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Experimental manipulations of black bear (*Ursus americanus*) and eastern coyote (*Canis latrans*) to improve caribou calf survival in southern Newfoundland 2008–2013

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Newfoundland Caribou Strategy

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Executive Summary

Since the late 1990s, the Newfoundland woodland caribou (*Rangifer tarandus*) population has declined from almost 94,000 animals in 1996 to almost 32,000 as of 2013. Research by the Department of Environment and Conservation from 2003 to 2007 indicated that poor calf survival was the primary demographic reason for the decline of the population and that the majority of caribou mortality was due to predation of newborn calves, largely by black bear (*Ursus americanus*) and eastern coyote (*Canis latrans*). In response to the declining caribou population, the Government of Newfoundland and Labrador created the *Caribou Strategy*, a research project led by the Sustainable Development and Strategic Science (SDSS) Division of the Department of Environment and Conservation. One purpose of the *Caribou Strategy* was to determine the effectiveness of manipulating predators, by lethal and non-lethal methods, to improve caribou calf survival. This report summarizes the experimental implementation and results of these efforts.

Predator manipulation did not begin until adequate baseline information was available, and lethal removals were only considered after evaluating non-lethal options. Non-lethal diversionary feeding, a widely accepted method to deter predators, was conducted in spring–summer of 2010 and 2011 in Middle Ridge South. In 2010 massive quantities of bakery waste were used to deter predators from predating calves. In the second year of the experiment (2011) beaver carcasses were also provided and used to target coyotes especially as these predator showed little to no use of bakery waste in 2010. Black bears continually visited both bait types and their spatial movements were altered from the “natural” pattern. However coyotes frequented neither bait type and therefore, spatial movements were not examined. Calf survival modestly improved in 2010 and 2011 compared with previous years, but in an effort to substantially increase caribou calf survival rates, lethal removal of coyotes began in 2012–2013. Sixteen and 24 coyotes were removed in 2012 and 2013, respectively. Based on estimates of coyote density from a previous study, we believe this indicates that a large percentage of the coyote population was removed each year immediately prior to caribou calving. Calf survival improved in both years but especially in 2013.

This study suggests that lethal removal of coyote could be a viable management option for improving calf survival and that diversionary feeding alone is not, but that both methods are expensive and logistically challenging. Specifically, this study suggests future manipulations will be successful if:

1. Conducted by Government or by the public but only if substantial Government support is provided.
2. Caribou are well aggregated on the calving grounds so that the predator removal effort has the maximum impact on predators for the greatest number of caribou.
3. The percentage of calves predated by coyotes is known to be high, which applies to many of the herds studied in Newfoundland (Lewis and Mahoney 2014).
4. Costs are minimized; costs of these efforts will decrease substantially in less remote areas, which will increase the efficacy of these management options.

5. There is a long-term (ca. 5 years) commitment to the predator manipulation effort since immigration can rapidly renew a local predator population.

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Introduction

With the exception of Newfoundland, all populations of woodland caribou (*Rangifer tarandus*) across Canada are designated as "At-Risk" by the Committee on the Status of Wildlife in Canada (COSEWIC 2002) warranting protection under the Species At Risk Act. However, the Newfoundland caribou population decreased from a peak of nearly 94,000 animals in the late 1990s to just over 40,000 in 2008. Since then the rate of decline has slowed, but in 2013, there were fewer than 32,000 caribou in Newfoundland. Population modeling indicates that under current demographic conditions the caribou population will continue to decline (Randell et al. 2012). Further, the current COSEWIC review, which began in 2013, will likely trigger some level of "At-Risk" designation that will have implications for caribou management, land management, the outfitting industry, and other industries through the environmental assessment process.

Low calf survival was identified as a major factor influencing the population decline (Mahoney and Weir 2009, Weir et al. 2014). In response, the Department of Environment and Conservation initiated the *Calf Mortality Study* in 2003 with the objective of determining calf survival rates and causes of calf mortality. This study found that calf survival to the first year of life was very low (Trindade et al. 2011, Lewis and Mahoney 2014) and the high mortality was largely attributed to predation by black bear (*Ursus americanus*) and eastern coyote (*Canis latrans*), although Canada lynx (*Lynx canadensis*) and Bald Eagle (*Haliaeetus leucocephalus*) also prey on caribou calves.

In response to the continuing decline of the caribou population, the Government of Newfoundland and Labrador announced $15.3 million in funding for a 5-year *Caribou Strategy* in February 2008. The *Caribou Strategy* was a comprehensive program to inform caribou management in Newfoundland by improving ecosystem-level knowledge of caribou and their predators. Specifically, the *Caribou Strategy* was to investigate the underlying causes of the decline including significantly increased examination of calf mortality, predator ecology, and to experimentally test options for improving calf survival.

Options for improving calf survival focused on means to reduce calf predation based upon 1) the results of the *Calf Mortality Study* and 2) research from other jurisdictions suggesting that predators limit the density and distribution of woodland caribou (Bergerud 1971, 1974, 1978, 1980, 1988, 1996, 2000, Schaefer et al. 1999, Harding et al. 2001, Mosnier et al. 2005). Several predator management tools were considered: 1) lethal removal, 2) predator relocation from the calving grounds, 3) providing predators with alternative food during calving time (i.e., diversionary feeding), 4) conditioning predators to avoid preying on caribou, and 5) sterilizing predators to eventually lower their populations. Relocation of predators, conditioning predators to avoid prey, and predator sterilization were rejected because of prohibitive logistic and financial challenges as well as the time frame of this study.

An increase in black bear and coyote predation on caribou calves since the late 1990s has resulted in poor recruitment into the population and a decrease in caribou populations.

The two remaining management tools, lethal removal and diversionary feeding of predators, were employed. The decision to use these two management tools was, in part, based on a review conducted by Soulliere et al. (2014) that determined both of these tools had been employed in successful predator manipulation programs, i.e., those that found an increase in the measured variable (e.g., calf:cow ratio, number of calves, calf survival rate, or population density) for the target prey at the end of the program. Lethal removal can improve calf survival by directly removing the main source of calf mortality. Diversionary feeding can improve calf survival by fulfilling the caloric needs of the predator, thereby reducing their need to predate calves, or by changing their behavior, i.e., the spatial ecology of the predator will change as they defend or stay in close proximity to the provided food.

The predator manipulations began with a diversionary feeding program before proceeding to lethal removal for several reasons. First, diversionary feeding is less invasive because it alters the behavior of wildlife rather than killing them. Second, there was a desire to determine whether this less invasive approach would be effective in improving calf survival as shown in other studies (Soulliere et al. 2014). Third, if diversionary feeding were preceded by lethal removal, rather than proceeding in the order we did, the results would have been seriously confounded and made interpretation difficult, i.e., testing the influence of diversionary feeding would be problematic without any predators. Fourth, there was a desire to test as many management options as possible within the time constraints of the *Caribou Strategy*. Fifth, the cost of employing multiple methods simultaneously would have been prohibitive. Finally, public acceptance is more easily gained using non-lethal methods (Regelin et al. 2005), and there were concerns over public opinion regarding lethal removal, especially of black bears (Sutherland 2010).

Diversionary feeding began during the 2010 calving season and was continued in 2011. Lethal removal of coyotes using neck snares took place immediately before the calving season in 2012 and 2013. Lethal snares were considered the best option for specifically targeting coyotes and removing enough coyotes from the study area to effectively improve calf survival. Snares are more cost-effective, humane, and logistically feasible removal method for a large remote area than aerial shooting or poisoning.

The study approach for the two predator manipulation methods was a Before-After-Control-Impact (BACI) design, which is frequently used to monitor the impacts of a change (or treatment) to a particular environment or study area. A BACI approach compares the "before the experiment" ("Before") to the "after the experiment" ("After") period (Smith 2002) and also the results from one or more areas where the treatments took place are compared with one or more areas that did not receive the treatment, i.e., the control areas. If the difference in the outcome of the experiment between the treatment and control areas is large and if there is a change in the treatment area between the "Before" and "After" periods, then usual interpretation is that the treatment had an effect, i.e., an impact.

The primary purpose of this report is to describe the methods employed and provide results in terms of responses in caribou calf survival rates to diversionary feeding of bears and coyotes and the lethal removal of coyotes. A secondary purpose is to examine factors that could improve future predator manipulation efforts such as the influence of land cover on predator utilization of bait during diversionary feeding and the influence of diversionary feeding on predator movement, i.e., predator spatial ecology. This report also makes recommendations for future caribou and predator management.

Methods

Study area

This study was conducted using the four caribou calving and post-calving areas of the *Caribou Strategy* (Figure 1; for detailed study area descriptions, see Fifield et al. (2013) or Lewis and Mahoney (2014); for details on determining the calving/post-calving areas, see Rayl et al. (2014)). These calving grounds were located in the three identified study areas of the *Caribou Strategy* (La Poile, Middle Ridge, and the Northern Peninsula) and were selected because 1) they were geographically distinct (allowing for the examination of island-wide trends), 2) there was an abundance of existing information on Middle Ridge and La Poile providing a solid baseline of data to assess long-term trends for the *Caribou Strategy*, and 3) these three areas together contain about 50% of the island caribou population. Furthermore, these three study areas were assumed to be independent sampling units because there is minimal mixing of caribou among these herds (Mahoney 2000, Wilkerson 2010).

The experimental treatments were implemented only at Middle Ridge South (Figure 1, MR South), a relatively small calving ground covering approximately 480 km^2 in southern Newfoundland. MR South was chosen for predator manipulations because it was remote enough to minimize the influence of fur trappers and other human influences yet could be reached efficiently by helicopter. Further, caribou calf annual survival rates in this area were extremely low in recent years (Lewis and Mahoney 2014 — see Appendix 2 of this document), which improved the chances of detecting increased survival rates due to predator manipulation.

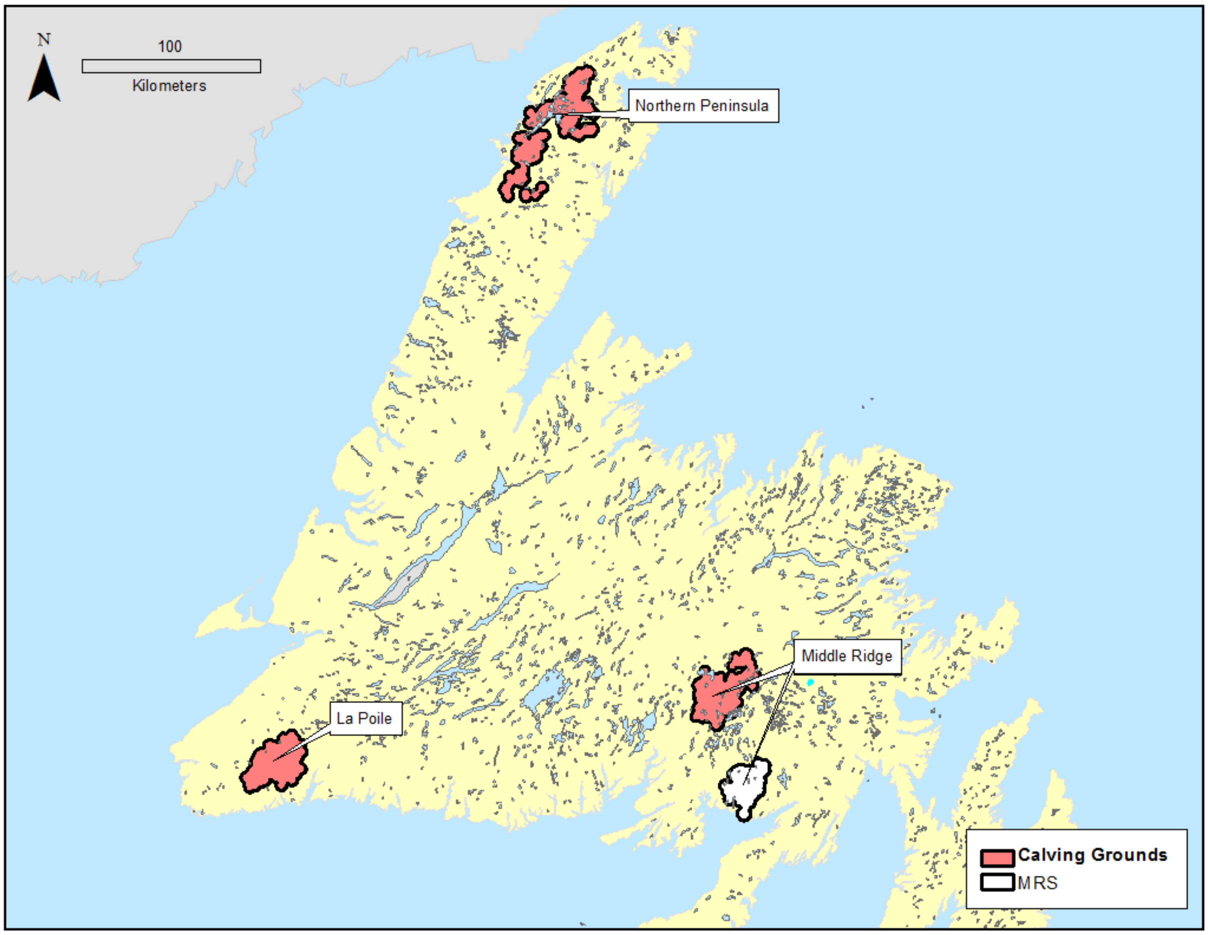


Figure 1. The locations of the calving and post-calving areas for the three herds of the *Caribou Strategy* (Rayl et al. 2014); control areas (Northern Peninsula, La Poile, and Middle Ridge North — red) are indicated separately from the area where the predator manipulations occurred (Middle Ridge South (MRS) — white).

Three control areas were established: the Middle Ridge North (MR North: 2008–2013) as well as La Poile and the Northern Peninsula (2008–2012) calving grounds. Animals that utilize the MR North and South calving grounds are considered to be from the Middle Ridge herd but the two calving areas are geographically separated and telemetry results confirm that females and their calves remain within a single area during the calving season.

Predator manipulation

Diversionary feeding

In 2010 and 2011, we provided food in the form of 500 kg bags of bakery waste distributed over a systematic grid of 4.5 km by 4.3 km quadrats that covered most of the MR South calving area (Figure 2). Bakery waste was placed at 25 bait stations at or near the center of each grid quadrat. Bait was transported via helicopter and first deposited before 25 May, a week prior to caribou calving.

Bait stations were then visited once per week until mid-July in both years. By mid-July, most of the surviving calves left the calving grounds and the greatest percentage of calf losses to predation occurred by this time (Lewis and Mahoney 2014). The amount of bakery waste consumed was estimated during each visit, and baits were replenished as necessary to ensure that essentially unlimited food was available to predators during the experimental period.

Coyotes rarely visited the bakery waste sites (as confirmed by automatic cameras — see next paragraph and Results). To further test whether coyotes would respond to diversionary feeding, beginning in mid-May 2011, six beaver carcasses (individually weighing 5–20 kg) were placed in suitable habitat on the intersections of the grid (Figure 2). Baits were replenished as needed, depending on the amount consumed, the weather, and the degree of bait decomposition.

We deployed motion-sensitive/infrared trail cameras (Stealthcam Prowler®) at each bait site to record the animal species visiting the bait stations (Figure 3). It was evident from many videos and field observations that black bears and other animals often consumed bait but this could not always be definitively determined due to video quality.

Coyote removal

Snaring

Favorable snaring locations were identified using information (i.e., tracks and sightings) from an earlier study on coyotes (Fifield et al. 2013), local knowledge from trappers employed in this study, and insights gained from a pre-snaring and pre-baiting effort in February–March of 2012 and 2013.

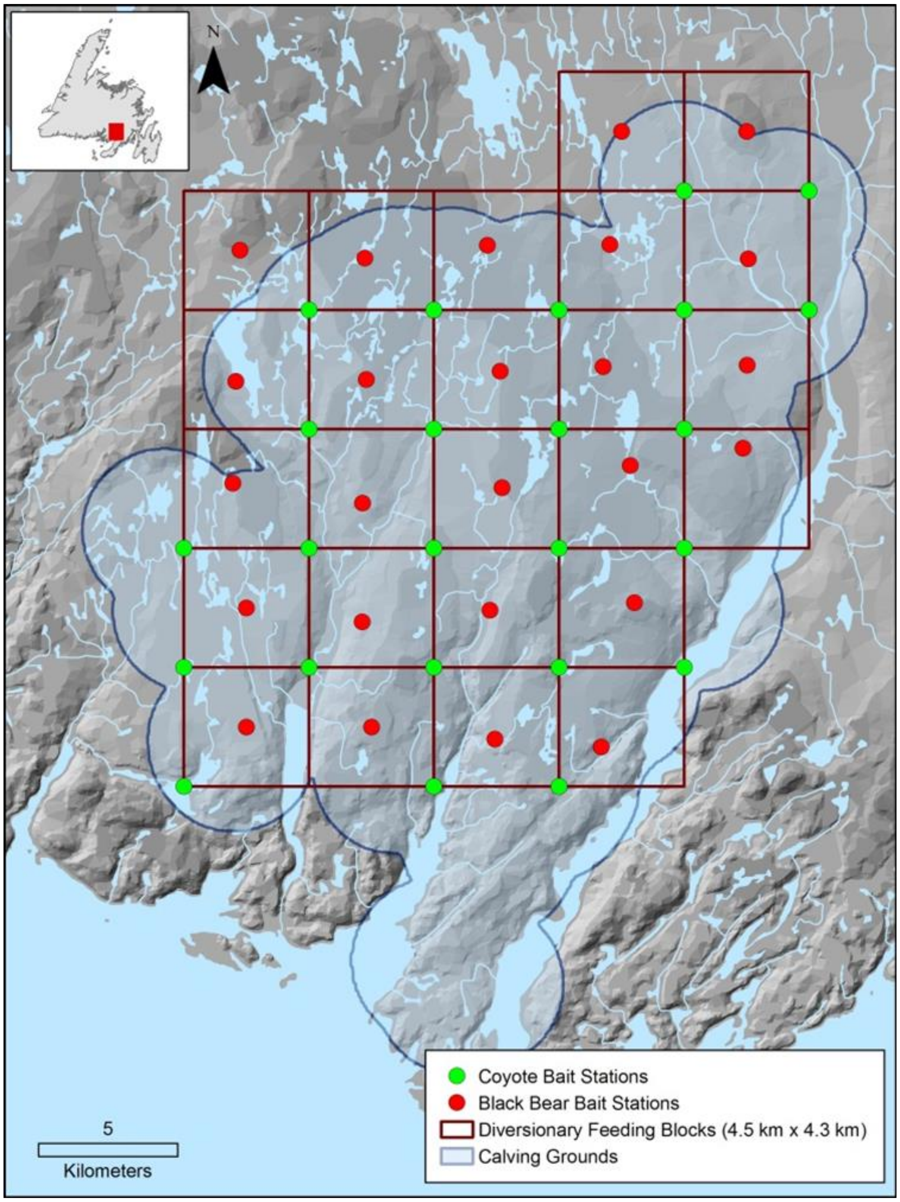


Figure 2. The diversionary feeding grid and the Middle Ridge South calving/post-calving ground (Rayl et al. 2014). Bakery waste was placed close to the center of each cell in the grid in both 2010 and 2011. Beaver carcasses were placed at each intersection of the lines in 2011.

In spring 2012 and 2013, 1039 and 927 lethal neck snares, respectively, were deployed for coyotes at MR South (Figure 4). Snaring occurred from 16–22 April until 2 weeks before calving started in 2012 and from 20–25 March until 1 week before calving started in 2013. The number of snares deployed in each quadrat was proportional to the amount of suitable coyote habitat and number of trees to which a snare could be attached (a mean of 11 ± 1.9 snares per site in 2012 and 10.3 ± 1.6 snares per site in 2013). Snares were checked every 7 to 10 days depending on the weather.

Figure 3. A radio-collared black bear on bakery waste at a diversionary feeding bait station. A trail camera (circled) records the presence of the black bear.

The snares were standard equipment used for trapping coyotes in Newfoundland, with breakaway swivel S-hooks used to aid in the release of non-target species like black bear and caribou. To reduce human scent, gloves were worn when handling snares and efforts were made to reduce disturbance around the snare. The methods followed the trapping guidelines of the Newfoundland Trappers Association. Coyote carcasses were retained so age and sex of the animals could be determined and used for future morphological studies.

Calf capture, handling, and determination of fate/mortality

Neonate caribou calf — capture and handling

To estimate caribou calf survival and thereby assess the effectiveness of the predator manipulation treatments, caribou calves were collared in the treatment and control areas from 2008 to 2012 and only at MR North (control area) and South (treatment area) in 2013 (Table 1). The years prior to the predator manipulations, i.e., 2008–2009, represent the Before period for the BACI analysis.

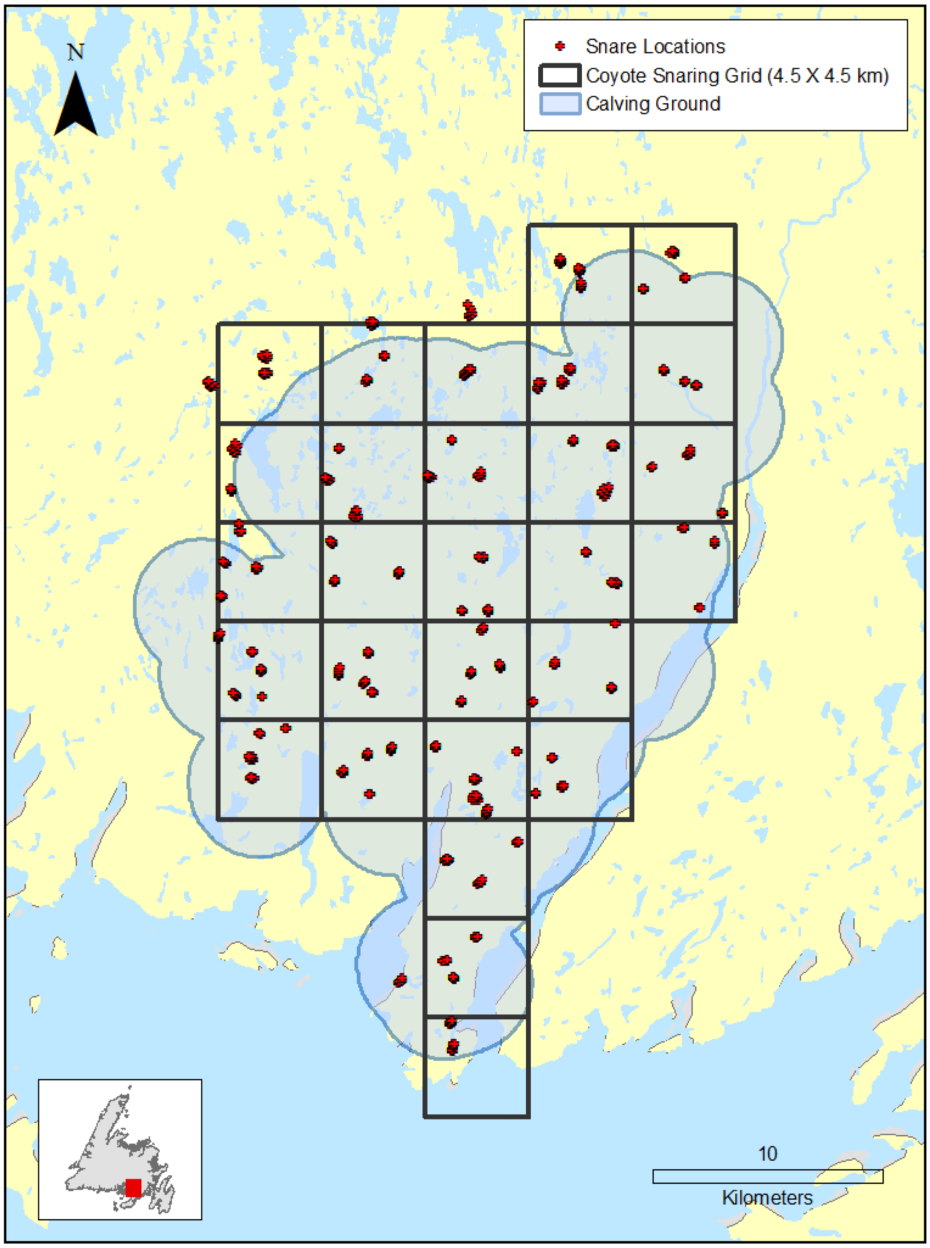


Figure 4. Snaring locations for the lethal removal of coyotes during 2012–2013. The number of snares at each snare location varied depending on suitable land cover for snaring stations.

To collar calves traditional calving areas were searched by helicopter in late May and early June to locate caribou does with newborn calves. Once doe–calf pairs were located, the age of the calf was assessed from the helicopter; calves that were less than a few days old were preferred to minimize capture times. Calves were captured on foot and fitted with expandable, mortality-sensing VHF radio-collars (Advanced Telemetry Systems and Sirtrack collars). For more details on the methods of calf capture, see Lewis and Mahoney (2014).

Table 1. The number of collared neonate calves in each study area by period and predator manipulation method.

Predator Manipulation Method	**Study Area**	**Period**		
		Before	**Diversionary Feeding**	**Lethal Removal**
Treatment	Middle Ridge South	26	42	52
Controls	Middle Ridge North	57	47	54
	La Poile/Northern Peninsula	136	73[a]	49[b]

[a] Calves collared in the Northern Peninsula in 2010 were censored from further analyses (Lewis and Mahoney 2014) because of a large number of collar malfunctions and inclement weather that delayed collaring, resulting in many large calves that could bias results.

[b] Animals were not collared in these areas in 2013.

