PROMOTION OF MOUNTAIN CARIBOU RECOVERY THROUGH ALTERNATIVE PREY MANAGEMENT

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ABSTRACT

One management action proposed to stop the decline of mountain caribou is to reduce moose numbers in adjacent areas so that wolf numbers will decline and caribou survival will increase. Although supported by the concept of apparent competition, this approach has never been tested. In 2006, in the Parsnip River drainage in central British Columbia, we doubled the number of Limited Entry Hunting permits, with the hope that hunters would reduce moose density. Moose numbers declined from 3000 in 2005 to 1000 in 2011. Although wolf numbers did not appear to decline, emigration by Parsnip wolves was higher than in adjacent wolf populations where moose numbers were stable. There were about the same number of caribou in the Parsnip herd in 2013 as in 2002 and over the time period when moose were declining, caribou numbers declined by 35%, from 200 in March 2007 to 121 in March 2013. Why then, in spite of a 66% reduction in moose numbers, did Parsnip Herd caribou numbers did not increase as hypothesised? Perhaps : 1) there is a longer than expected time lag required for a wolf numerical response, 2) the reduction in moose numbers was insufficient to result in a numerical response of wolves, 3) wolf numbers did decline but at the same time increased their predation on caribou, particularly calves, or 4) caribou survival and recruitment was more closely related to other factors (e.g., bear predation), than to moose/wolf abundance.

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1.0 INTRODUCTION

Woodland caribou (*Rangifer tarandus caribou*) are 1 of 5 extant sub-species of caribou in North America, and a species of high conservation concern in North America (Committee on the Status of Endangered Wildlife in Canada 2002). In British Columbia (B.C.), woodland caribou have been classified into 3 ecotypes based on variations in habitat choice and foraging habits: Northern, Boreal, and Mountain (Figure 1; (Bergerud 1978, Heard and Vagt 1998). Mountain caribou (*Rangifer tarandus caribou*) are unique among the ecotypes in that they reside almost exclusively in the subalpine forests of the interior wet belt that extends through the south eastern mountains of B.C. and into the northern tip of Idaho (Heard and Vagt 1998). Because they remain in this area of deep snow pack throughout the winter season, mountain caribou cannot crater for terrestrial lichens during the winter months, (a primary foraging habit of the other woodland caribou ecotypes), and instead forage on the arboreal lichens that are most abundant in old forests (Simpson et al. 1997, Wittmer, McLellan, et al. 2005).

Although population densities of mountain caribou are naturally low, there has been a decline in both population and range of mountain caribou in the past two decades (Simpson et al. 1997, Kinley and Apps 2001). Currently, the species population of mountain caribou is approximately 1,900 animals, with 12 of 16 herds at >50% risk of extirpation within 20 years (Wittmer, McLellan, et al. 2005, Hatter 2006). Because of this population decline, mountain caribou have been afforded protected species status through both federal and provincial species at risk legislation (Threatened; Committee on the Status of Endangered Wildlife in Canada 2002, and Red Listed [threatened], BC Conservation Data Centre 2010). Mountain caribou are also the focus of an active species recovery strategy implemented in 2007

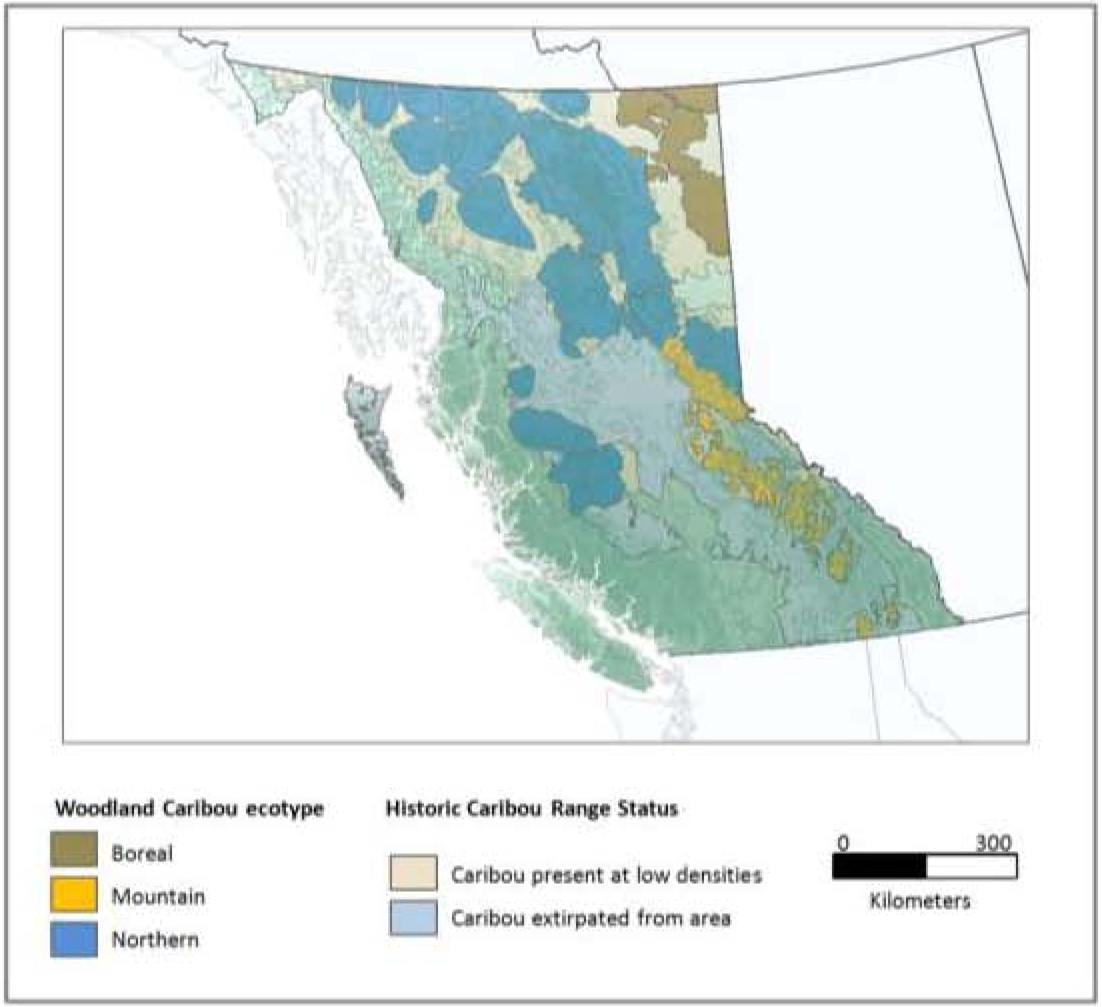

Figure 1 The distribution of the 3 ecotypes of Woodland Caribou (*Rangifer tarandus caribou*) within British Columbia (2012). Data provided by the British Columbia Ministry of Environment.

by the province of B.C. (Mountain Caribou Recovery Implementation Plan [MCRIP]). The goal of the recovery strategy is to stop the decline of mountain caribou herds and to restore total population levels to ~2,500 animals (1995 population estimate) by the year 2027.

Factors thought to have contributed to the decline of mountain caribou either singly or in combination are, excessive hunting (Stevenson and Hatler 1995), wolf predation (Bergerud and Elliott 1998), human disturbance (Seip et al. 2007), and anthropogenic changes in land cover and land use (Apps and McLellan 2006). Although predation is a common proximate cause of current declines, the ultimate cause is often identified as habitat change and its effect on altering predator-prey relationships in mountain caribou habitat (Bergerud and Elliot 1986, Seip 1992, Seip and Cichowski 1996, Wittmer, Sinclair, et al. 2005). The increase in the proportion of younger aged stands within mountain caribou range relative to the historical natural disturbance regime leads to an increase in the abundance of other ungulate species (moose, deer, and elk) that favour early-seral growth (Rempel et al. 1997). Although these species do not directly compete with caribou for resources, the increase in ungulate biomass within mountain caribou range supports a greater abundance of large predators (wolves [*Canis lupus*], bears [*Ursus sp*.], and cougars [*Puma concolor*]) that are then able to prey on mountain caribou (apparent competition; Bergerud and Elliot 1986, Seip 1992, Rettie and Messier 1998, Wittmer, Sinclair, et al. 2005).

Mountain caribou are typically part of multi-prey multi-predator systems where mountain caribou are the alternate prey source relative to other more abundant ungulate species (i.e., moose [*Alces alces*], elk [*Cervus canadensis*], or deer [*Odocoileus sp.*]). In the Northern portions of mountain caribou range, these systems are typically characterized by moose and caribou as prey species with wolves and bears as predator species (Wittmer, Sinclair, et al. 2005). Mountain caribou generally inhabit higher elevations relative to alternate prey and predator species, a strategy thought to reduce exposure to predators (Bergerud et al. 1984, Seip 1992). With increasing alternative prey and predator populations, however, the refugia effect of higher elevations may become less effective, and predation rates may increase.

Given the many factors that may have contributed to population declines, recovery of mountain caribou will require an approach that addresses both the long-term restoration of old growth habitat, as well as the more immediate reduction of both predators and alternate prey inhabiting lower elevations areas within and adjacent to mountain caribou range (Wilson 2009). Because restoration of a natural forest age structure will require decades to achieve, management of predators is necessary in the interim period to prevent caribou herds from declining further or potentially being extirpated before the benefits of habitat restoration are realized (Wilson 2009). According to previous research, a predator density of <6.5 wolves/1000 km^2 within caribou range and surrounding lower elevation areas is necessary to allow caribou herds to persist, depending on the size and magnitude of decline of the herd (Bergerud 1988). Where caribou herds are very small and in rapid decline, <1.5 wolves/1000 km^2 are predicted to be the necessary target to allow for caribou persistence (Wilson, 2009).

Although there are numerous examples of the immediate positive effects of direct predator reduction on caribou population growth (Boertje et al. 1996, Bergerud and Elliott 1998, Hayes et al. 2003), it is often viewed as an undesirable management option for a variety of social, economic, and ecological reasons (Wilson 2009). An indirect approach to reducing predators, namely through a reduction in the density of their primary prey, may be a more acceptable management strategy if proven effective. Densities of <300 moose/1000

km^2 in the lower elevation areas surrounding mountain caribou range could be expected to result in wolf densities of <6.5 wolves/ 1000 km^2, and <50 moose/1000 km2 will achieve wolf densities of <1.5 wolves/1000km^2 (Fuller 1989). This relationship assumes, however, that wolves will not compensate for the reduction in available moose by increasing predation on other available species. Further, the time lag required for a numerical response of wolves to reductions in primary prey is unknown but may take a few years (Bob Hayes pers comm).

The Parsnip Caribou Recovery Project tested an intermediate-term, alternate species management approach to caribou recovery, to better understand its feasibility as a general option for mountain caribou recovery. By increasing moose hunting opportunities within the study area we anticipated that hunters would reduce moose numbers and maintain moose numbers at a reduced level. We reasoned that this reduction in primary prey populations (moose) would lead to a smaller wolf population, thus reducing predation impacts of wolves on caribou and allowing caribou population growth.

1.1 Project Background

The study was initiated in 2005-2006, with baseline population surveys conducted for moose in the Parsnip River study area (hereafter PRSA), and for caribou populations in both the Parsnip herd and adjacent Hart South herd (which was considered a control population). Monitoring of wolf populations was also initiated at this time with capture and collaring of 2 wolves in the PRSA. In fall 2006, moose harvest quota in the Parsnip River area was altered to double the number of permits issued. In 2008 the regulations were altered again, to split and lengthen both the bull and cow seasons, and lengthen the open calf season. These 2008 regulation changes were anticipated to reduce crowding and increase hunter efficiency although the total number of permits issued remained unchanged (i.e., double the pre-2006 quota).

To evaluate the effectiveness of this approach to caribou recovery, we monitored the numbers of moose, wolves and caribou in the PRSA over the 6-year period (2006-2012) following the initial increase in moose hunting opportunities in 2006. We also examined the movements and hunting activity of wolves within caribou range to determine whether wolves responded to the decrease in moose by increasing their predation on caribou. Here we provide a summary of our project findings, and make inferences regarding the feasibility of using alternate prey management to increase mountain caribou populations. We also draw on findings made in a concurrent study examining the movements and diet of wolves in the Parsnip drainage during the same time period (Steenweg 2011) to better understand the dynamics of the wolf-moose-caribou system and how alternate prey management may affect its functioning.

1.2 Project Objectives

The overall objective of the Parsnip Caribou Recovery Project was to assist with the recovery of threatened caribou populations in the Southern Mountains National Ecological Area. The project evaluated the feasibility of increasing the Parsnip Caribou Herd population by reducing moose numbers in the area (using increased hunter harvest), which would result in fewer wolves and less predation on caribou. Specifically, the project aimed to:

- evaluate the feasibility of increasing the population of the Parsnip mountain caribou herd by reducing wolf predation through a reduction in area moose numbers;
- significantly increase caribou numbers, adult survival, and calf recruitment in the Parsnip mountain caribou herd relative to previous population parameters and a control population; and

- assist with the recovery of threatened caribou populations in the Southern Mountains National Ecological Area (the Recovery Plan objective is to increase caribou numbers in the Hart and Cariboo Mountains to >2000).

2.0 METHODS

2.1 Study Area

We studied wolf-moose-caribou dynamics within the Parsnip River Drainage located in the Omineca region of Northern British Columbia, Canada (center point: 54° 45'N latitude, and 121° 59' W longitude). The 5,634 km^2 area is encompassed by wildlife Management Units 7-16 and 7-23 (Figure 2). The Parsnip River bisects the study area, with rolling hills and plateaus to the southwest of the river, and the central Rocky Mountains to the northeast. Numerous tributaries run perpendicular to the Parsnip along the northeast side

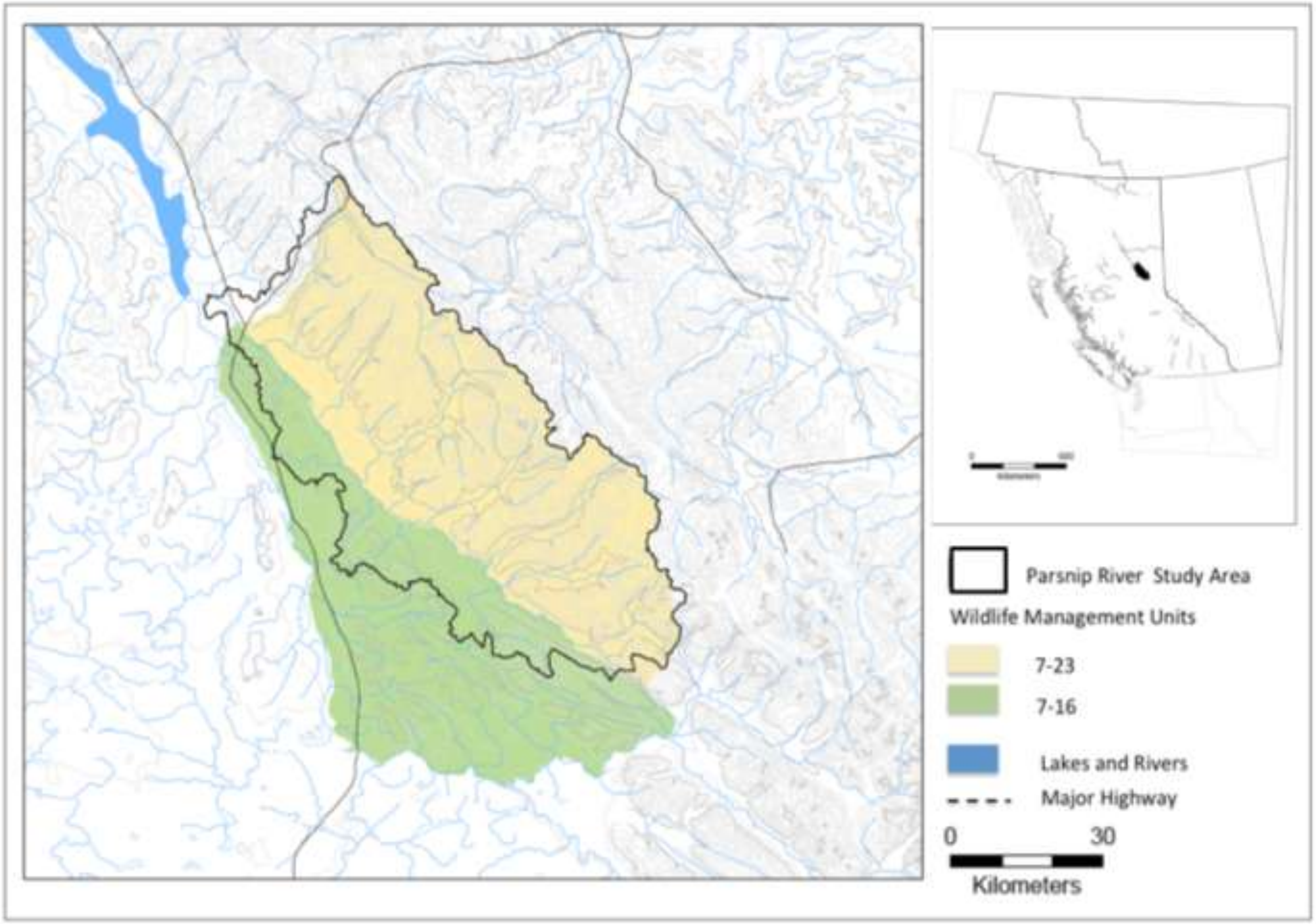

Figure 2 Location of Parsnip River Study Area showing relative location of wildlife management units 7-23 and 7-16 where experimental reduction of moose through increased moose harvest occurred from 2007-2012. Inset map indicates the location of the Parsnip River Drainage (black filled polygon) within the province of British Columbia.

of the river, resulting in extensive riparian areas. Elevations ranged from 434 m to 2,510 m with treeline occurring at approximately 1,550 m to 1,700 m.

Plant communities within the study area were characterized by 3 ecotypes: the sub-boreal spruce (SBS) biogeoclimatic (BEC) zone on the lower slopes and valley bottoms (600 m – 1,100 m); the Engelmann spruce-subalpine fir (ESSF) BEC zone at higher elevations (1,100 m – 1,700 m); and above tree line, the alpine tundra (AT) BEC zone (Coupe et al. 1991). Riparian areas were abundant in valley bottoms, and consisted of cottonwood (*Populus balsamifera*), willow (*Salix spp.*), alder (*Alnus spp.*), and red-osier dogwood (*Cornus stolonifera*). Environmental conditions were continental, resulting in short summers with moderate precipitation and winters that typically extended from November to May. Average annual temperatures ranged from 1.7°C to 5°C, with mean annual precipitation ranging from 440 mm - 900 mm with approximately 25 % -50% of precipitation received in the form of snow (Meidinger and Pojar 1991).

The Parsnip drainage supports a diverse predator-prey ecosystem. Carnivore species in the study area were: wolf, grizzly bear (*Ursus arctos*), black bear (*Ursus Americanus*), cougar (*Puma concolor*), coyote (*Canis latrans*), lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*) populations. Ungulate species were: elk (*Cervus elaphus*), moose (*Alces alces*), mountain caribou, mountain goats (*Oreamnos americanus*), and mule deer (*Odocoileus hemionus*). Moose were the most abundant ungulate in the study area, and are the primary prey of wolves. Deer, elk and mountain goats were rarely seen and we believe they were too rare to be significant to ecosystem processes. The most important non-ungulate prey species was beaver (*Castor canadensis*), which was abundant in riparian areas.

Forest harvesting was the primary landscape –level disturbance influencing lower elevation stands (< 1,100 m) within the Parsnip River study area, resulting in extensive areas of forest in early-seral growth stages. The majority of logging activity that has occurred the past 40 years has been in the southwest portion of the study area, with harvest occurring in ~21% of the study area to the southwest of the Parsnip River, and only in ~4% of the study area to the northeast (Steenweg 2011). Clear cut logging was the common harvest method in the area with many cutblocks larger than 2 km^2 (Heard et al. 1999). Other human activities on the landscape include hunting and trapping, with both resident and non-resident (guided) hunting of wildlife permitted. Highway 97 crossed a small section of the study area in the northwest edge of the study area, and a network of logging roads provided access to several lower elevation areas along the length of the Parsnip drainage.

2.2. Animal Capture

To assist in evaluating changes in population size, survival, and distribution of key species following an increased harvest of moose in the PRSA, we captured and collared representative samples of female caribou (n=28), female moose (n=23) and wolves of both sexes (n=38). Moose and caribou were captured using aerial net gunning during winter (November to March). Three other caribou in the Parsnip Herd radio-collared for a concurrent study (Seip, unpublished data) were also monitored, increasing the number of caribou monitored to 31.

Thirty-six of the 38 wolves were captured using a combination of aerial net-gunning and darting to administer immobilizing drugs (Telozol®; Fort Dodge Animal Health, Fort Dodge, Iowa). The remaining 2 wolves were captured using modified padded leg-hold traps (Braun Wolf Traps; Wayne's Tool Innovations, Inc., Campbell River, BC). Aerial based wolf captures took place during the winter (January - March) while the ground based leg-hold trapping occurred in July 2009. Wolves were fit with either VHF (n = 19) or GPS (n = 19) collars. GPS collars were pre-programmed to acquire locations every 6 – 12 h during the winter season, and every 2 – 4 h during the summer season. All capture and collaring activities were carried out by British Columbia government wildlife personnel and handling procedures were in accordance with B.C. Ministry of Environment protocols and the Guidelines of the Canadian Council on Animal Care (2003).

2.3 Population monitoring of key species

2.3.1 Estimating Population Size

2.3.1.1 Caribou

Each March, in conjunction with the Mountain Caribou Recovery Program, we performed a mountain caribou population census within the Prince George Forest District which included the Parsnip herd and the adjacent control Hart South herd (Figure 3). During population census surveys, we flew a helicopter along treeline within each watershed and searched for caribou tracks. When fresh tracks were located, we searched the area intensively to locate and count the caribou, and classify the animals as either adults or calves. The proportion of collared caribou found was used to determine the sightability correction factor used in calculating population estimates that accounted for missed animals (following mark-resight methodologies; Bartmann et al. 1987). To estimate total population size, we used the joint hypergeometric maximum likelihood estimator in program NOREMARK (White 1996).

Group size and composition of animal groups associated with the collared caribou were then recorded and the number of calves in the herd was presented as a percentage of the total herd.

2.3.1.2 Moose

To estimate population size of moose, an aerial survey was conducted in December following a stratified random block (SRB) design (Gasaway et al. 1986, Heard et al. 1999, Walker et al. 2006). Using land-cover data and remote imagery in GIS, we classified moose range within the study area as either strata 1 (S1): areas predicted to have high densities of moose (i.e., forests <40 years of age, riparian areas, and open shrub dominated meadows), or strata 2 (S2): areas predicted to have lower densities of moose (i.e., forests >40 years of age). Following its classification as S1 or S2, we divided the entire study area into a predetermined grid of 9 km^2 (3.2 × 2.8 km) blocks that contained varying amounts of high and low (i.e., S1 and S2) moose density stratum. Adjacent blocks were arbitrarily joined so that ≥ 4 km^2 of S1

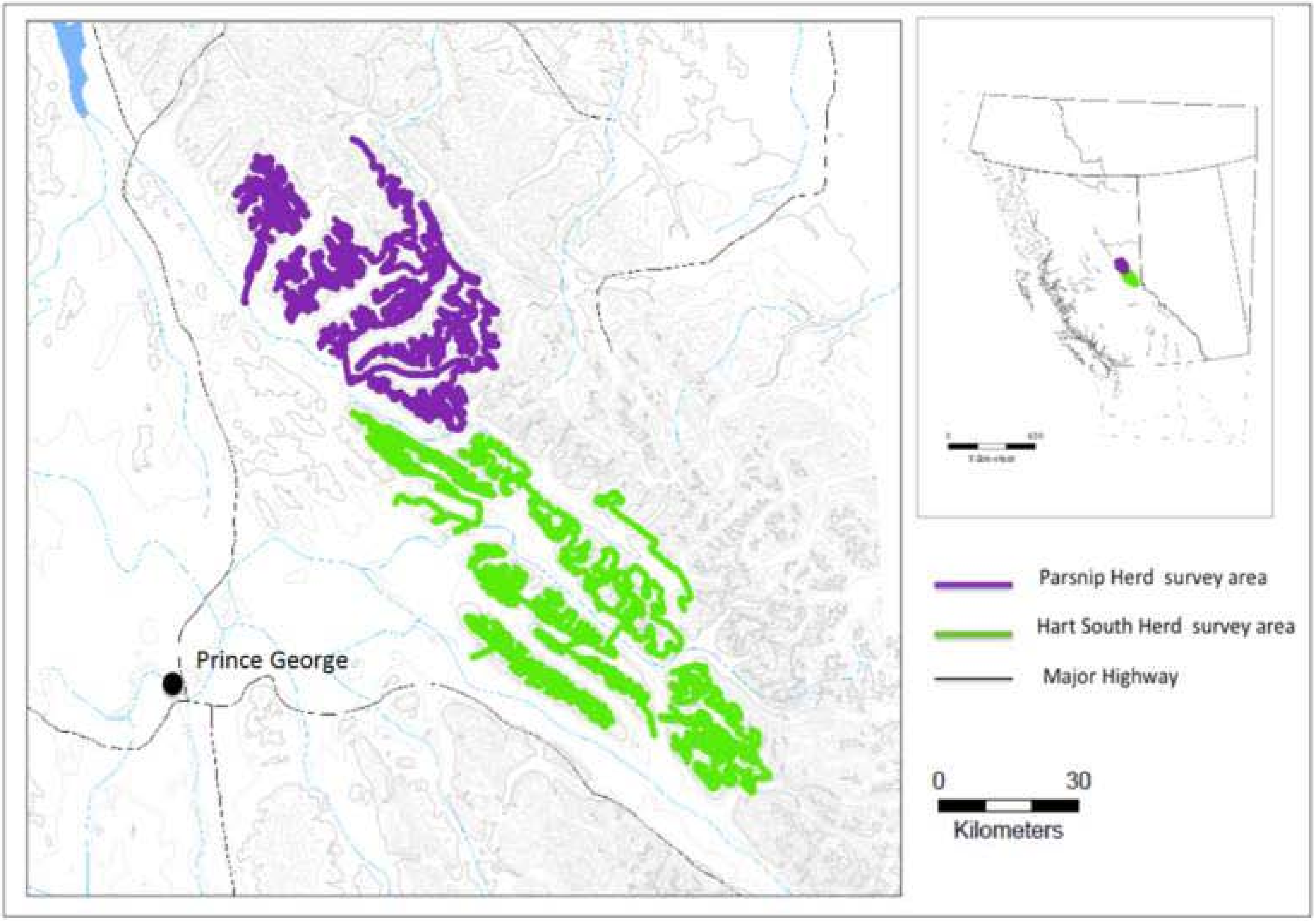

Figure 3 Flight lines representing the area covered during the mountain caribou census 22 to 31 March 2010 showing the locations of the Parsnip and Hart South herd ranges.

was present in each sample unit (SU). We then randomly selected S1 and S2 blocks to survey, with S1 areas surveyed more frequently than S2 areas.

Surveys were completed using Bell 206 helicopters flown 30-50 m above the ground. We circled each moose and recorded its age and sex as a calf (~ 8 months old), cow, bull or unclassified, based on the presence of a white vulva patch, the bell length and shape and facial colouration and morphology (Heard *et al.* 1999). We also recorded the percent vegetation cover, to the nearest 5%, within a 9 m radius of where the moose was first seen (Unsworth *et al.* 1998). Vegetation cover estimates were grouped into 5 classes each with a specific detection probability (DP) and sightability correction factor (SCF), as determined by Quayle *et al.* (2001), following the approach of Anderson and Lindzey (1996).

For each stratum of the survey area, a naïve population estimate and sampling variance for unequal sized sample units were calculated using Jolly (1969). Sightability and model variance were calculated using the program Aerial Survey (Unsworth *et al.* 1998) modified with data from Heard *et al.* (1999) and Quayle *et al.* (2001). We calculated the final population estimate as the product of the naïve population estimates for both strata and their SCF. The variance for the final population estimate was the sum of the sampling, sightability and model variances of both strata.

In the surveys that occurred from 2007 onward, only S1 areas were surveyed, and the S2 population estimate was based on the distribution of radio collared cow moose among the two strata at the beginning and the end of the survey. In other words, we estimated the total Parsnip moose population by dividing the S1 estimate by the fraction of collared moose in S1 (p). The variance of p was calculated using the binomial formula and the variance of the total was calculated using the formula for functions of random variables (Heard 1987). This approach allowed is to maximize survey efforts in S1 strata and increase survey efficiency, but was based on the assumption that distribution of the collared moose was representative of overall moose distribution with respect to stratum boundaries.

2.3.1.3 Wolves

To estimate the total number of wolves within the Parsnip caribou herd range, we performed aerial survey flights to locate radio-collared wolves and search areas where wolves have commonly been found in the PRSA (rivers and roads). Survey flights occurred during winter (November through March) when animals typically occur in packs. By monitoring the number of animals within each pack over a series of survey flights, we could calculate the minimum number of animals in each pack, and in turn the entire study area, for each year of the study.

We assigned wolves to packs according to their range on the landscape as well as their associations with other collared wolves. The numerous tributaries that flow into the Parsnip River were typically the core areas used by wolves and could be used to delineate pack boundaries. To determine if more than one radio-collared wolf was in a pack, we examined the proximity of all GPS and VHF wolf locations in time and space. When locations of wolves were ≤500 m apart and occurring within 1 h of each other, we considered the animals to be in the same pack.

We attempted to have at least one wolf collared in each pack each year, to allow us to consistently locate each pack and make reliable estimates of pack size and range. Because we often were not able to collar a wolf in every pack, (particularly in the earlier years of the study), annual minimum counts often underestimated the total number of wolves within the study area. To account for this, we determined a best estimate for annual total wolf populations for each year by correcting for under-counted packs based on counts from previous years, or estimates based on wolf sign within the area (i.e., tracks, howling). Although this method of population estimation is somewhat subjective, it was the most accurate way to assess population size given the difficulty of monitoring both individuals and packs within the study area.

2.3.2 Estimating Survival

Radio-collared animals were monitored for survival from fixed-wing aircraft (Guardian Aerospace, Vanderhoof, BC) throughout the duration of the study. Ungulate species were typically surveyed separately, with caribou monitored every 2 weeks and moose every 3 months. Wolves were monitored for survival opportunistically, typically during ungulate monitoring flights. Mortalities of all species were investigated in the field to determine cause of death whenever possible. Survival estimates for each species were calculated seasonally using the staggered entry Kaplan-Meier Estimator (Pollock et al. 1989). Using this method, monthly survival probabilities are estimated as the number of radio-collared animals that survived the month divided by the total number of radio-collared animals at the start of the month. Seasonal survival is then calculated as the product of all monthly survival probabilities encompassed by the year/season. This method allowed us to censor the data for individuals that were no longer able to be monitored for survival status due to collar failure or dispersal without affecting survival rate estimates.

2.3.3 Describing distribution and movement

Locations of VHF-collared caribou and moose recorded during population monitoring flights were examined spatially using ArcMap 9.3 (ESRI 2008). For each caribou and moose location, we queried the elevation using a Terrain Resource Information Management

(TRIM) 1:20,000 scale digital elevation model (LRDW, B.C. Government Forests, Lands, and Natural Resources Operations GeoBC; 25 m resolution; generated 12 December 2005). Because locations of ungulates were monitored infrequently across extended time periods (weeks to months) we could not reliably report movement rates or detailed home range statistics. To better understand the areas used by moose in the PRSA, we also utilized location and elevation data from 16 female moose collared during a previous study within the study area (n = 319; D.C. Heard, unpublished data, 1996 - 1998).

Movements and distribution of GPS- and VHF-collared wolves were analyzed using Spatial Viewer (M.P. Gillingham, unpublished program) and ArcMap 9.3 (ESRI 2008). For each wolf, we examined locations spatially and removed erroneous points and points with exceedingly high Degree of Precision (DOP) values (i.e., 3D locations with DOP >25 m and 2D fixes with DOP >10 m; Rempel and Rodgers 1997, Dussault et al. 2001). For the remaining reliable GPS locations, we determined the time between fixes and the distance moved between consecutive fixes. From these time and distance measures, we could determine movement rate, (Euclidian distance between consecutive GPS locations divided by the number of hours between fixes), and in turn, the average annual movement rate for each animal. We determined the elevation of each wolf location using ArcMap 9.3 (ESRI 2008) and calculated the annual home range (June-June) for each pack using a 100% Minimum Convex Polygon tool (Hawth Tools; Beyer 2004) in ArcMap 9.3 (ESRI 2008). Polygons were based on the collar locations (GPS and VHF) of all radio-collared individual(s) of the pack monitored that year.

In some instances, radio-collared wolves left the boundaries of the Parsnip River Drainage, and did not return during the monitoring period (either due to mortality events outside the study area, or establishment of a new territory outside the study area). We defined these long-term movements outside of the PRSA as dispersal events. To calculate annual dispersal rates, we used the staggered entry Kaplan-Meier Estimator (Pollock et al. 1989). Monthly dispersal probabilities were estimated as the number of radio-collared animals that remained in the PRSA at the end of the month divided by the total number of radio-collared animals that had been in the study area at the start of that month. Seasonal dispersal rates are then calculated as the product of all monthly dispersal probabilities encompassed by the year/season (for detailed methodology, please refer to Steenweg [2011]).

2.4 Quantifying Species Interactions

2.4.1 Quantifying Wolf Forays in Caribou Habitat

To quantify the hunting effort of wolf packs in caribou habitat, we examined the elevations used by GPS collared wolves (n = 20), with wolf locations above 1050 m considered to represent wolf use of caribou habitat. The threshold for caribou-selected elevations was based on the caribou habitat-selection model created for the Parsnip caribou herd (Jones 2007). Wolf locations below 1050 m were considered to represent wolves' use of den and rendezvous sites and hunting forays for lower elevation prey (i.e., moose and beaver). At the coarsest scale, we determined the percentage of time wolves were above 1050 m on a monthly basis. At a finer scale, we analyzed higher elevation movements spatially to determine whether the movements were likely associated with a hunting foray, and to partition series of high elevation locations into distinct hunting forays.

To determine if higher elevation movements were representative of a hunting foray, we used spatial viewer (M.P. Gillingham, unpublished program), which allowed us to: 1) partition groups of consecutive high elevation points into distinct hunting forays; and 2) exclude higher elevation wolf movements that were likely not associated with hunting effort (i.e., isolated movements to higher elevations between visits to a lower elevation kill or return visits to higher elevation kill site clusters). We considered the forays of individual collared wolves to represent the hunting efforts of the pack it was a part of, thereby providing a measure of caribou hunting effort for that pack. To prevent pseudo replication of hunting effort that might occur when 2 animals were collared within the same pack, we compared foray activity between animals to ensure shared forays were only counted once.

Because our ability to detect movements to higher elevations was limited by the frequency at which locations were acquired (i.e. the decreased fix acquisition rates of collars during the non-summer seasons), we also calculated a corrected foray frequency for each month. Corrected foray frequencies were calculated by dividing the number of forays observed that month by the total number of GPS locations acquired that month, then multiplying that number by a constant (Steenweg 2011).

3.0 RESULTS

3.1 Population monitoring of Key Species

3.1.1 Population trends of Key Species

Based on the results of winter census surveys, the number of caribou in the Parsnip herd ranged from approximately 230 animals in 2006, to a low count of 121 in 2013. In the interim years of the study, the population varied by as many as 50 animals annually, in some years increasing, in other years decreasing. When total counts from previous years are considered (i.e., 2002 onward), the population appears stable (Figure 4). The Hart South control herd, monitored simultaneously, ranged from a total count of 488 animals in 2006 to 338 animals in 2013. When total counts from previous years are considered, the Hart South herd also appears to be in relatively stable to slightly declining (Figure 4). Percent calves in the Parsnip herd varied between 9% and 20% (Figure 5), and typically corresponded to the estimated population of the herd with peak calf percentages occurring in 2006, when estimated caribou numbers were highest, and lowest percentages occurring in 2012, when herd numbers were lowest (Figure 5).

The number of moose in the PRSA declined by approximately 68%, from a peak population of ~3000 animals in 2005 to ~974 animals in 2011 (Figure 6). The decline has been primarily in the number of bull moose in the population based on a decline in the sex ratio from 112 bulls: 100 cows in 1998 to 44:100 in 2009 and the high survival of radio-collared female moose.

According to minimum count data, the number of wolves in the Parsnip River study area increased by 10 over the duration of the study, ranging from 27 animals in 2007 to 37 animals in 2011 (Figure 7). However, the ability to effectively monitor individual packs increased over the years as more wolves were collared, therefore leading to better minimum counts of animals, and therefore a larger minimum count estimates in the latter study years. If we assume that pack territories remained similar across years (i.e., no dispersal of entire packs), the total number of wolves in the PRSA remained relatively stable throughout the study period, ranging from 44 animals to 34 animals with an average of 38 animals (SD = 4) according to best estimates (Figure 7).

When we compared our minimum and best estimate counts of wolves in the study area to the number of wolves predicted to be supported by the density of primary ungulate prey on the landscape (i.e., moose; Fuller 1989), we found that wolf densities did not follow the trend predicted, with fewer wolves than predicted in the earlier study years when moose densities were highest, and more wolves than expected on the landscape in the later study years when moose were less abundant (Figure 7).

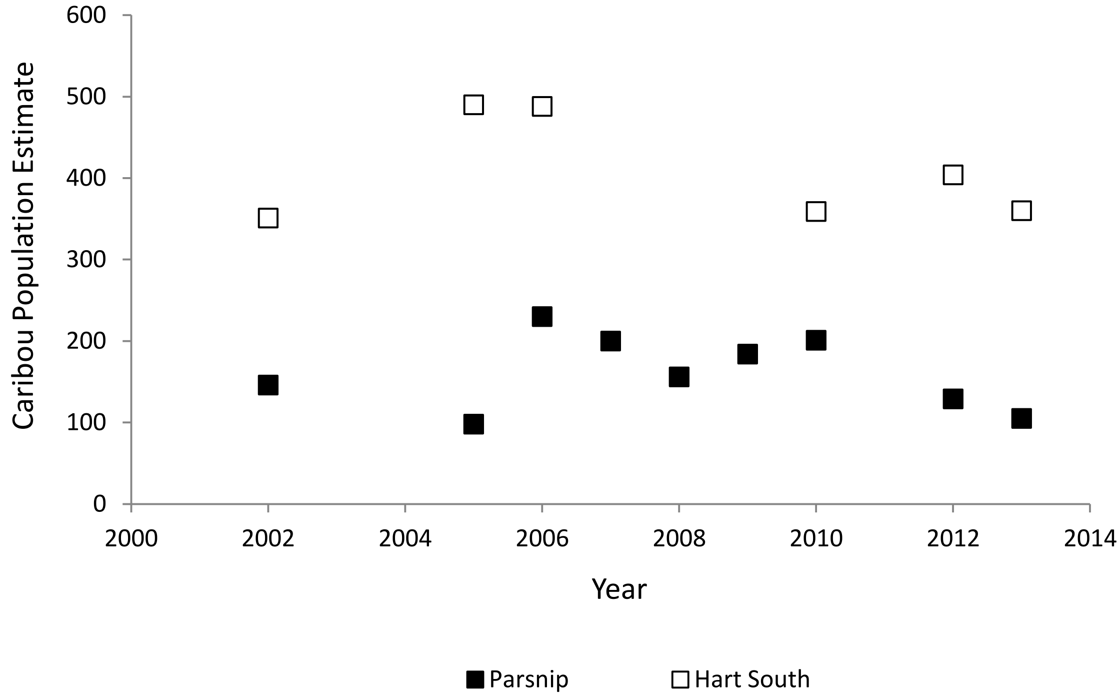

Figure 4 Number of caribou estimated in the Parsnip and Hart South caribou herds between 2002 and 2010. Shaded grey bar indicates the onset of the increase in moose harvest permits within the study area.

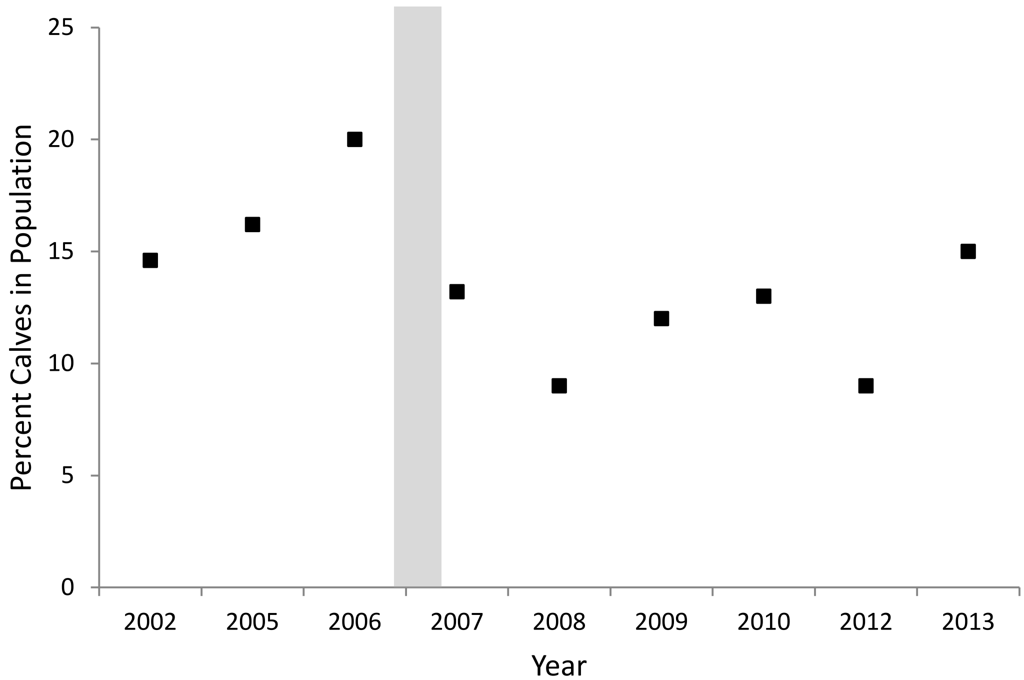

Figure 5 Percent calves in the Parsnip River caribou herd (2002-2012). Shaded grey bar indicates the onset of the increase in moose harvest permits within the study area.

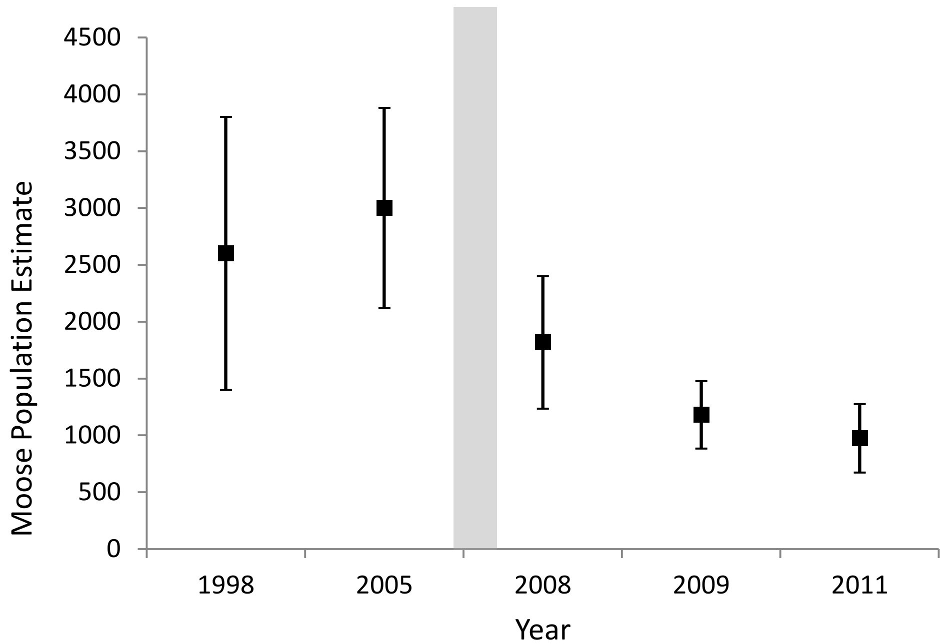

Figure 6 Change in the number of moose in the Parsnip population between 1998 and 2011 based on stratified random block density estimation surveys. Shaded grey bar indicates the onset of the increase in moose harvest permits within the study area.

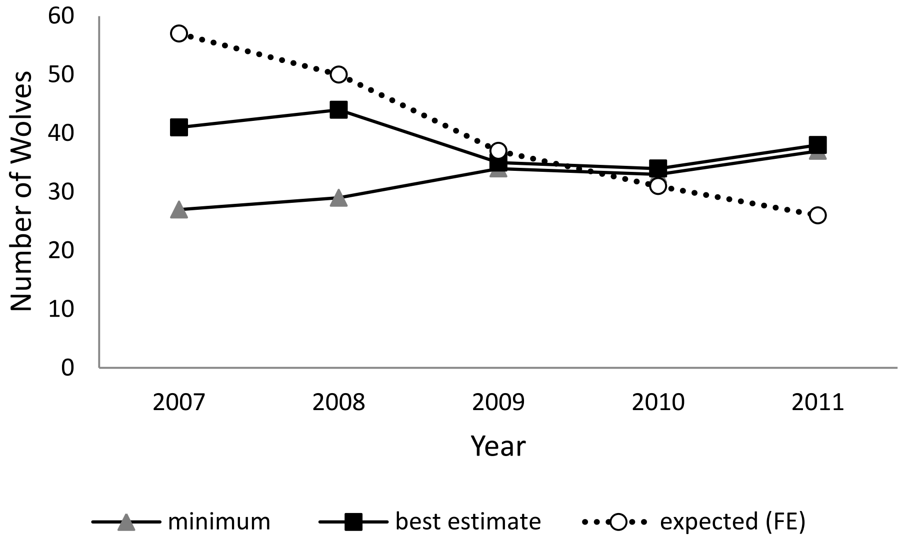

Figure 7 Change in the number of wolves inhabiting the Parsnip River Study Area from 2007-2012 indicated by minimum count data and the best estimates accounting for unaccounted for animals and packs. Graph also indicates the predicted number of wolves on the landscape given the annual density of moose (Fuller 1989).

3.1.2 Survival of Key Species

During the study period, 15 of 31 collared female caribou died, resulting in annual survival estimates that ranged from 81% to 100% with an average survival estimate of 89% (Table 2). Of the collared animals that died, 7 were killed by wolves, 1 by a bear, 1 by a wolverine, and 6 died of unknown causes. When collared caribou were killed by wolves, most mortalities occurred in both the winter and snow-free seasons, and almost all kills (6 of 7) occurred in the latter years of the study (2010-2011; Figure 8).

Over the duration of the study, 10 of 23 collared female moose died, resulting in annual survival estimates that ranged from 83% to 100% with an average survival rate estimate of 88% (Table 2). Of the collared animals that died, 5 were killed by wolves, 4 were killed by hunters, and 1 died due to a collision with a train. If human related causes of mortality were excluded, average survival of collared moose would have been approximately 94%.

Of the 38 wolves radio-collared from 2007-2012, 16 died during the period that they were collared, 14 were alive at the end of collaring, and 8 had unknown fates (due to dropped collars or collar failures). When we consider the survival rate of the animals that remained in the study area for the duration of the period they were collared, survival rates varied from 44% to 100% (Table 2). Of the radio collared wolves that died, 9 were legally shot or trapped, 3 died of unknown natural causes, 1 likely died of starvation, 1 died following a vehicle collision, 1 died due to complications with recapture, and 1 died of injuries after being kicked by a moose.

Table 1 Annual mortality rates (95% confidence intervals in parentheses) for caribou, moose, and wolves in the Parsnip River study area B.C. Moose numbers were reduced by approximately 50% between 2007-2009 through increasing the number of legal hunting permits allotted for the wildlife management units encompassing the study area (WM Units 7-16 and 7-23). Mortality rate was calculated using the Kaplan-Meier Estimator (Pollock et al. 1989), and *n* indicates the number of radio-collared animals monitored for survival over the annual period as a min-max range.

Species	Statistic	Year				
		2007	2008	2009	2010	2011
Caribou	mortality rate	0.81 (0.62-1.0)	0.95 (0.85-1.0)	0.83 (0.68-0.98)	0.90 (0.76-1.0)	0.82 (0.64-1.0)
	n	13-17	17-24	20-24	17-21	14-17
Moose	mortality rate	1	0.83 (0.67-0.98)	0.95 (0.85-1.0)	0.83 (0.66-1.0)	0.87 (0.70-1.0)
	n	23	19-23	18-19	15-18	13-15
Wolves	mortality rate	0.75 (0.73-0.77)	0.44 (0.42-0.46)	0.71(0.68-0.74)	0.55 (0.50-0.59)	1
	n	6-12	9-12	5-9	4-11	3-10

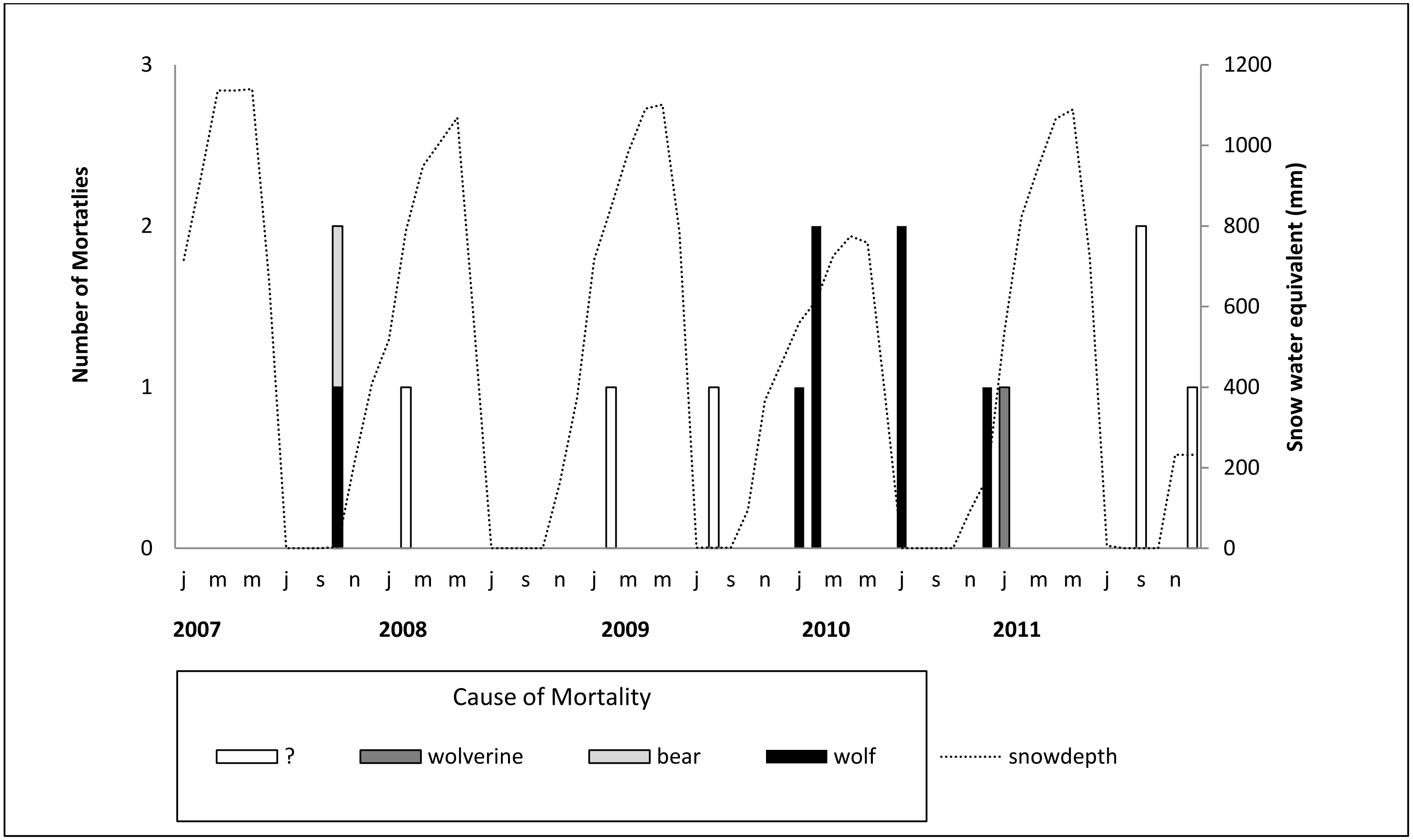

Figure 8 Timing and cause of mortality of collared female mountain caribou in the Parsnip River Study Area (2007-2011). Snow depth measurements show relative snow pack across the different season and years (Hedrick lake Automated snow pillow).

3.1.3 Distribution and movement of Key Species

From 2006-2012 we recorded 352 locations from 31 radio collared female caribou in the PRSA. Elevations used by collared caribou ranged from 739 m to 1965 m, with an average elevation of 1379 m ± 182 m ($\bar{x}$ ± SD). Ninety-five percent of collared caribou locations were above 1050 m (Figure 9). Over the same period, we collected 176 locations from 23 radio-collared female moose. When we considered these locations, in addition to the 319 locations obtained from previously collared female moose in the Parsnip (see capture section for details), elevations used by moose ranged from 711 m to 1452 m, with an average elevation use of 840 m ± 126 m ($\bar{x}$ ± SD). Ninety-three percent of moose locations were below 1050 m (Figure 9).

Over the course of the study we obtained 24,566 successful fixes from a total of 20 GPS-collared wolves, and 171 locations from 18 VHF-collared wolves. The average movement rate for all GPS collared wolves was approximately 425 m/h with a range of 155 m/h to 612 m/h (Table 3). From analyses of the distribution of radio-collared wolves and observations made during telemetry flights, there were 4 major wolf packs that inhabited or frequented the study area ("Reynolds-Anzac", "Anzac-Table", "Hominka-Missinka", "Whichcika-Seebach"; Figure 10).

Packs were often dynamic, covering different areas of their territories annually, and often splitting into smaller sub-packs, with membership of collared wolves within sub-packs often changing over the course of the year. This variation in territory size and location, as well as pack size, frequently led to spatial overlap in adjacent pack territories. Analyses of wolf location temporally, however, showed that packs were not in the same place at the same time, indicating that packs were distinct although spatially overlapping.

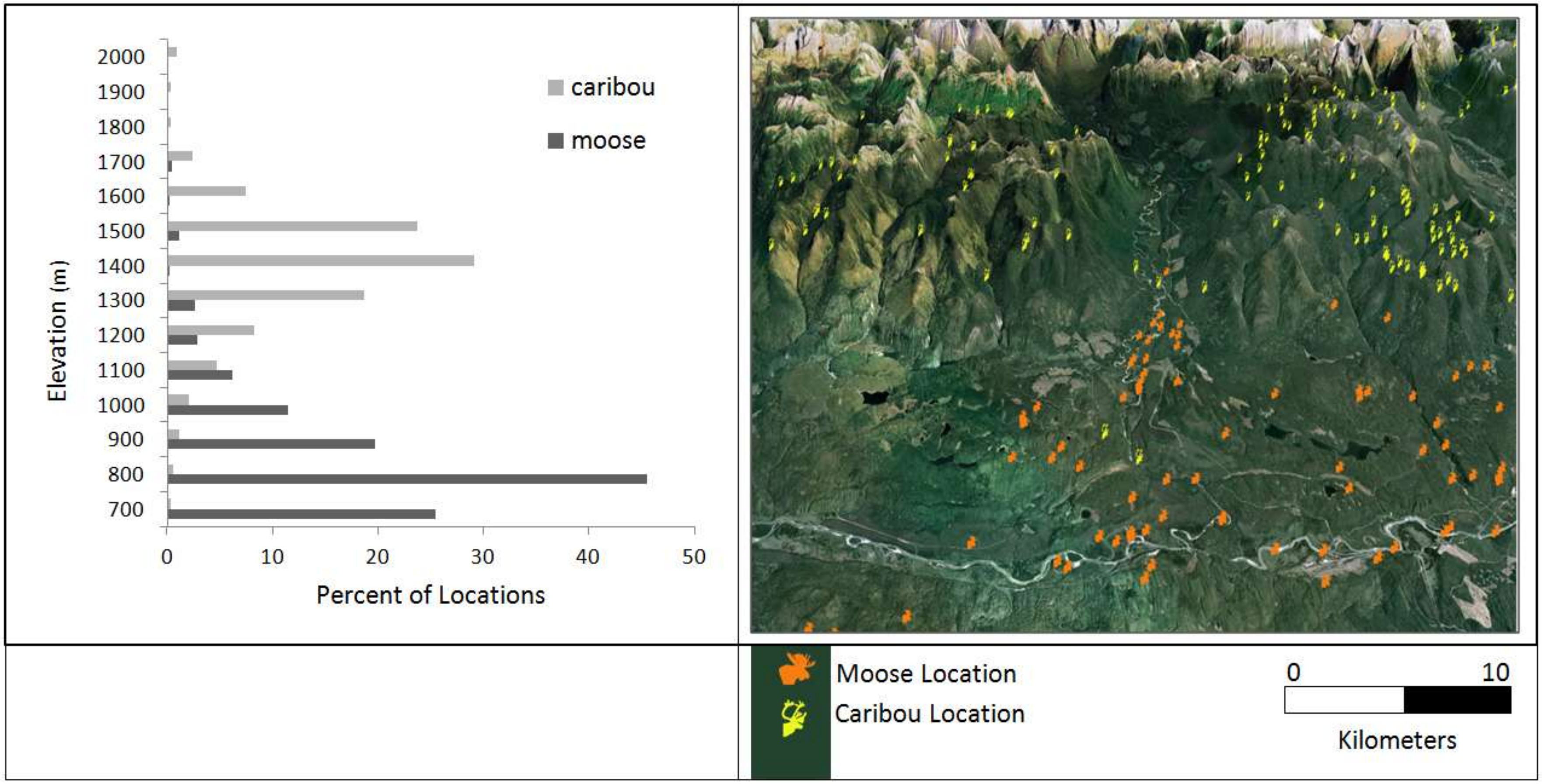

Figure 9 Use of elevation by collared female moose (*n* = 23; 495 locations) compared to collared female caribou (*n* = 31; 352 locations) in the Parsnip River Study Area (2007-2012). Y-axis labels represent midpoint of intervals (e.g., 1000m represents 950 m-1049 m) Image on right shows the species use of different elevations on the landscape graphically.

Table 2 Summary of GPS-collared wolves (n = 19) monitored within the Parsnip River Study Area from 2007-2012, including the duration the animal was collared, the number of fixes acquired, the fix success rate, and the average movement rate (m/h).

Wolf ID	Start Date	End Date	# Fixes	% Fix Rate	Movement Rate (m/h)
W10	14/03/2007	11/12/2007	843	80%	366
W11	23/01/2008	05/02/2008	59	97%	320
W12	22/01/2008	29/03/2008	294	95%	394
W16	27/02/2008	02/06/2008	352	84%	484
W18	29/02/2008	01/06/2008	3160	80%	495
W19	29/03/2008	23/08/2008	855	82%	367
W24	10/03/2009	Unknown fate- unable to acquire location data			
W25	29/03/2009	04/04/2009	62	91%	230
W26	24/07/2009	31/03/2010	2611	87%	424
W27	31/07/2009	22/08/2009	236	89%	168
W28	27/02/2010	12/02/2012	2677	95%	546
W29	08/03/2010	27/03/2012	Still alive at end of reporting period		
W32	08/02/2011	05/03/2011	48	96%	155
W33	18/02/2011	08/12/2011	2175	92%	517
W34	18/02/2011	09/02/2012	2244	91%	606
W35	18/02/2011	10/02/2012	2302	91%	483
W36	08/03/2011	01/02/2012	2208	90%	519
W37	08/03/2011	09/02/2012	2315	93%	612
W38	08/03/2011	10/02/2012	2125	89%	470

The annual home range size of wolf packs ranged from 391 km^2 to 5,098 km^2 with an average size of 2280 ± 1328 km^2 ($\bar{x}$ ± SD). Because range estimates were calculated using the 100% MCP algorithm, these estimates likely overestimate the amount of range used by the individual packs, and often include large portions of range that were unused. When we examined the spatial distribution of wolf points, we found that the elevations used by wolves ranged from 603 m to 1738 m, with 88% of wolf locations occurring at elevations <1050 m. When we plotted movement paths on the landscape, we could see that animals typically followed river valleys of the tributaries and mainstem Parsnip River within their territories, and used higher elevation areas less frequently (Figure 11).

3.2 Quantifying Species Interactions

3.2.1 Quantifying Wolves use of Caribou Habitat

The percentage of time wolves spent in caribou habitat (locations above 1050 m), varied seasonally and across years. Although data was not able to be gathered across all months and years due to lack of GPS collar data in several months, there is a general trend of increased use of higher elevations in the snow-free seasons, and infrequent use (<20%) when snow depths were high (Figure 12). The exception to this is the winter of 2010 when snow depths were low, and wolves' use of caribou habitat was up to 40% (Figure 12).

When we partitioned the time spent by wolves in caribou habitat (>1050 m) into distinct hunting forays, we isolated 52 hunting forays (across the 4 packs monitored) from the period of Feb 2011 to Feb 2012. The timing of forays seasonally reflected the time spent in caribou habitat, with hunting forays observed more frequently during the snow-free months, and decreasing in frequency as snow depth increased (Figure 13). When we corrected for the differences in monitoring intensity across the seasons, (which may cause us

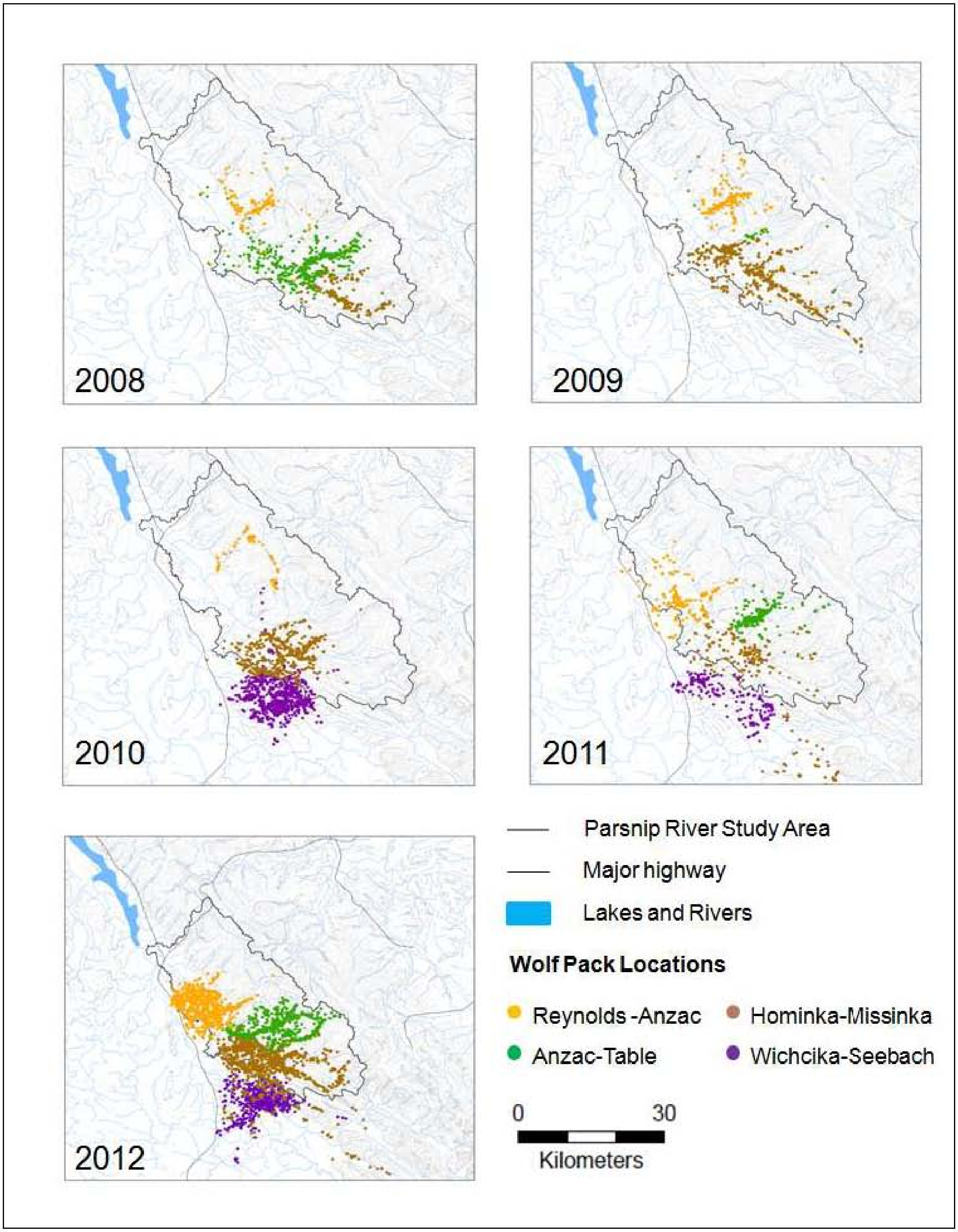

Figure 10 Annual wolf pack location in Parsnip River Study Area (June –June; 2008–2012). All locations from GPS-collared and VHF-collared wolves (n = 19 and n = 19 respectively).

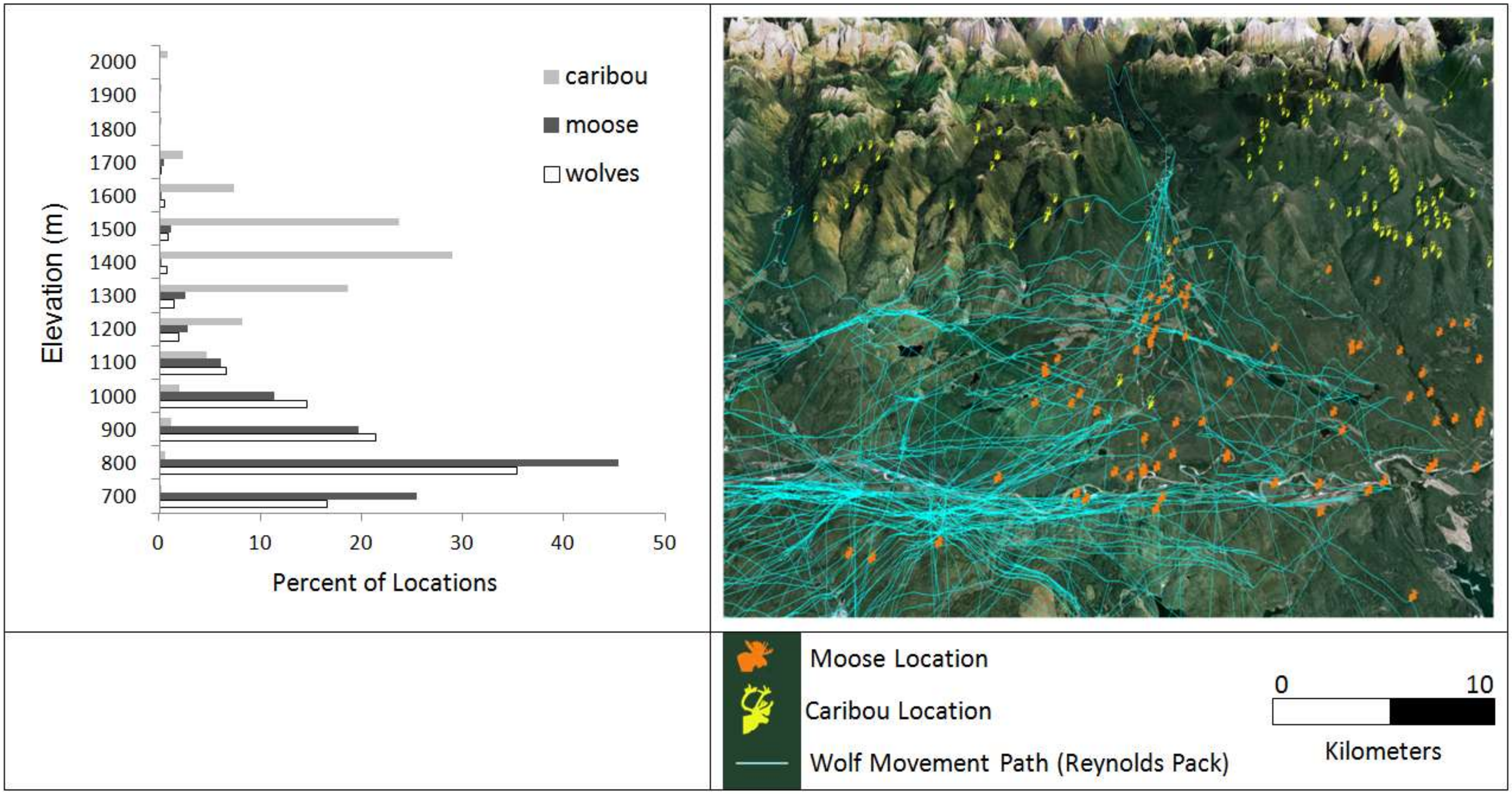

Figure 11 Use of elevation by collared wolves (*n* = 38; 24,566 locations) relative to collared female moose (*n* = 23; 495 locations) and collared female caribou (*n* = 31; 352 locations) in the Parsnip River Study Area (2007-2012) Y-axis labels represent midpoint of intervals (e.g., 1000m represents 950 m- 1049 m). Image on left graphically shows species use of different elevations on the landscape, with linear features showing the annual movement path of a GPS collared wolf within the Reynolds-Anzac pack during the 2012 season.

to underestimate the number of forays during periods when fixes were more infrequent), we saw a more stable trend, wherein the frequency of forays remains more consistent throughout the year (approximately 5 forays per month), regardless of month or snow depth.

Analyses of hunting forays in previous years of the study (Steenweg 2011) indicate similar trends of wolf activity, with a higher frequency of forays during the snow-free months relative to the times when snow depths were higher (Figure 14). Considering all years that wolves movements were monitored within the study area (2007-2012) we found 127 distinct forays into caribou habitat across the 4 major packs monitored.

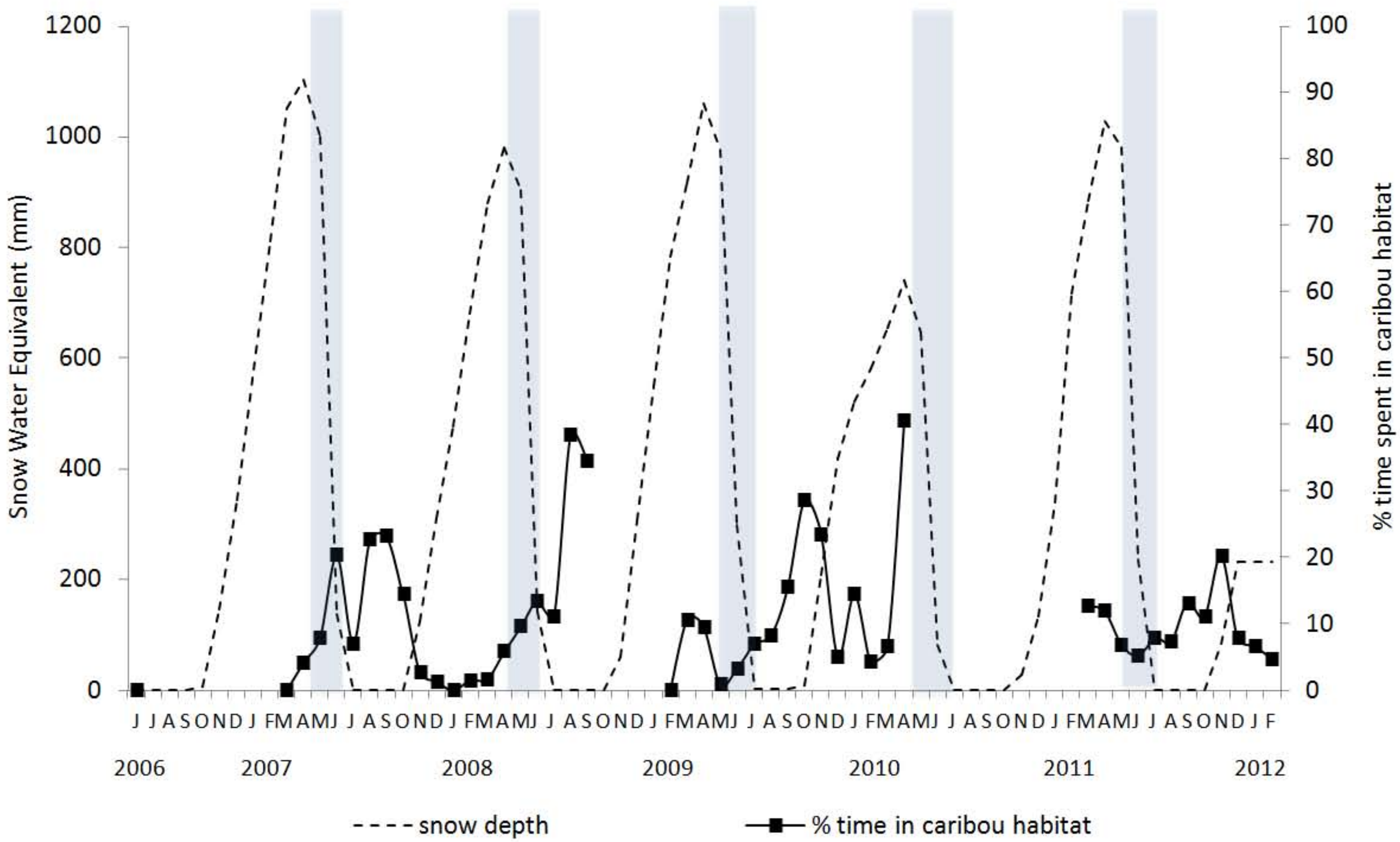

Figure 12 Average amount of time spent by wolves above 1050 m relative to average daily snow depth in the Parsnip River Study Area (2007-2012). Shaded areas approximate the peak calving period of mountain caribou inhabiting the study area.

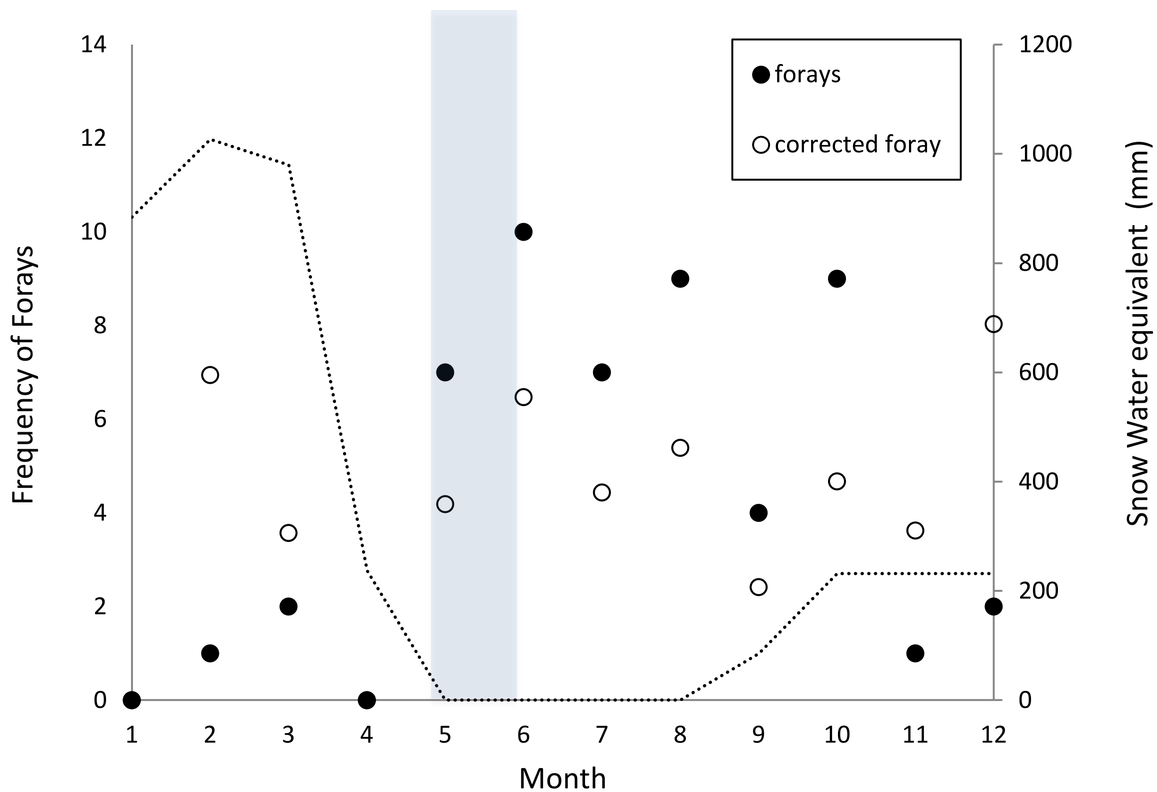

Figure 13 Frequency of hunting forays (both number of forays observed and number of forays corrected for monitoring intensity) in caribou habitat (elevations above 1050) by wolves (*n* = 4 packs) across the months (2012) in the Parsnip River Study Area. Dotted line indicates average daily snow depth for that year. Shaded areas approximate the peak calving period of mountain caribou inhabiting the study area.

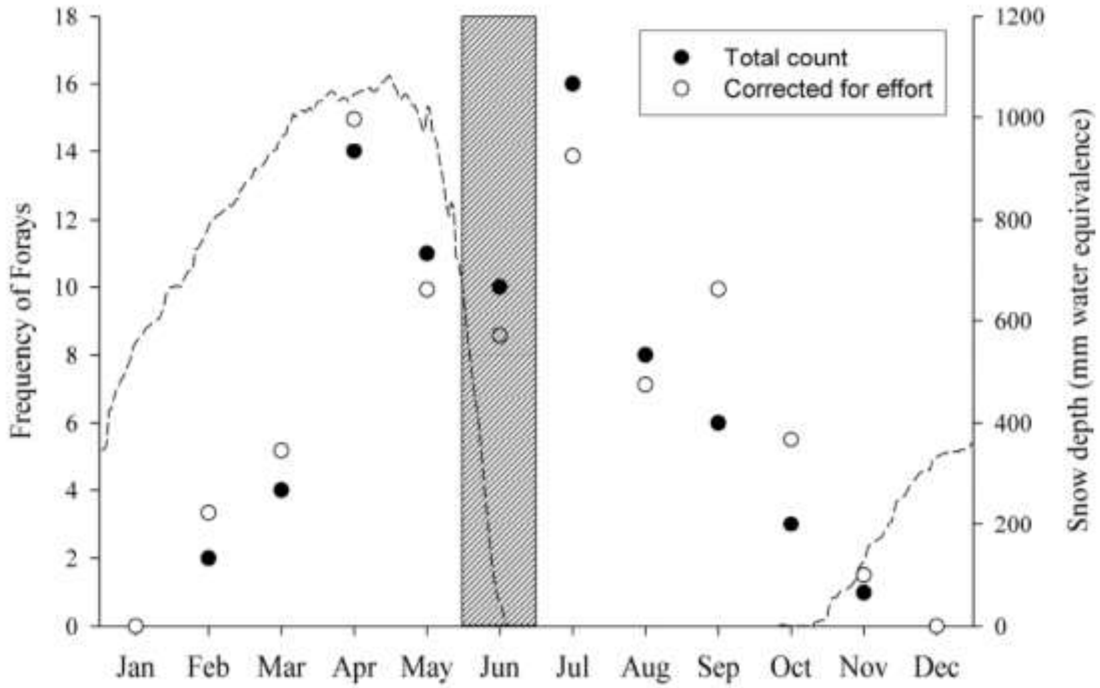

Figure 14 Frequency of hunting forays (both number of forays observed and number of forays corrected for monitoring intensity) in caribou habitat (elevations above 1050) by wolves (n = 3 packs; 2007-2009) in the Parsnip River Study Area. Dotted line indicates average daily snow depth for that year. Shaded areas approximate the peak calving period of mountain caribou inhabiting the study area.

4.0 DISCUSSION

The distribution of moose and wolves overlapped throughout the year as expected (Figure 11). Because caribou occupied higher elevations, there was little overlap between caribou and moose-wolf locations (Figure 9, 11). When wolves did go to caribou range, they spent more time there in the snow-free period than during winter (Figure 12). However, snow was not a barrier to wolf movement to caribou range and wolves made forays to caribou range at all times of the year (Figure 13, 14). Even though wolves spent relatively little time on caribou range, we do not interpret that as meaning wolf predation on caribou was low. Wolves could have been hunting calves, which are vulnerable during summer because of their small size. Their small size also means that they can be consumed quickly, thus not requiring wolves to spend much time there. The net result could be a relatively large impact on caribou population dynamics but relatively little affect on wolf nutrition.

As expected, moose numbers in the PRSA declined but the 2011 the density of 390 moose/1000km^2 was still higher than the maximum predicted for a numerical response in wolves that would result in caribou (i.e., 300 moose/1000km^2 , Fuller 1989). Wolf numbers did not appear to change during this study (Figure 7). The mean number of 38 wolves represents a density on moose winter range of 15 wolves/1000km^2 which was more than twice as high as the maximum Wilson (2009) predicted would be required for caribou recovery (6.5 wolves/1000km^2). Given such a high wolf density and the lack of a wolf population decline with declining moose numbers, then the lack of an increase in caribou numbers (Figure 4), was not surprising.

We do not know why there was no wolf numerical response but we suggest; 1) there may be a longer than expected time lag required for a wolf numerical response, or 2) the reduction in moose numbers was insufficient to result in a numerical response of wolves. We also considered the possibility that there was a numerical decline in wolves that we did not detect. If so, then the lack of a caribou population increase would suggest that as wolves became food stressed and numbers declined they also increased their predation on caribou, particularly calves. The high survival of adult female radio-collared caribou and the lack of any change in wolf use of caribou range throughout this study argues against that explanation. Finally, it is also possible that caribou survival and recruitment is more closely related to other factors (e.g., bear and wolverine predation), than to moose/wolf abundance.

5.0 MANAGEMENT IMPLICATIONS

Even though we saw no increase in caribou numbers relative to the control population, during this study, we recommend that the experiment continue because there is no risk and important benefits to doing so. The worst case alternative outcome, that food stressed wolves would increase their predation on caribou, did not occur. Wolf numerical response might still yet occur. Second, hunters are still benefitting from the increased hunting opportunities. If moose numbers decline further then the test of the alternative prey hypothesis will be stronger.

6.0 EXTENSION

A poster entitled "Primary-Prey Management as a Mountain Caribou Recovery Strategy in the Central Rockies, BC." was presented (R.W. Steenweg, M.P. Gillingham and

D.C. Heard) was presented at the 16th Annual Conference of The Wildlife Society, 19-24 September 2009, Monterey, California. This same poster was also presented at the Natural Resources and Environmental Studies Institute (NRESI) Grad Icebreaker and Poster Session (2 October 2009 at UNBC) and again at the NRESI Annual Lecture and Poster Session (18 March 2010 at UNBC). A second poster entitled “Sustaining Mountain Caribou Populations: Investigating Impacts of Alternate-Prey Management on the Parsnip Mountain Caribou Herd, BC.”(R.W. Steenweg, M.P. Gillingham and D.C. Heard) was presented at the 4th Annual UNBC Graduate Conference (3 April 2009), Prince George.

On June 16th 2009, Robin Steenweg presented “Mountain Caribou Recovery through Primary-Prey Management in the Parsnip River Area, BC.” to the Spruce City Wildlife Association (Prince George). Doug Heard and Robin Steenweg presented results on changes in moose, caribou and wolf numbers in the Parsnip to the McLeod Lake Indian Band. Among those attending were the band manager Adelle Chingee and Chief Derek Orr. November 5-10 2011, Robin Steenweg presented “Promoting caribou recovery by reducing predators through primary-prey management: evidence of increased wolf dispersal following increases in moose-hunting quotas” at the 18th Annual Conference of the Wildlife Society in Kona, Hawaii. In 2012, Doug Heard presented a presentation entitled “Does fewer moose lead to an increase in mountain caribou?” (D.C. Heard, M.P. Gillingham, R.S. Steenweg) to the 14th North American Caribou Workshop in Fort St. John B.C.

7.0 ACKNOWLEDGEMENTS

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APPENDIX A: SUMMARY OF VHF AND GPS COLLARED WOLVES MONITORED DURING THE STUDY PERIOD (2007-2012).

Summary of wolves monitored during the study period (2007-2012). Data includes collar type, the activation date of the collar, and the sex, age, and fate of the wolf if known.

ID	Collar Type	Activation Date	Sex	Age at Collaring	Fate	Age at Fate
W01	VHF	27-Jan-06	M	5+	Dispersed then shot	5+
W02	VHF	13-Mar-06	F	N/A	Collar Dropped	N/A
W03	VHF	09-Feb-07	M	N/A	Shot	N/A
W04	VHF	26-Feb-07	M	N/A	Unknown fate	N/A
W05	VHF	12-Mar-07	F	N/A	Shot	N/A
W06	VHF	12-Mar-07	M	2	Dispersed then Trapped	2
W07	VHF	12-Mar-07	F	1	Unknown Natural mortality	1.5
W08	VHF	12-Mar-07	M	5	Collar Dropped	5+
W09	VHF	12-Mar-07	M	1	Unknown fate	4.5
W10	GPS	13-Mar-07	M	5+	Vehicle Collision	5+
W11	GPS	22-Jan-08	F	2	Collar Dropped	1.5
W12	GPS	22-Jan-08	M	1	Dispersed	1
W13	VHF	13-Feb-08	F	2	Dispersed	2
W14	VHF	13-Feb-08	F	2	Dispersed then Trapped	4
W15	VHF	13-Feb-08	F	3	Unknown Natural Mortality	3
W16	GPS	26-Feb-08	M	4	Moose Kick mortality	5
W17	VHF	26-Feb-08	F	1	Dispersed then shot	3
W18	GPS	26-Feb-08	M	5+	Re-collar then Capture-mortality	5+
W19	GPS	28-Mar-08	M	1	Unknown fate	2
W20	VHF	21-Jan-09	M	2	shot	3
W21	VHF	06-Feb-09	M	1.5	Dispersed then shot	2
W22	VHF	06-Feb-09	M	3	Collar Dropped	4
W23	VHF	19-Feb-09	F	1	Alive at study end	2
W24	GPS pod	10-Mar-09	F	3.5	Unknown fate	4
W25	GPS pod	10-Mar-09	F	4	shot	4
W26	GPS	23-Jul-09	M	4	Alive at study end	2
W27	GPS	31-Jul-09	F	5+	Starved	5+
W28	GPS	26-Feb-10	F	2	Alive at study end	4
W29	GPS pod	08-Mar-10	F	5+	Alive at study end	5+
W30	VHF	08-Mar-10	F	2	Alive at study end	3
W31	VHF	12-Mar-10	F	1	Alive at study end	2
W32	GPS	08-Feb-11	F	3	Unknown Natural Mortality	3
W33	GPS	18-Feb-11	F	1	Alive at study end	2
W34	GPS	18-Feb-11	F	1	Alive at study end	2
W35	GPS	18-Feb-11	F	12	Alive at study end	13
W36	GPS	08-Mar-11	F	1	Alive at study end	2
W37	GPS	08-Mar-11	M	5	Alive at study end	6
W38	GPS	08-Mar-11	F	4	Alive at study end	5

APPENDIX B: WOLF KILL SITE INVESTIGATIONS

METHODS

We identified potential kill-sites of large prey (caribou and moose) by identifying location clusters of GPS collared wolves. Potential clusters were identified with Point Finder (M. P. Gillingham, unpublished program), a Visual Basic program that calculated the distance between wolf GPS location points and classified points within 100 m of each other into specific clusters. After isolating point clusters, we identified each cluster as either a bedsite, possible caribou kill, likely caribou kill, moose kill, rendezvous site, or den site. We classified clusters according to the size of the cluster, the time spent at the cluster, and whether or not the cluster was visited repeatedly over a longer period of time (Table 1, following Steenweg [2011]). To ensure we had correctly distinguished rendezvous and den

Table B.1 Size and Time thresholds used to classify wolf location clusters as either bed sites, den sites, or kill sites of specific ungulate prey species. Classification was applied to wolf location clusters (≥3 locations within 100m) in the Parsnip River Study Area (2007-2012).

Cluster classification	Size of cluster	Time spent at cluster
Bedsite	<50 m diameter	<8 h
Possible Caribou	≥90 m diameter	8h —24h
Likely Caribou	≥90 m diameter	24h —48h
Likely Moose	≥90 m diameter	48h —170h
Den or Rendezvous Site	≥90 m diameter	≥170 h

sites from kill sites, we also examined each cluster in the context of the surrounding movement paths and the time of year the cluster was used.

Because cluster analyses alone often leads to an overestimation of kill rates (Webb et al. 2008), we attempted to verify identified clusters with field investigations to search for evidence of a kill site, and the species killed. Due to the remote location of many clusters, however, we approached most clusters by helicopter, biasing our sample of potential kill sites for those in or near open-vegetated areas.

RESULTS

We identified 59 distinct wolf-location clusters (>3 locations and >8 h) within the PRSA. Closer inspection of these clusters in both GIS and Spatial viewer (Gillingham, unpublished program) indicated that 9 of these clusters were associated with den or rendezvous sites (determined by the timing of their use [April-June], as well as the total time spent at the clusters [> 170 h]). The remaining 50 clusters were classified as either caribou or moose kill sites according to the total time the wolf spent at the cluster and the size of the cluster (following Steenweg 2011). In total, we classified 7 "possible caribou" kill sites, 18 "likely caribou" kill sites, and 25 "likely moose" kill sites. Ten of 50 clusters contained locations for 2 collared wolves within the same pack. The average kill site elevation was 919 ± 175 m ($\bar{x}$ ± SD; n = 50), with 80% of kill site clusters occurring at elevation less than 1000 m (Figure 15). The highest elevation cluster was 1550 m.

Over the course of the study (2007-2012) we completed field investigations of 67 of 332 identified potential kill site clusters (Table 4). We found evidence of 2 caribou and 20 moose kills. Both caribou kill sites were at elevations >1250 m, and all moose kills were between 700m and 1250 m. We found no evidence of a kill site at the remaining 45 identified cluster sites visited.

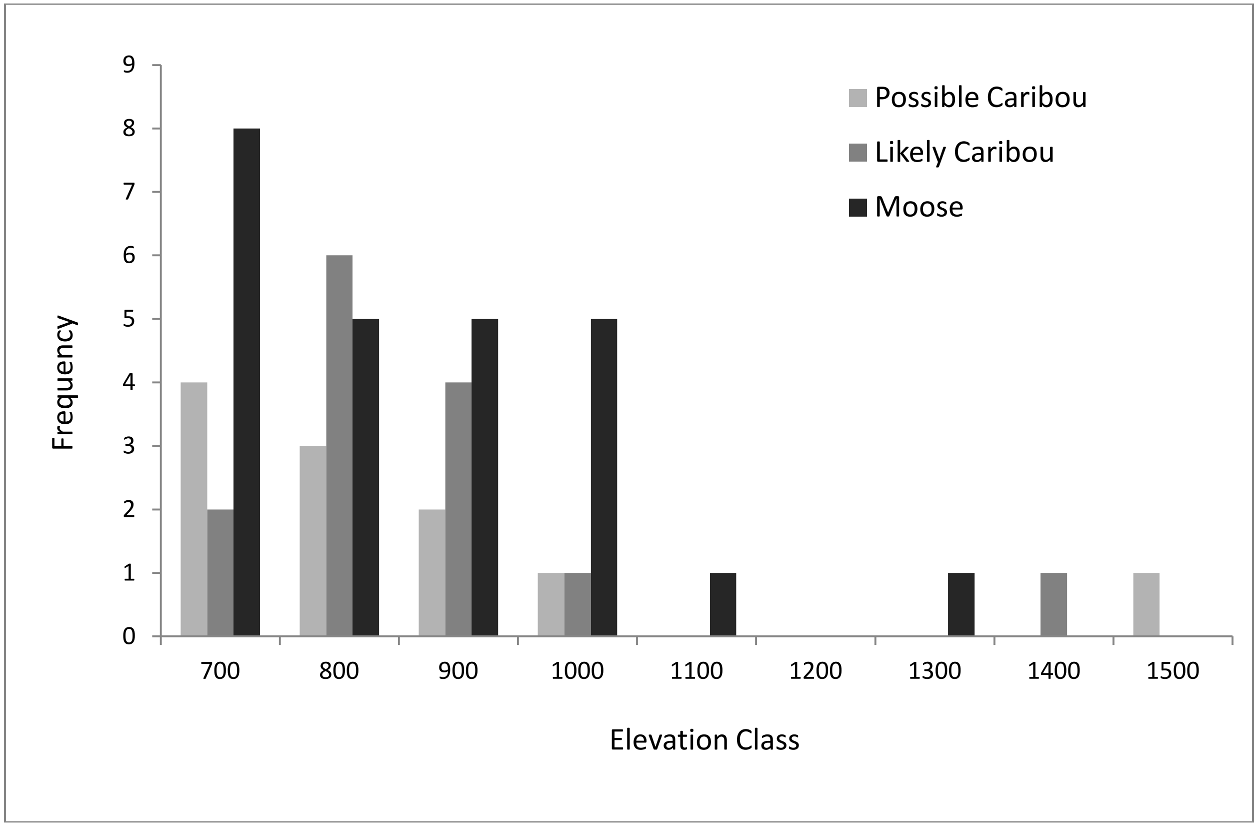

Figure B.1 Potential wolf kill sites clusters (possible caribou, likely caribou, and moose) in the Parsnip River Study Area (2011-2012). stratified by elevation class. Potential kill sites were identified using wolf location clusters examined spatially in GIS to determine size of the cluster and time spent at each cluster.////// so about 5% of kills>1300M and about 5% of time >1300m ?????

Table B.2 Summary of field investigations of potential wolf kill-sites in the Parsnip river study area (2007-2012) stratified by elevation.

Determination	Elevation		
	<1050m	**1050-1250m**	**1250m-1800**
Caribou kill	0	0	2
Moose kill	17	3	
No large kill	32	0	13
Total visited (identified)	49(299)	3(10)	15(23)

PEACE/WILLISTON FISH & WILDLIFE COMPENSATION PROGRAM

BC hydro

BRITISH COLUMBIA

Promotion of Mountain Caribou Recovery Through Alternate Species Management

D.C. Heard, M.P. Gillingham, R.W. Steenweg, and B. Cadsand

April 2013

PWFWCP Report No. XX

The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave. 3rd Floor, Prince George B.C. V2L 3H9

Website: *www.bchydro.com/pwcp/*

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ABSTRACT

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1.0 INTRODUCTION

Woodland caribou (*Rangifer tarandus caribou*) are 1 of 5 extant sub-species of caribou in North America, and a species of high conservation concern in North America (Committee on the Status of Endangered Wildlife in Canada 2002). In British Columbia (B.C.), woodland caribou have been classified into 3 ecotypes based on variations in habitat choice and foraging habits: Northern, Boreal, and Mountain (Figure 1; (Bergerud 1978, Heard and Vagt 1998). Mountain caribou (*Rangifer tarandus caribou*) are unique among the ecotypes in that they reside almost exclusively in the subalpine forests of the interior wet belt that extends through the south eastern mountains of B.C. and into the northern tip of Idaho (Heard and Vagt 1998). Because they remain in this area of deep snow pack throughout the winter season, mountain caribou cannot crater for terrestrial lichens during the winter months, (a primary foraging habit of the other woodland caribou ecotypes), and instead forage on the arboreal lichens that are most abundant in old forests (Simpson et al. 1997, Wittmer, McLellan, et al. 2005).

Although population densities of mountain caribou are naturally low, there has been a decline in both population and range of mountain caribou in the past two decades (Simpson et al. 1997, Kinley and Apps 2001). Currently, the species population of mountain caribou is approximately 1,900 animals, with 12 of 16 herds at >50% risk of extirpation within 20 years (Wittmer, McLellan, et al. 2005, Hatter 2006). Because of this population decline, mountain caribou have been afforded protected species status through both federal and provincial species at risk legislation (Threatened; Committee on the Status of Endangered Wildlife in Canada 2002, and Red Listed [threatened], BC Conservation Data Centre 2010). Mountain caribou are also the focus of an active species recovery strategy implemented in 2007

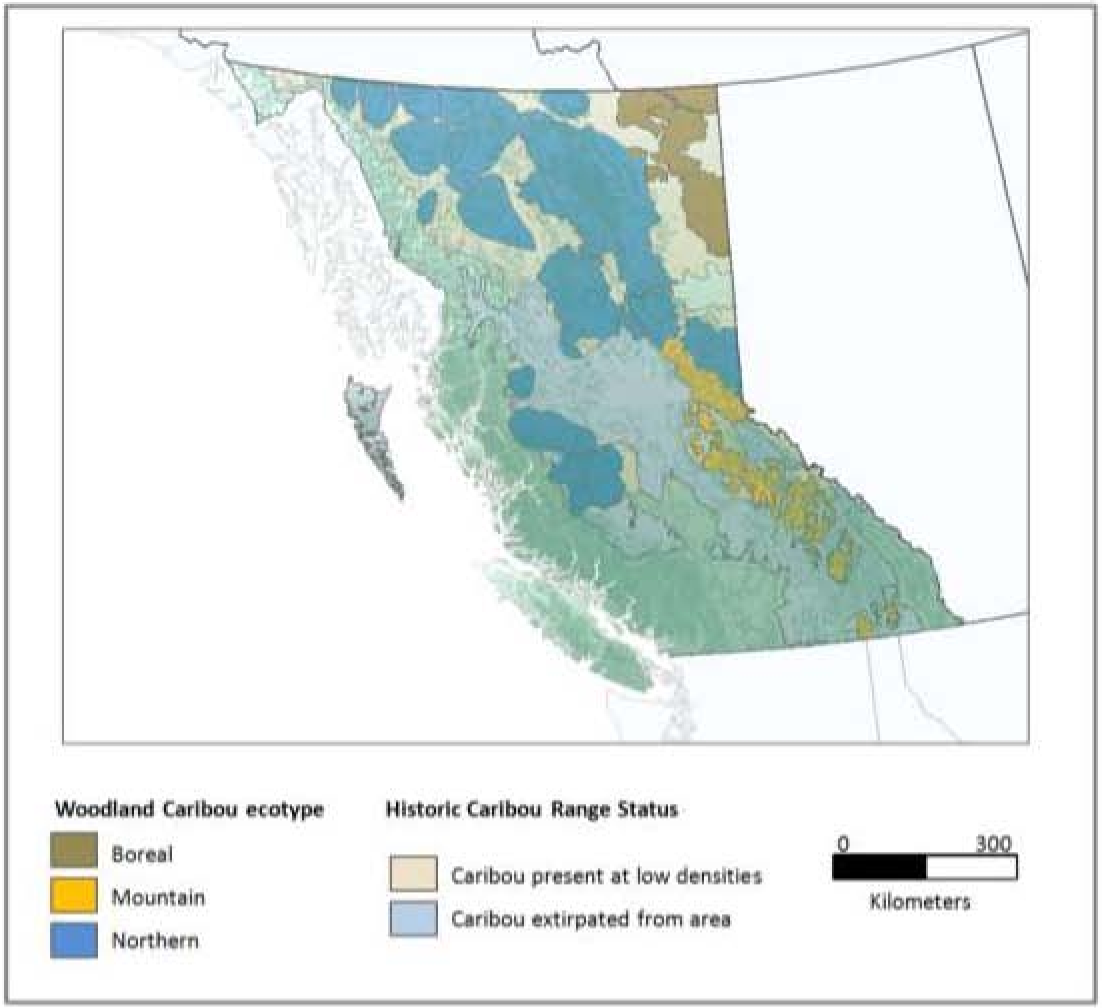

Figure 1 The distribution of the 3 ecotypes of Woodland Caribou (*Rangifer tarandus caribou*) within British Columbia (2012). Data provided by the British Columbia Ministry of Environment.

by the province of B.C. (Mountain Caribou Recovery Implementation Plan [MCRIP]). The goal of the recovery strategy is to stop the decline of mountain caribou herds and to restore total population levels to ~2,500 animals (1995 population estimate) by the year 2027.

Numerous factors are thought to contribute to the decline and extirpation of mountain caribou, including historic overharvest (Stevenson and Hatler 1995), predation (Bergerud and Elliott 1998), human disturbance (Seip et al. 2007), and the loss or change of habitat (Apps and McLellan 2006). Although predation is a common proximate cause of current declines, the ultimate cause is often identified as habitat change and its effect on altering predator-prey relationships in mountain caribou habitat (Bergerud and Elliot 1986, Seip 1992, Seip and Cichowski 1996, Wittmer, Sinclair, et al. 2005). The logging of old growth stands within mountain caribou habitat results in an increase in the abundance of other ungulate species (moose, deer, and elk) that favour early-seral growth (Rempel et al. 1997). Although these species do not directly compete with caribou for resources, the increase in ungulate biomass within mountain caribou range supports a greater abundance of large predators (wolves [*Canis lupus*], bears [*Ursus sp*.], and cougars [*Puma concolor*]) that are then able to prey on mountain caribou (apparent competition; Bergerud and Elliot 1986, Seip 1992, Rettie and Messier 1998, Wittmer, Sinclair, et al. 2005).

Mountain caribou are typically part of complex multi-prey multi-predator systems where mountain caribou are the alternate prey source relative to other more abundant ungulate species (i.e., moose [*Alces alces*], elk [*Cervus canadensis*], or deer [*Odocoileus sp.*]). In the Northern portions of mountain caribou range, these systems are typically characterized by moose and caribou as prey species with wolves and bears as predator species (Wittmer, Sinclair, et al. 2005). Mountain caribou generally inhabit higher elevations relative to alternate prey and predator species, a strategy thought to reduce exposure to predators (Bergerud et al. 1984, Seip 1992). With increasing alternative prey and predator populations, however, the refugia effect of their higher elevation habitats may become less effective, and predation rates may increase.

Given the myriad of factors that have contributed to population declines, recovery of mountain caribou will require an approach that addresses both the long-term restoration of old growth habitat, as well as the more immediate reduction of both predators and alternate prey inhabiting lower elevations areas within and adjacent to mountain caribou range (Wilson 2009). Because restoration of a natural forest age structure will require decades to achieve, management of predators is necessary in the interim period to prevent caribou herds from declining further or potentially being extirpated before the benefits of habitat restoration are realized (Wilson 2009). According to previous research, a predator density of <6.5 wolves/1000 km^2 within caribou range and surrounding lower elevation areas is necessary to allow caribou herds to persist, depending on the size and magnitude of decline of the herd (Bergerud 1988). Where caribou herds are very small and in rapid decline, <1.5 wolves/1000 km^2 are predicted to be the necessary target to allow for caribou persistence (Wilson, 2009).

Although there are numerous examples of the immediate positive effects of direct predator reduction on caribou population growth (Boertje et al. 1996, Bergerud and Elliott 1998, Hayes et al. 2003), it is often viewed as an undesirable management option for a variety of social, economic, and ecological reasons (Wilson 2009). An indirect approach to reducing predators, namely through a reduction in the density of their primary prey, may be a more acceptable management strategy if proven effective. Theoretically, it has been suggested that densities of <300 moose/1000 km^2 in the lower elevation areas surrounding mountain caribou range will result in wolf densities of <6.5 wolves/ 1000 km^2, and <50 moose/1000 km2 will achieve wolf densities of <1.5 wolves/1000km^2 (Fuller 1989). This relationship assumes, however, that wolves will not compensate for the reduction in available moose by increasing predation on other available species. Further, the numerical response of wolves to reductions in primary prey will not be immediate; and the length of time between the initial reduction in moose and corresponding expected reduction in wolves is not known.

The purpose of the Parsnip Caribou Recovery Project was to test an intermediate-term, alternate species management approach to caribou recovery, to better understand its feasibility as an option in mountain caribou recovery strategies. By increasing the opportunities for moose harvest within the study area we anticipated that hunters would reduce moose numbers and maintain the population at relatively low densities. We reasoned that this reduction in primary prey populations (moose) would lead to a smaller wolf population, in turn reducing the predation impacts of wolves on caribou.

1.1 Project Background

The study was initiated by the Ministry of Environment in 2005-2006, with baseline population surveys conducted for moose in the Parsnip River study area (hereafter PRSA), and for caribou populations in both the Parsnip herd and adjacent Hart South herd (which was considered a control population). Monitoring of wolf populations was also initiated at this time with capture and collaring of 2 wolves in the PRSA. In fall 2006, moose harvest quota in the Parsnip River area was altered to double the number of permits issued. In 2008 the regulations were altered again, to split and lengthen both the bull and cow seasons, and lengthen the open calf season. These 2008 regulation changes were anticipated to reduce crowding and increase hunter efficiency although the total number of permits issued remained unchanged (i.e., double the pre-2006 quota).

To evaluate the effectiveness of this approach to caribou recovery, we monitored the numbers of moose, wolves and caribou in the PRSA over the 4-year period following the initial increase in moose harvest (2006). We also examined the movements and hunting activity of wolves within areas of caribou habitat to determine whether wolves responded to the decrease in moose by increasing their predation on caribou. Here we provide a summary of our project findings, and make inferences regarding the feasibility of using alternate prey management to increase mountain caribou populations. We also draw on findings made in a concurrent study examining the movements and diet of wolves in the Parsnip drainage during the same time period (Steenweg 2011) to better understand the dynamics of the wolf-moose-caribou system and how alternate prey management may affect its functioning.

1.2 Project Objectives

The overall objective of the Parsnip Caribou Recovery Project was to assist with the recovery of threatened caribou populations in the Southern Mountains National Ecological Area. The project evaluated the feasibility of increasing the Parsnip Caribou Herd population by reducing moose numbers in the area (using increased hunter harvest), which would result in fewer wolves and less predation on caribou. Specifically, the project aimed to:

- evaluate the feasibility of increasing the population of the Parsnip mountain caribou herd by reducing wolf predation through a reduction in area moose numbers;

- significantly increase caribou numbers, adult survival, and calf recruitment in the Parsnip mountain caribou herd relative to previous population parameters and a control population; and

- assist with the recovery of threatened caribou populations in the Southern Mountains National Ecological Area (the Recovery Plan objective is to increase caribou numbers in the Hart and Cariboo Mountains to >2000).

2.0 METHODS

2.1 Study Area

We studied wolf-moose-caribou dynamics within the Parsnip River Drainage located in the Omineca region of Northern British Columbia, Canada (center point: 54° 45'N latitude, and 121° 59' W longitude). The 5,634 km^2 area is encompassed by wildlife Management Units 7-16 and 7-23 (Figure 2). The Parsnip River bisects the study area, with rolling hills and plateaus to the southwest of the river, and the central Rocky Mountains to the northeast. Numerous tributaries run perpendicular to the Parsnip along the northeast side

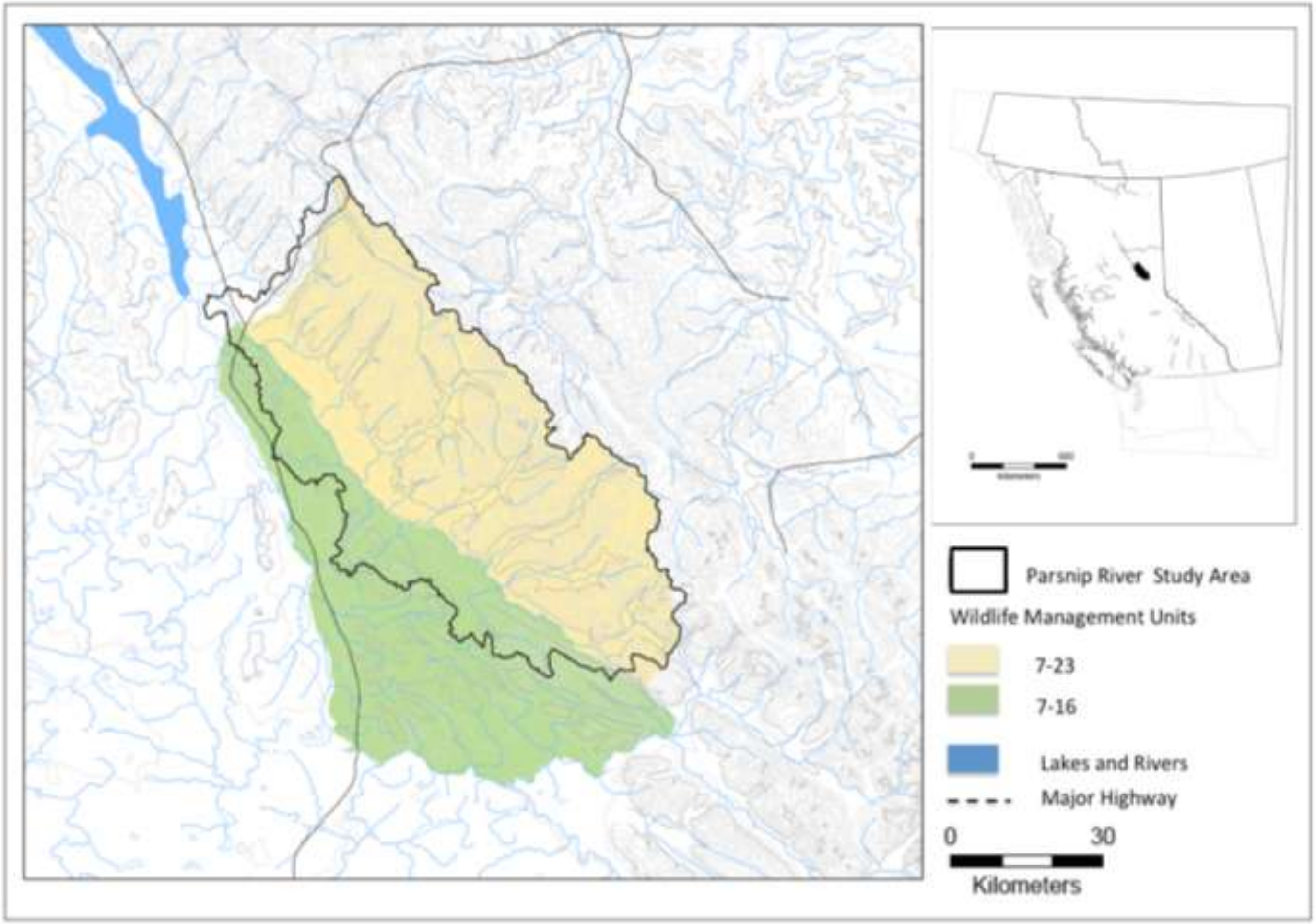

Figure 2 Location of Parsnip River Study Area showing relative location of wildlife management units 7-23 and 7-16 where experimental reduction of moose through increased moose harvest occurred from 2007-2012. Inset map indicates the location of the Parsnip River Drainage (black filled polygon) within the province of British Columbia.

of the river, resulting in extensive riparian areas. Elevations ranged from 434 m to 2,510 m with treeline occurring at approximately 1,550 m to 1,700 m.

Plant communities within the study area were characterized by 3 ecotypes: the sub-boreal spruce (SBS) biogeoclimatic (BEC) zone on the lower slopes and valley bottoms (600 m – 1,100 m); the Engelmann spruce-subalpine fir (ESSF) BEC zone at higher elevations (1,100 m – 1,700 m); and above tree line, the alpine tundra (AT) BEC zone (Coupe et al. 1991). Riparian areas were abundant in valley bottoms, and consisted of cottonwood (*Populus balsamifera*), willow (*Salix spp.*), alder (*Alnus spp.*), and red-osier dogwood (*Cornus stolonifera*). Environmental conditions were continental, resulting in short summers with moderate precipitation and winters that typically extended from November to May. Average annual temperatures ranged from 1.7°C to 5°C, with mean annual precipitation ranging from 440 mm - 900 mm with approximately 25 % -50% of precipitation received in the form of snow (Meidinger and Pojar 1991).

The Parsnip drainage supports a diverse predator-prey ecosystem. Carnivore species in the study area include: wolf, grizzly bear (*Ursus arctos*) and black bear (*Ursus Americanus*), cougar (*Puma concolor*), coyote (*Canis latrans*), lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*) populations. Ungulate species that are preyed upon by carnivores include: elk (*Cervus elaphus*), moose (*Alces alces*), mountain caribou, mountain goats (*Oreamnos americanus*), and mule deer (*Odocoileus hemionus*). Moose are the most abundant ungulate species in the study area, and are the primary prey of wolves. Non-ungulate prey species of note include beaver (*Castor canadensis*), which inhabit the numerous lower elevation riparian habitats.

Forest harvesting was the primary landscape –level disturbance influencing lower elevation stands (< 1,100 m) within the Parsnip River study area, resulting in extensive areas of forest in early-seral growth stages. The majority of logging activity that has occurred the past 40 years has been in the southwest portion of the study area, with harvest occurring in ~21% of the study area to the southwest of the Parsnip River, and only in ~4% of the study area to the northeast (Steenweg 2011). Clear cut logging was the common harvest method in the area with many cutblocks larger than 2 km^2 (Heard et al. 1999). Other human activities on the landscape include hunting and trapping, with both resident and non-resident (guided) hunting of wildlife permitted. Highway 97 crossed a small section of the study area in the northwest edge of the study area, and a network of logging roads provided access to several lower elevation areas along the length of the Parsnip drainage.

2.2. Animal Capture

To assist in evaluating changes in population size, survival, and distribution of key species following an increased harvest of moose in the PRSA, we captured and collared representative samples of caribou, moose and wolves. Throughout the study, we attempted to maintain a target radio-collared sample of 20 moose, 20 caribou, and 8 wolves. Consequently, additional animals were captured and collared each year to replace collars that were lost either through mortality, dispersal, or collar failure.

Moose (n = 23) and caribou (n = 28) were captured using aerial net gunning (Altoft Helicopters, Prince George, BC) during the winter months (November to March). Because project objectives focused on evaluating recruitment and productivity of ungulate species monitored, only female moose and caribou were captured and fit with VHF collars. Three other caribou in the Parsnip Herd radio-collared for a concurrent study (Seip, unpublished data) were also monitored, increasing the number of caribou monitored to 31.

In total, 38 wolves were collared over the course of the study. The majority of wolves (n = 36) were captured using a combination of aerial net-gunning (Altoft Helicopters, Prince George) and darting to administer immobilizing drugs (Telozol®; Fort Dodge Animal Health, Fort Dodge, Iowa). The remaining 2 wolves were captured using modified padded leg-hold traps (Braun Wolf Traps; Wayne's Tool Innovations, Inc., Campbell River, BC). Aerial based wolf captures took place during the winter months (January - March) while the ground based leg-hold trapping occurred in July 2009. Because of the difficulties assigning a sex to wolves when using aerial capture techniques, both male and female wolves were collared. Wolves were fit with either VHF (n = 19) or GPS (n = 19) collars. GPS collars were pre-programmed to acquire locations every 6 – 12 h during the winter season, and every 2 – 4 h during the summer season. All capture and collaring activities were carried out by Ministry of Environment personnel and handling procedures were in accordance with B.C. Ministry of Environment protocols and the Guidelines of the Canadian Council on Animal Care (2003).

2.3 Population monitoring of key species

2.3.1 Estimating Population Size

2.3.1.1 Caribou

Each March, in conjunction with the Mountain Caribou Recovery Program, we performed a mountain caribou population census within the Prince George Forest District which included the Parsnip herd and the adjacent control Hart South herd (Figure 3). During population census surveys, we flew a helicopter along treeline within each watershed and searched for caribou tracks. When fresh tracks were located, we searched the area intensively to locate and count the caribou, and classify the animals as either adults or calves. The proportion of collared caribou found was used to determine the sightability correction factor used in calculating population estimates that accounted for missed animals (following mark-resight methodologies; Bartmann et al. 1987). To estimate total population size, we used the joint hypergeometric maximum likelihood estimator in program NOREMARK (White 1996).

To estimate calf-cow ratios and compare over-summer and over-winter calf survival, caribou calf-count surveys were performed each November. During these surveys, all radio-collared caribou were monitored for and visually located using a Bell 206 helicopter (Altoft Helicopters, Prince George BC). Group size and composition of animal groups associated with the collared caribou were then recorded and the number of calves in the herd was presented as a percentage of the total herd.

2.3.1.2 Moose

To estimate population size of moose, an aerial survey was conducted each December following a stratified random block (SRB) design (Gasaway et al. 1986, Heard et al. 1999, Walker et al. 2006). Using land-cover data and remote imagery in GIS, we classified moose range within the study area as either strata 1 (S1): areas predicted to have high densities of moose (i.e., forests <40 years of age, riparian areas, and open shrub dominated meadows), or strata 2 (S2): areas predicted to have lower densities of moose (i.e., forests >40 years of age). Following its classification as S1 or S2, we divided the entire study area into a predetermined grid of 9 km^2 (3.2 × 2.8 km) blocks that contained varying amounts of high and low (i.e., S1 and S2) moose density stratum. Adjacent blocks were arbitrarily joined so that ≥ 4 km^2 of S1

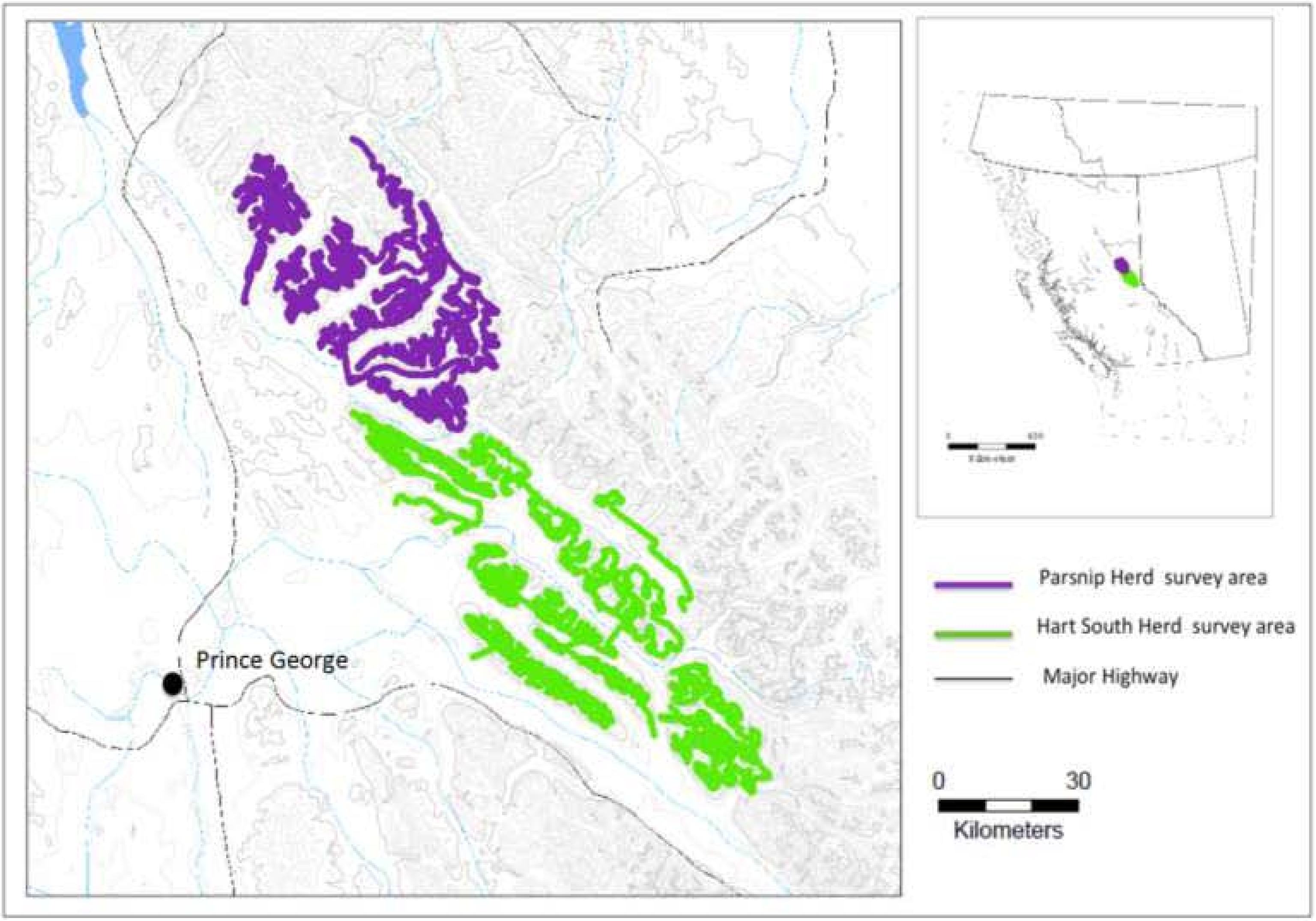

Figure 3 Flight lines representing the area covered during the mountain caribou census 22 to 31 March 2010 showing the locations of the Parsnip and Hart South herd ranges.

was present in each sample unit (SU). We then randomly selected S1 and S2 blocks to survey, with S1 areas surveyed more frequently than S2 areas.

Surveys were completed using Bell 206 helicopters flown 30-50 m above the ground. We circled each moose and recorded its age and sex as a calf (~ 8 months old), cow, bull or unclassified, based on the presence of a white vulva patch, the bell length and shape and facial colouration and morphology (Heard *et al.* 1999). We also recorded the percent vegetation cover, to the nearest 5%, within a 9 m radius of where the moose was first seen (Unsworth *et al.* 1998). Vegetation cover estimates were grouped into 5 classes each with a specific detection probability (DP) and sightability correction factor (SCF), as determined by Quayle *et al.* (2001), following the approach of Anderson and Lindzey (1996).

For each stratum of the survey area, a naïve population estimate and sampling variance for unequal sized sample units were calculated using Jolly (1969). Sightability and model variance were calculated using the program Aerial Survey (Unsworth *et al.* 1998) modified with data from Heard *et al.* (1999) and Quayle *et al.* (2001). We calculated the final population estimate as the product of the naïve population estimates for both strata and their SCF. The variance for the final population estimate was the sum of the sampling, sightability and model variances of both strata.

In the surveys that occurred from 2007 onward, only S1 areas were surveyed, and the S2 population estimate was based on the distribution of radio collared cow moose among the two strata at the beginning and the end of the survey. In other words, we estimated the total Parsnip moose population by dividing the S1 estimate by the fraction of collared moose in S1 (p). The variance of p was calculated using the binomial formula and the variance of the total was calculated using the formula for functions of random variables (Heard 1987). This approach allowed is to maximize survey efforts in S1 strata and increase survey efficiency, but was based on the assumption that distribution of the collared moose was representative of overall moose distribution with respect to stratum boundaries.

2.3.1.3 Wolves

To estimate the total number of wolves within the Parsnip caribou herd range, we performed aerial survey flights to locate radio-collared wolves and search areas where wolves have commonly been found in the PRSA (rivers and roads). Survey flights occurred during the winter season (November through March) when animals typically occur in large packs. By monitoring the number of animals within each pack over a series of survey flights, we could calculate the minimum number of animals in each pack, and in turn the entire study area, for each year of the study.

We assigned wolves to packs according to their range on the landscape as well as their associations with other collared wolves. The numerous tributaries that flow into the Parsnip River were typically the core areas used by wolves and could be used to delineate pack boundaries. To determine if more than one radio-collared wolf was in a pack, we examined the proximity of all GPS and VHF wolf locations in time and space. When locations of wolves were ≤500 m apart and occurring within 1 h of each other, we considered the animals to be in the same pack.

We attempted to have at least one wolf collared in each pack each year, to allow us to consistently locate each pack and make reliable estimates of pack size and range. Because we often were not able to collar a wolf in every pack, (particularly in the earlier years of the study), annual minimum counts often underestimated the total number of wolves within the study area. To account for this, we determined a best estimate for annual total wolf populations for each year by correcting for under-counted packs based on counts from previous years, or estimates based on wolf sign within the area (i.e., tracks, howling). Although this method of population estimation is somewhat subjective, it was the most accurate way to assess population size given the difficulty of monitoring both individuals and packs within the study area.

2.3.2 Estimating Survival

Radio-collared animals were monitored for survival from fixed-wing aircraft (Guardian Aerospace, Vanderhoof, BC) throughout the duration of the study. Ungulate species were typically surveyed separately, with caribou monitored every 2 weeks and moose every 3 months. Wolves were monitored for survival opportunistically, typically during ungulate monitoring flights. Mortalities of all species were investigated in the field to determine cause of death. Survival estimates for each species were calculated seasonally using the staggered entry Kaplan-Meier Estimator (Pollock et al. 1989). Using this method, monthly survival probabilities are estimated as the number of radio-collared animals that survived the month divided by the total number of radio-collared animals at the start of the month. Seasonal survival is then calculated as the product of all monthly survival probabilities encompassed by the year/season. This method allowed us to censor the data for individuals that were no longer able to be monitored for survival status due to collar failure or dispersal without affecting survival rate estimates.

2.3.3 Describing distribution and movement

Locations of VHF-collared caribou and moose recorded during population monitoring flights were examined spatially using ArcMap 9.3 (ESRI 2008). For each caribou and moose location, we queried the elevation using a Terrain Resource Information Management

(TRIM) 1:20,000 scale digital elevation model (LRDW, B.C. Government Forests, Lands, and Natural Resources Operations GeoBC; 25 m resolution; generated 12 December 2005). Because locations of ungulates were monitored infrequently across extended time periods (weeks to months) we could not reliably report movement rates or detailed home range statistics. To better understand the areas used by moose in the PRSA, we also utilized location and elevation data from 16 female moose collared during a previous study within the study area (*n* = 319; D.C. Heard, unpublished data, 1996 - 1998).

Movements and distribution of GPS- and VHF-collared wolves were analyzed using Spatial Viewer (M.P. Gillingham, unpublished program) and ArcMap 9.3 (ESRI 2008). For each wolf, we examined locations spatially and removed erroneous points and points with exceedingly high Degree of Precision (DOP) values (i.e., 3D locations with DOP >25 m and 2D fixes with DOP >10 m; Rempel and Rodgers 1997, Dussault et al. 2001). For the remaining reliable GPS locations, we determined the time between fixes and the distance moved between consecutive fixes. From these time and distance measures, we could determine movement rate, (Euclidian distance between consecutive GPS locations divided by the number of hours between fixes), and in turn, the average annual movement rate for each animal. We determined the elevation of each wolf location using ArcMap 9.3 (ESRI 2008) and calculated the annual home range (June-June) for each pack using a 100% Minimum Convex Polygon tool (Hawth Tools; Beyer 2004) in ArcMap 9.3 (ESRI 2008). Polygons were based on the collar locations (GPS and VHF) of all radio-collared individual(s) of the pack monitored that year.

In some instances, radio-collared wolves left the boundaries of the Parsnip River Drainage, and did not return during the monitoring period (either due to mortality events outside the study area, or establishment of a new territory outside the study area). We defined these long-term movements outside of the PRSA as dispersal events. To calculate annual dispersal rates, we used the staggered entry Kaplan-Meier Estimator (Pollock et al. 1989). Monthly dispersal probabilities were estimated as the number of radio-collared animals that remained in the PRSA at the end of the month divided by the total number of radio-collared animals that had been in the study area at the start of that month. Seasonal dispersal rates are then calculated as the product of all monthly dispersal probabilities encompassed by the year/season (for detailed methodology, please refer to Steenweg [2011]).

2.4 Quantifying Species Interactions

2.4.1 Quantifying Wolf Forays in Caribou Habitat

To quantify the hunting effort of wolf packs in caribou habitat, we examined the elevations used by GPS collared wolves (n = 20), with wolf locations above 1050 m considered to represent wolf use of caribou habitat. The threshold for caribou-selected elevations was based on the caribou habitat-selection model created for the Parsnip caribou herd (Jones 2007). Wolf locations below 1050 m were considered to represent wolves' use of den and rendezvous sites and hunting forays for lower elevation prey (i.e., moose and beaver). At the coarsest scale, we determined the percentage of time wolves were above 1050 m on a monthly basis. At a finer scale, we analyzed higher elevation movements spatially to determine whether the movements were likely associated with a hunting foray, and to partition series of high elevation locations into distinct hunting forays.

To determine if higher elevation movements were representative of a hunting foray, we used spatial viewer (M.P. Gillingham, unpublished program), which allowed us to: 1) partition groups of consecutive high elevation points into distinct hunting forays; and 2) exclude higher elevation wolf movements that were likely not associated with hunting effort (i.e., isolated movements to higher elevations between visits to a lower elevation kill or return visits to higher elevation kill site clusters). We considered the forays of individual collared wolves to represent the hunting efforts of the pack it was a part of, thereby providing a measure of caribou hunting effort for that pack. To prevent pseudo replication of hunting effort that might occur when 2 animals were collared within the same pack, we compared foray activity between animals to ensure shared forays were only counted once.

Because our ability to detect movements to higher elevations was limited by the frequency at which locations were acquired (i.e. the decreased fix acquisition rates of collars during the non-summer seasons), we also calculated a corrected foray frequency for each month. Corrected foray frequencies were calculated by dividing the number of forays observed that month by the total number of GPS locations acquired that month, then multiplying that number by a constant (Steenweg 2011).

3.0 RESULTS

3.1 Population monitoring of Key Species

3.1.1 Population trends of Key Species

Based on the results of winter census surveys, the number of caribou in the Parsnip herd ranged from approximately 230 animals in 2006, to a low count of 146 in 2012. In the interim years of the study, the population varied by as many as 50 animals annually, in some years increasing, in other years decreasing. When total counts from previous years are considered (i.e., 2002 onward), the population appears stable (Figure 4). The Hart South control herd, monitored simultaneously, ranged from a total count of 488 animals in 2006 to 404 animals in 2012, with the lowest population count occurring in 2010 with 359 animals.

When total counts from previous years are considered, the Hart South herd also appears to be in relatively stable to slightly declining (Figure 4). Percent calves in the Parsnip herd varied between 9% and 20% (Figure 5), and typically corresponded to the estimated population of the herd with peak calf percentages occurring in 2006, when estimated caribou numbers were highest, and lowest percentages occurring in 2012, when herd numbers were lowest (Figure 5).

The number of moose in the PRSA declined by approximately 68%, from a peak population of ~3000 animals in 2005 to ~974 animals in 2011 (Figure 6). The decline has been primarily in the number of bull moose in the population based on a decline in the sex ratio from 112 bulls: 100 cows in 1998 to 44:100 in 2009 and the high survival of radio-collared female moose.

According to minimum count data, the number of wolves in the Parsnip River study area increased by 10 over the duration of the study, ranging from 27 animals in 2007 to 37 animals in 2011 (Figure 7). However, the ability to effectively monitor individual packs increased over the years as more wolves were collared, therefore leading to better minimum counts of animals, and therefore a larger minimum count estimates in the latter study years. If we assume that pack territories remained similar across years (i.e., no dispersal of entire packs), the total number of wolves in the PRSA remained relatively stable throughout the study period, ranging from 44 animals to 34 animals with an average of 38 animals (SD = 4) according to best estimates (Figure 7).

When we compared our minimum and best estimate counts of wolves in the study area to the number of wolves predicted to be supported by the density of primary ungulate prey on the landscape (i.e., moose; Fuller 1989), we found that wolf densities did not follow the trend predicted, with fewer wolves than predicted in the earlier study years when moose densities were highest, and more wolves than expected on the landscape in the later study years when moose were less abundant (Figure 7).

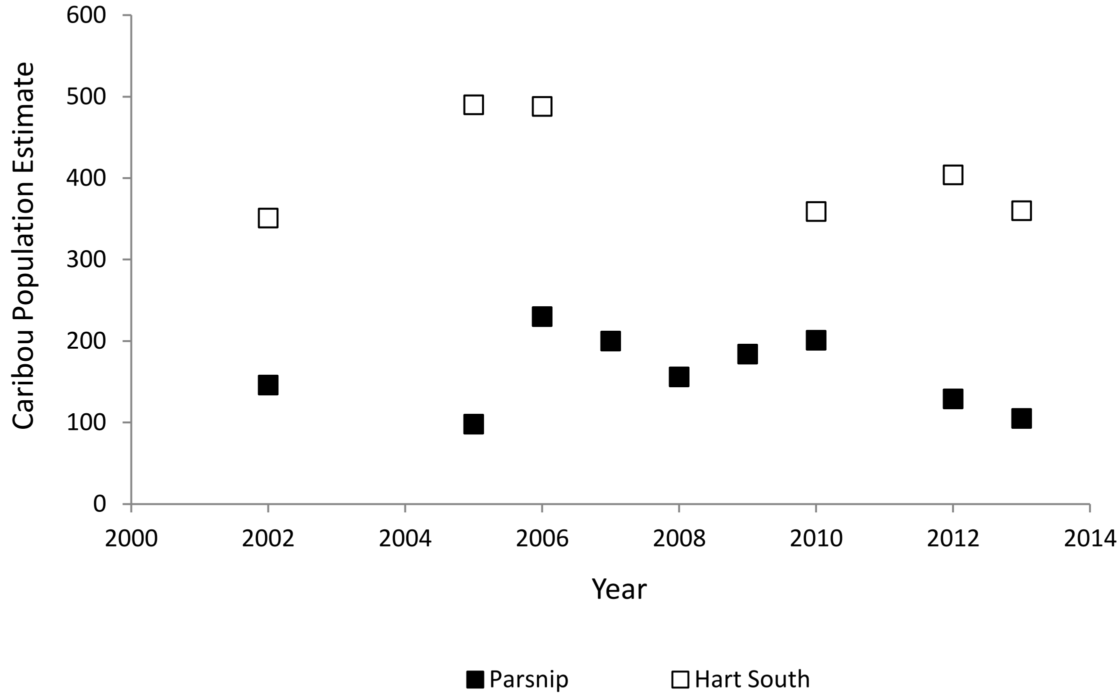

Figure 4 Number of caribou estimated in the Parsnip and Hart South caribou herds between 2002 and 2010. Shaded grey bar indicates the onset of the increase in moose harvest permits within the study area.

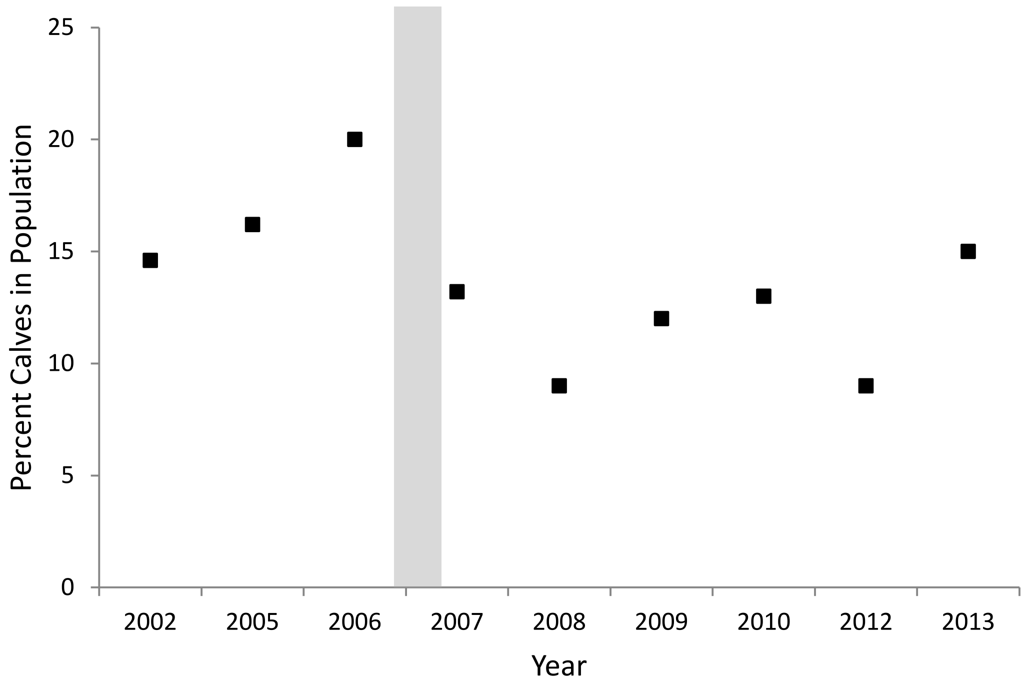

Figure 5 Percent calves in the Parsnip River caribou herd (2002-2012). Shaded grey bar indicates the onset of the increase in moose harvest permits within the study area.

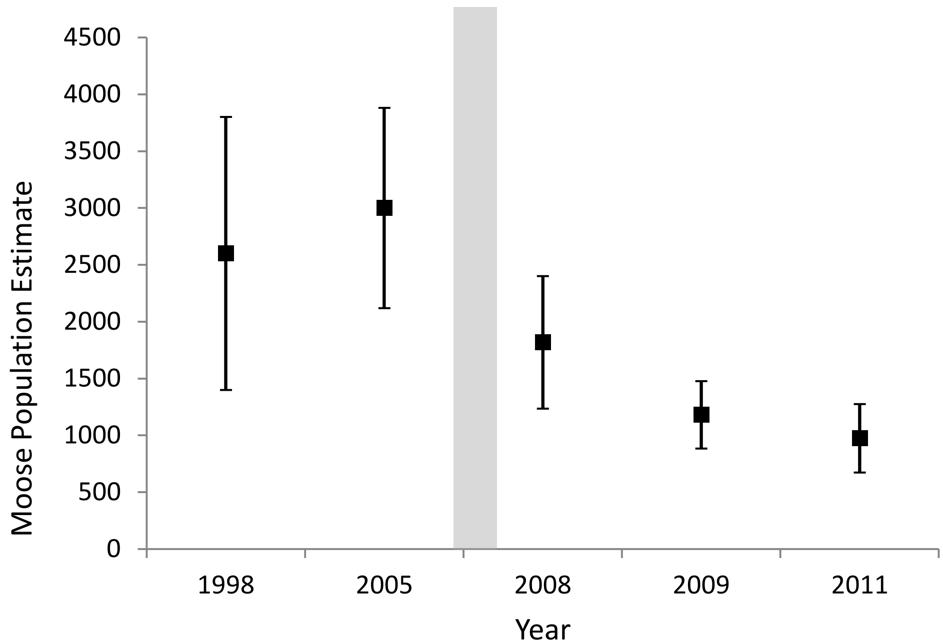

Figure 6 Change in the number of moose in the Parsnip population between 1998 and 2011 based on stratified random block density estimation surveys. Shaded grey bar indicates the onset of the increase in moose harvest permits within the study area.

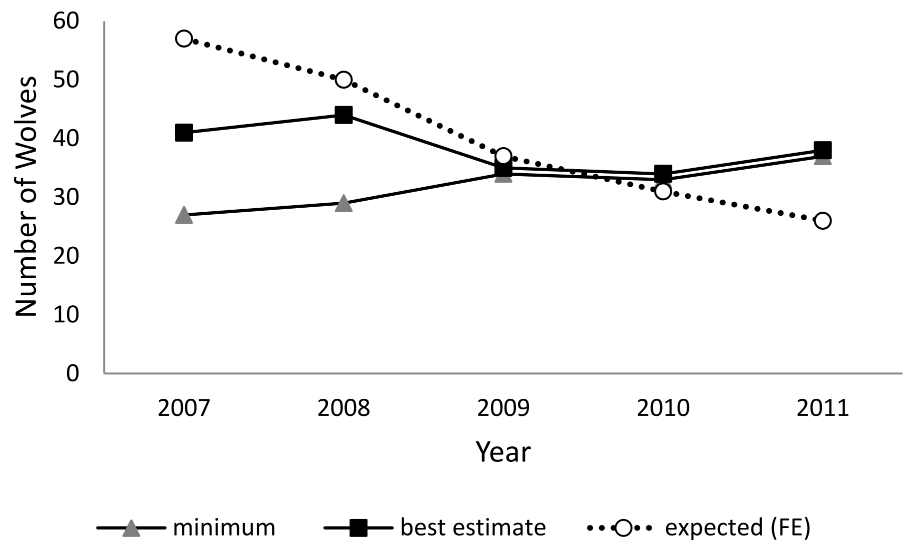

Figure 7 Change in the number of wolves inhabiting the Parsnip River Study Area from 2007-2012 indicated by minimum count data and the best estimates accounting for unaccounted for animals and packs. Graph also indicates the predicted number of wolves on the landscape given the annual density of moose (Fuller 1989).

3.1.2 Survival of Key Species

During the study period, 15 of 31 collared female caribou died, resulting in annual survival estimates that ranged from 81% to 100% with an average survival estimate of 89% (Table 2). Of the collared animals that died, 7 were killed by wolves, 1 by a bear, 1 by a wolverine, and 6 died of unknown causes. When collared caribou were killed by wolves, most mortalities occurred in both the winter and snow-free seasons, and almost all kills (6 of 7) occurred in the latter years of the study (2010-2011; Figure 8).

Over the duration of the study, 10 of 23 collared female moose died, resulting in annual survival estimates that ranged from 83% to 100% with an average survival rate estimate of 88% (Table 2). Of the collared animals that died, 5 were killed by wolves, 4 were killed by hunters, and 1 died due to a collision with a train. If human related causes of mortality were excluded, average survival of collared moose would have been approximately 94%.

Of the 38 wolves radio-collared from 2007-2012, 16 died during the period that they were collared, 14 were alive at the end of collaring, and 8 had unknown fates (due to dropped collars or collar failures). When we consider the survival rate of the animals that remained in the study area for the duration of the period they were collared, survival rates varied from 44% to 100% (Table 2). Of the radio collared wolves that died, 9 were legally shot or trapped, 3 died of unknown natural causes, 1 likely died of starvation, 1 died following a vehicle collision, 1 died due to complications with recapture, and 1 died of injuries after being kicked by a moose.

Table 1 Annual mortality rates (95% confidence intervals in parentheses) for caribou, moose, and wolves in the Parsnip River study area B.C. Moose numbers were reduced by approximately 50% between 2007-2009 through increasing the number of legal hunting permits allotted for the wildlife management units encompassing the study area (WM Units 7-16 and 7-23). Mortality rate was calculated using the Kaplan-Meier Estimator (Pollock et al. 1989), and *n* indicates the number of radio-collared animals monitored for survival over the annual period as a min-max range.

Species	Statistic	Year				
		2007	2008	2009	2010	2011
Caribou	mortality rate	0.81 (0.62-1.0)	0.95 (0.85-1.0)	0.83 (0.68-0.98)	0.90 (0.76-1.0)	0.82 (0.64-1.0)
	n	13-17	17-24	20-24	17-21	14-17
Moose	mortality rate	1	0.83 (0.67-0.98)	0.95 (0.85-1.0)	0.83 (0.66-1.0)	0.87 (0.70-1.0)
	n	23	19-23	18-19	15-18	13-15
Wolves	mortality rate	0.75 (0.73-0.77)	0.44 (0.42-0.46)	0.71(0.68-0.74)	0.55 (0.50-0.59)	1
	n	6-12	9-12	5-9	4-11	3-10

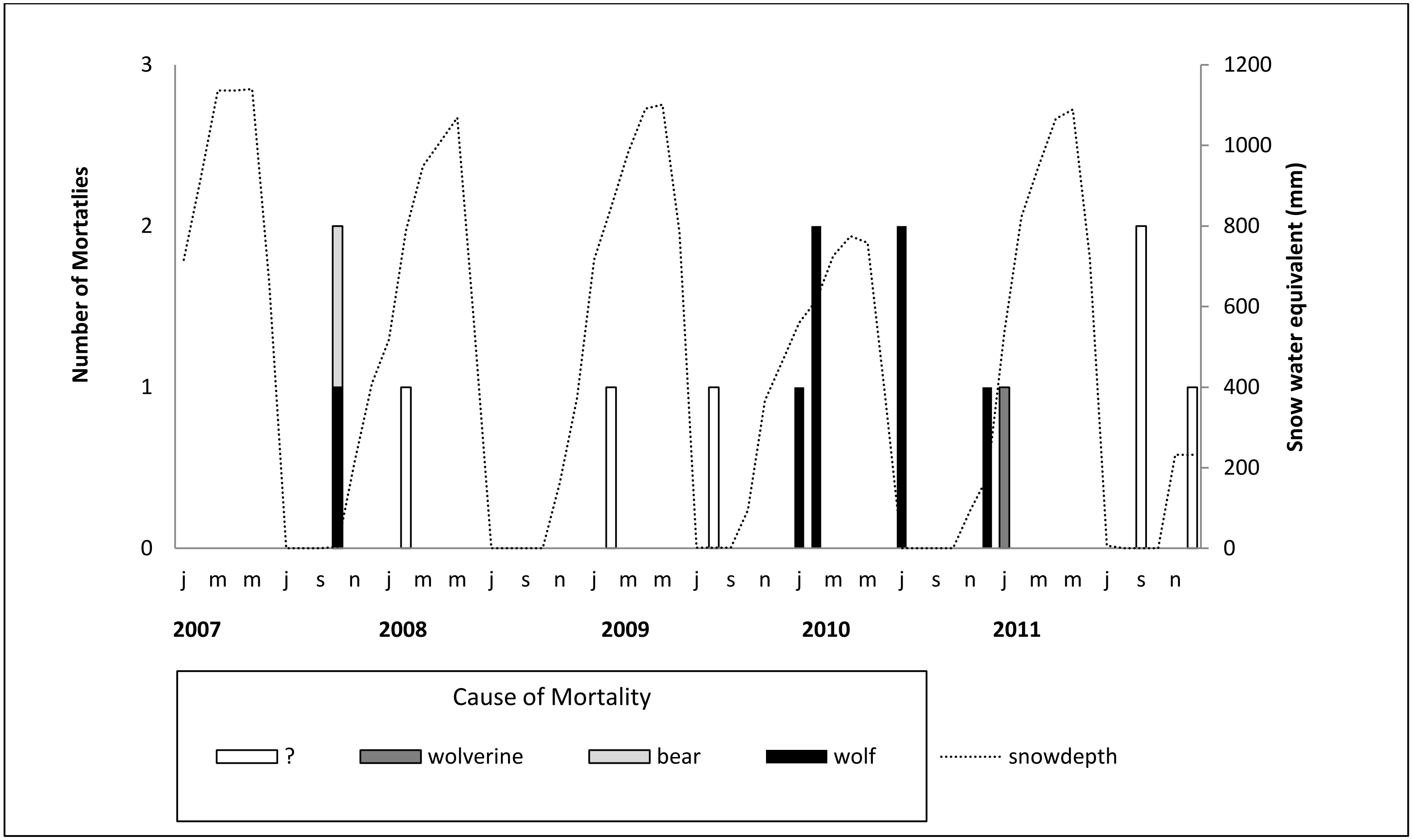

Figure 8 Timing and cause of mortality of collared female mountain caribou in the Parsnip River Study Area (2007-2011). Snow depth measurements show relative snow pack across the different season and years (Hedrick lake Automated snow pillow).

3.1.3 Distribution and movement of Key Species

From 2006-2012 we recorded 352 locations from 31 radio collared female caribou in the PRSA. Elevations used by collared caribou ranged from 739 m to 1965 m, with an average elevation of 1379 m ± 182 m ($\bar{x}$ ± SD). Ninety-five percent of collared caribou locations were above 1050 m (Figure 9). Over the same period, we collected 176 locations from 23 radio-collared female moose. When we considered these locations, in addition to the 319 locations obtained from previously collared female moose in the Parsnip (see capture section for details), elevations used by moose ranged from 711 m to 1452 m, with an average elevation use of 840 m ± 126 m ($\bar{x}$ ± SD). Ninety-three percent of moose locations were below 1050 m (Figure 9).

Over the course of the study we obtained 24,566 successful fixes from a total of 20 GPS-collared wolves, and 171 locations from 18 VHF-collared wolves. The average movement rate for all GPS collared wolves was approximately 425 m/h with a range of 155 m/h to 612 m/h (Table 3). From analyses of the distribution of radio-collared wolves and observations made during telemetry flights, there were 4 major wolf packs that inhabited or frequented the study area ("Reynolds-Anzac", "Anzac-Table", "Hominka-Missinka", "Whichcika-Seebach"; Figure 10).

Packs were often dynamic, covering different areas of their territories annually, and often splitting into smaller sub-packs, with membership of collared wolves within sub-packs often changing over the course of the year. This variation in territory size and location, as well as pack size, frequently led to spatial overlap in adjacent pack territories. Analyses of wolf location temporally, however, showed that packs were not in the same place at the same time, indicating that packs were distinct although spatially overlapping.

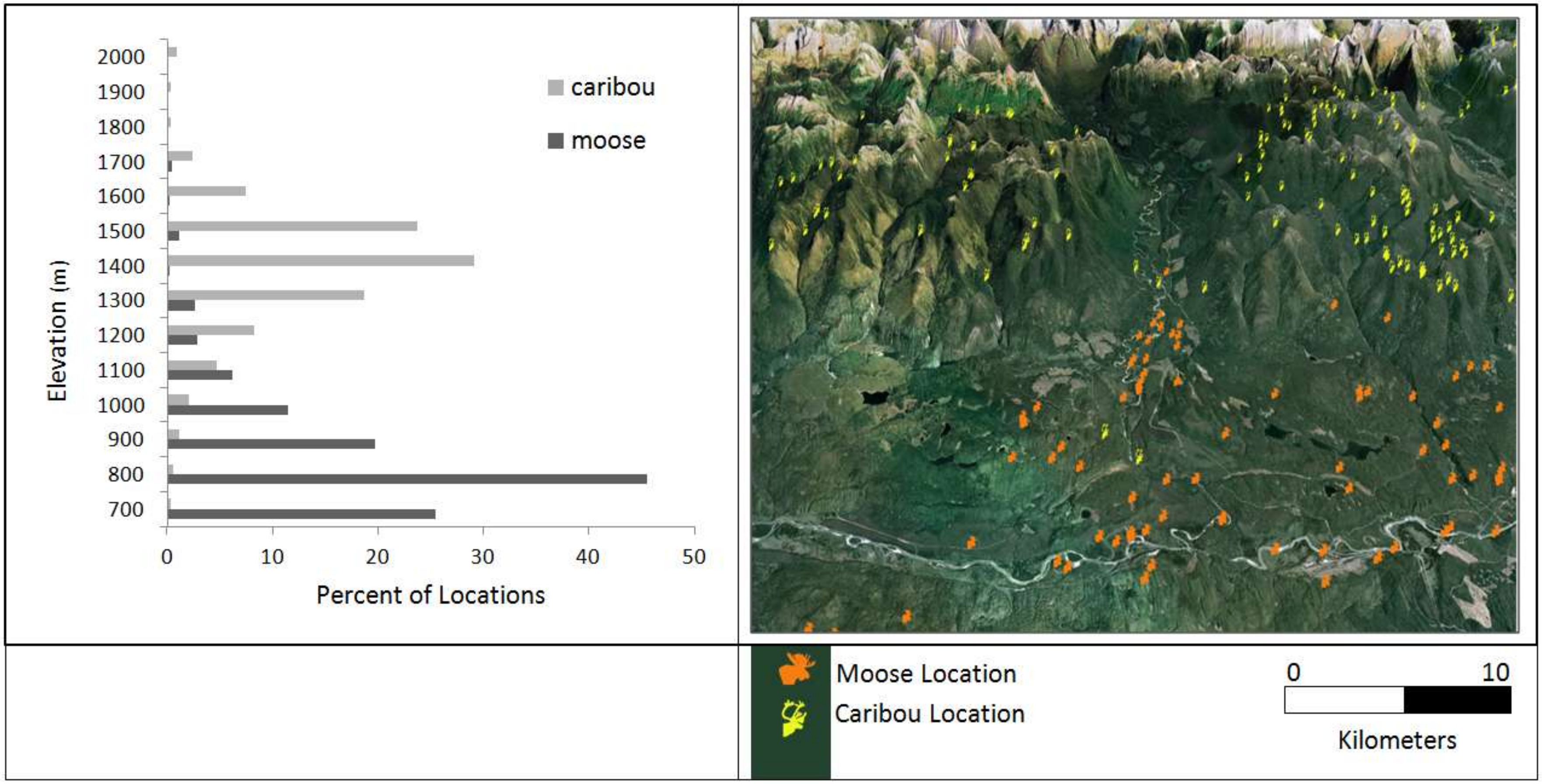

Figure 9 Use of elevation by collared female moose (*n* = 23; 495 locations) compared to collared female caribou (*n* = 31; 352 locations) in the Parsnip River Study Area (2007-2012). Y-axis labels represent midpoint of intervals (e.g., 1000m represents 950 m-1049 m) Image on right shows the species use of different elevations on the landscape graphically.

Table 2 Summary of GPS-collared wolves (n = 19) monitored within the Parsnip River Study Area from 2007-2012, including the duration the animal was collared, the number of fixes acquired, the fix success rate, and the average movement rate (m/h).

Wolf ID	Start Date	End Date	# Fixes	% Fix Rate	Movement Rate (m/h)
W10	14/03/2007	11/12/2007	843	80%	366
W11	23/01/2008	05/02/2008	59	97%	320
W12	22/01/2008	29/03/2008	294	95%	394
W16	27/02/2008	02/06/2008	352	84%	484
W18	29/02/2008	01/06/2008	3160	80%	495
W19	29/03/2008	23/08/2008	855	82%	367
W24	10/03/2009	Unknown fate- unable to acquire location data			
W25	29/03/2009	04/04/2009	62	91%	230
W26	24/07/2009	31/03/2010	2611	87%	424
W27	31/07/2009	22/08/2009	236	89%	168
W28	27/02/2010	12/02/2012	2677	95%	546
W29	08/03/2010	27/03/2012	Still alive at end of reporting period		
W32	08/02/2011	05/03/2011	48	96%	155
W33	18/02/2011	08/12/2011	2175	92%	517
W34	18/02/2011	09/02/2012	2244	91%	606
W35	18/02/2011	10/02/2012	2302	91%	483
W36	08/03/2011	01/02/2012	2208	90%	519
W37	08/03/2011	09/02/2012	2315	93%	612
W38	08/03/2011	10/02/2012	2125	89%	470

The annual home range size of wolf packs ranged from 391 km^2 to 5,098 km^2 with an average size of 2280 ± 1328 km^2 ($\bar{x}$ ± SD). Because range estimates were calculated using the 100% MCP algorithm, these estimates likely overestimate the amount of range used by the individual packs, and often include large portions of range that were unused. When we examined the spatial distribution of wolf points, we found that the elevations used by wolves ranged from 603 m to 1738 m, with 88% of wolf locations occurring at elevations <1050 m. When we plotted movement paths on the landscape, we could see that animals typically followed river valleys of the tributaries and mainstem Parsnip River within their territories, and used higher elevation areas less frequently (Figure 11).

3.2 Quantifying Species Interactions

3.2.1 Quantifying Wolves use of Caribou Habitat

The percentage of time wolves spent in caribou habitat (locations above 1050 m), varied seasonally and across years. Although data was not able to be gathered across all months and years due to lack of GPS collar data in several months, there is a general trend of increased use of higher elevations in the snow-free seasons, and infrequent use (<20%) when snow depths were high (Figure 12). The exception to this is the winter of 2010 when snow depths were low, and wolves use of caribou habitat was up to 40% (Figure 12).

When we partitioned the time spent by wolves in caribou habitat (>1050 m) into distinct hunting forays, we isolated 52 hunting forays (across the 4 packs monitored) from the period of Feb 2011 to Feb 2012. The timing of forays seasonally reflected the time spent in caribou habitat, with hunting forays observed more frequently during the snow-free months, and decreasing in frequency as snow depth increased (Figure 13). When we corrected for the differences in monitoring intensity across the seasons, (which may cause us

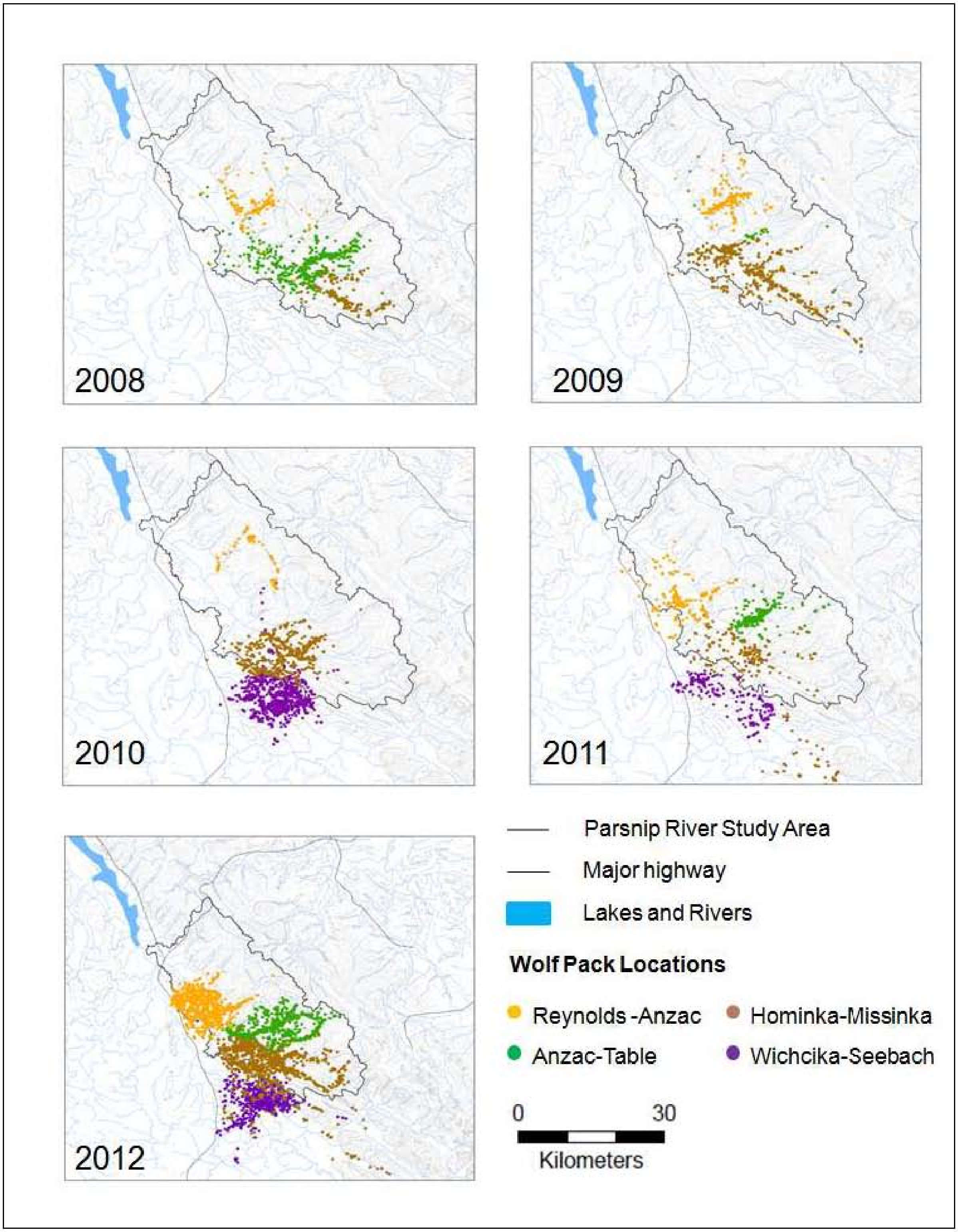

Figure 10 Annual wolf pack location in Parsnip River Study Area (June –June; 2008–2012). All locations from GPS-collared and VHF-collared wolves (n = 19 and n = 19 respectively).

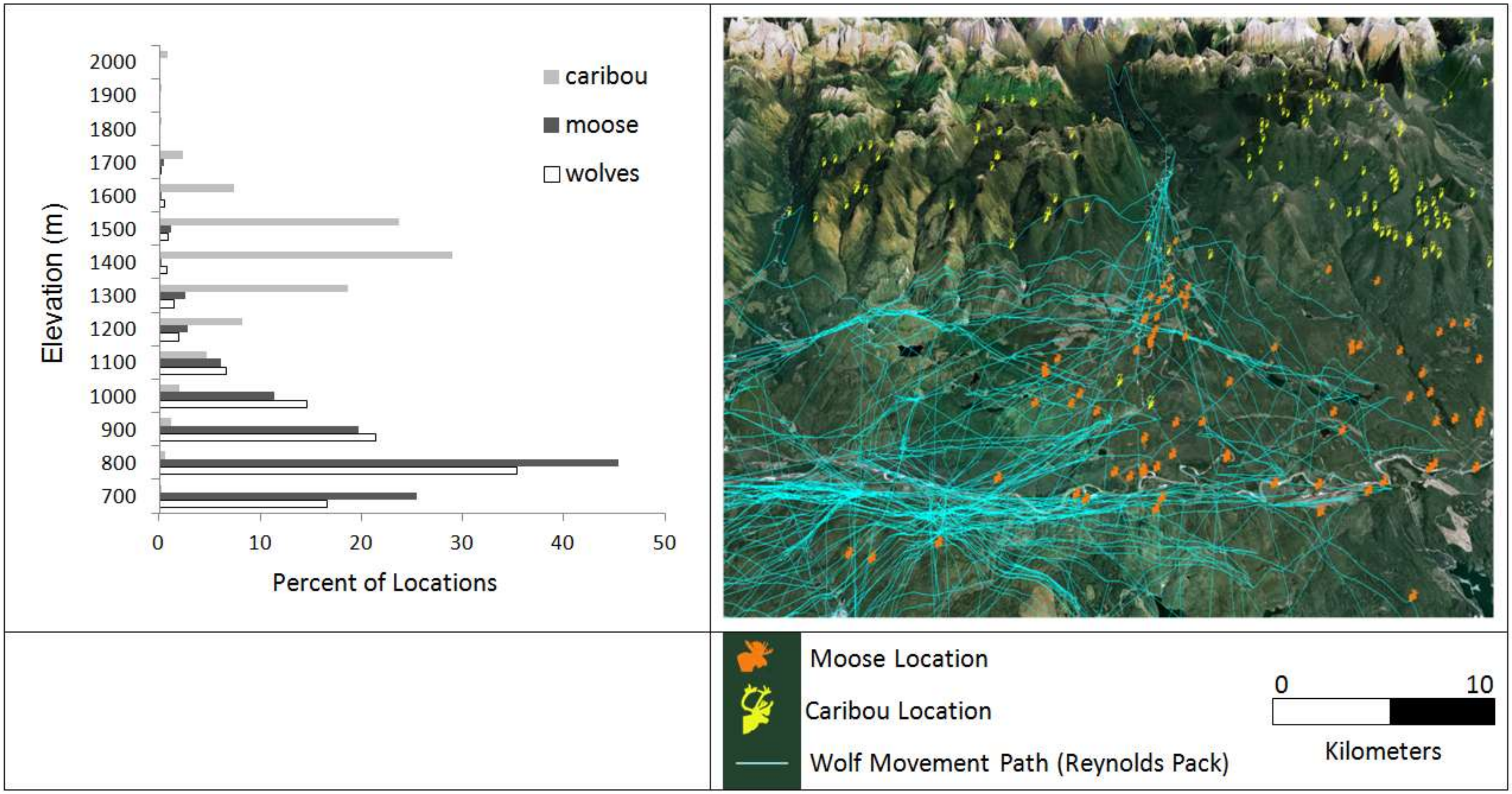

Figure 11 Use of elevation by collared wolves (*n* = 38; 24,566 locations) relative to collared female moose (*n* = 23; 495 locations) and collared female caribou (*n* = 31; 352 locations) in the Parsnip River Study Area (2007-2012) Y-axis labels represent midpoint of intervals (e.g., 1000m represents 950 m- 1049 m). Image on left graphically shows species use of different elevations on the landscape, with linear features showing the annual movement path of a GPS collared wolf within the Reynolds-Anzac pack during the 2012 season.

to underestimate the number of forays during periods when fixes were more infrequent), we saw a more stable trend, wherein the frequency of forays remains more consistent throughout the year (approximately 5 forays per month), regardless of month or snow depth.

Analyses of hunting forays in previous years of the study (Steenweg 2011) indicate similar trends of wolf activity, with a higher frequency of forays during the snow-free months relative to the times when snow depths were higher (Figure 14). Considering all years that wolves movements were monitored within the study area (2007-2012) we found 127 distinct forays into caribou habitat across the 4 major packs monitored.

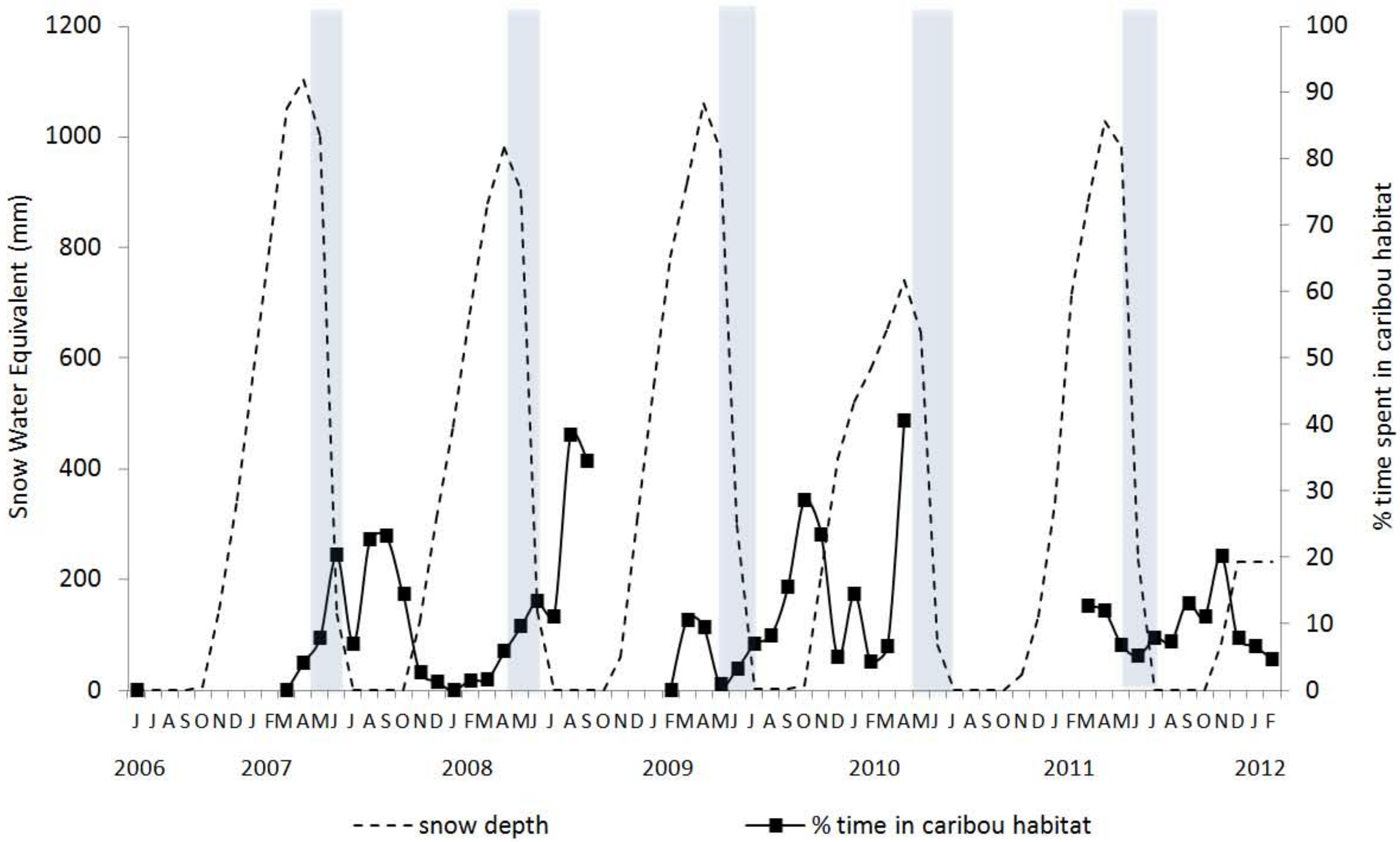

Figure 12 Average amount of time spent by wolves above 1050 m relative to average daily snow depth in the Parsnip River Study Area (2007-2012). Shaded areas approximate the peak calving period of mountain caribou inhabiting the study area**.**

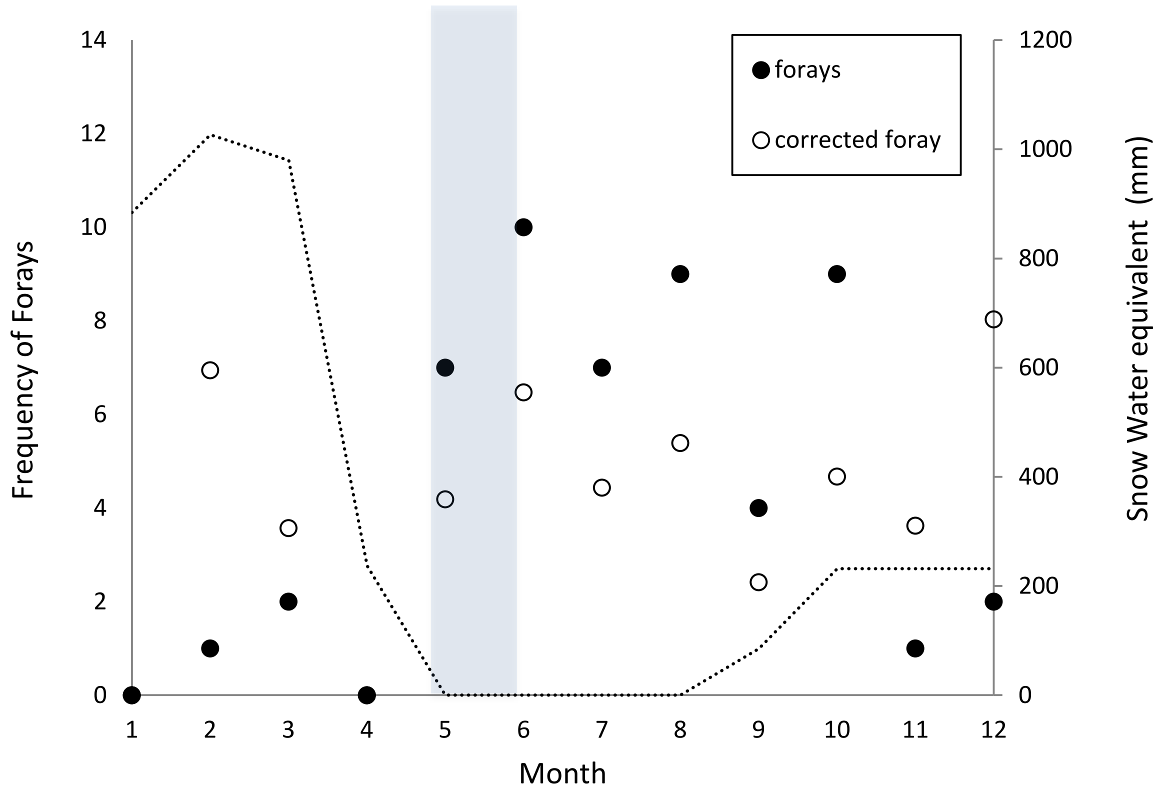

Figure 13 Frequency of hunting forays (both number of forays observed and number of forays corrected for monitoring intensity) in caribou habitat (elevations above 1050) by wolves (n = 4 packs) across the months (2012) in the Parsnip River Study Area. Dotted line indicates average daily snow depth for that year. Shaded areas approximate the peak calving period of mountain caribou inhabiting the study area.

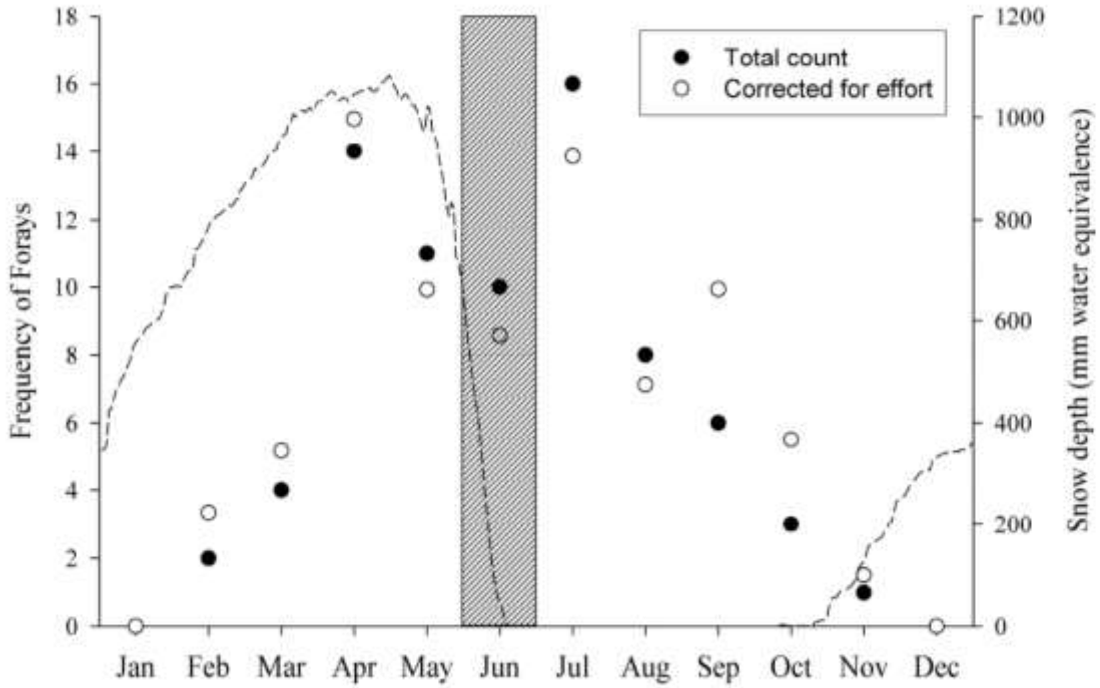

Figure 14 Frequency of hunting forays (both number of forays observed and number of forays corrected for monitoring intensity) in caribou habitat (elevations above 1050) by wolves (*n* = 3 packs; 2007-2009) in the Parsnip River Study Area. Dotted line indicates average daily snow depth for that year. Shaded areas approximate the peak calving period of mountain caribou inhabiting the study area. Used with permission, from (Steenweg 2011).

4.0 DISCUSSION

5.0 MANAGEMENT IMPLICATIONS

6.0 EXTENSION

A poster entitled “Primary-Prey Management as a Mountain Caribou Recovery Strategy in the Central Rockies, BC.” was presented (R.W. Steenweg, M.P. Gillingham and D.C. Heard) was presented at the 16th Annual Conference of The Wildlife Society, 19-24 September 2009, Monterey, California. This same poster was also presented at the Natural Resources and Environmental Studies Institute (NRESI) Grad Icebreaker and Poster Session (2 October 2009 at UNBC) and again at the NRESI Annual Lecture and Poster Session (18 March 2010 at UNBC). A second poster entitled “Sustaining Mountain Caribou Populations: Investigating Impacts of Alternate-Prey Management on the Parsnip Mountain Caribou Herd, BC.”(R.W. Steenweg, M.P. Gillingham and D.C. Heard) was presented at the 4th Annual UNBC Graduate Conference (3 April 2009), Prince George.

On June 16th 2009, Robin Steenweg presented “Mountain Caribou Recovery through Primary-Prey Management in the Parsnip River Area, BC.” to the Spruce City Wildlife Association (Prince George). Doug Heard and Robin Steenweg presented results on changes in moose, caribou and wolf numbers in the Parsnip to the McLeod Lake Indian Band. Among those attending were the band manager Adelle Chingee and Chief Derek Orr. November 5-10 2011, Robin Steenweg presented “Promoting caribou recovery by reducing predators through primary-prey management: evidence of increased wolf dispersal following increases in moose-hunting quotas” at the 18th Annual Conference of the Wildlife Society in Kona, Hawaii. In 2012, Doug Heard presented a presentation entitled “Does fewer moose lead to an increase in mountain caribou?" (D.C. Heard, M.P. Gillingham, R.S. Steenweg) to the 14th North American Caribou Workshop in Fort St. John B.C.

7.0 ACKNOWLEDGEMENTS

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APPENDIX A: SUMMARY OF VHF AND GPS COLLARED WOLVES MONITORED DURING THE STUDY PERIOD (2007-2012).

Summary of wolves monitored during the study period (2007-2012). Data includes collar type, the activation date of the collar, and the sex, age, and fate of the wolf if known.

ID	Collar Type	Activation Date	Sex	Age at Collaring	Fate	Age at Fate
W01	VHF	27-Jan-06	M	5+	Dispersed then shot	5+
W02	VHF	13-Mar-06	F	N/A	Collar Dropped	N/A
W03	VHF	09-Feb-07	M	N/A	Shot	N/A
W04	VHF	26-Feb-07	M	N/A	Unknown fate	N/A
W05	VHF	12-Mar-07	F	N/A	Shot	N/A
W06	VHF	12-Mar-07	M	2	Dispersed then Trapped	2
W07	VHF	12-Mar-07	F	1	Unknown Natural mortality	1.5
W08	VHF	12-Mar-07	M	5	Collar Dropped	5+
W09	VHF	12-Mar-07	M	1	Unknown fate	4.5
W10	GPS	13-Mar-07	M	5+	Vehicle Collision	5+
W11	GPS	22-Jan-08	F	2	Collar Dropped	1.5
W12	GPS	22-Jan-08	M	1	Dispersed	1
W13	VHF	13-Feb-08	F	2	Dispersed	2
W14	VHF	13-Feb-08	F	2	Dispersed then Trapped	4
W15	VHF	13-Feb-08	F	3	Unknown Natural Mortality	3
W16	GPS	26-Feb-08	M	4	Moose Kick mortality	5
W17	VHF	26-Feb-08	F	1	Dispersed then shot	3
W18	GPS	26-Feb-08	M	5+	Re-collar then Capture-mortality	5+
W19	GPS	28-Mar-08	M	1	Unknown fate	2
W20	VHF	21-Jan-09	M	2	shot	3
W21	VHF	06-Feb-09	M	1.5	Dispersed then shot	2
W22	VHF	06-Feb-09	M	3	Collar Dropped	4
W23	VHF	19-Feb-09	F	1	Alive at study end	2
W24	GPS pod	10-Mar-09	F	3.5	Unknown fate	4
W25	GPS pod	10-Mar-09	F	4	shot	4
W26	GPS	23-Jul-09	M	4	Alive at study end	2
W27	GPS	31-Jul-09	F	5+	Starved	5+
W28	GPS	26-Feb-10	F	2	Alive at study end	4
W29	GPS pod	08-Mar-10	F	5+	Alive at study end	5+
W30	VHF	08-Mar-10	F	2	Alive at study end	3
W31	VHF	12-Mar-10	F	1	Alive at study end	2
W32	GPS	08-Feb-11	F	3	Unknown Natural Mortality	3
W33	GPS	18-Feb-11	F	1	Alive at study end	2
W34	GPS	18-Feb-11	F	1	Alive at study end	2
W35	GPS	18-Feb-11	F	12	Alive at study end	13
W36	GPS	08-Mar-11	F	1	Alive at study end	2
W37	GPS	08-Mar-11	M	5	Alive at study end	6
W38	GPS	08-Mar-11	F	4	Alive at study end	5

APPENDIX B: WOLF KILL SITE INVESTIGATIONS

METHODS

We identified potential kill-sites of large prey (caribou and moose) by identifying location clusters of GPS collared wolves. Potential clusters were identified with Point Finder (M. P. Gillingham, unpublished program), a Visual Basic program that calculated the distance between wolf GPS location points and classified points within 100 m of each other into specific clusters. After isolating point clusters, we identified each cluster as either a bedsite, possible caribou kill, likely caribou kill, moose kill, rendezvous site, or den site. We classified clusters according to the size of the cluster, the time spent at the cluster, and whether or not the cluster was visited repeatedly over a longer period of time (Table 1, following Steenweg [2011]). To ensure we had correctly distinguished rendezvous and den

Table B.1 Size and Time thresholds used to classify wolf location clusters as either bed sites, den sites, or kill sites of specific ungulate prey species. Classification was applied to wolf location clusters (≥3 locations within 100m) in the Parsnip River Study Area (2007-2012).

Cluster classification	Size of cluster	Time spent at cluster
Bedsite	<50 m diameter	<8 h
Possible Caribou	≥90 m diameter	8h —24h
Likely Caribou	≥90 m diameter	24h —48h
Likely Moose	≥90 m diameter	48h —170h
Den or Rendezvous Site	≥90 m diameter	≥170 h

sites from kill sites, we also examined each cluster in the context of the surrounding movement paths and the time of year the cluster was used.

Because cluster analyses alone often leads to an overestimation of kill rates (Webb et al. 2008), we attempted to verify identified clusters with field investigations to search for evidence of a kill site, and the species killed. Due to the remote location of many clusters, however, we approached most clusters by helicopter, biasing our sample of potential kill sites for those in or near open-vegetated areas.

RESULTS

We identified 59 distinct wolf-location clusters (>3 locations and >8 h) within the PRSA. Closer inspection of these clusters in both GIS and Spatial viewer (Gillingham, unpublished program) indicated that 9 of these clusters were associated with den or rendezvous sites (determined by the timing of their use [April-June], as well as the total time spent at the clusters [> 170 h]). The remaining 50 clusters were classified as either caribou or moose kill sites according to the total time the wolf spent at the cluster and the size of the cluster (following Steenweg 2011). In total, we classified 7 "possible caribou" kill sites, 18 "likely caribou" kill sites, and 25 "likely moose" kill sites. Ten of 50 clusters contained locations for 2 collared wolves within the same pack. The average kill site elevation was 919 ± 175 m ($\bar{x}$ ± SD; n = 50), with 80% of kill site clusters occurring at elevation less than 1000 m (Figure 15). The highest elevation cluster was 1550 m.

Over the course of the study (2007-2012) we completed field investigations of 67 of 332 identified potential kill site clusters (Table 4). We found evidence of 2 caribou and 20 moose kills. Both caribou kill sites were at elevations >1250 m, and all moose kills were between 700m and 1250 m. We found no evidence of a kill site at the remaining 45 identified cluster sites visited.

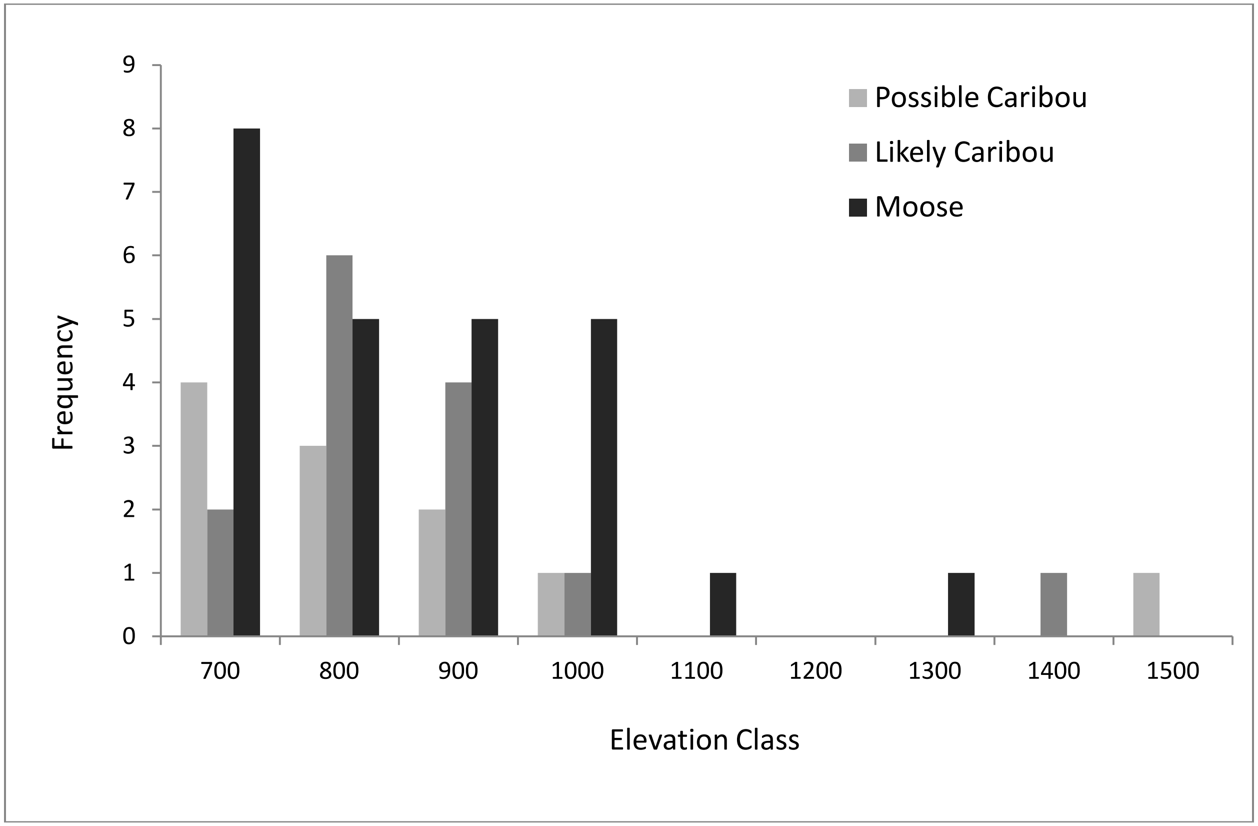

Figure B.1 Potential wolf kill sites clusters (possible caribou, likely caribou, and moose) in the Parsnip River Study Area (2011-2012). stratified by elevation class. Potential kill sites were identified using wolf location clusters examined spatially in GIS to determine size of the cluster and time spent at each cluster.////// so about 5% of kills>1300M and about 5% of time >1300m ?????

Table B.2 Summary of field investigations of potential wolf kill-sites in the Parsnip river study area (2007-2012) stratified by elevation.

Determination	Elevation		
	<1050m	**1050-1250m**	**1250m-1800**
Caribou kill	0	0	2
Moose kill	17	3	
No large kill	32	0	13
Total visited (identified)	49(299)	3(10)	15(23)

PARSNIP AND HART SOUTH CARIBOU COUNT SPRING 2013

Doug Heard
Jessica Courtier
Glen Watts

April 2013

INTRODUCTION

Parsnip Caribou Recovery Project (Gillingham et al. 2010) was designed to test an intermediate-term, alternate species management approach to increase mountain caribou numbers. By increasing the number of moose hunters, beginning in 2006, we anticipated that hunters would reduce moose numbers and maintain the moose population at relatively low density. We reasoned that this reduction in moose, the wolves' primary prey, would lead to a smaller wolf population, eventually reduce predation of wolves on caribou, and allow caribou numbers to increase in comparison to the adjacent Hart South herd (which served as a control population). This survey determined the trend in Parsnip caribou numbers relative to the trend in control population size.

METHODS

We used a standard mountain caribou survey protocol to estimate caribou numbers (Heard et al. 2010, 2012, Seip 2002). That method involved searching for caribou tracks, within traditionally surveyed herd areas (e.g., Heard et al. 2012). We flew in a helicopter at the subalpine treeline and when fresh tracks were located, followed them until we located caribou. All caribou were counted and classified as adults or calves and we looked for the presence of a radio-collar. After determining that we had counted all the caribou at a site, we listened to determine which, if any, radio collars we had seen or missed.

Surveys occurred on 8, 23, 24 and 27 March 2013. All radio-collared caribou were heard during a fixed wing flight on 13.03.01, the first time they had been listened for since March 2012, and all but one precisely located on 13.03.19.

We incorporated a sightability correction factor based on based on the proportion of the radio-collared cow caribou that we saw within the survey area and a herd correction factor based on the proportion of radio-collared caribou that were within the survey area.

RESULTS

Survival

Fifteen of the 16 radio-collared caribou that were alive in March 2012 (94%) were still alive on 19 March 2013. The caribou that died had been originally collared almost 10 years earlier (03.12.11).

Sightability

Caribou (C27A) was heard on 13.03.01 but not precisely located at that time and was not heard again, either on the 13.03.19 fixed wing flight or at any time during the helicopter survey. We therefore eliminated C27A from subsequent analyses. Of the remaining 14 collars, 2 were not seen during the survey because they were out of the traditional survey area (Figure 1) and 2 (C22A, CAR090) were overlooked during the survey. No tracks were detected during the survey where C22A had been located from the fixed wing 4 days earlier. CAR090 was located with C18A on 13.013.19 but when C18A was located the survey 3 days later, we neither saw nor heard CAR090.

Our sightabililty estimate was 0.83 (10/12) which is exactly the long term average sightability for caribou surveys of this type (Seip 2002).

Population closure

Two of the caribou originally collared in the Parsnip herd range had moved to the Hart South herd (and we saw them both during this survey) and 2 radio-collared caribou have immigrated to the Parsnip, one from Kennedy Siding and one from Quintette. The 2 radio-collared caribou that were just north of the survey area were in a place where we had never before located radio-collared caribou.

Herd numbers and composition

We counted 84 caribou in the Parsnip herd range which resulted in an estimate of 101 caribou after correction for sightability (84/.83). The total herd estimate, after accounting for the 2 caribou that were just outside the Parsnip's traditionally surveyed area was 121 caribou. Calves represented only 13% of the 84 caribou counted, which is less than the 15% required for population stability, and therefore suggests a decline in herd numbers between 2012 and 2013. The 2012 Parsnip estimate was 129 animals. Given the long history of monitoring radio-collared Parsnip caribou without ever having located caribou outside of the traditional survey area, the best estimate for the Parsnip in 2013 should 121 caribou, i.e., including those caribou outside of the 2013 survey area. This suggests the Parsnip herd decline by 6% between 2012 and 2013.

We were able to survey only 6 of the 8 blocks within the Hart South herd range (the Hedrick and Walker blocks were not counted in 2013) so we compared our 2013 counts to the number of caribou counted in those same mountain blocks counted in 2012. The distribution of caribou among those blocks was similar between years (Figure 2) but the 2013 count was only 84% of the 2012 total (Table 1). Assuming the same change occurred in the Walker and Hedrick blocks, the 2013 Hart South estimate was 338 caribou, 84% of the 2012 estimate of 404 (Heard et al. 2012). Calves represented only 11% of the 307 caribou counted, which is less than the 15% required for population stability and is therefore consistent with a decline between 2012 and 2013.

The 2013 estimates for the Parsnip and Hart South herds fit the decline projected 2012 (Figure 3 Heard et al. 2012). Parsnip and Hart South estimates combine to represent the estimate for the Hart Ranges.

Group sizes were typical of mountain caribou in March ranging from 1-16 with a mean of 6.1.

Table 1. Comparison between the 2012 and 2013 caribou counts by mountain blocks within the Hart South herd range

Block	2012 Count		2013 Count	
	Calves	Total	Calves	Total
Bearpaw	18	155	16	112
Arctic north	1	3	0	4
Otter	5	59	9	72
Sande	1	7	2	12
Torpy	3	30	1	22
Severide	6	53	6	35
Totals	34	307	34	257

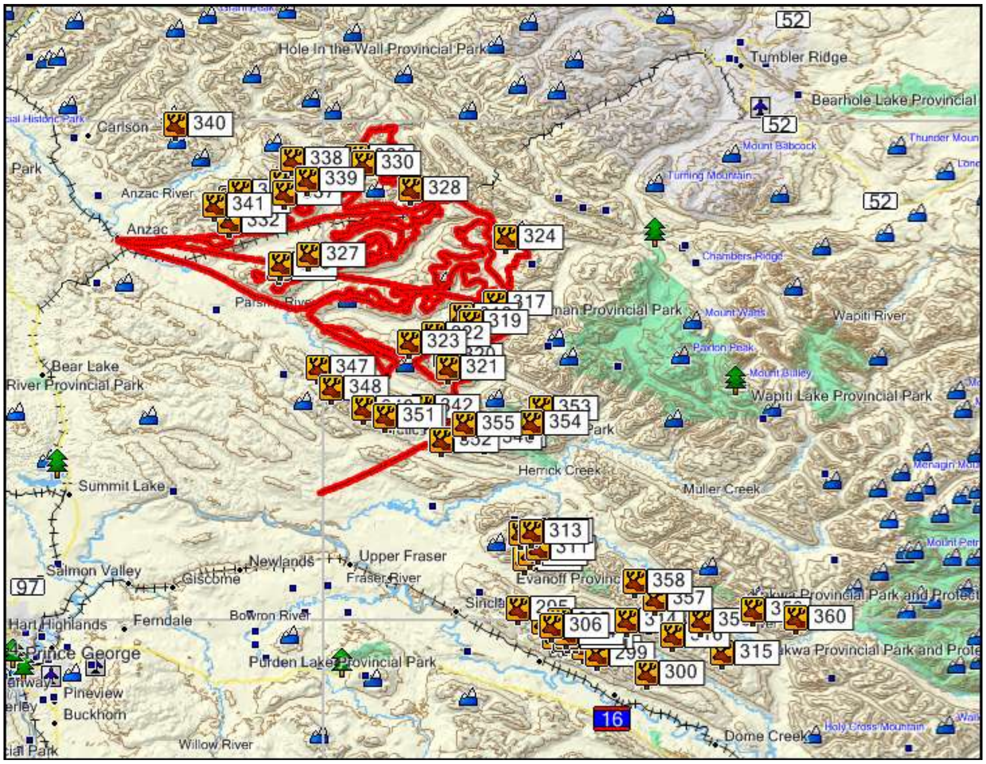

Figure 1A. Parsnip survey flight line (omitting the track between the Table and the Anzac Rivers, e.g., observation 340) and the locations where we observed caribou in both the Parsnip and the Hart South survey blocks.

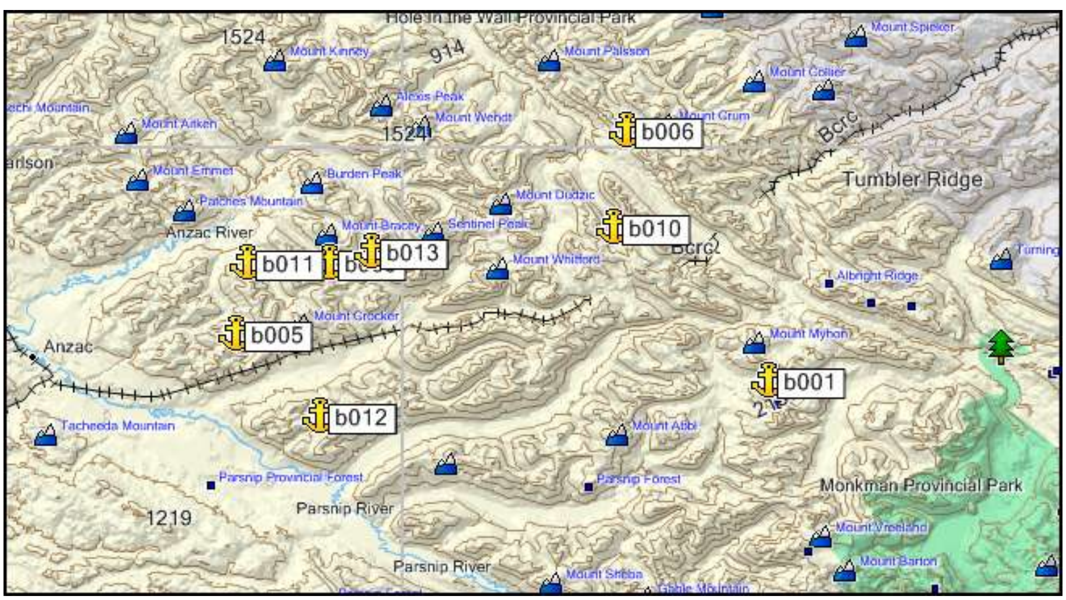

Figure 1B. Locations of radio-collared caribou in the Parsnip survey area March 2013. Caribou at points b006 and b010 were outside of the survey area.

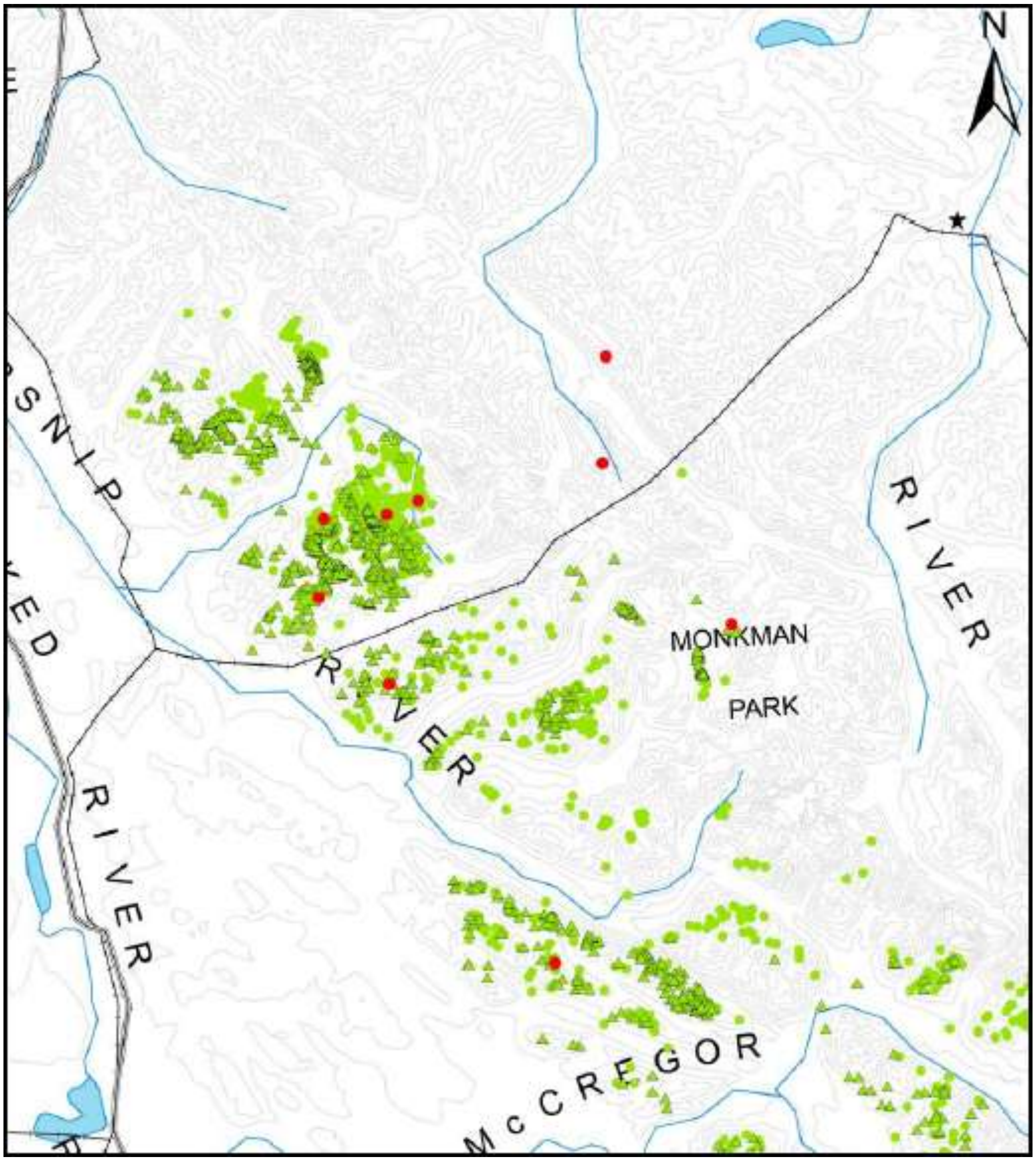

Figure 1C. Radio-collared locations for Hart Ranges caribou in the 1980's (in green dots [summer] and triangles [winter]) and during this survey (in red) showing how atypical the locations were for b006 and b010 from Figure 1B. Figure courtesy of Elena Jones.

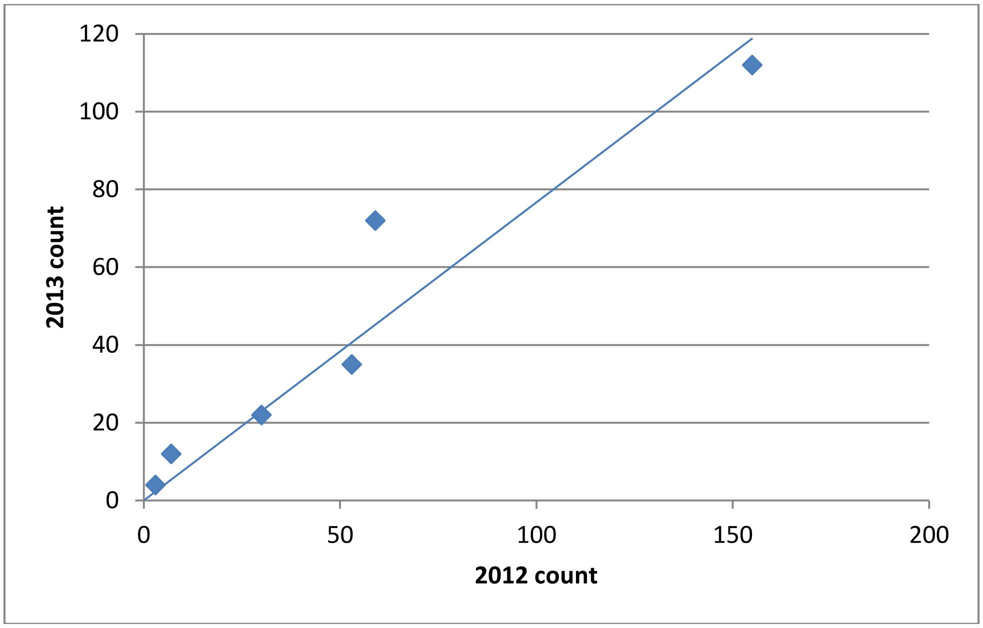

Figure 2. Comparison between the 2012 and 2013 caribou counts for the mountain blocks in Table 2.

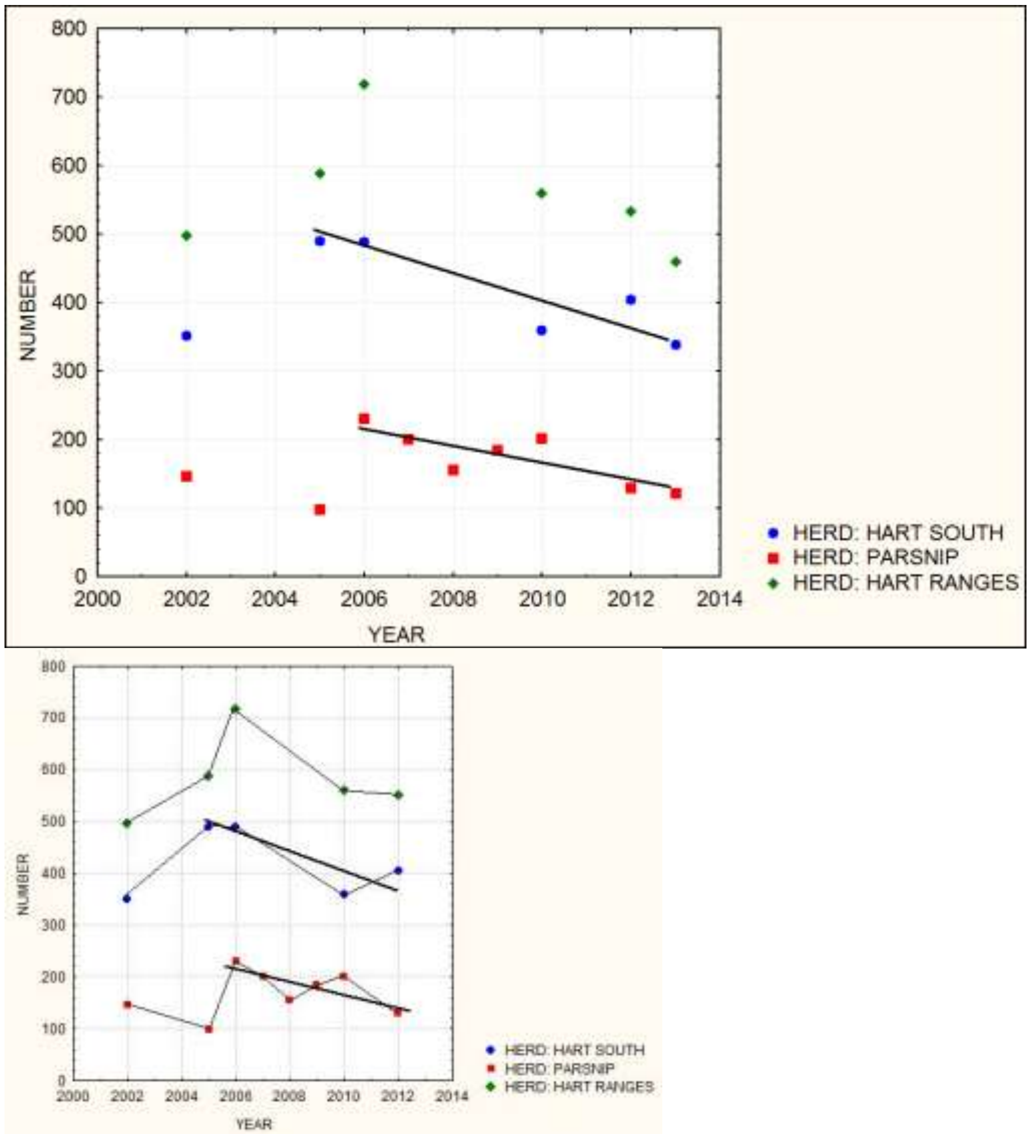

FIGURE 3
Changes in Parsnip, Hart South and Hart Ranges caribou numbers from 2002 to 2013 (upper graph). Black line represents the trend based from 2006 to 2012 (lower graph is Figure 6 from Heard et al. 2012).

ACKNOWLEDGEMENTS

We thank C. Ritchie, E. Stier, R. Altoft, B. Cadsand, and K. Sittler for assistance before, during and after this survey and E. Jones for Figure 1C. Funding for this project came from the Fish and Wildlife Compensation Program - Peace Region.

