WEST KITIKMEOT / SLAVE STUDY SOCIETY

Re: Bathurst Caribou Calving Ground Studies: Influence of Nutrition and Human Activity on Calving Ground Locations

STUDY DIRECTOR RELEASE FORM

The above publication is the result of a project conducted under the West Kitikmeot / Slave Study. I have reviewed the report and advise that it has fulfilled the requirements of the approved proposal and can be subjected to independent expert review and be considered for release to the public.

Study Director — Date: July 30/01

INDEPENDENT EXPERT REVIEW FORM

I have reviewed this publication for scientific content and scientific practices and find the report is acceptable given the specific purposes of this project and subject to the field conditions encountered.

Reviewer — Date: 29 August, 2001

INDEPENDENT EXPERT REVIEW FORM

I have reviewed this publication for scientific content and scientific practices and find the report is acceptable given the specific purposes of this project and subject to the field conditions encountered.

Reviewer — Date: Sep 7, 2001

BOARD RELEASE FORM

The Study Board is satisfied that this final report has been reviewed for scientific content and approves it for release to the public.

Chair
West Kitikmeot/Slave Study Society — Date: Feb 15/02

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BATHURST CARIBOU CALVING GROUND STUDIES: INFLUENCE OF NUTRITION AND HUMAN ACTIVITY ON CALVING GROUND LOCATION.

FINAL REPORT

Submitted to

West Kitikmeot Slave Study Society

Submitted By

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SUMMARY:

We conducted fieldwork on the calving and post-calving grounds of the Bathurst caribou herd, Nunavut, during 1998-99 and used supplemental data from 1996-97 to assess the calving and post-calving ecology of the herd. The calving grounds were located in the vicinity of the Hood River and were in roughly the same location, 1996-99. The calving and post-calving grounds were located in areas with high amounts of green plant biomass on 21 June, when energetic demand by lactating cows was expected to be high and local intensity of caribou use was high in Lichen Heath communities. This behavior may have offered cows the greatest options for meeting nutritional demands in an area that had substantial annual variation in forage availability. A climate-warming signature, in the form of increasing amount of green forage on 21 June during 1984-99, was evident on the calving and post-calving grounds but not on the adjacent historically used calving area east of Bathurst Inlet. Cows made substantial use of Lichen Heath and Moist Shrub vegetation types where lichens were most abundant, and reduced the abundance of lichens in the Lichen Heath vegetation type. Diets of caribou were dominated by lichens, and protein intake and biomass of forage was quite low compared to other herds. Time spent foraging was comparable to other herds, but low eating intensity indicated a relatively poor quality range; calf growth rates are likely to be low. Relatively low weights of Bathurst cows (~10 kg less than other migratory mainland herds) may facilitate their continued use of calving and post-calving ranges with a relatively low forage quantity and quality. Analysis of the isotropic signatures of heavy Nitrogen in the antlers of cows and in their forage suggested a diet shift to grass-like plants after they leave the calving ground. Displacement of calving grounds to the north or west, and post-calving grounds to the north, would likely result in reductions in the amount of green vegetation available to cows at the peak of lactation demand.

ACKNOWLEDGMENTS:

West Kitikmeot Slave Study Society funded the study. We thank the Board for their encouragement and we appreciate the continued help from John McCullum, Study Director, WKSS. The work reported here would not have been possible without the dedicated assistance of Annie Anavilok, Andrew Balser, Francis Blackduck, Marc Bonin, Violet Camsell-Blondin, Judy Dragon, Helmut Epp, Denis Fecteau, William Gould, Carrie Gray-Wolfe, Sheila Griffith, Jeff Jacobs, Jill Johnstone, Monica Kapakatoak, Real Marchand, Brent Patterson, David E. Taylor, Debbie van de Wetering, Amos Wamikom, Louie Whane, Rich Kedrowksi, Air Tindi, Canadian Helicopters, First Air, and the Polar Continental Shelf Project.

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OBJECTIVES:

The long term goals (purposes) of this project were to: 1) assess long term trends in forage production and phenology on the Bathurst caribou calving and post-calving ranges in relation to climate change, 2) to estimate the diet, net energy, and protein intake on calving and post-calving ranges of the Bathurst caribou herd and incorporate this information in models that clarify the relative importance of these seasonal ranges, 3) to estimate intensity of use of various habitats in the calving and post-calving areas and rank the value of habitats, 4) to indirectly assess whether Bathurst caribou rely on endogenous body protein reserves during nursing while using a diet low in protein, and 5) to estimate the effect of potential displacement of caribou by human activity on forage available to calving caribou. Understanding relative value of habitats to caribou is essential to the sustainability of human communities who depend on the Bathurst herd for cultural and nutritional subsistence.

The detailed objectives listed below are the items that were accomplished to attain our research goals.

1. Nutrition

1.1 Estimate the intensity of use of Lichen Heath, Wet Graminoid (grasslike), and Moist Shrub vegetation types on the Bathurst calving ground by conducting line transect estimates of pellet group density during calving and post-calving periods.

1.2 Estimate the calving and post-calving diet of Bathurst caribou from analysis of fecal pellets.

1.3 Estimate the nutritional content of calving and post-calving diets from collection of forage items on appropriate ranges and chemical analyses of these forages.

1.4 Determine if the Bathurst herd selects calving areas with high rate of increase in plant biomass (Normalized Difference Vegetation Index (NDVIrate)) during calving as seen for the Porcupine caribou herd and portions of the Central Arctic caribou herd.

1.5 Estimate the activity costs to caribou of obtaining calving and post-calving diets from behavioral monitoring of focal animals.

1.6 Incorporate estimates of diet, forage quantity and quality, and activity from the Bathurst herd into the Porcupine caribou herd energetics model and assess the relative importance of Bathurst calving and post-calving nutrition in comparison to other seasons and other migratory caribou herds (Porcupine caribou herd, George River caribou herd).

1.7 Determine if a global warming signature is present on seasonal ranges of the Bathurst caribou herd in the relative amount of plant biomass (Normalized Difference Vegetation Index (NDVI)) and rate of increase in plant biomass (NDVIrate, (phenology)) obtained from satellite based sensors (NOAA, AVHRR).

1.8 Assess the potential of using heavy Nitrogen signatures from food and feces to identify the magnitude of body protein mobilization by nursing caribou.

2. Human Activity

2.1 Assess the hypothetical effects of shifts in distribution of Bathurst concentrated calving that may be caused by human activity on forage quantity and forage quality.

DESCRIPTION:

The West Kitikmeot Slave Study (WKSS) Partners have identified caribou migration routes and calving grounds as priorities for collecting baseline information. This information is needed to identify, predict, and eventually mitigate any potential effects from development on traditional calving grounds and on post-calving ranges of the Bathurst caribou herd in Nunavut and the Northwest Territories. To have predictive ability, we need to identify the environmental variables (e.g. plant communities, amount of forage, and forage species) that caribou may respond to and to estimate the influence of these environmental variables on caribou. We conducted field studies on the calving and post-calving grounds of the Bathurst caribou herd, which are located west of Bathurst Inlet near the Hood River and in areas to the south, during 1998-1999 to document caribou habitat use, food availability, food habits, activity patterns, and forage. We: 1) estimated habitat use from fecal pellet transects in various habitats and from the distribution of satellite radio-collared cows; 2) estimated food availability from the analysis of percent cover and biomass of forage plants; 3) estimated food habits from the analysis of fecal pellets; 4) estimated activity patterns from observations of caribou; and 5) estimated forage value from the chemical analysis of food items. In addition, we used relocations of satellite collared cows obtained during 1996-1997 to assess habitat use in years outside our field studies.

STUDY AREA:

The study area is composed of the calving grounds, west of Bathurst Inlet near the Hood River, and post-calving areas used through approximately 30 June by the Bathurst caribou herd (Fig. 1). Additional investigations, using remotely sensed habitat data, were conducted on the historically used calving grounds, 1966-84, on the east-side of Bathurst Inlet (Fig. 1a) .

ACTIVITIES BY OBJECTIVE:

Fieldwork was conducted during 29 May – 11June in 1998, and 29 May – 14 June in 1999. We used supplemental data on food habitats obtained during 1997 and relocations of satellite-collared cows obtained during 1996-1997 to increase the number of years covered by some of the objectives.

1. Nutrition

Objective 1.1 Estimate the intensity of use of (*habitats*) ...

We originally used a TM derived vegetation map developed by William Gould and expanded to the extent of a WKSS owned TM scene by Andrew Balser that encompassed our initial estimates of the calving ground extent. Our field sampling stratification and all previous annual reports were based on this map, but some of the caribou distributions that we observed extended beyond this map. During the final year of the study, the vegetation map developed as a WKSS project became available and, for this final report, we reanalyzed our data in relation to the new WKSS map. The WKSKS map includes 18 categories, and we combined some of these categories to yield a simpler map of 6 vegetation types. The simplified vegetation types were Lichen Heath (LIHE), Moist Shrub (MOSH), Rock-Lichen Barrens (ROLI), Sand/Gravel (SAGR), Tall Shrub (TASH), and Wet Graminoid (grasslike, WEGR). Our previous map had included a Low Shrub (LOSH) and a Dry Non-acidic Dwarf Shrub Tundra (DNAD) type. Neither of these types are part of our current classification. LOSH is subsumed within MOSH because we became convinced that we could not reliably distinguish the two types in the field. It is not completely clear what class of the current map subsumes DNAD, but that type was a small portion of our previous map. The extent of our new map is 96,577 km^2, and it encompasses the calving and post-calving distributions of the Bathurst herd and most of the historically used calving area on the east side of Bathurst Inlet.

We used this map and the locations of satellite-collared cows to estimate habitat selection by caribou at three scales: 1) fourth order (Johnson 1980), concentrated use area/extent of annual use area, 2) third order, annual use area/extent of area used over a number of years, and 3) second order, extent of area used over a number of years/map extent.

We used KERNELHR (Seaman et al. 1996, Seaman et al. 1998) to estimate the geographical distribution (99% Utilization Distribution (UD)) and concentrated use area (greater than average observation density during calving (1-11 June) and during post-calving (13-26 June). Concentrated use areas typically contained 50% of the observation of satellite collared cows in 10% of the area of the UD; relative denisty of caribou was approximately an order of magnitude greater in concentrated than in peripheral use area. The specific dates of analysis encompassed available satellite radio-collar relocations. Because we generally had < 10 satellite collar relocations for each individual day, and small samples overestimate the extent of the area used (Silverman 1986), we combined observations of animals within the noted periods. Because we obtained only one relocation per animal per 5-day period, we assumed that the sequential relocations of individuals were statistically independent. The approximate 1-km location error of satellite collars was small in relation to the size of the 99% UD's and the sizes of the concentrated use areas ultimately estimated with KERNELHR. We did not use satellite collar locations for any purpose other than estimation of the UD's and concentrated use areas, so small-scale location error of the satellite collars was ignored.

In addition, we delineated the extent of historical calving on the east side of Bathurst Inlet as the outer perimeter of all calving distributions estimated from aerial surveys, 1966-1984 (Sutherland and Gunn 1996). We further delineated a frequently used zone within this historical calving distribution as the area occupied by caribou in $\geq$ 5 of the years with aerial survey data. No groundwork was conducted on the east side of Bathurst Inlet in our studies. We relied on satellite imagery to inventory the habitat content (vegetation type, NDVI, NDVI621, and NDVIrate) of the east-side area and to assess hypothetical habitat had the Bathurst caribou calved on the east side of Bathurst Inlet.

Because much of our large-scale habitat data was obtained from satellites, we were able to census, rather than sample, the habitats used by caribou. As a result, particularly for questions regarding second order habitat selection, there was no tractable variance associated with our calculation of the proportion of used and available habitats. For selection at third and fourth orders, we obtained an estimate of variance for selection of habitat attributes from the among year variance in use/availability ratios and report the standard errors thus obtained. These standard errors include variance attributable to years, animals, and sampling variance and would be conservative if used to declare selection in any one year.

Analysis periods were defined on the basis of average daily movement rates of satellite collared Bathurst cows and generally corresponded to annual life cycle periods defined for the Porcupine caribou herd (Russell et a. 1992). Very low movement rates (< 5 km/day) were used to identify the calving period based on similar observations obtained from the Porcupine caribou herd (Griffith, pers. obs.).

During the 25 days that the helicopter was available for use in 1998 and 1999, 134 randomly selected sites, stratified by vegetation type and relative caribou density obtained from kernel analyses of locations of satellite-collared cows, were visited. At each of these 134 sites, one to four 50-m line transects were sampled (total of 253 transects) to estimate the density of caribou pellet groups in different vegetation types. The vegetation type at the random site was sampled; then, the nearest patch(es) of additional vegetation type(s) were sampled. Only one transect per vegetation type was sampled at each site. Because we were time limited and initial surveys in 1998 revealed very few pellet groups in the Rock-Lichen Barrens vegetation type, we abandoned sampling of this type and concentrated on Lichen Heath, Moist Shrub, and Wet Graminoid vegetation types in 1999.

Transect orientations and starting points were randomly chosen from tables of random numbers. Observers walked transect lines, searched for fecal pellet groups, and recorded the perpendicular distance to each detected group. Groups were classified as current year or older based on color and consistency of the pellets. Pellet group transects give estimates of relative habitat use that are comparable to repeated locations of radio-collared mule deer (Loft and Kie 1988) and elk (Edge and Marcum 1989). We assumed that pellet densities gave unbiased estimates of the intensity of habitat use by caribou of the Bathurst herd in their concentrated use areas.

Caribou pellet densities were estimated using program DISTANCE (V3.5) (Buckland et. al. 1993). We estimated a detection function that defined the effective width of the sampled transects for each observer and vegetation type, then estimated the number of pellet groups/m^2. Because DISTANCE only provides an estimate of pellet density and variance for each stratum (i.e. vegetation type), and does not estimate density by transect nor provide direct tests among strata, tests of statistical differences in pellet density among vegetation type were accomplished by an *ad hoc* test functionally similar to a *t*-test. If confidence intervals on pellet density for one stratum failed to overlap the mean of another stratum, a significant difference was declared.

Objective 1.2 Estimate the calving and post-calving diet ...

To estimate the daily diet of the Bathurst caribou herd, 5 fecal pellets from each of 20 fresh fecal pellet groups were collected within the concentrated calving area on each of 8 different days, 3-11 June 1998, and on each of 13 different days, 31 May - 13 June 1999. Pellet groups were submitted for analysis for mean percent relative density of microhistological plant fragments, by genus, based on five slides and 20 fields per slide to the Composition and Analysis Laboratory Inc., Ft. Collins, CO.   Diet samples for each day were analyzed separately. Because forages differ in their digestibility and passage rates, we corrected the raw results using predictive relationships presented by Duquette (1984).

Objective 1.3 Estimate the nutritional content of calving and post-calving diets ...

We collected 34 samples of major forage species (as estimated from microhistological analysis of fecal pellets collected on the calving ground in 1997) during 3-11 June 1998, and 31May - 13 June 1999.   Samples were collected near the pellet transects but were not collected nor analyzed in a manner that allowed assessment of site specific variation in nutritional content. Plants collected were: *Eriophorum vaginatum* (cottongrass), *Oxytropis* roots, and the lichens *Masonhalea richardsonii*, *Stereocaulon* spp., *Sphaerophorus globosus*, *Peltigeria apthosa*, *Dactylina arctica*, *Alectoria nigricans*, *Alectoria ochroleauca*, *Cladina stellaris*, *Cladina rangiferina*, *Cladina arbuscula*, *Cetraria cucculata*, *Cetraria nivalis*, and *Cetraria ericetorum*.   We emphasized collection of lichens in 1999 based on their prevalence in the diet in 1997 and 1998 and the lack of detailed nutritional information in the literature for the wide array of lichens within the Bathurst calving ground.

Objective 1.4 Determine if the Bathurst herd selects for high rate of increase in plant biomass ...

Satellite (AVHRR) imagery for 1984-99 was processed to estimate the relative biomass of green plants available at calving (Normalized

Difference Vegetation Index, NDVI), the daily rate of accumulation of green plant biomass during lactation (NDVIrate), and the relative biomass of green vegetation at the putative peak of lactation on 21 June (NDVI621). We used this imagery and the relocations of satellite-collared cows to estimate habitat use and selection by caribou during calving, and post-calving periods in 1996-99. Further, we assessed what habitat selection would have been had caribou calved east of Bathurst Inlet within a historical calving ground estimated from historical data, 1966-84 (Sutherland and Gunn 1996). Where data was available, we compared the median NDVI, NDVIrate, and NDVI621 in the historical calving ground and frequently used area on the east side of Bathurst Inlet to the actually used calving ground, 1996-1999, of the Bathurst herd on the west side of Bathurst Inlet.

Objective 1.5 Estimate activity costs to caribou ...

We used instantaneous scan sampling (Altman 1974) to estimate the proportion of time that caribou spent foraging, bedding, standing, walking, and trotting, the proportion of foraging time spent actually eating (taking bites), and the diurnal pattern of activity. While transect crews collected fecal pellets, an activity crew monitored caribou groups within the concentrated calving area. The sampling unit for activity scans was the caribou group, which varied in size. Observers recorded the number of caribou engaged in each activity within each group at 10-minute intervals throughout the day. During 31 May - 10 June 1998, 22,147 observations of individual caribou were recorded during 372 scans of 72 different caribou groups. During 1-13 June 1999, 49,535 observations of individual caribou were recorded during 325 scans of 29 different caribou groups.

The definitions of the activity categories that we used were:

1. feeding – standing or walking posture, including pawing at snow patches, with the muzzle touching or nearly touching the ground;
2. lying – bedded on the ground, either upright or lying on the ground, in a resting or ruminating position;
3. standing – stationary in an upright, standing posture with head elevated above the ground, and usually above the knees;
4. walking – similar to standing posture but moving at a slow gait (< 5 km/h);
5. trotting/running – similar to standing posture but moving rapidly in a two-times symmetrical (5-11 km/h) or asymmetrical (>11km/h) gait.

Daily activity budgets were calculated as percent of time spent in each activity averaged over all animals. Estimates of active/rest cycle lengths were made using the 50% rule (Russell et al. 1993). Active/rest diurnal pattern was estimated by combining all data within hourly classes.

We observed focal animals to partition the feeding time. Only animals engaged in feeding activity were selected for observation. Eating intensity was estimated as the proportion of total feeding time spent eating (standing in one place with head to the ground ingesting forage) and grazing (head down while ingesting forage while walking).

Objective 1.6 Incorporate estimates of diet ... into energetics models (*and compare*) to other herds ...

In addition to the estimates of: 1) caribou diet composition obtained from fecal pellets, 2) forage quality obtained from chemical analysis of forage plants, and 3) activity obtained from scan samples, we need estimates of forage quantity to use the ENERGY model (Kremsater et al. 1989) to compare the relative nutritional status of the Bathurst herd to other Arctic calving herds.

To estimate relative quantity of forage species, we used visual estimates of percent cover obtained from 20x50cm Daubenmire plots (Mueller-Dombois and Ellenberg 1974) placed in a stratified random manner along approximately one-half of the 50-m pellet density transects described in Objective 1.1. We stratified each 50-m pellet density transect into five 10-m segments, randomly chose a plot location within each of the five 10-m strata, then randomly chose the order of plots for sampling. Usually, at least three of the five possible plots on a 50-m pellet density transect were sampled.

Cover of vascular plants was estimated from the 20x50cm plots. A 10x10 cm nested sub-plot, gridded at 1-cm intervals was used as an aid to cover estimation of vascular plants within these 20x50 plots. Cover of lichen species was estimated from a 10x10-cm sub-plot nested within a sampled 20x50-cm plot. The lichen cover sub-plot was randomly positioned at one of 10 possible locations inside the 20x50cm plots.

To estimate absolute quantity of forage species, we randomly chose at least one of the 20x50-cm plots that had been sampled for plant cover on the 50-m pellet density transects. We clipped vascular plants at ground level within the 20x50cm plot, and collected all lichens from within the 10x10-cm lichen cover sub-plot. These samples were air-dried in the field and sorted into species groups.

Cover and biomass of vascular plants was estimated by species where possible. For graminoid and *Salix* species, we could usually only identify species to the genus level. Cover of standing dead and green graminoid tissues were noted separately. For all other species, only live biomass cover was estimated. All moss species were grouped into a single class. Plants in the lichen cover plots were identified to the species or genus level. Voucher specimens were collected for any vascular plant or lichen species of uncertain identity.

Energetics Model structure:

Canadian Wildlife Service has developed a deterministic model that incorporates data on forage quality, forage quantity, diet and activity of caribou and calculates the daily growth of a caribou cow and her calf (Fig. 2). The energetics model consists of two submodels. The first is the energy submodel, which predicts daily changes in a cow's metabolizable energy intake (MEI) by calculating the cow's food intake and then simulating the functioning of the cow's rumen and her digestive kinetics on an hourly basis. The MEI predicted by the energy submodel is then fed into a growth submodel, which calculates the cow's energy balance and the subsequent daily change in weight of both the cow and her calf.

Specific objectives of the energy submodel are to:

- show effects of different environmental conditions and movement patterns (as reflected by changes in activity budgets, forage quality, and forage quantity) on MEI by female caribou;
- evaluate effects of human and natural disturbance (e.g., oil development, insect harassment) on MEI; and
- evaluate changing of winter severity (as reflected by snow depth) on MEI.

The broad purpose of the growth submodel is to evaluate effects of changes in seasonal activity budgets and metabolizable energy intake (MEI) on the energetics and reproductive status of a female caribou.

The growth submodel has two specific objectives:

- to evaluate the impact of changing activity costs, maintenance costs, and MEI on the cow's energy balance and subsequent growth; and
- to evaluate effects of the cow's energy balance on the growth of her fetus during pregnancy and her calf during lactation.

Model input data

Plant biomass

- o Plant group biomass was calculated by combining cover data for habitat types collected during the study (Tables 1-2), with the equations relating cover to biomass (Figs. 3-12), normalizing for bare ground and rock (Tables 1-2), and weighting for habitats utilized during the calving period by the Bathurst Herd cows (Table 3). As well, final biomass figures were routinely doubled to reflect caribou selection of patches of higher biomass during feeding.

Forage quality

- ♦ The model used the percent nitrogen, neutral detergent fiber, and digestibility (IVDMD) measured in this study (Table 4). Where specific data was not available for the Bathurst calving ground, we used appropriate data from the range of the Porcupine Caribou Herd or the George River Herd.

Diet

- Average diet among the years in this study (Table 5) was used in the simulations. As our data did not indicate substantial shifts in diet between 1 June and 15 June, the average diet was simulated through the whole period.

Baseline activity budgets

- Average activity budget of animals observed in 1998 and 1999 were used (Table 6).

Model run setup

- We simulated the energy relations of an adult cow Bathurst caribou between June 1 and June 15, the period that coincides with our fieldwork. In the model, cows were pregnant June 1 and gave birth June 3. To facilitate comparison with different herds, we simulated a similar time period for the Porcupine Caribou and the George River Herds using herd-specific habitat, diet and activity data.
- To learn about the energetic constraints on the Bathurst calving grounds, we varied the ability of the cow to mobilize fat reserves to provide the energy for milk production (fat mobilization rate, default 250 $g*d^{-1}$). We increased the constraint on fat mobilization above the default until calf growth rates were similar to the lower estimates for the Porcupine Caribou Herd (~300 $g*d^{-1}$, Griffith unpublished data).
- The low biomass of fruticose lichens, the dominant plant

group in Bathurst caribou diet at calving was expected to be an energetic constraint on food intake. As biomass is one of the most difficult variables to measure and as cows can behaviorally select for microsites of higher than average lichen biomass, we varied lichen biomass from 13 $g*m^{-1}$ to 50 $g*m^{-1}$ to determine the energetic response.

- From a comparison of North American data, it appears the Bathurst herd is very small bodied, thus we simulated the implications of having a larger body size on the poor quality habitats that the Bathurst Herd occupies. We simulated the energy relations using initial maternal body weights of 72 kg (Bathurst), 82 kg (George River), and 85 kg (Porcupine).

Output variables

- Energetic performance was evaluated one week after assumed calving (June 10^{th}). The following output variables were used:
  - food intake ($g*d^{-1}$)
  - nitrogen intake ($g*d^{-1}$)
  - milk production ($l*d^{-1}$)
  - calf growth rates ($g*d^{-1}$)

Objective 1.7 Determine if global warming signature is present on seasonal ranges ...

AVHRR imagery (Tucker 1979, Myneni et al. 1997) with suitably low cloud-cover was obtained for the Bathurst study area during the period 1984-99. Complete coverage throughout our study seasons was not available for all years. Imagery was chosen for near-nadir overpasses, as near solar zenith as possible, geo-referenced, and re-calibrated to account for known pre- and post-launch sensor drift. Adjacent days were composited where necessary to obtain increased coverage of our study areas. Our primary goal in this portion of the study was to obtain estimates of the Normalized Difference Vegetation Index (NDVI) on 21 June (NDVI621) each year. We tested for a global warming signature in habitats on the calving ground of the Bathurst herd and on historically occupied areas east of Bathurst Inlet by regressing NDVI621 on year.

Objective 1.8 ... identify magnitude of body protein mobilization by nursing caribou.

During the 1998-99 field season, 92 freshly shed female antlers and 138 soil samples were collected. Antlers were collected randomly during the course of other fieldwork. Soil samples were collected at the 10 m point on the transects used to estimate caribou fecal pellet density. A random selection of these samples was analyzed for $\delta^{15}N$ (heavy Nitrogen) signature. Soil signatures were stratified by organic and mineral soil classes. Fecal and forage samples collected during 1999 were also analyzed for $\delta^{15}N$ signature.

Heavy N signatures of antlers were compared to seasonal profiles of captive animals and to the Western Arctic herd that calves on ranges dominated by vascular plants to assess relative N intake for the Bathurst herd. The $\delta^{15}N$ of soil was regressed against new and old fecal pellet density of caribou to assess whether caribou fecal deposition was correlated with soil N properties. Seasonal profiles of $\delta^{15}N$ were constructed for fecal pellets to assess the N source of forage for caribou, and the $\delta^{15}N$ signatures of forage species on the calving ground were estimated to assist in this latter task.

In addition, indirect assessment of mobilization of body reserves was accomplished in the energetics modeling (Objective 1.6) portion of this study.

2. Human Activity

Objective 2.1 ... effects of shifts in (*caribou*) distribution ... on forage quantity and quality.

We estimated the effects of displacement of Bathurst caribou at calving and post-calving on the median NDVI621 (relative forage at peak of lactation) by shifting each calving and post-calving distribution, 1996-99, a total of 100 km, in 10 km intervals, in each of the four cardinal directions using GIS technology. We estimated the median NDVI621 within each 99% Utilization Distribution and within each concentrated use area at each shift, then performed regression analyses of NDVI621 on displacement distance for each cardinal direction and class of distribution.

RESULTS BY OBJECTIVE:

1. Nutrition

Objective 1.1 Estimate the intensity of use of (*habitats*) ...

Based on the midpoint of dates of daily movement < 5 km by satellite-collared cows, we estimated median calving date as 5 June 1996, 10 June 1997, 4 June 1998, and 8 June 1999 (Figs. 13-16). These dates are late in the range of observed median calving dates for the Porcupine caribou herd (B. Griffith, pers. obs.), but may not be as accurate as estimating median calving date based on a visual sample of collared cows that give birth. Calving would be expected to occur earlier in years when more forage was available for fall fattening of cows prior to conception, but we do not have sufficient late summer and fall habitat data to evaluate this prediction.

The 99% UD at calving (calving ground) ranged 1,310-4,112 km^2 in size and the concentrated calving area ranged 105-341 km^2 in size during 1996-99 (Table 3). All annual calving grounds were in a similar location with substantial overlap (Figs. 17-18). Concentrated calving areas included 5.2-8.5% of the area of the 99% UD. The outer perimeter of all annual calving grounds, 1996-99 encompassed 7,032 km^2.

The 99% UD during post-calving (post-calving ground) was larger than the calving ground and ranged 6,927-22,025 km^2 in size while the post-calving concentrated use area ranged 836-2,294 km^2 in size (Figs. 19-20; Table 3). The post-calving concentrated use area included 9.5-19.5% of the area of the 99% UD. The outer perimeter of all annual post-calving grounds, 1996-99 encompassed 29,138 km^2.

For both the calving and post-calving periods, the average size of areas occupied in 1998-99 were at least twice as large as the average size of areas occupied in 1996-97.

The extent of historical calving on the east side of Bathurst inlet, 1966-84 was 21,829 km^2 , and the extent of the frequently used calving area was 4,684 m^2 (Table 3).

Fecal pellet detection distance on transects was greatest in Lichen Heath followed by Moist Shrub, then Wet Graminoid, then Low Shrub vegetation types because pellet detection was inversely related to vegetation density. There was a slight difference between observers in detection functions for some vegetation types, but the rank order of pellet density by vegetation type was the same for observers. As a result, we combined observers for overall estimates of fecal pellet density.

Variability in fecal pellet density was substantial, but there was a general tendency toward higher pellet density in 1999 than in 1998 for both old and new pellets across all vegetation types (Table 7a, 7b). For Lichen Heath (LIHE), there was significantly higher pellet density in 1999 than in 1998 in 5 of 6 comparisons (Table 7a, 7b). Higher use of LIHE in 1999 was correlated with lower proportions of sedges and mosses in the diet than in 1997 or 1998. Sedges and mosses were more abundant in MOSH and WEGR communities than in LIHE (see Objective 1.2).

There were few differences in new pellet density by vegetation type between concentrated and peripheral use areas, but transects outside the calving ground had lower pellet density for LIHE in both years, and for Moist Shrub (MOSH) and Wet Graminoid (WEGR) in 1999. Old pellet density in LIHE was higher in concentrated use areas than in areas on the periphery or outside the calving ground in 1998, but the difference between concentrated and peripheral use was not preserved in 1999. Although not completely clear, a slight tendency toward higher pellet densities in LIHE and MOSH than in WEGR were consistent with the diets of caribou that were dominated by lichens and higher pellet densities in 1999 were consistent with having observed substantially more animals on activity scan samples in 1999 than in 1998.

At the landscape scale, caribou fecal pellet density was best predicted by the cover of four lichens, *Alectoria nigricans, Cetraria cucullata, Cladina stellaris* and *Cladonia* sp. Caribou may affect LIHE habitats by reducing the cover of preferred lichen species. Further details are provided in Appendix I.

To preserve continuity with other WKSS projects and to obtain sufficient coverage for analyses of calving grounds on both the east and west sides of Bathurst Inlet, we shifted our analyses of large scale habitat selection to the WKSS vegetation type map for the final report. In the analyses that follow, vegetation types resolution is 25-m pixels, and NDVI measurements and snow cover resolution is 1-km pixels.

Any class of snow cover could be selected at any scale for the Bathurst caribou calving ground (Figs. 21-23). Thus, within the short period that we investigated, 1996-99, snow cover was relatively uninformative for assessing habitat selection. This implies that caribou move to the calving ground and accept the snow cover that they find. A more fine scale analysis of actual sites used by caribou might reveal selection patterns that we were not able to detect with our low-resolution (1-km) satellite collar relocations and snow cover maps.

At second order selection, there was a tendency for the calving ground used by the Bathurst herd, 1996-99, to contain slightly more LIHE than expected from the content of the vegetation map (Fig. 24). At third order and fourth orders (Figs. 25-26), selection was variable among years and no consistent trends were evident. The fundamental habitat selection process appears to occur at second order.

During post-calving, second order selection tended to favor ROLI (Fig. 27), MOSH was selected at third order in 1996 and 1997 (Fig. 28), and there was a tendency toward selection of all vegetation types with substantial amounts of forage (LIHE, MOSH, TASH, and WEGR) at fourth order (Fig. 29). As the season progressed from calving to post-calving, habitat selection became more evident at higher orders. This implies a seasonally changing basis of selection. This may have been influenced by growth and appearance of green forage. Prior to green-up, caribou had no small scale basis for selection as green plants were not yet available.

Second order selection of vegetation types in the historically used calving area on the east side of Bathurst Inlet, tended to favor MOSH and WEGR types (Fig. 30). This reflects the greater abundance of MOSH and WEGR vegetation types on the east side of the inlet. The calving grounds east and west of Bathurst Inlet are located in areas with fundamentally different vegetation type dominance.

Had we persisted in use of the original vegetation maps that we employed in the early years of this study, we would have shown a tendency toward second order selection for LIHE and WEGR for both the calving and post-calving periods. Third and fourth order selection analyses for the alternate map would have produced the same types of generally inconclusive results for the calving ground as seen for the WKSS vegetation type map.

Objective 1.2 Estimate the calving and post-calving diet ...

In 1997-1999, the early June diet of the Bathurst herd was dominated by lichens (Fig. 31). Lichens of the genus *Cladonia* were dominant. Moss was a much larger component of the diet in 1999, when green-up was late, than in 1997 or 1998 (Fig. 31); and, grasses and sedges were a larger component of the diet in 1998 (when green-up was earlier) than in 1997 or 1999 (Fig. 31).

Analysis of the $\delta^{15}N$ signatures of antlers (See Objective 1.8 below) suggested an increase in the proportion of green grass-like vegetation in the diet during post-calving and later seasons, but this trend was not statistically significant. Two fecal pellet samples collected off the calving and post-calving grounds on 30 June and 15 July in 1999 suggested an approximate four-fold increase (27% vs. 7%) in the proportion of willow in the diet compared to the 31 May – 13 June period for 1999.

Objective 1.3 Estimate the nutritional content of calving and post-calving diets ...

For the forage samples collected in 1999, we acclimated the captive reindeer rumen liquor donors with lichens for two weeks prior to obtaining rumen liquor for the analysis. The acclimation increased the digestibility (IVDMD) of *Cetraria* and *Cladina* lichens by about 10% compared to the non-acclimated values estimated for 1998 (Table 4). There was wide variation in digestibility among lichens sampled in 1999 (Table 4). *In vitro* digestibility of lichens appears to be additively influenced by the source of rumen liquor (reindeer vs. caribou), acclimation time to lichens in the diet of liquor donors, proportion of lichens in the diet of donors, incubation time for digestion trials, N limitation for rumen micro-flora and micro-fauna, and perhaps the secondary compound content of the lichens. As a result, *in vitro* estimates of lichen digestibility may underestimate *in vivo* digestibility and the magnitude of the effect may not be consistent among lichen species. This is especially evident in comparison of IVDMD for the *Cladonia/Cladina* lichens (35%) and *Cetraria* lichens (60%) (Table 4). *Cladonia/Cladina* lichens are at least four times more abundant in the diet of Bathurst caribou than are *Cetraria* lichens even though they are much less available (Table 2) in the environment and have lower IVDMD. The somewhat unclear nature of IVDMD for lichens would not influence estimates of N intake by caribou, as lichens are generally quite low in N (Table 4).

Oxytropis rhizomes, which caribou routinely dug up and consumed in 1999, and *Peltigera* lichens were quite high in nitrogen (Table 4). Other sources of N for the Barhurst caribou at calving included birch (*Betula nana*), sedges (*Carex aquatilis*), cottongrass (*Eriophorum vaginatum*), and

Ledum palustre (Table 4), but these types of plants made up little of the calving diet of the Bathurst caribou herd (Fig. 31; Table 5)

Objective 1.4 Determine if the Bathurst herd selects for high rate of increase in plant biomass ...

Variability in use/availability ratios for NDVIrate was generally high (Figs. 32-37). As a result, selection for high NDVIrate was not strong among scales of analysis, among years, and between the calving and post-calving periods. Perhaps the selection for high NDVIrate seen in the Porcupine caribou herd (Griffith, pers. obs.) needs a number of years to manifest itself statistically. Our short-term study may not have had sufficient power to detect long-term selection. Alternately, the lichen rich habitats on the calving ground of the Bathurst herd may provide an alternate forage source, compared to green vascular plants, that is sufficient in this case. Alternately, the basis of selection may be different on the Bathurst than on the Porcupine herd calving grounds.

However, the total amount of green forage available to cows at the putative peak of lactation demand (NDVI621) was the most consistently selected habitat attribute at second order selection for both the calving ground and the post-calving ground (Figs. 32, 35). Selection of NDVI621 was less variable among years than selection for forage biomass at calving (NDVI) or the daily rate of accumulation of forage biomass (Figs. 32, 35) and the use/availability ratio was always > 1.

Once the calving ground was located where the proportion of area with high NDVI621 was greater than expected, there was no consistent selection for NDVI measures within this area (third order) (Figs. 33, 36). At fourth order, concentrated use, selection for high NDVI621 was evident for the post-calving ground, but not for the calving ground (Figs. 34, 37). Reappearance of selection for high NDVI621 at fourth order for the post-calving ground may have been expressed because the dates of post-calving encompass 21 June.

Thus, it appears that cows locate their calving ground in an area that will provide high levels of green plant biomass at peak lactation when their nutritional demands are the greatest. Selecting this type of area for calving, and using it during post-calving, ensures that the cows and calves will not have to move far from the calving ground to enhance their forage intake. Selecting an area with high green biomass at peak energetic demands, yet using lichens as a forage base prior to full green-up, may offer caribou the opportunity to hedge their bets against late green-up. If green-up is late, lichens may sustain them. If green-up is early, they can take advantage of high protein foods as soon as they become available.

Objective 1.5 Estimate activity costs to caribou ...

Overall activity budgets for 1998 and 1999 were similar (Table 6), except for a 4% increase in the percent of day spent feeding in 1999. The values obtained for the Bathurst herd in 1998 were nearly identical to those recorded for the Porcupine caribou Herd during the 1-10 June period (Russell et al. 1993, p 98). Mean active cycle lengths were 98 $\pm$ 34.3 min, (n=13) and rest cycle lengths were 73 min $\pm$ 26.9. These values are comparable to those recorded for the Porcupine caribou herd during the calving period (99 and 75 min respectively) and are indicative of caribou on poor quality forage. (Russell et al. 1993). For the Porcupine caribou herd these lengths decreased to 42 and 66 min respectively by late June when high quality forage was available (Russell et al. 1993). No trend toward shorter cycle lengths, as might be expected with increasing forage quality, was observed during our limited sampling periods on the Bathurst calving ground.

Eating intensity did not differ among vegetation types: 90.3% (n=43) for lichen heath, 90.7% (n=29) for moist shrub and 92.2% (n=4) for wet graminoid. The mean eating intensity was 90.6%$\pm$ 9.00% (n=76) which is considerably lower than intensities recorded for the Porcupine Caribou Herd (98%, Russell et al. (1993)) during the calving period. The low eating intensities may be indicative of low forage biomass on the Bathurst calving grounds, as animals would need to spend a greater proportion of their feeding time searching for suitable micro-feeding sites.

The Bathurst Herd was most active at 0900 hours, at 1400 hours, and at 1800 hours (Fig. 38). Corresponding peaks in rest cycles occurred at 1100 hours and between 1500 and 1700 hours. The afternoon peak in active and resting periods were less distinct than the morning peaks.

Objective 1.6 Incorporate estimates of diet ... into energetics models (*and compare*) to other herds ...

A total of 313 quadrats on 122 transects were sampled for both vascular and non-vascular plant cover in 1998 and 1999. Lichens, evergreen shrubs, and rock were the most common coverage in Lichen Heath vegetation type, moss and dead graminoids were the most common in Moist Shrub, and standing dead *Carex* and graminoids were most abundant in Wet Graminoid (Tables 1-2). *Cladonia* and *Cladina* lichens (the type dominating the diet of caribou in 1998) were most common in the Lichen Heath vegetation type (Table 2).

Among vascular plants, the greatest amount of vegetative cover was found in Wet Graminoid, followed by Moist Shrub, and Lichen Heath vegetation types, respectively (Table 1). Much of the cover in Wet Graminoid and Moist Shrub vegetation types consisted of dead graminoids. Moss was common in all vegetation types. The dominant live vascular plant genus by vegetation type was: 1) Lichen Heath – *Betula, Cassiope, Empetrum,* and *Vaccinium*, 2) Moist Shrub – *Betula,* and *Dryas*, and 3) Wet Graminoid – *Carex, Cassiope*, and *Sphagnum* (Table 1).

There were useful, but sometimes noisy, relationships between biomass and cover for *Cladina* (Fig. 3), *Cetraria* (Fig. 4), and other (Fig. 5) lichens and for standing dead graminoids (Fig. 6), live graminoids (Fig. 7), live *Eriophorum* (Fig. 8), live *Carex* (Fig. 9), *Ledum* (Fig. 10), *Vaccinium* (Fig. 11), and evergreens (Fig. 12).

Model Incorporation

Biomass:

Cows of the George River Herd, the Porcupine Herd and the Bathurst Herd occupy ranges with low forage quantity and quality during the pre-calving period. This is the time when snow is actively melting away but prior to significant new plant growth. For the Porcupine Herd, the cows have left the lichen-rich winter range and essentially exist on moss and evergreen shrubs until the new growth of *Eriophorum* flowers followed rapidly by deciduous shrubs and forbs becomes available. For the George River Herd, available biomass is primarily confined to standing dead graminoids, low in nitrogen but surprisingly digestible. In contrast to the Porcupine Herd, the Bathurst Herd does not leave lichens when they move north of tree line. The dietary mix available to the Bathurst herd is of average or lower quality. However, the low biomass results in very restricted food intake. Biomass on the George River herd range is 4-fold higher than the Bathurst and the Porcupine Herd range has a 8-fold advantage over the Bathurst (Table 8) and biomass of forage on the calving ground is the primary nutritional distinction among the herds.

Diet:

Graminoids dominate the diet of the George River Herd with standing dead predominating early and live green plant parts dominating, as they become available (Table 5). The shift is relatively rapid from the limited amount of data available. In contrast, the Bathurst cows maintain a diet dominated by lichens throughout the June period, with a suggestion of greater use of shrubs and a decline in mosses as green-up proceeds. Cows in the Porcupine Herd rely heavily on mosses and lichens in the pre-calving period with a rapid switch to *Eriophorum* flowers, shrubs and forbs as they become available.

Food Intake:

Eating rates in caribou are primarily a function of mouth size, plant group and available biomass (Shipley and Spalinger 1992). Thus the primary differences in the ranges of the three herds is the mix of plant groups (mosses, lichens, etc) and the biomass of these plant group. The dramatically lower biomass of most plant groups in the range of the Bathurst Herd results in very lower simulated intake rates compared to the two other herds. The George River herd took in about 4 times as much food as the Bathurst Herd and the Porcupine Herd consumed almost 4.5 times as much food according to our simulations. It is conceivable that cows could increase their intake rates by selecting microsites of higher lichen biomass. To illustrate this point, we simulated the intake rates if Bathurst cows were able to access sites with biomass of 13 (measured in this study), 25 and 50 $g*m^2$ (Table 9). Even at 50 $g*m^{2,}$ however, Bathurst cows did not match intake rates of the George River Herd.

Even more dramatic was the extremely low simulated intake of nitrogen by the Bathurst herd. Lichens and dead graminoids dominate the diet at this time and both are very low in nitrogen (0.5%, 0.7% respectively). In contrast both the Porcupine and George River Herd benefit from higher overall intake rates and rapid switching to shrubs and forbs which contain higher nitrogen concentrations (4.5%, 3.5%, respectively). Not represented in the simulations of the Bathurst herd is their observed intake of *Oxytropis* rhizomes. Often we observed cows, tugging at something on the ground. Upon inspecting recent feeding areas, we determined that they were pulling up *Oxytropis* rhizomes. Chemical analysis determined that the rhizomes had a relatively high nitrogen concentration (3.5%). Cows would only have to eat about 70 grams DW of root per hour of grazing time to increase their daily nitrogen intake to 30 grams.

Milk production and calf growth rates:

In the model, metabolizable energy intake is used first to satisfy the maintenance requirements of the cow (basal metabolic rate + activity costs). For a lactating cow, energy in excess of this amount is used to produce milk for the calf. For the first few weeks of life (i.e. during our simulation period) calf growth rate is solely a function of milk production. As well as relying on metabolizable energy intake, cows can catabolize stored fat to synthesize additional milk to try to meet a target milk production, a function of calf age. In the model we restrict the amount of fat that a cow can mobilize for milk production. Simulation of milk production for the Bathurst Herd (Table 10) indicates that they never reach target milk production for the day of our comparisons (2.02 $l * d^{-1}$, June 10). Given the conditions we simulated, both the George River and the Porcupine Herd were able to meet the target milk production while using less than the 250 $g*d^{-1}$ of fat allowed to be catabolized from body reserves. Increasing the maximum mobilization to 300 grams, did allow for a growth rate (282 $g*d^{-1}$) similar to lower estimates for the Porcupine Herd (300 $g*d^{-1}$, Griffith, unpublished data).

Effect of body size:

From an energetic standpoint it doesn’t pay to be big when you are occupying marginal habitats. Cows with a higher body size need a greater proportion of their energy intake to maintain basal metabolic processes. We asked the question “How would cows with spring weights similar to Porcupine and George River cows (85 and 82 kg respectively) perform on Bathurst calving grounds as compared to average Bathurst adult cow weights (72 kg). From this exercise we simulated that 82 kg cows would produce 13%

less milk and their calves would have 29% lower growth rates compared to 72 kg cows. For an 85 kg cow these rates would be reduced by 16% and 37%, respectively.

Objective 1.7 Determine if global warming signature is present on seasonal ranges ...

There was a significant ($P < 0.05$) increase in forage for cows at the putative peak of lactation demand, 1984-99 on both the calving ground (Fig. 39) and post-calving ground (Fig. 40) of the Bathurst caribou herd. Slopes and intercepts of the equations for regression of NDVI621 on year did not differ ($P > 0.05$) between the calving and post-calving grounds (Figs. 39-40). There was no corresponding trend for the area historically used for calving east of Bathurst Inlet (Fig. 41); forage remained relatively constant through time. Since about 1986, NDVI621 on the area used by Bathurst caribou for calving, 1996-99, has been generally greater than on the area historically used for calving on the east side of Bathurst Inlet, 1966-84 (Fig. 42).

Objective 1.8 ... identify magnitude of body protein mobilization by nursing caribou.

Antler core isotope values reflect the nitrogen accumulated in antler early in the growing season, whereas the periosteum (outer hardened part of antler) values are reflective of the diet later in the summer. Although antler core growth may be initiated on the calving ground, the periosteum is deposited while the animals are on late-summer and early-fall ranges south of the calving ground.

Captive animals (LARS) kept on a constant diet exhibited no change in the core vs. periosteum values (Fig. 43). Core and periosteum values for the Western Arctic herd were lower than LARS suggesting a less $\delta^{15}N$ enriched diet than LARS animals, but exhibited the same constancy from core to periosteum (Fig. 43). This constancy suggests as consistent type of diet (e.g. vascular plants) throughout the antler development for the Western Arctic herd. However, the Bathust caribou samples suggest enrichment in antler $\delta^{15}N$ values, from the core to the periosteum (Fig. 43). Although this observation is not statistically significant, it is consistent with a diet that shifts from deciduous shrubs or lichens early in the summer, to increasing emphasis on graminoids as the growing season progresses for the Bathurst herd.

The plant $\delta^{15}N$ values (Fig. 44) from the Bathurst calving ground are similar to values obtained from similar plant groups from northern and western Alaskan caribou summer ranges (K. Kielland, pers. obs.). There are marked differences among plant functional types (Fig. 44). Lichens (*Cetraria*) are very low in nitrogen and tend to have a depleted $\delta^{15}N$ signature, graminoids (*Carex*) have intermediate tissue N concentrations and are consistently enriched in their isotopic signature, deciduous shrubs (*Betula*) exhibit high leaf nitrogen concentrations but have a depleted $\delta^{15}N$ value, and evergreen shrubs (*Ledum*) are both low in total N and have highly depleted $\delta^{15}N$ values (Fig. 44).

The $\delta^{15}N$ signature in fecal pellets of the Bathurst herd (Fig. 45) averaged approximately –0.36 during the calving period for 1999. The $\delta^{15}N$ signature of the diet averaged –2.49 during the same period. The increase in the $\delta^{15}N$ signature in the fecal pellets compared to the diet

(2.13) is about what would be expected as the forage is processed in the caribou body.

The $\delta^{15}N$ signature in mineral soil was significantly ($r^2 = 0.68$; $P = 0.004$) correlated with old fecal pellet density (Fig. 46). This finding, though preliminary, is consistent with high fecal and urinary input to the soil from caribou, given the isotope signatures of the lichens (Fig. 44) that dominate their diets while on the calving ground.

2. Human Activity

Objective 2.1 ... effects of shifts in (*caribou*) distribution ... on forage quantity and quality.

Displacement of annual calving grounds and concentrated calving areas to the north and to the west resulted in reduced ($P < 0.006$) availability of green forage at the peak of lactation demand (NDVI621) (Figs. 47-50). Although the relationships were significant, they were noisy and explained about one third of the variance in forage (Figs. 47, 49) for a northward shift of the calving grounds. The effect increased as displacement distance increased, and was stronger for northward than for westward displacement (Figs. 47, 49 vs. Figs. 48, 50). There were no effects on NDVI621 for displacements to the east and south ($P > 0.05$).

Displacement of the annual post-calving grounds and post-calving concentrated use areas resulted in reduced availability of green forage at the peak of lactation demand only for northward shifts (Figs. 51-52); the strength of this correlation was less than for the calving ground proper.

Other directional displacements had no significant effect ($P > 0.05$) on forage availability for the post-calving ground.

CONCLUSIONS:

Caribou may be selecting a position on the landscape that provides diversity in vegetation types and that may provide variable benefits depending on whether the spring is early or late. In late springs, Lichen-Heath communities can provide lichen forage and in early springs the Moist Shrub and Wet Graminoid vegetation types may provide nutritious forage from greening vascular plants. During 1997-1999 the diet during calving was dominated by lichens, so we may not have observed the complete range of foraging behavior that is possible on the Bathurst caribou calving ground. Regardless, green plant biomass is evidently important to these animals based on consistent selection for calving and post-calving ranges that have relatively high amounts of green forage on 21 June at the approximate peak of lactation demand. The climate-warming signature on the calving grounds, in terms of an increasing amount of green forage at the peak of lactation demand, suggests that current habitat trends on the calving and post-calving ranges are positive. Conversely, the historical use area on the east side of Bathurst inlet shows no evidence of warming and has had less available green biomass at the peak of lactation demand than has the Bathurst calving ground on the west side of Bathurst Inlet. Calving on the east side would probably need to be about a week later to match conditions on the west side of the Inlet.

It seems clear that the quality of the Bathurst calving range is poor compared to the George River and the Porcupine Caribou Herds. Biomass is low and consequently eating intensities are reduced. Both factors result in low food and nitrogen intake rates. Thus calf growth rates likely suffer from sub-optimum milk production. However, the size and growth of the Bathurst herd suggests that compensation for poor nutrition on the calving and post-calving ranges is occurring on other seasonal ranges. These other seasonal ranges may be quite important to the long-term health of the herd and investigations regarding their value would be advisable.

The Bathurst cows appear to be trying to compensate for the low nitrogen intake by exploiting the high nitrogen concentrations in *Oxytropis* rhizomes. We were not able to measure the consumption rates of these rhizomes. We have also shown that cows can also improve their energy balance dramatically by seeking out the highest lichen biomass at a mircosite scale. Shifting calving grounds to regions of high lichen biomass may not be feasible, as they have to balance energy intake with nitrogen intake. Reduced availability of green forage on 21 June, predicted from our analyses of northward calving ground displacement, is consistent with this hypothesis. Nitrogen is a critical element to post-calving caribou in its role for milk production and protein deposition. Regions with a high lichen biomass (to the north, for example) may not have the graminoid or shrub biomass that would be needed once green-up started.

In our modeling exercise we assumed a 2 June calving date (calves had been born by June 2) although peak of calving of the Bathurst Herd is slightly later. Later calving dates would better coincide with green-up and available nitrogen and indicate better nutritional conditions for cows than our models assume. However, for us to model the energetic impact of later calving dates, our biomass trend data would have to extend beyond the 15 June date of termination of our fieldwork. Little green-up had occurred by mid-June especially in 1999.

There are substantial differences in seasonal weights of adult female caribou among herds (Fig. 53). These data demonstrate that throughout the year members of the Bathurst Herd have smaller body masses than other mainland herds. Although sample sizes are small, there appears to be a steeper decline in body size in June for the Bathurst Herd than the Porcupine and George River Herds. Indeed Bathurst cows are the smallest among North American mainland migratory caribou where data are available. We hypothesize the small size is a result of lower initial calf growth rates and is maintained in the population by selection against the offspring of large bodied cows during the calving period. Small size may facilitate their use of relatively low quality calving and post-calving ranges because smaller animals require less absolute amounts of forage.

Because the current calving and post-calving range quality is relatively poor, and because areas to the north and west are composed of vegetation types with substantial lichen components, displacement to the north and west would likely be detrimental to nutrition of the herd. The relationship between displacement and forage availability is noisy, but long term displacements would likely reduce the amount of protein available to cows and thus to their offspring during lactation.

LINKS WITH PARALLEL STUDIES:

Our research is linked with the Tuktu and Nogak traditional knowledge project , the satellite tracking of seasonal movements project, and the parasite on calving grounds project.

TRAINING ACTIVITIES AND RESULTS:

Training was provided to five community representatives, two from Cambridge Bay, one from Kugluktuk, and two from Rae Edzo. One graduate student and one Nunavut, DSD, manager were trained as well. These people received training in activity scan sampling, line-transect sampling, plant identification, and food habits data collection.

SCHEDULE AND ANY CHANGES:

The project is complete

LITERATURE CITED:

Altman, J. 1974. Observational study of behaviour: sampling methods. *Behaviour* 49:227-265.

Buckland, S. T., Anderson, D. R., Burnham, K. P., and Laake, J. L. 1993. Distance Sampling Estimating abundance of biological populations. Chapman and Hall, New York, 486pp.

Duquette, L. S. 1984. Patterns of activity and their implications to the energy budget of migrating caribou. M. Sc. Thesis, Univ. Alaska, Fairbanks, 95pp.

Edge, W. D., and C. L. Marcum. 1989. Determining elk distribution with pellet-group and telemetry techniques. *J. Wildl. Manage*. 53:621-624.

Folstad, I., A. Nilsen, O. Halvorsen, and J. Andersen. 1991. Parasite avoidance: the cause of post-calving migrations in *Rangifer*? *Can. J. Zool*. 69:2423-2429.

Gunn, A, and M. Sutherland. 1997. Surveys of the Beverly calving grounds, 1957-1994. Dept. Resources, Wildlife, & Economic Development, Govt. Northwest Territories, Yellowknife, NT. File report 120. 119pp.

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

Kremsater, L. L., F. W. Hovey, D. E. Russell, R. G. White, F. L. Bunnell, and A. M. Martell. 1989. Computer Simulation Models of the Porcupine Caribou

Herd I: Energy. Tec. Rep. Ser. No. 53. Canadian Wildl. Serv., Pacific and Yukon Region.

Kremsater, L. L. 1991. Brief descriptions of the computer simulation models of the Porcupine Caribou herd. Pages 299-313 in Butler, C. E. and Mahoney, S. P., eds., Proc. 4th N. Amer. Caribou Workshop. St. John's, Newfoundland.

Loft, E. R., and J. G. Kie. 1988. Comparison of pellet-group and radio triangulation methods for assessing deer habitat use. *J. Wildl. Manage*. 52:524-527.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, 547pp.

Myneni, R. B., Keeling, C. D., Tucker, C. J., Asrar, A. & Nemani, R. R. 1997. Increased plant growth in the northern high latitudes from 1981 to 1991. *Nature* 386:698-702.

Russell, D. E. 1991. The Porcupine caribou model - real life scenarios. Pages 316-333 in Butler, C. E. and Mahoney, S. P., eds., Proc. 4th N. Amer. Caribou Workshop. St. John's, Newfoundland.

Russell, D. E., Martell, A. M. and Nixon, W. A. C. 1993. Range ecology of the Porcupine caribou herd in Canada. *Rangifer Spec. Iss*. 8 168 pp.

Seaman, D. E. and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77:2075-2085.

Seaman, D. E., B. Griffith, and R. A. Powell. 1998. KERNELHR: a program for estimating animal home ranges. *Wildl. Soc. Bull*. 26:95-100.

Shipley, L. A., and D. E. Spalinger. 1992. Mechanics of browsing in dense food patches - effects of plant and animal morphology on intake rate. *Can. J. Zool.* 70:1743-1752.

Silverman, B. W. 1986. Density estimation for statistics and data analysis. Monogr. Stat. Appl. Prob. 26. Chapman and Hall, New York, 175pp.

Sutherland, M., and A. Gunn. 1996. Bathurst calving ground surveys, 1965-1996. Dept. Resources, Wildlife, & Economic Development, Govt. Northwest Territories, Yellowknife, NT. File report 118. 97pp.

Tucker, C. J. 1979. Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sens. Environ*. 8:127-150.

White, R. G. 1991. Validation and sensitivity analysis of the Porcupine caribou Herd model. Pages 334-355 in Butler, C. E. and Mahoney, S. P., eds., Proc. 4th N. Amer. Caribou Workshop. St. John's, Newfoundland.

Table 1. Percent cover of vascular plants, rock, and snow by vegetation type during 1998 (121 quads at 53 sites) and 1999 (192 quads at 69 sites), Bathurst caribou calving ground, Canada.

	Mean Percent Cover by Vegetation Type					
	Lichen Heath		Moist Shrub		Wet Graminoid	
Species (form)	1998	1999	1998	1999	1998	1999
Andromeda polifolia	0.00	0.15	0.36	0.27	0.84	0.09
Arctostaphylos alpina	0.01	0.01	0.00	0.00	0.08	0.00
Betula glandulosa	0.00	0.00	0.00	0.08	0.00	0.00
Betula glandulosa (bud/leaf)	1.28[a]	0.00[b]	0.63[a]	0.00[b]	0.00	0.00
Betula glandulosa (bud/stem)	1.18	1.23	1.38	2.04	0.01	0.00
Carex spp. (green)	0.04	0.02	1.47[a]	0.70[b]	1.37	0.53
Carex spp. (standing dead)	0.06	0.00	0.20	0.03	0.00	0.54
Cassiope tetragona	2.57	2.21	1.78	1.30	0.64	0.00
Dryas integrifolia	0.65	2.58	1.82	2.41	0.65	0.15
Empetrum nigrum	3.11	0.93	0.29	0.05	0.00	0.00
Eriophorum angustifolium	0.00	0.00	0.00	0.00	0.00	0.19
Eriophorum angustifolium (flower)	0.00	0.00	0.00	0.00	0.00	0.00
Eriophorum angustifolium (green)	0.00	0.02	0.28[a]	0.10[b]	0.09	0.13
Eriophorum spp. (flower)	0.00	0.00	0.01	0.00	0.00	0.00
Eriophorum spp. (green)	0.01	0.00	0.41[a]	0.01[b]	0.00	0.23
Eriophorum spp. (standing dead)	0.00	0.00	7.01[a]	0.00[b]	0.00	0.00
Eriophorum vaginatum	0.00	0.00	0.00	0.00	0.00	0.00
Eriophorum vaginatum (flower)	0.00	0.00	0.00	0.00	0.00	0.00
Eriophorum vaginatum (green)	0.00	0.00	0.17[a]	0.88[b]	0.07	0.13
Forb	0.00	0.00	0.02	0.00	0.01	0.00
Graminoid (green)	0.00	0.00	0.30	0.05	0.27	0.00
Graminoid (standing dead)	1.83[a]	0.75[b]	17.67	13.41	42.52	43.92
Grass	0.00	0.00	0.00	0.01	0.00	0.00
Juncus spp.	0.00	0.00	0.01	0.00	0.00	0.00
Kobresia (green)	0.00	0.01	0.00	0.00	0.00	0.00
Ledum palustre	4.77[a]	2.79[b]	0.99[a]	1.78[b]	0.14	0.00
Litter	0.00	0.05	0.00	0.00	0.00	0.00
Loisleuria procumbens	0.12	0.00	0.00	0.00	1.67	0.00
Luzula arctica (green)	0.01	0.00	0.00	0.00	0.04	0.00
Luzula confusa (green)	0.01	0.00	0.01	0.00	0.00	0.00

[a] and [b] indicate that percent cover of the plant was significantly different between years within the vegetation type.
Sample quadrats were averaged for each site.

Table 1 (continued). Percent cover of vascular plants, rock, and snow by vegetation type during 1998 (121 quads at 53 sites) and 1999 (192 quads at 69 sites), Bathurst caribou calving ground, Canada.

	Mean Percent Cover by Vegetation Type					
	Lichen Heath		Moist Shrub		Wet Graminoid	
Species (form)	1998	1999	1998	1999	1998	1999
Luzula spp. (standing dead)	0.00	0.00	0.00	0.00	0.00	0.00
Lycopodium selago	0.00	0.00	0.01	0.00	0.00	0.00
Moss	0.00	4.79	0.00	15.37	0.00	0.83
Oxycoccus microcarpus	0.00	0.01	0.00	0.00	0.00	0.00
Oxytropis spp.	0.00	0.01	0.00	0.00	0.00	0.00
Pedicularis spp.	0.00	0.00	0.01	0.00	0.00	0.00
Poacea spp. (green)	0.01	0.00	0.06	0.00	0.00	0.00
Poacea spp. (standing dead)	0.01	0.00	0.57	0.00	0.00	0.00
Polygonum spp.	0.00	0.00	0.00	0.00	0.00	0.00
Pyrola spp.	0.07	0.00	0.02	0.00	0.00	0.00
Rhododendron lapponicum	0.00	0.04	0.01	0.00	0.02	0.00
Rock	24.70	17.81	8.77	1.60	17.50	0.00
Salix spp. (bud/leaf)	0.00[a]	0.00[b]	0.35[a]	0.00[b]	0.00	0.00
Salix spp. (bud/stem)	0.07[a]	0.00[b]	0.23[a]	0.00[b]	0.33	0.00
Salix spp. (stem)	0.00	0.04	0.00	0.36	0.00	0.00
Sausurea spp.	0.00	0.00	0.00	0.00	0.00	0.00
Saxifraga oppositifolia	0.00	0.01	0.00	0.03	0.00	0.00
Saxifraga tricuspidata	0.00	0.03	0.00	0.00	0.00	0.00
Silene acaulis	0.00	0.00	0.04	0.34	0.00	0.00
Snow	0.00	1.24	0.00	0.80	0.00	5.00
Sphagnum spp.	0.00	0.00	0.00	0.00	0.00	0.00
Stellaria spp.	0.00	0.01	0.01	0.00	0.00	0.00
Tofieldia spp.	0.05	0.05	0.01	0.02	0.03	0.00
Unknown	0.00	0.02	0.00	0.00	0.00	0.00
Vaccinium spp.	0.00	0.00	0.00	0.00	0.00	0.00
Vaccinium uliginosum (bud)	0.00	0.00	0.00	0.00	0.00	0.00
Vaccinium uliginosum (green)	0.00[a]	0.00[b]	0.75[a]	0.00[b]	0.00	0.00
Vaccinium uliginosum (stem)	0.84	0.49	0.71	1.15	0.50	0.00
Vaccinium vitis-idaea	6.57	4.73	1.99	1.71	0.12	0.01
Total Vascular Plant Cover	23.29	20.98	39.57	42.10	49.41	46.75

[a] and [b] indicate that percent cover of the plant was significantly different between years within the vegetation type.
Sample quadrats were averaged for each site.

Table 2. Percent cover of lichens in lichen heath, moist shrub, and wet graminoid vegetation types during 1998 (121 quads at 53 sites) and 1999 (192 quads at 69 sites), Bathurst caribou calving ground, Canada.

	Mean Percent Cover by Vegetation Type					
	Lichen Heath		Moist Shrub		Wet Graminoid	
Lichen Species (form)	1998	1999	1998	1999	1998	1999
Alectoria nigricans	2.46	2.29	0.09	0.05	0.00	0.00
Alectoria ochroleuca	2.11	3.74	0.54	0.13	0.06	0.00
Cetraria cucuollata	5.42[a]	3.00[b]	2.51	1.67	0.58	0.00
Cetraria ericetorum/islandica	1.07	1.12	7.16[a]	0.77[b]	0.29	0.00
Cetraria nivalis	3.24	4.05	1.34	0.96	0.58	0.00
Cladina arbuscula	0.04[a]	1.76[b]	0.16	0.26	0.00	0.33
Cladina mitis	0.00	0.00	0.00	0.00	0.00	0.00
Cladina rangiferina	0.33	1.75	0.77	0.01	0.04	0.00
Cladina stellaris	0.27	3.72	0.02	0.00	0.00	0.00
Cladonia spp.	0.00	0.08	0.00	0.76	0.00	0.00
Cladonia spp. (cup)	0.13	0.01	0.22	0.04	0.13	0.00
Cladonia spp. (finger)	0.06	0.00	0.00	0.00	0.00	0.00
Cladonia uncialis	0.30[a]	0.00[b]	0.04	0.00	0.00	0.00
Dactylina arctica	0.30	0.36	0.40	0.34	0.25	0.00
Hypogymnia spp.	0.00	0.01	0.00	0.03	0.00	0.00
Masonhalea richardsonii	0.25	0.30	0.00	0.03	0.00	0.00
Peltigera apthosa	0.00	0.14	0.00	0.03	0.00	0.00
Spaerophorus globosus	1.41	0.72	0.12	0.32	0.00	0.00
Stereocaulon	0.25	0.35	0.00	0.00	0.00	0.00
Thamnolia spp.	0.38	0.50	0.60	0.36	0.17	0.00
Unknown Lichen	0.00	0.10	0.00	0.00	0.00	0.00
% Cover of all lichens	18.02	24.00	13.96	5.75	2.10	0.33

[a] and [b] indicate that percent cover of the plant was significantly different between years within the vegetation type.

Sample quadrats were averaged for each site.

Table 3. Percent vegetation composition and area for annual use area and concentrated use area, 1996-99, Bathurst caribou herd, Nunavut; and, historic calving area, east side of Bathurst Inlet, 1966-84.

	Percentage Compostition by Vegetation Type						
	LIHE	MOSH	ROLI	SAGR	TASH	WEGR	Area (km2)
Map Extent	36.2	11.7	37.4	3.2	1.0	10.5	96,577
1996							
Calving:							
A99	53.3	2.9	34.1	2.6	0.4	6.7	1,310
CCA	47.6	0.1	47.3	2.4	0.0	2.6	105
Post-Calving:							
A99	34.5	9.0	46.5	2.1	0.5	7.4	10,190
CUA	43.1	11.6	31.0	1.0	0.5	12.8	1,740
1997							
Calving:							
A99	50.3	5.8	33.8	2.3	0.5	7.3	2,548
CCA	42.7	0.5	49.5	3.0	0.1	4.3	132
Post-Calving:							
A99	34.3	10.3	44.7	1.3	0.4	9.0	6,927
CUA	48.8	9.9	30.0	1.2	0.4	9.7	836
1998							
Calving:							
A99	42.9	4.8	39.7	4.0	0.6	8.0	4,033
CCA	35.8	10.2	40.9	3.7	1.4	8.0	258
Post-Calving:							
A99	34.3	7.0	47.1	2.3	0.4	8.8	21,639
CUA	58.3	13.7	15.7	1.4	0.8	10.1	2,294
1999							
Calving:							
A99	47.9	5.0	35.4	3.1	0.5	8.0	4,112
CCA	42.6	6.7	38.4	2.2	0.3	9.9	341
Post-Calving:							
A99	34.9	7.4	46.4	2.5	0.4	8.5	22,025
CUA	57.6	13.0	15.2	1.5	0.9	12.0	2,056
Extent of Calving	46.4	5.7	35.6	3.3	0.6	8.3	7,032
Extent of Post-calving	33.3	6.6	48.5	2.4	0.4	8.7	29,138
Historic Eastern Area							
extent of calving	32.4	25.0	26.8	1.3	1.1	13.4	21,829
frequent calving	32.4	26.2	27.1	0.7	0.1	13.6	4,684

LIHE = Lichen Heath; MOSH = Moist Shrub; ROLI = Rock Lichen Barrens; SAGR = Sand/Gravel;
TASH = Tall Shrub; WEGR = Wet Graminoid
A99 = 99% Utilization distribution; CCA = Concentrated Calving Area; CUA = Concentrated Use Area

Table 4. Nutritional quality of forage species, Bathurst caribou calving grounds, 1998 and 1999.

Species		status	Date	% Ash	Energy (cal/g)	%Ca	%Mg	%P	%C
1998									
Betula	*nana*		10 Jun 98	3.3	5262	0.31	0.23	0.49	52.2
Betula	*nana*		11 Jun 98	3.6	5406	0.31	0.21	0.51	53.0
Ledum	*palustre*		3 Jun 98	2.2	5391	0.70	0.14	0.13	53.3
Ledum	*palustre*		5 Jun 98	1.8	5379	0.66	0.12	0.11	53.3
Ledum	*palustre*		6 Jun 98	2.0	5447	0.68	0.13	0.11	53.6
Ledum	*palustre*		8 Jun 98	2.2	5319	0.75	0.12	0.10	52.7
Ledum	*palustre*		10 Jun 98	1.7	5420	0.65	0.13	0.13	53.4
Ledum	*palustre*		11 Jun 98	1.7	5317	0.61	0.13	0.12	52.8
Carex	*aquatalis*		3 Jun 98	3.8	.	0.17	0.11	0.15	46.4
Carex	*aquatalis*		5 Jun 98	3.8	.	0.24	0.15	0.16	46.5
Carex	*aquatalis*		8 Jun 98	3.9	.	0.19	0.14	0.18	46.3
Carex	*aquatalis*		10 Jun 98	4.2	4877	0.17	0.14	0.20	46.3
Carex	*aquatalis*		11 Jun 98	3.9	.	0.24	0.16	0.18	46.6
Carex	*sp.*	dead	throughout	4.8	4829	0.66	0.13	0.03	45.9
Cetraria	*cucullata*		throughout	2.1	4228	0.40	0.06	0.05	44.4
Cetraria	*ericetorum*		throughout	3.0	.	0.49	0.05	0.06	43.5
Cetraria	*nivalis*		throughout	3.1	3982	0.79	0.12	0.04	42.8
Cladina	*stelaris*		throughout	1.5	4235	0.07	0.02	0.03	44.3
1999									
Eriophorum	*vaginatum*	live	6 June 99	2.5	4696	0.13	0.11	0.16	48.1
Eriophorum	*vaginatum*	dead	6 June 99	1.9	4617	0.35	0.08	0.03	47.7
Oxytropis		rhizomes	11 June 99	9.0	4696	0.70	0.21	0.27	46.1
Masonhalea	*richardsonii*		4 June 99	1.4	4692	0.46	0.04	0.07	48.4
Stereocaulon			4 June 99	1.2	4707	0.12	0.05	0.07	46.8
Sphaerophor	*globosus*		4 June 99	0.7	4317	0.11	0.02	0.03	45.3
Peltigera	*apthosa*		4 June 99	3.8	4638	0.14	0.08	0.14	46.4
Dactylina	*arctica*		4 June 99	1.4	4350	0.24	0.09	0.06	45.9
Alectoria	*nigricans*		4 June 99	1.2	4400	0.05	0.03	0.03	45.5
Alectoria	*ochroleauca*		4 June 99	0.6	4390	0.10	0.03	0.03	46.2
Cladina	*stellaris*		4 June 99	0.7	4374	0.07	0.03	0.03	45.0
Cladina	*rangiferina*		4 June 99	1.2	4399	0.13	0.06	0.04	45.6
Cladina	*arbuscula*		4 June 99	0.8	4325	0.08	0.04	0.04	44.8
Cetraria	*cucculata*		4 June 99	1.2	4510	0.13	0.06	0.06	45.8
Cetraria	*nivalis*		4 June 99	4.3	4181	0.67	0.11	0.05	43.6
Cetraria	*ericetorum*		4 June 99	.	.	0.12	0.05	0.04	45.5

Table 4 (continued). Nutritional quality of forage species, Bathurst caribou calving grounds, 1998 and 1999.

Species		status	Date	%N	% NDF	%ADF	% IVDMD
1998							
Betula	*nana*		10 Jun 98	4.2	32.2	20.3	54.9
Betula	*nana*		11 Jun 98	4.2	33.0	19.3	55.3
Ledum	*palustre*		3 Jun 98	1.4	37.7	28.3	50.4
Ledum	*palustre*		5 Jun 98	1.4	42.3	31.7	47.2
Ledum	*palustre*		6 Jun 98	1.3	40.3	30.1	50.1
Ledum	*palustre*		8 Jun 98	1.3	44.5	34.3	42.7
Ledum	*palustre*		10 Jun 98	1.5	39.4	29.2	46.2
Ledum	*palustre*		11 Jun 98	1.3	38.9	29.3	47.7
Carex	*aquatalis*		3 Jun 98	1.6	63.2	25.9	55.5
Carex	*aquatalis*		5 Jun 98	2.2	63.4	24.9	60.9
Carex	*aquatalis*		8 Jun 98	1.9	63.2	26.4	57.7
Carex	*aquatalis*		10 Jun 98	2.0	65.0	28.6	59.3
Carex	*aquatalis*		11 Jun 98	2.2	61.7	26.0	55.6
Carex	*sp.*	dead	throughout	0.7	72.1	35.7	42.6
Cetraria	*cucullata*		throughout	0.3	31.1	2.2	45.7
Cetraria	*ericetorum*		throughout	0.5	38.9	5.7	67.7
Cetraria	*nivalis*		throughout	0.3	26.5	2.1	32.1
Cladina	*stelaris*		throughout	0.3	77.5	2.9	30.2
1999							
Eriophorum	*vaginatum*	live	6 June 99	1.8	68.2	31.3	45.5
Eriophorum	*vaginatum*	dead	6 June 99	0.5	78.1	43.7	29.7
Oxytropis		rhizomes	11 June 99	3.5	57.2	43.1	48.6
Masonhalea	*richardsonii*		4 June 99	0.5	20.4	2.8	95.2
Stereocaulon			4 June 99	1.1	70.9	12.6	44.4
Sphaerophor	*globosus*		4 June 99	0.3	60.4	8.4	33.6
Peltigera	*apthosa*		4 June 99	3.1	62.4	16.4	40.9
Dactylina	*arctica*		4 June 99	0.4	40.6	4.0	63.7
Alectoria	*nigricans*		4 June 99	0.4	28.3	5.8	77.3
Alectoria	*ochroleauca*		4 June 99	0.3	12.8	0.7	43.8
Cladina	*stellaris*		4 June 99	0.3	80.9	1.3	36.3
Cladina	*rangiferina*		4 June 99	0.4	81.6	16.7	20.9
Cladina	*arbuscula*		4 June 99	0.3	81.8	3.2	48.7
Cetraria	*cucculata*		4 June 99	0.3	33.6	2.1	58.5
Cetraria	*nivalis*		4 June 99	0.4	37.2	4.9	44.3
Cetraria	*ericetorum*		4 June 99	0.4	48.8	3.8	77.2

Table 5. Calving diets of cows in the George River, Bathurst and Porcupine Caribou Herd.

	George River			Bathurst			Porcupine		
	25-May	4-Jun	14-Jun	25-May	4-Jun	14-Jun	25-May	4-Jun	14-Jun
Moss	0.39	0.04	0.04	0.05	0.05	0.05	0.39	0.47	0.06
Lichens	0.25	0.03	0.03	0.62	0.62	0.62	0.25	0.17	0.14
Mushrooms	0	0	0	0	0	0	0	0	0
Horesetails	0.03	0	0.02	0.01	0.01	0.01	0.03	0	0.02
Graminoids	0	0.2	0.25	0.02	0.02	0.02	0	0	0
Deciduous shrubs	0.03	0.07	0.07	0.03	0.03	0.03	0.03	0.01	0.32
Evergreen shrubs	0.08	0.2	0	0.07	0.07	0.07	0.08	0.08	0.05
Forbs	0.01	0	0.01	0	0	0	0.01	0.02	0.29
Standing dead	0.21	0.46	0.58	0.2	0.2	0.2	0.06	0.06	0.05
Eriophorum heads	0	0	0	0	0	0	0.15	0.19	0.07

Table 6. Mean daily percentages of caribou activity in each of five categories (lying, standing, walking, trotting, and feeding) on the Bathurst calving grounds 1998 and 1999.

Year	Groups	Scans	%Lie	%Stand	%Walk	%Trot	%Feed
1998	72	372	34.0	5.8	9.4	0.9	49.9
1999	29	325	35.0	3.3	7.4	0.1	54.2
Avg.			34.5	4.5	8.4	0.5	52.1
Porcupine Caribou Herd[1]			33	1	10	1	54

[1] from *Russell et al 1993* for the calving period, p.98

Table 7a. Fresh fecal pellet density estimates, Bathurst caribou calving ground, 1998 and 1999.

	Fecal Pellet Groups / m^2					
	Fresh Pellets					
	Calving Ground					
Vegetation	Concentrated Use		Periphery		Outside	
Type [a]	1998	1999	1998	1999	1998	1999
LIHE						
mean	0.034	0.122	0.026	0.057	0.002	0.006
lcl[b]	0.014	0.083	0.015	0.033	0.000	0.002
ucl[c]	0.079	0.177	0.045	0.099	0.010	0.015
n[d]	4	24	27	16	9	31
MOSH						
mean	0.051	0.067	0.066	0.062	0.019	0.009
lcl	0.024	0.050	0.044	0.032	0.006	0.003
ucl	0.112	0.090	0.100	0.119	0.061	0.023
n	7	16	28	16	10	18
WEGR						
mean	0.015	0.038	0.026	0.057	0.021	0.002
lcl	0.001	0.014	0.014	0.031	0.003	0.000
ucl	0.260	0.105	0.048	0.103	0.153	0.015
n	2	6	11	4	2	6
LOSH						
mean	.	.	.	0.024	.	0.006
lcl	.	.	.	0.007	.	0.002
ucl	.	.	.	0.090	.	0.020
n	0	0	0	1	0	8
ROLI						
mean	0.000	.	0.000	.	.	.
lcl	.	.	.	.	.	.
ucl	.	.	.	.	.	.
n	2	0	5	0	0	0

[a] LIHE=Lichen Heath; MOSH=Moist Shrub; WEGR=Wet Graminoid;
LOSH=Low Shrub; ROLI=Roch-lichen
[b] lower confidence limit (P = 0.05)
[c] upper confidence limit (P = 0.05)
[d] number of transects sampled

Table 7b. Old fecal pellet density estimates, Bathurst caribou calving ground, 1998 and 1999.

	Fecal Pellet Groups / m^2					
	Old Pellets					
	Calving Ground					
Vegetation	Concentrated Use		Periphery		Outside	
Type [a]	1998	1999	1998	1999	1998	1999
LIHE						
mean	0.046	0.148	0.076	0.136	0.034	0.038
lcl[b]	0.010	0.113	0.059	0.102	0.016	0.025
ucl[c]	0.224	0.192	0.098	0.180	0.073	0.058
n[d]	4	24	27	16	9	31
MOSH						
mean	0.053	0.091	0.077	0.135	0.033	0.081
lcl	0.023	0.064	0.056	0.096	0.018	0.041
ucl	0.118	0.127	0.105	0.189	0.061	0.160
n	7	16	28	16	10	18
WEGR						
mean	0.020	0.028	0.022	0.061	0.018	0.004
lcl	0.000	0.010	0.008	0.015	0.000	0.001
ucl	1064.100	0.080	0.064	0.245	703.040	0.022
n	2	6	11	4	2	6
LOSH						
mean	.	.	.	0.136	.	0.036
lcl	.	.	.	0.075	.	0.021
ucl	.	.	.	0.246	.	0.063
n	0	0	0	1	0	8
ROLI						
mean	0.002	.	0.039	.	.	.
lcl	0.000	.	0.004	.	.	.
ucl	148.130	.	0.370	.	.	.
n	2	0	5	0	0	0

[a] LIHE=Lichen Heath; MOSH=Moist Shrub; WEGR=Wet Graminoid; LOSH=Low Shrub; ROLI=Roch-lichen
[b] lower confidence limit (P = 0.05)
[c] upper confidence limit (P = 0.05)
[d] number of transects sampled

Table 8. Biomass values used in the model for the George River, Bathurst and Porcupine Caribou Herds (g/m^2).

	George River			Bathurst			Porcupine		
	25-May	4-Jun	14-Jun	25-May	4-Jun	14-Jun	25-May	4-Jun	14-Jun
Moss	40	40	40	20	20	20	40	40	40
Lichens	8	8	8	13	13	13	10	10	10
Mushrooms	0	0	0	0	0	0	0	0	0
Horesetails	1	0	0	1	1	1	1	10	10
Graminoids	7	80	90	2	2	2	9	11	29
Deciduous shrubs	9	0	0	1	1	1	20	20	20
Evergreen shrubs	76	76	76	10	10	10	76	76	76
Forbs	1	1	1	1	1	1	20	20	20
Standing dead	60	60	40	14	14	14	250	250	250
Eriophorum heads	0	0	0	1	1	1	1	2	5
TOTAL	202	265	255	63	63	63	427	439	460

Table 9. Simulated food and nitrogen intake rates for cows of the George River, Bathurst and Porcupine Caribou Herds during the calving period.

HERD	LICHEN BIOMASS	FOOD INTAKE ($g.d^{-1}$)	NITROGEN INTAKE ($g.d^{-1}$)*
Bathurst	13	475	1.9
	25	697	2.7
	50	1091	4.3
George River		1969	27.4
Porcupine		2578	37.8

***** contribution of *Oxytropis* rhizomes to nitrogen intake not included but is discussed in text

Table 10. Simulated calf growth rates and milk production for the Bathurst, George River and Porcupine Herds.

HERD	MAX ALLOWABLE FAT MOBILIZED ($g.d^{-1}$)	CALF GROWTH RATE ($g.d^{-1}$)	MILK PRODUCTION ($l.d^{-1}$)*
Bathurst	250	150	1.09
	300	282	1.44
	350	407	1.79
George River	250	493	2.02
Porcupine	250	493	2.02

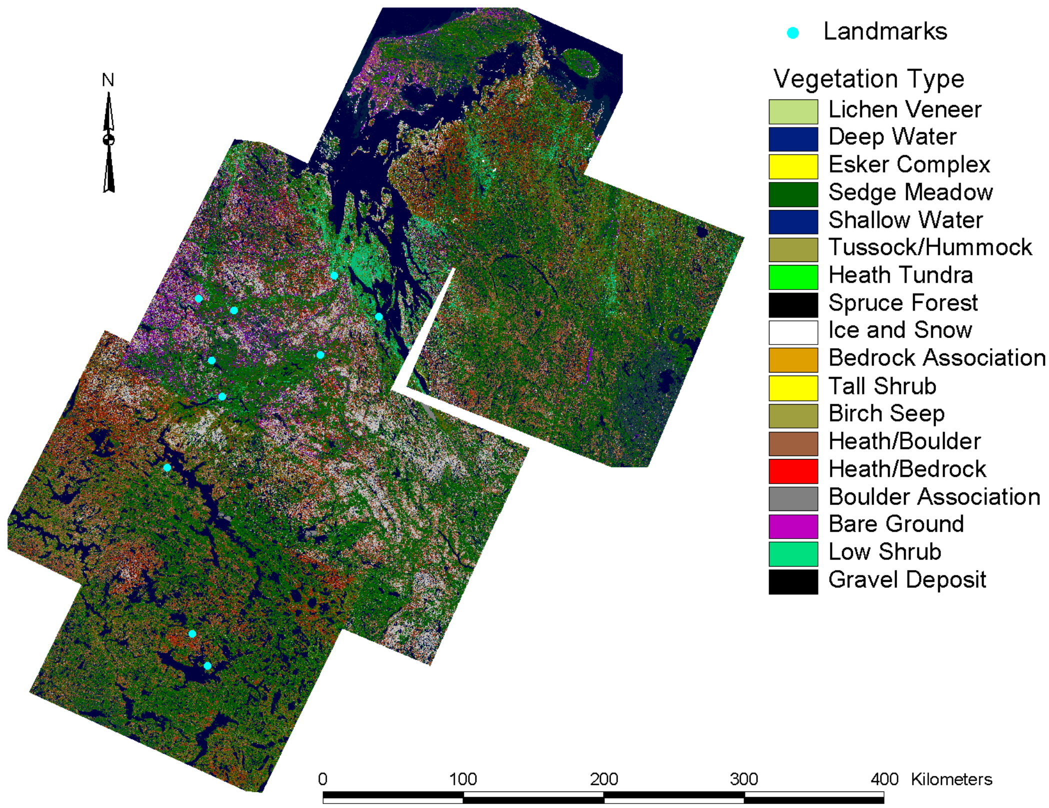


Figure 1. Vegetation types in the Bathurst caribou herd calving ground study area. WKSS map derived from Thematic Mapper (TM) images.

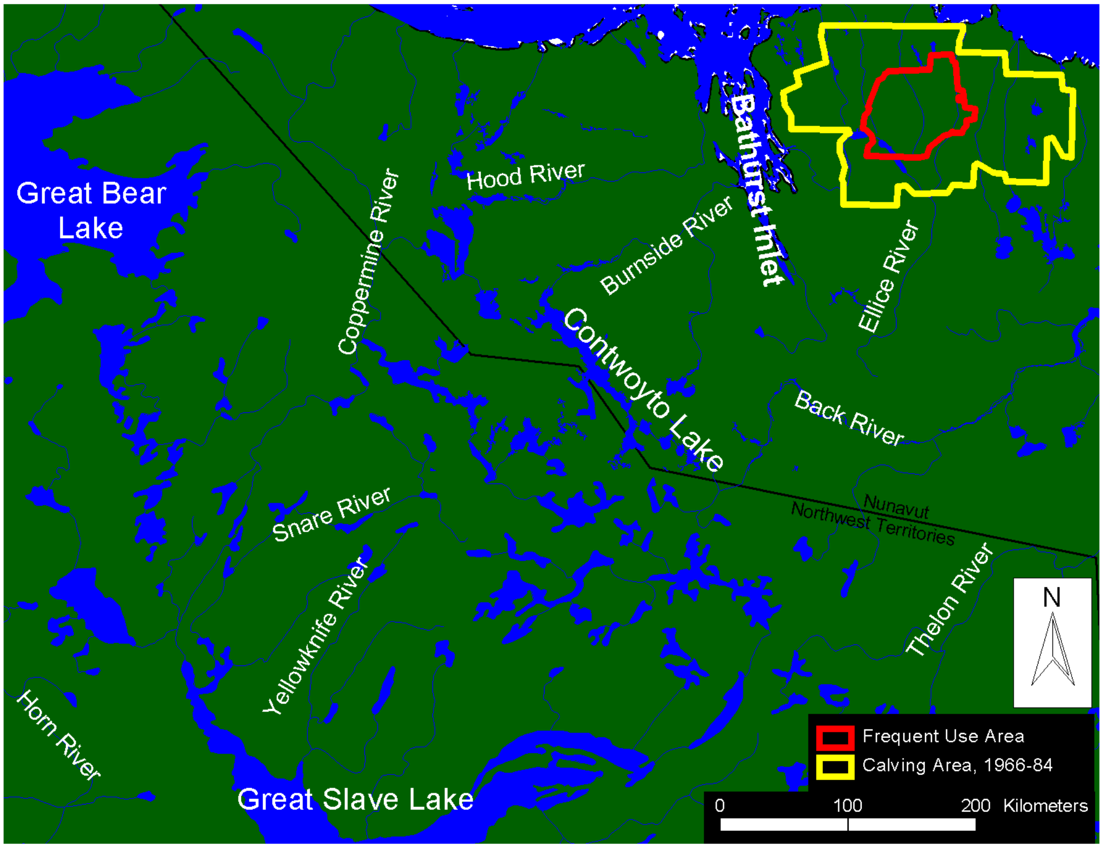


Figure 13. Historical distribution of frequently used areas (areas occupied >5 years) and the calving ground (outer perimeter of all calving distributions) east of Bathurst Inlet, 1966-84.

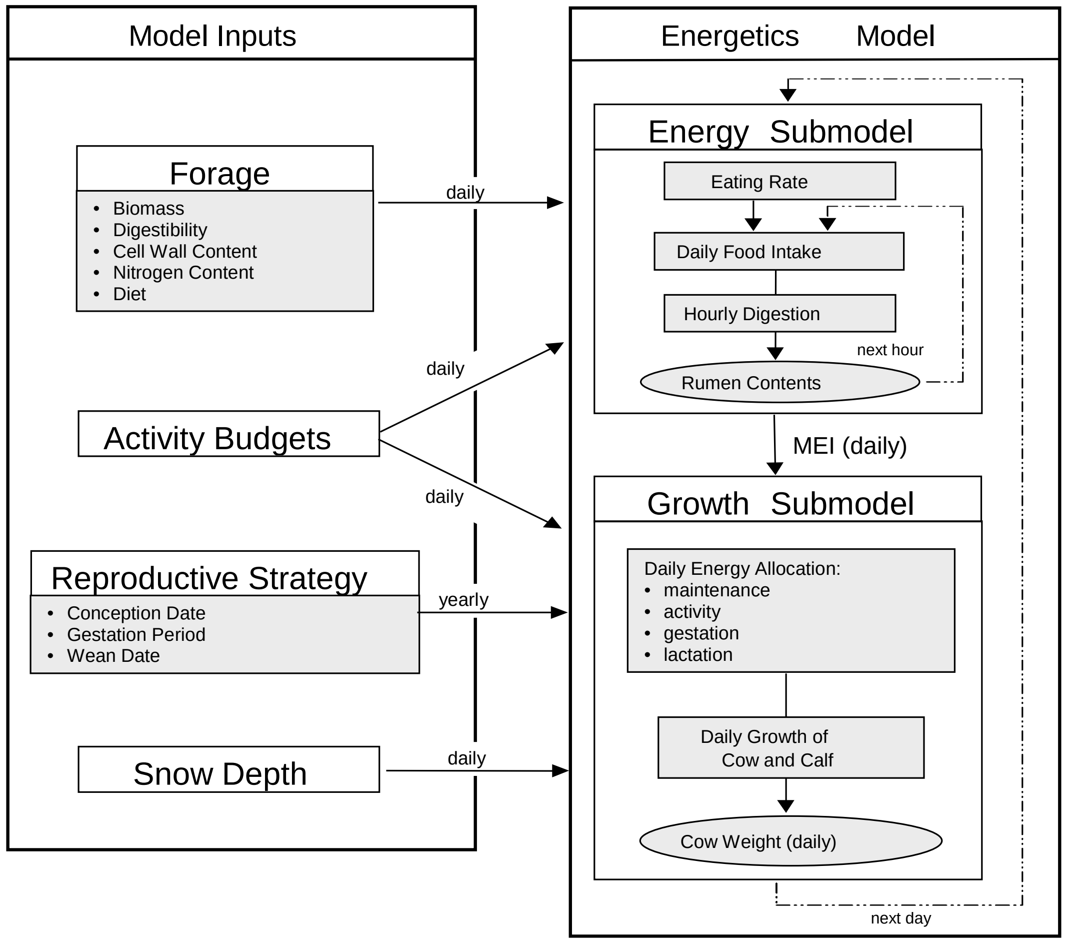


Figure 2. Caribou energetics and growth model schematic.

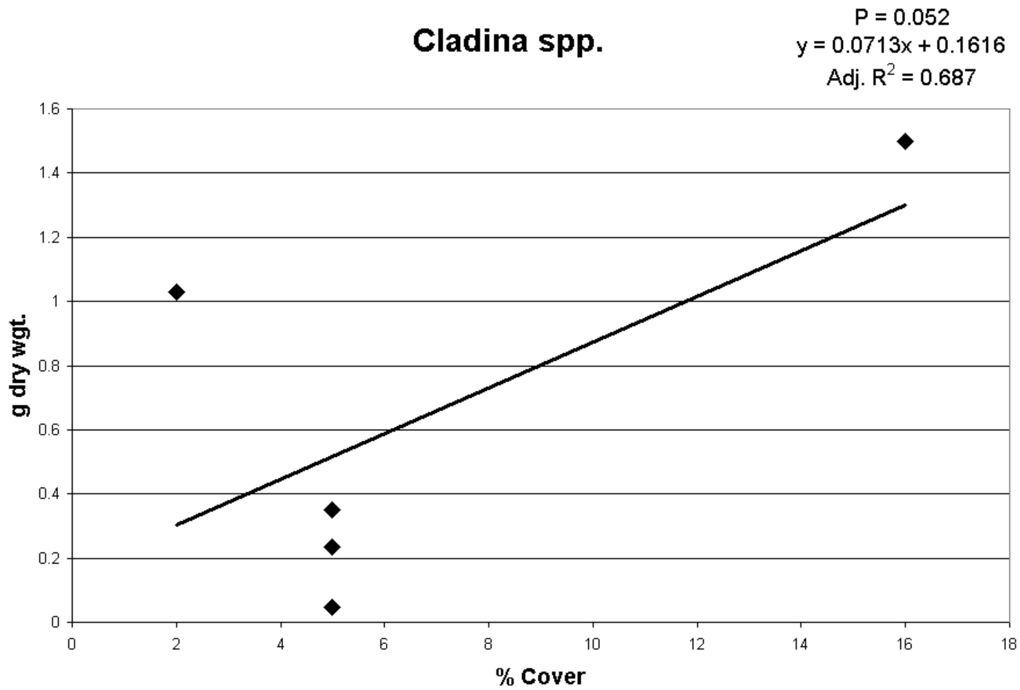


Figure 3. Biomass:cover relationship of *Cladina* on the Bathurst caribou calving ground, 1998-99.

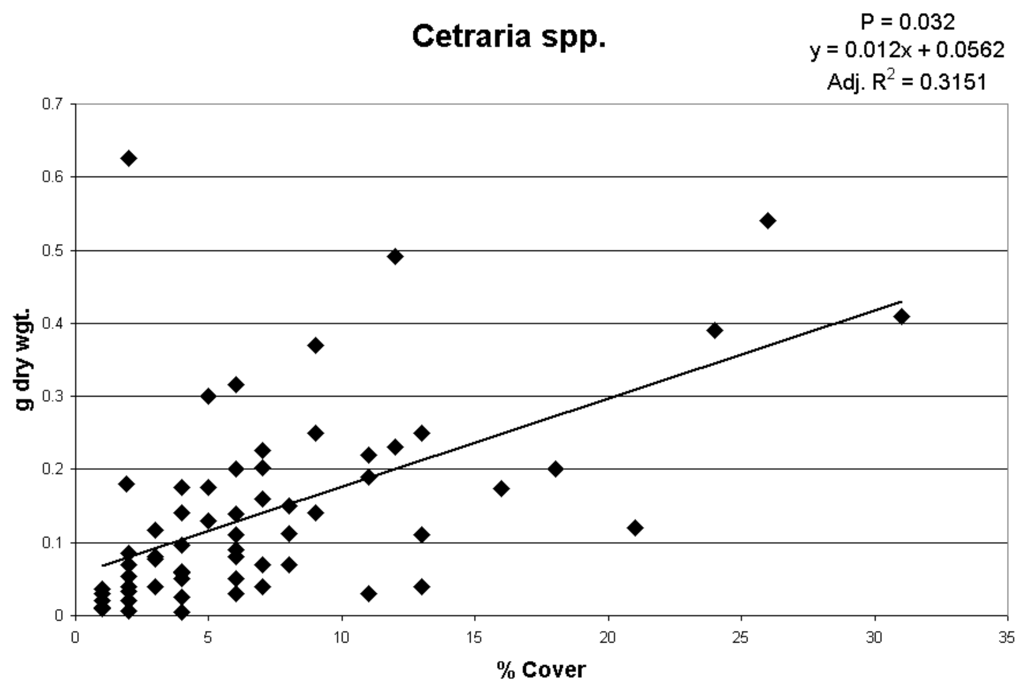


Figure 4. Biomass:cover relationship of *Cetraria* on the Bathurst caribou calving ground, 1998-99.

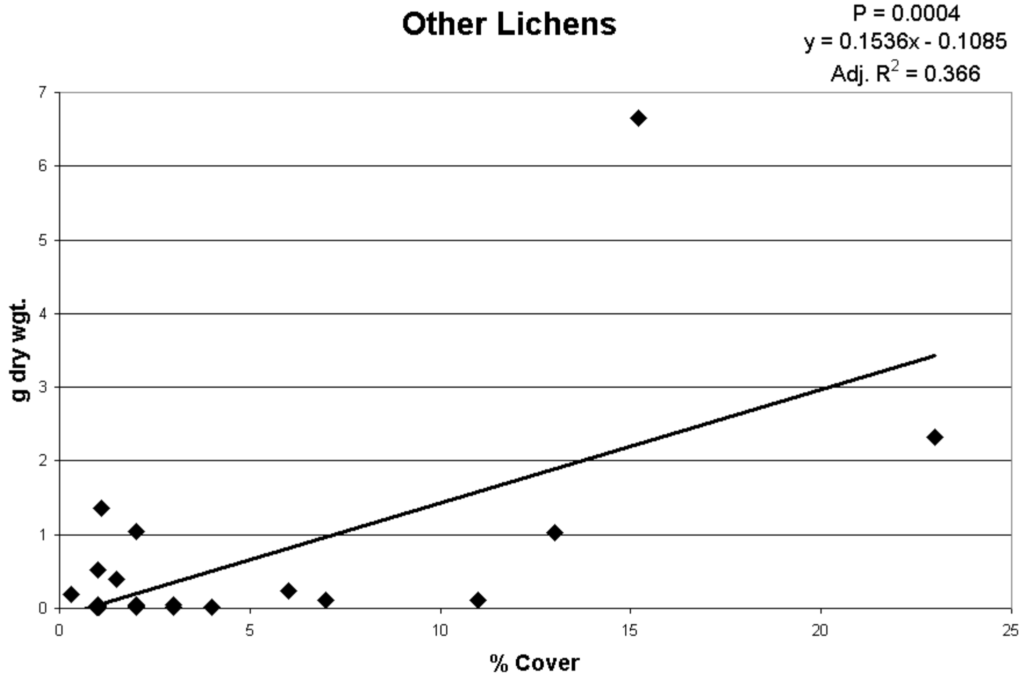


Figure 5. Biomass:cover relationship of lichens (*Dactylina, Hypogymnia, Masonhalea, Peltigera, Spaerophorus, Stereocaulon, Thamnolia*) on the Bathurst caribou calving ground, 1998-99.

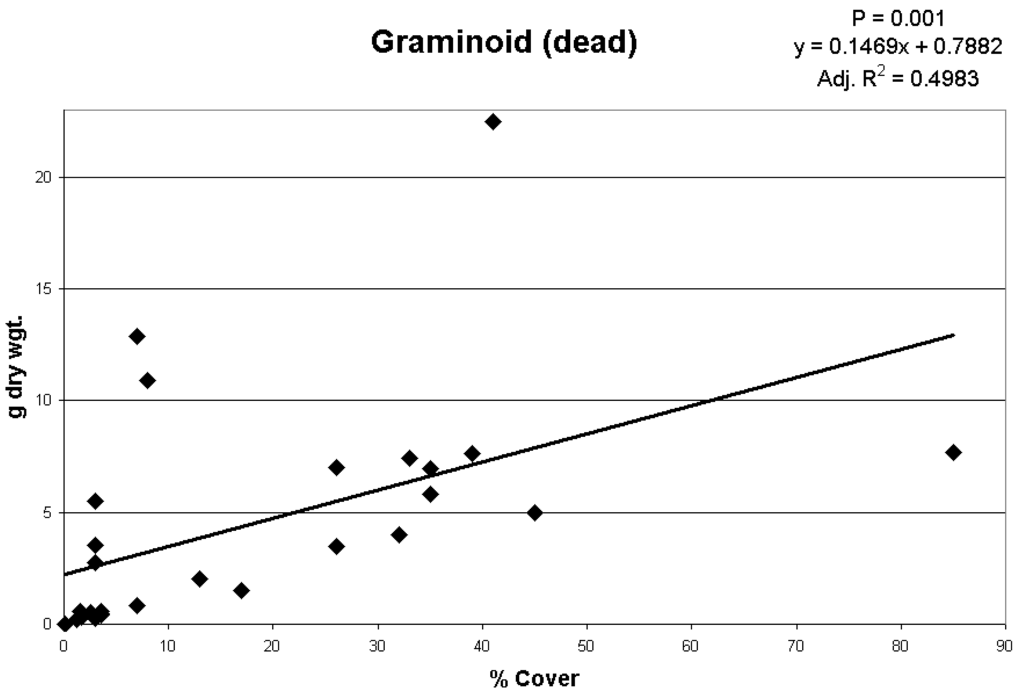


Figure 6. Biomass:cover relationship of dead graminoids on the Bathurst caribou calving ground, 1998-99.

