Ecology of Boreal Woodland Caribou in the Lower Mackenzie Valley, NT:

Work Completed in the Inuvik Region April 2003 to November 2004

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1.0 Introduction

Until recently, little scientific knowledge was available for boreal woodland caribou (*Rangifer tarandus caribou*) that occur along the Mackenzie River Valley from the NWT/Alberta border in the South Slave Region to the Mackenzie Delta in the Inuvik Region. Unlike barren-ground (*R. t. groenlandicus*), Peary (*R. t. pearyi*), and mountain woodland caribou (*R. t. caribou*), these caribou had not been the focus of biological studies in the NWT.

Threats to boreal woodland caribou habitat include oil and gas exploration and development, the potential for road and hydro development, increased tourism and other non-consumptive human activity, forest fire, and climate change. The degree of impact of these past human disturbances and wildfires on boreal woodland caribou in the NWT is not known, although where these woodland caribou occur elsewhere across Canada the cumulative effects of human activities and natural habitat disturbances have been shown to be negative to the point of caribou extirpation in many areas, including entire provinces (e.g., Nova Scotia and New Brunswick). At present, much of the boreal woodland caribou range in the Inuvik Region has been altered by past seismic work, wildfires, and road access (Figure 1). The Inuvik Region, particularly the Mackenzie Delta area, is currently experiencing a significant increase in oil and gas exploration and extraction activities. A pipeline along the Mackenzie River valley has been proposed to deliver natural gas to the south. These activities may have an impact on boreal woodland caribou and their habitats in the Inuvik Region.

Linear disturbances such as seismic lines, roads, and cutlines, have been shown to significantly impact wildlife populations throughout the world. Many wildlife species have been documented to avoid habitats with high densities of linear disturbances (McLellan and Shackleton 1988). Renewed oil and gas development in the north will cause higher densities of linear disturbance, resulting mainly from seismic activity. Over 37,000 km of seismic lines were cut in the Mackenzie River delta from 1960 to 1990 (National Energy Board Records). Recent exploration activities in this area may increase line densities to over 2 km per square kilometer in some areas. The impacts of linear disturbance on wildlife in a northern environment have been poorly studied, however it is clear that permafrost terrain is easily degraded (Lambert 1972; Mackay 1970; Nicholas and Hinkel 1996; Zoltai and Pettapiece 1973) and vegetation is slow to recover (Billings 1987; Harper and Kershaw 1996). This suggests that 1) disturbance is more likely to alter wildlife habitat in the north; and 2) any alteration of wildlife habitat will persist for a longer period of time.

Climate change models for the Mackenzie River Valley predict an increase in wildfire frequency and severity (Kadonga 1997), increased snowfall across the region, the incursion of new species including forest pests (Sieben et al. 1997) and parasites (Kutz 1999), and significant changes in forest composition (Hartley and Marshall 1997). All of these could impact boreal woodland caribou, although the potential extent is unknown.

In response to these changes, the Department of Resources Wildlife and Economic Development in partnership with the Gwich'in Renewable Resource Board began collecting baseline information on boreal woodland caribou in the Inuvik Region. Traditional knowledge of woodland caribou in these regions was documented during winter 2001/2002. In fall 2001 a project was initiated to collect baseline scientific information on boreal woodland caribou in the

Lower Mackenzie River area (Inuvik Region). The primary objectives of this study are as follows:

- obtain estimates of the number of boreal woodland caribou in the core study area
- obtain estimates of productivity, recruitment, and survival (calf and adult female) rates
- obtain estimates of home range size and seasonal movements rates
- determine seasonal patterns of habitat use and selection including use of areas burned by wildfires and use of areas in relation to linear anthropogenic features such as seismic lines
- map the relative probability of occurrence of boreal woodland caribou across the Inuvik Region using caribou use (satellite tracking) data and existing Landsat TM based vegetation maps
- identify seasonal habitats that may be limiting for boreal woodland caribou in the Inuvik Region

This report summarizes work done in the Inuvik Region between April 2003 and November 2004.

2.0 Study Area

The 13,216 km^2 core study area is north of the Arctic Circle (66.66^o latitude) and is primarily in the Gwich'in Settlement Area in the Northwest Territories, although the south western portion extends into the Yukon Territory (Figure 1). The area is adjacent to the southern extent of the Mackenzie River Delta and is approximately 130 km north of the Mackenzie Mountains and 30 km east of the Richardson mountains. Topographically the area is relatively flat to rolling with elevations ranging from near sea level to 400 m above sea level (asl). The median elevation is approximately 90 m asl. Open black spruce forests, fens, and shrub meadows dominate upland and lowland areas. White spruce and mixed stands of spruce and paper birch occur on steeper slopes along rivers and streams. Approximately 43 percent of area has been burned by wildfires since 1960.

Approximately 33 km of the Dempster Highway follows the northwestern boundary of the core study area between Tsiigehtchic (population approximately 150 people) and Fort McPherson (population approximately 800 people). There are approximately 17,954 km of seismic lines within the core study area. Approximately 3 percent of these were cut in 1965, 69 percent in 1970, 3 percent in 1973, <1 percent in 1974, 3 percent in 1975, and 4 percent in 1983. The years when 19 percent of these lines were cut is unknown. The majority of the seismic lines occur on the eastern and southern portions of the core study area.

The core study area lies between the ranges of the Porcupine barren-ground caribou herd to the west and the Cape Bathurst and Bluenose-West barren-ground caribou herds to the north and east (Figure 2). Moose occur throughout the area but are at low densities. Predators include wolves, black bears, and lynx, but numbers of wolves and black bears appear to be relatively low based on frequency of sightings.

Figure 1. Location of the core boreal woodland caribou study area in the Inuvik Region, Northwest Territories.

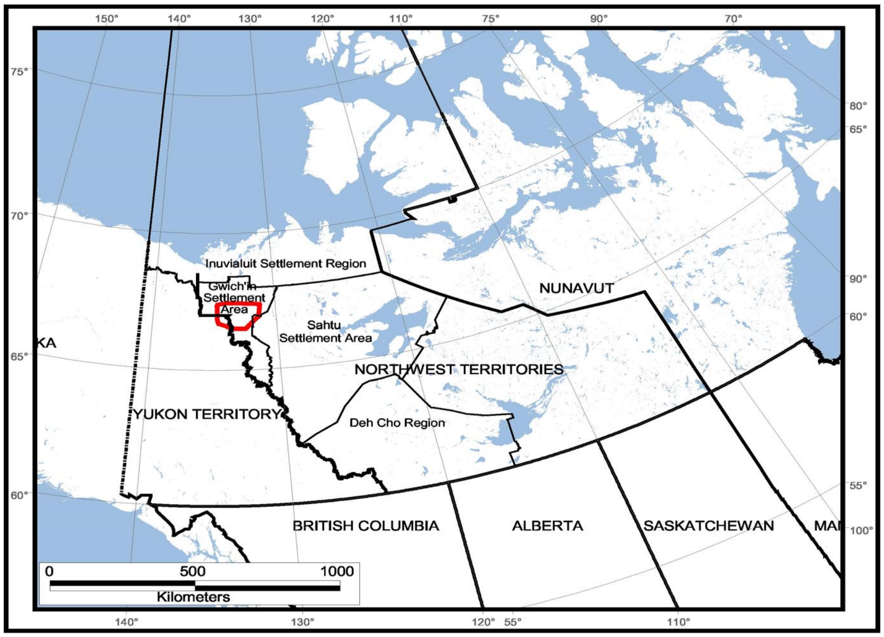
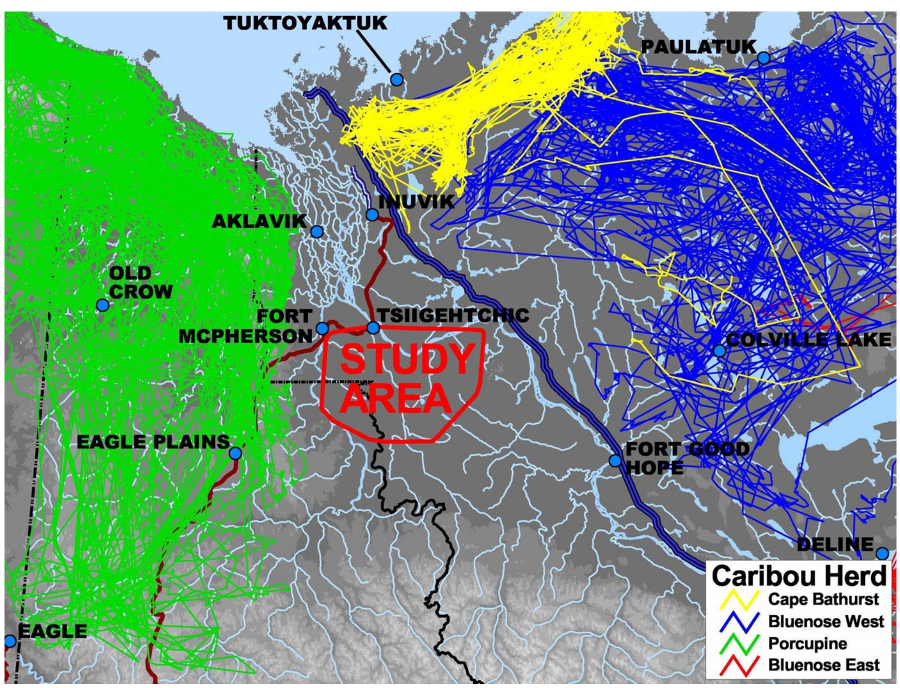


Figure 2. Location of core study area in relation to the ranges of the Porcupine, Cape Bathurst, and Bluenose-West barren-ground caribou herds.



3.0 Methods

3.1 Capture and Collaring Work

Reconnaissance surveys were conducted with a Cessna 206 or 185 fixed wing aircraft to locate caribou or fresh caribou sign (tracks and cratering sites). The pilot of the fixed wing aircraft reported the GPS coordinates of caribou observed to the capture crew via radio. Caribou were captured using a net gun fired from a Bell 206B helicopter. Caribou were equipped with GPS, ARGOS, and VHF radio collars (Telonics, Mesa, Arizona). GPS collars were programmed to provide 3 locations per day (01:00 h, 09:00 h, and 17:00 h). ARGOS satellite collars were programmed to provide one location per day between 15 May and 21 June, and one location every 5 days for the remainder of the year. All collars were equipped with CR2-2a release mechanism (Telonics, Mesa, Arizona). Hair and blood samples were collected for DNA. Feces were collected to determine diet and prevalence and intensity of infection by gastrointestinal parasites. Sightings of boreal woodland caribou, barren-ground caribou, moose, wolves, and other wildlife were recorded. Garmin 12 XL or Garmin 12 CX GPSs were used to record waypoints for all wildlife sightings and to create track files for flights conducted. Caribou observed during these surveys were classified as cows, calves, yearlings, bulls (young and mature, if possible), or unknown.

3.2 Population Estimates, Productivity, Recruitment, Survival Rates, and Typical Group Size

Telemetry surveys were conducted during late May and early June 2003 and 2004 to determine whether collared cows had calves at side (productivity). Color, size and mobility were used to estimate the age of calves. Telemetry surveys were conducted each month from late June to early November 2003 and in late September, late October, and early November 2004 to determine over-summer survival of collared cows and calves born to these cows. Telemetry surveys were conducted in March and April 2004 to determine over-winter survival of collared cows and calves born to these cows (recruitment). Caribou observed during these flights were classified as cows, calves, yearlings, bulls (young and mature if possible), or unknown.

Surveys done in fall/early winter (October and November) and late winter (March and April) provided estimates of the minimum number of caribou within the core study area. Productivity and recruitment were estimated as the number of calves born per 100 radio-collared cows in May/early June and the number of calves per 100 radio-collared cows that survived to late March/early April, respectively. Calf survival was estimated as the ratio of calves that survived to late March/early April to the number born to radio-collared cows. Survival rates of radio-collared caribou were estimated (Krebs 1999; Krebs 2003). Typical group size (TGS) was calculated by month (March through November) using the following method described by (Jarman 1982) where:

$$TGS = \sum_{i=1}^{m} n_i^2 \Big/ \sum_{i=1}^{m} n_l,$$

$$Standard\ Error\ of\ TGS = \left\{ \left[\sum_{i=1}^{m} n_1^{\ 3} - \left(\sum_{i=1}^{m} n_i^{\ 2} \right)^2 \ / \ \sum_{i=1}^{m} n_1 \right] \Big/ \left(\sum_{i=1}^{m} n_1 - 1 \right) \right\}^{0.5}, \text{ and}$$

n = number of individuals observed, m = number of groups observed, and n_i = number of individuals in group i.

3.3 Home Range Size, Seasonal Movement Rates, and Calving Dates

Annual home ranges were calculated for locations obtained for each caribou during 1 May (year 1) to 30 April (year 2). The annual home range size was estimated using the minimum convex polygon function in ArcView extension Animal Movement V.2.0.

Monthly variations in movement rates were determined by calculating the distance between sequential locations obtained between 2 May 2002 and 30 April 2004 for caribou equipped with GPS collars. The distances for locations that were obtained approximately 8 hours apart (range 7:57 to 8:03 hours) were assigned to one of the following time periods:

- early morning: 01:00 to 09:00 h,
- mid day: 09:00 to 17:00 h, and
- evening: 17:00 to 01:00 h.

Kruskal-Wallis nonparametric tests were used to compare distances between locations for each of the 3 8-hour time periods among months and among the 3 8-hour time periods by month. For comparisons that were significantly different ($P \leq .05$), we used the Mann-Whitney U nonparametric test to identify months or time periods where movement rates were significantly different.

We estimated calving dates for caribou equipped with GPS collars by plotting the distances between locations obtained at 8-hour and 24-hour intervals (Nagy et al. 2003). Calving was assumed to have occurred during the period when the distances between locations converged to near zero for 3 to 5 days during May or early June. For caribou equipped with ARGOS satellite collars, we calculated the harmonic and arithmetic mean location for all class 2, and 3 locations obtained each day during the period 1 May to 15 June (Dixon and Chapman 1980). We then calculated the distance between successive harmonic and arithmetic mean locations for each animal. Calving was assumed to have occurred during the period when the distances between locations converged to near zero for 3 to 5 days during May or early June. We calculated the distance between successive annual calving locations for individual caribou. In 2003 and 2004 these caribou were located in late May/early June to determine if they had calved.

3.4 Characteristics of Sites Used by Boreal Woodland Caribou

The locations obtained for all collared caribou except one were east of the Peel River. One caribou made a long-range movement west of the Peel River in late June 2003 but returned to the study area in late July 2003 and remained in this area. The core study area was defined by creating a minimum convex polygon (MCP) around all caribou locations obtained east of the Peel River during the period 1 May 2002 to 30 April 2004. This polygon was buffered by 3,176 m (95th percentile distance between locations obtained at 8 hour intervals for GPS collared caribou). The resulting core study area was 13,216 km^2.

Between 1 May 2002 and 30 April 2004 we obtained 4,710 caribou locations (n = 4,382 GPS; n = 328 ARGOS) in the core study area. We generated 5,000 random non-overlapping locations within the core study area (minimum distance between locations set at 864 m). The satellite and random locations were buffered by 432 m (50th percentile distance between locations obtained at 8 hour intervals for GPS collared caribou). Our primary interest was to assess the characteristics of the areas at and around each location GPS or ARGOS satellite location (Rettie and Messier, 2000).

3.4.1 Distance to nearest seismic line

The distance from GPS radio-collared caribou (n = 4382) and random (n = 5000) locations to the nearest seismic line was measured in GIS. We calculated the difference between the mean caribou and the mean random distance to the nearest seismic line, respectively. We used a t-test to determine if the average of these distances was equal to zero (James 1999). We repeated these analyses for monthly caribou distances and all random points.

For distance measures ≤ 1000 m, we re-classified the locations into one of 10 equal interval distance to seismic line classes (0-100 m, 101-200 m, …901 to 1000 m). Chi-square tests were used to determine if the distribution of caribou and random locations among distance classes differed significantly by month and for all months combined.

The density of seismic lines (km per km^2) within the 432 m buffer around each GPS caribou and random locations was determined using GIS. These data were re-classified into the follow seismic line density classes:

1 no seismic lines
2 0.1 to 0.5 km per km^2
3 0.6 to 1.0 km per km^2
4 1.1 to 1.5 km per km^2
5 > 1.5 km per km^2

Chi-square tests were used to determine if the distribution of caribou and random locations among seismic line density classes differed significantly by month and for all months combined.

3.4.2 Use of areas burned by wildfires

The GPS radio-collared caribou and random locations were overlaid on the fire history layers provided by Forest Management, DRWED, Fort Smith. For locations that fell within areas that were burned, the year that the burn occurred was identified. For analysis the data were grouped into the following seven fire history classes:

1 burned between 1960 and 1974
2 burned between 1975 and 1984
3 burned between 1985 and 1989
4 burned between 1990 and 1994
5 burned between 1995 and 2003
6 year of burn not known
7 not burned

The data were also grouped into two general fire history classes:

1 burned
2 not burned

Chi-square tests were used to determine if the distribution of caribou and random locations among fire history classes was significantly different. Chi-square tests were used to determine if the distribution of caribou locations among the general fire history classes differed significantly among month.

3.5 Habitat Selection during Summer and Late Winter

We used logistic regression models to assess habitat selection during summer (1 June to 31 August) and late winter (1 February to 15 April). Summer corresponds to period between green-up and senescence, the period with warmest temperatures during the year when caribou are subjected to insect harassment, the period when use of areas burned by wild fires was greatest, and the period between calving and rut. Late winter corresponds to the period of deepest snow and coldest annual temperatures, lowest movement rates observed during the year, the period when use of burned areas was the lowest, and the last trimester of pregnancy.

Approximately 80% of the core boreal woodland caribou study area overlapped the Landsat TM satellite image based earth cover map produced by Ducks Unlimited for Lower Mackenzie River/Peel Plateau (Ducks Unlimited 2002; Ducks Unlimited 2003). The caribou (use data) and random (availability data) locations for summer and late winter were overlaid on these earth cover maps and the amount (decimal percent) of each earth cover class present within a 432 m radius around each location was calculated. Because this area around some use and random locations either overlapped or fell outside of the boundaries of the earth cover map, we selected only those for which $\geq$ 90% of the buffered area fell on the earth cover map. In addition, the vegetation cover in portions of the core study area had been altered by wildfires since the satellite images were taken. These areas were re-classified in the earth cover database as "unknown". We selected only those use and random locations for which $\geq$ 90% of the vegetation cover in the area around the locations was known. The density of seismic lines (km per km^2) within the area around each location was calculated. The area around the caribou locations provided information on the associations of vegetation cover classes and density of seismic lines associated with known areas of use. The area around the random locations provided information on the associations of vegetation cover classes and density of seismic lines available within the core study area.

We determined the frequency of occurrence of 0-values for each earth cover class by data type (use and availability). If the frequency of 0-values for an earth cover class was $\geq$ 90 percent in the use and random location data, the data for this cover class was pooled with that of a similar earth cover class. If the frequency of 0-values for the resulting pooled cover classes was $\geq$ 90 percent in the use and availability data, the data for pooled earth cover class was removed from further analyses. The resulting variables were tested for correlation and collinearity using Pearsons Corelation and linear regressions, respectively. The use and availability data were tested separately. The use and availability data for the remaining cover classes and density of seismic lines were then analyzed using a logistic regression. Variables with large confidence intervals were deleted from further analyses. The remaining variables were used to fit RSF models of the form:

$$w(x) = \exp(\exists_1 x_1 + \exists_2 x_2 + \ldots. + \exists_n x_n) \qquad \text{(equation 1)}$$

We ran logistic regression analyses in SPSS 11.5 (SPSS Inc. 2002)for summer and late winter. We used 10 variables in the analyses: 9 earth cover classes and density of seismic lines (Table 10). We used Akaike's information criterion differences for small samples (AIC_c) to evaluate and select the most parsimonious RSF model (i.e. the fewest variables to explain the greatest amount of variation) (Johnson et al. 2004). The model with the lowest AIC_c score is the most parsimonious and appropriated for explaining the observed data (Johnson et al. 2004). In these models selection for variables is indicated by positive ∃ coefficients and avoidance is indicated by negative ∃ coefficients.

To examine model performance, we investigated the pattern of predicted RSF scores for partitioned testing data (use data) against categories of RSF scores (bins) (Boyce et al. 2002). A Spearman-rank correlation between area-adjusted frequency of cross-validation points within individual bins and the bin rank was calculated for each cross validation models (Boyce et al. 2002; Johnson et al. 2004). Using Huberty's (1994 cited by (Johnson et al. 2004)) training to testing ratio, 5 testing models were generated by withholding 20 percent of the locations data for each model. Area-adjusted frequencies in this case were simply the frequency of cross-validated use locations with a bin adjusted (divided) by the area of that range of RSF scores available across the landscape (available data) (Boyce et al. 2002). A model with good predictive performance would be expected to be ones with a strong positive correlation, as more use locations (area adjusted) would continually fall within the higher RSF bins (Boyce et al. 2002). To determine bin size and number, we divide RSF values available across the landscape (available data) greater than 0 into 10 equal-interval percentile bins. Zero values were assigned to a separate bin. The resulting 11 bins were simplified into 5 by merging bins with no or a low number of validation points.

3.6 Mapping the Relative Probability of Occurrence of Boreal Woodland Caribou at the Landscape Level

We overlaid a 1 km x 1 km grid over the Ducks Unlimited earth cover map (Ducks Unlimited 2002; Ducks Unlimited 2003) and calculated the amount (decimal percent) of each earth cover class and the density of seismic lines (km per km^2) present within each grid cell. The log-linear model (equation 1) were used to estimate and project spatially a relative probability of occurrence (w) for the 1 km x 1 km grid cells across the DU vegetation map (Johnson *et al*. 2004). We excluded grid cells from these analyses if >10% of the cells fell outside the earth cover map. The predicted values (w) for grid cells for which >10% of the earth cover was unknown were classified as "unknown" and for grid cells with >90% water were classified as water.

We used a linear stretch to scale the predicted values (w) of the RSF between 0 and 1 (equation 2)(Johnson et al. 2004). The linear stretch takes the form :

$$w = ((w(x) - w_{min})/(w_{max} - w_{min})) \qquad \text{(equation 2)}$$

where w(x) is the product of equation 1 for each grid cell and w_{min} and w_{max} represent the smallest and largest predicted values of the RSF (Johnson et al. 2004). As scaled values (w) approach 1, the spatial location is interpreted as having a relatively greater likelihood of being occupied or selected by caribou (Johnson et al. 2004). The outcome of the linear stretch procedure is sensitive to the w_{max} selected. Relative probability of occurrence may be underestimated if the w_{max} selected is too high. Conversely, relative probability of occurrence may be overestimated if the w_{max} selected is too low. To derive a defendable estimate of w_{max}, we extracted the predicted values (*w*) for grid cells that were used by caribou. Cells that were used by caribou should have a relative probability of use of 1. We then sorted these predicted values (*w*) for occupied cells in ascending order and calculated the percent of caribou locations found within these cells. Using the minimum predicted values (*w)* for occupied cells as the w_{max} for the scaling procedure may over estimate relative probability of use because caribou at times may be found in areas of poor habitat quality. To compensate for this, we selected the predicted value (*w*) of the cell in which the 15th cumulative percent of locations occurred as the w_{max}. Cells with predicted values (*w*) with this value or greater then had a relative probability of occurrence of 1. As a result, cells with a relative probability of occurrence of 1 had predicted values (*w*) that were similar to those of cells in which 85% of the caribou locations were found.

We grouped the scaled relative probability of occurrence values for the 1 km x 1 km grid into the following categories:

- rare = relative probability of occurrence 0
- low = relative probability of occurrence >0 and <0.4
- moderate = relative probability of occurrence $\geq$0.4 and <0.7, and
- high = relative probability of occurrence $\geq$0.7.

We then mapped the spatial distribution of these relative probability of occurrence categories across the area mapped by Ducks Unlimited (Ducks Unlimited 2002; Ducks Unlimited 2003). We then overlaid all incidental sightings of boreal woodland caribou made during May 2002 to September 2004 on this map to obtain a general assessment of the accuracy the model.

3.7 Late Winter Snow Conditions

We documented snow conditions within the core study area during mid and late April 2004. We found fresh caribou cratering areas by flying with a helicopter to the most recent satellite locations for the 8 satellite collared caribou. The exact location of each animal was determined by tracking the VHF beacons on these collars. Snow depth was measured at 7 areas in mid April and 4 in late April. Measurements were taken along trails leading to cratering areas and immediately adjacent to craters. Approximately 10 measurements were taken within each crater area.

4.0 Results

4.1 Capture and Collaring Work

We deployed 2 GPS collars on 2 May 2002, 3 GPS and 4 ARGOS satellite collars during 28

March to 2 April 2003, and 9 VHC collars during 4-9 March 2004, and 6 VHF collars on 1-2 April 2004. No capture or post-capture mortalities occurred during 2002 and 2003. In 2004 one caribou died during capture. The animal was processed and samples were collected. The meat was salvaged and given to the Tsiigehtchic Renewable Resource Council for distribution in the community. The 15 caribou captured and collared in 2004 were located at least once during telemetry surveys conducted on 13, 17, 18, or 30 April to determine if any post capture mortalities occurred. All were alive. In addition, 12 of these caribou were located at least once during telemetry surveys conducted on 22, 24, 28, 29, or 30 May 2004. These caribou were alive. We were not able to locate the remaining 3 VHF collars after an extensive telemetry search and concluded that these collars had failed.

4.2 Population Estimates, Productivity, Recruitment, Survival Rates, and Typical Group Size

4.2.1 Population estimates

Surveys were not conducted to obtain an estimate of the number of boreal woodland caribou in the core study area. However, based on surveys done during fall 2003 and late winter 2004 we are able to provide an estimate of the minimum number of caribou within the area. On 27 October and 5 November 2003 we completed a survey to locate the 8 collared animals within the core study area. We observed a total of 103 caribou during this survey. On 17 and 18 April 2004 we completed a survey to locate the 23 collared animals within the core study area. We observed a total of 133 caribou during this survey. We believe that there are conservatively between 150 and 200 boreal woodland caribou in the core study area. This would give a minimum density of 1.1 to 1.5 caribou per 100 km^2.

4.2.2 Productivity, recruitment, and calf survival rates

In 2003, 8 of the 9 collared cows had calves at side in late May/early June giving a calving rate of 88 calves per 100 cows. Five calves survived to late October/early November 2003 giving an over-summer survival rate of 62.5 percent. Three of these calves survived to late March/early April 2003 giving a recruitment rate of 33.3 calves per 100 cows and a calf survival rate of 37.5 percent. We recognize that our samples size was small.

In 2004, 14 of 19 collared cows had calves at side in late May giving a calving rate of 73.7 calves per 100 cows. Based on analyses of movement data, we believe that 2 GPS collared cows calved in mid May but lost their calves by late May. As a result, the calving rate may have been as high as 84.2 calves per 100 cows. Six calves survived to late October/early November 2004, giving over-summer survival rate of 37.5 to 42.8 percent. We recognize that our samples size was small.

4.2.3 Adult survival rates

We collared 2 cows in early May 2002. Both of these cows were alive in April 2003.

In April 2003, we had active collars on 9 cows (2 deployed in May 2002 and 7 deployed in late

March/early April 2003). The CR2-2a collar release mechanism on the collar of PTTID 36187 deployed prematurely in early November and, as a result, the status of this animal in April 2003 was not known. The remaining 8 cows were alive in April 2004, giving a minimum survival rate of 88.9 percent. We recognized that our sample size was small.

In late April/early May 2004 we had active satellite or VHF radio collars on 23 cows. PTTID 35983 was killed by wolves in mid May 2004. PTTID 35981 and BWC14 died of natural causes in early July 2004. The collar release mechanism on PTTID 36182 was programmed to deploy in early June 2004 and therefore was not included in the sample used to estimate over-summer survival. In addition the collars on 3 cows could not be located following an extensive telemetry search of the area. We believe that these collars failed during May 2004. Based on an effective sample size of 22 animals in late April/early May 2004, the over-summer adult survival rate was estimated at 86.7 percent. We recognized that our sample size was small.

4.2.4 Typical group size

We observed a total of 219 groups during various surveys conducted between May 2002 and November 2004 (Table 1). Typical group size ranged from 11.3 to 11.9 caribou during late winter (March and April), 3.6 during calving (May), 1.5 to 2.2 during summer (June through August), and 8.8 to 9.6 during fall (September through early November) (Table 1). The largest groups were observed in March and April (25 and 26 caribou) when the caribou were on late winter ranges and in September and October during the rut and post rut period (20 and 26 caribou). In mid to late April the collared cows dispersed and were usually found in cow:calf pairs or were solitary during most of the summer.

4.3 Home Range Size, Seasonal Movement Rates, and Calving Dates

4.3.1 Home range size

We estimated the size of annual home ranges (1 May to 30 April) for 2 GPS satellite collared female caribou during 2002-2003 and for 5 GPS and 3 ARGOS satellite collared female caribou during 2003-2004 (Table 2). The number of locations obtained by month for these caribou are given in Table 3. The annual home ranges, locations, and movements of individual caribou tracked during 2002-2003 are given in Figures 3 and 4, and those for caribou tracked during 2003-2004 are given in Figures 5 to 13. The distribution of annual home ranges for caribou tracked during 2002-2003 and 2003-2004 are given in Figures 14 and 15, respectively.

Median home range size was 2,080 km^2 (range 481 to 10,326 km^2). PTTID 36188 migrated to the southern Richardson Mountains (approximately 100 km west of the core study area) during 16-17 June 2003 and returned to the core study area during 26 to 31 July 2003 (Figure 12). This animal's home range was 10,326 km^2. The median home range size for those females that remained within the core study area was 1,985 km^2 (range 481 to 6,021 km^2). The CR2-2a release mechanism on the collar of PTTID 36187 deployed prematurely on 3 November 2003, as a result the data for this animal were excluded from these analyses.

Table 1. **Typical boreal woodland caribou group size by month, May 2002 to November 2004.**

Month	Typical Group Size[1]	SE	Minimum Groups Size	Maximum Group Size	Number of Caribou Observed (n)	Number of Groups Observed (m)
March	11.9	0.4	2	26	255	34
April	11.3	0.6	1	25	422	57
May	3.6	0.5	1	8	86	34
June	1.8	0.4	1	2	26	16
July	1.5	1.0	1	2	4	3
August	2.2	0.6	1	4	22	13
September	9.4	1.2	1	26	141	29
October	8.8	1.0	1	20	114	21
November	9.6	1.1	2	15	92	12

[1] Methods used to calculate typical group size follows Jarman (Jarman 1982).

Table 2. **Size of home ranges of boreal woodland caribou tracked with GPS and ARGOS satellite collars during May 2002 to April 2004.**

PTTID	Collar Type	Period	Number of Locations	Area (km2)
35983	GPS	1 May 2002 to 30 Apr 2003	454	1,843
36182	GPS	1 May 2002 to 30 Apr 2003	605	1,985
35981	GPS	1 May 2003 to 30 Apr 2004	670	2,828
35982	GPS	1 May 2003 to 30 Apr 2004	705	1,550
35983	GPS	1 May 2003 to 30 Apr 2004	441	481
35984	GPS	1 May 2003 to 30 Apr 2004	645	5,696
36182	GPS	1 May 2003 to 30 Apr 2004	686	2,175
36186	ARGOS	1 May 2003 to 30 Apr 2004	103	6,021
36187[1]	ARGOS	1 May 2003 to 3 Nov 2003	68	471
36188[2]	ARGOS	1 May 2003 to 30 Apr 2004	103	10,326
36189	ARGOS	1 May 2003 to 30 Apr 2004	103	557

[1]The CR2-2a release mechanism on the collar of PTTID 36187 deployed prematurely on 3 November 2003.

[2]PTTID 36188 migrated to the southern Richardson Mountains during 16-17 June 2003 and returned to the core study area during 26 to 31 July 2003.

Table 3. Number of locations used to calculate the size of home ranges of boreal woodland caribou tracked with GPS and ARGOS satellite collars during May 2002 to April 2004.

		PTT ID									
Caribou		GPS					ARGOS				
Year	Month	35981	35982	35983	35984	36182	36186	36187	36188	36189	total
2002-2003	May	-	-	61	-	68	-	-	-	-	129
	June	-	-	45	-	43	-	-	-	-	88
	July	-	-	41	-	42	-	-	-	-	83
	August	-	-	35	-	55	-	-	-	-	90
	September	-	-	52	-	45	-	-	-	-	97
	October	-	-	50	-	34	-	-	-	-	84
	November	-	-	38	-	49	-	-	-	-	87
	December	-	-	34	-	45	-	-	-	-	79
	January	-	-	10	-	45	-	-	-	-	55
	February	-	-	18	-	49	-	-	-	-	67
	March	-	-	18	-	69	-	-	-	-	87
	April	-	-	52	-	61	-	-	-	-	113
	Sub total	-	-	454		605	-	-	-	-	1,059
2003-2004	May	72	74	42	65	63	20	20	20	20	396
	June	55	65	63	51	68	22	22	22	22	390
	July	47	76	44	58	58	7	7	7	7	311
	August	46	60	48	65	55	6	6	6	6	298
	September	55	40	54	69	51	6	6	6	6	293
	October	51	40	52	45	50	6	6	6	6	262
	November	41	48	34	41	35	6	1	6	6	218
	December	43	42	18	41	47	6	-	6	6	209
	January	60	54	7	47	59	6	-	6	6	245
	February	65	49	17	56	63	6	-	6	6	268
	March	59	75	20	58	73	6	-	6	6	303
	April	76	82	42	49	64	6	-	6	6	331
	Sub total	670	705	441	645	686	103	68	103	103	3,524
total		670	705	895	645	1,291	103	68	103	103	3,524

Figure 3. Annual home range of PTTID 35983 (1,843 km^2) for the period May 2002 to April 2003.

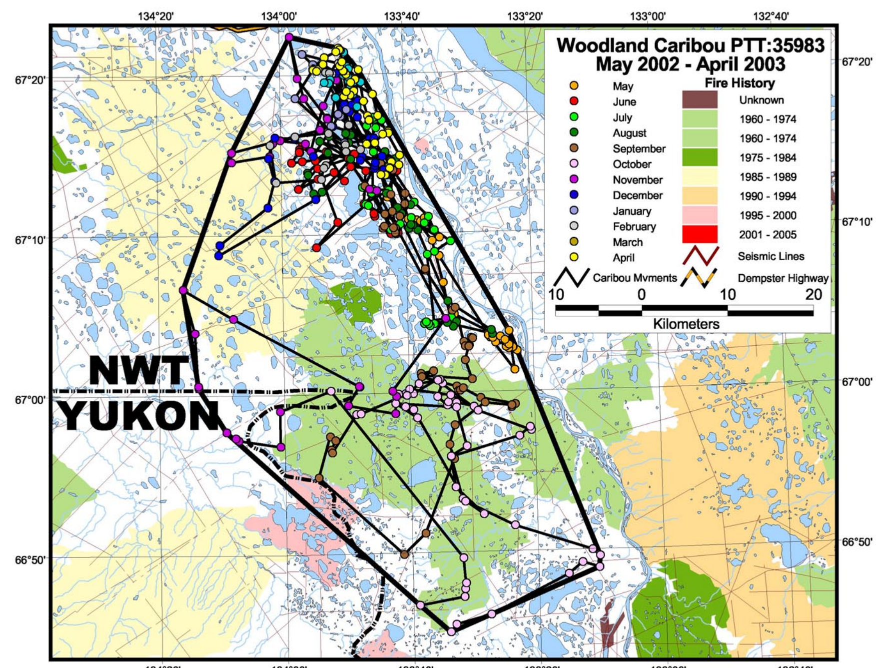


Figure 4. Annual home range of PTTID 36182 (1,985 km^2) for the period May 2002 to April 2003.

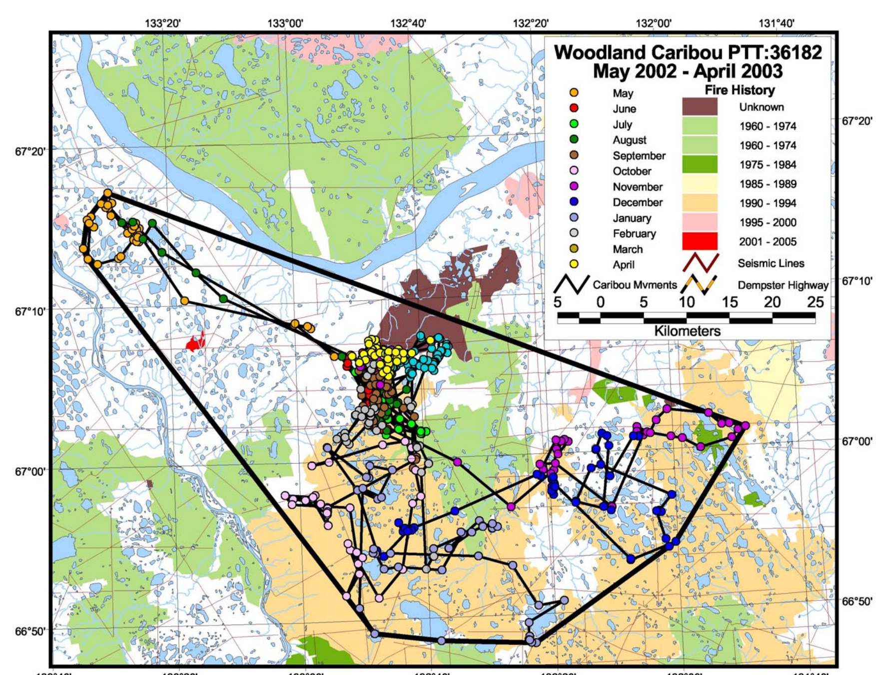


Figure 5. **Annual home range of PTTID 35981 (2,828 km^2) for the period May 2003 to April 2004.**

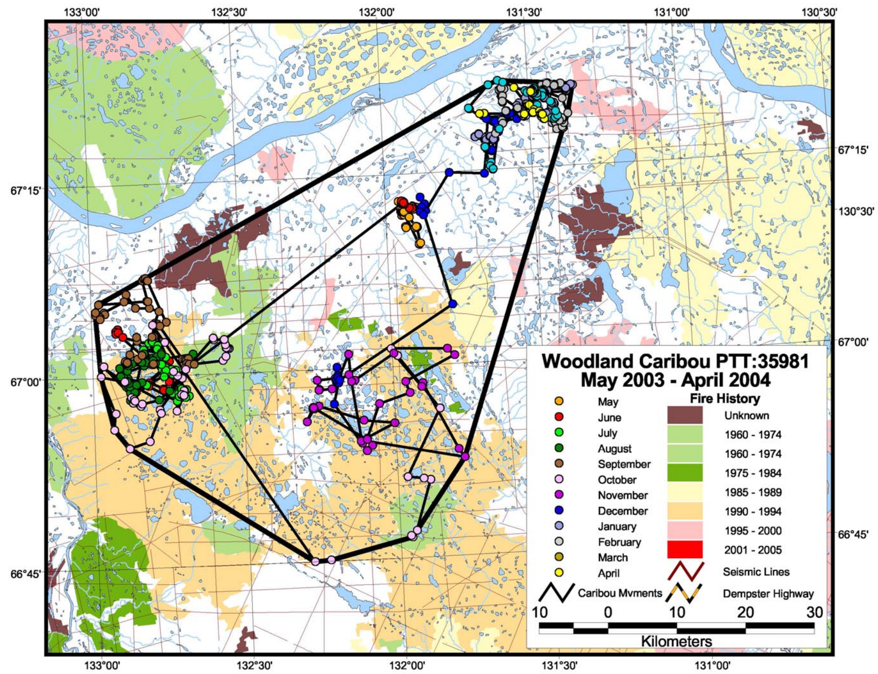


Figure 6. **Annual home range of PTTID 35982 (1,550 km^2) for the period May 2003 to April 2004.**

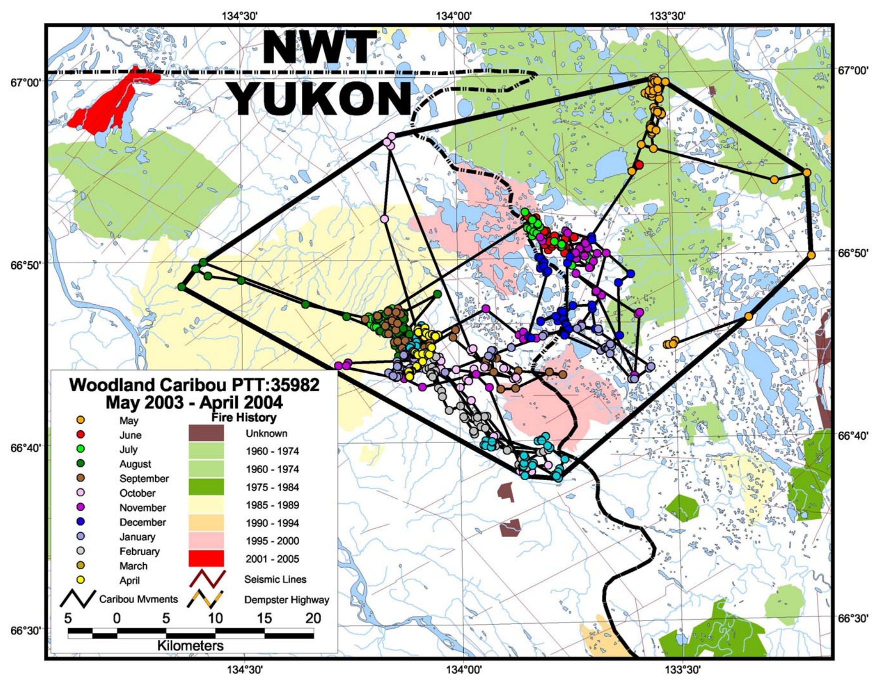


Figure 7. **Annual home range of PTTID 35983 (481 km^2) for the period May 2003 to April 2004.**

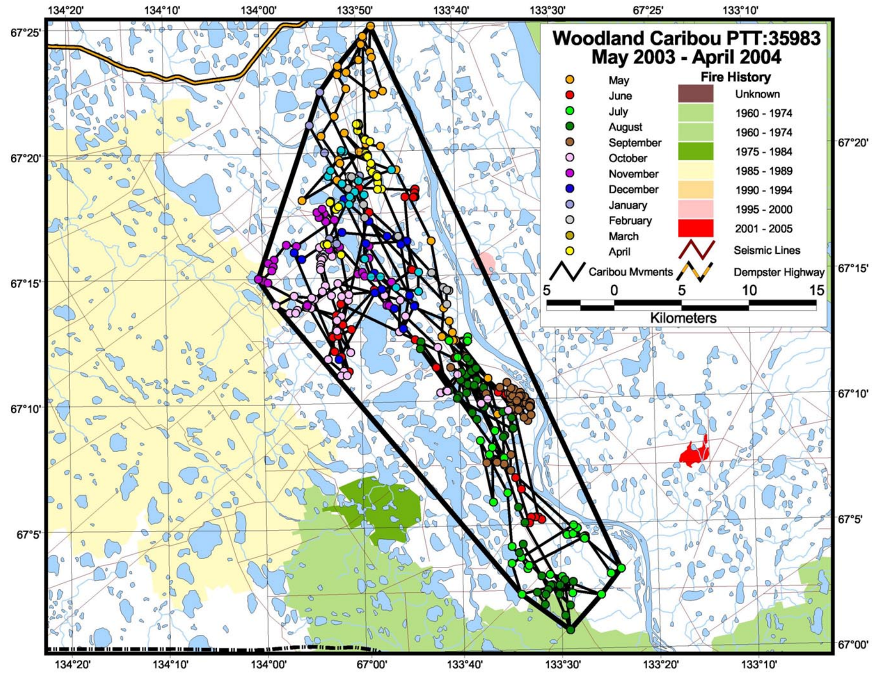


Figure 8. **Annual home range of PTTID 35984 (5,696 km^2) for the period May 2003 to April 2004.**

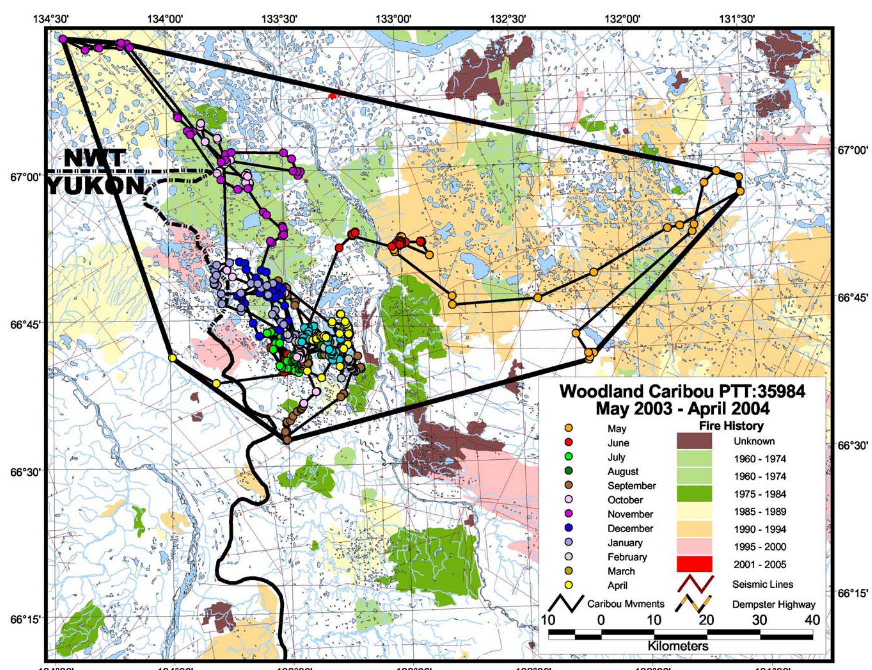


Figure 9. **Annual home range of PTTID 36182 (2,175 km^2) for the period May 2003 to April 2004.**

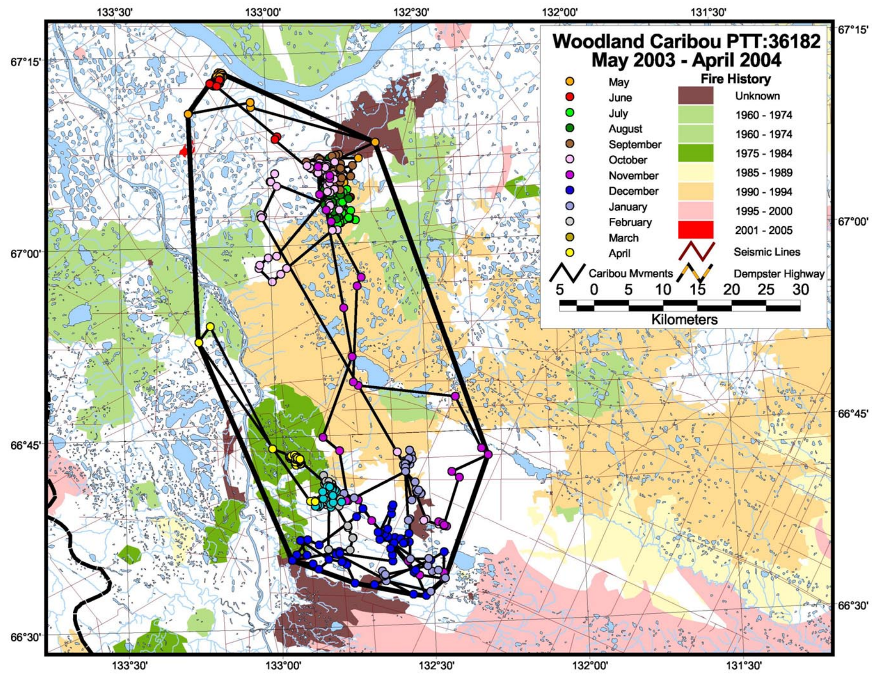


Figure 10. **Annual home range of PTTID 36186 (6,021 km^2) for the period May 2003 to April 2004.**

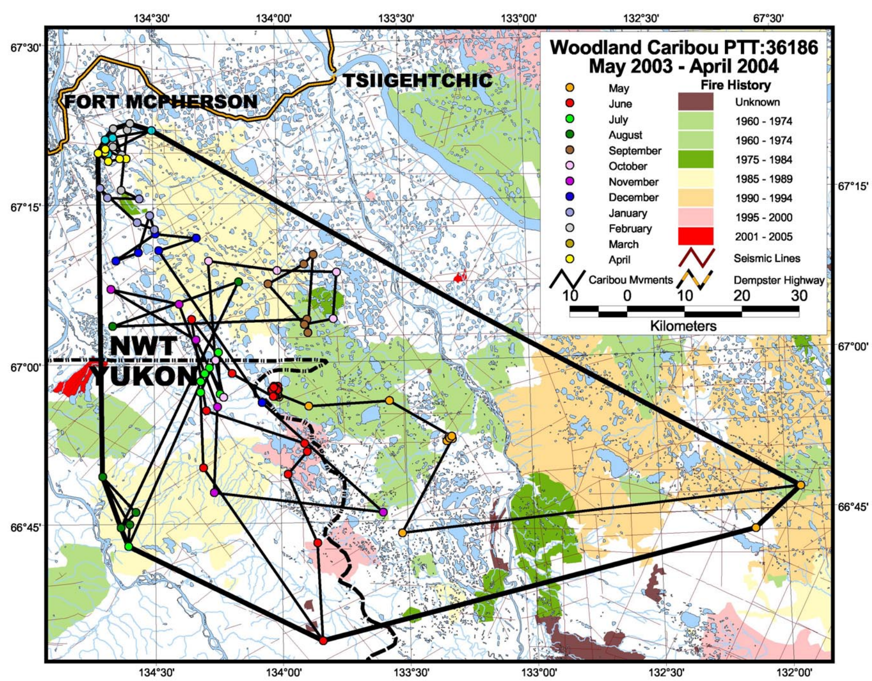


Figure 11. Home range of PTTID 36187 (471 km^2) for the period May 2003 to November 2003.