Determination of caribou fate and the cause of mortality

Calf fate is a more general term applied to whether a calf was alive, lost its collar, died because of a variety of causes, or could not be determined. Mortality indicates that the animal died because of predation, an accident, natural causes (e.g., disease, starvation, orphaned), or unknown causes.

Newborn calves were collared and monitored in the study area and control areas to determine whether the treatments were changing calf survival.

Several methods were employed to assess calf fate and cause of mortality. First, a standardized field investigation of the calf remains and field site was conducted. Calf remains were examined for indicators of the cause of mortality. When predation was the cause of death, indicators of predator species, such as the location and type of wounds and handling techniques, presence of predator tracks, hair, and (or) feces, were recorded. A general search of the field sites was conducted to obtain additional evidence for cause of mortality within at least a 30 m radius of the carcass. Second, when sufficient calf remains were available, these were forwarded to a veterinarian for independent necropsy and evaluation (see George et al. (2008)). Finally, beginning in 2010, sterile cotton swabs were used to sample hemorrhaged and non-hemorrhaged wounds for residual predator DNA from saliva. Samples were genetically analyzed to determine the predator species, individual, and sex (Mumma et al. 2014). Individual calf fates were assessed collectively by experienced SDSS staff, and the most likely predator was chosen based on the weight of the field, necropsy, and genetic evidence. For full details of these methods, see Lewis and Mahoney (2014).

Predator capture and handling

Black bears (n = 18) were collared as part of the *Caribou Strategy* in MR North (control area) and South (experimental area) over the period of 2008 and 2009 (see Fifield et al. (2013)

for full details). These collared animals were used to determine the influence of diversionary feeding on black bear spatial ecology, i.e., would the black bears move less and concentrate their foraging on and around the bait stations?

The sample size of collared black bears used to test the effects of diversionary feeding on predator spatial ecology suffered because some black bears did not utilize the diversionary feeding grid, some were shot by hunters or died of other causes, or there were collar malfunctions.

Data analysis

Calf survival

Calf survival was calculated using the Nest Survival Model within Program MARK (White and Burnham 1999, Dinsmore et al. 2002, Rotella et al. 2004). This method is appropriate for telemetry studies where the interval between monitoring surveys varies (Lewis and Mahoney 2014). The information-theoretic approach was employed with Akaike's Information Criterion (AIC) corrected for small sample sizes and AIC weights (Burnham and Anderson 2002) to evaluate multiple models of survival.

To assess the influence of predator manipulation over time, two model sets were developed. The first model set was for 70 days, approximately the period after which most calves leave the calving area and during which most of the predator-caused mortality occurs (Lewis and Mahoney 2014). The second model set was for 6 months (i.e., 182 days). This second model set was employed to determine whether the effect of predator manipulation on calf survival lasted beyond the treatment period and whether compensatory mortality occurred post-treatment after the calves had left the calving ground.

For each model set the global model for survival was a BACI model with the following variables. Time had three levels: the Before period, the Diversionary Feeding period, and the Lethal Removal period. Years within each time period were pooled to increase the sample size and improve the ability to detect an experimental treatment effect. Treatment (Treat) had three levels: the control areas consisting of La Poile and the Northern Peninsula, a second control area, MR North, and a treatment area, MR South. La Poile and the Northern Peninsula were pooled to increase sample sizes but MR North was kept separate to control for any influence of the predator manipulation treatment in MR South. In addition, there was an intercept (Int) and an interaction between Time and Treatment (Time*Treat) in the global model. The variable "Date" was added to account for non-constant survival in caribou calves (Lewis and Mahoney 2014). Date was defined in the analysis as the time interval divided into periods of survival, based on the number of days when 25% of the calves died. In addition, each model set included subsets of the global model (see Results, Table 2). However, we did not consider the "Treatment only" model because the treatment variable was strongly confounded with the study area, i.e., the study areas were not randomly chosen and MR South had very low calf survival relative to the other study areas in the first two time periods. Therefore, this model was not informative.

Bait consumption in relation to land cover

Observations in the field suggested that consumption of bakery waste was highly variable across the diversionary feeding grid and could be related to land cover type. To assess the effect of land cover type on the consumption of bait by black bears, we used an ecological land cover classification at a resolution of 30 m per pixel (Integrated Informatics, Inc. 2013; Figure 5, Appendix 1). Bait stations were placed in open land cover types because the helicopter could not land in dense forest, and therefore, all bait stations were placed in conifer scrub, lichen heathland, wetlands, or aquatic wetlands (i.e., wetlands saturated with water). The influence of land cover type on bait consumption was examined at two descriptive levels: 1) all land cover types individually and 2) land cover types grouped as either open (i.e., lichen heathland, wetlands, and aquatic wetlands) or forest (i.e., conifer scrub).

Further, selection of land cover by black bears can occur at multiple spatial scales (Obbard et al. 2010). Black bears generally prefer forested land cover (Obbard et al. 2010); the amount of bait consumed was therefore modeled in relation to the proportion of forest (including conifer forest, conifer scrub, mixedwood forest, or broadleaf forest) within the given distance of the bait station for the 100, 500, and 1000 m scales. The proportion of forest was calculated using the Zonal Histogram tool in ArcGIS 10.0.

The effect of land cover type and year (and their interaction) on bait consumption was investigated using linear mixed effects models (Pinheiro and Bates 2000) as implemented in the *nlme* package (Pinheiro et al. 2013) using the statistical language *R* (R Core Team 2012). Individual bait stations were included as a random intercept in all models to account for repeated samples that would otherwise invalidate model assumptions and constitute pseudo-replication. Assumptions of the model were tested and ameliorated using appropriate methods for mixed models (see Zuur et al. 2009 and Fifield et al. 2013).

Influence of diversionary feeding on predator spatial ecology

Home range size and daily movement rates of black bears during the study period were calculated and compared both before (2008–2009) and during diversionary feeding (2010–2011) and between treatment and control areas to determine whether diversionary feeding altered the spatial ecology of these animals. Home range size and daily movement rates were calculated in ArcView 3x using the Animal Movement extension. All home ranges were generated using a 95% kernel density estimate and accepting all defaults. The movement patterns of black bears were mapped and qualitatively compared between the Before period and Diversionary Feeding periods as well as between treatment and control areas.

Coyotes rarely visited either bait type (see Results), and therefore, we did not calculate home range sizes or daily movement rates for this study. For full details on the spatial ecology of black bears and coyotes, see Fifield et al. (2013).

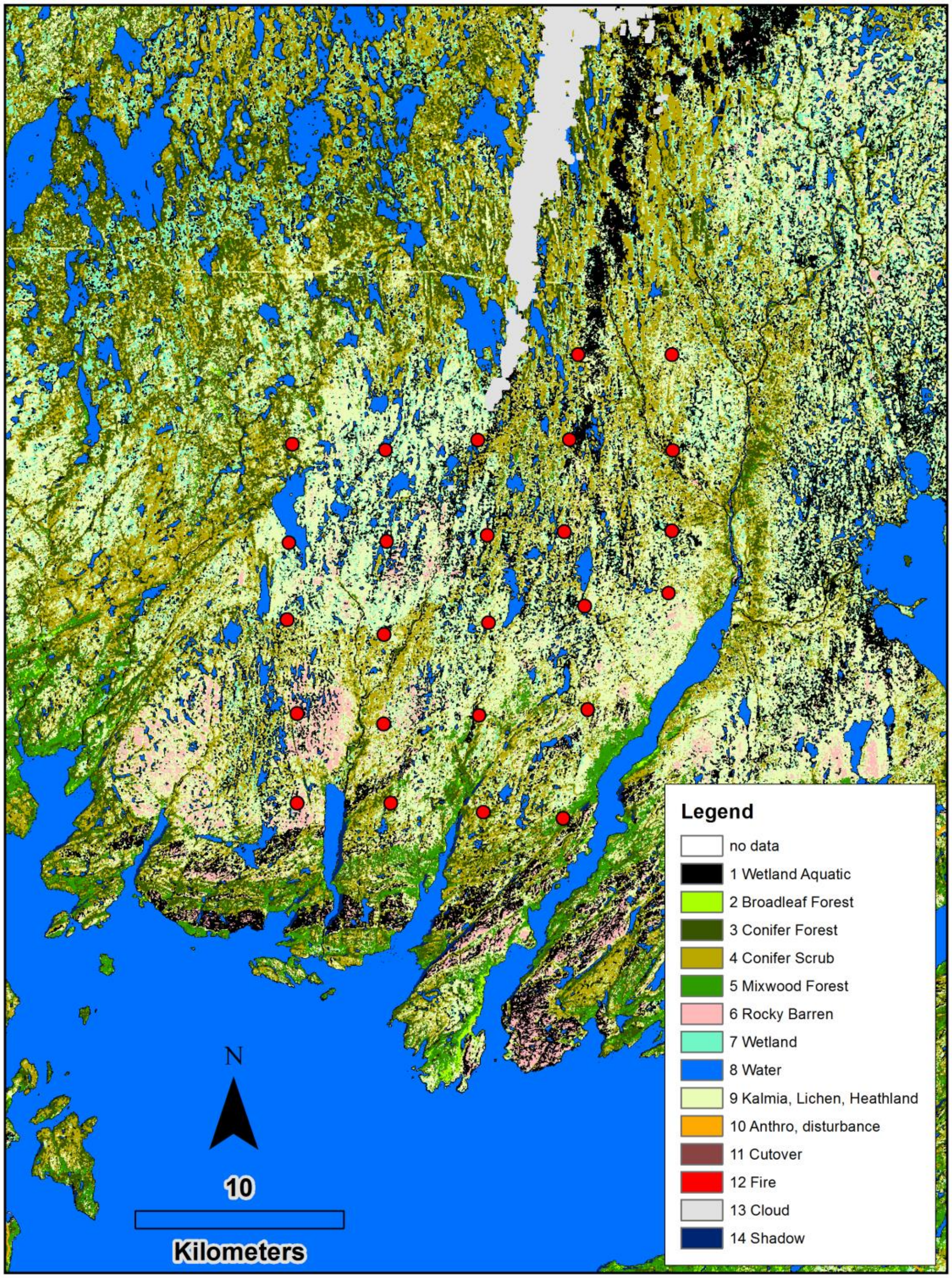


Figure 5. The land cover classification within the grid of the Middle Ridge South study area for the diversionary feeding period. Red circles show locations of bakery waste bait stations. See Appendix 1 for a description of the land cover types.

Results

Predator manipulation

Diversionary feeding

The total amount of bakery waste consumed was approximately 11,700 kg in 2010 and 16,800 kg in 2011. The amount of bait consumed varied greatly among bait stations and between years ranging from no consumption for some bait stations to over 2500 kg at others (Figure 6A & B). Most of the bait was consumed on the northern and southeastern bait stations of the grid in both years. Beaver carcasses were consumed at all bait stations. Approximately 539 beaver carcasses were consumed (3.5 ± 2.6 per station) in 2011.

Black bears utilized bakery waste in both years. One or more black bears, often sows with cubs, were observed at bakery waste bait stations in 502 videos in 2010 and 670 videos in 2011. Other species were observed at the bakery waste but only Common Raven (*Corvus corax* — 138 and 150 videos in 2010 and 2011, respectively) and snowshoe hare (*Lepus americanus* — 21 and 32 videos in 2010 and 2011, respectively) were observed more than five times. In 2011, black bears were observed at beaver carcass bait stations in 348 videos while coyotes were observed around these stations in only three videos. In all cases, coyote remained near the beaver carcass bait station very briefly and did not consume any of the bait. Bald Eagles and Common Ravens were observed at beaver carcass bait stations on 469 and 292 videos, respectively, while red fox were observed on only eight videos.

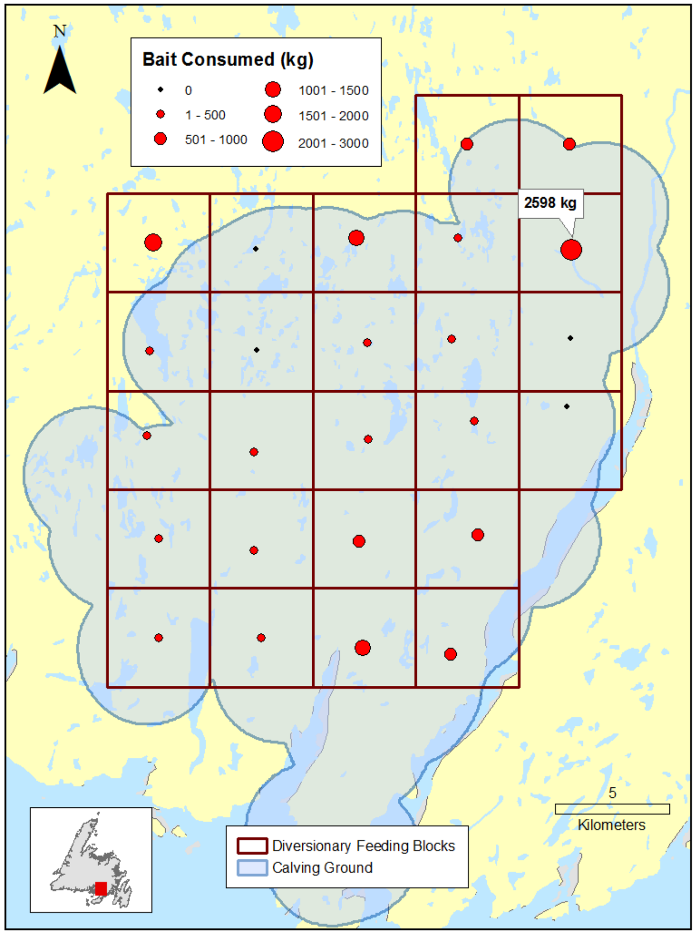
Coyote removal

In 2012, 11 male and five female coyotes (n = 16) were removed over 24,498.5 trap nights (0.00065 coyotes per trap night), whereas in 2013, 17 male and seven female coyotes (n = 24) were removed over 52,221.5 trap nights (0.00046 coyotes per trap night).

Calf survival

A comparison of the models examining calf survival rates for 70 days and 182 days are presented in Table 2A & B, respectively. For both model sets, the global model (1) was the model with the most support. Under the global model, there was almost no change in calf survival rates in the control areas over the 6-year period, i.e., these study areas were good controls, but there was a substantial increase in calf survival rates for the treatment area (Figure 7). The confidence intervals for MR South do not overlap between the Before and Lethal Removal periods indicating a difference in survival rates between these periods. Further, for both model sets during the Before period, the confidence intervals for the survival rates at MR South do not overlap the other study areas but do overlap during the Lethal Removal phase. These results suggest that changes in calf survival rates in MR South may be due to the treatment effect. The confidence intervals for the Diversionary Feeding treatment for MR South increase but broadly overlap indicating a modest improvement due to this treatment.

A)



B)

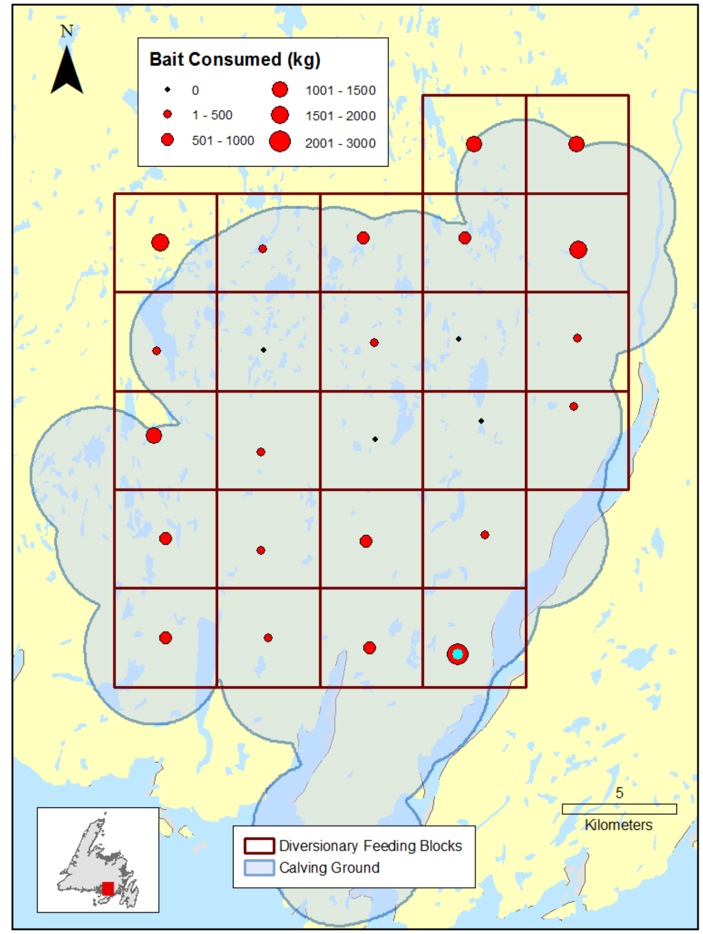


Figure 6. Approximate consumption of bakery waste, primarily by black bears, at each bakery waste bait station in A) 2010 and B) 2011.

Table 2. Model selection summary of the Before-After-Control-Impact (BACI) analysis of neonate calf survival to A) 70 days and B) 182 days[1]. Int = Intercept, Treat = Treatment (i.e., control or treatment area), and Time = Time period (i.e., Before treatment, Diversionary Feeding, or Lethal Removal).

A) 70 days

Model Number	**Model**	**AIC_c[a]**	**ΔAIC_c[b]**	**ω_i[c]**	**Likelihood[d]**	**K[e]**	**Deviance**
1	Int+Treat+Time + Treat*Time	1834.60	0.00	0.83	1.00	10	1814.6
2	Int+Treat+Time	1837.77	3.17	0.17	0.20	6	1825.8
3	Int+Date	1865.48	30.89	<0.01	<0.01	2	1861.5
4	Int+Time	1868.56	33.97	<0.01	<0.01	4	1860.6
5	Int	1946.55	111.96	<0.01	<0.01	1	1944.6

B) 182 days

Model Number	**Model**	**AIC_c[a]**	**ΔAIC_c[b]**	**ω_i[c]**	**Likelihood[d]**	**K[e]**	**Deviance**
1	Int+Treat+Time + Treat*Time	2151.07	0.00	0.54	1.00	10	2131.1
2	Int+Treat+Time	2151.41	0.34	0.46	0.84	6	2139.4
3	Int+Date	2176.53	25.46	0.00	0.00	2	2172.5
4	Int+Time	2177.30	26.23	0.00	0.00	4	2169.3
5	Int	2411.69	260.62	0.00	0.00	1	2409.7

[a] Akaike's Information Criterion adjusted for small sample size. The AIC_c is a measure of the balance between how well the model fits the data (deviance) with the complexity of the model (K). Lower scores are considered better models and are ranked as such.

[b] The AIC differences are the differences between each model and the one with the lowest AIC score. The ΔAIC_c indicates how plausible the model is compared with the most supported model ($\Delta AIC_c < 2$ = substantial support, 4–7 = considerably less support, and > 10 = essentially no support (Burnham and Anderson 2002).

[c] AIC weight indicates the weight of evidence of a given model being the best model. Values sum to 1 with larger values indicating a greater strength of evidence. These values are used to measure model support and are presented in the text.

[d] ω_i for model of interest / ω_i of the best model. The value represents the strength of evidence of the model compared with the other models. Values range from 0 to 1; larger values indicate a greater strength of evidence.

[e] The number of parameters in the model.

[1] The term 'Date' is not shown but was included in all models except the 'Int' model.

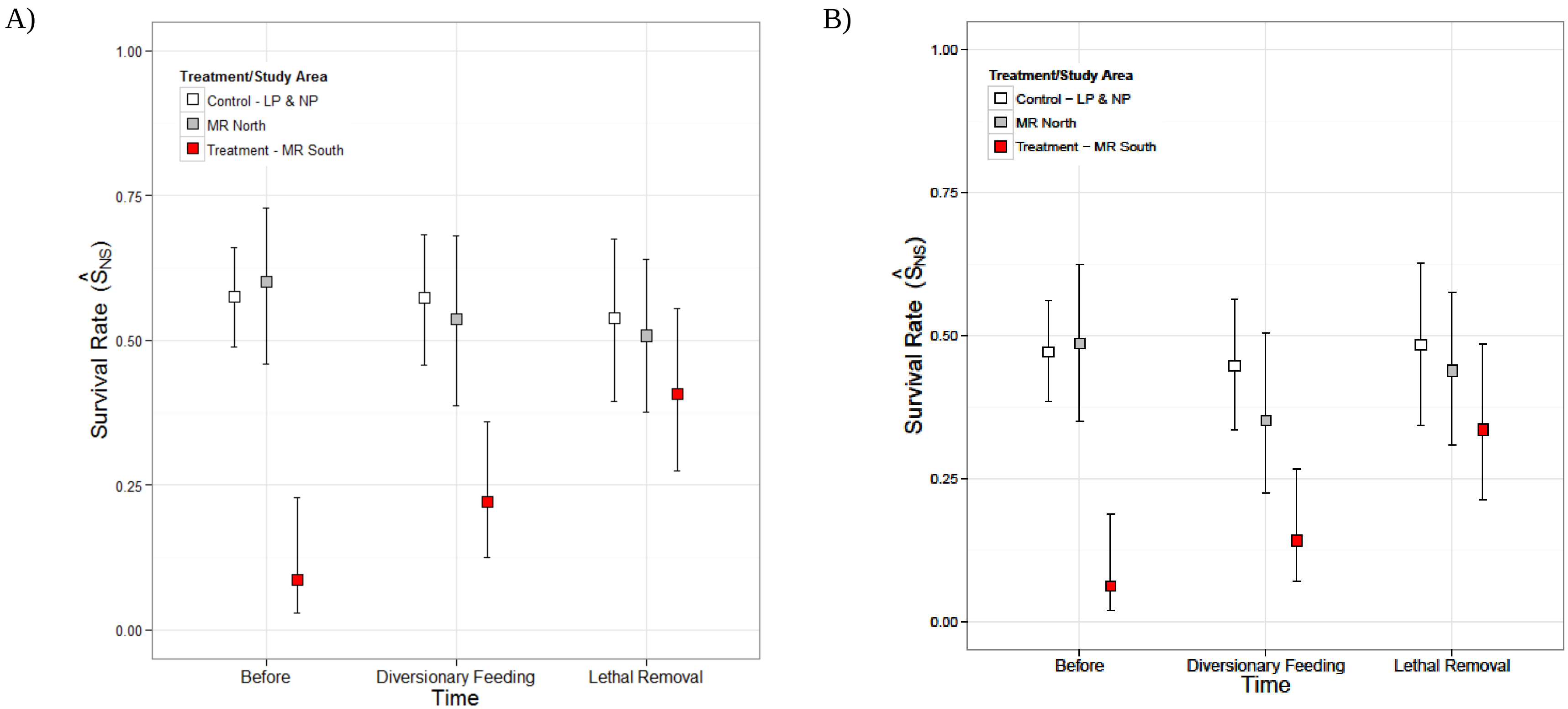


Figure 7. Estimated survival rates (±95% CI) of neonate calves from 2008 to 2013 during the Before, Diversionary Feeding, and Lethal Removal time periods for La Poile (LP) and the Northern Peninsula (NP) combined, Middle Ridge North (MR North), and Middle Ridge South (MR South) for up to A) 70 days for Model 1 (Table 2A) and B) 182 days for Model 1 (Table 2B). See Appendix 2 for values of estimates and CIs.

There was a moderate level of support for the Treatment + Time model (2) for the 70 day model set but substantial support for the 182 day model set. An examination of the logit link function parameters, i.e., the beta values, for the 182 day version of this model suggests that, as expected, there is a strong study area effect. In both model sets, there was almost no support for a model with constant survival across treatment/study area and time periods (3), a time only model (4), or a constant survival model (5).

Calf fate and mortality

Trends in calf fate and cause of mortality are more generally discussed in Lewis and Mahoney (2014) but predation was the leading cause of mortality for collared caribou calves during this study. A greater percentage of calves was predated in MR South than in the control areas during the Before and Diversionary Feeding time periods (Figure 8, Figure 9). Only following lethal removal of coyotes did the percentage of calves predated in MR South diminish to approach those in the control areas.

The dominant predator varied by study area. Coyotes were the dominant predator in MR South, while black bear was dominant in MR North and La Poile/Northern Peninsula during the Lethal Removal time period. Consistent with expectations, the percentage of calves predated by black bear and coyote in MR South declined during the Diversionary Feeding and Lethal Removal periods, respectively, but there was no similar pattern in the controls areas (Figure 8, Figure 9).

Secondary analyses

Bait consumption in relation to land cover

Variation in the amount of bait consumed at individual bait stations was large but there was a significant difference in bait consumption among land cover types at the scale of the bait station ($F_{3,21}$ = 4.06, p = 0.02). The bait stations in wetlands and aquatic wetlands appeared to have higher amounts of consumption than the other habitat types (Figure 10A). There was no significant difference between bait consumed in open vs. forest land cover types ($F_{1,23}$ = 0.126, p = 0.73; Figure 10B) at the bait station scale despite the large difference in the median values.

The effect of "Proportion Forested" on bait consumption was not significant at 100 m ($F_{1,23}$ = 4.04, p = 0.056; Figure 11A). The effect of "Proportion Forested" was weakly significant at 500 m ($F_{1,23}$ = 5.84, p = 0.024; Figure 11B) and at 1000 m ($F_{1,23}$ = 4.68, p = 0.041; Figure 11C).

A)

B)

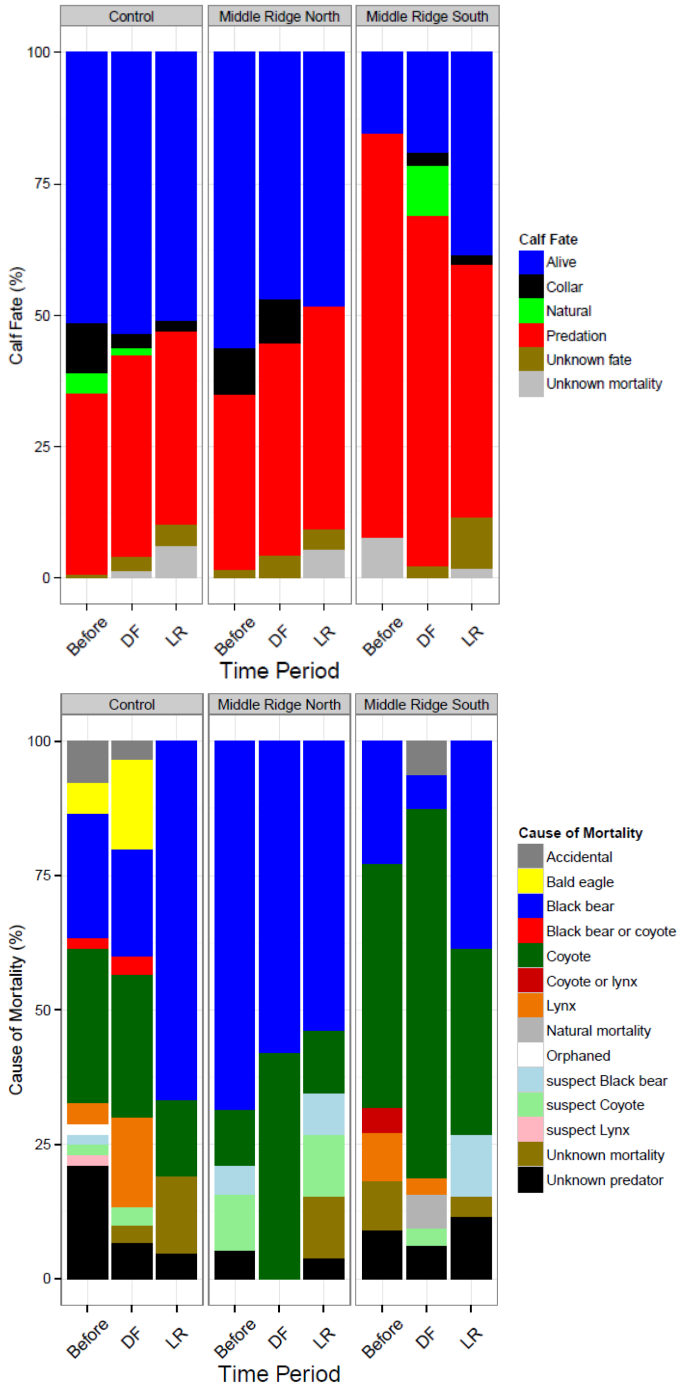


Figure 8. A) Fate and B) cause of death of neonate calves to 70 days by time period (DF = Diversionary Feeding and LR = Lethal Removal) in the different study areas (Control = La Poile and the Northern Peninsula) during the predator manipulation study (see Appendix 3 for data).

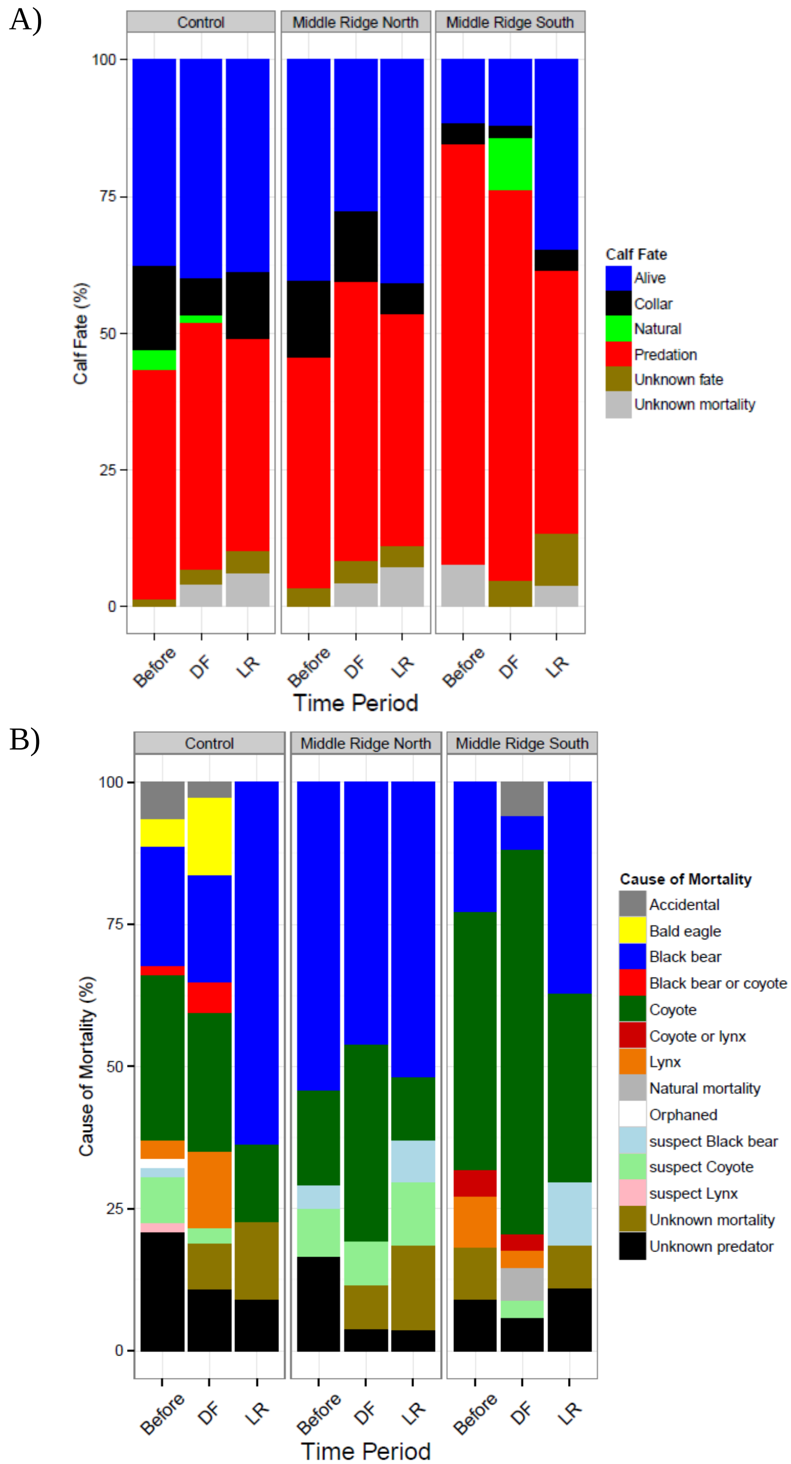
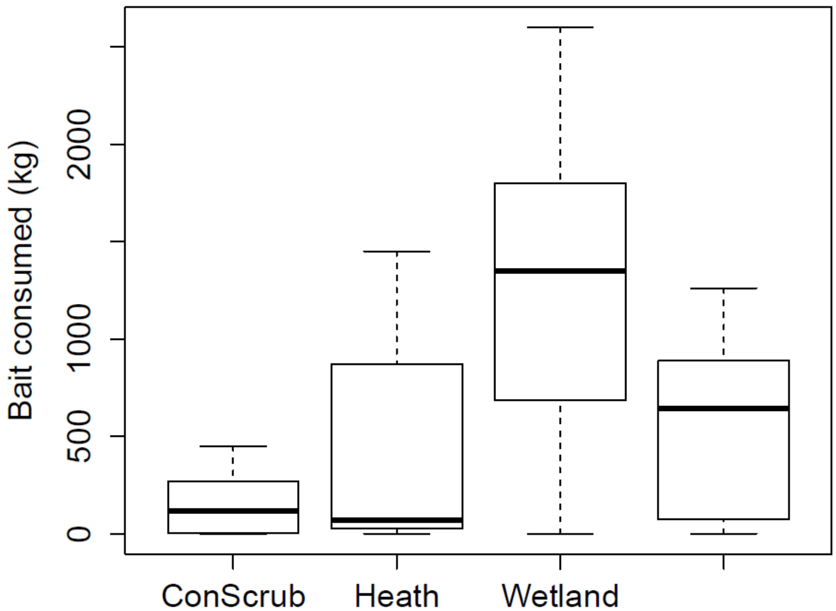


Figure 9. A) Fate and B) cause of death of neonate calves to 182 days by time period (DF = Diversionary feeding and LR = Lethal Removal) in the different study areas (Control = La Poile and the Northern Peninsula) during the predator manipulation study (see Appendix 3 for data).

A)



B)

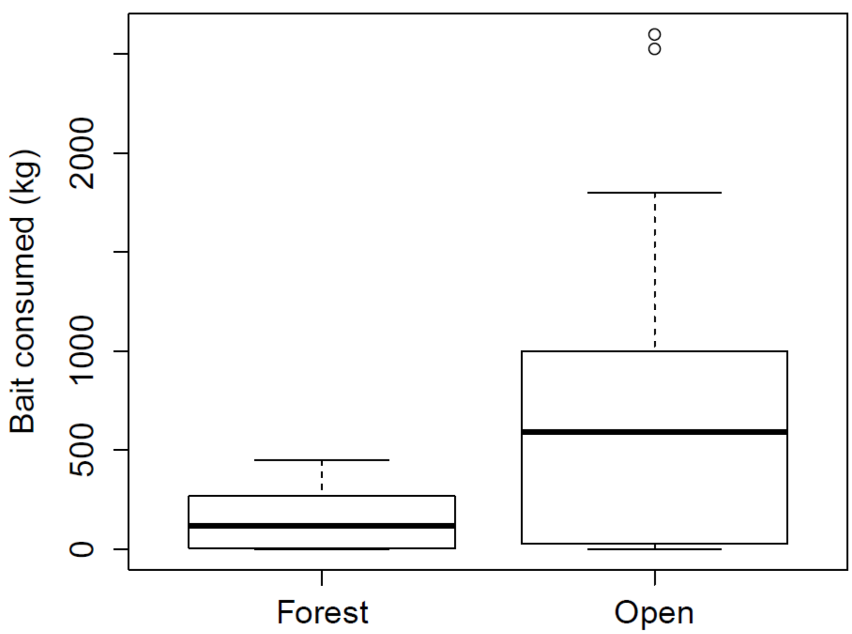


Figure 10. Bait consumed in relation to land cover at bait station locations (point scale) for A) separate and B) forested (i.e., conifer scrub) and open (i.e., conifer scrub, wetland, and aquatic wetland) land cover types. ConScrub = conifer scrub, Heath = heathland, and WetlandAq = aquatic wetlands.

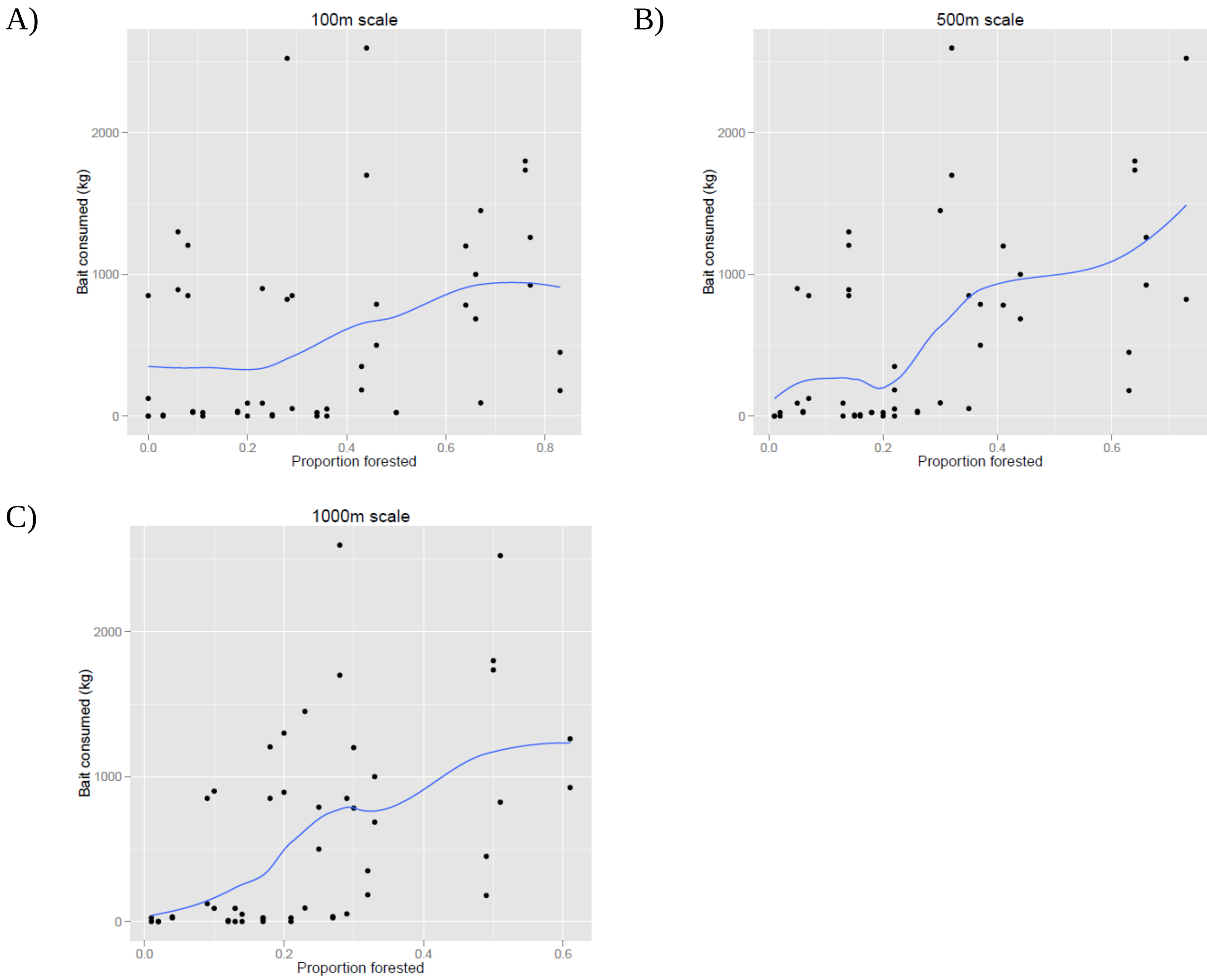


Figure 11. Bait consumed in relation to proportion of pixels forested within A) 100 m, B) 500 m, and C) 1000 m of bait stations. The blue line is a LOESS (locally weighted scatterplot smoothing) smoothing curve.

