Jul 1 1200 - 700	Jul 14-15 2130 - 2100
total hours	31	19	24
movements (km)			
$\bar{X}$ ± s.e. (n)	1.75±0.34(4)	1.19±0.23(4)	3.46±0.17(3)
number of movements	5	7	8
period of the day			
dawn (700-900)	1	-	2
mid-day (900-1900)	0	1	1
dusk (1900-2200)	1	4	4
night (2200-700)	3	2	1

There was no significant difference between activity of individual animals due to sex, age or reproductive status (Fig. 25), but the sample size was too small for adequate testing. A collared three year old male (If), did show a significant increase in activity in the 1980 fall breeding period.

In conclusion: no daily activity patterns were detected which would distinguish between feeding or walking versus bedding behavior. But during the summer months, movements of greater than 0.1 km did describe a daily crepuscular pattern.

Figure 25. Changes in activity patterns between individual caribou for summer (C) and fall (D) readings.


100
75
50
25
0
PERCENT ACTIVITY (N)
(41)
(45)
(43)
(47)
(30)
(45)
(38)
(38)
(11)
(24)
C D
MA
C D
RANG
C D
IF
C D
TU
C D
BO

5.12 Bias in Line-transect Censusing

Possible bias in line transect censusing can occur if caribou detectability varies due to temporal or spatial changes in behavior. The locations of caribou observed on census lines were randomly distributed over the island (2-tailed Poisson variance test) suggesting that the census lines covered the variations in habitat and that caribou were not clumped during the censusing period. No significant differences were detected between the three daylight periods (Table 29) or the four seasons (Table 30), concerning the sightability of caribou (number observed/km walked). Flushing distances and behavior were correlated with age, sex and reproductive status (cows with calves) and varied seasonally with changes in floral density. To minimize these problems censusing should probably be conducted over a short period in early spring (May) before calving, when differences in age, sex and reproductive status are less marked.

Table 29. Caribou seen/km walked during three daily periods (pooled 1978-80 years).

time	n	km	caribou seen	caribou seen/km walked	no. caribou seen/line
6-12	30	127.4	23	0.18	0.227
12-17	67	253.1	50	0.20	0.259
17-19	20	70.7	12	0.17	0.521

Table 30. Caribou observed/km walked during four seasonal periods. (L = total distance of lines walked in km, C/km = caribou observed/km).

			Seasonal Period							
Year	Average		April 1- May 20		May 21- June 30		June 30- Sept. 1		Sept. 1 Oct. 31	
	L	C/km	L	C/km	L	C/km	L	C/km	L	C/km
1978	151.6	0.19	64.1	0.20	60.2	0.18	27.3	0.18		
1979	201.4	0.18	34.9	0.40	81.8	0.17	84.7	0.11		
1980	282.2	0.14	130.4	0.15	18.1	0.17			133.7	0.13
1981	307.5	0.13	140.0	0.20	167.5	0.13				

One of the basic assumptions of line transect theory is that the population is immobile before detection. From my telemetry observations, it appears that the caribou move randomly with respect to the observer before detection. With the sound of an approaching observer, caribou will stop their movement to identify the sound by sight or smell. The animals typically alert to sound and flush to sight and movement. Their initial reaction is a hard flush which is easily heard and located by an observer walking on a quiet day. The distance from the observer to where the caribou flushed from was relatively uniform (22.6 ± 6.49 m, n=70) varying slightly due to seasons, age, sex, reproductive status and the caribou's previous activity. Schweder (1977, cited in Burnham et al. 1980) has shown that random movement of the animals that is slow relative to the observer (animals not counted more than once) is not a practical problem for the usual estimation theory. It is my experience from telemetry observations that I walk faster than caribou on census lines (2.08 km/hr) and that seldom do the animals move in response to the observer before detection (ie. evasive movement). Therefore there is no need to use procedures for mobile populations in analyzing this transect data (eg, monotonically decreasing estimators such as exponential polynomial). However, if there was unobserved movement, such as that described below then the estimate of density will be biased negatively.

There was some indication that cow-calf pairs may move away from the observer without being detected. With the initial burst of a hard flush Ma ran an average of 0.9 km in 3.48 minutes (12km/hr, n=6). Five of nine approaches to Ma and her calf (April 28 - June 16, 1980), resulted in the two moving away from the observer without a hard flush. The radiod cow and calf moved away at long distances which did not permit detection by sight or sound. This indicated that female caribou with their calves are more alert and can move away from an observer without being detected, thereby violating the line transect census assumption of equal observability. Downing et al. (1977) did not believe there was a period during summer or fall in which each sex and age class of white-tailed deer was equally observable. Unequal observability was believed caused by differences in feeding and bedding time.

There are three differences between the approach of an observer towards a caribou when walking with an antennae and receiver, and when walking on a line transect:

1. the sounds of an aluminum antennae snagging underbrush and the beeping of the receiver;
2. the walking pace is much slower and cautious, perhaps more closely imitating the approach of a predator;
3. and instead of a straight line the direction of travel is erratic and repetitious with more area being covered.

Because of these differences, I believe a fast (2.0 km/hr), even pace which does not prevent an animal's flush from being heard, will reduce the possibility of not detecting reproductive females. Still it is suggested that censusing occur in May before calving begins.