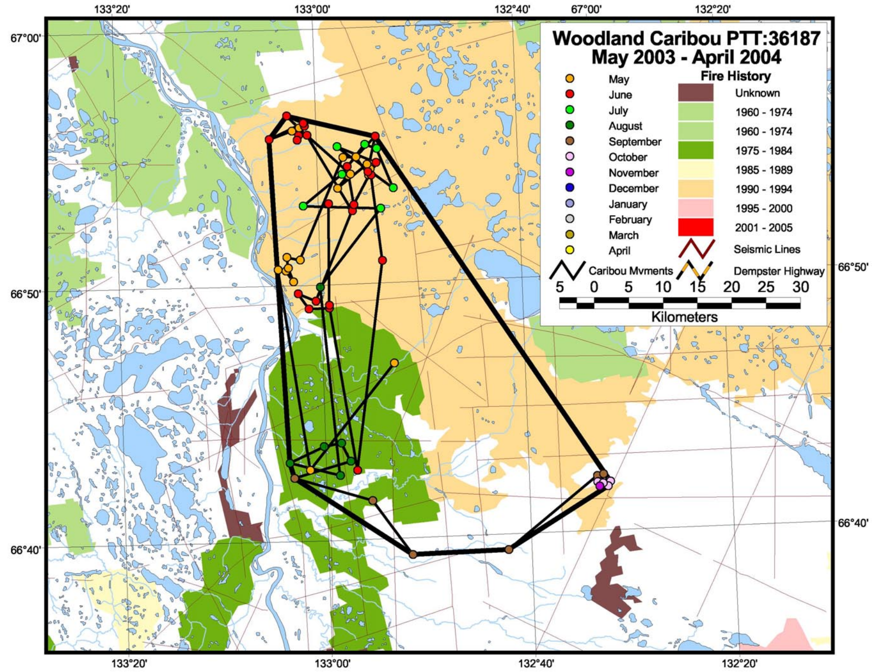


Figure 12. Annual home range of PTTID 36188 (10,326 km^2) for the period May 2003 to April 2004.

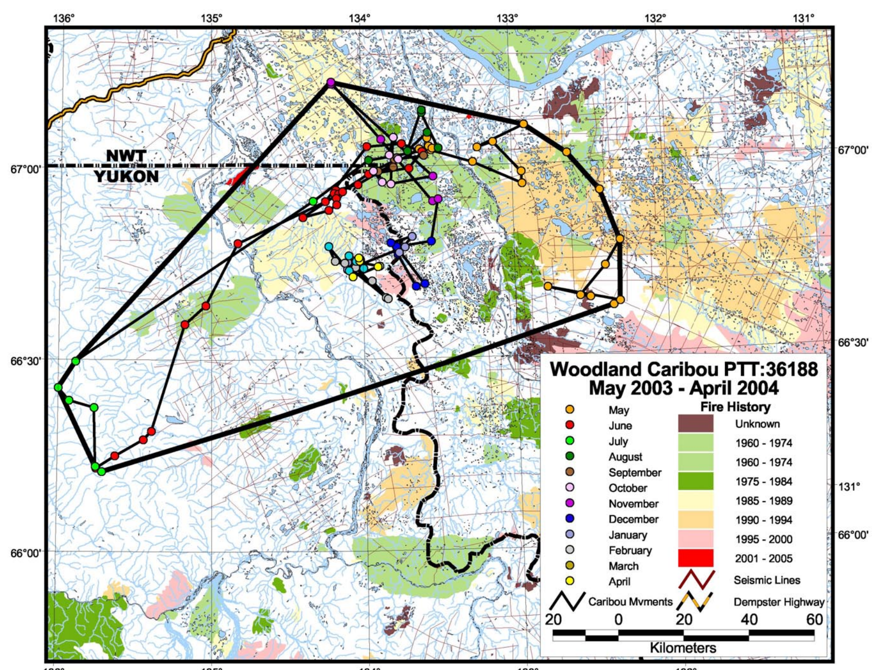


Figure 13. Annual home range of PTTID 36189 (557 km^2) for the period May 2003 to April 2004.

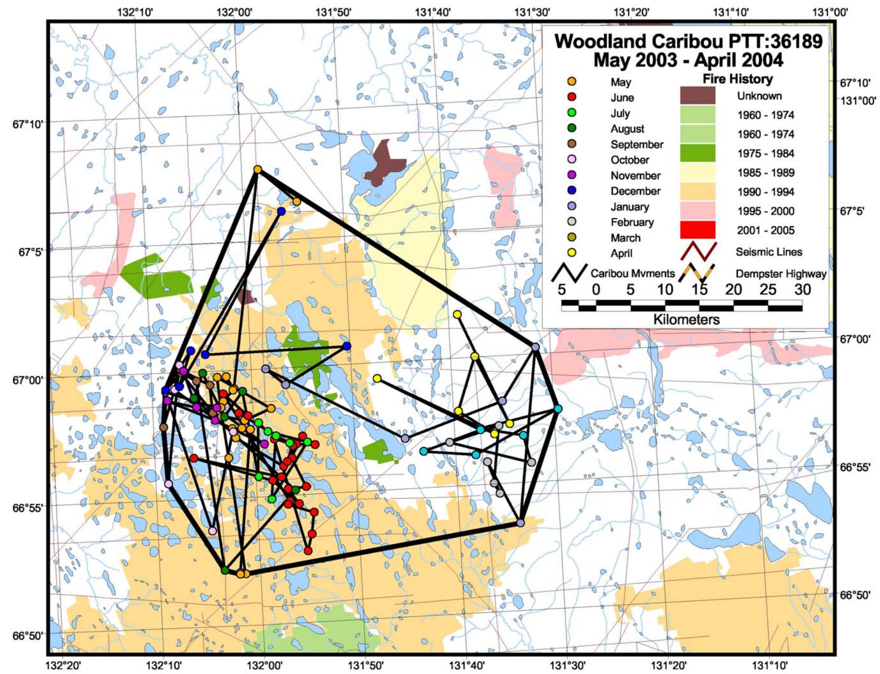


Figure 14. Distribution of annual home ranges of caribou tracked with GPS satellite collars during the period 1 May 2002 to 30 April 2003.

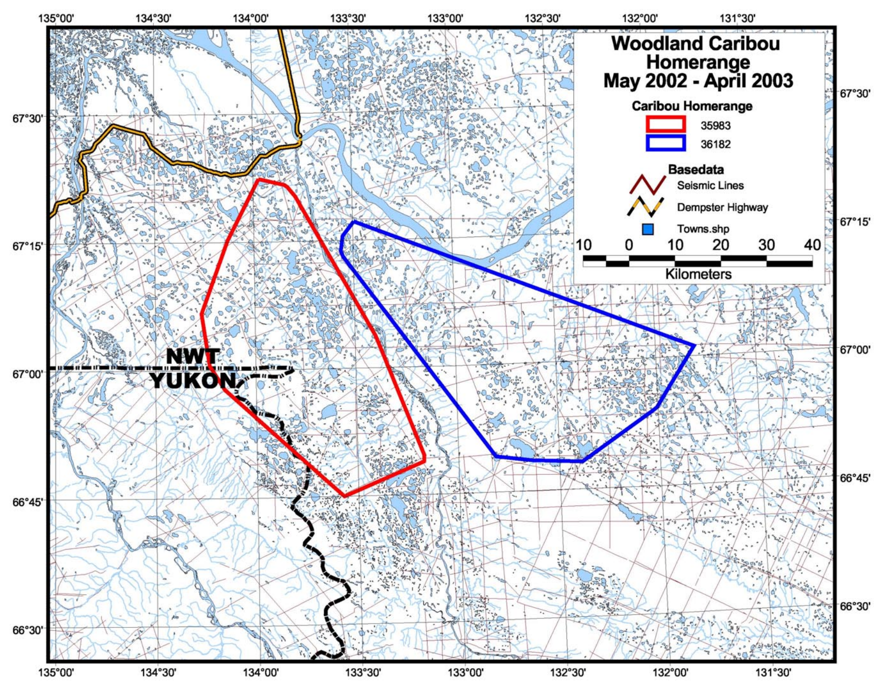
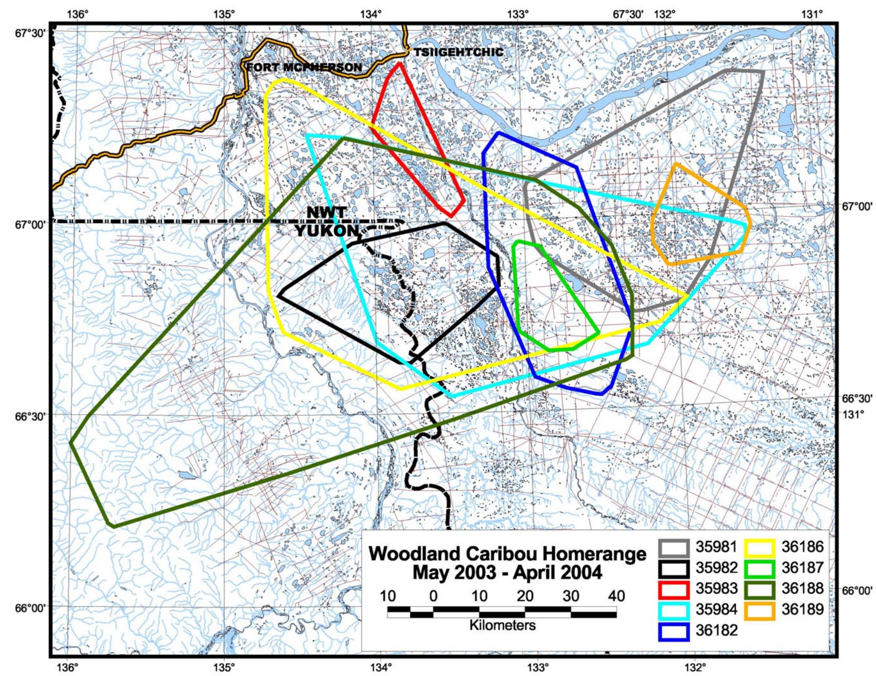


Figure 15. Distribution of home ranges of caribou tracked with GPS and ARGOS satellite collars during the period 1 May 2003 to 30 April 2004.



4.3.2 Seasonal movement rates

The mean, median, minimum, and maximum distances between locations obtained during the early morning (01:00 h to 09:00 h), mid day (09:00 h to 17:00 h), and evening (17:00 h to 01:00 h) by month are given in Tables 4, 5, and 6. The median distance between locations obtained during these periods by month is shown in Figure 16. Early morning movement rates were significantly lower during January through May than during June through December (Table 4, Figure 16). Movement rates during June were significantly lower than during July and August, and July and August movement rates were significantly greater than those during September through December for this period (Table 4, Figure 16). Mid day movement rates were generally significantly lower during April through July than during the remaining months (Table 5, Figure 16). Evening movement rates were generally significantly lower during January through June than during the remaining months (Table 6, Figure 16). These analyses suggest that boreal woodland caribou are more active during the early morning during summer (June, July and August) and are more active during the mid day and evening during the rest of the year.

The distances traveled during the early morning, day, and evening differed significantly for all months except June (Table 7). During December, January, and February the distances traveled were greatest during the day, while those during the evening and early morning were not significantly different (Table 7). In March and April the distances traveled during the early morning were significantly lower than those during the day and evening, and distances traveled during the day and evening were not significantly different (Table 7). During June, July, and August the distances traveled were generally significantly greater during the early morning than those during the day or evening, and distances traveled during the day were significantly lower or equal to those during the evening (Table 7). In September and October distances travelled were significantly greater during the day than those during the evening or early morning, and distances traveled during the evening and early morning were not significantly different. These data suggest that the daily activity patterns of boreal woodland caribou vary during the year. In general, boreal woodland caribou in the study area appear to be more active during the day during spring, fall, and winter and more active during the early morning and evening during the summer.

4.3.3 Calving dates

Calving dates and the distance between sequential calving locations by years for caribou tracked using GPS and ARGOS satellite collars during 2002-2004 are given in Table 8. The distribution of calving sites of the radio-collared caribou is given in Figure 17. The earliest and latest calving dates were 10-11 May and 8-9 June, respectively. Most calves were born between 15 and 25 May. The distance between sequential calving sites was variable (Table 8). The minimum and maximum distances between sequential calving sites for individual caribou were 5.1 km and 84.5 km. We obtained calving sites for PTTID 36182 during 2002, 2003, and 2004. The distance between sequential calving sites for this animal ranged from 12.8 to 84.5 km. Calving sites were dispersed throughout the core study area.

Table 4. **Mean (SD), median, minimum, and maximum distances between locations obtained during the early morning (01:00 h day 1 and 09:00 h day 1) by month. P values (2-tailed) for Mann-Whitney U tests for comparisons of distances observed between months are provided.**

Month	Mean	N	Std. Deviation	Median	Minimum	Maximum	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Jan	0.540	81	0.918	0.202	0.000	4.807	--	--	--	--	--	--	--	--	--	--	--	--
Feb	0.431	87	0.646	0.216	0.011	4.400	0.66	--	--	--	--	--	--	--	--	--	--	--
Mar	0.282	91	0.272	0.187	0.022	1.300	0.78	0.33	--	--	--	--	--	--	--	--	--	--
Apr	0.513	182	1.242	0.119	0.000	9.663	0.03	0.01	0.03	--	--	--	--	--	--	--	--	--
May	0.937	144	1.925	0.240	0.000	13.626	0.44	0.59	0.18	0.00	--	--	--	--	--	--	--	--
June	1.258	125	1.751	0.632	0.014	11.706	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	--	--	--	--	--	--	--
July	1.508	108	1.653	0.900	0.033	9.656	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	--	--	--	--	--	--
Aug	1.464	116	1.421	1.160	0.004	8.945	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.49	--	--	--	--	--
Sept	0.904	103	1.088	0.599	0.014	7.684	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.66	**0.00**	**0.00**	--	--	--	--
Oct	1.058	102	1.168	0.631	0.014	6.400	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.67	**0.02**	**0.00**	0.32	--	--	--
Nov	1.028	107	1.295	0.657	0.014	8.113	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.80	**0.00**	**0.00**	0.82	0.51	--	--
Dec	1.103	88	1.706	0.616	0.026	13.957	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.99	**0.01**	**0.00**	0.67	0.72	0.78	--

Median distance and P values (2-tailed) for comparisons between months that are significant at $P \leq .05$ are in bold.