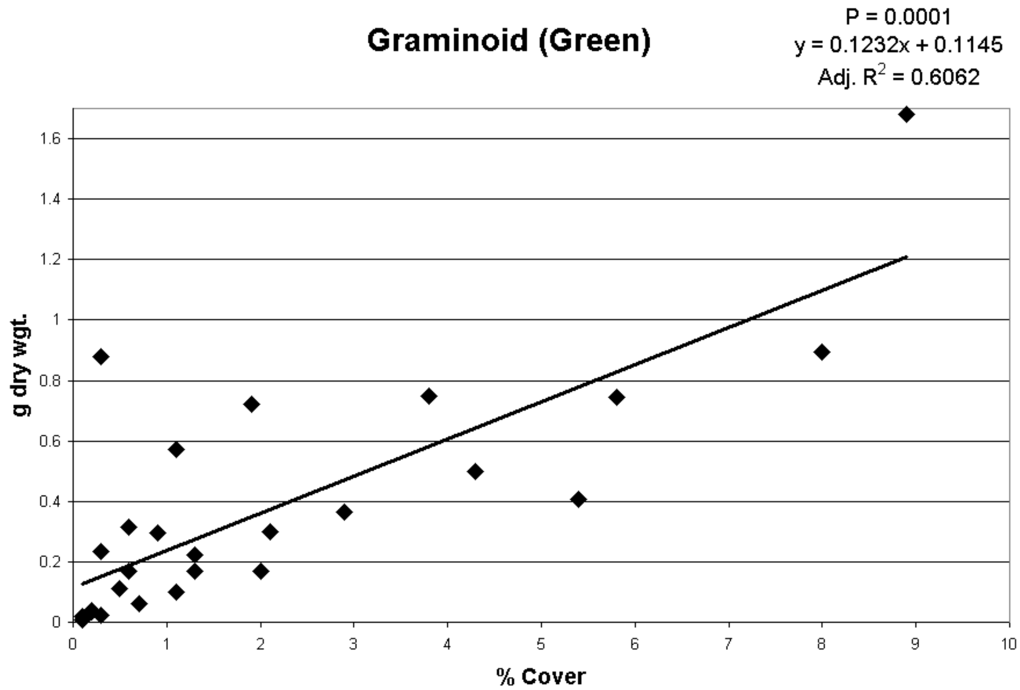


Figure 7. Biomass:cover relationship of live graminoids on the Bathurst caribou calving ground, 1998-99.

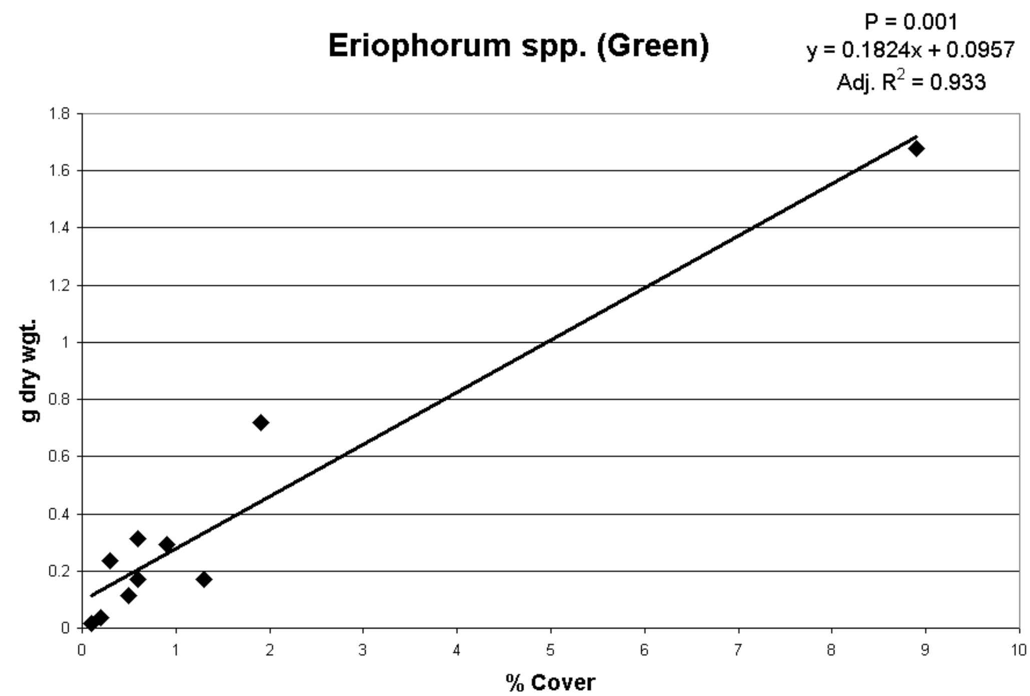


Figure 8. Biomass:cover relationship of live *Eriophorum* on the Bathurst caribou calving ground, 1998-99.

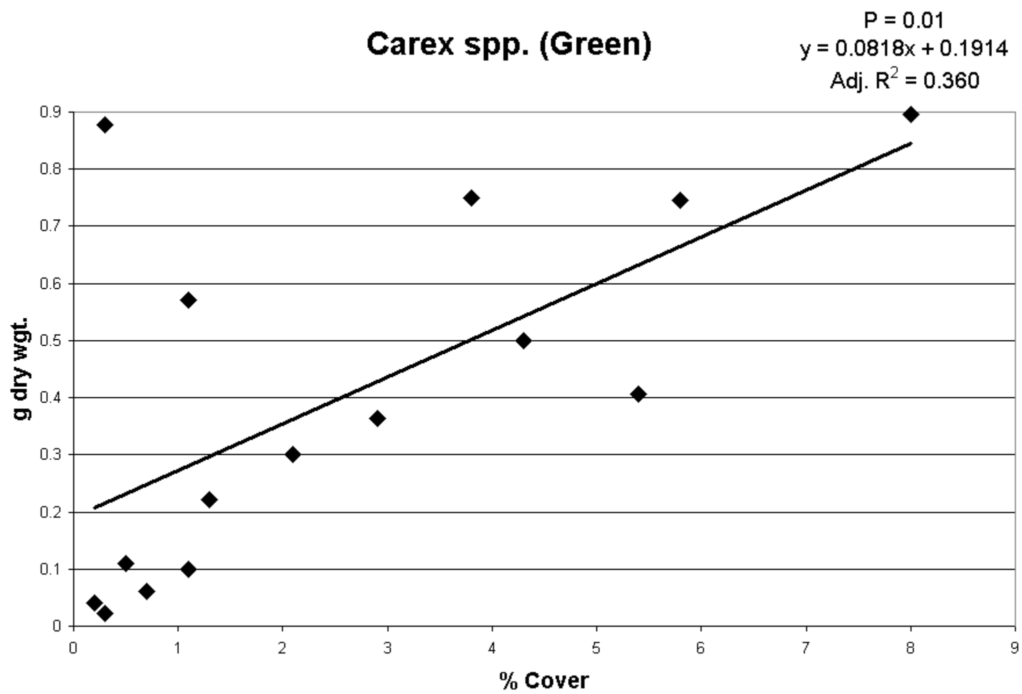


Figure 9. Biomass:cover relationship of live *Carex* on the Bathurst caribou calving ground, 1998-99.

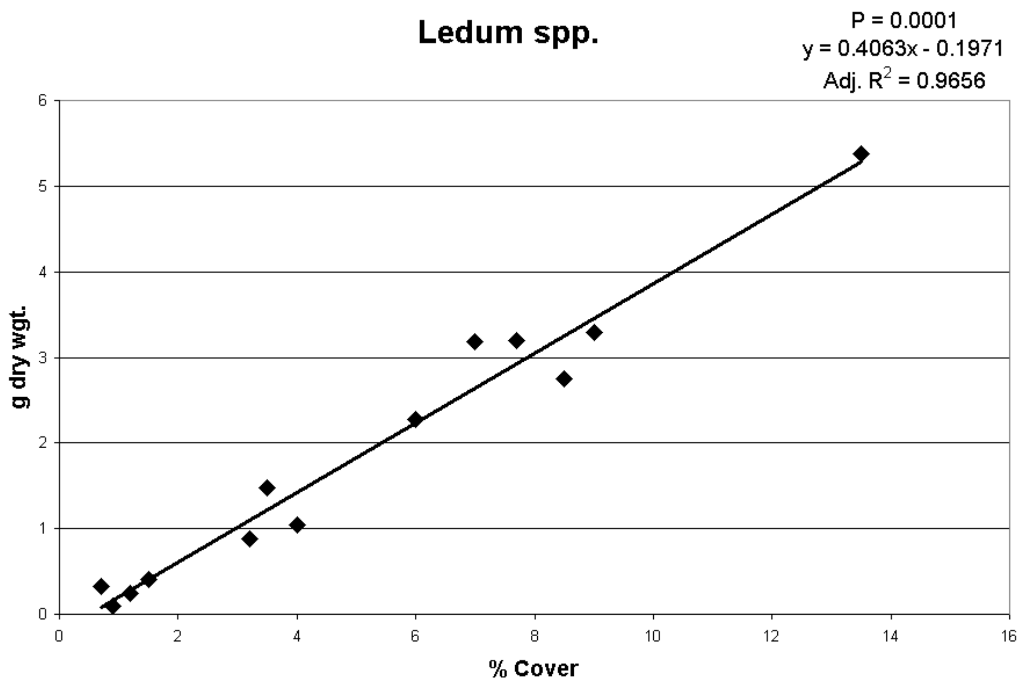


Figure 10. Biomass:cover relationship of *Ledum* on the Bathurst caribou calving ground, 1998-99.

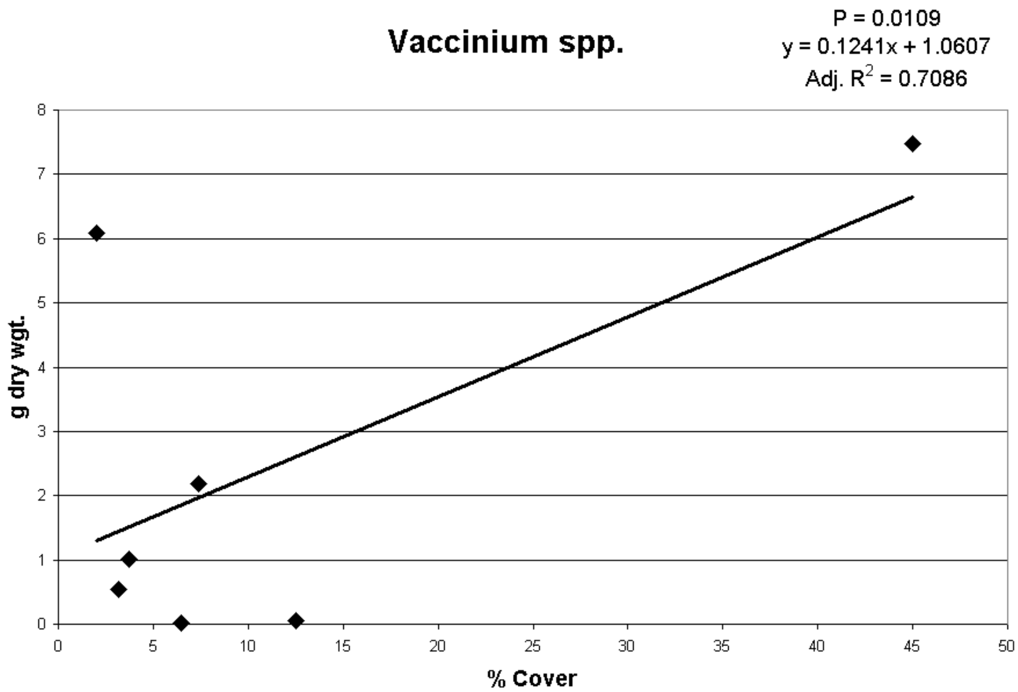


Figure 11. Biomass:cover relationship of *Vaccinium* on the Bathurst caribou calving ground, 1998-99.

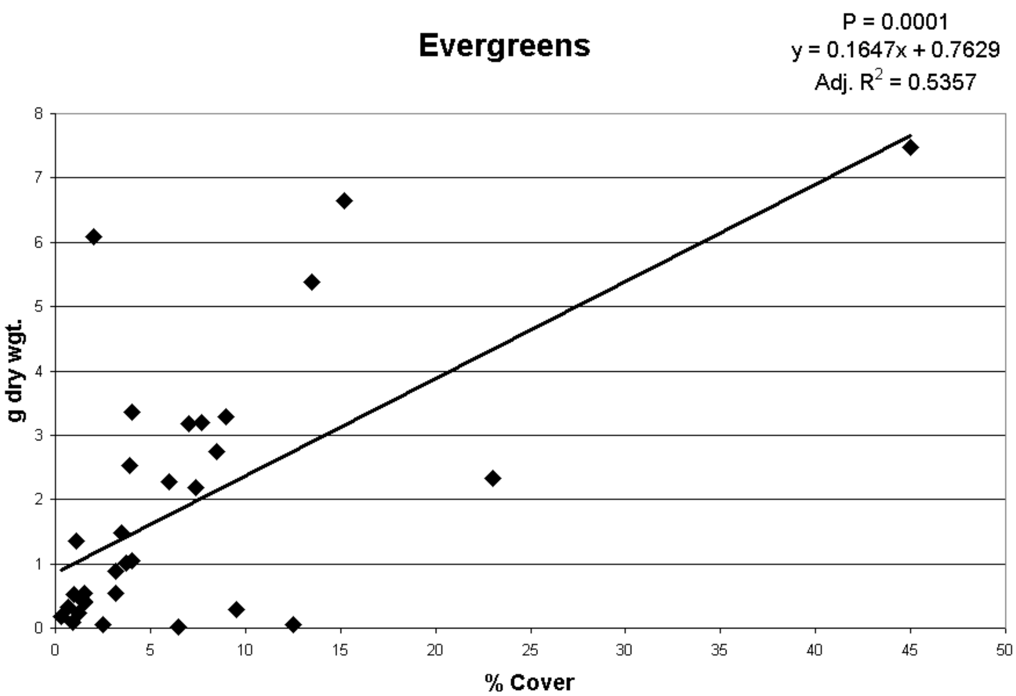


Figure 12. Biomass:cover relationship of Evergreen plants on the Bathurst caribou calving ground, 1998-99.

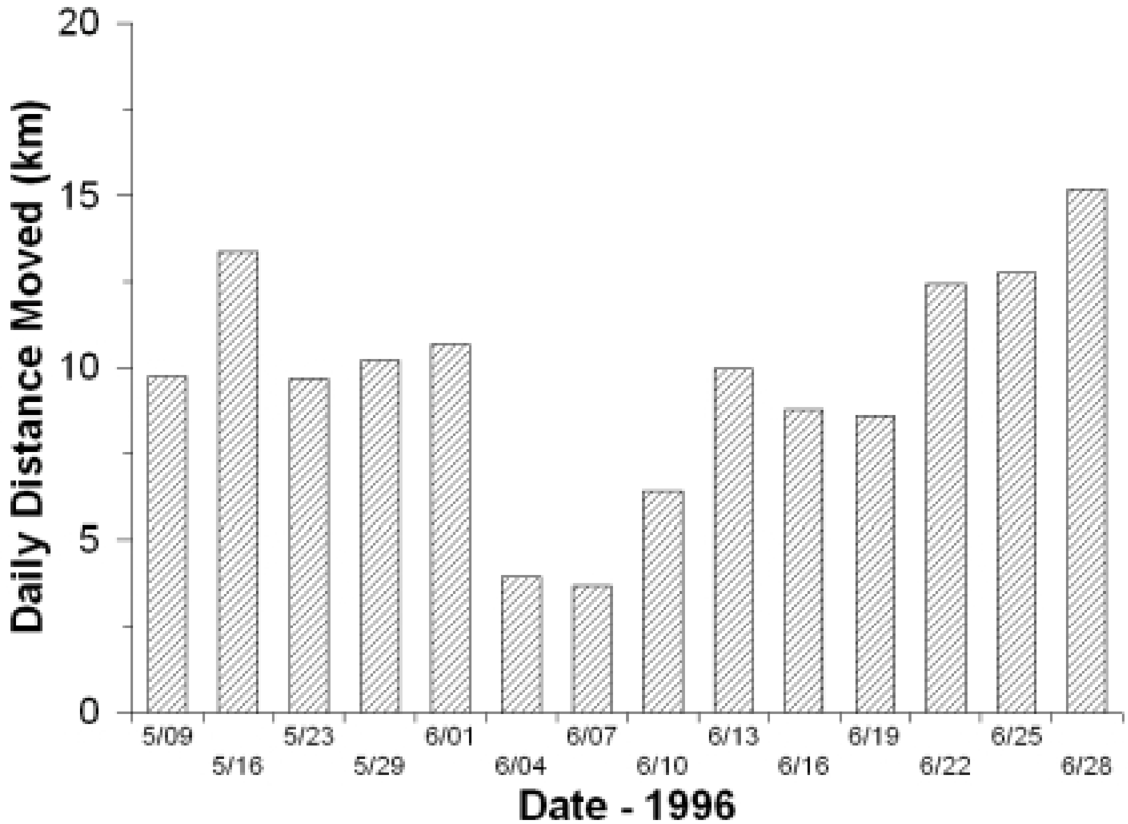


Figure 13. Average daily travel distance of satellite-collared Bathurst caribou, 1996.

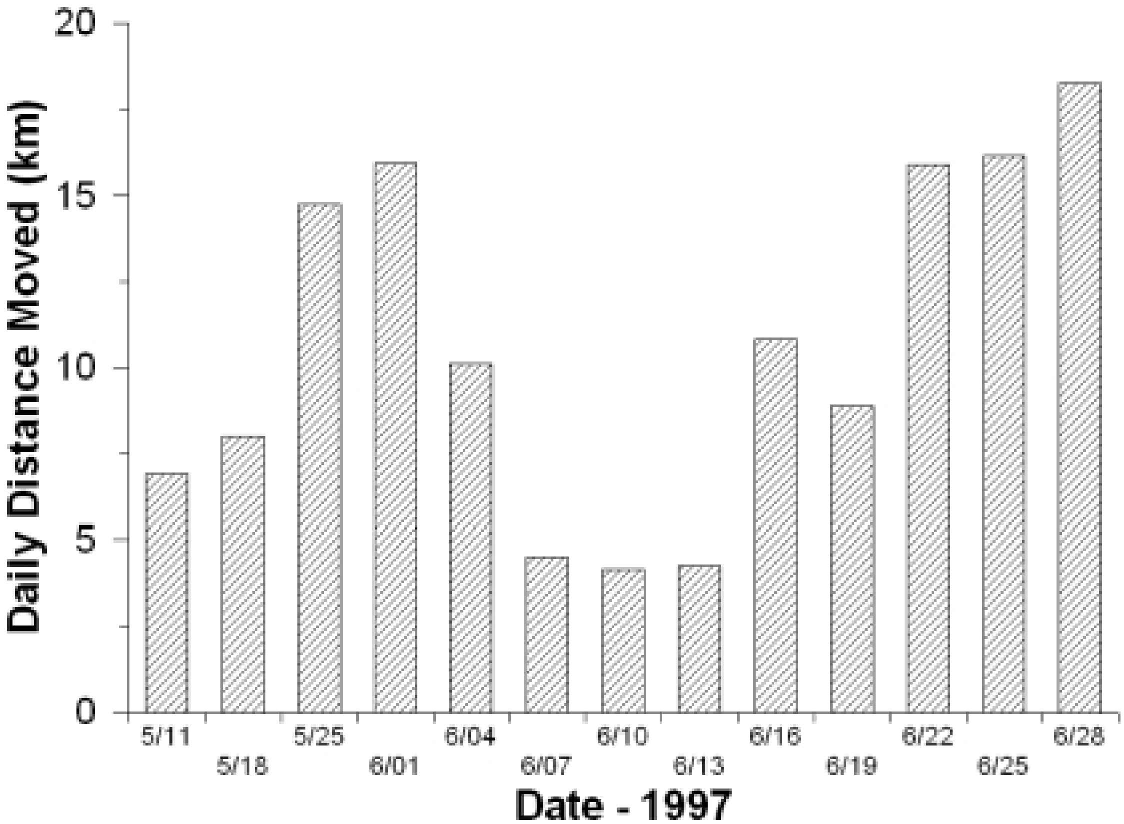


Figure 14. Average daily travel distance of satellite-collared Bathurst caribou, 1997.

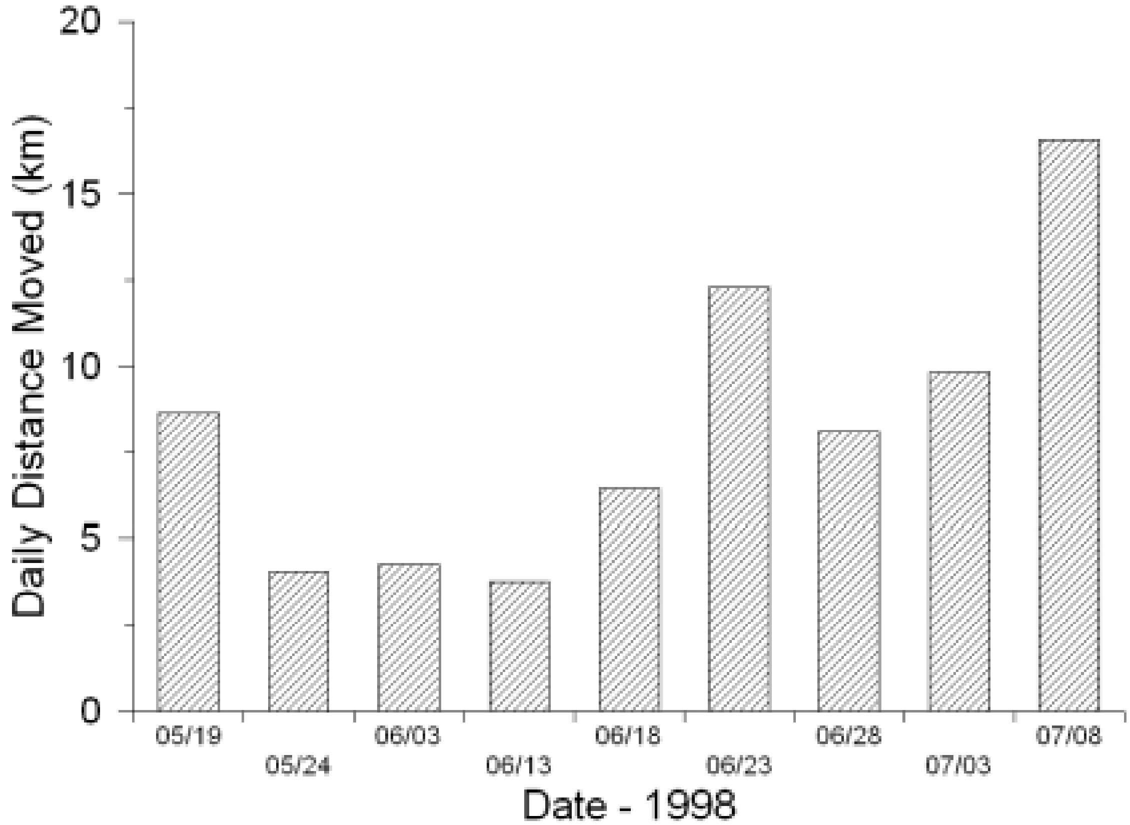


Figure 15. Average daily travel distance of satellite-collared Bathurst caribou, 1998.

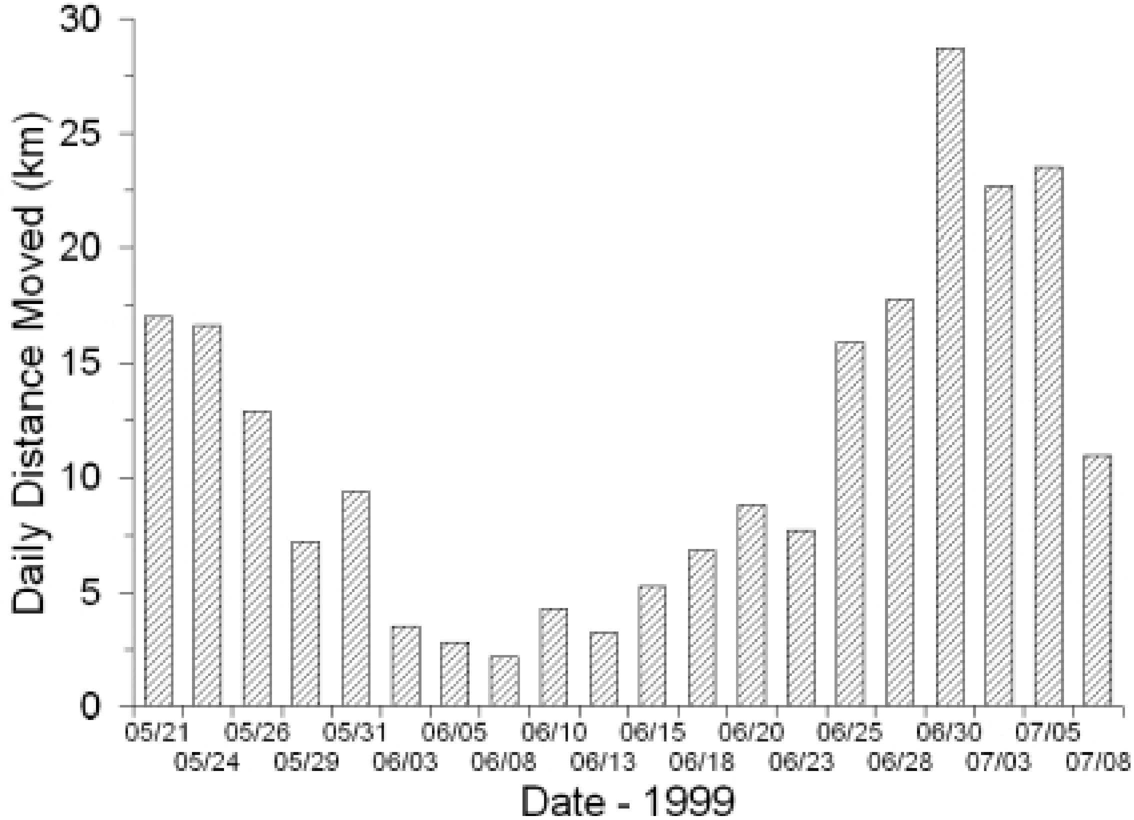


Figure 16. Average daily travel distance of satellite-collared Bathurst caribou, 1999.

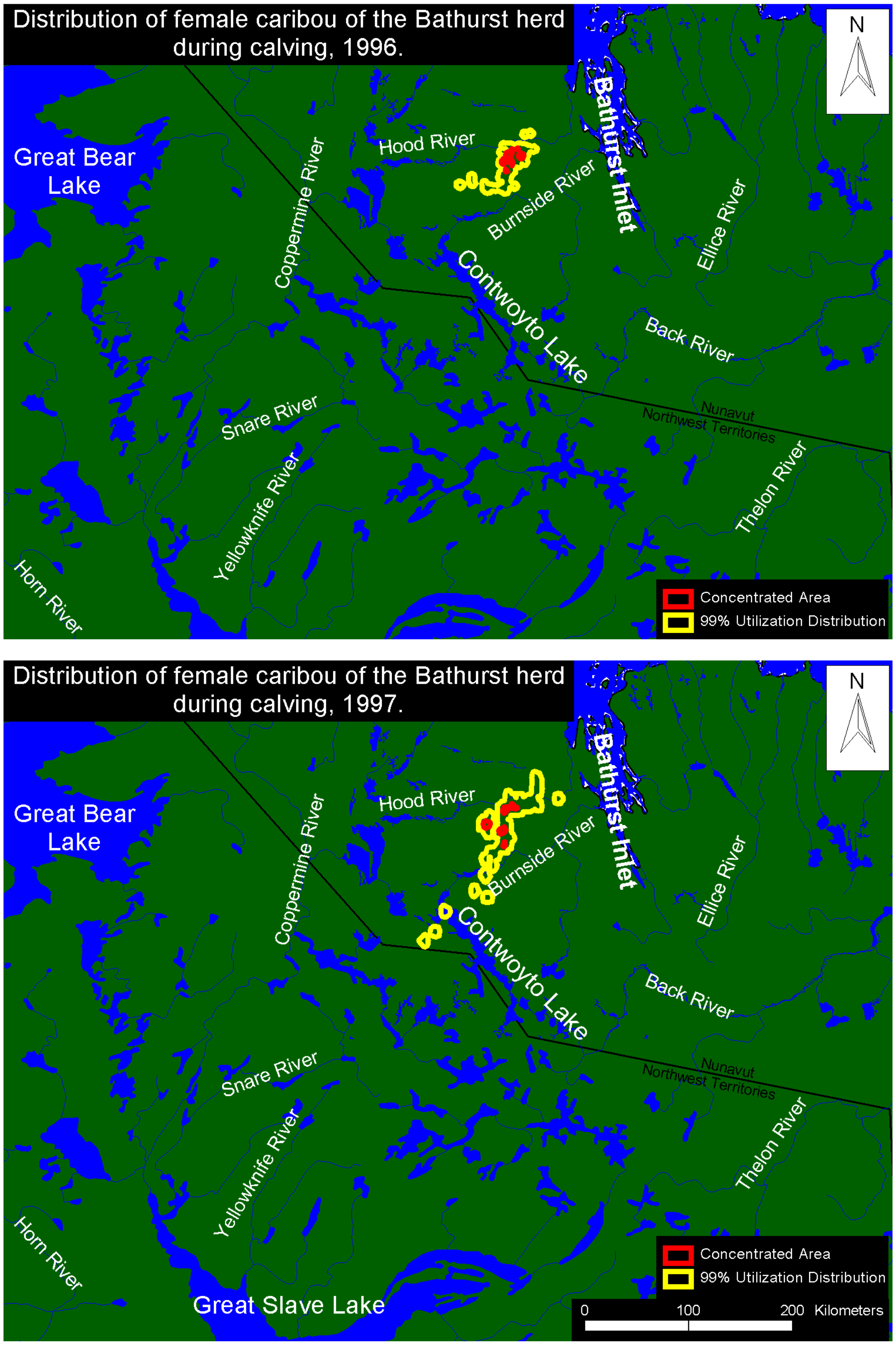
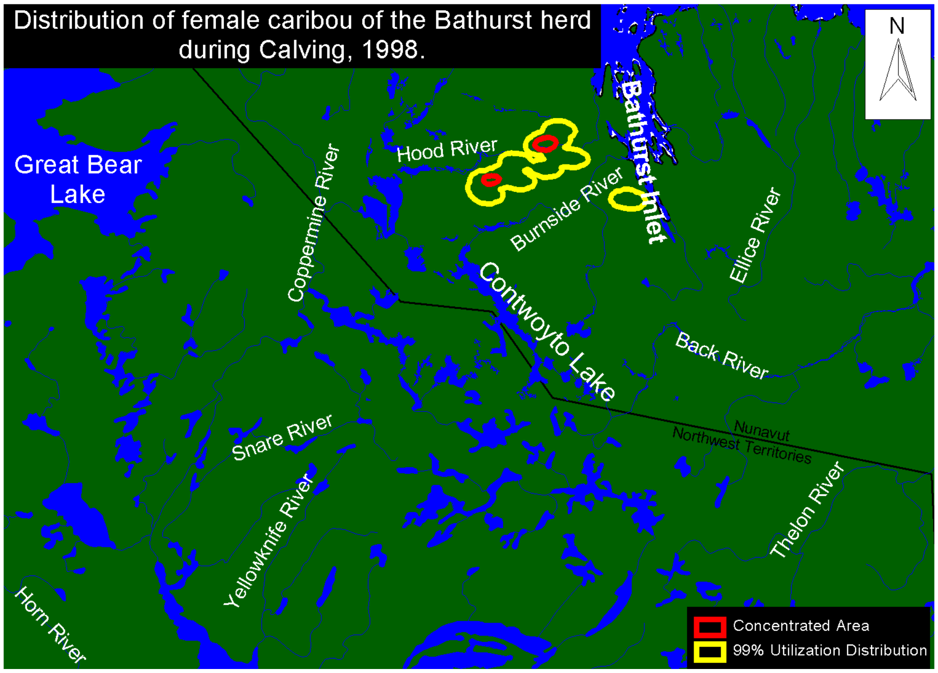


Figure 17. Calving distributions of Bathurst Caribou, 1996 and 1997.



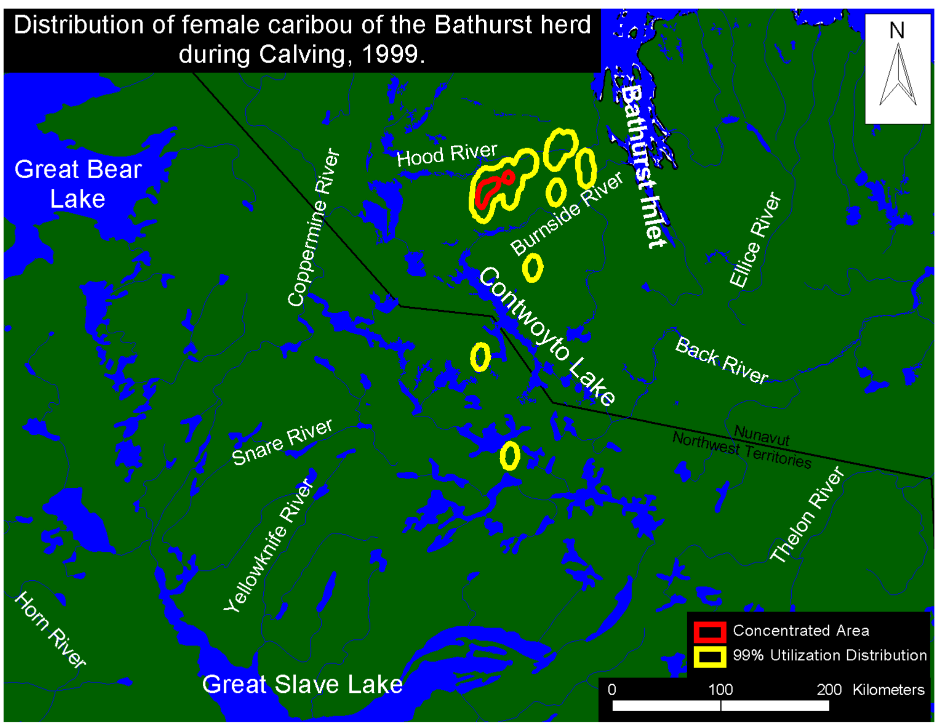


Figure 18. Calving distributions of Bathurst caribou, 1998 and 1999.

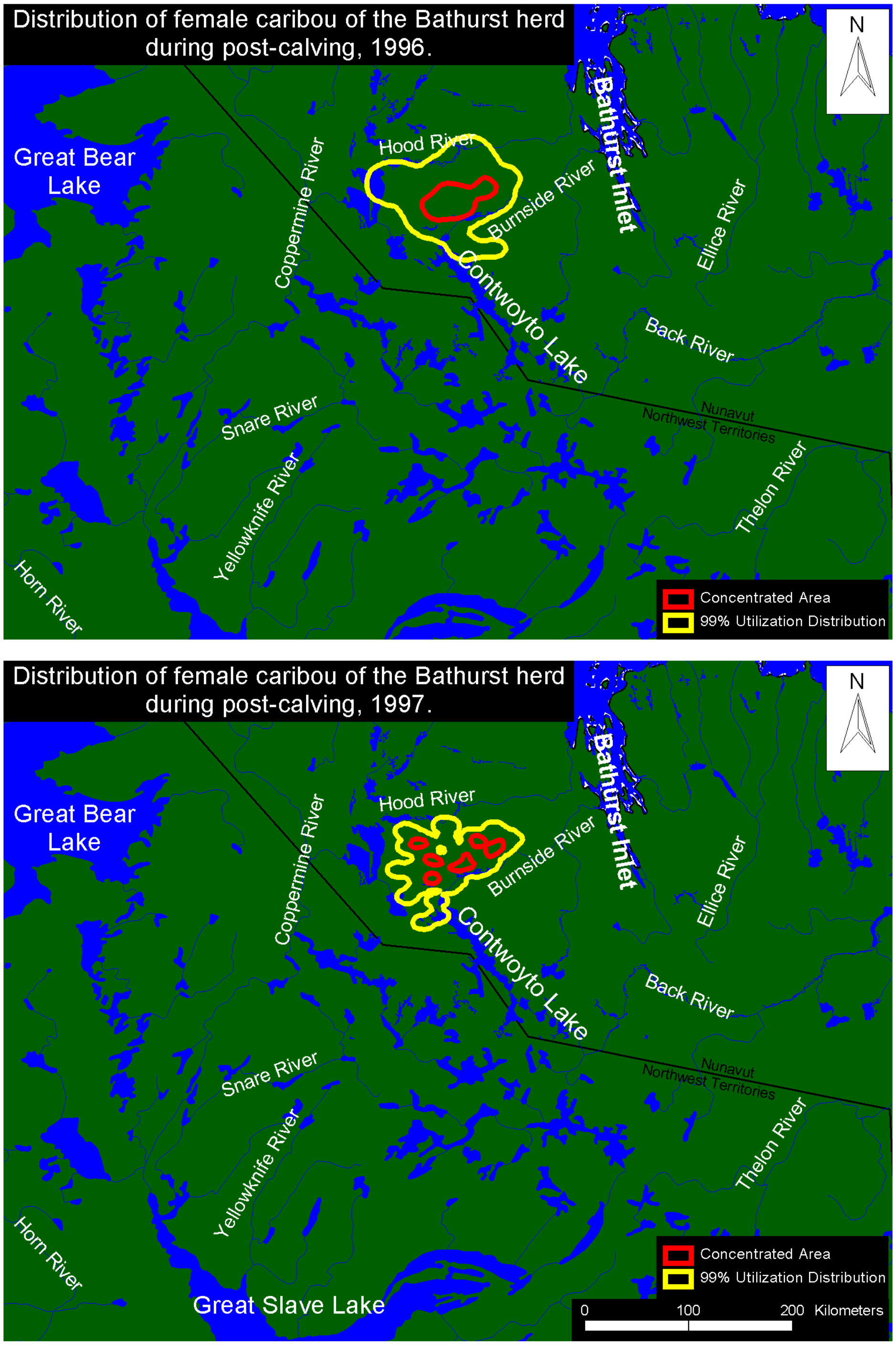


Figure 19. Post-calving distributions of Bathurst caribou, 1996 and 1997.

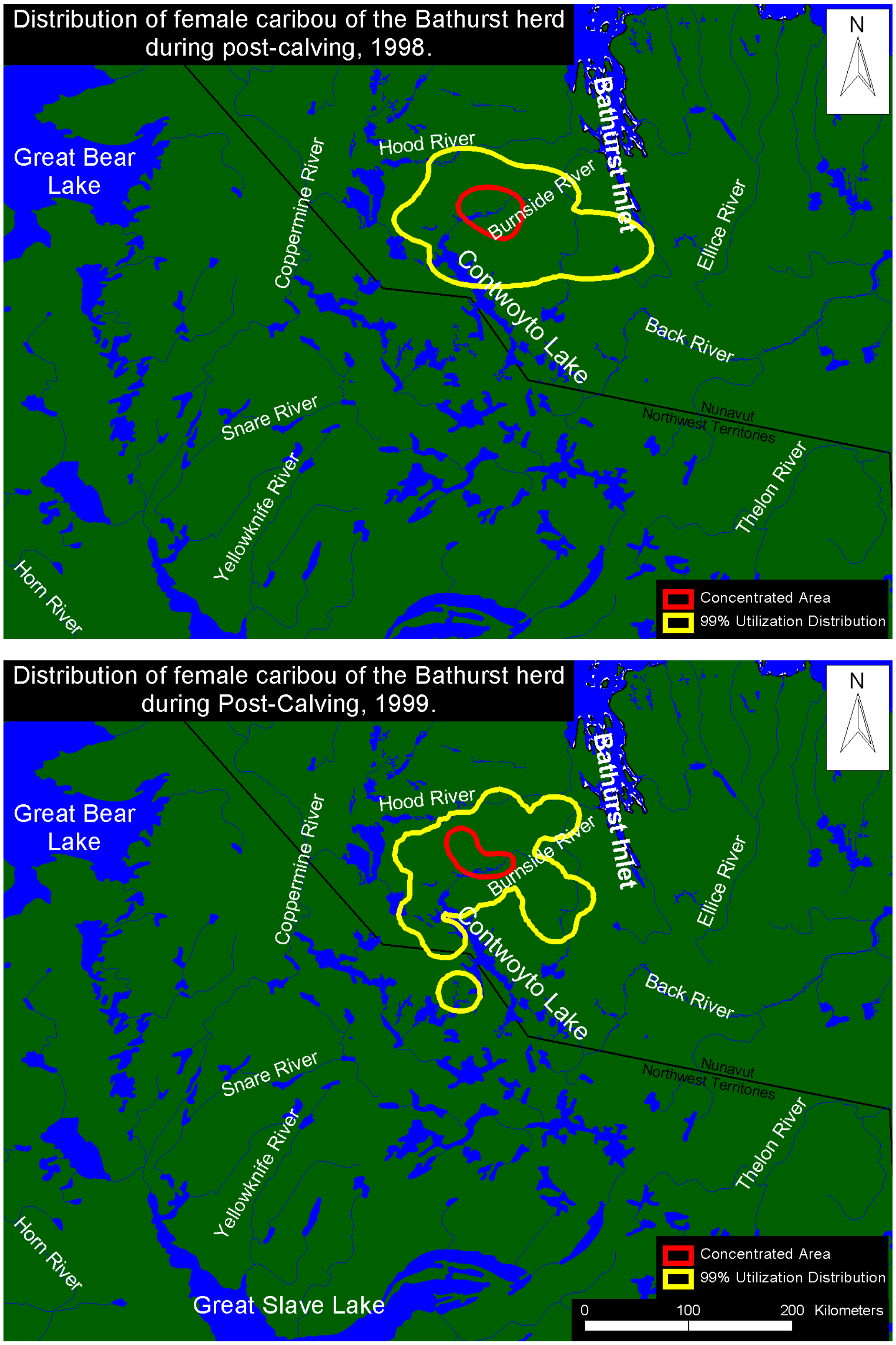


Figure 20. Post-calving distributions of Bathurst caribou, 1998 and 1999,

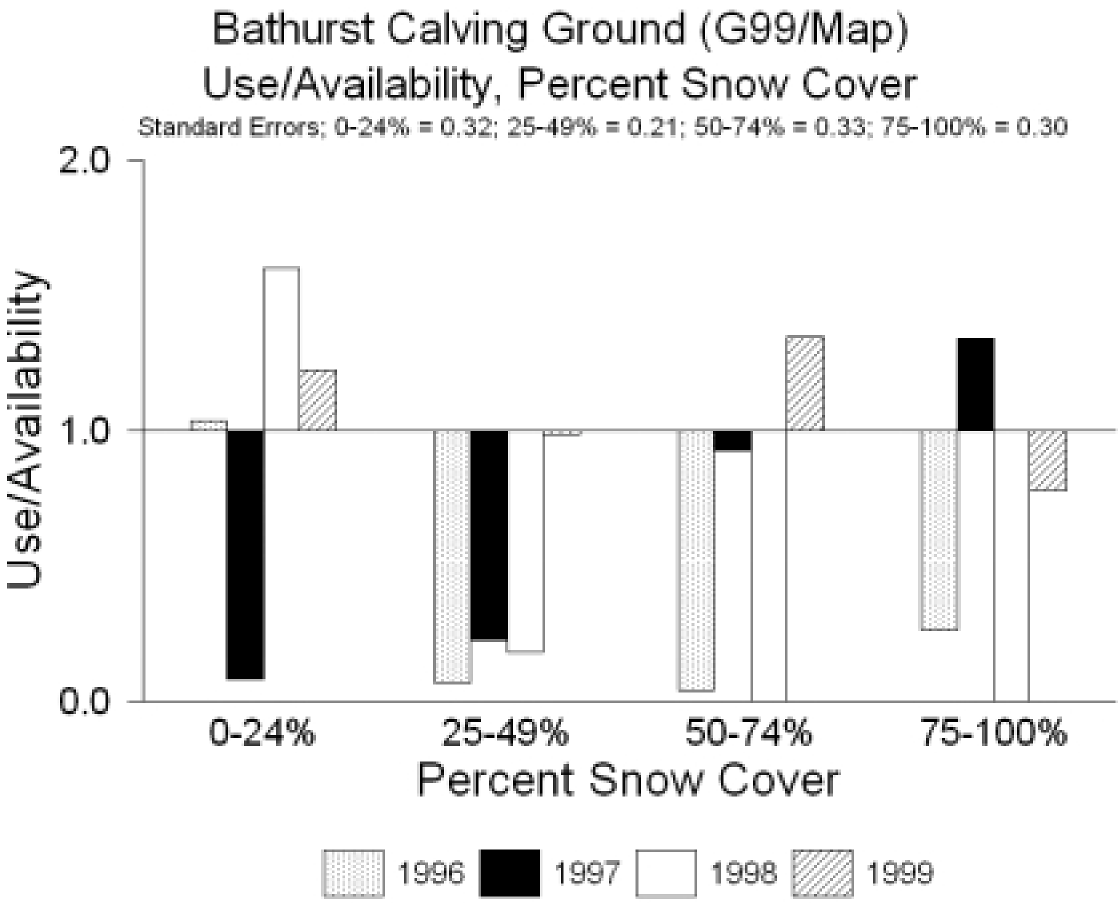


Figure 21. Second order (G99/Map; outer perimeter of all annual calving grounds/map extent) use/availability of snow cover classes at calving, 1996-99, Bathurst caribou calving ground, Nunavut.

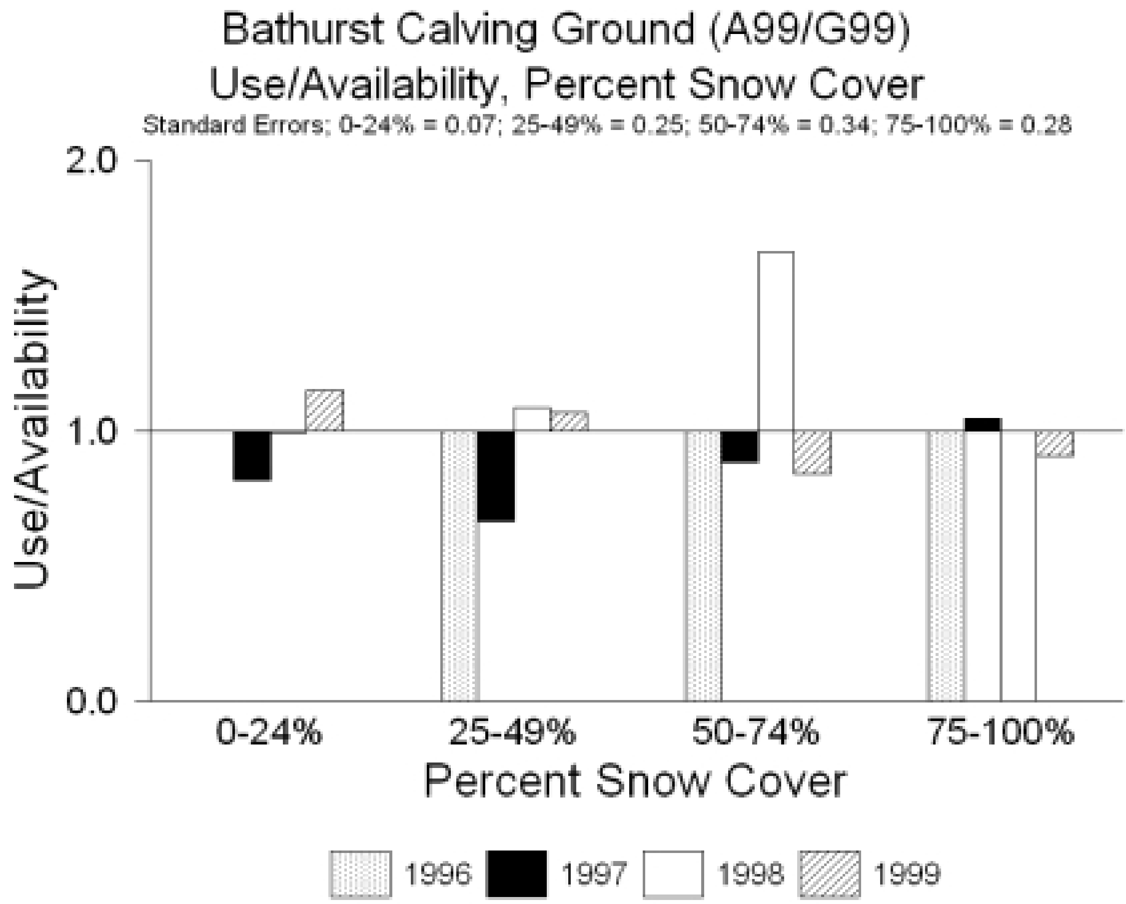


Figure 22. Third order (A99/G99; annual calving ground/outer perimeter of all annual calving grounds) use/availability of snow cover classes at calving, 1996-99, Bathurst caribou calving ground, Nunavut.

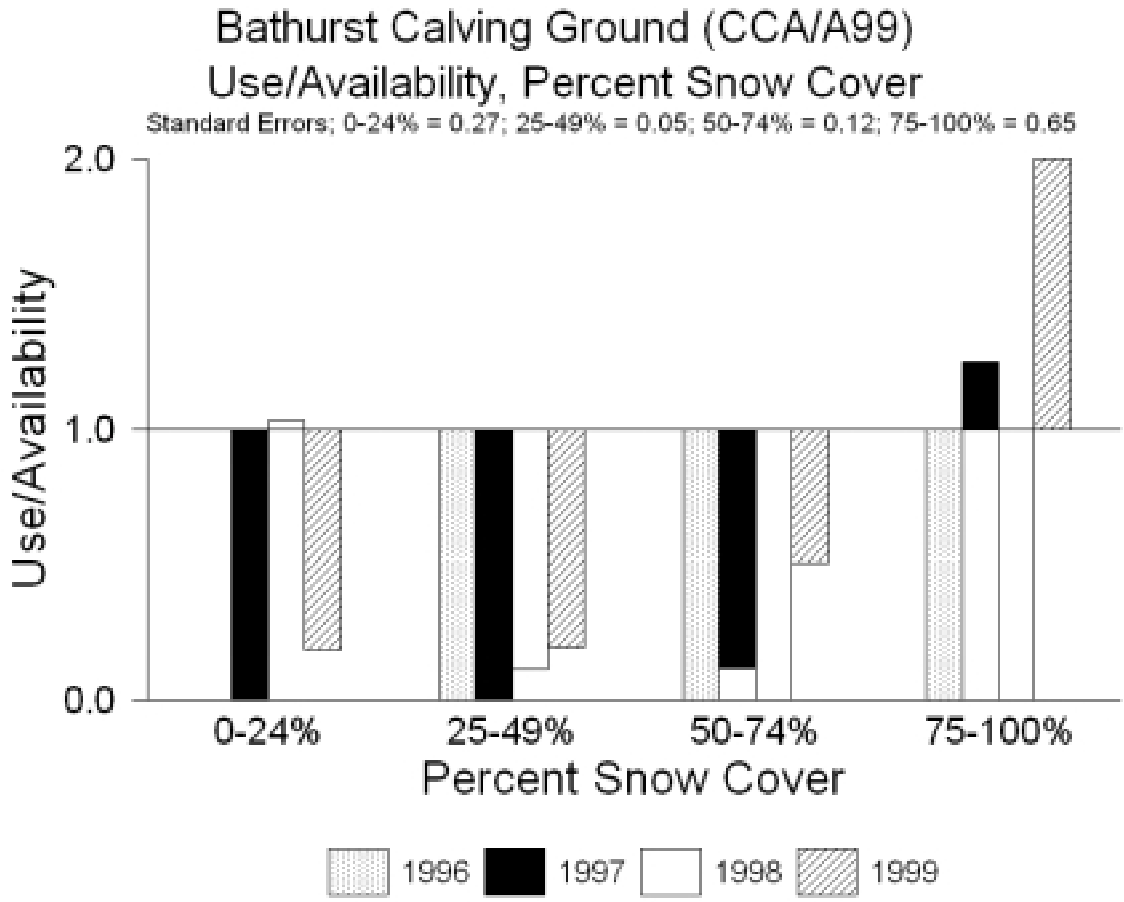


Figure 23. Fourth order (CCA/A99; annual concentrated calving area/annual calving ground) use/availability of snow cover classes at calving , 1996-99, Bathurst caribou calving ground, Nunavut.

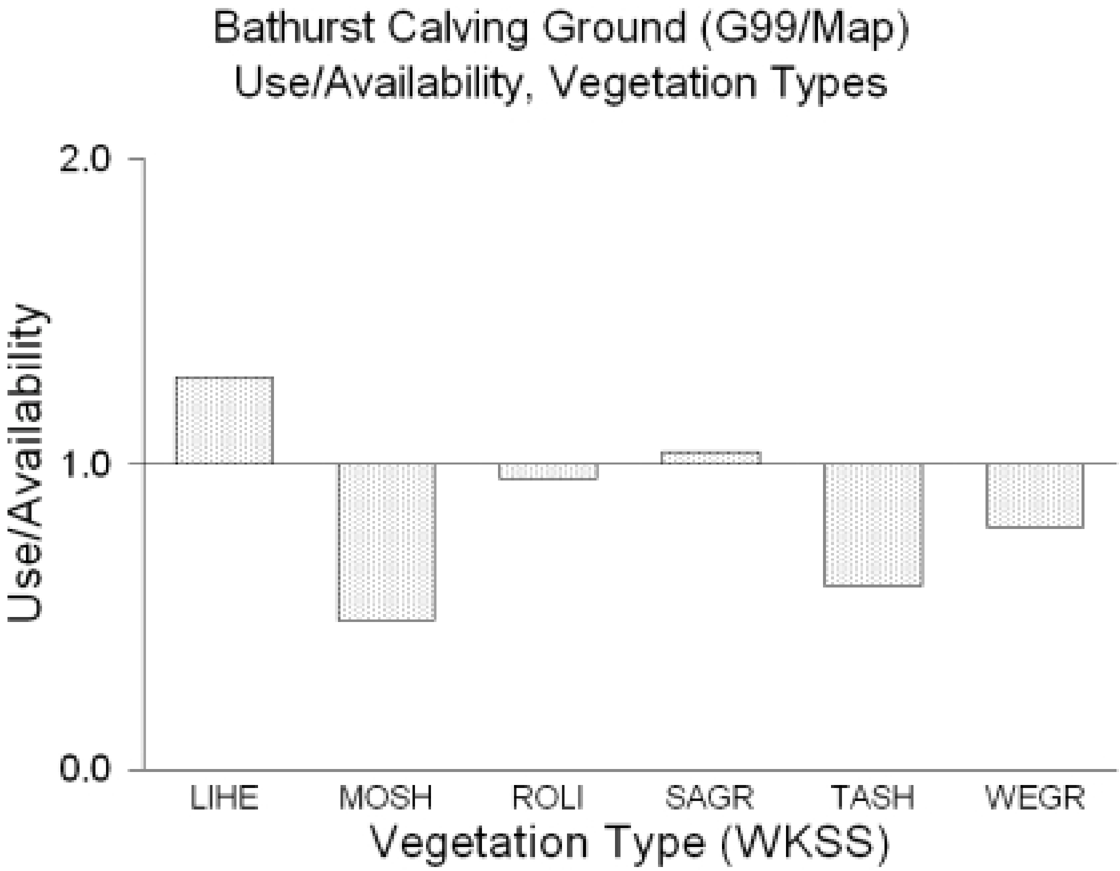


Figure 24. Second order (G99/Map; outer perimeter of all annual calving grounds/map extent) use/availability of vegetation types, 1996-99, Bathurst caribou calving ground, Nunavut. Vegetation types are: 1) LIHE – Lichen Heath; 2) MOSH – Moist Shrub; 3) ROLI – Rock Lichen Barrens; 4) SAGR – Sand and Gravel; 5) TASH – Tal Shrub; and 6) WEGR – Wet Graminoid, based on a reclassification of the WKSS vegetation map.

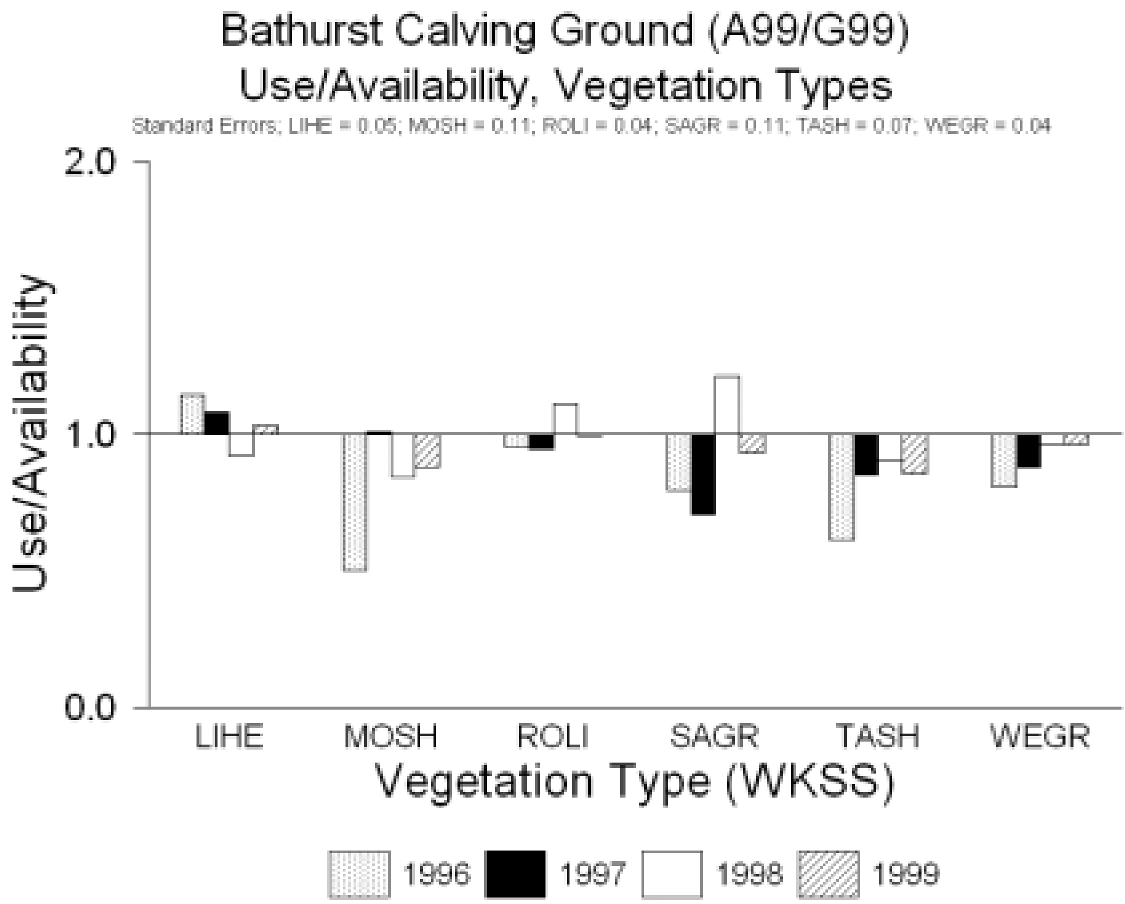


Figure 25. Third order (A99/G99; annual calving ground/outer perimeter of all annual calving grounds) use/availability of vegetation types, 1996-99, Bathurst caribou calving ground, Nunavut. Vegetation types are: 1) LIHE – Lichen Heath; 2) MOSH – Moist Shrub; 3) ROLI – Rock Lichen Barrens; 4) SAGR – Sand and Gravel; 5) TASH – Tal Shrub; and 6) WEGR – Wet Graminoid, based on a reclassification of the WKSS vegetation map.

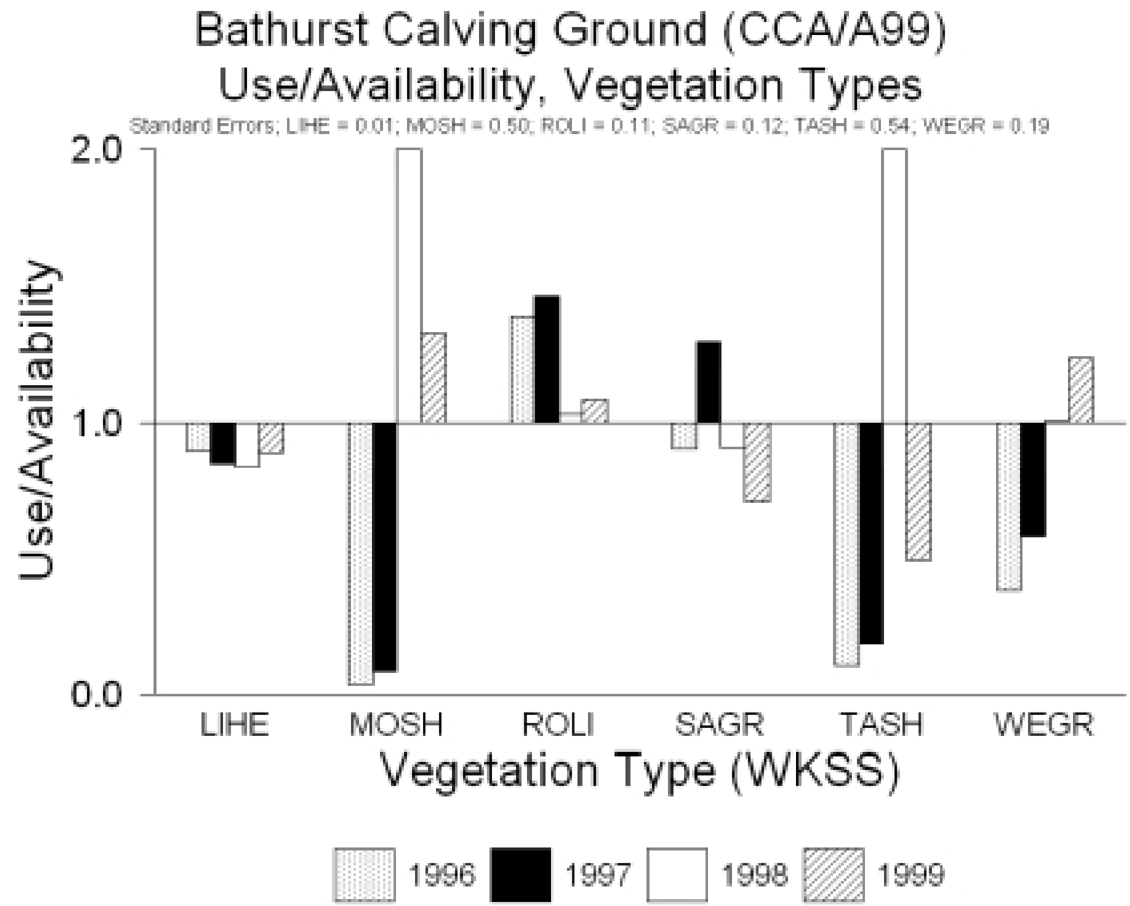


Figure 26. Fourth order (CCA/A99; annual concentrated calving area/annual calving ground) use/availability of vegetation types, 1996-99, Bathurst caribou calving ground, Nunavut. Vegetation types are: 1) LIHE – Lichen Heath; 2) MOSH – Moist Shrub; 3) ROLI – Rock Lichen Barrens; 4) SAGR – Sand and Gravel; 5) TASH – Tal Shrub; and 6) WEGR – Wet Graminoid, based on a reclassification of the WKSS vegetation map.

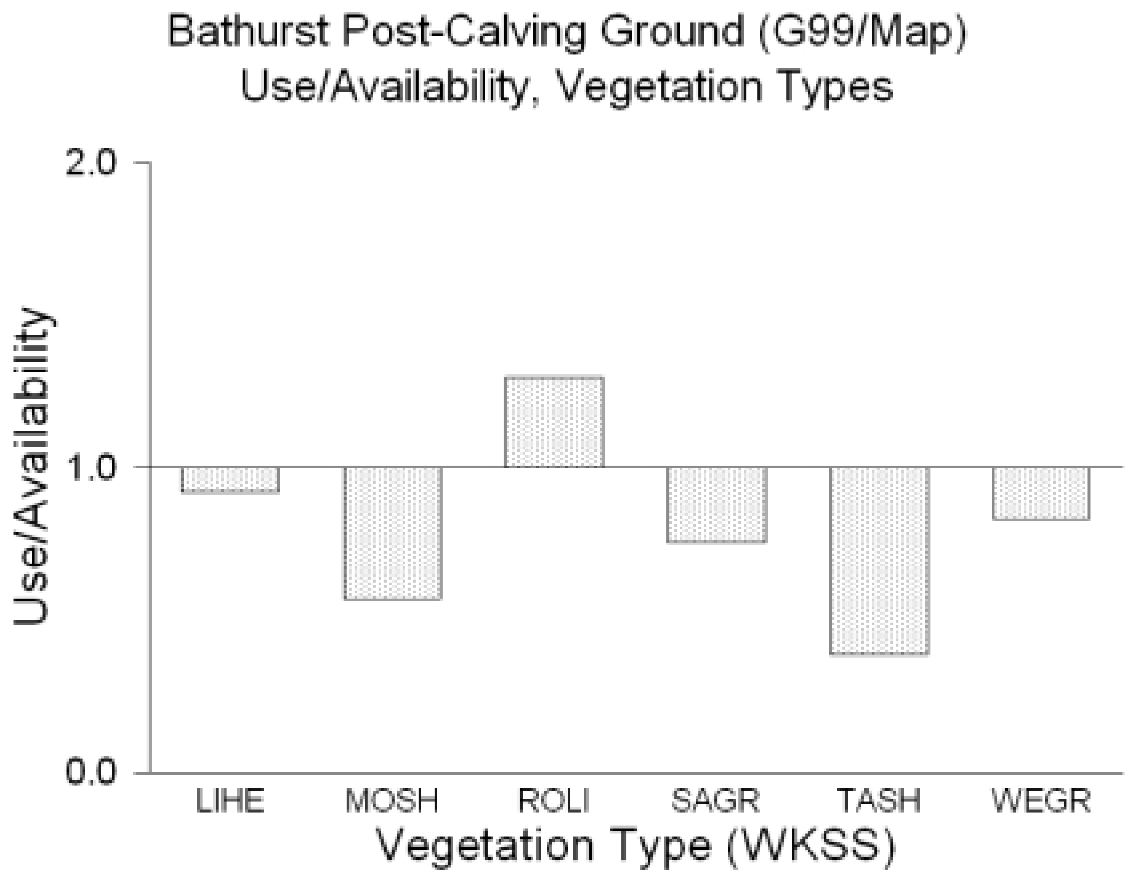


Figure 27. Second order (G99/Map; outer perimeter of all annual post-calving grounds/map extent) use/availability of vegetation types, 1996-99, Bathurst caribou post-calving ground, Nunavut. Vegetation types are: 1) LIHE – Lichen Heath; 2) MOSH – Moist Shrub; 3) ROLI – Rock Lichen Barrens; 4) SAGR – Sand and Gravel; 5) TASH – Tal Shrub; and 6) WEGR – Wet Graminoid, based on a reclassification of the WKSS vegetation map

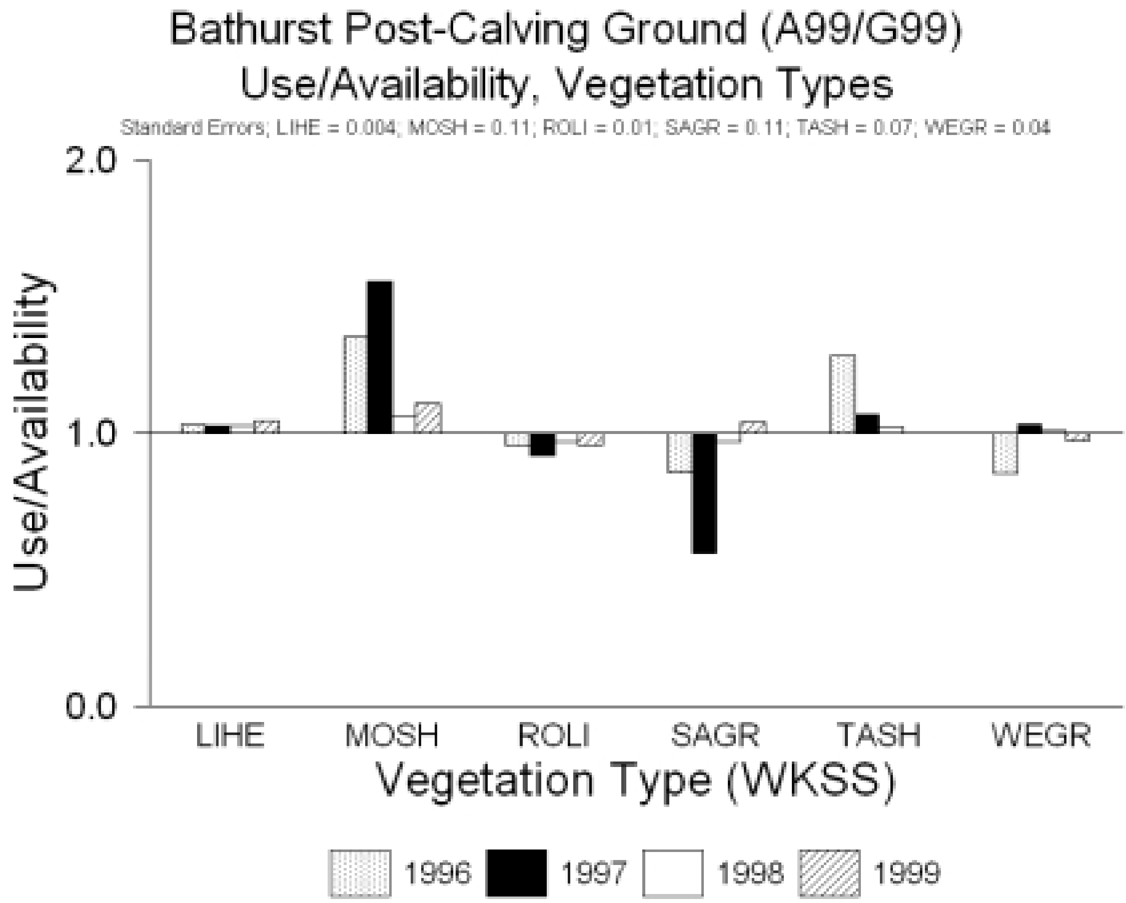


Figure 28. Third order (A99/G99; annual post-calving ground/outer perimeter of all annual post-calving grounds) use/availability of vegetation types, 1996-99, Bathurst caribou calving ground, Nunavut. Vegetation types are: 1) LIHE – Lichen Heath; 2) MOSH – Moist Shrub; 3) ROLI – Rock Lichen Barrens; 4) SAGR – Sand and Gravel; 5) TASH – Tal Shrub; and 6) WEGR – Wet Graminoid, based on a reclassification of the WKSS vegetation map.