5.13 Parasites

When food is limiting numbers, animals are generally in poor physiological condition, and often heavy parasitec burdens occur because of lowered resistence. Higher densities also allow increased opportunity for transmissicn of the infective agent. Winter tick (*Dermacentor albipictus*) were commonly found on the caribou; notabley the younger caribou captured in April. Calves and yearlings characteristically have lower resistance to parasites and disease (Wcolf 1978). None of the caribou feces examined by Dr. M.W. Lankester for larvae using the Baermann technique revealed any spined larvae which are common in mcose, deer and caribcu in the area (Lankester *et al.* 1976).

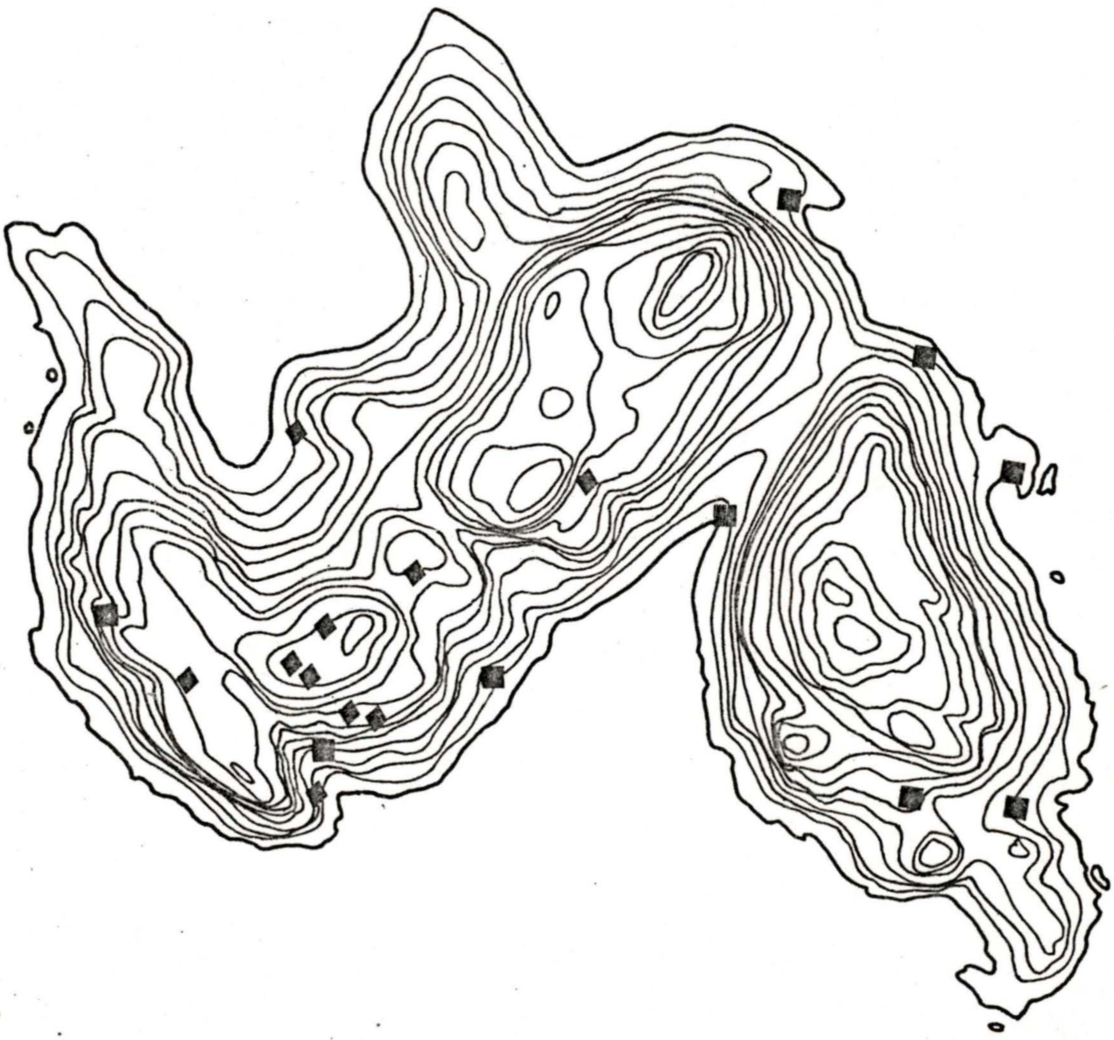
5.14 Cast antlers

All antlers found on Pic Island (n = 19) could be classified as being located in one or both of two habitat types (Fig. 26). Ten were found in open ground lichen flats which suggests that the caribou used these areas during late fall. Most of these antlers were large, indicating that they were male antlers and it is during the late fall that males are expected to drop their antlers (Bergerud 1975). Otherwise the caribou, likely females or ycung animals because of their smaller antler size, were lost within 1/2 km of Lake Superior (n = 12).

Figure 26. Locations of caribou cast caribou antlers found on Pic Island.

antlers found within lichen bedrock areas

other locations



VITA

Surname: FERGUSON Given Names: STEVEN HAROLD

Place of Birth: MARINETTE, WISCONSIN
Date of Birth: Sept. 29, 1956

Educational Institutions Attended, with Dates of Entering and leaving:

UNIVERSITY OF GUELPH, GUELPH, ONT. 1974 to 1979

UNIVERSITY OF VICTORIA, B.C. 1979 to 1982

____________________ ____ to ____

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

B.Sc. (Honors) 1979 University of Guelph, Guelph

Honors and Awards:

Publications: