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SHIFTS IN CARIBOU CALVING HABITAT AND SPACE-USE

By

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Thesis

presented in partial fulfillment of the requirements
for the degree of

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in Wildlife and Fisheries Biology

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FOREWORD

The thesis presented herein represents research conducted as part of a larger research effort in Newfoundland (i.e., the Caribou Strategy), which has been ongoing since 2008. The Caribou Strategy is a project funded by the Government of Newfoundland and Labrador's Department of Environment and Conservation, in conjunction with the Institute for Biodiversity, Ecosystem Science, and Sustainability, and involves multiple partners, research institutions, graduate students, and funders who are all collaborating to understand the causes of caribou decline in Newfoundland.

I present the thesis in the first person plural, as it is written and formatted as a manuscript that will be submitted for publication in the *Journal of Wildlife Management*, with the following coauthors: Daniella Dekelaita, Paul R. Krausman, and Shane P. Mahoney.

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SHIFTS IN CARIBOU CALVING HABITAT AND SPACE-USE

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ABSTRACT

The woodland caribou (*Rangifer tarandus caribou*) population in Newfoundland has been declining since the mid-1990s, and will likely continue to decline into the foreseeable future. This decrease in numbers has been accompanied by a large drop in recruitment. Predation is the primary cause of caribou calf mortality in Newfoundland, and since 2003, >80% of radio-collared calves died within the first 6 months of life. Two Newfoundland herds also have shifted their calving grounds over the past 15 to 20 years. Our objective was to investigate why these shifts have occurred. We analyzed female telemetry locations spanning 29 years, to delineate early-use (1980s and 1990s) and late-use (2003 and 2010) calving grounds, and to compare use and availability within and across these early- and late-use areas. We used a resource selection framework and evaluated shifts with respect to land-use, landcover, and NDVI over time. We found that females were not avoiding human disturbance or responding to climatic changes, but instead were changing selection choices. Models indicated that caribou were selecting for post-burn vegetation and more cover in late-use calving grounds. These results will likely help direct future research and management decisions to boost calving success in Newfoundland.

KEYWORDS

Calving grounds, caribou, Newfoundland, resource selection, shifts, space-use, telemetry

INTRODUCTION

The woodland caribou (*Rangifer tarandus caribou*) population in Newfoundland has declined since 1997, from 95,810 to 32,170 animals in 2008, and will likely continue to decline in the future with or without hunting pressure (Mahoney and Weir 2009). This population decrease can be attributed to a reduction in recruitment from 25-30% to <10% due to calf mortality from predation (Mahoney and Weir 2009). As a result of low recruitment, the population is aging, further lowering productivity. Additionally, antler size, adult jawbone length, and calf birth weights have decreased, signaling a decline in the overall health of the population (Forchhammer et al. 2001, Thomas and Barry 2005, Post and Forchhammer 2007, Gunn and Nixon 2008, Mahoney et al. 2011). Consequently, biologists in the Newfoundland and Labrador Department of Environment and Conservation (NLDEC) are working to minimize future population declines of caribou in Newfoundland. An effective management strategy will be necessary to prevent further reduction of this population, and biologists therefore need to identify and target the significant causes of decline.

Predation is the primary cause of caribou calf mortality in Newfoundland, and since 2003, 80% of radio-collared calves died within the first 6 months of life (Mahoney and Weir 2009). Reduced recruitment is an obvious factor linked to population decline, and predation is one proximate cause, but there are additional factors that may contribute to poor reproductive performance. Human disturbance from land-use associated with resource extraction and development may cause displacement and have negative impacts on calving, as animals may be driven into suboptimal habitat or exposed to greater predation risk (Cameron 1983, Schaefer and Mahoney 2007, Weir et al. 2007). Also, climatic variation may be causing changes in plant phenology that result in trophic mismatch, where peaks in calving are no longer coinciding with peaks in forage availability (Post and Forchhammer 2007). In effect, trophic mismatch or human disturbance, or both, could be leading to nutritional or other stress that diminishes health and recruitment.

Two herds in Newfoundland (Middle Ridge and La Poile) have also shifted their use of calving habitat (i.e., spatial area occupied during the calving season) over the past 29 years. These shifts in space-use imply changes in resource selection on multiple scales. We refer to the hierarchical orders of selection defined in Johnson (1980), where home range is identified as 2nd order selection, and site-level is identified as 3rd order selection. In this study, we restrict home range to the calving range, and consider changes in selection at the 2nd and 3rd order scales (Johnson 1980), alternately referred to as the broad and fine scales. At the broad scale, use is compared to availability across pre- and post-shift calving ranges. At the fine scale, use is analyzed within a single calving range.

There are discrepancies in the caribou literature as to the start and end dates of the calving season, as timing of parturition can vary (Bergerud 1975, Bergerud et al. 1984, Harrington and Veitch 1992, Schaefer et al. 2000, Weir et al. 2007). For the purposes of this study we will consider pre-calving (early-May to late-May; Harrington and Veitch 1992, Weir et al. 2007), calving (late-May to early-June; Bergerud 1975, Harrington and Veitch 1992, Schaefer et al. 2000) and post-calving (early-June to late-June; Harrington and Veitch 1992) as component parts of the calving season. While biologists do not know whether spatial shifts and decreases in calf survival are related, shifts are notable because caribou characteristically demonstrate strong site-fidelity to calving grounds (Bergerud et al. 1984, Brown et al. 1986, Schaefer et al. 2000, Ferguson and Elkie 2004, Wittmer et al. 2006). Shifts suggest that animals may be responding to changes on the landscape and may be selecting different resources than they did prior to shifts.

Landscape level changes that could affect space-use include cutblock expansion (i.e., expansion of logged areas; Schaefer and Mahoney 2007) and availability of nutrient-rich forage due to climatic variation (Post et al. 2008, Mahoney et al. 2011, Taillon et al. 2012). Changes in spatial use could also be the result of altered habitat use, or a change in resource preference (Johnson 1980, Nudds 1980, Mysterud and Ims 1998, Beyer et al. 2010) due to a change in habitat condition, like increased predation risk (Bergerud and Page 1987, Mahoney and Virgl

2003). For example, landcover is an especially important resource for calving females (Bergerud 1988, Bergerud 1996, Barten et al. 2001, Gustine et al. 2006), because females must make tradeoffs between hiding cover and forage quality to balance predation risk and nutritional intake (Bergerud et al. 1984, Ferguson et al. 1988, Bongi et al. 2008, Poole 2007, Parker et al. 2009). In this way, calving habitat likely influences the survival of young (Cameron 1983). As such, an increase in predation risk can lead to selection of more hiding cover and less availability of quality forage, causing shifts that in effect can be implicated in calving success. Identifying the factors precipitating shifts can, therefore, potentially shed light on the ultimate causes of caribou population decline in Newfoundland.

Our objective is to investigate why female caribou in the Middle Ridge and La Poile herds of Newfoundland shifted annual calving grounds between 1982 and 2010. To answer this question, we first define the term “annual calving ground,” as no universally accepted definition exists (Gunn and Miller 1986, Taillon et al. 2012). Shifts in calving grounds have been observed in barren-ground caribou across the circumpolar North, indicating that calving grounds are dynamic (Bergerud et al. 1984, Gunn and Miller 1986, Wittmer et al. 2006, Nagy et al. 2011, Taillon et al. 2012). An accurate definition must therefore capture the spatial variability of a calving ground, which Gunn and Miller (1986) achieved. They defined calving grounds as the overall area used annually by most calving females in a herd. This definition includes core and secondary calving areas. A core calving area supports the majority of females, and secondary areas support fewer females (Gunn and Miller 1986). For our study, we adopted this definition, but eliminated secondary calving areas from our analysis, as we wanted to examine shifts in the distribution of the majority of females within each study area. We refer to early-use core calving areas as traditional calving grounds, and late-use core calving areas as nontraditional calving grounds. A shift from traditional to nontraditional calving grounds has occurred if the distribution of parturient females shifts away from the center of a traditionally-used area for >1 year.

We have 3 hypotheses and associated predictions. First, animals are tracking changes in plant phenology across the landscape, resulting in shifts in space-use (H_1). Our assumption is that the normalized difference vegetation index (NDVI) can be used to ascertain changes in the timing of green-up (Pettorelli et al. 2005). We predict that if changes in plant phenology are inducing spatial shifts, NDVI values will be higher at used locations than random locations. Second, females are avoiding human disturbance (H_2). Our assumption is that cutovers (i.e., logged areas also referred to as cutblocks) are the only major disturbance feature in the study area (roads are also present, but are not considered here, as they are confounding with cutovers and are not dated). We predict that if females are abandoning traditional calving grounds to avoid human disturbance, females will exhibit strong avoidance of cutovers in resource selection analyses. Finally, females have altered their use of habitat (H_3). Our assumption is that selection of landcover characterizes habitat use for calving caribou. We predict that if altered habitat use is causing shifts, females will exhibit differences in landcover preference across traditional and nontraditional calving grounds.

STUDY AREA

Middle Ridge

The Middle Ridge study area (13,260 $km^{2)}$ is in east-central Newfoundland, Canada (47^{o}N, 53^{o}W; Fig. 1). Study area boundaries were based on known ranges of the herds, and were established prior to current telemetry data (C. Soulliere, NLDEC, personal communication). Within the area, caribou occupied approximately 9,800 km^2 in the late 1980s and early 1990s

(Mahoney et al. 2011). Other mammal species present in Middle Ridge include black bear (*Ursus americanus*), lynx *(Lynx canadensis)*, coyote (*Canis latrans*), little brown bat (*Myotis lucifugus*), Keen's bat (*Myotis keenii*), arctic hare (*Lepus arcticus*), snowshoe hare (*Lepus americanus*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), meadow vole (*Microtus pennsylvanicus*), river otter (*Lontra canadensis*), mink (*Neovison vison*), and pine marten (*Martes martes*). Major avian predators include bald eagles (*Haliaeetus leucocephalus*) and golden eagles (*Aquila chrysaetos*). Biting insects are common in spring and summer, and spruce budworm (*Choristoneura fuminferana*) infestations have also affected forest stands within the study area (Lavigne 2013).

Middle Ridge is characterized as maritime barrens, which is comprised of softwood forests and open landscapes featuring bog complexes with stunted tree growth, low-lying shrubs, mosses and lichen (Bell 2002, Mahoney et al. 2011). The dominant tree species is balsam fir (*Abies balsamea*), but fire generated stands of black spruce (*Picea mariana*), balsam fir, tamarack (*Larix laricina*), white birch (*Betula papyrifera*), shrubs, mosses and lichen also occur. Land-use in this area consists of logging, hunting, and recreation. The northern part of Middle Ridge has a high density of forest and has sustained industrial timber harvesting since the 1950s. As a result, cutovers are scattered throughout the north (Schaefer and Mahoney 2007), along with a network of logging roads. In 1986, a wildfire burned approximately 700 km^2 in what is now the nontraditional calving ground for the caribou herd (B. Slade, Newfoundland Helicopters, personal communication), which is west-centrally located in Middle Ridge.