Influence of diversionary feeding on predator spatial ecology

There were three collared black bears on or near the diversionary feeding grid in 2009 (Before) and 2010 (Treatment) and five in Middle Ridge North. None of the collared bears utilized the diversionary feeding grid in 2011.

One of the three black bears (MR0806) was present in MR South for part of 2009, but most of the home range was east of the diversionary feeding grid for the summer of 2010 and therefore could not be used in this analysis. The two other bears had considerably larger home ranges in 2009 during the Before period than they did during the Diversionary Feeding period in 2010 (Figure 12; 365.4 and 494.2 km^2 vs. 93.8 and 249.7 km^2 for 2009 and 2010, respectively). For MR North, home range size averaged 448 ± 154 km^2 (±SD) in 2009 but increased to 672 ± 438 km^2 (±SD) in 2010.

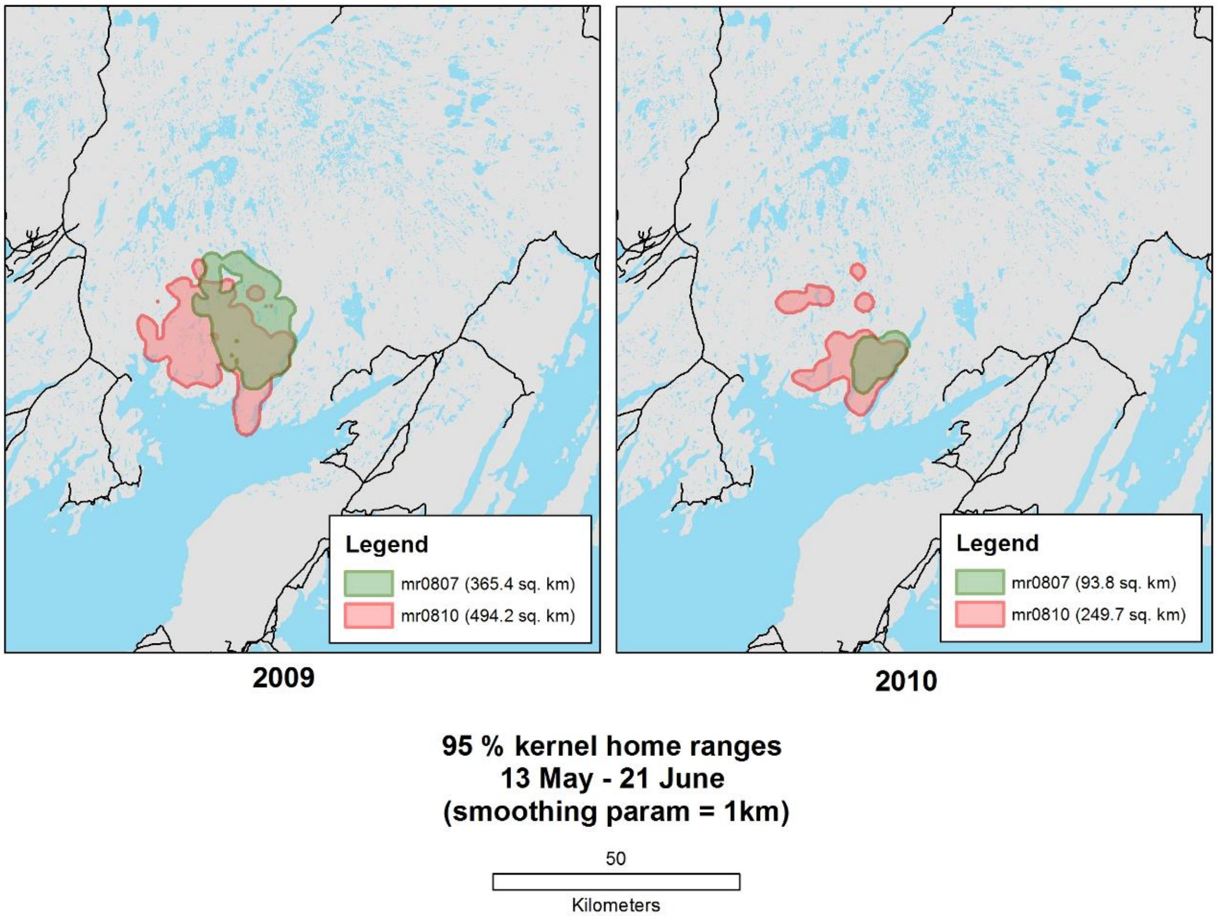


Figure 12. Two black bears' home ranges in Middle Ridge South based on 95% kernel estimates for 2009 (Before) and 2010 (Diversionary Feeding treatment).

For both black bears in MR South, daily movement rates decreased considerably during the Diversionary Feeding period. The daily movement rate was 12.0 and 11.9 km/day in 2009 (Before period) and 8.7 and 5.1 km/day in summer 2010 (Diversionary Feeding period). Bears in MR North showed considerable variation in daily movement rates between years, ranging from 2.6 to 12 km/day. The average movement rate for the five collared MR North bears was 9.0 km/day in 2009 and 8.0 km/day in 2010, a far less dramatic change compared with black bear movement rates in MR South.

Movement patterns of black bears in MR South during the Diversionary Feeding period also differed greatly from their movement patterns during the Before period (Figure 13A & B) and compared with bears in control areas.

A) B)

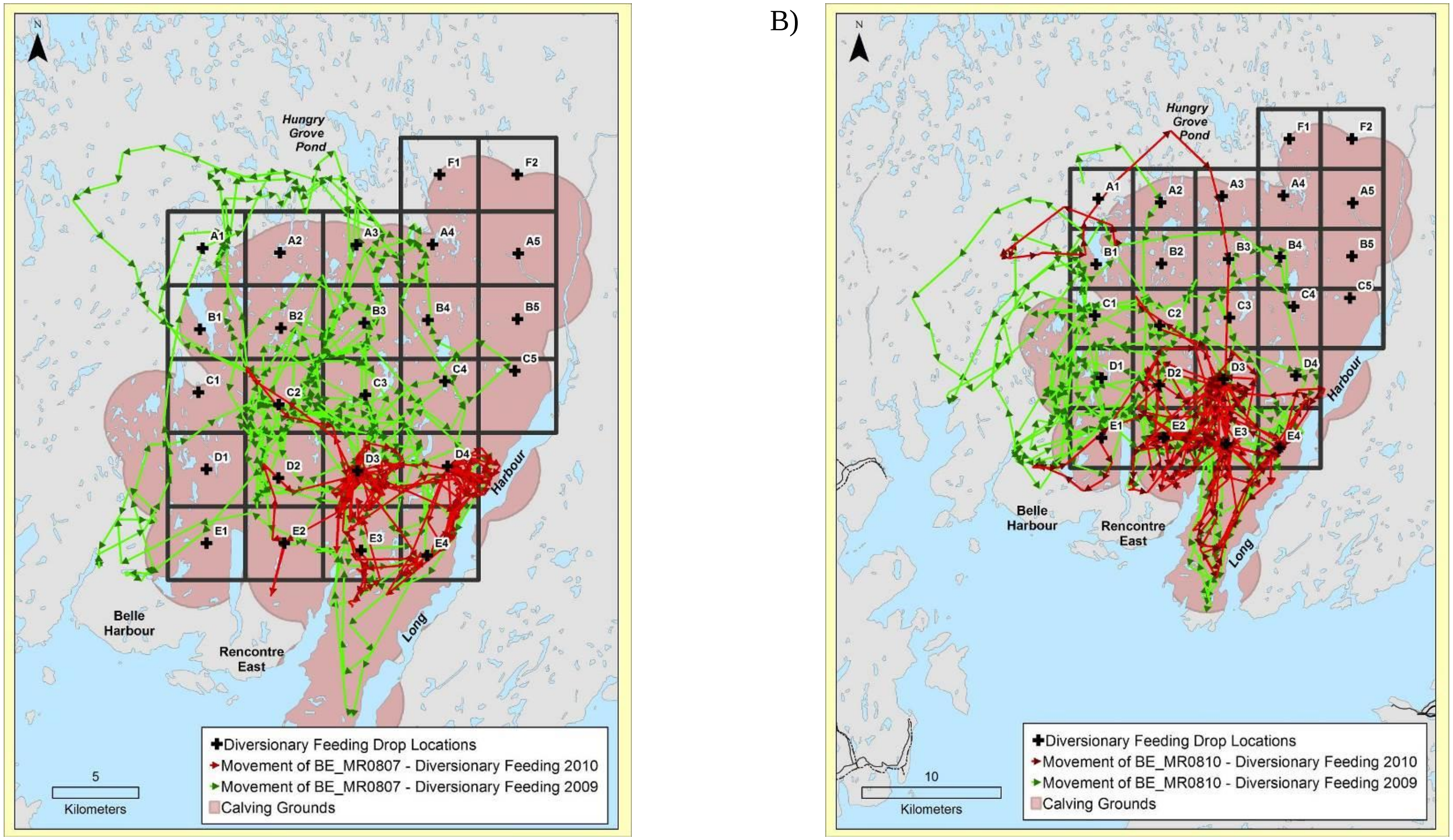


Figure 13. An example of the movements of bear A) MR0807 and B) MR0810 in Middle Ridge South. The tracks for 2009 (green), the Before period, are compared with 2010 (red), the Diversionary Feeding period, where the movements are mainly around four bait stations in the southeastern corner of the grid. The Before movement patterns were similar to those in Middle Ridge North.

Discussion

The primary goal of both predator manipulation treatments was to determine whether caribou calf survival could be improved by providing predators with an alternative food source during the calving/post-calving periods or by removing coyotes from the landscape altogether. Diversionary feeding of black bears and coyotes was associated with a small improvement in calf survival. Lethal removal of coyotes was associated with a more striking increase in calf survival, i.e., removing coyotes likely improved the proportion of caribou calves that survived through the summer and to 6 months of age.

Diversionary feeding

The experimental diversionary feeding of predators was the first of its kind in Newfoundland. Black bears were attracted to and consumed large amounts of bakery waste and beaver carcasses, but coyotes were attracted to neither. While we did not quantify how much bait was consumed by different species or the number of individuals that visited a bait station, the frequency with which black bears were observed on the videos, and the size difference between black bears and other observed species suggests that virtually all of the bakery waste, and a great deal of the beaver bait, was consumed by black bears. Consistent with the intent of diversionary feeding, black bear home range sizes and movement patterns were greatly altered (Figure 12, Figure 13) and the percentage of calf predation due to black bears decreased, although the absolute difference was small (Figure 8, Figure 9). Most importantly, calf survival improved as expected but to a limited degree (Table 2, Figure 7, Appendix 2).

The results of this study were surprising given that in three Alaskan studies, provision of road-killed moose successfully reduced predation on moose (*Alces alces)* calves by gray wolf (*Canis lupus*), brown bear (*Ursus arctos*), and black bear (National Research Council 1997). The results of this study may differ from the Alaskan studies for several reasons. First, although the intention was to divert both black bear and coyote, the effective treatment of only black bears could have led to compensatory mortality, i.e., as predation by bears decreased, predation by coyotes increased. Second, although black bears were seemingly diverted to bait stations (but see Secondary analyses below), it does not necessarily preclude predation on caribou calves by black bears. Finally, the percentage of calf predation by black bears in MR South was lower than in other study areas (Lewis and Mahoney 2014). Perhaps if this experiment was attempted in an area with higher black bear predation, the likelihood of improving calf survival would have increased. Insufficient bait has been cited as a reason for diversionary feeding trials to be unsuccessful (Soulliere et al. 2014), but we believe this is unlikely for this study.

It is unknown why coyotes did not utilize the beaver carcasses, but there are several possibilities: 1) alternative food sources were available to coyotes including caribou calves, snowshoe hares, and small mammals, and these food sources could be preferred over beaver carcasses, 2) coyotes may have detected human scent or presence around or on the beaver bait piles although precautions were taken to avoid these issues (see Methods), or 3) black bears displaced coyotes from bait stations. Other bait material, such as moose, may be more effective for diverting coyotes. Given the lack of response by coyotes to diversionary feeding, this treatment was discontinued.

Coyote lethal removal

This was the first lethal removal experiment on coyotes in Newfoundland and one of few removal studies on animals other than wolves and bears in northwestern North America. This is also the only study to our knowledge to obtain absolute estimates of predator density (National Research Council 1997, Soulliere et al. 2014). Density is a critical but often ignored aspect of predator removal studies. Density is required to calibrate effort and the success of the predator removals, i.e., that change in prey survival can be attributed to an experimental reduction in predator density. Similar to other successful predator removal studies (Soulliere et al. 2014) we believe that a large percentage of the local coyote population was removed in our experiment. Estimates of coyote density in 2011 were 0.02 coyotes/km (Fifield and Lewis 2013), which equates to 11.6 coyotes in MR South. That the number of coyotes taken in 2012 (16 coyotes) exceeds the estimated number suggests that density was underestimated (Fifield and Lewis 2013 but see next paragraph). However, this result, combined with the failure to obtain sufficient samples to estimate density in 2012, suggests that a large percentage of the coyote population was removed prior to calving in both years. Sampling to estimate coyote density was not attempted in 2013 for budgetary reasons.

The increase in the number of coyotes snared from 2012 to 2013 suggests that a large percentage of the coyotes in MR South may have been replaced by immigration to the study area between 2012 and 2013. Fifield et al. (2013) showed that about one quarter of the Newfoundland coyote population is transient, that these coyotes can cross the island in a few weeks, and that resident coyotes have very large home ranges compared with other jurisdictions. These results are similar to Bergerud and Elliot (1998) who found wolves quickly recolonized areas following lethal removal. Collectively, these studies suggest that to relieve predation pressure on caribou calves, removal of these canid predators must occur regularly and over a large enough spatial extent to limit immigration.

After the reduction of coyote numbers in 2012, calf survival rates improved, and after additional coyote removal in 2013, survival rates improved further and became comparable with those in the control study areas for the first time since 2004 (Appendix 2) suggesting that the coyote removal may have improved caribou calf survival in MR South (Figure 7). These results are similar to an experiment in Middle Ridge and Pot Hill as well as on the Avalon herd in the 1960s, in which lynx were lethally removed from both calving grounds in an attempt to improve calf survival (Bergerud 1971). At that time, evidence suggested that lynx were the dominant predator on caribou calves. Following removal, calf survival was 85% in Middle Ridge where lynx were removed and 49% in Pot Hill, i.e., the control area. On the Avalon, in the year prior to removal, calf survival was 27% and then 85% following lynx removal. These results were also similar to many other removal studies that have shown a short-term improvement in ungulate survival or recruitment rates after predator removal (Soulliere et al. 2014).

However, the results of this experiment may have been influenced by the location of the treatment area. MR South may be a particularly suitable location for improving calf survival by removing coyotes. Coyotes were the dominant predator there, unlike on some other calving grounds (Lewis and Mahoney 2014). The efficiency of predator removal efforts in MR South, but especially other calving grounds where coyote are not the dominant predator, could likely be improved by expanding the removal program to include other species such as black bears and employing more targeted removal approaches. For example, non-lethal removal methods such as translocation of black bears has increased elk (*Cervus elaphus*) recruitment (Yarkovich et al. 2011) and this method could be employed in addition to a lethal removal program. Alternately or in addition, an improved understanding of predator biology could improve predator removal efforts. Coyotes in this study were removed indiscriminately of age or behavior, but other studies have successfully decreased predation by targeting alpha coyotes that often specialize on certain prey (Blejwas et al. 2002, Jaeger 2004). Finally, further research could help determine the social structure of coyotes in Newfoundland and whether specific animals are caribou calf specialists.

Secondary analyses

There was a significant effect of land cover on bait consumption, largely because bait consumption was high in wetlands and aquatic wetlands compared with conifer scrub and lichen heathland (Figure 10). This is contrary to studies that have shown black bears prefer forested land cover (Day 1997, Carter et al. 2010) and the multi-scale analysis that showed bait consumption generally increased with proximity to forested area (Figure 11). However, upon closer inspection, many of the wetlands were small in size and surrounded by other land covers, i.e., forested land cover. Collectively, these results and the spatial variation in bait consumption (Figure 5, Figure 6) suggest that placing diversionary food in open areas will attract predators as long as there is an adequate amount of preferred land cover in close proximity, i.e., future diversionary feeding efforts should take into account the habitat preferences of the target species.

Diversionary feeding appeared to induce measurable changes in black bear home range size, daily movement rates, and movement patterns although our conclusions are tenuous given the small sample size (Figure 12, Figure 13 — see next section). The provision of a large supply of bakery waste likely met most of the caloric needs of the black bears that utilized the bait stations during the Diversionary Feeding period, presumably reducing their inclination to search for other foods such as caribou calves. Although we could not determine to what extent black bears that utilized the bait stations also foraged on other food sources, these changes in black bear spatial ecology may have had some influence on calf survival by reducing the likelihood of predatory encounters with caribou.

Limitations of the study

In addition to the above concerns over the unique attributes of MR South, many studies of predator manipulation, or any large-scale environmental study, suffer from similar problems in that they can achieve only partial control over confounding factors, i.e., the limitations of quasi-experimental designs are well known (Kamil 1989). For example, although there are broad similarities between La Poile and MR South as well as the Northern Peninsula and MR North, these study areas differ in many ways that cannot be controlled for. However, we believe that these differences among study areas have a minimal impact on the overall study because many demographic and morphological variables appear to change synchronously over time among Newfoundland caribou herds (Mahoney et al. 2014a, b). Further, predator manipulations are expensive, and even for well-funded studies, such as the *Caribou Strategy*, it is a challenge to conduct these experiments in multiple treatment areas. Yet, this study did have multiple control areas that were monitored continually over the study period that makes this study design superior to many other studies of predator control that lack temporal or spatial replication (National Research Council 1997). Multiple treatment areas would have strengthened this study but at enormous financial cost, and another treatment herd would be problematic because of some or all of the following reasons: lack of baseline data, small herd size, herds located on off-shore islands are not comparable with the study areas, and spatial overlap with the three main study areas. In addition, as in many large-scale environmental studies, MR South was not chosen randomly and this inevitably resulted in a strong study area effect (Table 2). This action was deliberate for the reasons outlined in the Study area section and was done in consultation with a group of expert wildlife ecologists that advised the *Caribou Strategy* (i.e., the Academic Team). Finally, perhaps the most unfortunate flaw in this study, common to many predator removal studies, was the duration (National Research Council 1997). While there was adequate data for the baseline predator manipulation periods, there was no assessment of caribou calf survival after the cessation of the lethal removal. A decrease in survival rates in MR South and maintenance of constant survival in the control areas would have provided strong evidence that the observed changes were not a site effect. In conclusion, although there are limitations with funding cycles and quasi-experimental designs, we believe that, based on experience and a thorough literature review (Soulliere et al. 2014) and given the circumstances, the best possible study design was applied to the question at hand.

Issues of study design extend beyond the main study question. Estimating the absolute density of predators before and after manipulations is a critical and challenging aspect of predator manipulation experiments (National Research Council 1997, Peek et al. 2012). Studies that have successfully incorporated relative density estimates have usually involved wolves or coyotes, which can be easily measured by aerial observation or based on removal efforts, respectively. The former method was not possible for black bear and coyote and the latter method does not allow estimating density for the Before treatment periods thereby limiting the inference on the effect of this treatment. This study capitalized on the great advances that have been made in estimating density for these animals through noninvasive genetic sampling (Long et al. 2008, see Fifield and Lewis 2013. However, estimating density remains a challenge and estimates are often highly variable. Further, post-removal estimates were not possible because of the low number of samples, although perhaps this is an indication that the removal was effective. The conclusions of the secondary analyses suffer mainly from small sample size. The *Caribou Strategy* collared 95 black bears, 49 of which were in Middle Ridge, and 126 coyotes, 67 of which were in Middle Ridge. However, animals were often collared opportunistically in conjunction with other work, often do not remain in the study area, and suffer mortality or collar failure. Although we could only examine two black bears in MR South, given the amount of bait consumed and the large number of videos with black bears consuming bait, we believe that these results can be extrapolated to other black bears in the study area.

Conclusions and recommendations

This study showed that removing a single dominant predator can potentially increase caribou calf survival on a small calving ground that has experienced very high predation and that diversionary feeding by itself is unlikely to do so. However, given that compensatory predation may have occurred, an “all-out” approach, targeting coyote and black bears by removal, translocation, diversionary feeding, or some combination of these methods, may have been even more successful in improving calf survival rates (National Research Council 1997, Soulliere et al. 2014).

The results of this study suggest that removal efforts are only likely to be effective if supported by Government. Although we acknowledge that recreational hunters can remove large numbers of animals from the land, given the transitory nature of coyote in Newfoundland (Fifield et al. 2013), it is essential that hunters/trappers access the calving grounds in the period just before calving. Further, the effort required will likely tax even the most committed recreational hunter/trapper; over 50,000 trap nights and substantial air support were required to remove 24 coyotes. We suggest that the only way for a public removal effort to be effective is with substantial government support, perhaps by shooting predators near baits but that would likely be publicly controversial.

Predator manipulation in remote areas is very costly and these expenses are likely prohibitive for Government to consider on a large scale (e.g., island-wide), unless the island caribou population is faced with extinction or is endangered. The choice of which treatment to employ would depend on which predators are dominant in the area (i.e., whether it was primarily coyotes or bears that killed most calves in the past). Specifically, we suggest that lethal removal may be a useful management option under the following circumstances. First, caribou should be well aggregated on the calving grounds so that the removal effort has the maximum impact on predators for the greatest number of caribou. Second, the percentage of calves predated by black bears or coyotes is known to be high, which applies to many of the herds studied in Newfoundland (Lewis and Mahoney 2014). Third, the closer the calving grounds are to roads the less prohibitive costs associated with removing predators will be. Finally, a long-term (ca. 5 years) commitment to the predator manipulation effort is required since immigration can rapidly renew a local predator population.

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Appendix 1. Land cover classification scheme

Land cover within the study area was classified according to the scheme in Table A1-1 (Integrated Informatics, Inc. 2013).

Table A1-1. Land cover classification scheme for the study area for diversionary feeding trial.

Land cover type	Description
No data	Areas where no data was available.
Aquatic wetland	Characterized by open or ponded water. Dominated by aquatic and submerged vegetation such as yellow pond lily and rushes.
Broadleaf forest	Dominated by broadleaf trees namely white birch with a tree canopy of greater than 25% coverage. White birch is the dominant species within the broadleaf class.
Conifer forest	The dominant tree species is typically balsam fir or black spruce with a lesser amount of larch. Numerous ericaceous shrub species are found in this habitat type with sheep laurel, black spruce, or balsam fir being most common.
Conifer scrub	Plant species similar to the conifer forest but with poor growing conditions producing a stunted tree layer. This habitat is often found in the transition zone between conifer forest and lichen heathland. The sparsely defined tree layer is dominated by black spruce with minor amounts of mainly coniferous species and various ericaceous shrubs.
Mixedwood forest	Species-rich and may be transitional between conifer forest and broadleaf forest. Contains black spruce, balsam fir, and white birch with a shrub layer similar to that found in conifer forest.

Land cover type	Description
Rocky barren	Windswept with a thin layer that is composed of bedrock, exposed soil, stone, and boulders. The shrub layer is composed mainly of ericaceous shrubs. Ground cover consists of grasses, lichens, mosses, and smaller berry plants such as black crowberry.
Wetland	Composed predominantly of fens, bogs, and saturated soil. Tree layer is sparse to none; shrubs are sparse and dominated by ericaceous shrubs. The ground layer is composed of sphagnum moss, deergrass, and sedges.
Water	Includes lakes, reservoirs, rivers, and salt water.
Lichen heathland	A non-forested shrub-dominated habitat found on hummocky terrain and may have thin soils with exposed bedrock. Ericaceous shrubs dominate having relatively high percent cover values. Tree species are always stunted and rarely grow above the shrub layer. The herb layer, also species-rich, is nearly always dominated by ground lichen and, in particular, reindeer lichen.
Exposed earth or anthropogenic	Non-vegetated habitat area characterized by river sediments, exposed soil, pond or lake sediments, beaches, landings, mudflats, cutbacks, moraines, or other non-vegetated surfaces. Anthropogenic areas: clearings for human settlements, major transportation routes, or other areas associated with anthropogenic impact.
Cutover	Logged area generally in transition back to a forested state. It is the result of recent forest harvesting and is often found near the conifer forest and mixedwood forest habitat types. Site conditions are highly variable from wet to dry and from exposed to sheltered. The vegetation is also often highly variable, sometimes dominated by shrubs and at other times by herbs and grass species.