Table 5. **Mean, median, minimum, and maximum distances between locations obtained during mid day (09:00 h day 1 and 17:00 h day 1) by month. P values (2-tailed) for Mann-Whitney U tests for comparisons of distances bserved between months are provided.**

Month	Mean	N	Std. Deviation	Median	Minimum	Maximum	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Jan	1.041	59	1.142	0.659	0.084	5.069	--	--	--	--	--	--	--	--	--	--	--	--
Feb	0.751	70	0.782	0.457	0.012	4.032	0.20	--	--	--	--	--	--	--	--	--	--	--
Mar	0.562	78	0.545	0.386	0.017	2.608	**0.01**	0.18	--	--	--	--	--	--	--	--	--	--
Apr	0.490	136	0.859	0.267	0.004	8.206	**0.00**	**0.00**	**0.01**	--	--	--	--	--	--	--	--	--
May	0.783	98	2.217	0.186	0.012	16.152	**0.00**	**0.00**	**0.00**	0.53	--	--	--	--	--	--	--	--
June	0.796	88	2.587	0.266	0.000	22.299	**0.00**	**0.00**	**0.04**	0.60	0.21	--	--	--	--	--	--	--
July	0.532	87	0.646	0.291	0.004	3.363	**0.00**	**0.01**	0.13	0.43	0.28	0.83	--	--	--	--	--	--
Aug	1.263	71	2.851	0.800	0.000	24.204	0.20	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	--	--	--	--	--
Sept	2.020	64	3.002	0.891	0.080	14.873	0.15	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.57	--	--	--	--
Oct	3.156	43	4.347	1.248	0.052	22.990	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.04**	--	--	--
Nov	2.527	31	2.578	1.496	0.040	9.390	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.05	0.98	--	--
Dec	1.411	39	1.086	1.085	0.112	5.120	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	0.28	0.20	0.18	--

Median distance and P values (2-tailed) for comparisons between months that are significant at P $\leq$ .05 are in bold.

Table 6. Mean, median, minimum, and maximum distances between locations obtained during the evening (17:00 h day 1 and 1:00 h day 2) by month. P values (2-tailed) for Mann-Whitney U tests for comparisons of distances observed between months are provided.

Month	Mean	N	Std. Deviation	Median	Minimum	Maximum	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Jan	0.534	43	0.682	0.273	0.013	3.862	--	--	--	--	--	--	--	--	--	--	--	--
Feb	0.531	66	0.760	0.304	0.030	5.313	0.93	--	--	--	--	--	--	--	--	--	--	--
Mar	0.464	106	0.471	0.295	0.018	2.254	0.92	0.99	--	--	--	--	--	--	--	--	--	--
Apr	0.517	129	0.765	0.276	0.004	5.296	0.40	0.29	0.26	--	--	--	--	--	--	--	--	--
May	0.501	102	0.820	0.146	0.000	5.968	**0.04**	**0.01**	**0.01**	0.12	--	--	--	--	--	--	--	--
June	0.611	80	0.692	0.308	0.012	3.245	0.82	0.85	0.79	0.21	**0.01**	--	--	--	--	--	--	--
July	0.850	64	0.767	0.724	0.028	4.196	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	--	--	--	--	--	--
Aug	1.081	73	0.729	0.945	0.045	3.347	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	--	--	--	--	--
Sept	0.811	87	0.854	0.527	0.018	4.874	**0.02**	**0.01**	**0.00**	**0.00**	**0.00**	**0.03**	0.33	**0.00**	--	--	--	--
Oct	1.116	57	1.182	0.662	0.024	5.140	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.46	0.18	0.09	--	--	--
Nov	1.539	34	1.588	0.937	0.075	6.872	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**	0.57	**0.00**	0.15	--	--
Dec	1.150	35	2.133	0.702	0.009	13.051	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	0.55	0.14	0.17	0.95	0.12	--

Median distance and P values (2-tailed) for comparisons between months that are significant at $P \leq .05$ are in bold.

Figure 16. **Median distance between locations during early morning (01:00 h day1 to 09:00 h day 1), mid day (09:00 h day 1 to 17:00 h day 1), and evening (17:00 h day 1 to 01:00 h day 2) by month.**

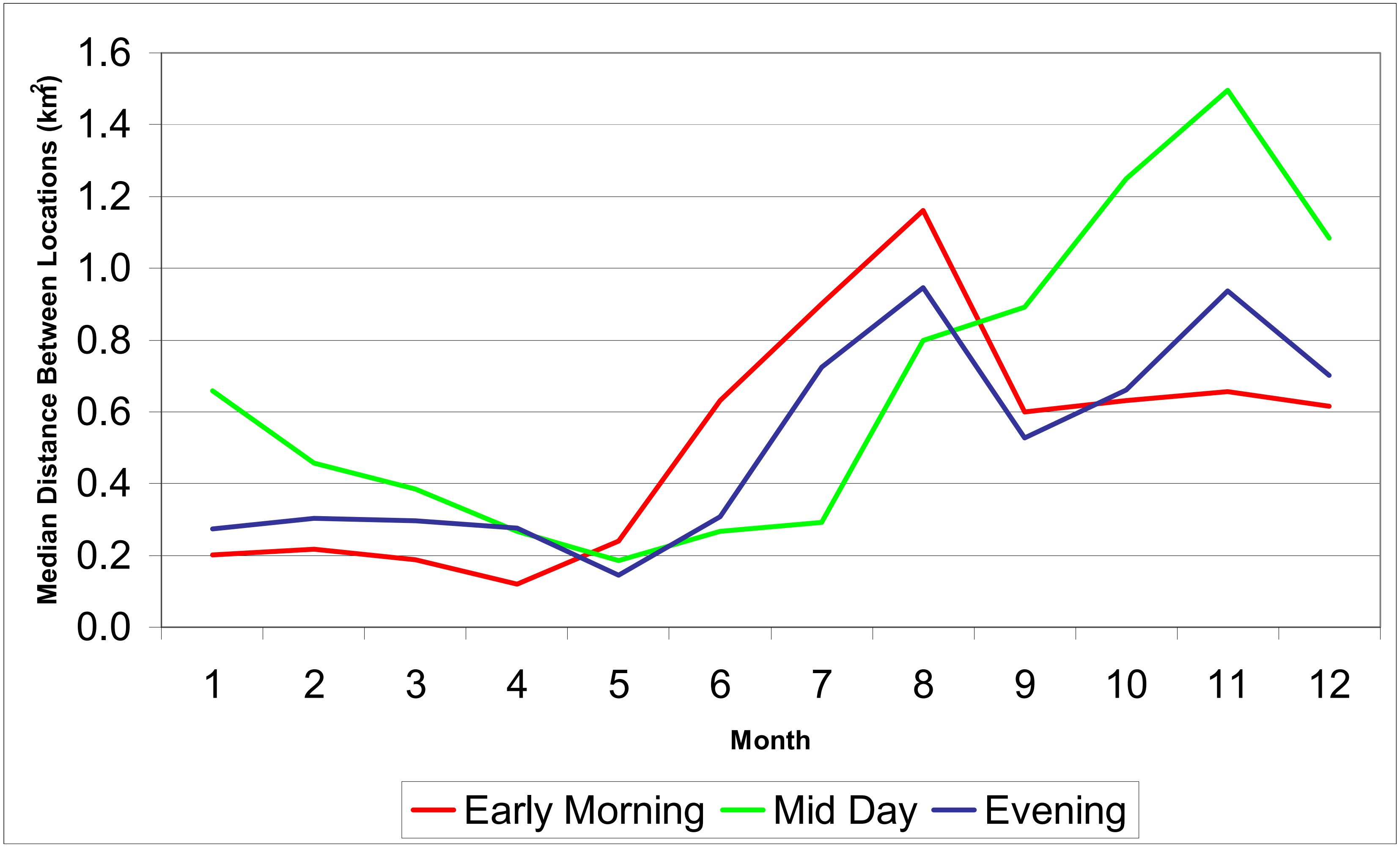


Table 7. Comparison of early morning, day, and evening travel rates by month for boreal woodland caribou tracked with GPS satellite collars, May 2002 to April 2004.

					Comparison of Distance Traveled[1]					
		Sample Size by Period			Early Morning vs Day		Early Morning vs Evening		Day vs Evening	
Month	P value[2]	12	23	31	P value[3]	Difference[4]	P value[3]	Difference[4]	P value[3]	Difference[4]
January	0.00	81	59	43	0.00	12 < 23	0.12	=	0.00	23 > 31
February	0.00	87	70	66	0.00	12 < 23	0.11	=	0.02	23 > 31
March	0.00	91	78	106	0.00	12 < 23	0.00	12 < 31	0.14	=
April	0.00	182	136	130	0.00	12 < 23	0.00	12 < 31	0.72	=
May	**0.06**	**178**	**109**	**113**		=		=		=
June	0.00	125	88	80	0.00	12 > 23	0.00	12 > 31	0.35	=
July	0.00	108	87	64	0.00	12 > 23	0.01	12 > 31	0.00	23 < 31
August	0.04	116	71	73	0.01	12 > 23	0.16	=	0.29	=
September	0.03	103	64	87	0.03	12 < 23	0.55	=	0.01	23 > 31
October	0.00	102	43	57	0.00	12 < 23	0.62	=	0.00	23 > 31
November	0.00	107	31	34	0.00	12 < 23	0.03	12 < 31	0.12	=
December	0.02	88	39	35	0.01	12 < 23	0.63	=	0.03	23 > 31

[1] Period 12 = 01:00 h to 09:00 h, Period 23 = 09:00 h to 17:00 h, and Period 31 = 17:00 h to 01:00 h.

[2] P value for Kruskal Wallis test for comparisons among periods.

[3] P value for Mann-Whitney U tests for comparisons between periods.

[4] < significantly less than, = not significantly different, and > significantly greater than

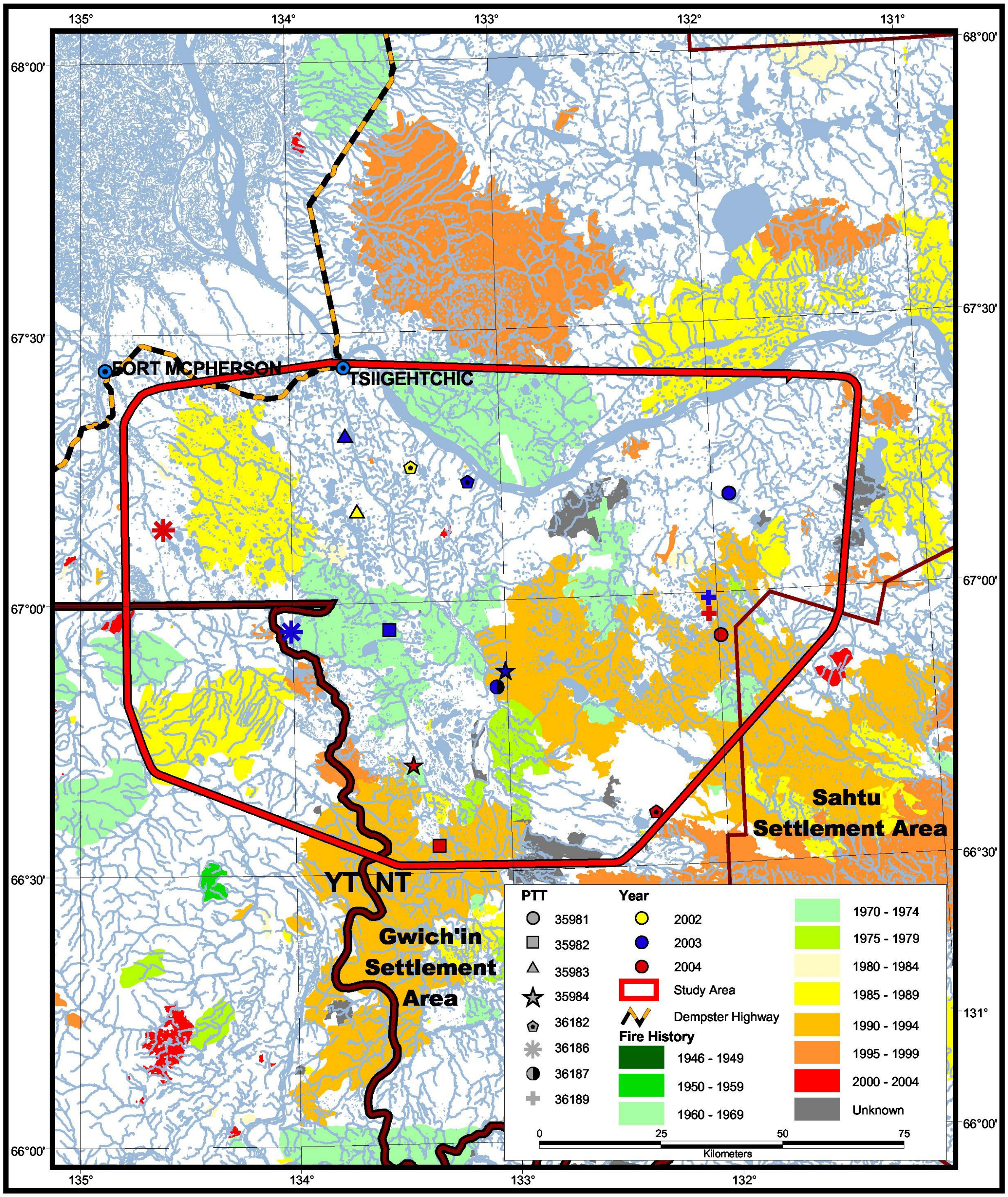
Table 8. Calving dates and distance between sequential calving locations by years for boreal woodland caribou tracked with GPS and ARGOS satellite collars, 2002-2004.

PTTID	Estimated Calving Dates by Year			Distance Between Calving Locations Between Years (km)		
	2002	2003	2004	2002-2003	2003-2004	2002-2004
35981	-	15-17 May	18-20 May	-	29.4	-
35982	-	10-11 May	12-14 May	-	45.3	-
35983	20-23 May	8-9 June	N/A[1]	15.6	-	-
35984	-	18-22 May	18-20 May	-	27.7	-
36182	18-20 May	14-15 May	8-10 May	12.8	76.5	84.5
36186	-	23-25 May	18-19 May	-	32.3	-
36187	-	14-16 May	N/A[2]	-	-	
36188	-	no calf	22-24 May	-	-	-
36189	-	12-15 May	16-20 May	-	5.1	-

[1] PTTID 35983 was killed by wolves on approximately 15 May 2004.

[2] The CR2-2a release mechanism on the collar of PTTID 36187 deployed prematurely on approximately 3 November 2003.

Figure 17. Distribution of calving sites for boreal woodland caribou tracked with GPS and ARGOS satellite collars during 2002, 2003, and 2004.



4.4 Characteristics of Sites Used by Boreal Woodland Caribou

4.4.1 Distance to nearest seismic line

Overall, the mean distance of collared caribou to the nearest seismic line was 1300 m, while that for random locations was 1208 (Table 9). Caribou locations were significantly further from seismic lines ($P < 0.001$). The mean distance of collared caribou to the nearest seismic line by month is given in Table 9. Caribou locations were significantly further from seismic lines during March ($P = 0.001$), June ($P = 0.013$), July ($P = 0.001$), August ($P < 0.001$), and September ($P = 0.005$), and approached significance during May ($P = 0.070$) (Table 9). Caribou locations were significantly closer during November ($P < 0.001$). Differences were not significant during the remaining months. Overall, caribou used areas within 400 m of seismic lines significantly less than expected ($P < 0.001$) (Table 10).

Overall, the mean density of seismic lines with the 432 m buffer around caribou locations was 0.25 km per km^2, while that for random locations was 0.34 km per km^2 (Table 11). Caribou locations were in areas with significantly lower densities of seismic lines ($P < 0.001$). Caribou were in areas with significantly lower densities of seismic lines during all months except November and December (Table 11). Overall, caribou were observed in areas with no seismic lines more than expected and in areas with seismic lines less than expected (Table 12). This pattern was consistent for all months except November, December, and January (Table 12).

4.4.2 Use of areas burned by wildfires

Overall, the distribution of caribou and random locations among year of burn classes was significantly different ($P < 0.001$). Year of burn classes 1975-1984, 1990-1994, and unburned areas were used more than expected (Table 13, Figure 18). Approximately 67 percent of the caribou locations fell within areas that had not been burned by wild fires.

Caribou use of areas burned and not burned by wild fires differed significantly by month ($P < 0.001$). Areas burned by wildfires were used less than expected during the period December through May. Between 69 and 89 percent of the locations obtained for satellite collared caribou during these months were in areas that were not burned by wild fires. Caribou use of areas burned by wild fires was greater than expected during the period June through November (Table 14, Figure 19). Between 40 and 61 percent of the locations obtained for satellite collared caribou during these months were in areas that were burned by wild fires. These data suggest that the patterns of habitats use may be quite different during winter and spring (December through May) and than during summer and fall (June through November).

Table 9. Distance relationships among GPS and random location relative to seismic lines.

Location Data Sets	Number of Locations	Distance to Nearest Seismic Line (km per km^2)		Parameters of t-test for Comparison Between Caribou and Random Distances		
		Mean	**SE**	**P value**	**Mean Difference**	**SE of Difference**
Random	5000	1208	15.9			
All caribou	4382	1300	16.0	$P < 0.001$	-92.3	22.5
January caribou	282	1298	69.6	P = 0.208	-90.1	71.4
February caribou	317	1172	47.8	P = 0.474	36.1	50.4
March caribou	382	1377	46.1	P = 0.001	-168.9	48.6
April caribou	592	1206	45.8	P = 0.961	2.4	48.4
May caribou	445	1290	42.2	P = 0.070	-81.7	45.1
June caribou	390	1327	45.0	P = 0.013	-119.4	47.7
July caribou	366	1409	60.4	**P = 0.001**	-200.8	62.4
August caribou	364	1658	64.9	**$P < 0.001$**	-449.8	66.8
September caribou	366	1388	61.6	**P = 0.005**	-179.8	63.6
October caribou	322	1267	56.1	P = 0.313	-58.9	58.3
November caribou	286	960	50.9	$P < 0.001$	248.0	53.3
December caribou	270	1184	73.1	P = 0.744	24.4	74.8

Table 10. Relationships among GPS and random locations relative to categorized distance to seismic lines.

Distance to Nearest Seismic Line (m)	Count	Type of Location		Total
		Random	Use	
0 -100	Observed	341	**251**	592
	Expected	322.6	269.4	592.0
101-200	Observed	305	**246**	551
	Expected	300.2	250.8	551.0
201-300	Observed	340	**197**	537
	Expected	292.6	244.4	537.0
301-400	Observed	311	**233**	544
	Expected	296.4	247.6	544.0
401-500	Observed	264	245	509
	Expected	277.4	231.6	509.0
501-600	Observed	284	233	517
	Expected	281.7	235.3	517.0
601-700	Observed	242	226	468
	Expected	255.0	213.0	468.0
701-800	Observed	220	229	449
	Expected	244.7	204.3	449.0
801-900	Observed	194	209	403
	Expected	219.6	183.4	403.0
901-1000	Observed	193	181	374
	Expected	203.8	170.2	374.0
Total	Observed	2,694	2,250	4,944
	Expected	2,694.0	2,250.0	4,944.0

Chi-square P value < 0.001 (2 sided).

Table 11. Relationships among GPS and random locations relative to the density of seismic lines within the 432 m buffer.

Location Data Sets	Number of Locations	Density of Seismic Lines in Buffer (km per km^2)		Parameters of t-test for Comparisons Between Caribou and Random Locations		
		Mean	SE	P value	Mean Difference	SE of Difference
Random	5000	0.34	0.009			
All caribou	4382	0.25	0.008	$P < 0.001$	0.09	0.012
January caribou	282	0.26	0.032	$P = 0.020$	0.08	0.033
February caribou	317	0.24	0.029	$P = 0.001$	0.10	0.031
March caribou	382	0.12	0.020	**$P < 0.001$**	0.22	0.021
April caribou	592	0.28	0.024	$P = 0.026$	0.06	0.025
May caribou	445	0.24	0.024	$P < 0.001$	0.10	0.025
June caribou	390	0.23	0.027	**$P < 0.001$**	0.11	0.028
July caribou	366	0.26	0.028	$P = 0.010$	0.08	0.029
August caribou	364	0.21	0.026	$P < 0.001$	0.13	0.027
September caribou	366	0.24	0.028	$P = 0.001$	0.10	0.029
October caribou	322	0.23	0.030	$P = 0.001$	0.11	0.031
November caribou	286	0.37	0.039	**$P = 0.428$**	-0.03	0.040
December caribou	270	0.29	0.035	$P = 0.170$	0.05	0.037

Table 12. Observed and expected boreal woodland caribou use of areas relative to categories densities of seismic lines within the buffer around GPS collar locations by month.

Period	Chi Square P-value	Density of Seismic Lines in Buffer (km per km^2)[1]				
		0	0.1 - 0.5	0.6 - 1.0	1.1 - 1.5	> 1.5
January	P = 0.053	O = E	O = E	O = E	O = E	O = E
February	P = **0.004**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
March	**P < 0.001**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
April	P = **0.025**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
May	**P < 0.001**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
June	**P < 0.001**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
July	P = **0.027**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
August	**P < 0.001**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
September	P = **0.003**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
October	P = **0.002**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**
November	P = 0.532	O = E	O = E	O = E	O = E	O = E
December	P = 0.201	O = E	O = E	O = E	O = E	O = E
All	**P < 0.001**	**O > E**	**O < E**	**O < E**	**O < E**	**O < E**

[1] O is observed, E is expected, > = greater than, < is less than, = is equal to.

Table 13. Observed and expected distribution of random and boreal woodland caribou locations within areas of known fire history.

Year of Burn	Count	Type of Location: Random	Use	Total
1960-1974	Observed	622	442	1,064
	Expected	544.7	519.3	1,064.0
1965-1974	Observed	24	0	24
	Expected	12.3	11.7	24.0
1975-1984	Observed	89	147	236
	Expected	120.8	115.2	236.0
1985-1989	Observed	531	160	691
	Expected	353.8	337.2	691.0
1990-1994	Observed	771	769	1,540
	Expected	788.4	751.6	1,540.0
1995-2003	Observed	66	15	81
	Expected	41.5	39.5	81.0
not burned	Observed	2,820	3,160	5,980
	Expected	3,061.5	2,918.5	5,980.0
total	Observed	4,923	4,693	9,616
	Expected	4,923.0	4,693.0	9,616.0

Chi-square P value < 0.001 (2 sided).

Table 14. Observed and expected boreal woodland caribou use of areas burned by wild fires and unburned areas by month within the core study area.

Month	Count	Not Burned	Burned	Total
January	Observed	216	76	292
	Expected	195.9	96.1	292.0
February	Observed	294	40	334
	Expected	224.1	109.9	334.0
March	Observed	337	63	400
	Expected	268.4	131.6	400.0
April	Observed	564	69	633
	Expected	424.7	208.3	633.0
May	Observed	360	160	520
	Expected	348.9	171.1	520.0
June	Observed	268	179	447
	Expected	299.9	147.1	447.0
July	Observed	150	232	382
	Expected	256.3	125.7	382.0
August	Observed	184	198	382
	Expected	256.3	125.7	382.0
September	Observed	233	155	388
	Expected	260.3	127.7	388.0
October	Observed	165	179	344
	Expected	230.8	113.2	344.0
November	Observed	170	132	302
	Expected	202.6	99.4	302.0
December	Observed	219	67	286
	Expected	191.9	94.1	286.0
Total	Observed	3,160	1,550	4,710
	Expected	3,160.0	1,550.0	4,710.0

Chi-square P value < 0.001 (2 sided).

Figure 18. **Percent distribution of random and caribou locations within areas of known fire history.**

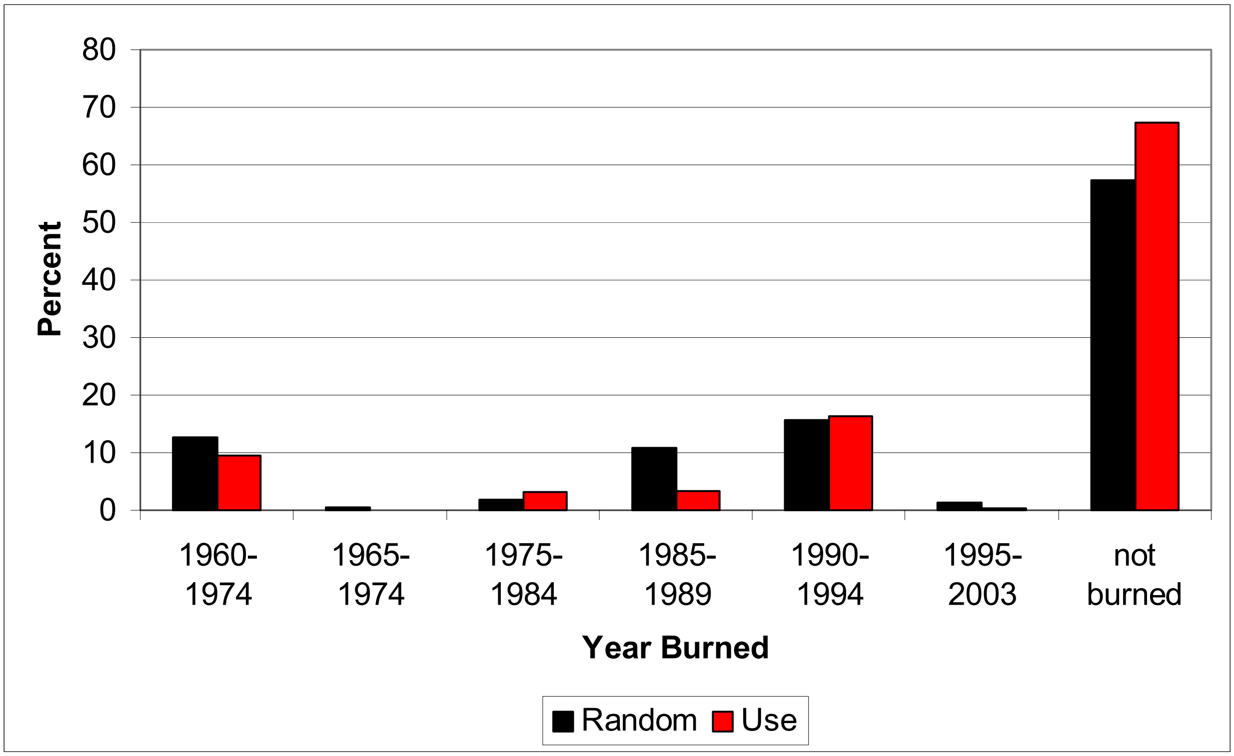
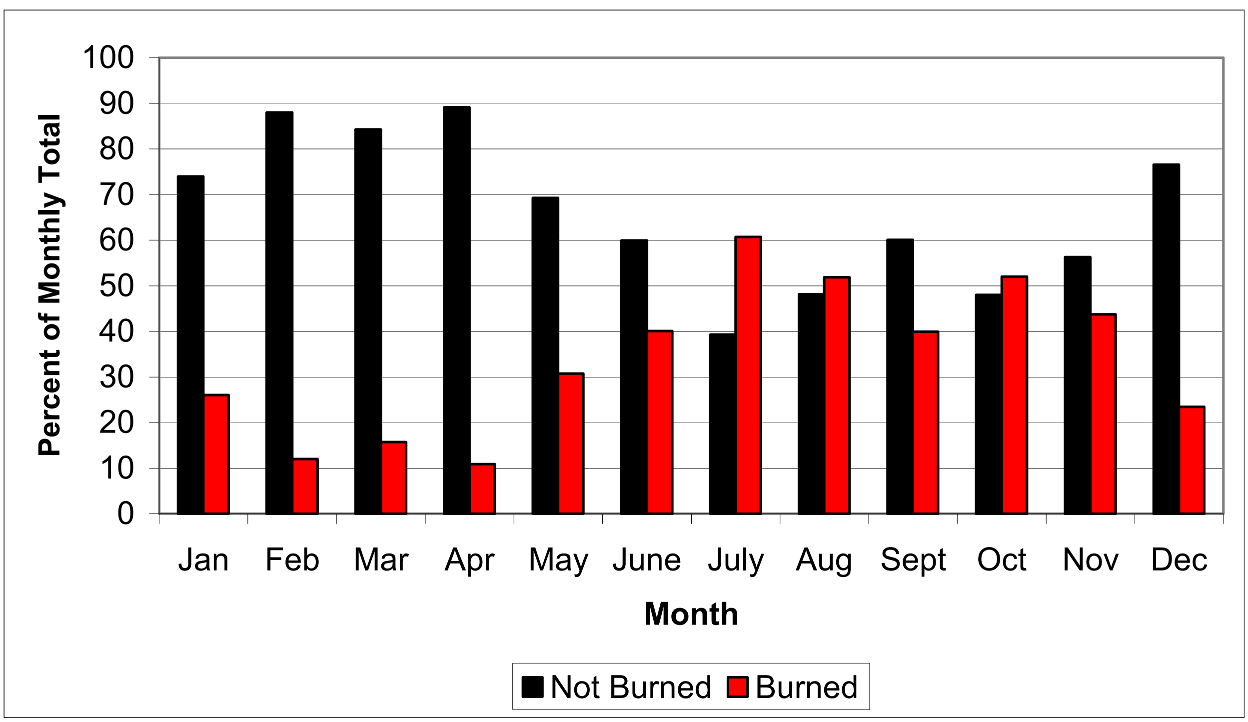


Figure 19. **Proportion of caribou locations found in unburned areas and areas burned by wild fires by month.**



4.5 Habitat Selection during Summer and Late Winter

Logistic regression analyses of the data for summer did not yield a useful model. The independent variables used to derive the RSF model for late winter are given in Table 15. The coefficients of the most parsimonious RSF model for selection of habitat variables for late winter are given in Table 16. Area-adjusted frequencies displayed significant positive rank values (Spearman-rank correlation) across RSF bins for the late winter model (Table 17). All individual late winter models demonstrated significant Spearman-rank correlations, indicating little evidence for poor model performance.

These analyses indicate that the boreal woodland caribou in the study area selected for areas with closed spruce, open spruce, open mixed needle leaf deciduous, woodland needle leaf, and/or tall shrub earth cover types during late winter. Caribou avoided areas with closed deciduous and low shrub earth cover, water, and/or areas with seismic lines.

4.6 Mapping the Relative Probability of Occurrence of Boreal Woodland Caribou at the Landscape Level

The categorized late winter probability of occurrence of boreal woodland caribou was mapped across the Lower Mackenzie River/Peel Plateau earth cover maps by Ducks Unlimited (Ducks Unlimited 2002; Ducks Unlimited 2003) (Figure 20). Approximately 81 percent of the core study area overlapped this area, and approximately 47 percent of this area was classified as high probability of occurrence for boreal woodland caribou, 11 percent as moderate, and 32 percent as low. In comparison, approximately 32 percent of the area was classified as high probability of occurrence for boreal woodland caribou for the Lower Mackenzie/Peel Plateau area, 9 percent as moderate, and 42 as low probability of occurrence. This suggests that there is a higher proportion of high quality habitat available in the core study area than is available at the regional level.