In the south, the study area is bounded by the Atlantic Ocean. Elevations within the study area range from sea level to 250 m above sea level, and a mixture of sedimentary rock and granite define the terrain (Bell 2002). Erosion in upland areas has created a rugged, rocky landscape, while lowland areas have a less rocky topography (Bell 2002). The Atlantic Ocean and the North Atlantic Oscillation influence the climate in this area, with extended periods of fog, cool summers, and moderate winters that are more severe further inland (Bell 2002, Mahoney et al. 2011). Summers in this ecoregion are cool with a mean temperature of 5.5°C, and winters are generally moderate with a mean temperature of -1°C (Bell 2002). The area receives mean annual precipitation ranging from 1200 mm to over 1600 mm (Bell 2002).

La Poile

The La Poile study area (11,250 km$^{2)}$ in southwestern Newfoundland, Canada (48^{o}N, 58^{o}W; Fig. 2) occurs within the Long Range Mountains, but the southeastern edge extends into the maritime barrens ecoregion. The Long Range Mountains are part of Newfoundland's highland forests ecoregion, defined by lowland areas and upland areas that extend from the southwestern coast northward into the Northern Peninsula (Bell 2002, McGinley 2012). This ecoregion contains forest patches of stunted black spruce and balsam fir, mingled with shrub, moss, and dwarf kalmia (*Kalmia polifolia*) communities (McGinley 2012). Much of the spruce-fir forest in the study area was blighted by a spruce budworm outbreak in the 1970s and 1980s, and remnant stands are marked by dead standing and fallen wood (Thompson et al. 2003, Lavigne 2013). Vegetation on the barrens includes alpine azalea (*Loiseleuria procumbens*), diapensia (*Diapensia lapponica*), pink crowberry (*Empetrum eamesii*), and sheep laurel (*Kalmia angustifolia*; Mahoney et al. 2011). Exposed rocky areas at higher elevations contain mixed evergreen and deciduous shrub communities (Bell 2002). Elevation within the study area ranged from sea level to 815 m above sea level (Bell 2002). Summers in this ecoregion are cool with a mean temperature of 12^{o}C, and winters are cold and snowy, with a mean temperature of -4^{o}C

(Bell 2002). The area receives mean annual precipitation ranging from 1000 mm to 1400 mm (Bell 2002).

The study area supports the same host of species described for Middle Ridge. The range of the caribou herd in La Poile occupied 7,000 km^2 of the study area in the early 1990s, encompassing barrens, rocky areas, forested river valleys, and wetlands including bogs, fens, and ponds (Mahoney et al. 2011). In 1986, the Hope Brook gold mine, which measures about 2 km^2, was established in the southwestern corner of the study area, within the calving range of the herd (Weir et al. 2007). The mine remained in operation until 1991 (Weir et al. 2007). At present, land-use in the study area consists of hunting, recreation, and logging. Roads are not widely present throughout the study area, but flank the perimeter from the northeast to the northwest, and are most dense on the northwest side.

MATERIALS AND METHODS

Telemetry Data

The datasets were provided by NLDEC, and consist of very high frequency (VHF; Samuel and Fuller 1996, Schwartz and Arthur 1999), Argos Satellite (Argos; Fancy et al. 1988, Harris et al. 1990, Schwartz and Arthur 1999), and Global Positioning System (GPS; Rodgers et al. 1996, Schwartz and Arthur 1999) locations for collared females and calves from 1982 to 2010. For adult females in the Middle Ridge herd, VHF data were collected from 1982 to 1996, and GPS data were collected from 2009 to 2010. The VHF data were collected for calves from 1993 to 1997 and 2003 to 2010. For adult females in the La Poile herd, VHF data were collected from 1985 to 1990, ARGOS data were collected from 2005 to 2010, and GPS data were collected from 2007 to 2008. The VHF data were collected for calves from 2003 to 2010.

Adult female caribou and calves were captured by the Sustainable Development and Strategic Science Division (SDSS) and the Wildlife Division of the Government of Newfoundland and Labrador. In the 1980s and 1990s, females and calves were fitted with VHF transmitters from Lotek Engineering (Aurora, Ontario; models unknown) and Telonics (Mesa, Arizona; models unknown). In the 2000s, calves were fitted with the following VHF transmitters: Telemetry Solutions Model TS-37 (Telemetry Solutions, Concord, California), Lotek Model LMRT-3 (Lotek Wireless, Newmarket, Ontario), Advanced Telemetry Systems Model M4210 (Advanced Telemetry Systems, Isanti, Minnesota), and Sirtrack Model V5C181H (Sirtrack Limited, North Liberty, Iowa). Females were fitted with the following Argos collars: Telonics Model ST-20 ARGOS (Telonics, Mesa, Arizona), Lotek Model ArgosTrack (Lotek Wireless, Newmarket, Ontario, Canada), and the following GPS collars: Lotek Model GPS4400M (Lotek Wireless, Newmarket, Ontario, Canada), Lotek Model Iridium Track3D (Lotek Wireless, Newmarket, Ontario, Canada). Argos data were received through the ARGOS satellite system from Service Argos (Landover, Maryland), and GPS data were either downloaded through an ultra-high frequency (UHF; Schwartz and Arthur 1999) modem or received through the Iridium satellite system (Iridium Communications, McLean, Virginia). Argos and GPS location fixes were recorded at varying time intervals, with the most frequent observations recorded approximately every 2 hours throughout the calving period. Animals with VHF transmitters were monitored approximately every 2 weeks, with more frequent surveys of females in the summer (Schaefer and Mahoney 2007), and more frequent surveys of calves during the first few weeks after collaring (Lewis 2013). Locations were obtained at altitude via fixed-wing aircraft or helicopter (Mahoney and Schaefer 2002).

All animals were captured on Crown land under the management authority of NLDEC. Adult females were net-gunned or darted from helicopter, chemically immobilized, and collared on wintering grounds (Lewis 2013). Caribou calves were captured on foot and collared on calving grounds 1-5 days post-partum (Lewis 2013). Animals were sampled in open habitat, where visibility was high, using an opportunistic approach (1980s and 1990s), or stratified random sampling design (2000s). The Middle Ridge dataset contained 89 adult females and 75 calves with VHF transmitters for the 1980s and 1990s. For the 2000s, the dataset contained 24 adult females with GPS collars and 343 calves with VHF transmitters. The La Poile dataset contained 150 females and 79 calves with VHF transmitters for the 1980s and 1990s. For the 2000s, the dataset contained 22 adult females with Argos collars and 17 adult females with GPS collars. Accuracy for GPS locations ranges from 4 to 100 m (Schwartz and Arthur 1999), and is ≤1.5 km for Argos locations (Schwartz and Arthur 1999). Accuracy of VHF locations was determined to be ≤500 m, based on repeated blind-test positioning of VHF transmitters (Schaefer and Mahoney 2007).

Delineation of Calving Grounds

Using ArcGIS 10 (Environmental Systems Research Institute 2011, Redlands, California), we created a subset of points for the calving period by selecting all locations from May 1 to June 31. We then used ArcGIS 10 to produce kernel density home range estimates based on default settings for calculating bandwidth (i.e., shortest dimension of the input feature divided by 30). We compared these estimates to kernels generated in Geospatial Modelling Environment (GME; Beyer 2012), using plug-in, smoothed cross-validation, biased cross-validation, and least squares cross-validation algorithms to calculate bandwidths, and found that because we are estimating use intensity at the population level, the parameters applied in GME

(Beyer 2012) over-smoothed kernel boundaries and resulted in the inclusion of outliers that were disjointed from the whole and only representative of solitary animals. This test warranted using the default kernel estimates from ArcGIS 10 with the following bandwidths (*h*) for traditional and nontraditional calving grounds in Middle Ridge and La Poile respectively: $h = 3359.27$, $h = 3009.19$, $h = 3900.02$, and $h = 6198.37$.

To determine core-use annual calving grounds (Gunn and Miller 1986) for the 1980s, 1990s, and 2000s within the 2 study areas, we used 90% home range estimates to capture the majority of use per decade (Seaman and Powell 1996, Börger et al. 2006, Formica et al. 2010). Although 90-95% volume contours typically define an animal's home range, and 50-60% contours are used to define "core" areas (Seaman and Powell 1996, Börger et al. 2006, Formica et al. 2010), we used a 90% contour to identify "core-use" of the calving range, in keeping with the biological definition of a core calving ground as described by Gunn and Miller (1986; i.e., the area supporting the majority of females). All females in core calving grounds were assumed to be with calves or with parous females.

To derive kernel density estimates, we combined all data for all animals within a given decade, regardless of differences in telemetry type and error. We assumed the error associated with each of the telemetry technologies canceled out, given no directional bias in error (Visscher 2006; B. Steele, University of Montana, personal communication). In both study areas, we merged core calving grounds for the 1980s and 1990s, as kernel estimates revealed core-use remained consistent between the 2 decades. Ultimately, the analysis yielded 2 core calving grounds in each study area (Fig.1-2), which we identified as the traditional calving grounds (used from the 1980s through the 1990s) and the non-traditional calving grounds (used since the 2000s).

Resource Selection Modeling

We used a resource selection framework to test hypotheses at the broad and fine scales. In modeling resource selection, high accuracy data are critical for best results (Montgomery et al. 2011). To improve data quality, GPS points were discarded if <4 satellites were used for the fix, yielding data accurate to <10 m (Rempel and Rodgers 1997, Moen et al. 1997, Schwartz and Arthur 1999). Argos data were not used to analyze resource selection, as high quality Argos data has an accuracy within 250 m at best (Morehouse and Boyce 2013) and GPS data was available for the same time period. To account for the low accuracy of VHF locations ($\leq$500 m), we used a different method for processing location data, than that which was used for processing GPS locations (see section on testing hypotheses).

We eliminated all data points that fell outside of 90% kernel boundaries, so that datasets only represented individuals on the calving grounds during the calving season. To analyze resource selection, we used multiple logistic regression to fit the data and estimate the relative probability of use, using a use-availability design (Hosmer and Lemeshow 2000, Manly et al. 2002, Johnson et al. 2006). The resource selection function (RSF) defined by Manly et al. (2002) explains this modeling approach:

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n) \qquad \text{(eq. 1)}$$

where $w(x)$ is the predicted relative probability, $\beta_1 ... \beta_n$ are parameter estimates, and $x_1 \ldots x_n$ are parameter values. For all datasets, used and available points were differentiated by a “use” category, where available points were coded with a value of “0” and used points were coded with a value of “1” to enable multiple logistic regression analysis (Hosmer and Lemeshow 2000). We adopted the separate samples of available and used units design proposed by Manly et al. (2002:99-102) for modeling the relative probability of use. To account for auto-correlation in GPS data, and specify individual animals as the appropriate sample unit (Gillies et al. 2006), we used a mixed-effects model adapted from eq. 1, correcting for disproportionate sampling and individual variance (Skrondal and Rabe-Hesketh 2004):

$$Logit(Y_{ij}) = \beta_{0j} + \beta_1 x_{ij} + .. + \beta_n x_{ij} + \gamma_{0j} + \varepsilon_{ij} \qquad \text{(eq. 2)}$$

where $\gamma_{0j} + \varepsilon_{ij}$ is a random intercept and random effect for each individual j (group of used and available points for a given individual) and every location i.

We generated random points in ArcGIS 10 to account for available sites, matching VHF data with a random sample 10 times greater than the number of used points (Johnson et al. 2004, Buskirk and Millspaugh 2006), and matching GPS data with random samples 5 times greater than the number of used points (Cooper and Millspaugh 1999). The VHF datasets consist of only several hundred used points, and therefore a larger multiplier is needed to provide an accurate representation of the landscape (Buskirk and Millspaugh 2006).

To analyze resource selection across traditional and nontraditional calving grounds, and examine if shifts were the result of caribou selecting different resources at the broad scale, we generated a single set of random points within the boundaries of the traditional and non-traditional calving grounds, and compared separately to the 1980s and 1990s dataset, and the 2000s dataset. To analyze resource selection within traditional and nontraditional calving grounds, and examine if resource preference had changed at the fine scale between the 2 calving grounds, 2 sets of random points were created. One random set was distributed throughout the traditional calving ground, and compared only to the 1980s and 1990s data. The other random set was distributed throughout the nontraditional calving ground, and compared only to the data from the 2000s.

Covariates: NDVI, Landcover, and Burn

The NDVI data were collected with the Advanced Very High Resolution Radiometer (AVHRR) instrument on board National Oceanic and Atmospheric Administration (NOAA) weather satellites, and were produced by the Canada Centre for Remote Sensing (Latifovic et al. 2005). These data are part of the AVHRR time-series from 1985 to present, which consists of 10-day composites at a resolution of 1 km (Latifovic et al. 2005).

We used a landcover data layer based on Earth Observing System Data (EOSD) from the National Aeronautics and Space Administration (NASA), to extract landcover values in ArcGIS 10. The EOSD-based layer was compiled circa 2000 and has a resolution of 25m by 25m and an accuracy rating of 41% (Wulder et al. 2007). The layer contains multiple landcover classifications, which we reduced to 5 covariates (Table 1), increasing accuracy to >41% (Hosmer and Lemeshow 2000). Classifications were combined based on common features we deemed qualitatively comparable for this study. Resultant covariates included forest, nonvegetated land, shrubland, wetland, and water. In the Middle Ridge study area, we included burn as an additional covariate.

To classify burn and create a burn layer for the 1986 wildfire in Middle Ridge, we manually interpreted NDVI data from 1987 using supervised classification (Horning et al. 2010), and digitized a wildfire footprint in ArcGIS 10. ‘Training areas’ (Horning et al. 2010) were defined using fire delineations of documented fires (provided by the Canadian Forest Service) that occurred on the edges of the nontraditional calving ground in 1986. The delineations were projected against the NDVI composite from 1-10 June 1987, to identify NDVI values associated with post-fire plant growth. All pixels in the nontraditional calving ground having values within the range of those in the training areas were then selected and classified as “burn,” yielding a wildfire footprint, or burn layer. The burn class has an accuracy of 90%, as evidenced by ground-truthed locations surveyed in the summer of 2012 (D. Dekelaita, unpublished data).

Testing Hypotheses

To test whether changes in phenology induced shifts in space-use (H_1), used locations were categorized by date and divided into subsets matching the 10-day composite intervals for NDVI. Random points were proportionately allocated to each subset according to the number of used points in the subset. For GPS data, we extracted NDVI values to used and available points in ArcGIS 10, using the appropriate 10-day composite for each subset. For VHF data, we calculated NDVI values for used and available points by averaging NDVI values within a 500 m buffer around each point in ArcGIS 10. We then removed the date designations and constructed boxplots to compare used and available values overall in Program R (R; R Core Team 2013, Vienna, Austria), visualizing selection of NDVI values at the broad and fine scales for the 1980s and 1990s (VHF data) and the 2000s (GPS data). Differences between the distributions of used and available values would indicate the extent to which NDVI could help explain variance in the data, and whether to include NDVI as a covariate in RSF models to further test the hypothesis.

To test H_2 (i.e., avoidance of cutovers) and H_3 (i.e., altered habitat use), VHF and GPS data were processed differently, using either of 2 techniques to obtain covariate values for landcover in ArcGIS 10 (cutover was treated as a landcover type). The first technique calculates the proportion of landcover within an area around a point, which we applied to VHF data. The second technique involves direct data extraction, which was applied to GPS data.

We employed the first technique to account for error in VHF datasets for the 1980s and 1990s. Used and available points were buffered with the error radius of 500 m. The area of each landcover type within a single buffer was then calculated and divided by the total area of the buffer, yielding proportionate values of landcover. These values can be regarded as weights reflecting the abundance of each landcover type associated with the area around a given point or location. In this way, landcover was modeled as a continuous variable, but because the values were derived based on their relationships to each other, there was an inherent dependence on 1, or a unit constraint among the covariates (Aebischer et al. 1993). To remove the unit constraint, water was eliminated as a model covariate (B. Steele, University of Montana, personal communication), as water is a ubiquitous feature on the landscape in Newfoundland, and is likely insignificant in terms of selection because it is so pervasive. Moreover, there is likely strong collinearity between water and wetland features, which would further complicate the analysis (Hosmer and Lemeshow 2000). We tested this method for obtaining landcover values by randomly repositioning each data point to within 500 m in GME (Beyer 2012). By simulating error in a known dataset and reevaluating selection based on use and availability, we affirmed our results and confirmed the legitimacy of this method.

The second technique was employed for analyzing GPS locations in the 2000s. Given the high accuracy of these locations (Montgomery et al. 2011), landcover type was extracted directly to used and available points in ArcGIS 10. In this way, each point was associated with a single landcover type, and landcover was modeled as a categorical variable. Water was designated as the reference category in these models for reasons described above. Calf locations for the 2000s were not analyzed, due to the low accuracy of VHF data.

To isolate effects of the 1986 wildfire in Middle Ridge, we separated data into preburn and postburn subsets, where preburn locations occurred in 1986 or prior, and postburn locations occurred after 1986. To isolate the effects of cutovers in Middle Ridge, we further subsetted points that were in or within 500 m of a cutover. The effects of cutovers were analyzed separately by pooling years with greater than 100 observations, matched with random points accordingly. To account for an expanding cutover footprint on the landscape, we created unique landcover layers for each year in ArcGIS 10. Cutovers that were coincident with a given year, were assumed to have occurred after the calving season and were not represented in the layer for that year. For the Middle Ridge analysis, separate model sets were fitted for preburn and postburn data, with and without cutovers. Burn was incorporated into the analysis as a landcover type in the 1980s and 1990s, but treated as an additional feature, separate from landcover, in the 2000s. This difference is a function of the different techniques used for processing VHF and GPS data.

Model Selection and Fit Testing

To determine the best predictive covariates, we developed different a-priori candidate model sets (Burnham and Anderson 2010), incorporating different covariate combinations for analyses at the broad and fine scales. Model sets varied with respect to the presence of burned vegetation and cutovers on the landscape. Models were fit using R (R Core Team 2013, Vienna, Austria). We compared models using second-order Akaike information criterion (AICc; Akaike 1973, Hurvich and Tsai 1989), and determined the top models based on Akaike (AICc) weights and ΔAICc scores (Burnham and Anderson 2010). To calculate scores and select top models, we used the “AICcmodavg” package in R (Mazerolle 2013; R Core Team 2013, Vienna, Austria). In cases where >1 model was supported, model-averaged estimates were calculated for all parameters (Burnham and Anderson 2002, 2010). We interpreted models with ΔAICc scores ≤ 2 to be strongly supported, and scores >2 but ≤ 7 to be weakly supported (Burnham and Anderson 2010). Models with the highest AICc weights (Burnham and Anderson 2010, Anderson 2010) were selected for model averaging.

To test model performance, we used *k*-fold cross validation and partitioned each of the datasets into random subsets ranging from 3 to 5 (*k* = 3, 4, or 5) depending on sample size, and evaluated probability of occurrence for top RSFs (Boyce et al. 2002, Pearce and Boyce 2006). We used the "kxv" module in R (Brzustowksi 2005; R Core Team 2013, Vienna, Austria) to cross-validate the models and bin results into 4, 5, 6, or 10 categories of RSF scores (binned RSF scores; Boyce et al. 2002, Pearce and Boyce 2006). We created graphs of the area-adjusted frequency of occurrence compared to binned RSF scores and calculated Spearman-rank correlations for the best models (Boyce et al 2002). Models with high correlations (i.e., rho values that approach 1) displayed goodness-of-fit and were identified as having strong predictive capabilities.

RESULTS

NDVI Analysis

In testing H_1 (i.e., climatic changes inducing shifts in space-use), boxplots indicated no significant difference between used and available values in broad and fine scale analyses for traditional and nontraditional calving grounds in both study areas (Fig. 3-4). Consequently, we concluded that changes in plant phenology were not causing shifts, as plant productivity appeared consistent throughout traditional and nontraditional calving grounds in both study areas, over the entire study period; NDVI was therefore not included as a covariate in resource selection models for Middle Ridge or La Poile.

Middle Ridge Resource Selection Analysis for H_2 and H_3

In Middle Ridge, for the 1980s and 1990s, the dataset comprises 1,113 adult female and calf VHF locations. The dataset consists of 74 preburn locations and 1,039 postburn locations. Of the postburn locations, 151 occurred in or near cutovers ($\leq$500 m), yielding 888 postburn locations >500 m from cutovers. For the preburn analysis, we generated 740 random points to quantify available landcover, and for the postburn analysis, we generated 8880 random points. To analyze the effects of cutovers, we used years with $\geq$100 observations, which included 1988 (*n* = 143), 1989 (*n* = 133), 1993 (*n* = 110), 1994 (*n* = 130), 1995 (*n* = 157), and 1996 (*n*=137), and created random points accordingly. For the 2000s (2009 and 2010), the dataset comprises 14,579 female GPS locations.

In so far as evaluating resource selection, there was not enough data to analyze cutover effects in preburn years, and there were no cutovers in the nontraditional calving ground. As such, cutover was not a covariate in preburn models, and was not a covariate in models analyzing broad and fine scale selection in the nontraditional calving ground. Preburn analysis in the traditional calving ground yielded 2 model sets (Table 2A -2B). Postburn models analyzing broad and fine scale selection in the traditional calving ground were fit with and without cutovers, yielding 4 model sets (Table 3A-3D). The analysis for the 2000s (selection in the nontraditional calving ground) only required 2 model sets (Table 4A-4B).

Each model set contained 10 apriori models. In model sets where >1 model was supported, parameter values were averaged over all models within the set. The 95% confidence intervals for the preburn analysis are large (Table 2A-2B), due to a small sample size. Therefore, if the distribution for a given parameter includes 0, but appears skewed to the left or right, we concluded there was weak support for the parameter. In the preburn analysis, caribou strongly preferred wetland (β = 6.44, SE = 2.1) and avoided nonvegetated land (β = -8.86, SE = 3.36) on the broad scale (Table 5A). There is weak evidence that caribou were also selecting shrubland (β = 7.16, SE = 4.87) and forest (β = 2.64, SE = 1.74; Table 5A). At the fine scale, there is strong evidence that caribou favored wetland (β = 6.54, SE = 2.2; Table 5B), and moderate evidence that caribou were selecting forest (β = 3.18, SE = 1.62; Table 5B). There is weak support suggesting that caribou also favored shrubland (β = 6.3, SE = 4.61) and were avoiding nonvegetated land (β = -5.2, SE = 3.18; Table 5B).

In the postburn analysis without cutovers, caribou were strongly selecting wetland (β = 4.15, SE = 0.49), followed by forest (β = 1.31, SE = 0.33), then burn (β = 0.82, SE = 0.34) on the broad scale (Table 6A). Similarly, on the fine scale, caribou strongly preferred wetland (β = 3.38, SE = 0.5), but had a higher preference for burn (β = 1.21, SE = 0.36) than forest (β = 0.96, SE = 0.33; Table 6B). In both broad and fine scale analyses, caribou avoided nonvegetated land (β = -2.81, SE = 1.22; β = -2.44, SE = 1.17) and shrubland did not appear to be statistically significant (β = 0.45, SE = 1.3; β = -0.68, SE = 1.31; Table 6A-6B). In the postburn analysis with cutovers, caribou most strongly preferred wetland (β=3.21, SE=0.52), followed by cutover (β=2.04, SE=0.71), forest (β=1.61, SE=0.34), then burn (β = 0.88, SE = 0.36), on the broad scale (Table 7A). Caribou preferred the same landcover types on the fine scale: wetland (β = 2.59, SE = 0.53), forest (β = 1.09, SE = 0.34), burn (β = 1.17, SE = 0.36), with the exception of cutover, which was not significant (β = 1.13, SE = 0.71; Table 7B). Nonvegetated land and shrubland were not significant in both broad and fine scale analyses (Table 7A-7B).

In the data-analysis for the 2000s, the global model was exclusively supported in both model sets (Table 4A-4B). Mixed effects models revealed negligible variance around the random intercepts at the broad and fine scales (Table 8A-8B), indicating little to no heterogeneity across individuals. At the broad scale, caribou strongly preferred burn ($\beta = 3.55$, SE = 0.04), and of burned or unburned vegetation, caribou selected in order of preference nonvegetated land ($\beta = -0.66$, SE = 0.07), wetland ($\beta = -0.69$, SE = 0.07), shrubland ($\beta = -0.95$, SE = 0.08), and forest ($\beta = -1.31$, SE = 0.07; Table 8A). Selection was similar at the fine scale, but caribou preferred wetland slightly over nonvegetated land (Table 8B).

Most preburn and postburn models for the 1980s and 1990s had high Spearman-rank correlation scores ($\rho>0.8$; Table 13A) and low P-values ($P<0.05$; Table 13A), except for the fine scale postburn models without cutover, which did not predict well ($\rho\leq0.5$; Table 13A). The global model for the 2000s, broad scale analysis, was robust to cross-validation ($\rho = 0.92$; Table 13B), but had a high P-value ($P = 0.072$; Table 13B). The global model for the 2000s, fine scale analysis, was not as robust to cross-validation ($\rho = 0.73$; Table 13B), and had a high P-value ($P = 0.21$; Table 13B) as well.

La Poile Resource Selection Analysis for H_2 and H_3

In La Poile, for the 1980s and 1990s, the dataset comprises 538 adult female and calf VHF locations. For the 2000s (2007-2009), the dataset comprises 19,750 female GPS locations. The analysis yielded 4 model sets, each containing 10 apriori models. In the 1980s and 1990s, multiple models were supported and parameter values were averaged (Table 9A-9B; Table 10A-10B). In the 2000s, the global model was exclusively supported in each model set (Table 11A-11B), and results from the global mixed-effects models are provided (Table 12A-12B). Cutovers are only present in the nontraditional calving ground, and are therefore only included in analyses for the 2000s.

In the 1980s and 1990s, caribou selected wetland (β = 8.82, SE = 0.73) and avoided nonvegetated land (β = -2.55, SE = 0.53) at the broad scale, and forest and shrubland were insignificant (Table 10A). At the fine scale, caribou favored shrubland (β= 4.36, SE=0.84), followed by wetland (β = 3.84, SE = 0.84), then forest (β = 1.04, SE = 0.36), and nonvegetated land was insignificant (β = -0.45, SE=0.71; Table 10B). For the analysis in the 2000s, variance was negligible around the random intercepts, and results matched at both broad and fine scales. Caribou preferred shrubland (β = 1.05, SE = 0.04; β = 1.04, SE = 0.04), but selected nonvegetated land almost as strongly (β = 1.04, SE = 0.04; β = 0.97, SE = 0.04), and selected wetland and forest less strongly; cutover was insignificant (Table 12A-12B).

All but 1 of the top models for the 1980s and 1990s had high Spearman-rank correlation scores ($\rho \geq 0.8$; Table 14A) and low *P*-values ($P<0.05$; Table 14A), indicating strong predictive power. The global model for the 2000s, broad scale analysis, did not predict well ($\rho = 0.57$; Table 14B). The global model for the 2000s, fine scale analysis, was robust to cross-validation ($\rho = 0.9$; Table 14B), but had a high *P*-value ($P=0.21$; Table 14B).

DISCUSSION

Prior to the 1986 wildfire in Middle Ridge, females were primarily selecting wetland and secondarily selecting forest, which is consistent with findings from studies by Mahoney and Schaefer (2002) and Schaefer and Mahoney (2007), in Middle Ridge and on the nearby Buchans Plateau in Newfoundland. Female caribou have been observed calving in open areas with scattered forests, which dually provides visibility and nearby escape cover to minimize predation risk (Mahoney and Schaefer 2002, Schaefer and Mahoney 2007). Postburn analyses indicate that females continued selecting wetland and forest after the fire, but postburn vegetation was most important. Fire has been linked to improved forage quality over the long-term (>50 years) in many studies (Klein 1982, Schaefer and Pruitt 1991, Thomas et al. 1996, Collins et al. 2010), and other research indicates that recent burns are detrimental to caribou in terms of limiting forage availability and increasing predation risk (Joly et al. 2003, Rupp et al. 2006, Robinson et al.2010), but there is little research to suggest short-term (<50 years) benefits of fire (Thomas et al. 1996, Dunford et al. 2006). Early to intermediate succession vegetation, however, is typically higher in nutrition than mature forage (Eastland et al. 1989, Post et al. 2003, Street et al. 2013), and parturient females in Middle Ridge are likely selecting post-burn vegetation for this reason.

Cutovers were insignificant at the fine scale, but appear slightly selected at the broad scale, which is likely due to the lack of cutovers in the nontraditional calving ground. There is some disagreement as to whether calving females avoid timber harvesting and if they are negatively affected by such anthropogenic disturbance (Schaefer and Mahoney 2007, DeCesare 2012, Dussault et al. 2012, Hébert 2012, Leclerc et al. 2012). The evidence to support the use of cutovers in this study is not overwhelming, and the slight bias could be a function of limited availability of cutovers in the traditional calving ground, and lack of availability in the nontraditional calving ground.

In the nontraditional calving ground, caribou showed very strong preference for postburn vegetation. Of burned vegetation, wetland and nonvegetated land were the strongest predictors of use, followed by shrubland and forest. According to the EOSD landcover classification key (Table1), nonvegetated land consists of <5% vegetation. The EOSD landcover layer used in this analysis, however, has recently been reclassified by NLDEC biologists, and discrepancies exist between the 2 layers. Seventy -three percent of the nonvegetated land in the nontraditional calving ground was reclassified as wetland, 16% was reclassified as shrubland, and <6% was reclassified as developed or rocky and barren. The reclassified layer is more precise than the original, but has not yet been finalized and assessed for accuracy (K. Lewis, personal communication, NLDEC). As such, we need to better understand the accuracy of nonvegetated land, before it can be regarded as a predictor of use. We therefore conclude that in the traditional calving ground, caribou are selecting postburn vegetation and are most strongly selecting wetland, followed by shrubland, then forest. Shrubland may be favored over forest following a fire, as shrubland may offer better foraging opportunities (Bergerud 1971, Schaefer and Pruitt 1991).

In La Poile, caribou showed strong selection for shrubland and wetland, and weaker selection for forest at the fine scale in the traditional calving ground. In the nontraditional calving ground, at the fine scale, caribou showed strong preference for shrubland, nonvegetated land, and wetland, and weaker preference for forest. Fifty percent of nonvegetated land in the nontraditional calving ground was reclassified as wetland, 24% was reclassified as shrubland, and 22% was reclassified as rocky and barren, however. As such, results for nonvegetated land can corroborate selection of wetland and shrubland, but until we know more about the accuracy of the nonvegetated land classification, it should not be used as a predictor of use. Resource use therefore appears to be the same in both traditional and nontraditional calving grounds.

At the broad scale, in the traditional calving ground, wetlands were a strong predictor of use, and shrubland and forest are insignificant, likely because wetlands were more abundant in the traditional calving ground than in the nontraditional calving ground, and shrublands and forests were more abundant in the nontraditional calving ground. At the broad scale, in the nontraditional calving ground, shrubland and nonvegetated land are strong predictors of use, and wetland and forest are weaker predictors. Based on these results, with the omission of nonvegetated land, caribou appear to have moved from an area with more wetland to an area with more shrubland. As such, while caribou still exhibit the same resource preferences at the fine scale, the shift from traditional to nontraditional calving ground in La Poile may be due to caribou selecting for more cover on the landscape in response to some unknown change in their environment (e.g. increased predation risk).

In effect, results from this study provide evidence countering our first 2 hypotheses, which state that climatic changes or anthropogenic activity are causing shifts. Conversely, evidence supports our third hypothesis, which states that shifts are the result of females altering their resource preferences. The shift in calving grounds in Middle Ridge appears to be the result of a change in resource availability as a result of fire, which has allowed caribou to select a resource that was not previously available. In La Poile, the cause is not as clear, but evidence suggests that resource preference may have changed on the broad scale, which begs the question: Why?

Both herds have undergone declines since the mid-1990s (Fig. 5), which seem to reflect a classic trend in population cycles exhibited by caribou, and can be described as a density-dependent response (Gunn 2003). Density-dependence was not a consideration in this study, but there is a possibility that shifts coincided with the population peaks and subsequent declines experienced in the mid-1990s (Fig. 5). Particularly in La Poile, where the population appeared to stabilize then falter (1985 to 1996), caribou may have been experiencing density-dependent competition (Bergerud 1971). In effect, females may have moved from their traditional calving range as a result of degraded forage quality from overgrazing (Bergerud 1996). If females in La Poile appear to be preferring a different resource at the larger scale, but selecting for the same resources at the fine scale, perhaps females are selecting suboptimal habitat in search of better foraging opportunities, which by extension, could be further suppressing population growth.

Increased predation risk is also proposed as a possible factor influencing the shift in La Poile, as caribou are likely to avoid high risk areas (Mahoney and Virgl 2003, Robinson et al. 2012). Instances of habitat avoided by caribou include burns and cutovers, where early-seral stage growth attracts predators seeking alternate prey species (e.g., moose) and high quality forage in the case of bears (Mahoney and Virgl 2003, Robinson et al. 2012). Hence, the spruce budworm outbreak of the 1970s and 1980s (Lavigne 2013), which led to widespread forest regeneration, might have increased predator densities, prompting caribou to shift their distribution and perhaps select for more hiding cover at the coarse scale, to reduce predation risk (Mahoney and Virgl 2003).

In contrast, however, the sudden population peak and sharp decline in the mid-1990s in Middle Ridge seem to coincide with the shift to nontraditional calving ground, where post-burn growth is abundant and significant bear activity has been observed (T. Porter, NLDEC, personal communication). As such, the nontraditional calving ground in Middle Ridge may serve as something of an ecological trap (Schlaepfer et al. 2002) for caribou, who may be lured there for better foraging opportunities, trading-off the safety of their young. Caribou, like many ungulates, typically demonstrate vigilance and predator avoidance, especially during parturition (Zwank et al. 1979, Bergerud et al. 1984, Fox and Krausman 1994, Bowyer et al. 1999, Barten et al. 2001), but given the choice of optimal and abundant forage, ungulates may expose themselves to higher predation risk, as evidenced by white-tailed deer (*Odocoileus virginianus*) selecting preferred vegetation in the clearing of a cutover (Williamson and Hearth 1985).

MANAGEMENT IMPLICATIONS

Internal government documents from Newfoundland indicate that the Middle Ridge and La Poile caribou herds occupied traditional calving grounds as of the 1950s and 1960s, establishing a period of use spanning approximately 40 years (NLDEC, unpublished data). Caribou commonly exhibit strong site fidelity to calving grounds (Bergerud et al. 1984, Brown et al. 1986, Schaefer et al. 2000, Ferguson and Elkie 2004, Wittmer et al. 2006), but many studies also show that calving grounds are dynamic (Bergerud et al. 1984, Gunn and Miller 1986, Wittmer et al. 2006, Nagy et al. 2011, Taillon et al. 2012). The sudden shift in space-use patterns may seem innocuous at first glance, but coupled with population declines in Newfoundland, these shifts raise some concern. The findings presented herein suggest there have been changes in the environment that have caused caribou to alter resource preferences, resulting in spatial shifts. Shifts appear to coincide with population declines that began in the mid-1990s, which are the direct result of calf mortality from predation. Based on our results, we offer ideas as to how declines may be related to shifts, including density-dependent competition (Bergerud 1971), increased predation risk (Mahoney and Virgl 2003, Robinson et al. 2012), and ecological entrapment (Schlaepfer et al. 2002).

This study provides tentative answers given the available data. If shifts are a way for animals to cope with changing circumstances in their environment, the question remains, why is the population not rebounding? Alternately, what are the factors that continue to suppress population growth? As a next step to this research, we recommend studying forage quality to determine how this factor may be influencing population dynamics and spatial trends. Perhaps controlled burning can be a tool for improving forage quality on the calving range to boost calving success, provided it can be applied in a manner that would not increase predation risk.

Furthermore, if degraded forage quality can be implicated in calving ground shifts, land managers will be wise to anticipate changes in space-use when population health appears to be declining. In addition, given the apparently dynamic nature of calving grounds, we would recommend protecting large expanses of land to accommodate periodic shifts by calving caribou and safeguard their future in this system.

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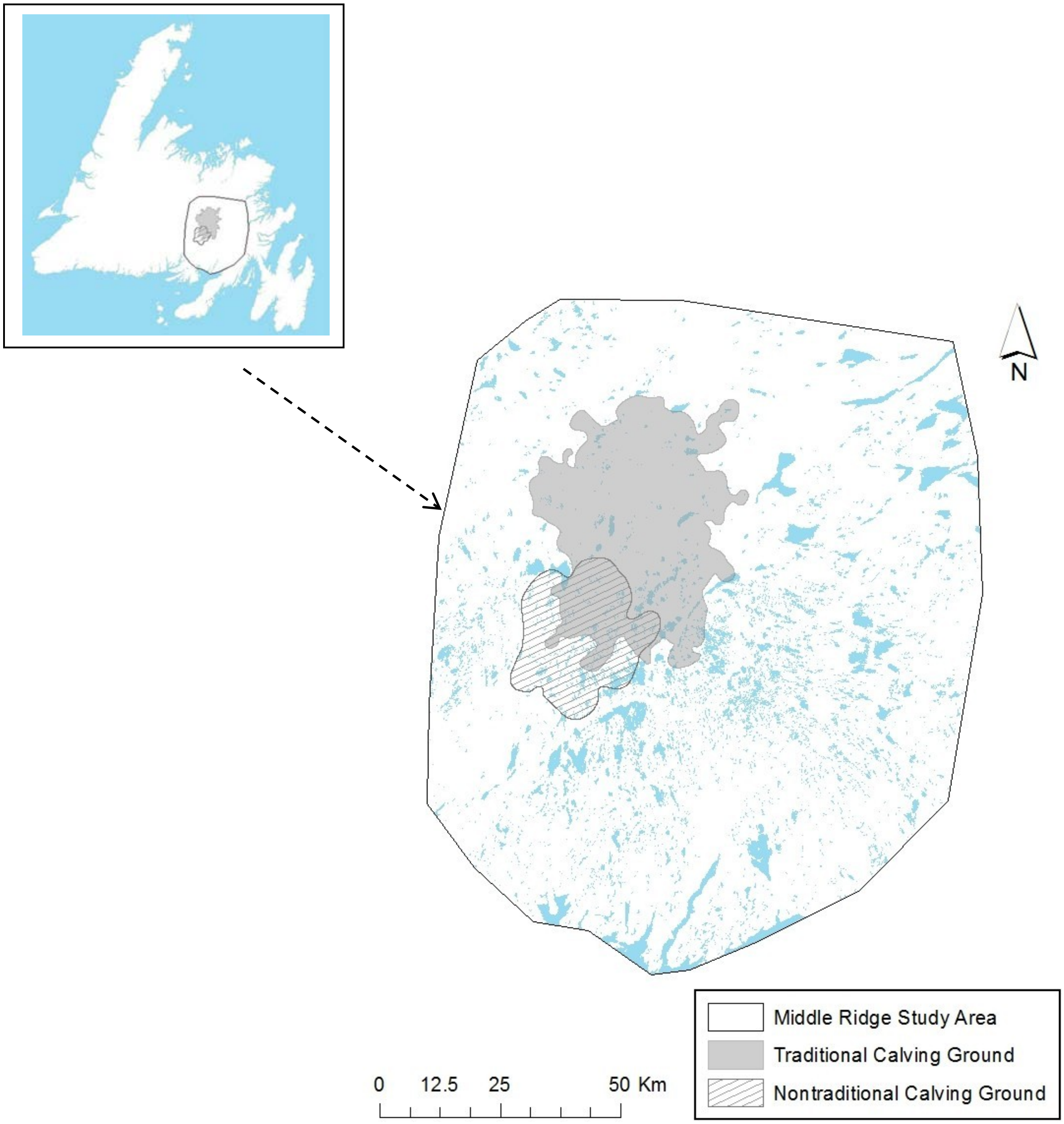

FIGURE 1. Ninety-percent kernel density estimates delineating core-use of female woodland caribou during the calving season in the 1980s and 1990s (traditional calving ground) and 2000s (nontraditional calving ground), Middle Ridge study area, Newfoundland, Canada.

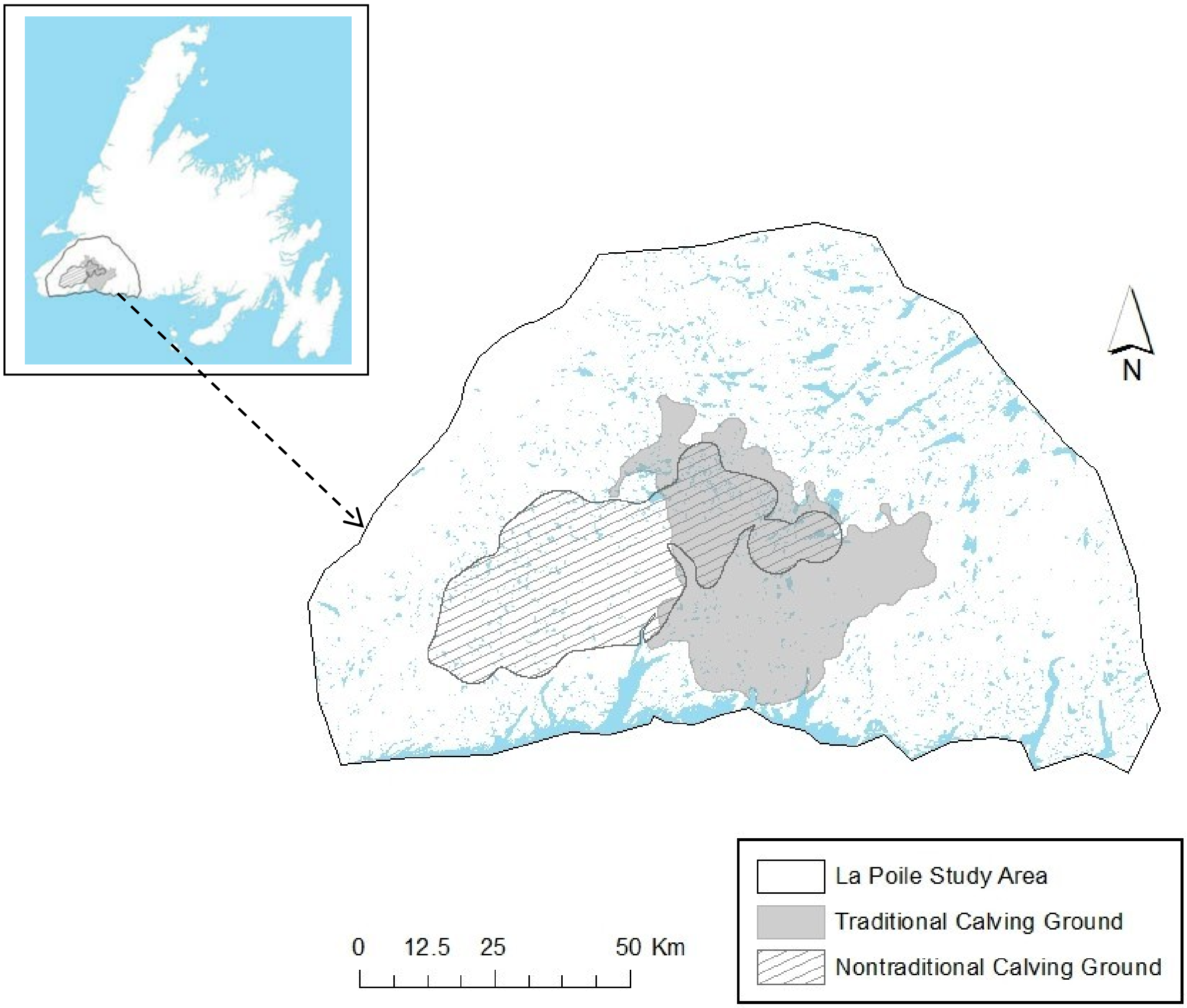

FIGURE 2. Ninety-percent kernel density estimates delineating core-use of female woodland caribou during the calving season in the 1980s and 1990s (traditional calving ground) and 2000s (nontraditional calving ground), La Poile study area, Newfoundland, Canada.

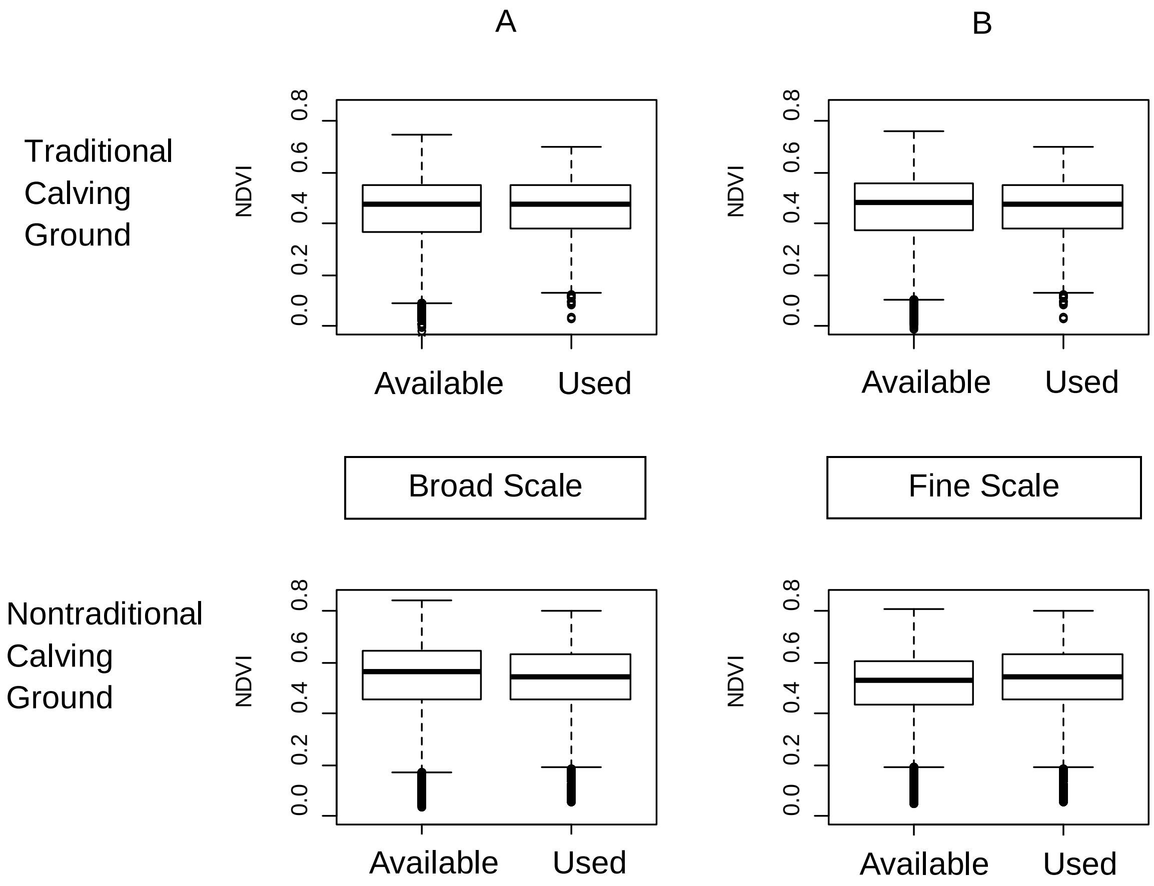

FIGURE 3. Boxplots comparing used and available NDVI values at the broad scale (column A) and fine scale (column B) in the traditional calving ground (top row), and the nontraditional calving ground (bottom row), for female woodland caribou in the Middle Ridge study area, Newfoundland, Canada. Values appear on the y-axis, and are designated as available and used on the x-axis.

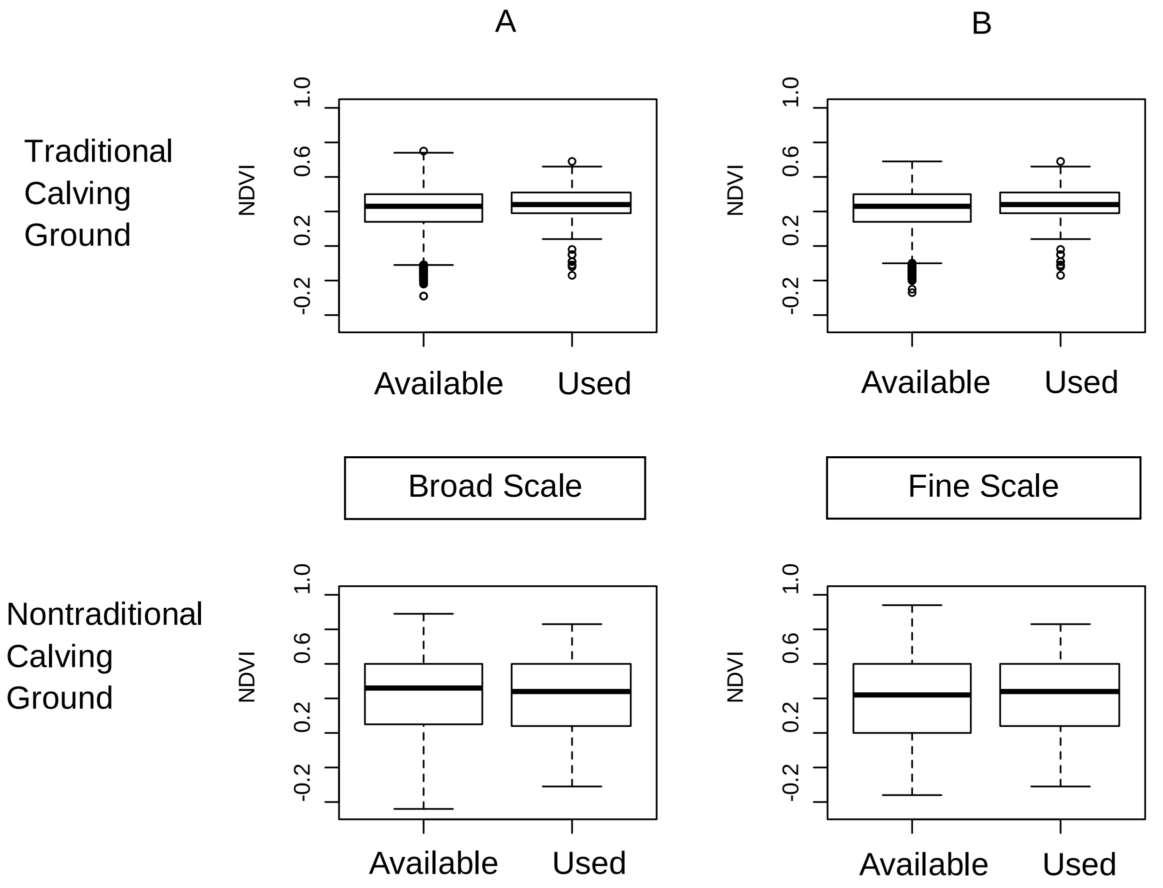

FIGURE 4. Boxplots comparing used and available NDVI values at the broad scale (column A) and fine scale (column B), in the traditional calving ground (top row A), and the nontraditional calving ground (bottom row), for female woodland caribou in the La Poile study area, Newfoundland, Canada. Values appear on the y-axis, and are designated available and used on the x-axis.

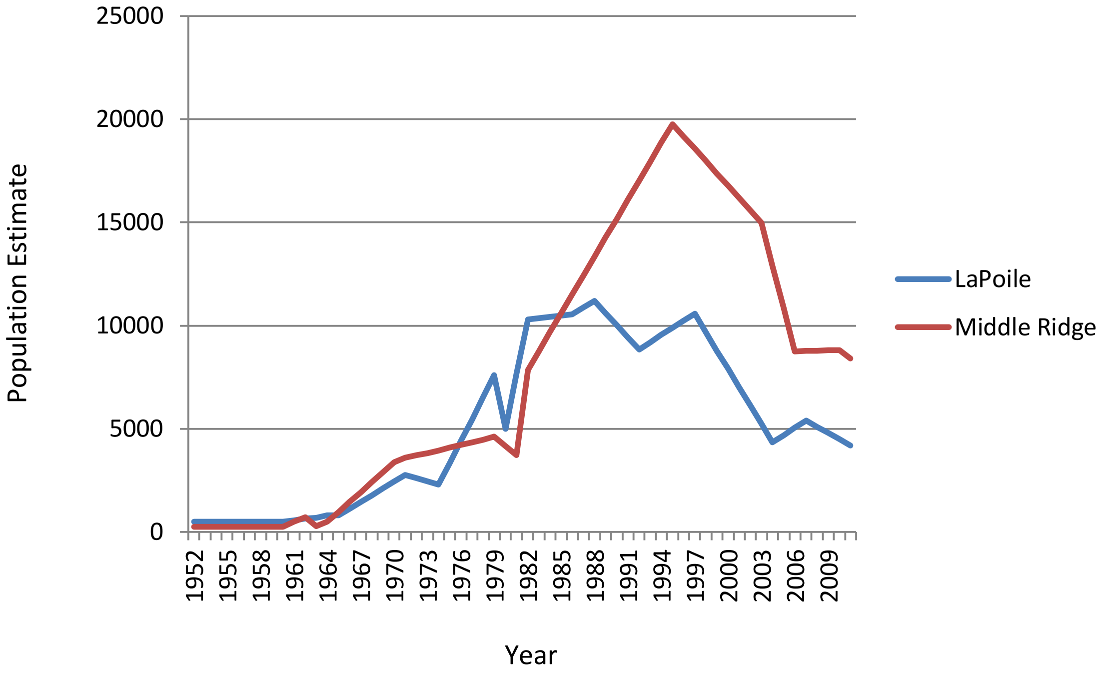

FIGURE 5. Graph of population estimates from 1952 to 2011 for La Poile and Middle Ridge herds in Newfoundland, Canada. Estimates are from unpublished survey data.

TABLE 1: Landcover classification key for EOSD layer, showing organization of original landcover classes into 5 covariates used to analyze resource selection by female caribou in Middle Ridge and La Poile study areas, Newfoundland, Canada. Original class descriptions are located in the EOSD Land Cover Classification Legend Report (Wulder and Nelson 2003).

Original Landcover Class	Landcover Covariate
Water (pond, lake, stream, reservoir)	Water
Snow/Ice	Nonvegetated Land
Rock/Rubble	
Exposed Land/Developed (<5% vegetation; hard-surface features)	
Wetland-Treed (stunted trees dominant)	Wetland
Wetland-Shrub (shrubs dominant)	
Wetland-Herb (herbs dominant)	
Bryoids (moss, lichen, liverworts)	
Herb (grasses, forbs)	
Shrub Tall (30% shrub; average height ≥2 m)	Shrubland
Shrub Low (30% shrub; average height <2 m)	
Coniferous Forest Dense (≥75% conifer; >60% crown closure)	Forest
Coniferous Forest Open (≥75% conifer; 26-60% crown closure)	
Coniferous Forest Sparse (≥75% conifer; 10-25% crown closure)	
Broadleaf Forest Dense (≥75% broadleaf; >60% crown closure)	
Broadleaf Forest Open (≥75% broadleaf; 26-60% crown closure)	
Broadleaf Forest Sparse (≥75% broadleaf; 10-25% crown closure)	
Mixedwood Forest Dense (no dominant species; >60% crown closure)	
Mixedwood Forest Open (no dominant species; 26-60% crown closure)	
Mixedwood Forest Sparse (no dominant species; 10-25% crown closure)	

TABLE 2A: Model set for 1980s and 1990s Middle Ridge broad scale analysis of preburn data for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Forest+Nonvegetated+Shrubland+Wetland	5	471.68	0.00	0.32	-230.80
Forest+Nonvegetated+Wetland	4	472.05	0.37	0.27	-232.00
Nonvegetated+Wetland	3	472.73	1.05	0.19	-233.35
Nonvegetated+Shrubland+Wetland	4	473.29	1.61	0.14	-232.62
Forest+Shrubland+Wetland	4	474.61	2.93	0.07	-233.28
Forest+Wetland	3	480.41	8.73	0.00	-237.19
Shrubland+Wetland	3	486.51	14.82	0.00	-240.24
Nonvegetated+Shrubland	3	493.13	21.45	0.00	-243.55
Forest+Shrubland	3	493.76	22.08	0.00	-243.87
Forest+Nonvegetated	3	493.78	22.09	0.00	-243.87

TABLE 2B: Models set for 1980s and 1990s Middle Ridge fine scale analysis of preburn data for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Forest+Shrubland+Wetland	4	478.46	0.00	0.25	-235.21
Forest+Nonvegetated+Wetland	4	478.46	0.00	0.25	-235.21
Forest+Nonvegetated+Shrubland+Wetland	5	479.17	0.70	0.18	-234.55
Nonvegetated+Wetland	3	479.83	1.37	0.13	-236.90
Forest+Wetland	3	479.86	1.40	0.12	-236.91
Nonvegetated+Shrubland+Wetland	4	481.17	2.71	0.06	-236.56
Shrubland+Wetland	3	485.76	7.29	0.01	-239.86
Forest+Shrubland	3	494.63	16.17	0.00	-244.30
Forest+Nonvegetated	3	496.08	17.61	0.00	-245.02
Nonvegetated+Shrubland	3	497.21	18.75	0.00	-245.59

TABLE 3A: Model set for 1980s and 1990s Middle Ridge broad scale analysis of postburn data without cutovers for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Burn+Forest+Nonvegetated+Wetland	5	5800.98	0.00	0.62	-2895.49
Burn+Forest+Nonvegetated+Shrubland+Wetland	6	5802.89	1.90	0.24	-2895.44
Burn+Forest+Wetland	4	5804.74	3.75	0.10	-2898.37
Burn+Forest+Shrubland+Wetland	5	5806.49	5.51	0.04	-2898.24
Burn+Nonvegetated+Wetland	4	5817.41	16.42	0.00	-2904.70
Burn+Nonvegetated+Shrubland+Wetland	5	5819.07	18.08	0.00	-2904.53
Burn+Shrubland+Wetland	4	5829.22	28.23	0.00	-2910.61
Burn+Forest+Shrubland	4	5875.59	74.61	0.00	-2933.79
Burn+Nonvegetated+Shrubland	4	5877.87	76.88	0.00	-2934.93
Burn+Forest+Nonvegetated	4	5886.25	85.26	0.00	-2939.12

TABLE 3B: Model set for 1980s and 1990s Middle Ridge fine scale analysis of postburn data without cutovers for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Burn+Forest+Nonvegetated+Wetland	5	5897.19	0.00	0.54	-2943.59
Burn+Forest+Nonvegetated+Shrubland+Wetland	6	5898.88	1.69	0.23	-2943.44
Burn+Forest+Wetland	4	5899.8	2.61	0.15	-2945.90
Burn+Forest+Shrubland+Wetland	5	5901.67	4.48	0.06	-2945.83
Burn+Nonvegetated+Wetland	4	5904.14	6.95	0.02	-2948.07
Burn+Nonvegetated+Shrubland+Wetland	5	5905.95	8.76	0.01	-2947.97
Burn+Shrubland+Wetland	4	5913.12	15.93	0.00	-2952.56
Burn+Forest+Shrubland	4	5949.67	52.48	0.00	-2970.83
Burn+Forest+Nonvegetated	4	5952.43	55.24	0.00	-2972.21
Burn+Nonvegetated+Shrubland	4	5954.58	57.39	0.00	-2973.29

TABLE 3C: Model set for 1980s and 1990s Middle Ridge broad scale analysis of postburn data with cutovers for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Burn+Cutover+Forest+Wetland	5	5312.06	0.00	0.38	-2651.03
Burn+Cutover+Forest+Shrubland+Wetland	6	5312.33	0.26	0.33	-2650.16
Burn+Cutover+Forest+Nonvegetated+Wetland	6	5313.76	1.69	0.16	-2650.87
Burn+Cut+Forest+Nonvegetated+Shrubland+Wetland	7	5314.13	2.07	0.13	-2650.06
Burn+Cutover+Nonvegetated+Shrubland+Wetland	6	5336.44	24.38	0.00	-2662.22
Burn+Cutover+Nonvegetated+Wetland	5	5337.02	24.96	0.00	-2663.51
Burn+Cutover+Shrubland+Wetland	5	5337.17	25.11	0.00	-2663.58
Burn+Cutover+Forest+Shrubland	5	5348.17	36.11	0.00	-2669.08
Burn+Cutover+Nonvegetated+Shrubland	5	5349.32	37.26	0.00	-2669.66
Burn+Cutover+Forest+Nonvegetated	5	5357.68	45.62	0.00	-2673.84

TABLE 3D: Model set for 1980s and 1990s Middle Ridge fine scale analysis of postburn data with cutovers for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Burn+Cutover+Forest+Wetland	5	5409.68	0.00	0.53	-2699.84
Burn+Cutover+Forest+Nonvegetated+Wetland	6	5411.66	1.98	0.20	-2699.83
Burn+Cutover+Forest+Shrubland+Wetland	6	5411.68	2.00	0.20	-2699.83
Burn+Cutover+Forest+Nonvegetated+Shrubland+Wetland	7	5413.66	3.98	0.07	-2699.82
Burn+Cutover+Nonvegetated+Wetland	5	5420.41	10.73	0.00	-2705.20
Burn+Cutover+Shrubland+Wetland	5	5421.16	11.48	0.00	-2705.57
Burn+Cutover+Nonvegetated+Shrubland+Wetland	6	5422.36	12.68	0.00	-2705.18
Burn+Cutover+Nonvegetated+Shrubland	5	5434.20	24.52	0.00	-2712.10
Burn+Cutover+Forest+Shrubland	5	5435.10	25.42	0.00	-2712.55
Burn+Cutover+Forest+Nonvegetated	5	5436.49	26.81	0.00	-2713.24

TABLE 4A: Model set for 2000s Middle Ridge broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top model is shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Burn+Forest+Nonvegetated+Shrubland+Wetland	6	53716.86	0.00	1	-26852.43
Burn+Forest+Shrubland+Wetland	5	53791.92	75.06	0	-26890.96
Burn+Forest+Shrubland	4	53803.88	86.94	0	-26897.90
Burn+Forest+Nonvegetated+Wetland	5	53859.99	143.14	0	-26925.00
Burn+Forest+Nonvegetated	4	53863.78	146.92	0	-26927.89
Burn+Forest+Wetland	4	53866.54	149.68	0	-26929.27
Burn+Nonvegetated+Shrubland+Wetland	6	54007.66	290.80	0	-26997.83
Burn+Nonvegetated+Wetland	4	54062.76	345.90	0	-27027.38
Burn+Shrubland+Wetland	4	54323.70	606.84	0	-27157.85
Burn+Nonvegetated+Shrubland	4	54454.11	737.25	0	-27223.06

TABLE 4B: Model set for 2000s Middle Ridge fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top model is shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Burn+Forest+Nonvegetated+Shrubland+Wetland	6	74580.62	0.00	1	-37284.31
Burn+Nonvegetated+Shrubland+Wetland	6	74631.21	50.59	0	-37319.60
Burn+Forest+Nonvegetated+Wetland	5	74691.13	110.52	0	-37340.57
Burn+Nonvegetated+Wetland	4	74696.95	116.33	0	-37344.47
Burn+Forest+Shrubland+Wetland	5	74770.74	190.13	0	-37380.37
Burn+Forest+Wetland	4	74772.40	191.78	0	-37382.20
Burn+Forest+Shrubland	4	74792.89	212.28	0	-37392.45
Burn+Forest+Nonvegetated	4	74811.91	231.29	0	-37401.95
Burn+Shrubland+Wetland	4	74899.47	318.85	0	-37445.73
Burn+Nonvegetated+Shrubland	4	75084.49	503.87	0	-37538.24

TABLE 5A: Results for Middle Ridge 1980s and 1990s preburn data, broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Forest	2.64	1.74	[-0.76, 6.05]
Nonvegetated	-8.86	3.36	[-15.43, -2.28]
Shrubland	7.16	4.87	[-2.38, 16.70]
Wetland	6.44	2.10	[2.33, 10.55]

TABLE 5B: Results for Middle Ridge 1980s and 1990s preburn data, fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Forest	3.18	1.62	[0.01, 6.35]
Nonvegetated	-5.20	3.18	[-11.44, 1.04]
Shrubland	6.30	4.61	[-2.74, 15.34]
Wetland	6.54	2.20	[2.22, 10.86]

TABLE 6A: Results for Middle Ridge 1980s and 1990s postburn data without cutovers, broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Burn	0.82	0.34	[0.16, 1.49]
Forest	1.31	0.33	[0.67, 1.96]
Nonvegetated	-2.81	1.22	[-5.2, -0.42]
Shrubland	0.45	1.30	[-2.1, 2.99]
Wetland	4.15	0.49	[3.19, 5.10]

TABLE 6B: Results for Middle Ridge 1980s and 1990s postburn data without cutovers, fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Burn	1.21	0.36	[0.5, 1.91]
Forest	0.96	0.33	[0.31, 1.60]
Nonvegetated	-2.44	1.17	[-4.73, -0.16]
Shrubland	-0.68	1.31	[-3.25, 1.90]
Wetland	3.38	0.50	[2.40, 4.36]

TABLE 7A: Results for Middle Ridge 1980s and 1990s postburn data with cutovers, broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Burn	0.88	0.36	[0.17, 1.60]
Cutover	2.04	0.71	[0.64, 3.43]
Forest	1.61	0.34	[0.95, 2.28]
Nonvegetated	-0.60	1.20	[-2.95, 1.75]
Shrubland	1.80	1.38	[-0.90, 4.51]
Wetland	3.21	0.52	[2.18, 4.24]

TABLE 7B: Results for Middle Ridge 1980s and 1990s postburn data with cutovers, fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Burn	1.17	0.36	[0.47, 1.87]
Cutover	1.13	0.71	[-0.27, 2.53]
Forest	1.09	0.34	[0.42, 1.76]
Nonvegetated	-0.18	1.21	[-2.56, 2.20]
Shrubland	0.11	1.37	[-2.57, 2.79]
Wetland	2.59	0.53	[1.55, 3.63]

TABLE 8A: Mixed-effects model output for Middle Ridge 2000s data, broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows random intercept for individual, variance and standard deviation (SD) for random effects, and fixed-effects parameter values (β), standard error (SE), *Z*-values (*Z*), and *P*-values (*P*) from global model.

Random effects (Intercept):

	Variance	SD
	3.06e-5	0.005531

Fixed effects:

Parameter	β	SE	*Z*	*P*
(Intercept)	-3.02333	0.05680	-53.22	<2e-16
Burn	3.54704	0.03941	90.01	<2e-16
Forest	-1.30680	0.06829	-19.14	<2e-16
Nonvegetated	-0.66248	0.07303	-9.07	<2e-16
Shrubland	-0.95183	0.07586	-12.55	<2e-16
Wetland	-0.69315	0.06968	-9.95	<2e-16

TABLE 8B: Mixed-effects model output for Middle Ridge 2000s data, fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows random intercept for individual, variance and standard deviation (SD) for random effects, and fixed-effects parameter values (β), standard error (SE), *Z*-values (*Z*), and *P*-values (*P*) from global model.

Random effects (Intercept):

	Variance	SD
	1.46e-8	0.000121

Fixed effects:

Parameter	β	SE	*Z*	*P*
(Intercept)	-3.40036	0.05605	-60.66	< 2e-16
Burn	1.21619	0.03950	30.79	< 2e-16
Forest	0.49378	0.06833	7.23	4.96e-13
Nonvegetated	0.95189	0.07111	13.39	< 2e-16
Shrubland	0.76741	0.07401	10.37	< 2e-16
Wetland	0.97258	0.06896	14.10	< 2e-16

TABLE 9A: Model set for 1980s and 1990s La Poile broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Nonvegetated+Wetland	3	3439.01	0.00	0.45	-1716.50
Forest+Nonvegetated+Wetland	4	3440.27	1.26	0.24	-1716.13
Nonvegetated+Shrubland+Wetland	4	3440.45	1.44	0.22	-1716.22
Forest+Nonvegetated+Shrubland+Wetland	5	3442.07	3.06	0.10	-1716.03
Forest+Wetland	3	3450.57	11.56	0.00	-1722.28
Forest+Shrubland+Wetland	4	3452.28	13.27	0.00	-1722.14
Shrubland+Wetland	3	3488.56	49.55	0.00	-1741.28
Forest+Nonvegetated	3	3583.85	144.84	0.00	-1788.92
Nonvegetated+Shrubland	3	3596.63	157.62	0.00	-1795.31
Forest+Shrubland	3	3608.32	169.31	0.00	-1801.16

TABLE 9B: Model set for 1980s and 1990s La Poile fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top models are shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Forest+Shrubland+Wetland	4	3560.67	0.00	0.66	-1776.33
Forest+Nonvegetated+Shrubland+Wetland	5	3562.55	1.88	0.26	-1776.27
Nonvegetated+Shrubland+Wetland	4	3564.98	4.30	0.08	-1778.48
Shrubland+Wetland	3	3572.47	11.80	0.00	-1783.23
Forest+Shrubland	3	3580.94	20.27	0.00	-1787.47
Nonvegetated+Shrubland	3	3580.96	20.28	0.00	-1787.48
Nonvegetated+Wetland	3	3585.28	24.61	0.00	-1789.64
Forest+Nonvegetated+Wetland	4	3587.11	26.44	0.00	-1789.55
Forest+Wetland	3	3587.56	26.89	0.00	-1790.78
Forest+Nonvegetated	3	3609.77	49.10	0.00	-1801.88

TABLE 10A: Results for La Poile 1980s and 1990s data, broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Forest	0.37	0.48	[-0.57, 1.31]
Nonvegetated	-2.55	0.53	[-3.58, -1.52]
Shrubland	-0.54	0.83	[-2.17, 1.1]
Wetland	8.82	0.73	[7.4, 10.24]

TABLE 10B: Results for La Poile 1980s and 1990s data, fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows model-averaged parameter values (β), standard error (SE), and 95% confidence intervals (CI).

Parameter	β	SE	CI
Forest	1.04	0.36	[0.34, 1.73]
Nonvegetated	-0.45	0.71	[-1.84, 0.95]
Shrubland	4.36	0.84	[2.72, 6]
Wetland	3.84	0.84	[2.19, 5.49]

TABLE 11A: Model set for 2000s La Poile broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top model is shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Cutover+Forest+Nonvegetated+Shrubland+Wetland	6	104473.9	0.00	1	-52230.93
Cutover+Nonvegetated+Shrubland+Wetland	5	104727.4	253.55	0	-52358.71
Cutover+Nonvegetated+Shrubland	4	104807.2	333.33	0	-52499.60
Cutover+Forest+Nonvegetated+Wetland	5	105583.5	1109.66	0	-52786.76
Cutover+Forest+Nonvegetated	4	105629.9	1156.09	0	-52810.98
Cutover+Forest+Shrubland+Wetland	5	105698.9	1225.02	0	-52844.44
Cutover+Forest+Wetland	4	105799.8	1325.97	0	-52895.92
Cutover+Forest+Shrubland	4	105823.4	1349.58	0	-52907.72
Cutover+Nonvegetated+Wetland	4	105864.6	1390.71	0	-52928.28
Cutover+Shrubland+Wetland	4	106290.4	1816.56	0	-53141.21

TABLE 11B: Model set for 2000s La Poile fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows number of parameters (*k*), AICc score, AICc weight (AICcWt), and log-likelihood (LL). Top model is shown in bold.

Model Parameters	*k*	AICc	ΔAICc	AICcWt	LL
Cutover+Forest+Nonvegetated+Shrubland+Wetland	6	105175.6	0.00	1	-52581.82
Cutover+Nonvegetated+Shrubland+Wetland	5	105625.6	449.97	0	-52807.81
Cutover+Nonvegetated+Shrubland	4	105716.6	541.01	0	-52854.33
Cutover+Forest+Shrubland+Wetland	5	106278.2	1102.60	0	-53134.12
Cutover+Forest+Nonvegetated	4	106278.6	1102.97	0	-53135.31
Cutover+Forest+Nonvegetated+Wetland	5	106280.4	1104.71	0	-53135.18
Cutover+Forest+Shrubland	4	106283.0	1107.38	0	-53137.51
Cutover+Nonvegetated+Wetland	4	106335.6	1159.92	0	-53163.78
Cutover+Shrubland+Wetland	4	106407.6	1232.01	0	-53199.83
Cutover+Forest+Wetland	4	106421.9	1246.23	0	-53206.94

TABLE 12A: Mixed-effects model output for La Poile 2000s data, broad scale analysis for female caribou during calving in Newfoundland, Canada. Table shows random intercept for individual, variance and standard deviation (SD) for random effects, and fixed-effects parameter values (β), standard error (SE), *Z*-values (*Z*), and *P*-values (*P*) from global model.

Random effects (Intercept):	Variance	SD
	4.00e-5	0.006326

Fixed effects: Parameter	β	SE	*Z*	*P*
(Intercept)	-2.28479	0.03598	-63.51	<2e-16
Cutover	0.06515	0.25794	0.25	0.8000
Forest	0.37111	0.03846	9.65	<2e-16
Nonvegetated	1.03802	0.03848	26.98	<2e-16
Shrubland	1.05303	0.04014	26.23	<2e-16
Wetland	0.53232	0.04284	12.42	<2e-16

TABLE 12B: Mixed-effects model output for La Poile 2000s data, fine scale analysis for female caribou during calving in Newfoundland, Canada. Table shows random intercept for individual, variance and standard deviation (SD) for random effects, and fixed-effects parameter values (β), standard error (SE), *Z*-values (*Z*), and *P*-values (*P*) from global model.

Random effects (Intercept):	Variance	SD
	4.82e-9	0.000069

Fixed effects: Parameter	β	SE	*Z*	*P*
(Intercept)	-2.35832	0.03580	-65.87	<2e-16
Cutover	-0.46435	0.25218	-1.84	0.0656
Forest	0.55896	0.03838	14.56	<2e-16
Nonvegetated_Land	0.96895	0.03828	25.31	<2e-16
Shrubland	1.04044	0.03995	26.04	<2e-16
Wetland	0.70445	0.04284	16.44	<2e-16

TABLE 13A: Results from *k*-fold cross validation of top resource models analyzing selection by female caribou during calving in the 1980s and 1990s, Middle Ridge study area, Newfoundland, Canada. Table shows Spearman-rank correlation scores (ρ), *P*-values (*P*), number of subsets (*k*), and number of bins (*n*).

Middle Ridge Models for 1980s and 1990s				
Preburn – broad scale	ρ	*P*	*k*	*n*
Forest+Nonvegetated+Shrubland+Wetland	0.87	0.042	3	6
Forest+Nonvegetated+Wetland	0.79	0.100	3	6
Nonvegeted+Wetland	0.82	0.060	3	6
Nonvegetated+Shrubland+Wetland	0.79	0.090	3	6
Preburn – fine scale				
Forest+Shrubland+Wetland	0.89	0.020	3	6
Forest+Nonvegetated+Wetland	0.82	0.060	3	6
Forest+Nonvegetated+Shrubland	0.78	0.100	3	6
Nonvegetated+Wetland	0.85	0.040	3	6
Forest+Wetland	0.90	0.021	3	6
Postburn without cutover – broad scale				
Burn+Forest+Nonvegetated+Wetland	0.89	0.003	5	10
Burn+Forest+Nonvegetated+Shrubland	0.90	0.001	5	10
Burn+Forest+Wetland	0.84	0.009	5	10
Postburn without cutover – fine scale				
Burn+Forest+Nonvegetated+Wetland	0.81	0.010	5	10
Burn+Forest+Nonvegetated+Shrubland+Wetland	0.79	0.009	5	10
Burn+Forest+Wetland	0.74	0.019	5	10
Postburn with cutover – broad scale				
Burn+Cutover+Forest+Wetland	0.82	0.010	5	10
Burn+Cutover+Forest+Shrubland+Wetland	0.83	0.009	5	10
Burn+Cutover+Forest+Nonvegetated+Wetland	0.82	0.013	5	10
Burn+Cutover+Forest+Nonvegetated+Shrubland+Wetland	0.83	0.008	5	10
Postburn with cutover – fine scale				
Burn+Cutover+Forest+Wetland	0.51	0.12	5	10
Burn+Cutover+Forest+Nonvegetated+Wetland	0.43	0.33	5	10
Burn+Cutover+Forest+Shrubland+Wetland	0.50	0.21	5	10

TABLE 13B: Results from *k*-fold cross validation of global mixed-effects resource model analyzing selection by female caribou during calving in the 2000s, Middle Ridge study area, Newfoundland, Canada. Table shows Spearman-rank correlation scores (ρ), *P*-values (*P*), number of subsets (*k*), and number of bins (*n*).

Global model for 2000s – broad scale	ρ	*P*	*k*	*n*
Burn+Forest+Nonvegetated+Shrubland+Wetland	0.92	0.072	5	5
Global model for 2000s – fine scale				
Burn+Forest+Nonvegetated+Shrubland+Wetland	0.73	0.210	5	5

TABLE 14A: Results from *k*-fold cross validation of top resource models analyzing selection by female caribou during calving in the 1980s and 1990s, La Poile study area, Newfoundland, Canada. Table shows Spearman-rank correlation scores (ρ), *P*-values (*P*), number of subsets (*k*), and number of bins (*n*).

Models for 1980s and 1990s – broad scale	ρ	*P*	*k*	*n*
Nonvegetated+Wetland	0.91	0.002	5	10
Forest+Nonvegetated+Wetland	0.90	0.001	5	10
Nonvegetated+Shrubland+Wetland	0.89	0.004	5	10
Forest+Nonvegetated+Shrubland+Wetland	0.90	0.001	5	10
Models for 1980s and 1990s – fine scale				
Forest+Shrubland+Wetland	0.77	0.02	5	10
Forest+Nonvegetated+Shrubland+Wetland	0.80	0.02	5	10

TABLE 14B: Results from *k*-fold cross validation of global mixed-effects resource model analyzing selection by female caribou during calving in the 2000s, La Poile study area, Newfoundland, Canada. Table shows Spearman-rank correlation scores (ρ), *P*-values (*P*), number of subsets (*k*), and number of bins (*n*).

Global model for 2000s – broad scale	ρ	*P*	*k*	*n*
Cutover+Forest+Nonvegetated+Shrubland+Wetland	0.57	0.53	5	4
Global model for 2000s – fine scale				
Cutover+Forest+Nonvegetated+Shrubland+Wetland	0.90	0.21	5	4