Land cover type	Description
Fire	Documented areas that have been impacted by forest fires since 2003.
Cloud cover	Areas where cloud cover made satellite-imagery-based classification impossible.
Shadow	Areas where hill (orthographic) shadow or cloud shadow made satellite-imagery-based classification impossible.

Appendix 2. Neonate caribou survival

Table A2-1. Estimated survival rate for neonate calves by study area from 2009 to 2013 for A) 70 days ($S_{NS\text{-}70days}$) and B) 182 days ($S_{NS\text{-}6months}$)[2]. SE = standard error of S, LL = lower 95% confidence interval, UL = upper 95% confidence interval, Treat = the control areas consisting of La Poile and the Northern Peninsula, a second control level, Middle Ridge North (MRN), and a treatment level, Middle Ridge South (MRS). Time has three levels: the Before period, the Diversionary Feeding period, and the Lethal Removal period. Years within each time period were pooled to increase the sample size and ability to detect an effect of the experimental treatment.

A)

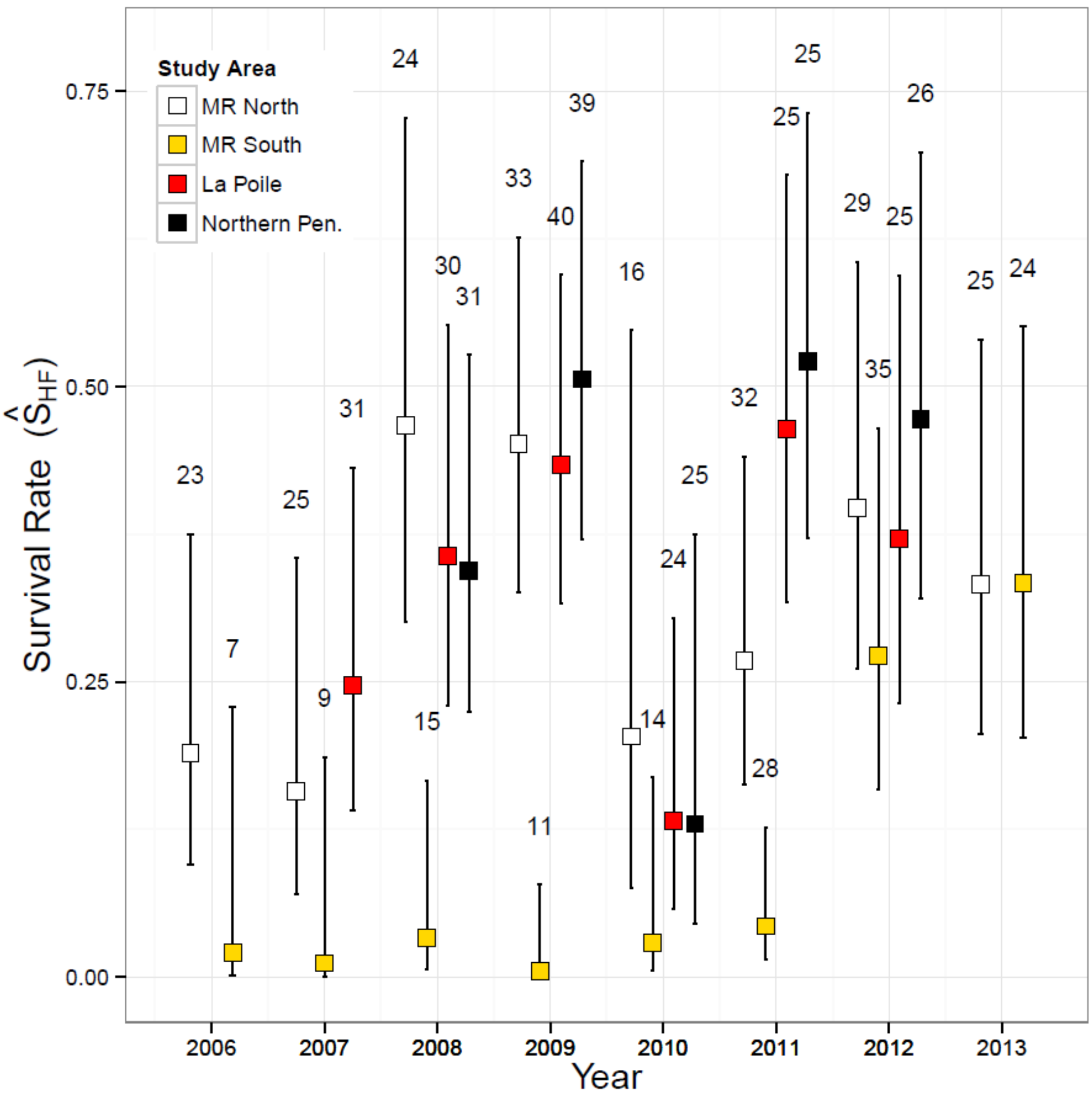
$S_{NS\text{-}70days}$	SE	LL	UL	Treat	Time
0.58	0.04	0.49	0.66	Control	Before
0.60	0.07	0.46	0.73	MRN	Before
0.09	0.05	0.03	0.23	MRS	Before
0.57	0.06	0.46	0.68	Control	Diversionary Feeding
0.54	0.08	0.39	0.68	MRN	Diversionary Feeding
0.22	0.06	0.13	0.36	MRS	Diversionary Feeding
0.54	0.07	0.40	0.67	Control	Lethal Removal
0.51	0.07	0.38	0.64	MRN	Lethal Removal
0.41	0.07	0.27	0.55	MRS	Lethal Removal

B)

$S_{NS\text{-}6months}$	SE	LL	UL	Treat	Time
0.47	0.05	0.38	0.56	Control	Before
0.49	0.07	0.35	0.62	MRN	Before
0.06	0.04	0.02	0.19	MRS	Before
0.45	0.06	0.33	0.56	Control	Diversionary Feeding
0.35	0.07	0.22	0.50	MRN	Diversionary Feeding
0.14	0.05	0.07	0.27	MRS	Diversionary Feeding
0.48	0.08	0.34	0.63	Control	Lethal Removal
0.44	0.07	0.31	0.58	MRN	Lethal Removal
0.34	0.07	0.21	0.49	MRS	Lethal Removal

[2] S = estimate of survival. NS = the estimate was generated using the Nest Survival Model (see Methods – Data analysis – Calf survival). 6months = the interval over which survival was estimated.

Figure A2-1. Estimated survival rates ($S_{HF\text{-}6month}$ ± 90% confidence interval (CI)) to 182 days for neonate calves by study area from 2003 to 2013 (see Lewis and Mahoney (2014) for details)[3]. Sample size per year is given above each CI.



[3] S = estimate of survival. HF = the estimates were generated using the simpler Heisey-Fuller method (but see Lewis and Mahoney 2014 for a comparison of these approaches). S = estimate of survival. 6months = the interval over which survival was estimated.

Appendix 3. Neonate caribou fate and cause of mortality

Table A3-1. Fate of neonate calves and cause of mortality to A) 70 days and B) 182 days for all study areas from 2008 to 2013.

A)

Year	Study area	Accidental	Alive	Bald eagle	Black bear	Black bear or coyote	Collar-slip	Coyote	Coyote or lynx	Lynx	Natural mortality	Orphaned	Suspect black bear	Suspect coyote	Suspect lynx	Unknown fate	Unknown mortality	Unknown predator
2008	La Poile	2	16	0	1	0	3	3	0	1	0	0	0	0	0	1	0	3
2008	Middle Ridge North	0	10	0	5	0	5	1	0	0	0	0	1	1	0	1	0	0
2008	Middle Ridge South	0	3	0	2	0	0	4	0	2	0	0	0	0	0	0	2	2
2008	Northern Peninsula	0	12	0	6	1	1	4	0	0	0	0	1	0	0	0	0	3
2009	La Poile	1	25	2	2	0	0	5	0	1	0	1	0	1	1	0	0	1
2009	Middle Ridge North	0	22	0	8	0	0	1	0	0	0	0	0	1	0	0	0	1
2009	Middle Ridge South	0	1	0	3	0	0	6	1	0	0	0	0	0	0	0	0	0
2009	Northern Peninsula	1	17	1	3	0	9	3	0	0	0	0	0	0	0	0	0	4
2010	La Poile	0	9	4	5	0	2	2	0	1	0	0	0	0	0	0	1	0
2010	Middle Ridge North	0	5	0	5	0	4	1	0	0	0	0	0	0	0	1	0	0
2010	Middle Ridge South	0	2	0	1	0	1	9	0	0	1	0	0	0	0	0	0	0
2011	La Poile	1	15	1	1	1	0	3	0	1	0	0	0	1	0	0	0	1
2011	Middle Ridge North	0	17	0	6	0	0	7	0	0	0	0	0	0	0	1	0	0
2011	Middle Ridge South	2	6	0	1	0	0	13	0	1	1	0	0	1	0	1	0	2
2011	Northern Peninsula	0	15	0	0	0	0	3	0	3	0	0	0	0	0	2	0	1
2012	La Poile	0	13	0	9	0	1	1	0	0	0	0	0	0	0	0	1	0
2012	Middle Ridge North	0	15	0	6	0	0	0	0	0	0	0	1	2	0	1	3	1
2012	Middle Ridge South	0	12	0	7	0	1	7	0	0	0	0	0	0	0	5	0	2
2012	Northern Peninsula	0	12	0	5	0	0	2	0	0	0	0	0	0	0	2	2	1
2013	Middle Ridge North	0	11	0	8	0	0	3	0	0	0	0	1	1	0	1	0	0
2013	Middle Ridge South	0	8	0	3	0	0	2	0	0	0	0	3	0	0	0	1	1

B)

Year	Study area	Accidental	Alive	Bald eagle	Black bear	Black bear or coyote	Collar-broken	Collar-slip	Coyote	Coyote or lynx	Lynx	Natural mortality	Orphaned	Suspect black bear	Suspect coyote	Suspect lynx	Unknown fate	Unknown mortality	Unknown predator
2008	La Poile	2	11	0	2	0	0	3	5	0	1	0	0	0	0	0	1	0	5
2008	Middle Ridge North	0	9	0	5	0	1	5	1	0	0	0	0	1	1	0	1	0	0
2008	Middle Ridge South	0	3	0	2	0	0	0	4	0	2	0	0	0	0	0	0	2	2
2008	Northern Peninsula	0	12	0	6	1	0	1	4	0	0	0	0	1	0	0	0	0	3
2009	La Poile	1	15	2	2	0	5	1	6	0	1	0	1	0	4	1	0	0	1
2009	Middle Ridge North	0	14	0	8	0	2	0	3	0	0	0	0	0	1	0	1	0	4
2009	Middle Ridge South	0	0	0	3	0	1	0	6	1	0	0	0	0	0	0	0	0	0
2009	Northern Peninsula	1	13	1	3	0	1	10	3	0	0	0	0	0	1	0	1	0	4
2010	La Poile	0	4	4	6	1	2	2	3	0	1	0	0	0	0	0	0	1	0
2010	Middle Ridge North	0	2	0	5	0	1	5	1	0	0	0	0	0	1	0	1	0	0
2010	Middle Ridge South	0	1	0	1	0	0	1	9	0	0	1	0	0	0	0	1	0	0
2011	La Poile	1	14	1	1	1	0	0	3	0	1	0	0	0	1	0	0	1	1
2011	Middle Ridge North	0	11	0	7	0	0	0	8	0	0	0	0	0	1	0	1	2	1
2011	Middle Ridge South	2	4	0	1	0	0	0	14	1	1	1	0	0	1	0	1	0	2
2011	Northern Peninsula	0	11	0	0	0	1	0	3	0	3	0	0	0	0	0	2	1	3
2012	La Poile	0	7	0	9	0	3	3	1	0	0	0	0	0	0	0	0	1	1
2012	Middle Ridge North	0	12	0	6	0	0	3	0	0	0	0	0	1	2	0	1	3	1
2012	Middle Ridge South	0	11	0	7	0	0	2	7	0	0	0	0	0	0	0	5	0	2
2012	Northern Peninsula	0	12	0	5	0	0	0	2	0	0	0	0	0	0	0	2	2	1
2013	Middle Ridge North	0	10	0	8	0	0	0	3	0	0	0	0	1	1	0	1	1	0
2013	Middle Ridge South	0	7	0	3	0	0	0	2	0	0	0	0	3	0	0	0	2	1

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