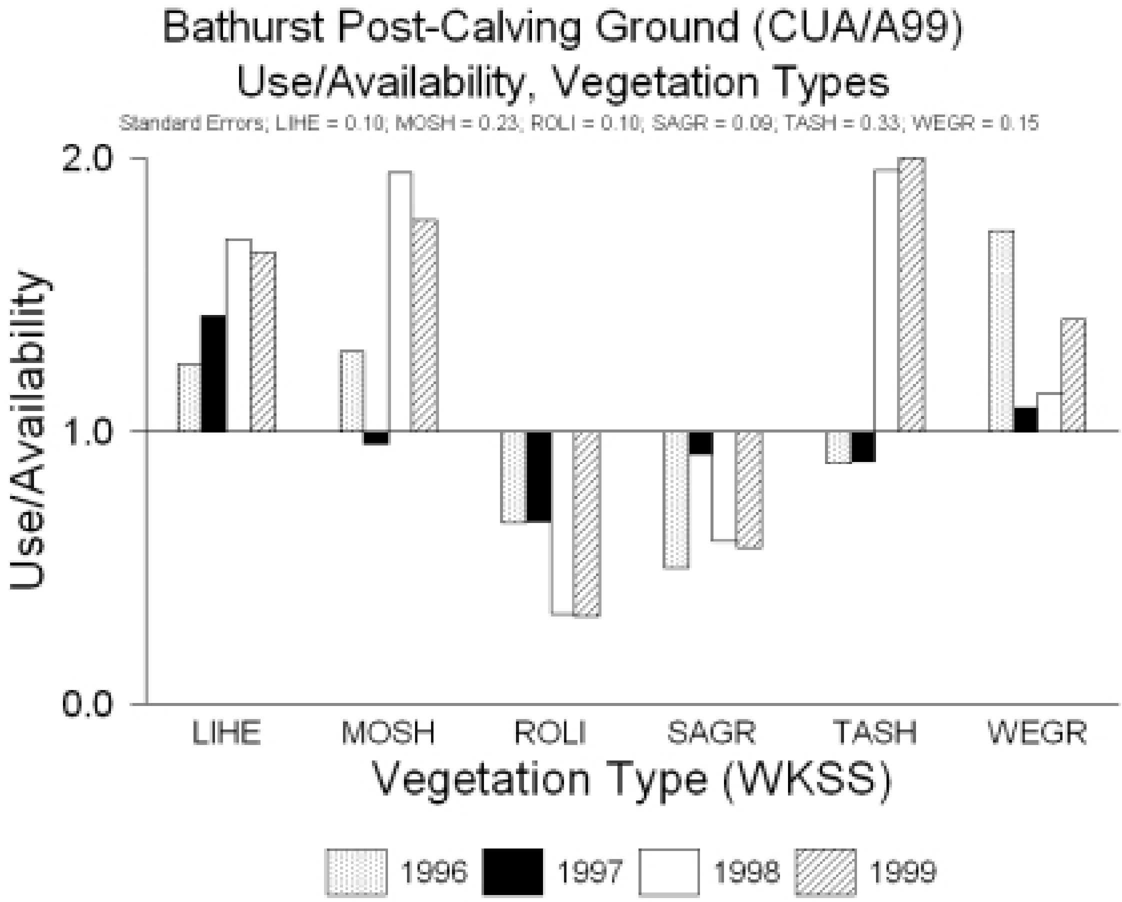


Figure 29. Fourth order (CUA/A99; annual post-calving concentrated use area/annual post-calving ground) use/availability of vegetation types, 1996-99, Bathurst caribou calving ground, Nunavut. Vegetation types are: 1) LIHE – Lichen Heath; 2) MOSH – Moist Shrub; 3) ROLI – Rock Lichen Barrens; 4) SAGR – Sand and Gravel; 5) TASH – Tal Shrub; and 6) WEGR – Wet Graminoid, based on a reclassification of the WKSS vegetation map.

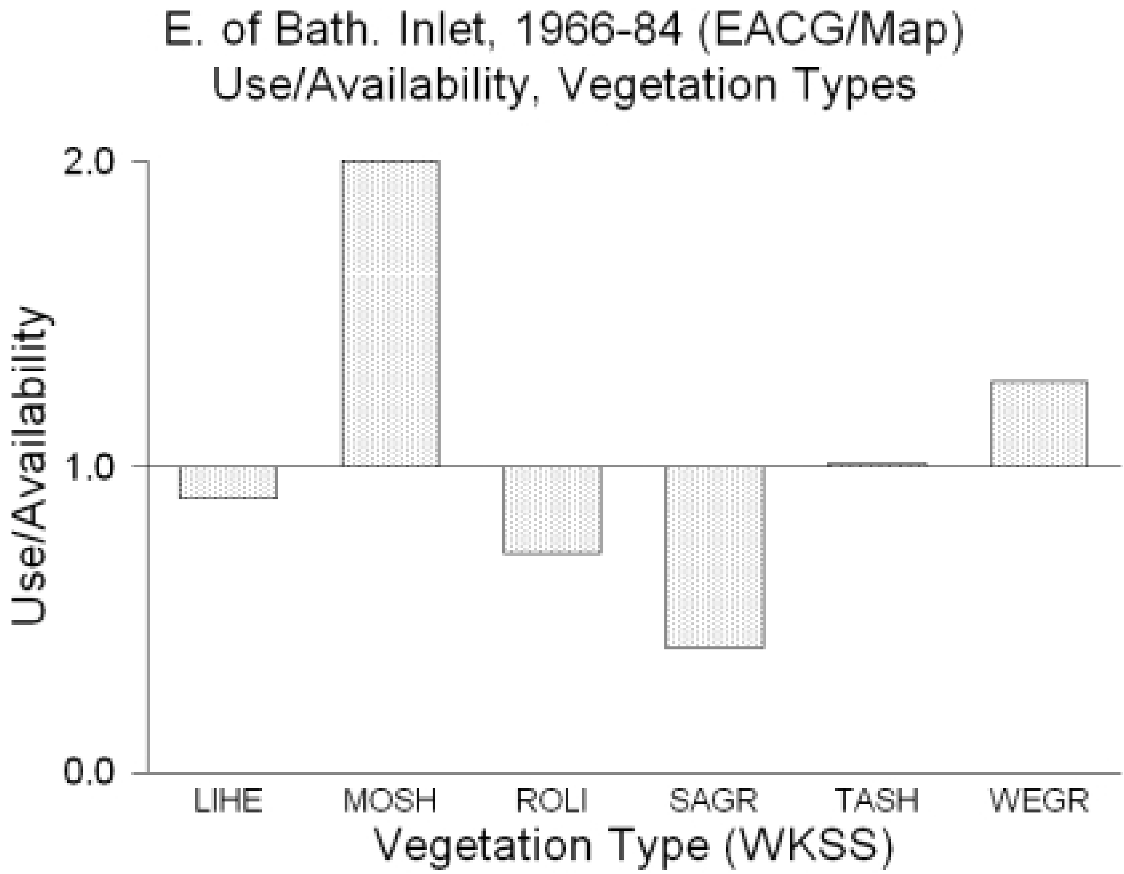


Figure 30. Second order (EACG/Map; outer perimeter of all annual calving grounds/map extent) use/availability of vegetation types, 1966-84, caribou calving ground east of Bathurst Inlet, Nunavut. Vegetation types are: 1) LIHE – Lichen Heath; 2) MOSH – Moist Shrub; 3) ROLI – Rock Lichen Barrens; 4) SAGR – Sand and Gravel; 5) TASH – Tal Shrub; and 6) WEGR – Wet Graminoid, based on a reclassification of the WKSS vegetation map.

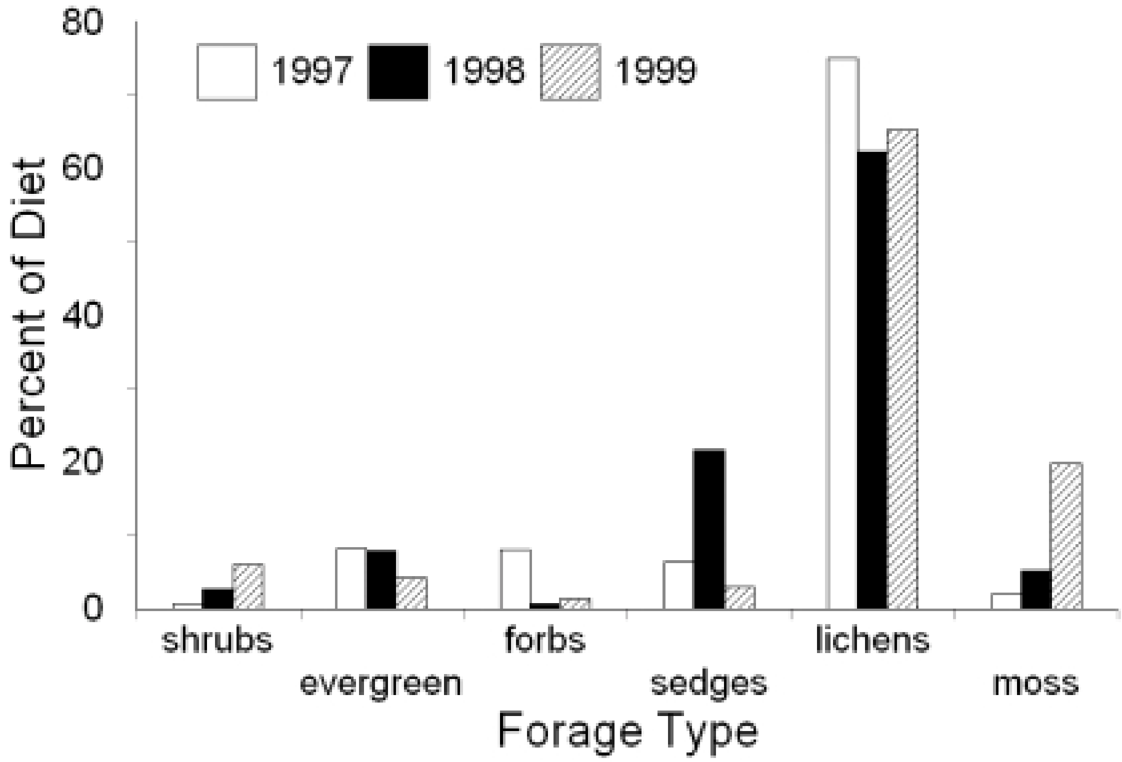


Figure 31. Diet of Bathurst caribou herd during calving, 1997-1999.

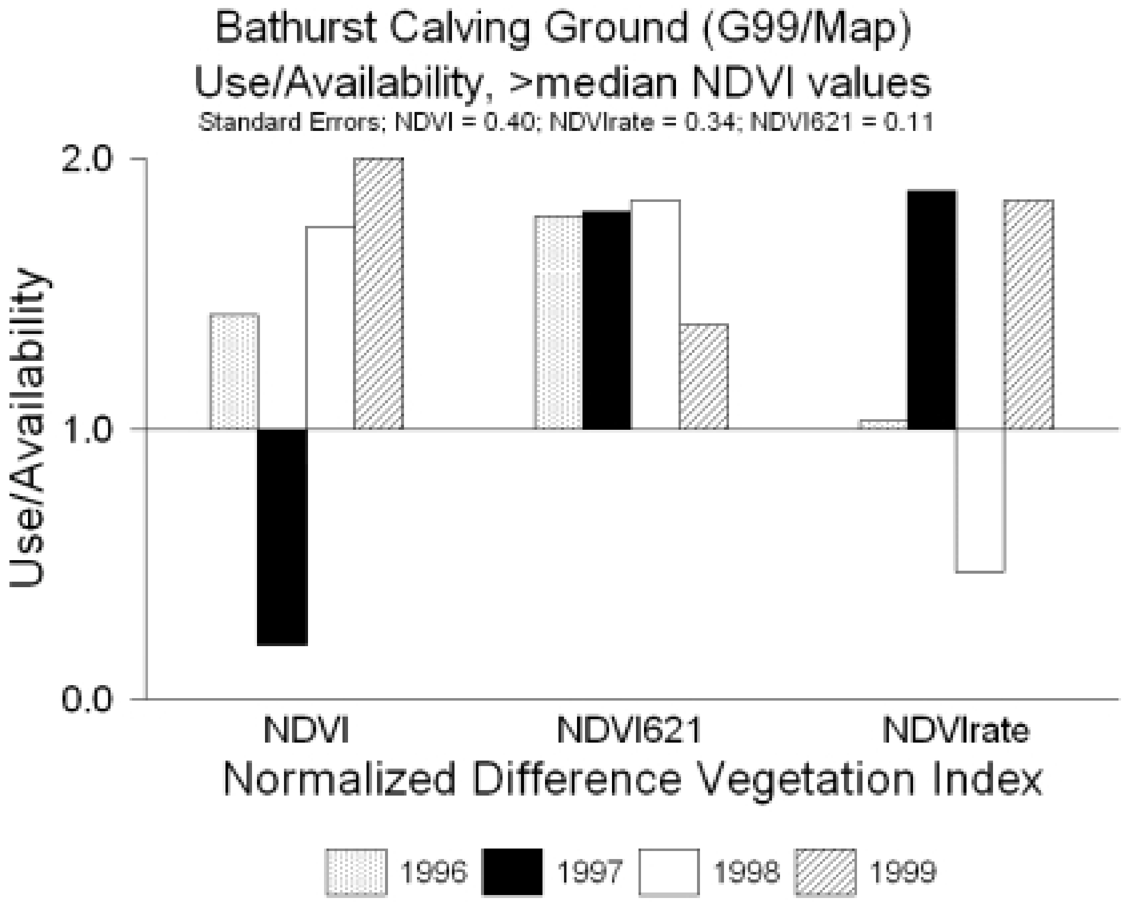


Figure 32. Second order (G99/Map; outer perimeter of all annual calving grounds/map extent) use/availability of Normalized Difference Vegetation Index (NDVI) greater than the median value for the available area, 1996-99, Bathurst caribou calving ground, Nunavut. NDVI classes are: 1) NDVI – NDVI at calving; 2) NDVI621 – NDVI on 21 June; and 3) NDVIrate – daily rate of increase in NDVI from calving to approximately 21 June.

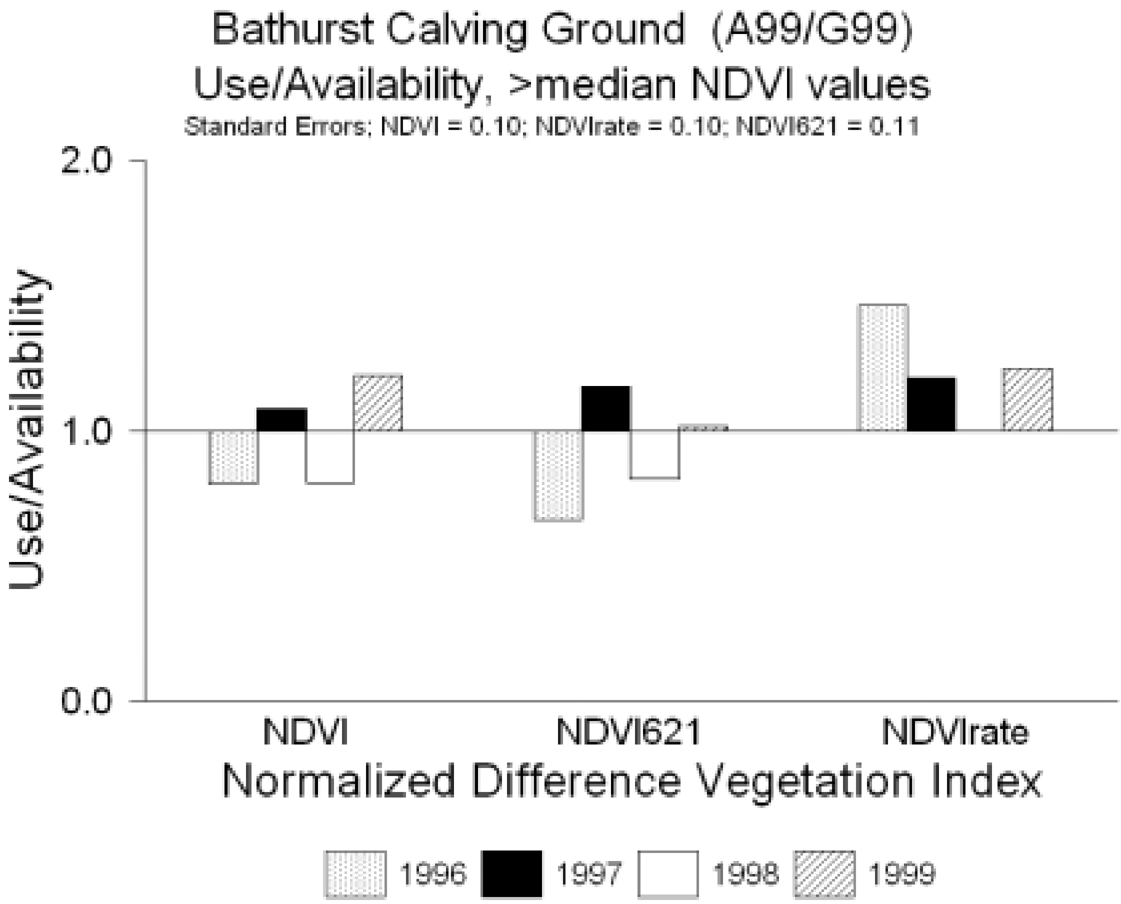


Figure 33. Third order (A99/G99; annual calving ground/outer perimeter of all annual calving grounds) use/availability of Normalized Difference Vegetation Index (NDVI) greater than the median value for the available area, 1996-99, Bathurst caribou calving ground, Nunavut. NDVI classes are: 1) NDVI – NDVI at calving; 2) NDVI621 – NDVI on 21 June; and 3) NDVIrate – daily rate of increase in NDVI from calving to approximately 21 June.

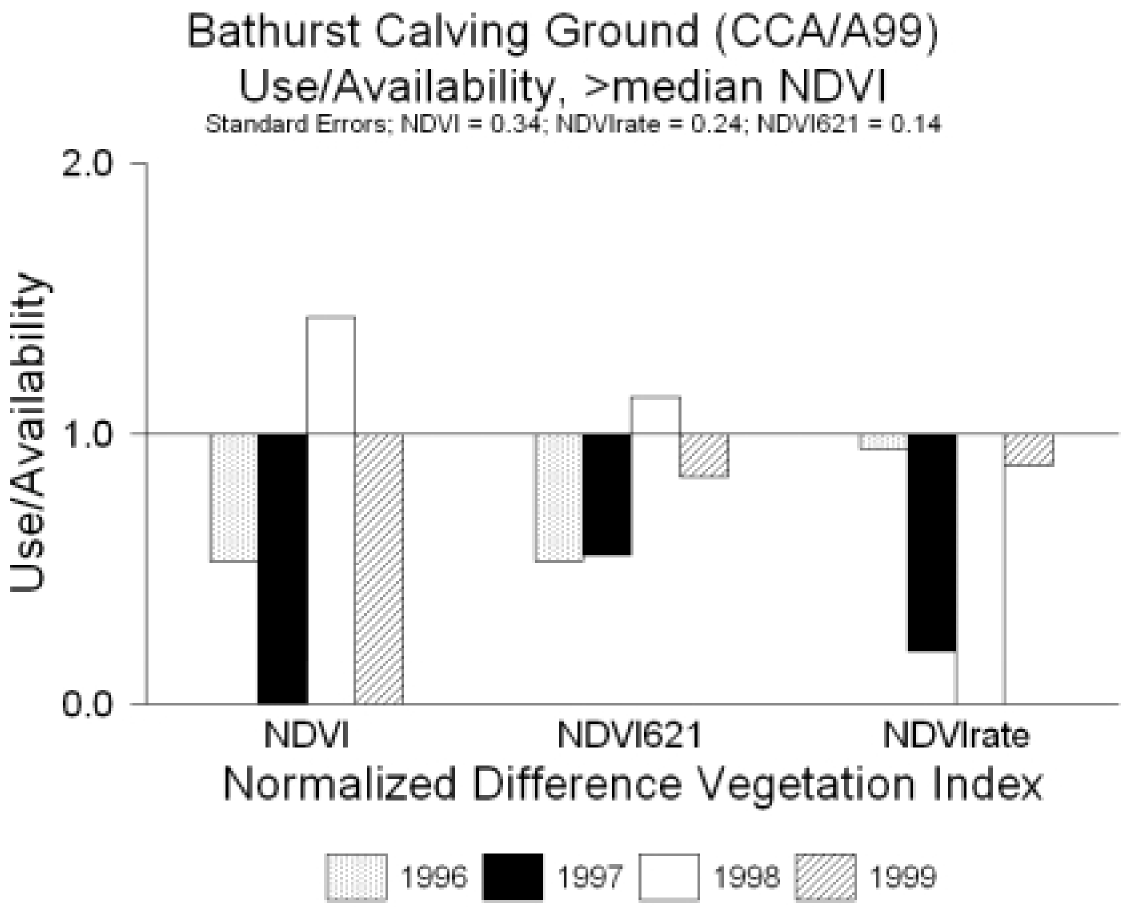


Figure 34. Fourth order (CCA/A99; annual concentrated calving area/annual calving ground) use/availability of Normalized Difference Vegetation Index (NDVI) greater than the median value for the available area, 1996-99, Bathurst caribou calving ground, Nunavut. NDVI classes are: 1) NDVI – NDVI at calving; 2) NDVI621 – NDVI on 21 June; and 3) NDVIrate – daily rate of increase in NDVI from calving to approximately 21 June.

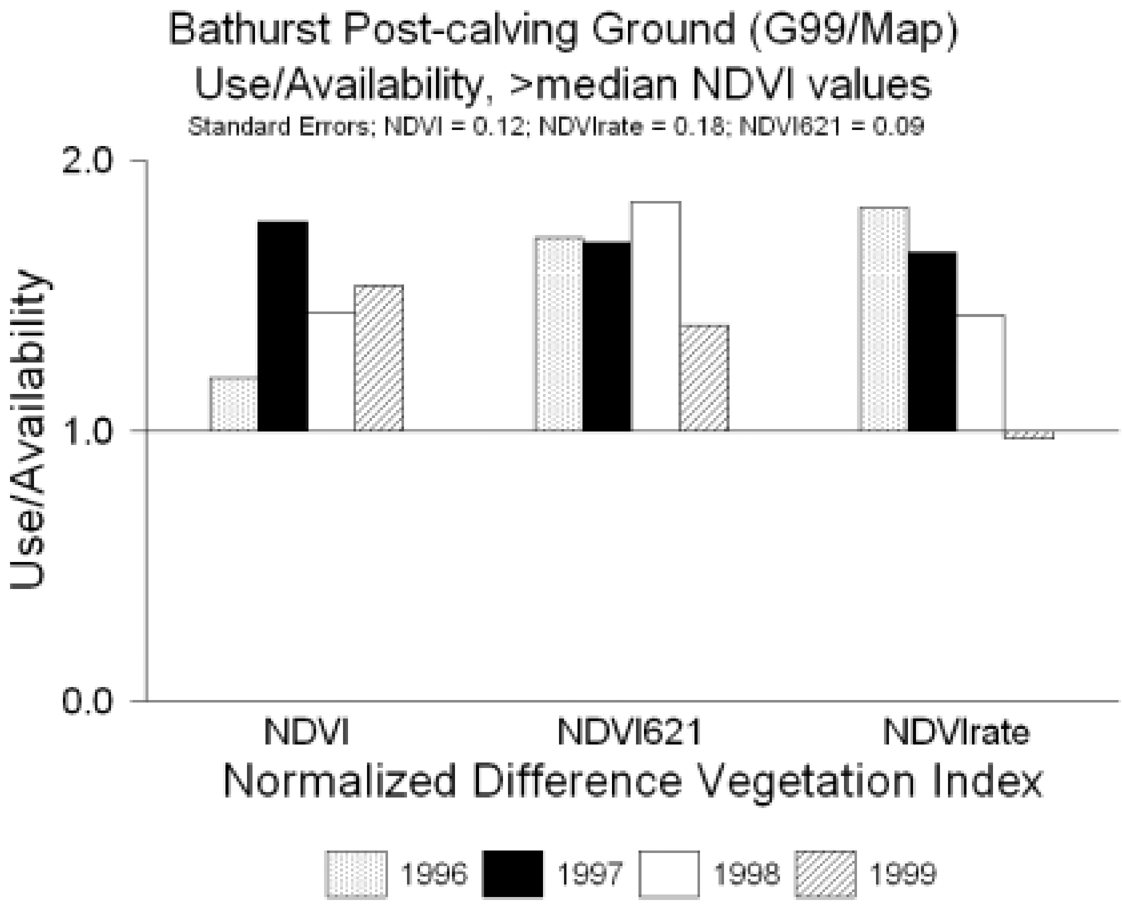


Figure 35. Second order (G99/Map; outer perimeter of all annual post-calving grounds/map extent) use/availability of Normalized Difference Vegetation Index (NDVI) greater than the median value for the available area, 1996-99, Bathurst caribou post-calving ground, Nunavut. NDVI classes are: 1) NDVI – NDVI at calving; 2) NDVI621 – NDVI on 21 June; and 3) NDVIrate – daily rate of increase in NDVI from calving to approximately 21 June.

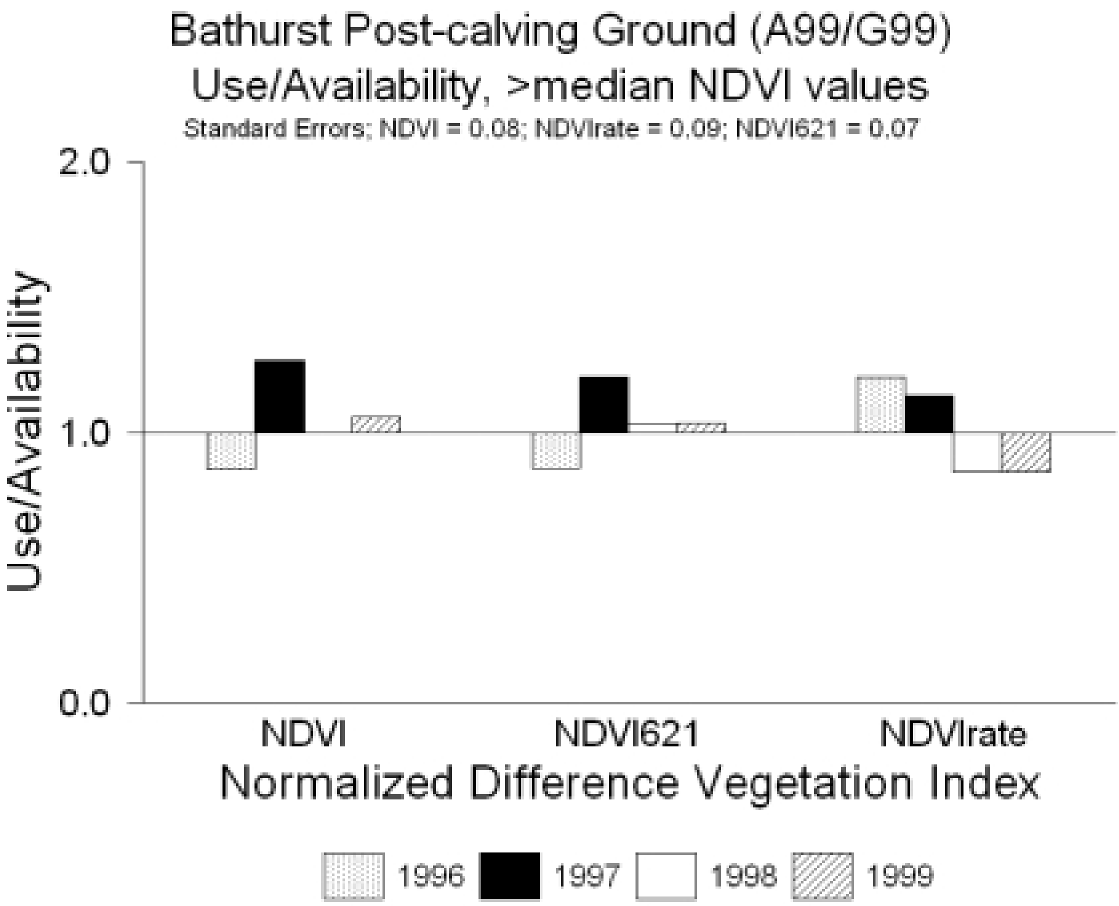


Figure 36. Third order (A99/G99; annual post-calving ground/outer perimeter of all annual post-calving grounds) use/availability of Normalized Difference Vegetation Index (NDVI) greater than the median value for the available area, 1996-99, Bathurst caribou calving ground, Nunavut. NDVI classes are: 1) NDVI – NDVI at calving; 2) NDVI621 – NDVI on 21 June; and 3) NDVIrate – daily rate of increase in NDVI from calving to approximately 21 June.

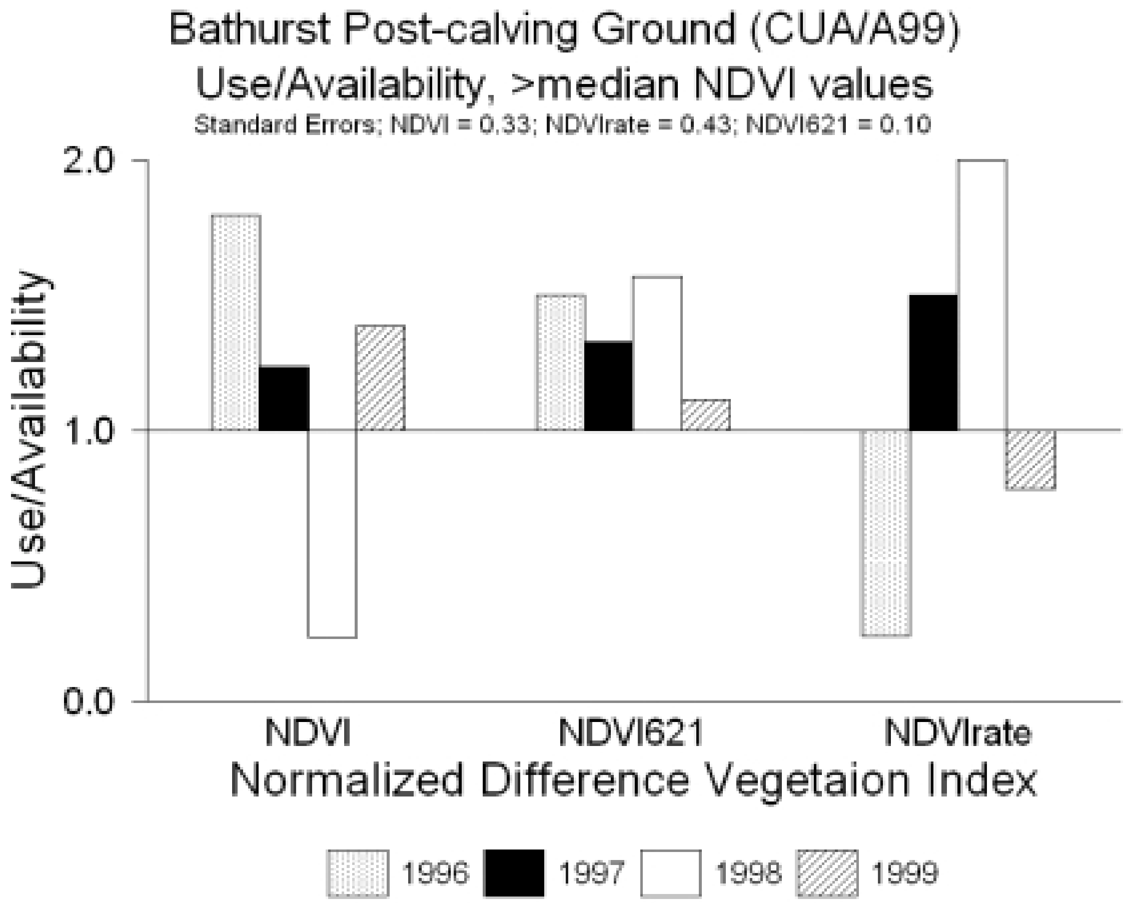


Figure 37. Fourth order (CCA/A99; annual post-calving concentrated use area/annual post-calving ground) use/availability of Normalized Difference Vegetation Index (NDVI) greater than the median value for the available area, 1996-99, Bathurst caribou calving ground, Nunavut. NDVI classes are: 1) NDVI – NDVI at calving; 2) NDVI621 – NDVI on 21 June; and 3) NDVIrate – daily rate of increase in NDVI from calving to approximately 21 June.

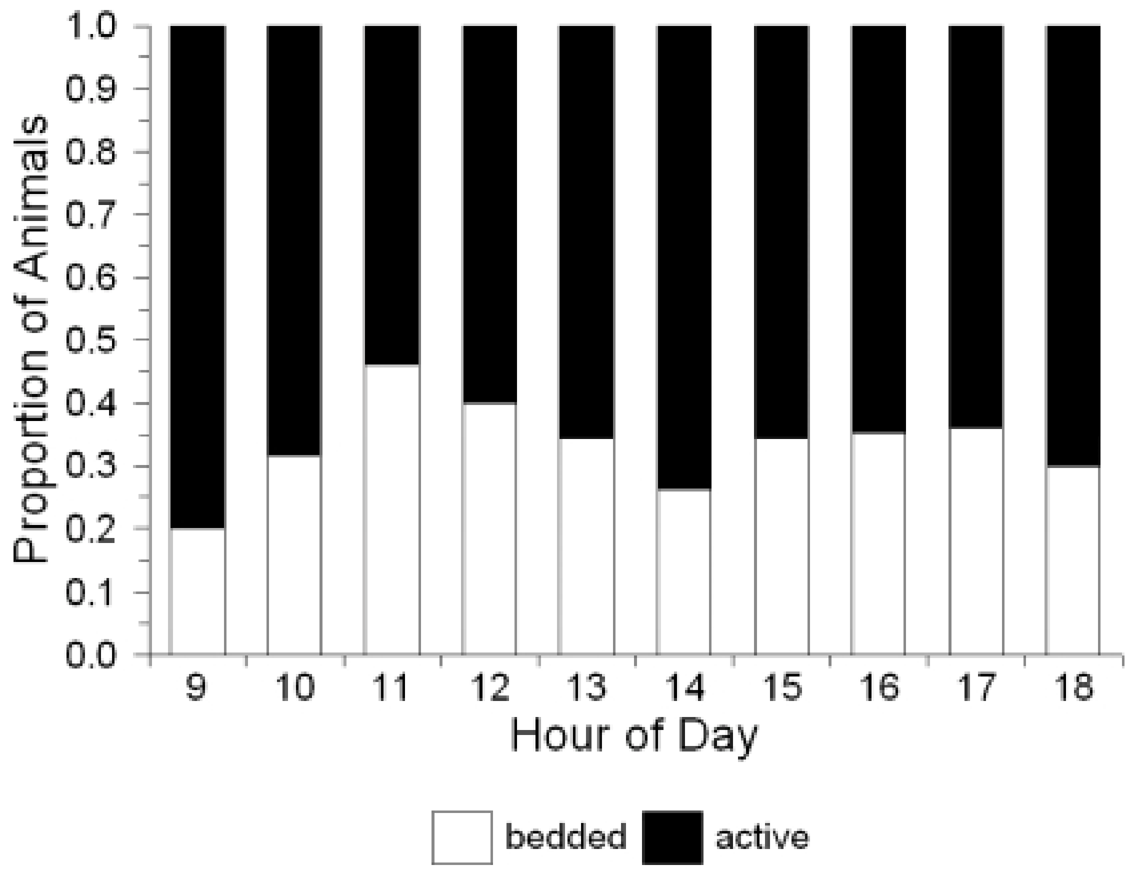


Figure 38. Diurnal pattern of active/bedded cycles in the Bathurst caribou herd, 1-13 June 1999.

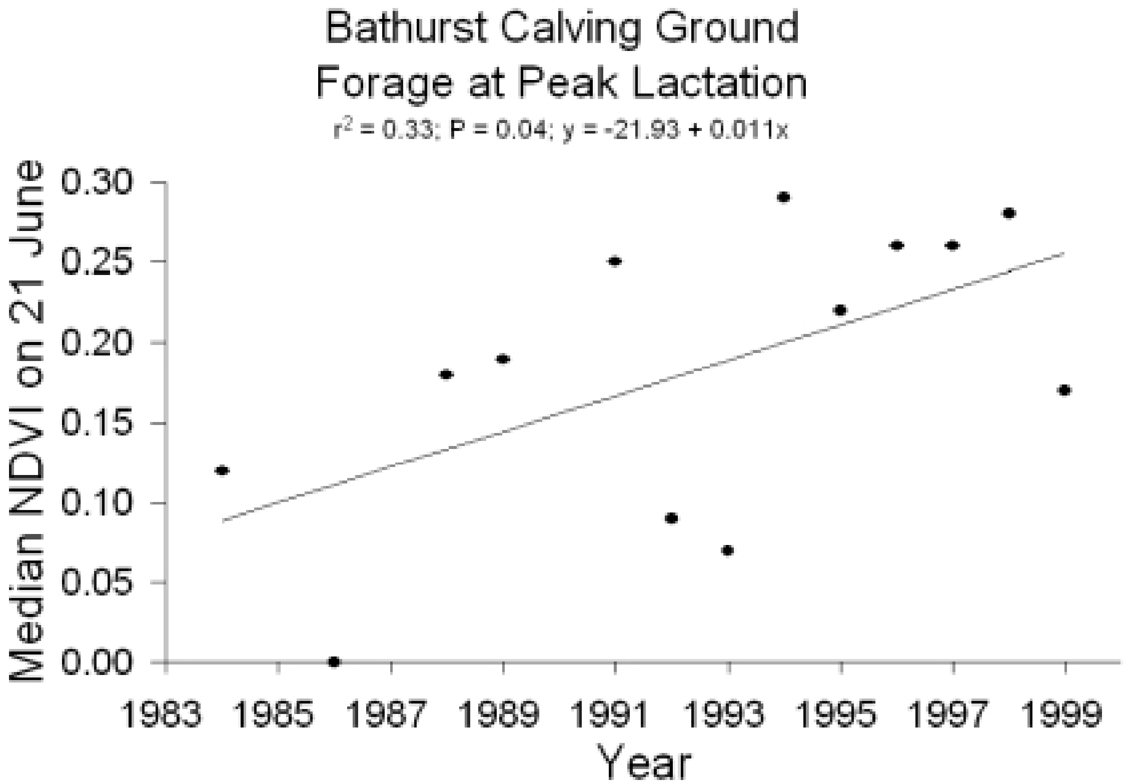


Figure 39. Median NDVI on 21 June, 1984-1999, within the outer perimeter of all annual calving grounds of the Bathurst caribou herd observed during 1996-99, west of Bathurst Inlet, Nunavut.

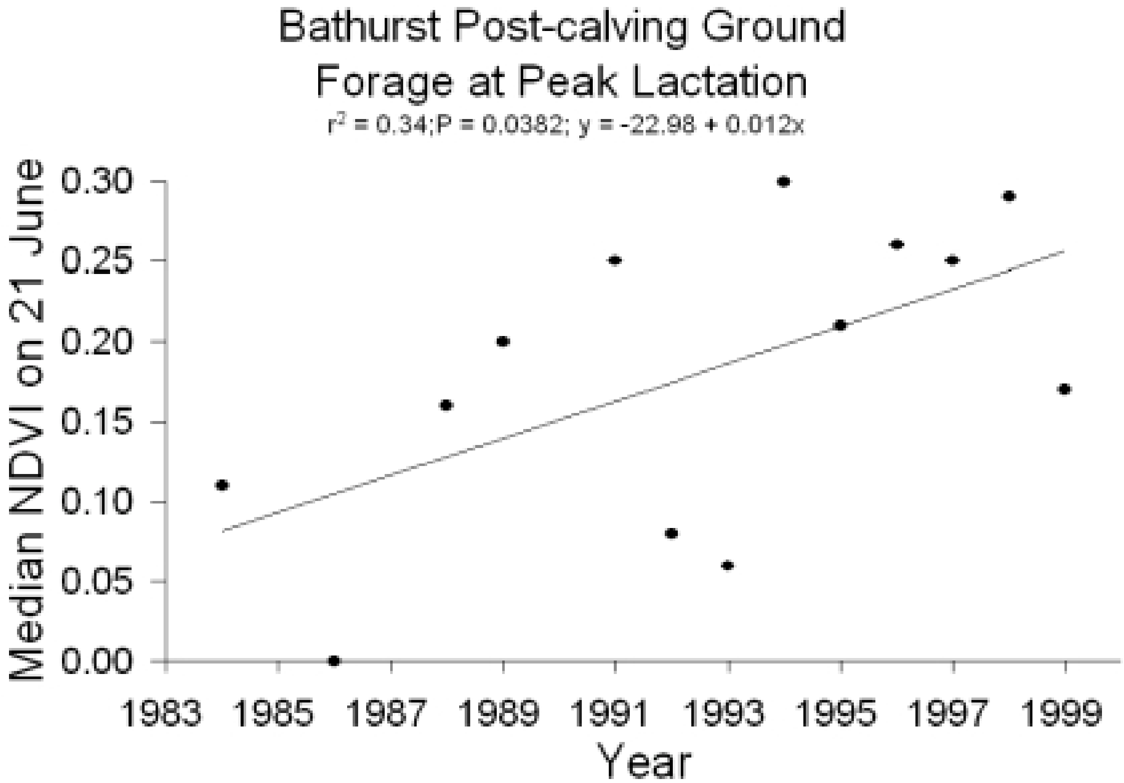


Figure 40. Median NDVI on 21 June, 1984-1999, within the outer perimeter of all annual post-calving grounds of the Bathurst caribou herd observed during 1996-99, west of Bathurst Inlet, Nunavut.

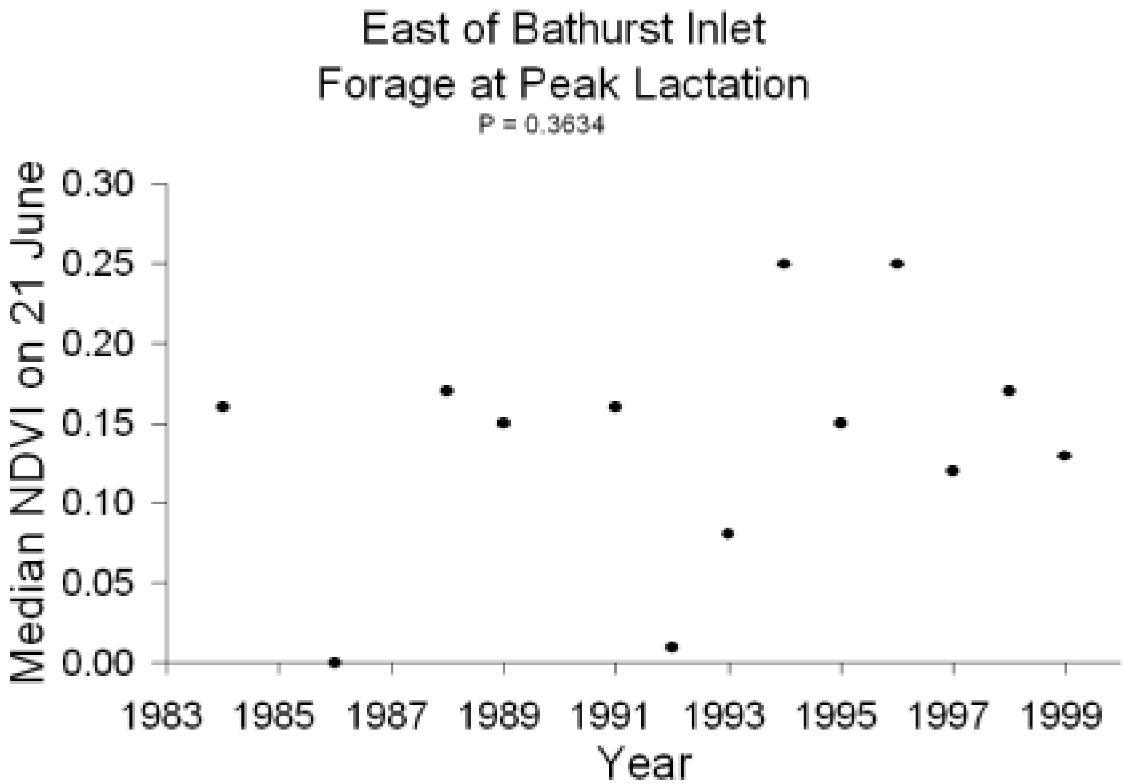


Figure 41. Median NDVI on 21 June, 1984-1999, within the outer perimeter of all annual calving grounds observed during 1966-84, on the east side of Bathurst Inlet, Nunavut.

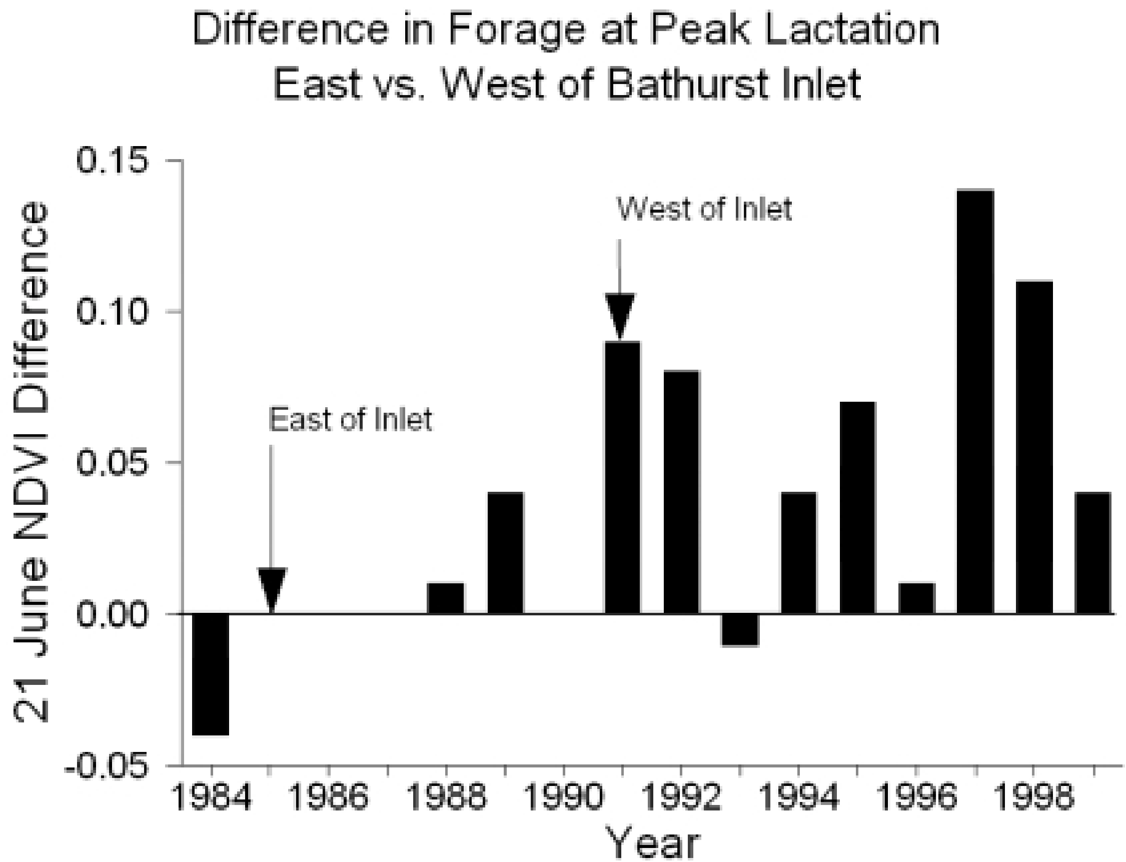


Figure 42. Difference in median forage at peak lactation (NDVI on 21 June) for regions east (solid horizontal line) and west (filled bars) of Bathurst Inlet, 1984-99. The area west of the inlet encloses the outer perimeter of all annual calving grounds observed for the Bathurst caribou herd, 1996-99. The area east of the inlet encloses the outer of perimeter of all annual caribou calving grounds observed, 1966-84.

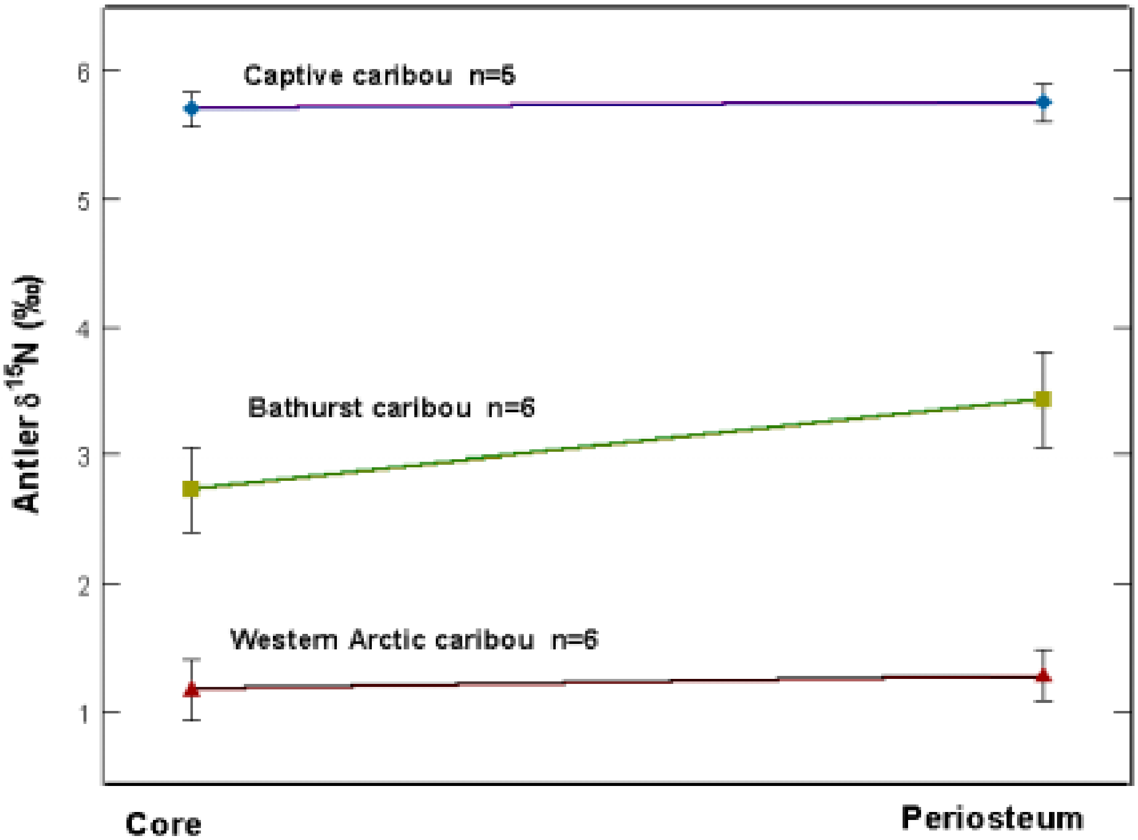


Figure 43. ^{15}N natural abundance in hardened antler of caribou from the Western Arctic Herd, the Bathurst Herd, and captive animals at the Large Animal Research Station (LARS), University of Alaska, Fairbanks.

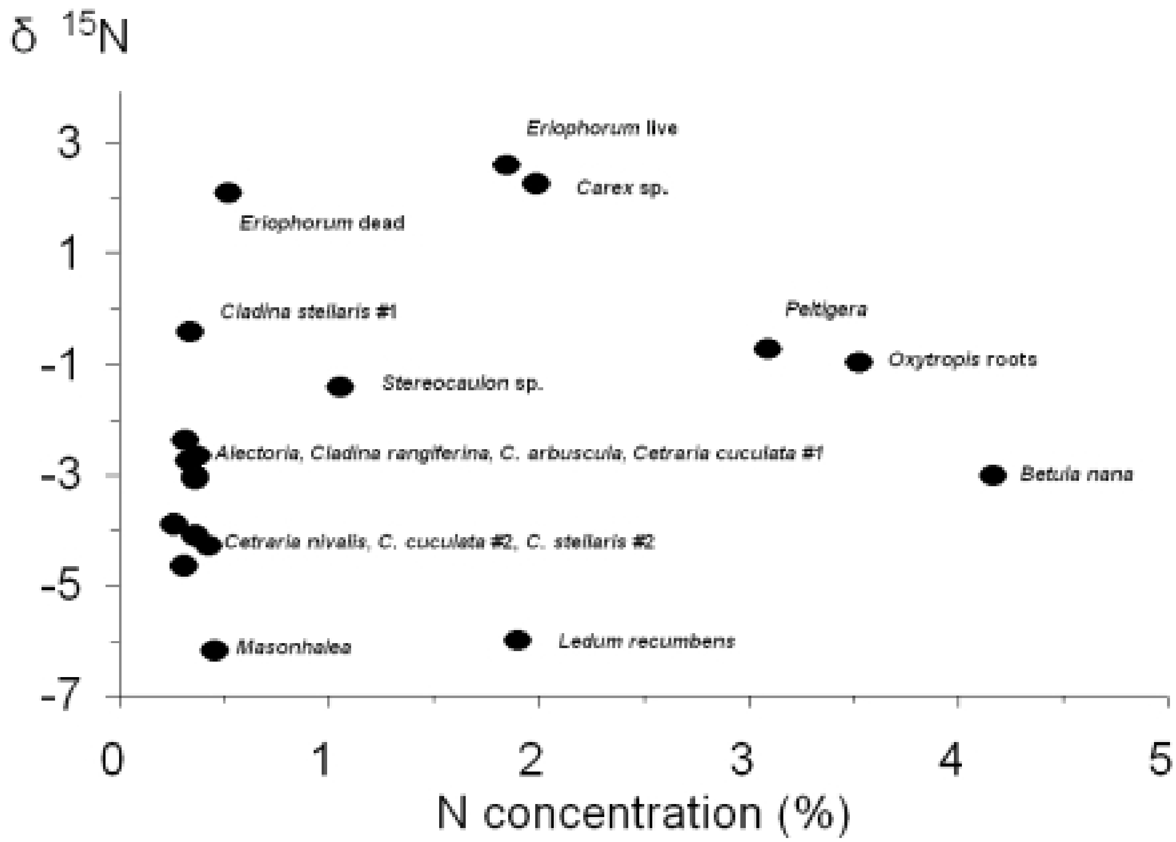


Figure 44. Tissue nitrogen concentrations and ^{15}N natural abundance values for major caribou forage plants on the Bathurst calving ground, June 1999.

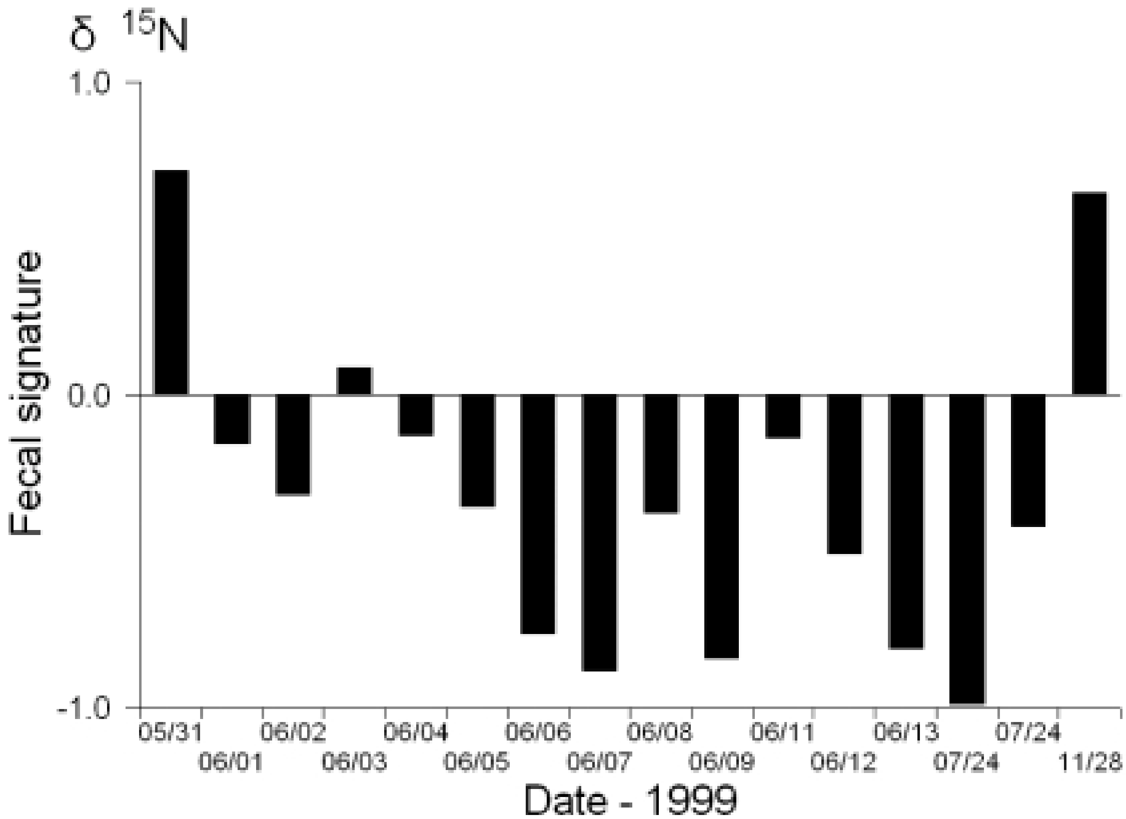


Figure 45. Abundance of ^{15}N in fecal pellets of caribou of the Bathurst herd, 1999.

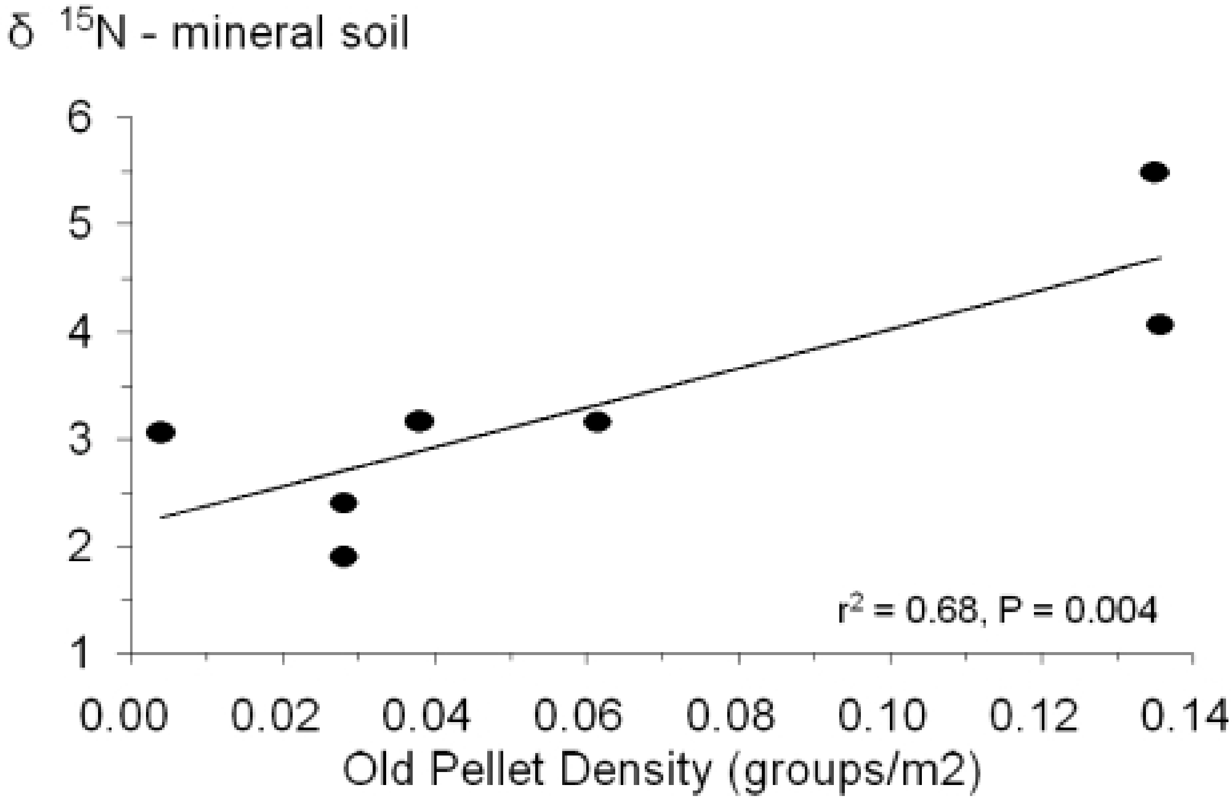


Figure 46. Relationship between old fecal pellet density and ^{15}N abundance in mineral soil on the Bathurst calving ground, 1999.

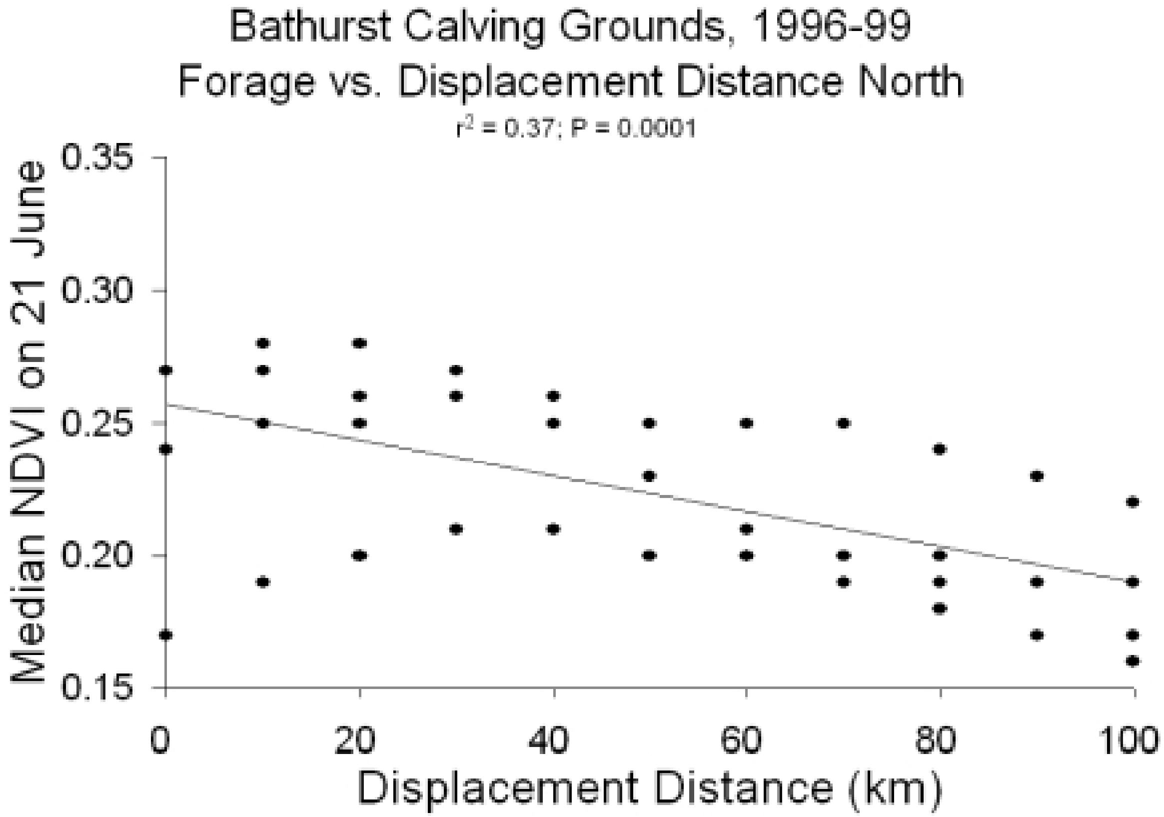


Figure 47. Reduction in forage available at peak lactation (NDVI on 21 June) as a function of northward displacement distance of the Bathurst caribou calving grounds, 1996-99.

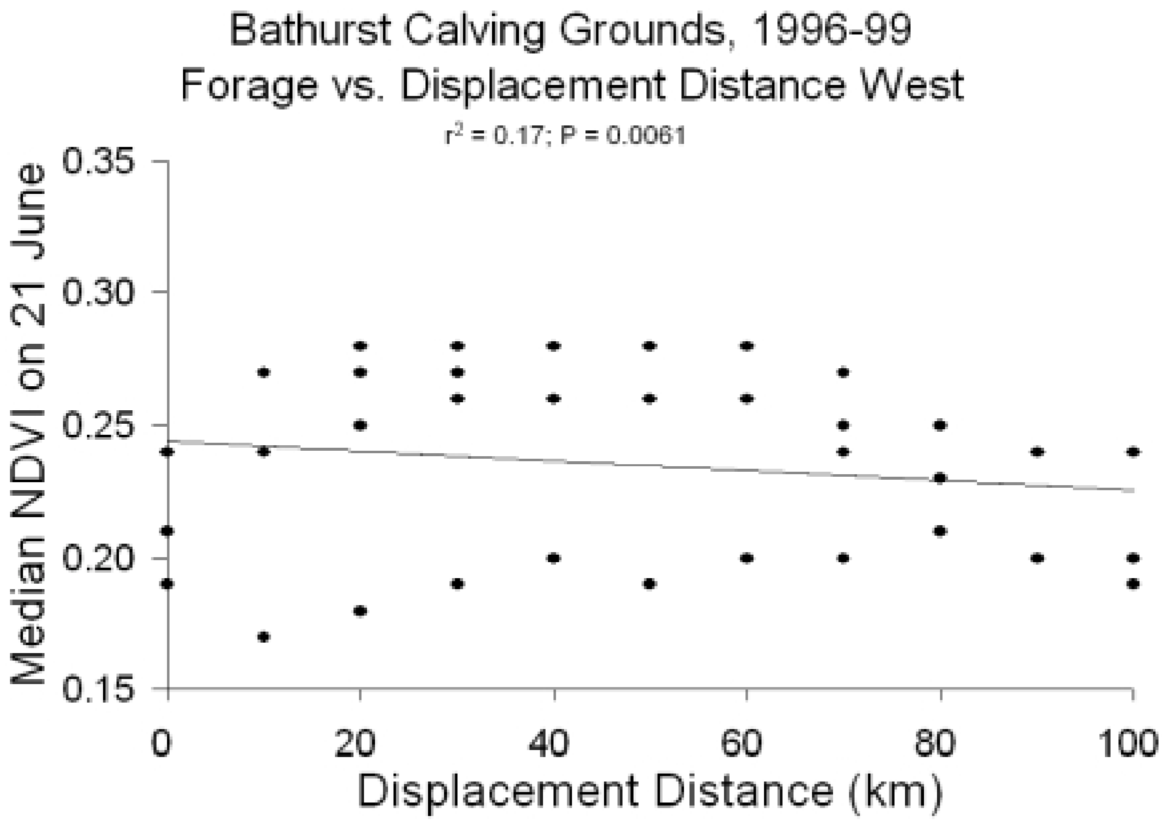


Figure 48. Reduction in forage available at peak lactation (NDVI on 21 June) as a function of westward displacement distance for the Bathurst caribou calving grounds, 1996-99.

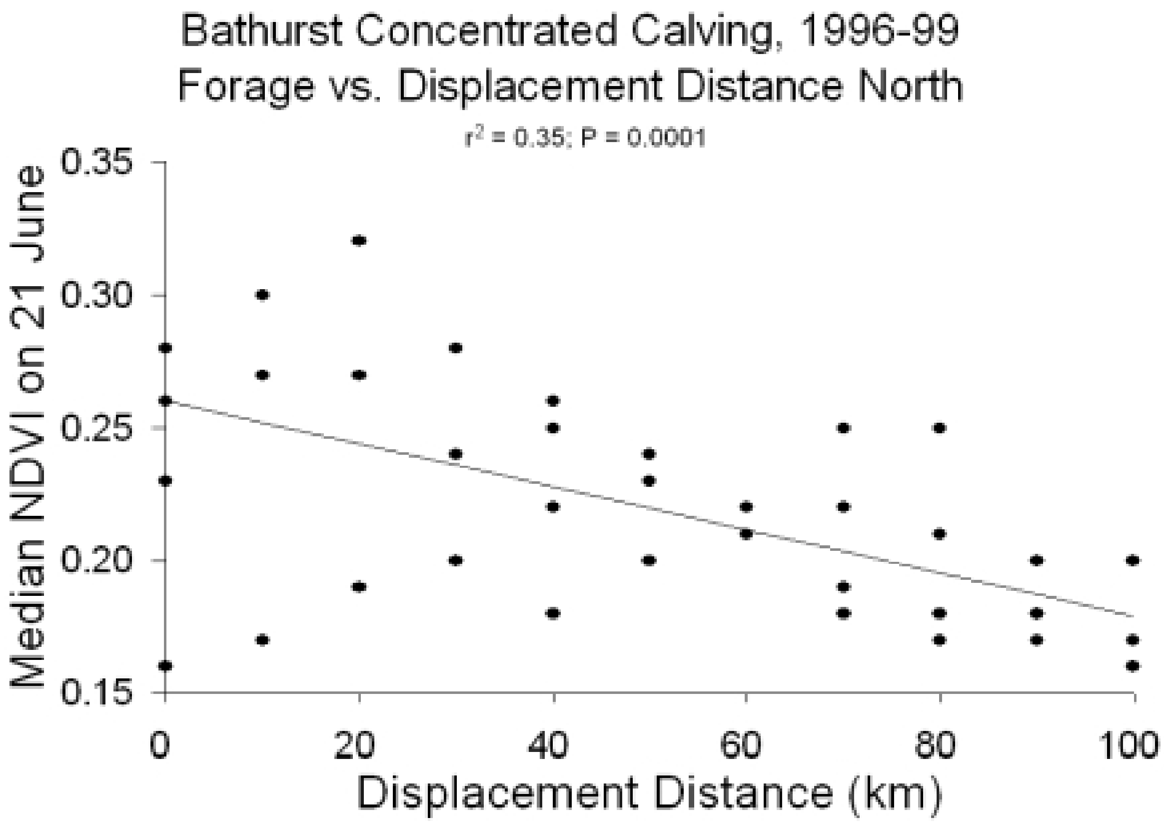


Figure 49. Reduction in forage available at peak lactation (NDVI on 21 June) as a function of northward displacement distance for the Bathurst caribou concentrated calving area, 1996-99.

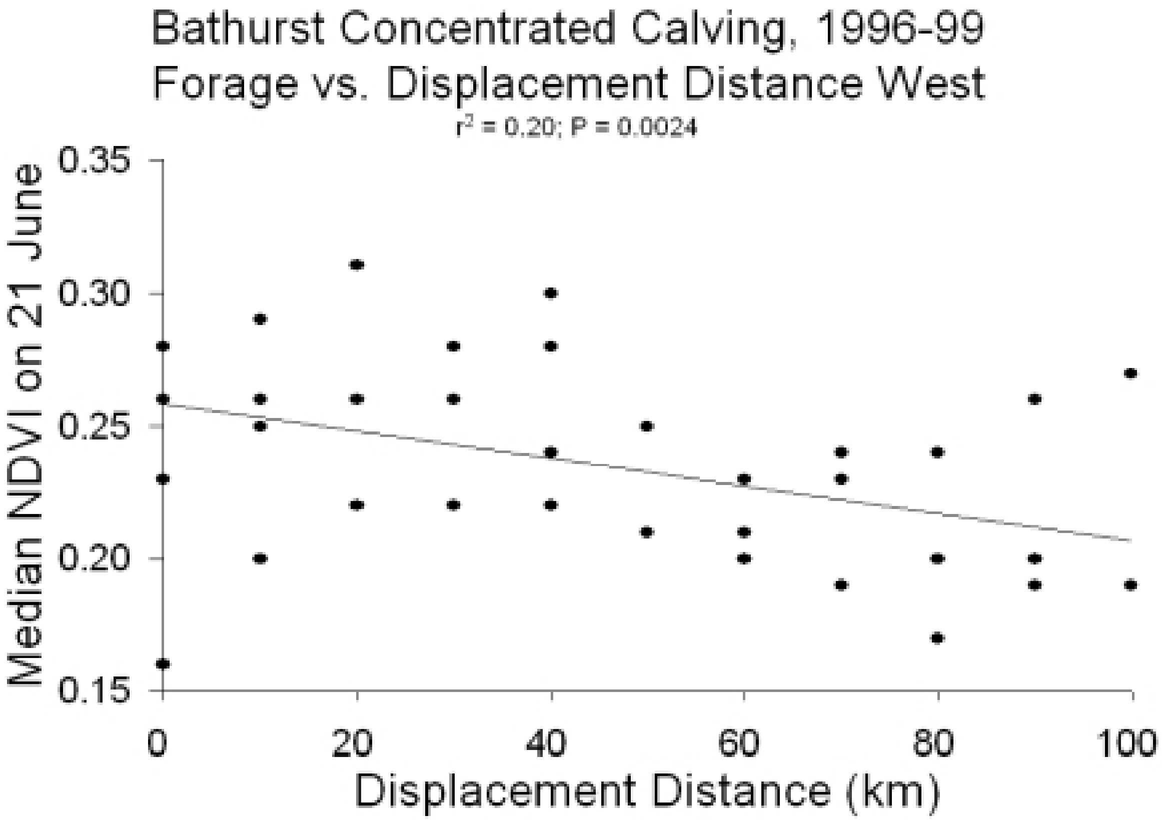


Figure 50. Reduction in forage available at peak lactation (NDVI on 21 June) as a function of westward displacement distance for the Bathurst caribou concentrated calving area, 1996-99.

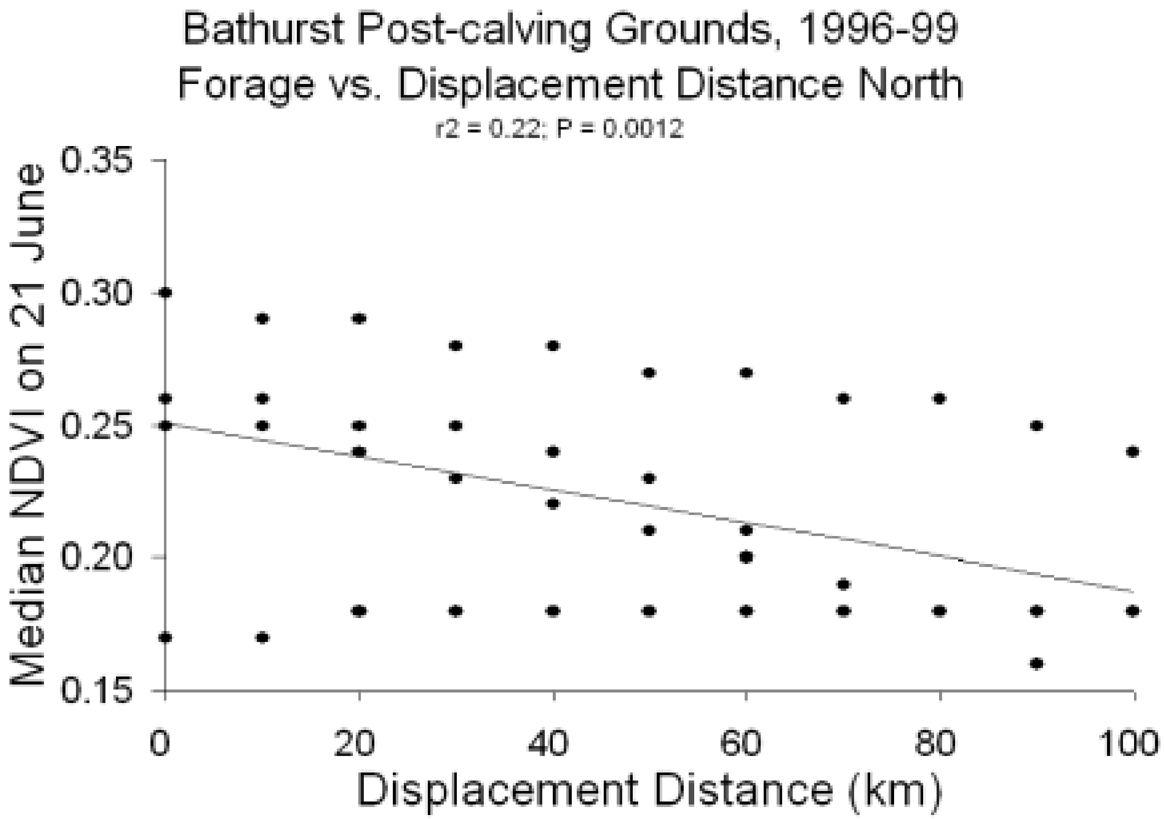


Figure 51. Reduction in forage available at peak lactation (NDVI on 21 June) as a function of northward displacement distance for the Bathurst caribou post-calving grounds, 1996-99.

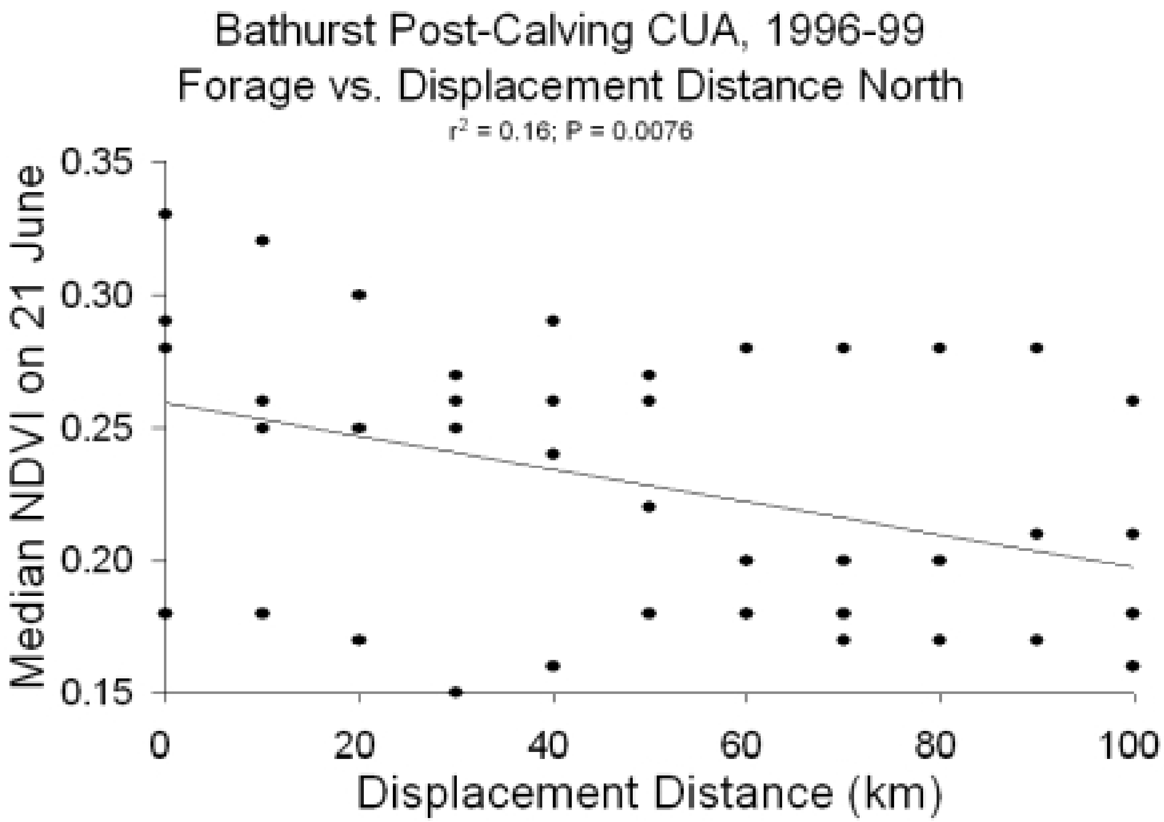


Figure 52. Reduction in forage available at peak lactation (NDVI on 21 June) as a function of northward displacement distance for the Bathurst caribou post-calving concentrated use area, 1996-99.

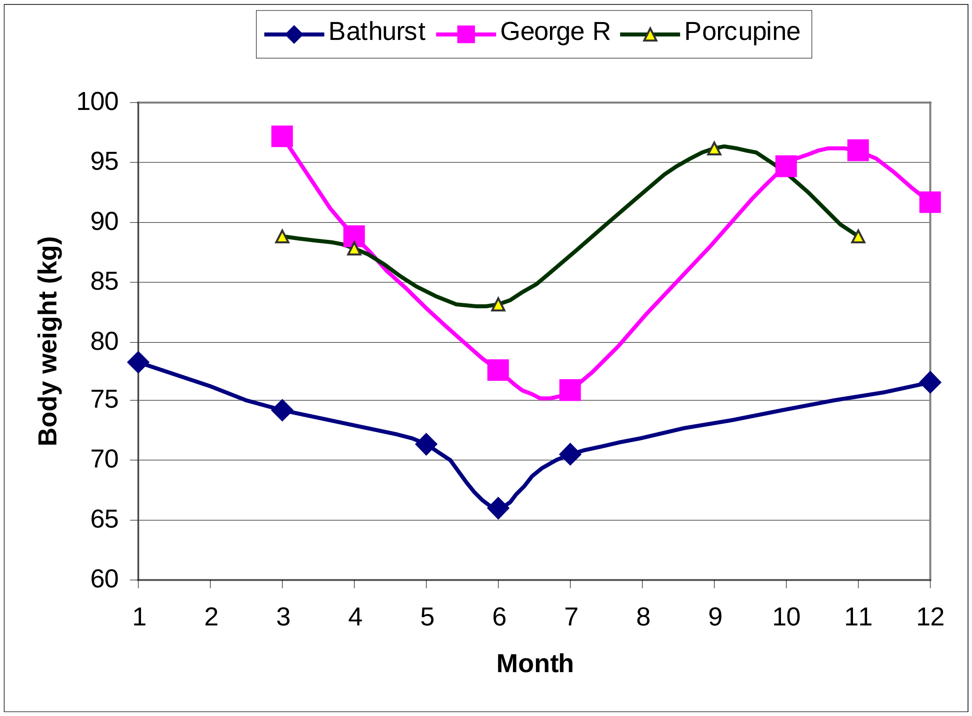


Figure 53. Seasonal body weights of adult female caribou in the Bathurst, George River, and Porcupine Caribou Herds.

Appendix I.

Caribou effects on plant community composition in the Bathurst caribou herd calving grounds, Nunavut, Canada.

Jill Johnstone

Introduction

Calving and post-calving periods are a critical time for barren-ground caribou populations, because of the high energetic demands of lactation during a period of relatively low plant biomass availability (Russell et al., 1993). Caribou of the Bathurst herd feed primarily on lichens during the calving period, with additional moderate intake of sedges and dwarf shrubs (Griffith et al., 1999). Concentrations of barren ground caribou are annually at their highest on the calving grounds, and females and young animals group together for approximately 1-3 weeks in late spring (e.g. Russell et al., 1993). The combination of high calving ground densities and selective grazing of forage types create the potential for these herbivores to affect the vegetation composition of habitats used during the calving period. This research project uses paired estimates of vegetation cover and caribou use inside and outside the Bathurst caribou herd calving grounds to test for evidence of caribou effects on vegetation. The bounds of the analysis are constrained to a single vegetation type, the lichen heath community, which is heavily utilized by Bathurst caribou (Griffith et al., 1999). Within this vegetation community, I hypothesize that high levels of caribou use will cause a decrease in cover of preferred forage species, but will not affect less-preferred forage groups or species. Among forage species, slower growing types are expected to be most sensitive to removal by grazing. If caribou have strong effects on vegetation composition of lichen heath communities within the calving region, it should consequently be possible to predict the level of caribou use at a site from observations of vegetation cover.

Methods and statistical analysis

Data on vegetation cover and caribou used were collected during caving and post-calving periods (late May – mid June) inside and outside the calving grounds of the Bathurst herd in 1998 and 1999. The calving area was located on the west side of Bathurst Inlet, NWT, Canada in the tundra zone of the continental Northwest Territories. Core calving areas used by the herd were determined from movement of satellite-collared female caribou (Griffith et al., 1999), and overlapped during the two years of the study.

Sample sites were randomly selected inside and outside the calving area using a computer program. Access to sites was by helicopter. At each site, we located the closest homogeneous patch (>50 m^2) of either lichen heath, moist shrub, or wet graminoid vegetation, and randomly positioned a 50 m transect within that community type. Relative caribou use was estimated by counting all caribou fecal pellet groups visible from a single pass along the 50 m transect. Vegetation cover was measured by visual cover estimates in 3 quadrats that were randomly positioned along the transect. Cover of vascular plants was measured in 20x50 cm quadrats (0.1 m^2), and cover of lichens and moss was estimated in a randomly selected 10x10 (0.01 m^2) subsection of the vascular plant quadrat. All vegetation cover estimates were made by the same person. A total of 49 lichen heath sites were sampled in the two years.

The analyses reported here were performed only on vegetation within the lichen heath community type to avoid confounding grazing effects with independent changes in vegetation or pellet group visibility associated with different plant communities. Lichen heath vegetation was classified in this study as well-drained vegetation communities with >25% vegetation cover, dominated by evergreen shrubs and lichens.

I used a hierarchical application of simple linear regression (SLR) in order to test for relationships between the number of caribou fecal groups observed (an index of caribou use) and cover of different plant groups. Regression analysis was applied first to plant growth form groupings. If a given growth form exhibited a significant relationship ($p<0.05$), the group was divided into palatable and non-palatable sub-groups and regression analysis was performed on the sub-group. A significant relationship at the sub-group level was further broken down into regression analyses of the component species. Species or groups that were present in less than 10% of the samples, or had maximum cover of <1% were excluded from analysis. The distribution of almost all variables and regression residuals were both skewed and heteroscedastic. Arithmetic transformations were not able to fully correct deviations from normality or homogeneity of variances, and variables were rank-transformed for the SLR analysis. Observations of zero cover of the dependent variable were dropped from the SLR dataset. To test for the possibility that the presence or absence of a plant was related to caribou use, differences in mean fecal group number between present and absent categories were tested for each species using a Wilcoxon two-sample test on ranks. Because the distributions of presence/absence data were assumed to be independent among species, I did not adjust the probability level ($\alpha=0.05$) used to estimate a significant effect in this series of tests.

To test whether the caribou use could be predicted by measurements of vegetation cover, I used stepwise multiple linear regression to predict the number of fecal pellet groups. Analysis was performed for each plant community separately, and all plant species in a community were eligible for inclusion in the model (rare species were excluded as described above). Only variables significant at α=0.05 were included in the model. Input cover values and fecal pellet counts were log-transformed (after adding 1 to all values to account for zeros) to normalize the distribution of error terms and correct heteroscedasticity of error variance. The final regression modeld satisfied distributional assumptions of linear regression, as determined by a K^2 test for normality of error terms, a Durbin-Watson test for autocorrelation, and a Chi-square test of first and second moment specification to test for heteroscedasticity (Marshall et al, 1995; SAS v. 8.01).

I also used logistic regression to develop a model to predict, from plant cover values, whether a site fell inside or outside the core calving area zone derived from the movements of collared animals in the herd. Input variables were not transformed, as the maximum likelihood procedure used in estimating the model is expected to be robust against non-normality in the distribution of error terms (Jongman et al., 1995). Selection of the best model was done using a stepwise selection procedure, choosing a model where all included variables were significant at α=0.05 (Chi-square test, df=1), and which minimized the –2 Log L residual deviance and percent discordance, and maximized the estimated R^2 and percent concordance.

Results

For most species in the lichen heath community, the number of observed caribou fecal groups did not differ depending on the presence or absence of that species (Table 1). Caribou use was higher where *Alectoria ochroleuca, Cetraria islandica, Dactylina arctica*, *Sphaerophorus globosus* (all lichens) and *Dryas integrifolia* (a dwarf shrub) were present, compared to where they were absent. This effect is opposite to that expected if caribou were negatively affecting species abundance by grazing. Only one species, the lichen *Cladina stellaris*, showed higher caribou use where it was absent, which would be consistent with grazing removal of this species.

Ranked percent cover of most plant growth forms was not related to rank of number of caribou fecal groups observed (Table 2). The exception to this was the lichen group, where smaller values of lichen cover were associated with larger numbers of caribou fecal groups (Table 2; slope ± st.err. = -0.380 ± 0.130). When the lichen group was broken down into preferred (*Cladina* and *Cladonia* species) and non-preferred groups (*Alectoria*, *Cetraria*, and other species), only cover of the preferred group was significantly related to number of fecal groups. This relationship was also negative (slope ± st.err. = -0.477 ± 0.150). Further decomposition of the preferred group into composit species showed that two lichens, *Cladina stellaris* and *Cladonia* spp., exhibited significant decreases in cover as number of fecal groups increased (Table 2; *C. stellaris* slope ± st.err.= -0.600 ± 0.242, *Cladonia* slope ± st.err.= -0.652 ± 0.210).

The best multiple regression model was developed relating the number of caribou fecal groups to cover of four lichens, *Alectoria nigricans, Cetraria cucullata, Cladina stellaris* and *Cladonia* sp. This model accounted for 48% of the variation in caribou fecal numbers (Table 3). Stepwise selection in the logistic regression model-building resulted in a model which included three of the four cover variables used in the multiple regression model (Table 4). This model was reasonably successful at predicting the probability of a site being located outside the calving grounds from observations of lichen cover (maximum likelihood residual deviance = 28.7; generalized R^2 = 0.53; percent concordance = 93.4).

Discussion

In general, the patterns of results observed here support expectations of caribou having the largest effect on vegetation composition through grazing on slow-growing lichen species. Two important lichen forage species showed significant negative relations with estimated caribou use, and similar relations were apparent for both all preferred lichens, and all lichens grouped together. The lack of significant negative relationships between cover of non-lichen plant groups and caribou use, both in the univariate and multivariate regression procedure, indicates that caribou effects on the lichen heath primarily occur via effects on lichen abundance in general, and on forage lichen abundance specifically. *Cladina*/*Cladonia* lichens form 30-60% of the calving and post-calving diet of the Bathurst herd, with other lichen species (primarily *Alectoria*, *Cetraria*, and *Peltigera*) composing an additional 8-27% portion (Griffith et al., 1999). A high rate of lichen consumption, combined with the slow re-growth capacity of lichens, makes this group the most vulnerable to grazing effects in this system.

Comparison of fecal group numbers between areas where a given species was present or absent suggests that some species may, however, show a positive relationship to caribou use. Positive relationships between species abundance and caribou use were only apparent in comparison of presence/absence data, and did not appear in the regressions of percent cover where a species was present. There are several possible mechanisms for this pattern, including caribou selection of sites within the lichen heath habitat, or differences in community composition inside and outside the calving area. It does not appear that these relationships are dominant at a landscape scale, however, because they are not important in the regression models developed to predict landscape-scale caribou use.

At the landscape scale, lichens were the most important vegetation component for predicting caribou use, as demonstrated by the stepwise selection in the multivariate regression model-building procedure. The inclusion of both preferred (*Cladina, Cladonia*) and non-preferred (*Alectoria, Cetraria*) lichen species in the multivariate models suggests that caribou removal of preferred species biomass is not the only mechanism by which caribou may be affecting lichen species composition. Other potential interactions include mediation of competitive interactions among lichen species, and fine-resolution habitat selection. Discussion of these potential interactions is unfortunately beyond the scope of this paper.

In conclusion, the analyses presented here suggest that Bathurst caribou affect vegetation composition in the lichen heath habitat by reducing cover of preferred lichen forage species. Although the observational nature of this study does not allow clear demonstration of causal relationships, the presence of negative correlations between cover and caribou use within a single community type, and field observations of fragmented lichens in areas with high fecal counts, suggests that the observed patterns result from caribou effects on vegetation. However, these results could also be explained by selective foraging by caribou, or differences in environment inside and outside the calving grounds. Further study with experimental tests are needed to conclusively demonstrate which causal mechanisms are important. Nevertheless, lichen cover is clearly related to caribou use in the Bathurst caribou calving grounds. These relationships strongly suggest that there are important caribou/vegetation interactions occurring in the lichen heath communities in this region.

Literature Cited

Griffith, B., A. Gunn, D. Russell, K. Kielland and S. Wolfe. 1999. Bathurst caribou calving ground studies: influence of nutrition and human activity on calving ground location. 1999 Final Report, West Kitikmeot Slave Study, Yellowknife, NWT. 58 pp.

Jongman, R.H.G., C.J.F. Ter Braak and O.F.R. Van Tongeren. 1995. Data Analysis in Community and Landscape Ecology. Cambridge: Cambridge University Press, 299 pp.

Marshall, P., T. Szikszai, LeMay, V. and Kozak, A. 1995. Testing the distributional assumptions of least squares linear regression. Forestry Chronicle 71(2): 213-218.

Russell, D.E., A.M. Martell and W.A.C. Nixon. 1993. Range ecology of the Porcupine caribou herd. Rangifer Sp. Issue 8: 1-167.

Appendix Table 1. Results of Wilcoxon two-sample tests for differences in mean caribou pellet group densities between areas where a given species is present or absent. Significance of the test (H_0: equal means among groups) is indicated in the table by single ($p<0.05$) or double ($p<0.01$) asterisks.

Species	**n absent**	**n present**	**'absent' mean score**	**'present' mean score**	**Z**	**Prob > Z**
Alectoria nigricans	16	33	22.5	26.2	-0.8534	0.3935
Alectoria ochroleuca	14	35	18.3	27.7	-2.0707	0.0385*
Betula glandulosa	34	15	26.8	20.8	-1.3350	0.1819
Cetraria cucullata	3	46	20.0	25.3	-0.6051	0.5451
Cetraria islandica	21	28	19.4	29.3	-2.3855	0.0171*
Cetraria nivalis	4	45	19.1	25.5	-0.8404	0.4007
Cladina arbuscula	24	25	24.0	26.0	-0.4703	0.6381
Cladina rangiferina	34	15	27.4	19.5	-1.7800	0.0751
Cladina stellaris	36	13	28.2	16.1	-2.6173	0.0089**
Cladonia spp.	35	14	25.6	23.4	-0.4872	0.6261
Cassiope tetragona	11	38	20.0	26.5	-1.3188	0.1872
Dactylina arctica	33	16	21.8	31.6	2.2401	0.0251*
Dryas integrifolia	30	19	20.0	32.9	3.0594	0.0022**
Empetrum nigrum	28	21	22.4	28.5	1.4556	0.0728
Graminoids, dead	18	31	27.2	23.7	0.8197	0.4124
Ledum palustre	6	43	25.4	24.9	0.0610	0.9513
Moss	31	18	25.3	24.5	-0.1660	0.8681
Masonhalea richardsonii	42	7	23.8	32.0	1.3866	0.1656
Sphaerophorus globosus	29	20	19.5	32.9	3.2162	0.0013**
Thamnolia spp.	23	26	21.3	28.2	-1.6739	0.0942
Vaccinium uliginosum	19	30	26.9	23.8	0.7392	0.4598
Vaccinium vitis-idaea	3	46	17.2	25.5	-0.9598	0.3372

Appendix Table 2. Summary of regression statistics from analyses of caribou fecal group counts vs. percent cover of different plant groups. A significant regression at a composite group level resulted in further investigation of relationships among smaller component groups. Significance of the regression (H_0: slope = 0) is indicated in the table by single (p<0.05) or double (p<0.01) asterisks.

Plant group	**DF**	**F**	**Pr>F**	**R^2**
deciduous shrubs	39	2.26	0.1412	
evergreen shrubs	47	0.49	0.4873	
forbs	12	0.78	0.3941	
graminoids – dead	30	0.03	0.8715	
graminoids – live	18	0.02	0.8774	
lichens	47	7.74	0.0078**	0.14
non-preferred lichens	47	0.70	0.4079	
preferred lichens	35	10.09	0.0032**	0.23
Cladina arbuscula	24	1.43	0.2443	
Cladina rangiferina	14	2.15	0.1662	
Cladina stellaris	12	6.13	0.0308*	0.36
***Cladonia* spp.**	13	9.65	0.0091**	0.45
moss	17	1.69	0.2124	

Appendix Table 3. Details of the stepwise model-building procedure for a multiple regression model predicting number of caribou fecal groups. All variables are log -transformed.

step in procedure	**variable entered**	**model R^2**	**Mallow's C(p)**	**F**	**Prob>F**
1	Cladina stellaris	0.2657	11.72	17.01	0.0002
2	Alectoria nigricans	0.3326	8.56	4.61	0.0371
3	Cetraria cucullata	0.4124	4.39	6.11	0.0173
4	Cladonia sp.	0.4819	1.03	5.90	0.0193

Appendix Table 4. Comparison of multiple linear and logistic regression equations for predicting caribou use from measurements of vegetation cover.

Regression type	**Predicted variable**	**Equation**
Multiple linear	ln(number caribou fecal groups)	2.97 – 0.84*ln(Cladina stellaris) – 0.54*ln(Alectoria nigricans) + 0.64*ln(Cetraria cucullata) – 0.75*ln(Cladonia sp.)
Logistic	log(probability of outside calving area)	2.145 +7.226*Cladina stellaris – 2.1451*Cetraria cucullata – 2.262*Alectoria nigricans