Based on our knowledge of the Lower Mackenzie River/Peel Plateau area, we believe that the RSF model reasonably predicts the distribution of high quality late winter boreal woodland caribou habitat. Areas known to be poor late winter habitat (recent burns) were consistently classified as areas where the predicted probability of occurrence of boreal woodland caribou was low. Un-burned areas within burns that were used by radio-collared caribou were classified as areas where the predicted probability of occurrence was moderate to high.

To further validate the model, we mapped the track files for all surveys (reconnaissance, capture, and telemetry) conducted during April 2002 to November 2004 (Figure 21). Although a majority of surveys were conducted in the core study area, the area north of the core study area, in particular the area along the proposed Mackenzie Valley Pipeline, received extensive coverage. We mapped all sightings of caribou, including radio-collared animals (GPS, ARGOS, and VHF), made during these surveys (Figure 22). The majority of these sightings were made within the core study area, however, a number of sightings were made north of the core study area within areas were the predicted probability of occurrence of boreal woodland caribou was moderate to high. These data indicate that the late winter model reasonably predicts areas of where the probability of occurrence of boreal woodland caribou is moderate to high. In addition,

Table 15. Independent variables used to derive RSF values for the late winter boreal woodland caribou model.

Variable	DU Earth Cover Types Pooled	Variable Code	Value
Closed Black Spruce		CSP	decimal percent
Open Black Spruce	open black spruce lichen, open black spruce other	OSP	decimal percent
Closed Deciduous	closed deciduous and closed birch	CDEC	decimal percent
Closed Mixed Needle Leaf Deciduous		CMNDLDEC	decimal percent
Open Mixed Needle Leaf Deciduous		OMNDLDEC	decimal percent
Woodland Needle Leaf		WNDL	decimal percent
Tall Shrub		TSH	decimal percent
Low Shrub	low shrub other, low shrub tussock tundra, and low shrub lichen	LSHALL	decimal percent
Water		WATER	decimal percent
Density of Seismic Lines		SEISDEN	km per km^2

[1] Based on the Ducks Unlimited Canada Earth Cover Classification (Ducks Unlimited 2002; Ducks Unlimited 2003).

Table 16. Coefficients and SE of the most parsimonious RSF model for selection of habitat variables for the late winter.

Variable	∃ coefficient	S.E of ∃
Closed Spruce	0.516	0.610
Open Spruce	3.671	0.346
Closed Deciduous	-37.366	11.314
Closed Mixed Needle Leaf Deciduous	-7.259	2.286
Open Mixed Needle Leaf Deciduous	0.405	0.679
Woodland Needle Leaf	3.141	0.381
Tall Shrub	0.466	0.793
Low Shrub	-3.643	0.541
Water	-0.560	0.479
Density of seismic lines	-0.690	0.090

Table 17. Cross-validated Spearman-rank correlations (r_s) between RSF bin ranks and area-adjusted frequencies for individual and averaged model sets for late winter.

Set	**Late Winter**[a]	
	r_s	**P**
1	0.90	0.037
2	0.90	0.037
3	0.90	0.037
4	0.90	0.037
5	1.00	0.010
Average	0.90	0.037

[a]Late winter (1 February to 15 April).

Figure 20. **Categorized probability of occurrence of boreal woodland caribou across the Lower Mackenzie River/Peel Plateau area, Inuvik Region, NT.**

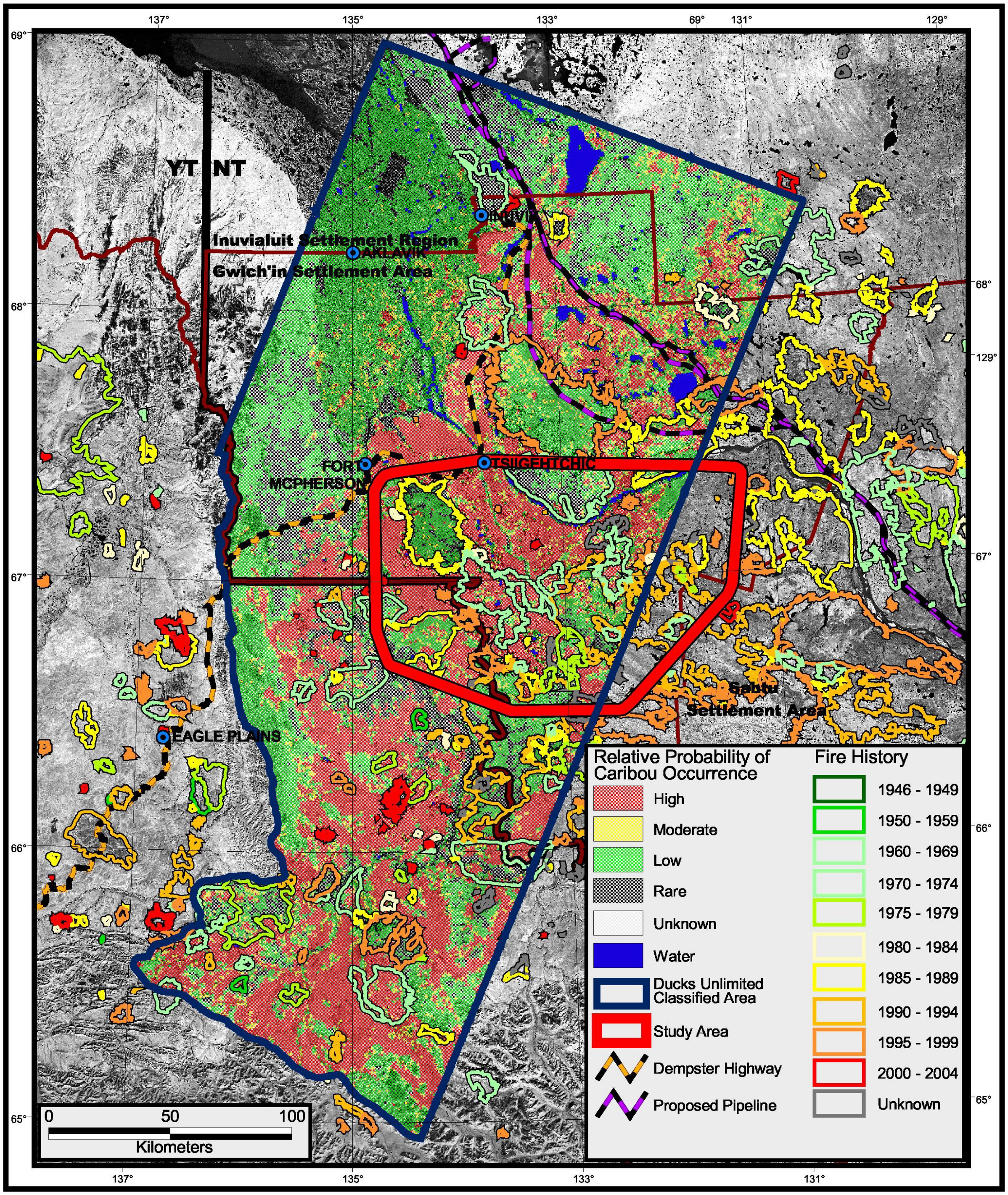


Figure 21. Distribution of flight lines for surveys flown (capture and telemetry) between April 2002 and November 2004.

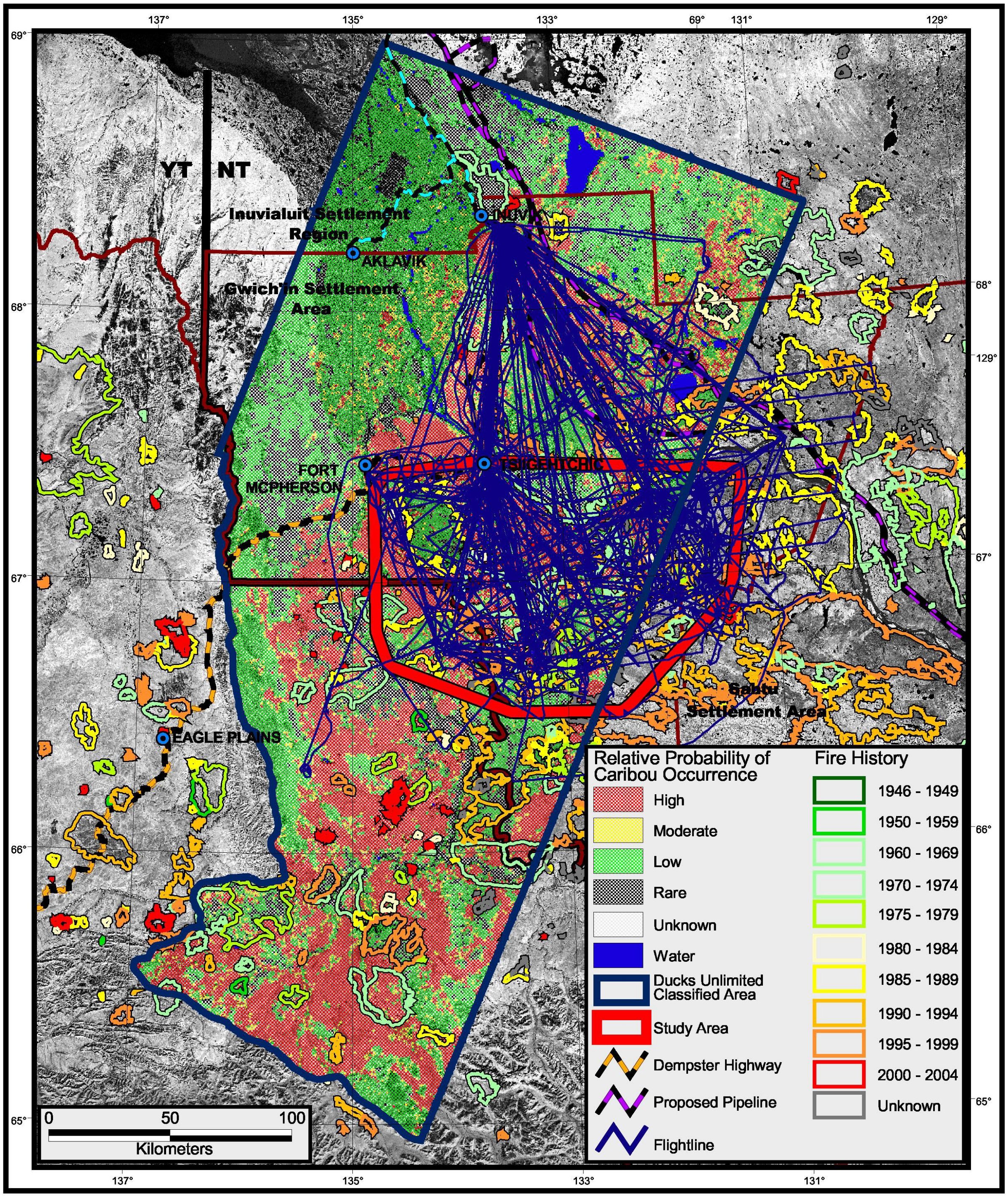
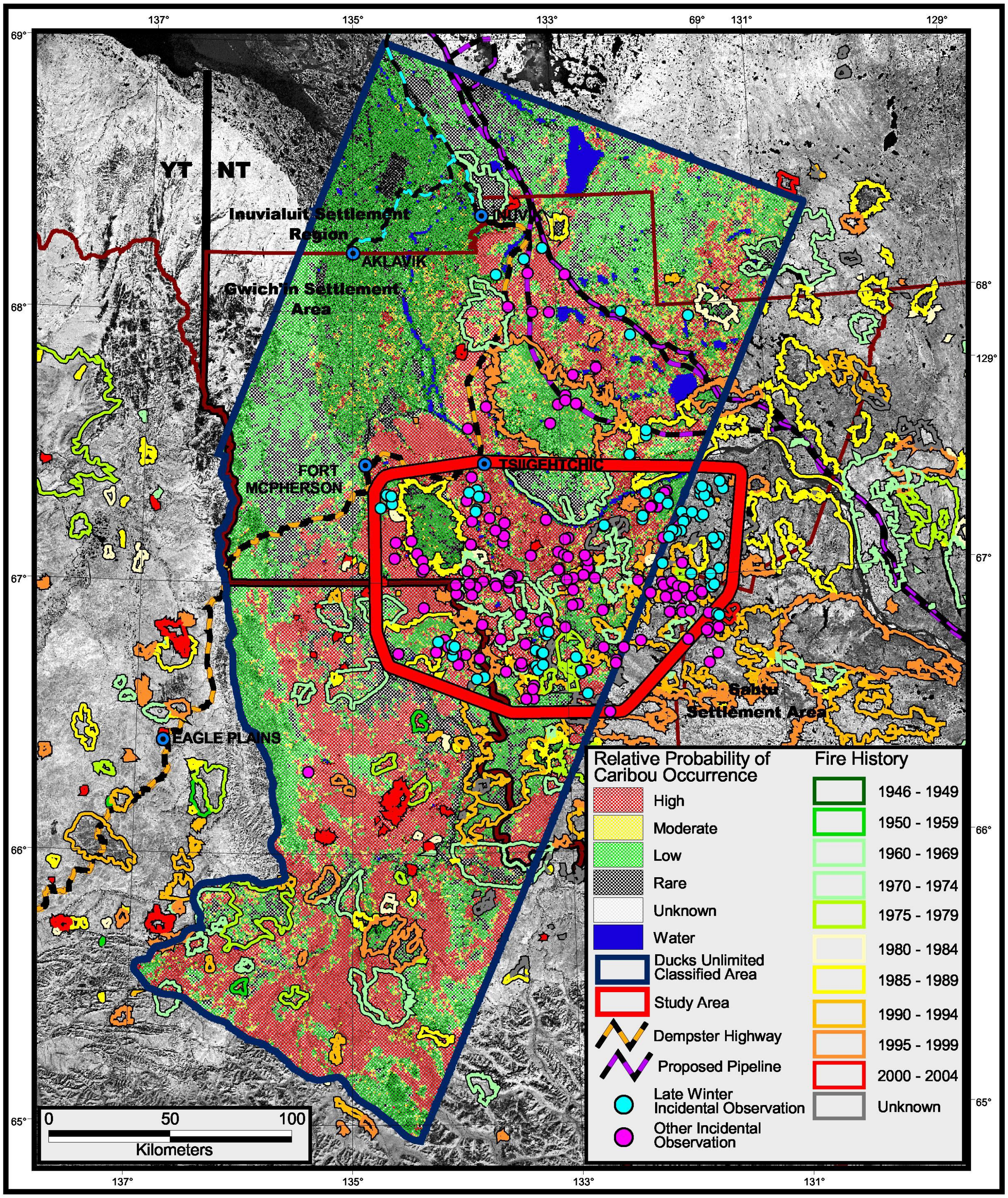


Figure 22. Distribution of sightings of radio-collared and un-collared caribou made during surveys conducted between April 2002 and November 2004.



the incidental sightings indicate that the areas identified as moderate to high quality boreal woodland caribou habitat along the proposed Mackenzie Valley Pipeline route were occupied.

4.7 Late Winter Snow Conditions

During early March 2004 snow depth in the area appeared to be within the normal range (approximately 45-60 cm). Between mid March and early April 2004 the area experienced unusually high snowfall. Snow depths in the area by early April 2004 had reached levels not previously experienced by people in the communities. During capture work in early April 2004 we found that the boreal woodland caribou and moose in the core study area had great difficulty traveling through the snow. Snow depths along lakeshores and within forested areas were above the belly lines of boreal woodland caribou and moose (Figure 23).

On 8 April 2004, snow depth was measured at 3 sites adjacent to craters and at one site adjacent to trails in forested areas (Figure 24). The mean snow depth in areas adjacent to cratering sites was 82.2 cm (range 61 to 102 cm) (Table 18), while that for areas adjacent to trails was 89.2 cm (range 81 to 95 cm). Air temperatures during the day reached +15 ^{o} C within the core study area causing the surface snow to melt and made travel with snowshoes extremely difficult. Warm daytime temperatures persisted until approximately 12 April 2004. By 13 April 2004, daytime air temperatures had returned to the –15 to –20^{o} C range.

On 13 April 2004, snow depth was measured at 4 sites (Figure 24). In forested areas, the mean snow depth in areas adjacent to cratering sites was 71.4 cm (range 51 to 99 cm), while that for areas adjacent to trails was 78.6 cm (range 69 to 97 cm). In non-forested areas, the mean snow depth in areas adjacent to cratering sites was 56.4 cm (range 48 to 61 cm). In non-forested areas, an approximately 2.5 cm ice layer had formed below the surface of the snow (Figure 25). This ice layer was strong enough to hold the weight of adult caribou in most areas. However, in some areas the ice layer collapsed under the weight of the animals. Hair loss resulting from the animals breaking through the ice layer was observed (Figure 26). In forested areas, the surface of the snow was crusted, but no ice layer was evident.

On 30 April 2004, snow depth was measured at 4 sites (Figure 24). Daytime temperatures were above zero during this period. In forested areas, the mean snow depth in areas adjacent to cratering sites was 51.3 cm (range 36 to 71 cm), while that for areas adjacent to cratering sites in non-forested areas was 45.1 cm (range 23 to 61 cm). In forested and non-forested areas the snow had collapsed and was saturated with water.

On 29 May 2004 there was snow cover on approximately 50 to 60 percent of the northern portion of the core study area. Ice cover was present on all lakes.

Figure 23. **Boreal woodland caribou experienced deep snow conditions from approximately mid March to the end of April, 2004. Snow depths in areas along lakeshores and within forested areas were above the belly line of adult caribou.**

Figure 24. Distribution of snow sampling sites, April 2004.

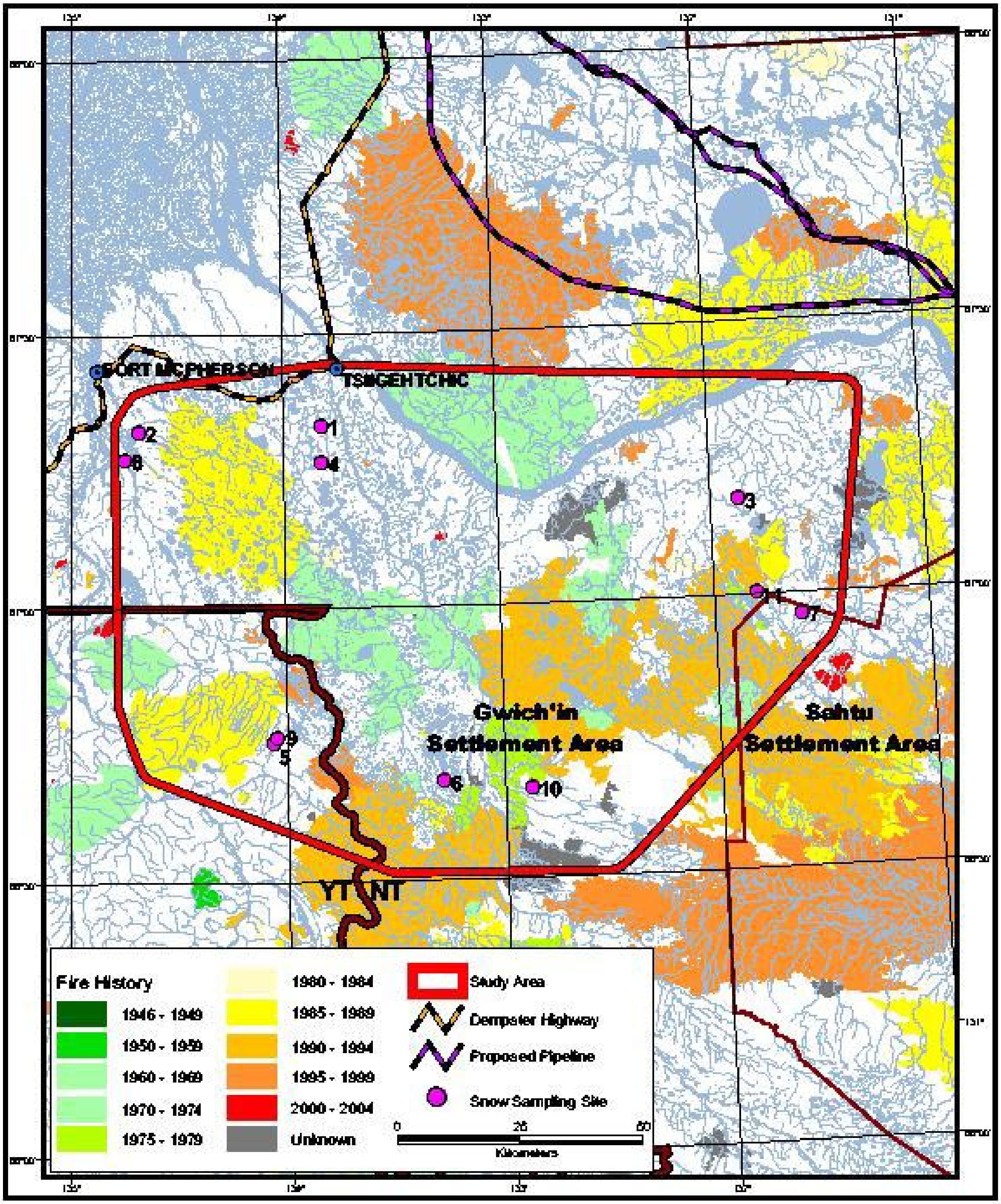


Table 18. Summary of snow depth measurements taken during April 2004.

Date	Site Location	Site	N	Mean (cm)	SE	95 Percent CI lower	95 Percent CI upper
8-Apr-04	adjacent to craters in forested area	1.b	5	89.2	4.6	76.4	101.9
		2	6	84.2	2.3	78.4	90.1
		3	5	72.6	3.7	62.3	83.0
		total	16	82.2	2.6	76.7	87.6
8-Apr-04	adjacent to trails	1.a	5	89.2	2.3	82.8	95.5
13-Apr-04	adjacent to craters along lake shore	4.a	5	59.2	0.9	56.8	61.6
		6.a	2	49.5	1.3	33.4	65.7
		total	7	56.4	1.9	51.8	61.1
13-Apr-04	adjacent to craters in forested area	4.c	10	82.0	2.9	75.6	88.5
		5.b	10	69.2	1.5	65.8	72.6
		6.b	10	69.5	3.1	62.5	76.4
		7	11	65.5	1.9	61.2	69.7
		total	41	71.4	1.5	68.3	74.5
13-Apr-04	adjacent to trails	4.b	4	86.4	4.0	73.6	99.1
		5.a	5	72.4	1.9	67.2	77.6
		total	9	78.6	3.1	71.4	85.8
30-Apr-04	adjacent to craters in non-forested area	10.a	10	38.9	2.4	33.4	44.3
		11.a	10	51.3	1.5	47.9	54.7
		total	20	45.1	2.0	40.9	49.9
30-Apr-04	adjacent to craters in forested area	8	10	59.4	1.7	55.7	63.2
		9	10	52.2	1.2	49.5	54.9
		10.b	10	47.2	1.8	43.1	51.4
		11.b	10	46.5	1.8	42.4	50.6
		total	40	51.3	1.1	49.0	53.7

Figure 25. Approximately 2.5 cm ice layer in snow along boreal woodland caribou trail in non-forested areas, 13 April 2004.

Figure 25. Hair loss resulting from boreal woodland caribou breaking through ice layer in snow in non-forested areas, 13 April 2004.

5.0 Discussion

5.1 Population Estimates, Productivity, Recruitment, Survival Rates, and Typical Group Size

Although we did not conduct surveys to estimate population numbers, we believe that there are conservatively between 150 and 200 boreal woodland caribou within the core study area giving a minimum density of approximately 1.1 to 1.5 caribou per 100 km^2. Although samples sizes of radio-collared cows were small in 2003 and 2004, calving rates and adult and calf survival rates appear to be similar to those reported in Cameron Hills area of the Deh Cho, Northwest Territories (D. Johnson, pers. comm.). Calving rates and adult and calf survival rates did not appear to be affected by the severe late winter conditions experienced by caribou in our study area during winter 2003-2004. Typical group sizes were comparable to those observed in the Cameron Hills area during most months between May and November (D. Johnson, pers. comm.), although late winter groups sizes (March) appeared to be larger in our study area. In March typical group size in our study area was 11.3 caribou while that for the South Slave study area was 8.2 (D. Johnson, pers. comm.). Late winter group size may be related to the distribution and availability of suitable habitat and snow depth.

5.2 Home Range Size, Seasonal Movement Rates, and Calving Dates

Although our sample size of satellite radio-collared caribou is small, preliminary results indicate that annual ranges of adult female boreal woodland caribou in our study are among the largest recorded within their range in Canada. The median home range size (100% MCP) for 13 adult female boreal woodland caribou in the Fort Smith Region was 574 km^2 (range 75 to 1235 km^2), although these may have been underestimated due to a low number of relocation per animal (D. Johnson, pers. comm.). Annual range sizes (100% MCP) for female boreal woodland caribou in five populations in central Saskatchewan ranged from 208-1240 km^2 (Rettie and Messier 2001). Boreal woodland caribou in the Lower Mackenzie River area are at the northern limit of their range in the NWT. The proximal distribution and relative availability high quality seasonal habitats may influence home range size. Approximately 43 percent of the core study area has been burned by wildfires since 1960, and approximately 16 percent of the area burned during 1990 to 1994. The total area burned is extensive in some portions of the core study area because burns of various ages abut each other. In comparison, approximately 16 percent of the core boreal woodland caribou study in the Cameron Hills, NWT (D. Johnson, pers. comm.) and approximately 21 percent of the boreal woodland caribou range in the Sahtu Region, NWT was burned during this time period (A. Veitch, pers. comm.). Caribou in our study area may have to travel greater distances to access seasonally important habitats than those in other areas of the NWT and southern Canada.

In the early morning, boreal woodland caribou in our study area appeared to be more active in summer then during fall, winter and spring. At mid-day and in the evening, they appeared to be more active in fall, winter, and spring. When movement rates were compared during the day, boreal woodland caribou in our study area appeared to be more active during the early morning and evening in summer and more active during mid-day in fall, winter, and spring. During summer, caribou may be more active in early morning when temperatures are cooler and insect harassment may be reduced. In fall, winter, and spring caribou were more active during mid day and evening indicating that they are diurnal during this period.

Although our size was small, calving dates appeared to be consistent with those reported for boreal woodland caribou in the Cameron Hills area (D. Johnson, pers. comm.). Calving sites of radio-collared caribou were dispersed throughout the core study area and were in a range of vegetation types including black spruce forests (closed and open), bog/fen complexes, and in open burns. Boreal woodland caribou in our study area do not appear to show fidelity to specific calving sites.

5.3 Characteristics of Sites Used by Boreal Woodland Caribou

Overall, our data suggest that boreal woodland caribou used areas further away from seismic lines and used areas with a lower density of seismic lines (within 432 m buffer around locations) than expected if site selection was random. Caribou also used areas within 400 m of seismic lines less than expected if site selection was random.

Caribou used areas that were further from seismic lines during the summer than during the fall, winter, and spring suggesting avoidance of seismic lines varied seasonally. Based on our observations we believe that wolf numbers were relatively low within the core study area. Moose occur in or adjacent to areas recently burned by wild fires throughout the core study area, but numbers are relatively low. The core study area falls between the winter ranges of the Porcupine barren-ground caribou herd to the west and that of the Cape Bathurst and Bluenose-West barren-ground caribou herds to the east. We believe that most of the wolves in the region maybe associated with these barren-ground caribou herds during winter, thus reducing predation risk for boreal woodland caribou in the core study area. Predation risk may be higher during summer when black bears are also active.

Boreal woodland caribou use of areas burned by wild fires varied during the year. Use of areas burned by wild fires was less than expected during winter and spring (December to May). Caribou appear to be more reliant on mature open black spruce and woodland needle leaf forests that offer terrestrial lichens and security and thermal cover during these periods. The energetic costs of cratering for terrestrial lichens may be lower in forested areas than in open areas where the snow cover is more likely to be modified by winds and daily temperature fluctuations. Use of areas burned by wild fires was greater than expected during summer and fall (June to November). Caribou may select open habitats during this period to access other high quality forage sources (herbaceous vegetation and shrubs), to avoid predators, for insect relief, or to rut.

5.4 Habitat Selection during Summer and Late Winter

Logistic regression analyses indicated that boreal woodland caribou in the core study area selected areas with closed spruce, open spruce, open mixed needle leaf, woodland needle leaf deciduous, and/or tall shrub earth cover types during late winter. They avoided areas with closed deciduous and low shrub earth cover, water, and/or areas with seismic lines during this time. Logistic regression models for summer did not yield a useful model. This may be due to the small sample size of caribou satellite locations available for this time period or caribou may use a broader range of habitat types during summer making it more difficult to assess selection and avoidance at the scale of our analyses (432 m buffer around caribou and random locations). These analyses will be re-run during winter 2004-2005 using smaller buffers around the caribou and random locations and using the caribou and random locations as point data. More detailed analyses of the caribou location data are required to define seasons.

5.5 Mapping the Relative Probability of Occurrence of Boreal Woodland Caribou at the Landscape Scale

Approximately 47 percent of the core study area and 32 percent of the Lower Mackenzie River/Peel Plateau area mapped by Ducks Unlimited was classified as high quality late winter habitat. Comparative data are not currently available for other portions of boreal woodland caribou range in the NWT. Our model indicates that high quality boreal woodland caribou late winter habitat extends in to the Yukon Territory south of the core study area. In addition, our model indicates that high quality boreal woodland caribou late winter habitat occurs in the area north of the core study area, and in particular along the proposed Mackenzie Valley Pipeline route. Based on sightings made during various surveys completed since April 2002, we know that boreal woodland caribou habitats north of the core study area, and in particular along the proposed Mackenzie Valley Pipeline route, are currently occupied. Additional work is required to verify if areas identified as high quality woodland caribou habitat south of the core study area in the Yukon Territory are occupied.

5.6 Critical Boreal Woodland Caribou Habitat

The distribution and relative abundance of boreal woodland caribou in an area may be limited by the proximal distribution, relative availability, and patch size of calving, summer and late winter habitats. During calving and summer these caribou are either solitary or occur in cow:calf pairs, or in small groups, and appear to use non-forested areas (bogs, fens, and open burns) that are in area that are distant from linear anthropogenic features. Caribou may select these areas to access higher quality forage, for insect relief, and to reduce predation risk, particularly for calves. In late winter these caribou occur in small groups, and appear to primarily use areas of mature open spruce and woodland needle leaf forests where terrestrial lichens are available. These typically occur in forested areas that have not been burned within the past 40-50 years by wildfires. Caribou in our study area did not appear to avoid seismic lines during this time period, however, this may be due to the apparent low number of predators in the area during late winter. Caribou may select these areas because terrestrial lichens are more accessible and for thermal cover. If distances between patches of late winter habitat are large, caribou may aggregate in larger groups or more groups may use available patches of these habitats during winter. This may lead to increased vulnerability to predators, harvesters, and impacts of development activity.

To ensure long-term survival of boreal woodland caribou in the NWT, the impacts of wildfires, timber harvesting, and other development activities (linear anthropogenic features resulting from oil and gas exploration) may need to be managed to ensure that areas of secure seasonally important habitats that are in relatively close proximity, are available within their current range.

6.0 Plans for 2005-2006

Complete analyses to develop resource selection function models for all caribou seasons. The satellite location data obtained during late winter 2004-2005 will be used to validate the existing late winter RSF model. A new late winter model will be generated if required.

Additional satellite collars (GPS and ARGOS) will be deployed in March 2005 to maintain the current sample size of 19 radio-collared adult female caribou (GPS, ARGOS, and VHF) within the core study area, and to deploy at least 6 satellite collars (GPS) in the area along the proposed Mackenzie Valley Pipeline route.

Work will continue to determine calving rates and calving times of radio-collared (GPS, ARGOS, and VHF) animals in the study area and to determine adult cow and calf survival rates and recruitment rates.

Work will be completed to design and test survey techniques that may provide reliable estimates of numbers of boreal woodland caribou within the core study area and adjacent areas.

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