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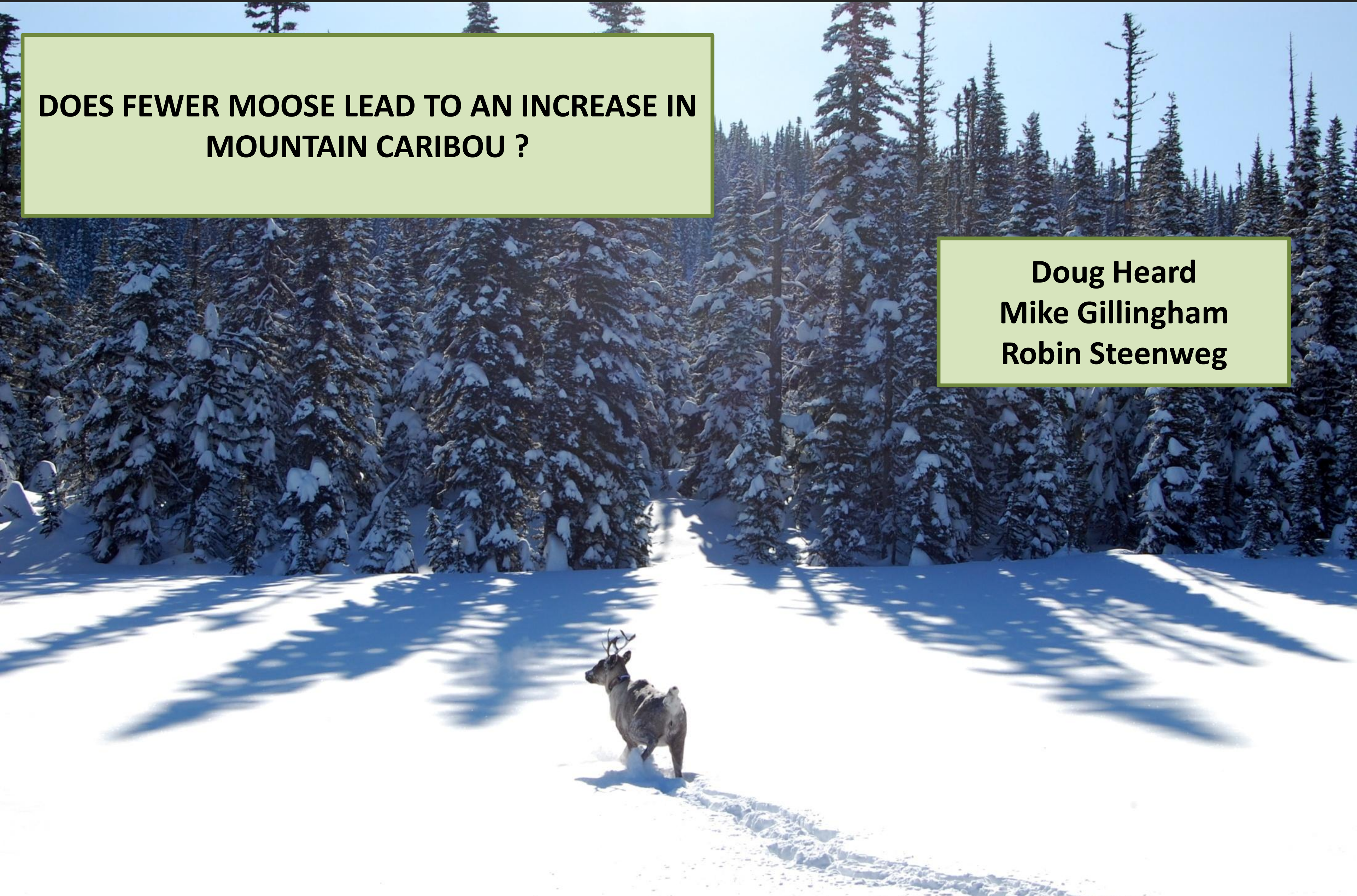
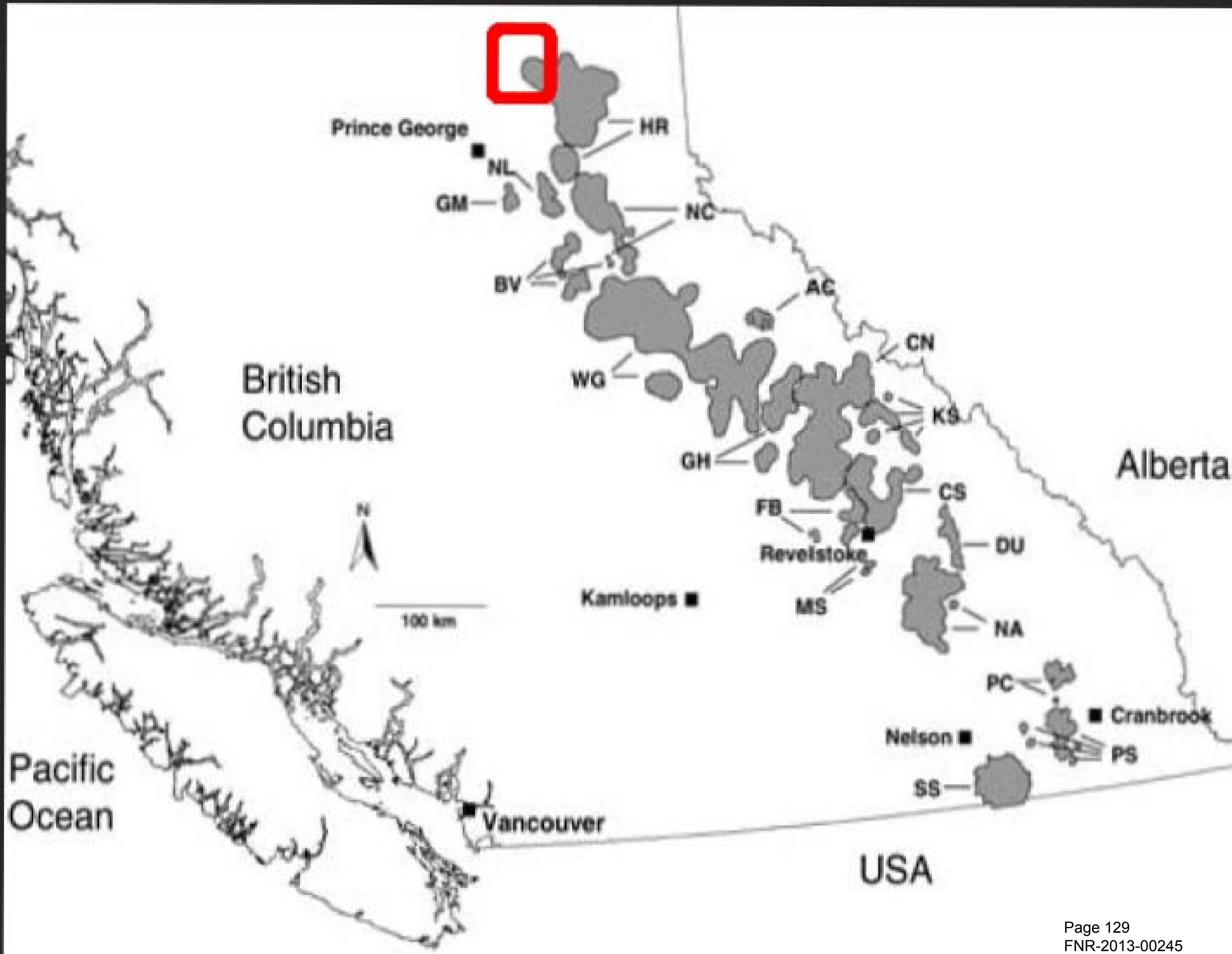
DOES FEWER MOOSE LEAD TO AN INCREASE IN MOUNTAIN CARIBOU ?

Doug Heard
Mike Gillingham
Robin Steenweg





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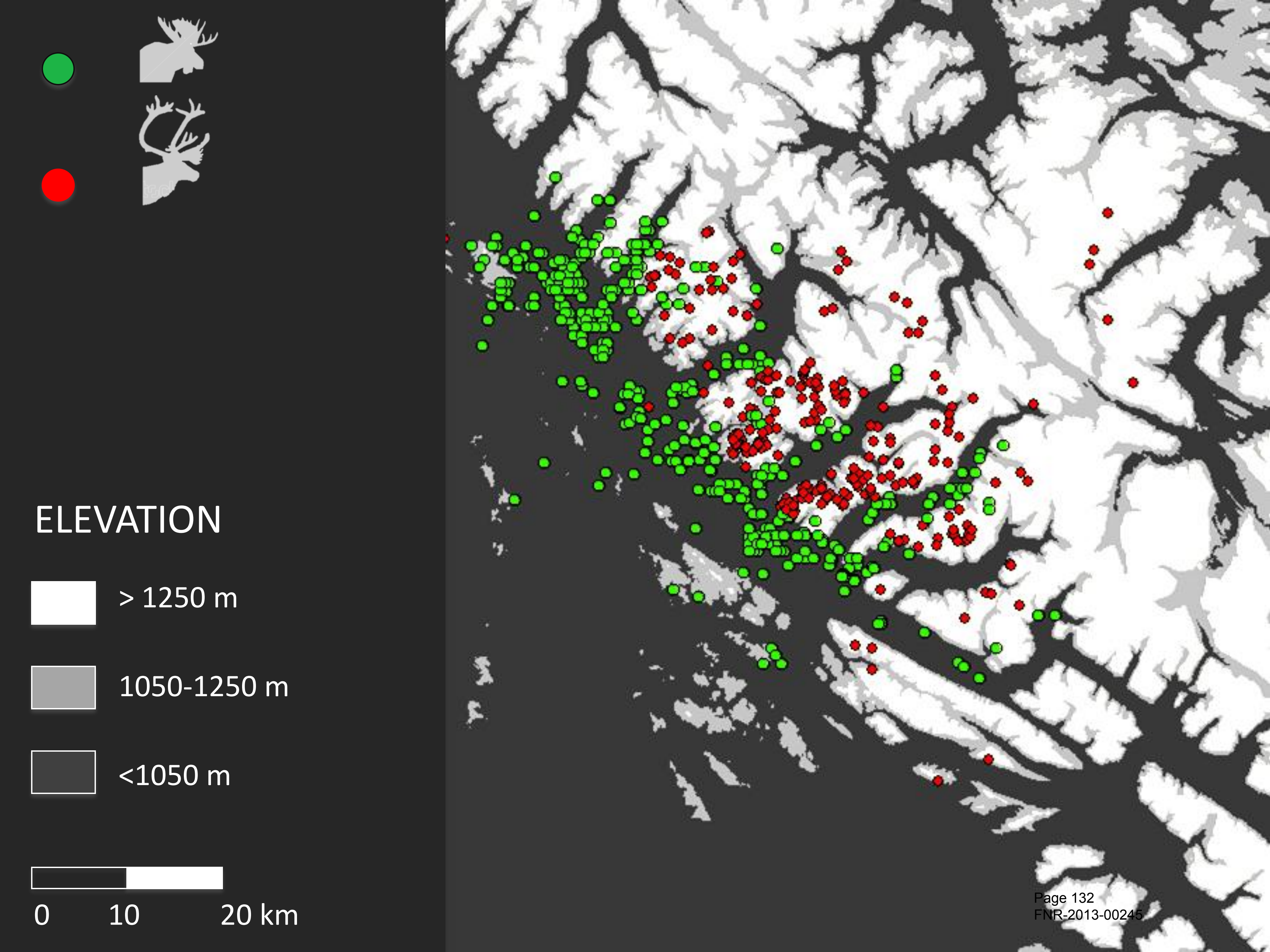
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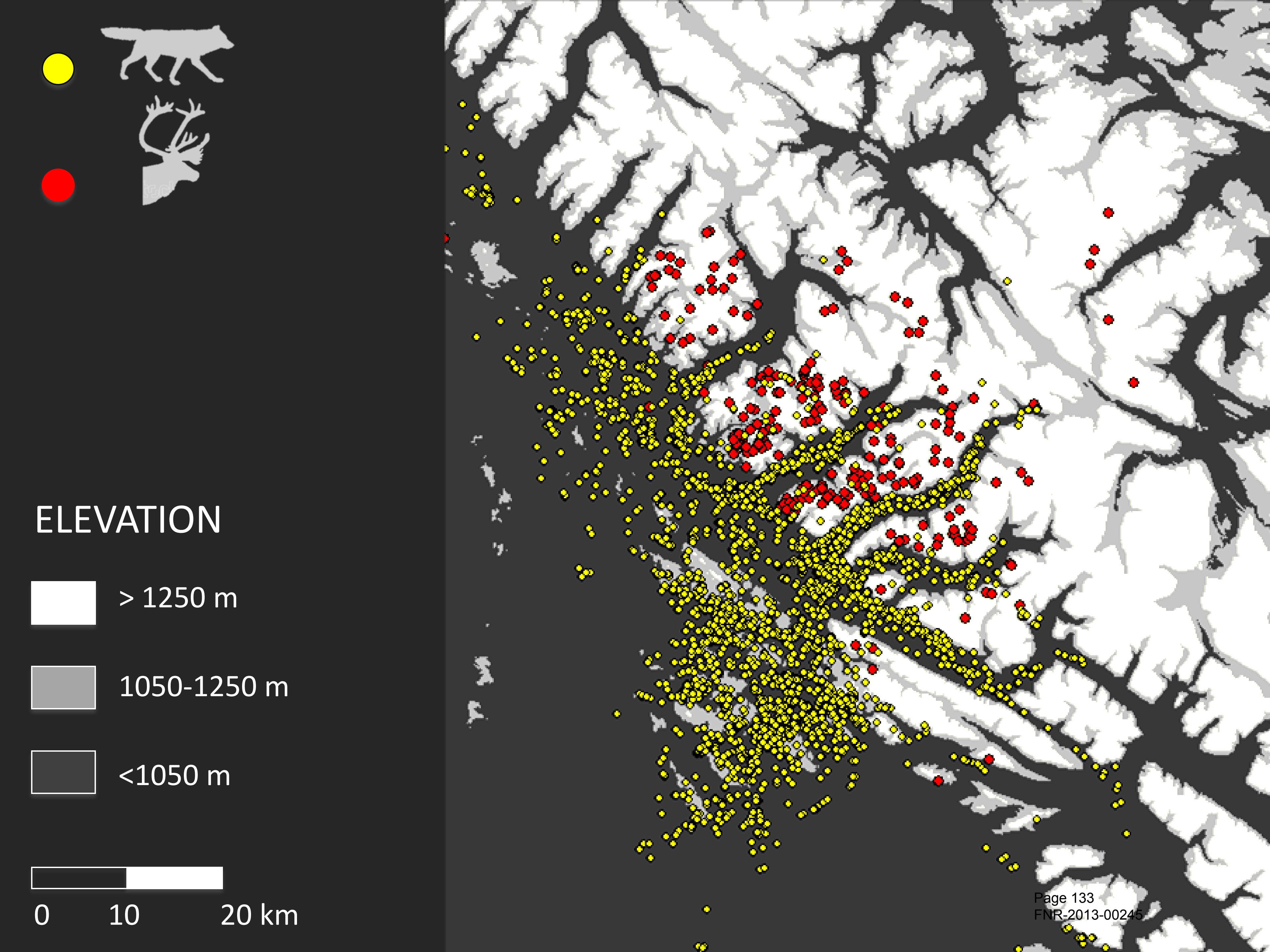
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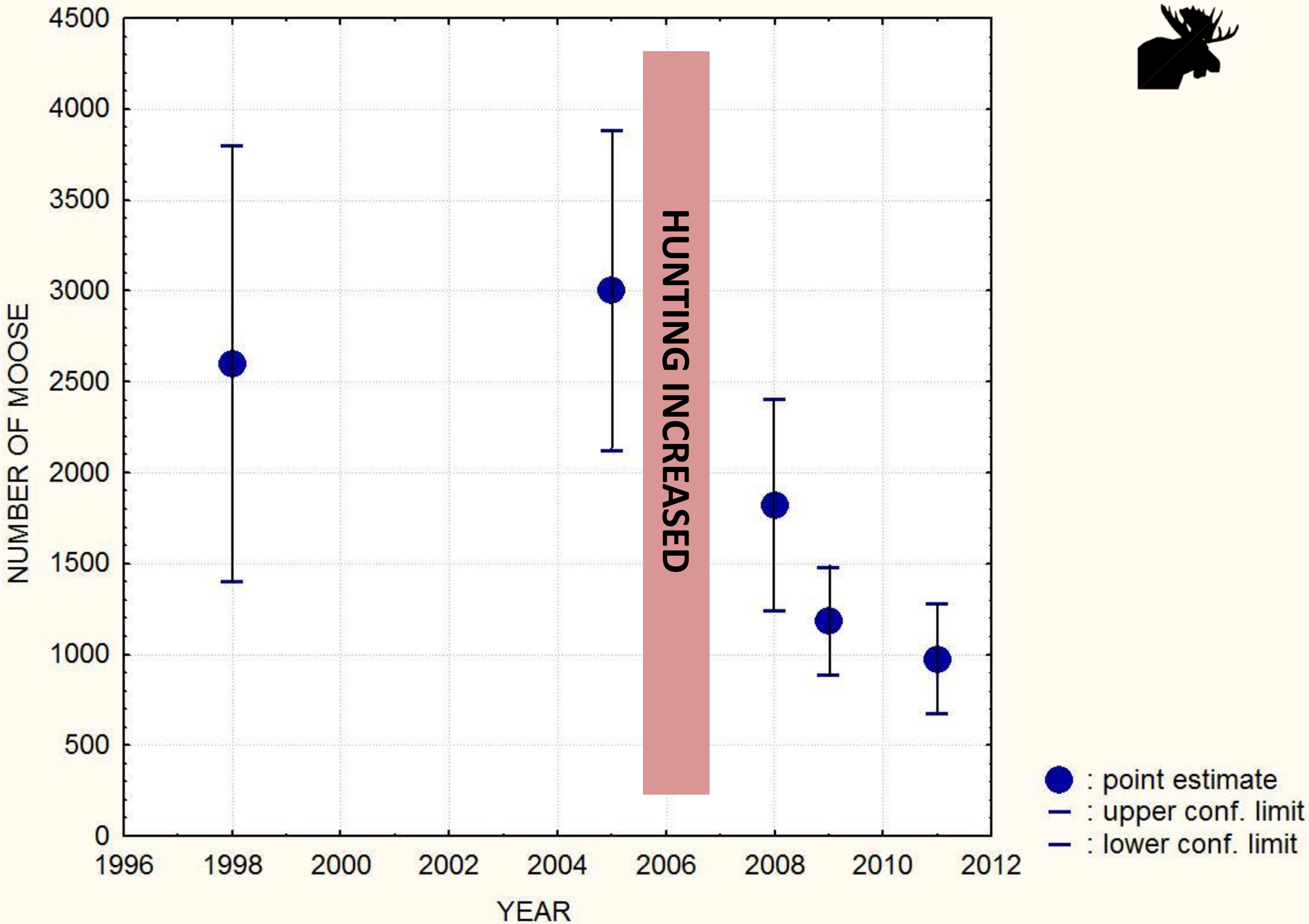
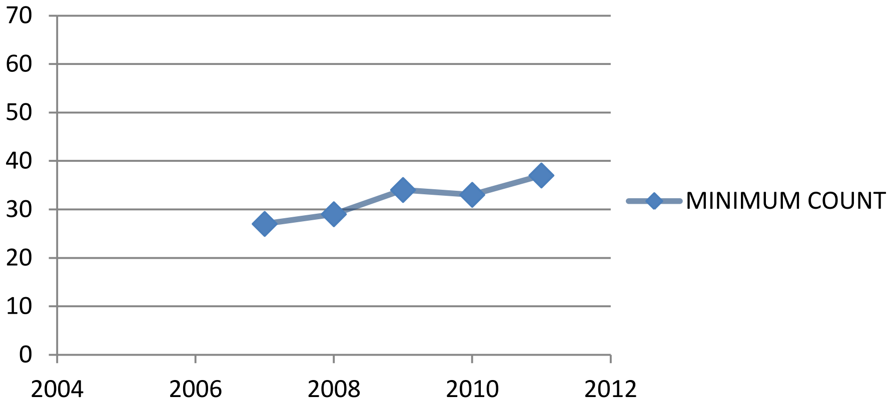
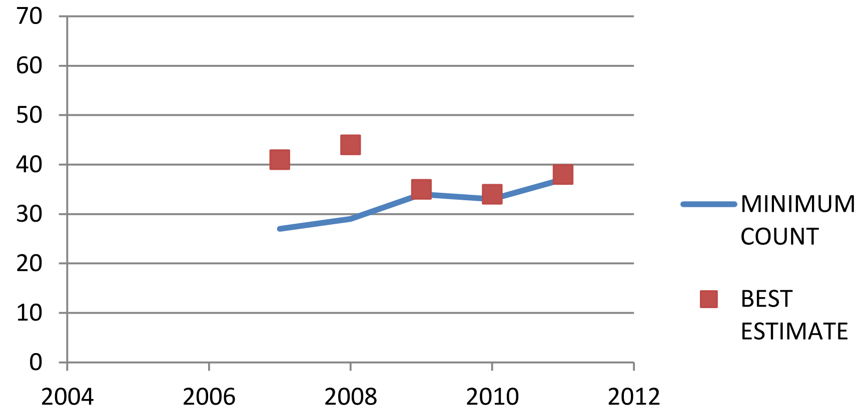
CHANGES IN MOOSE NUMBERS







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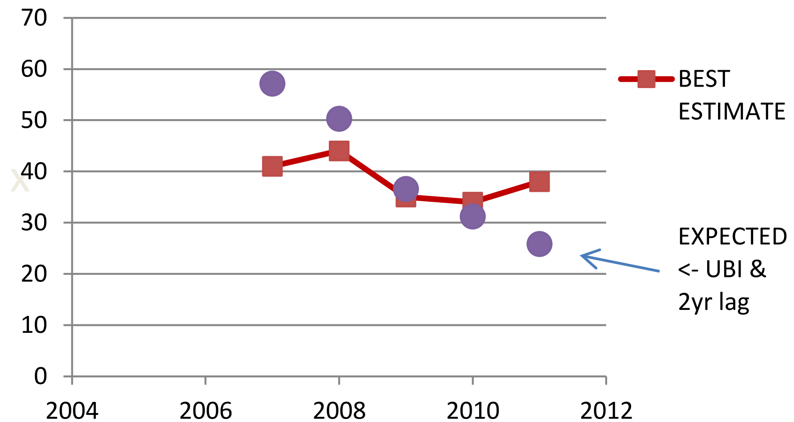
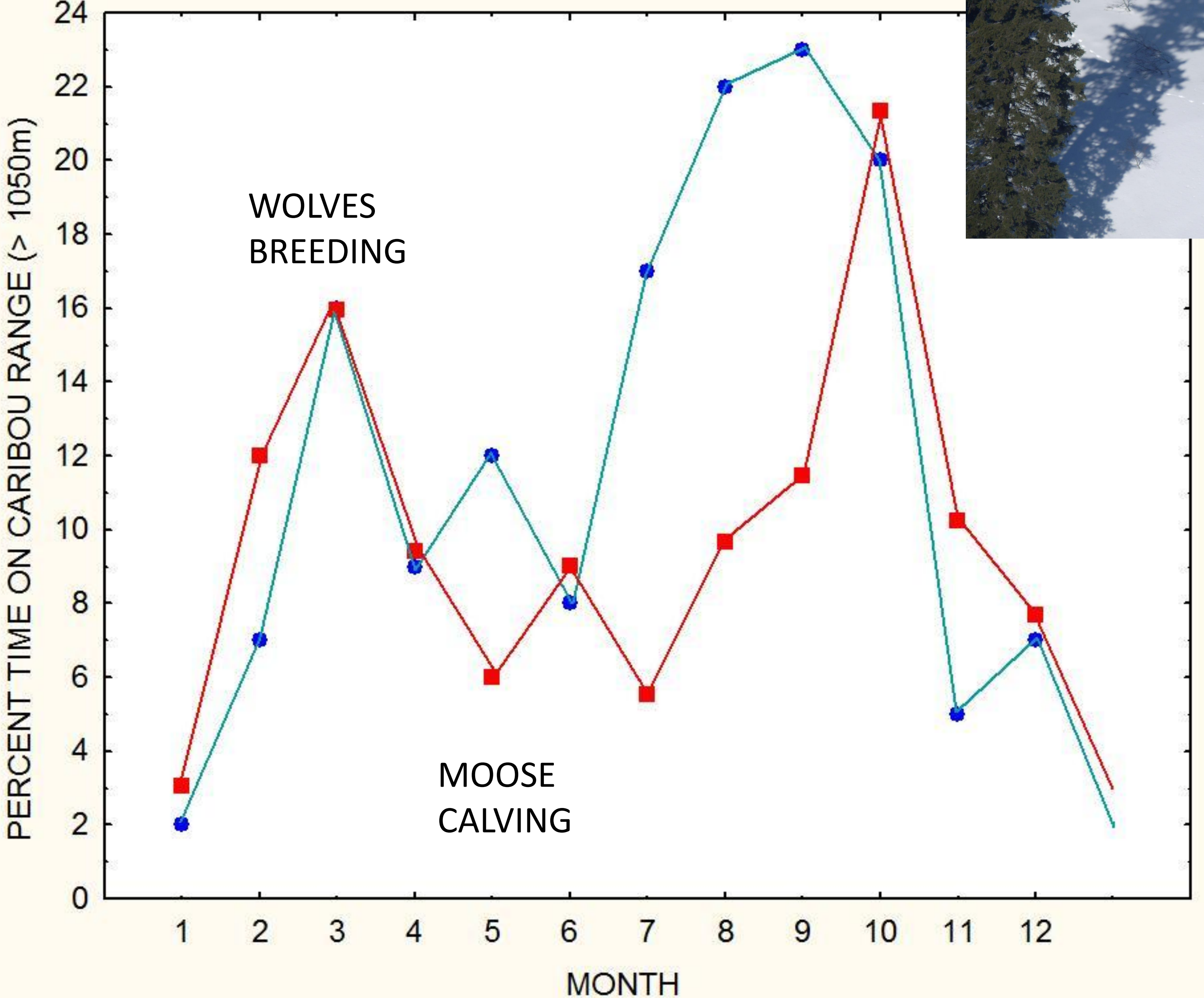


WOLVES' USE OF CARIBOU RANGE



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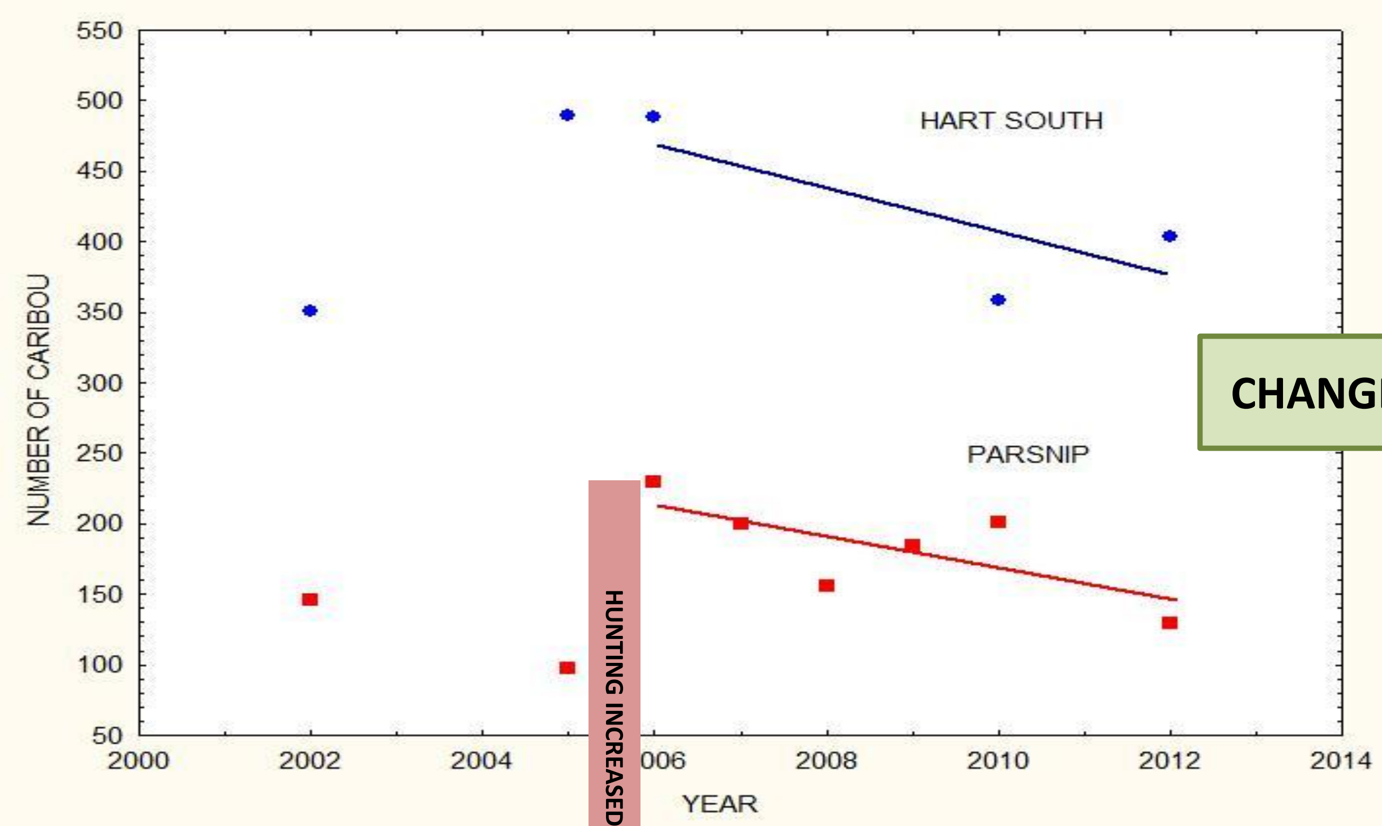

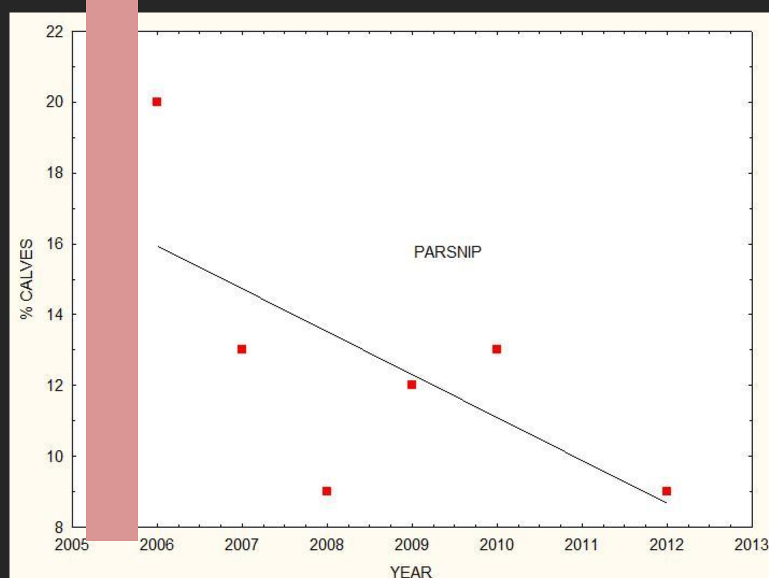

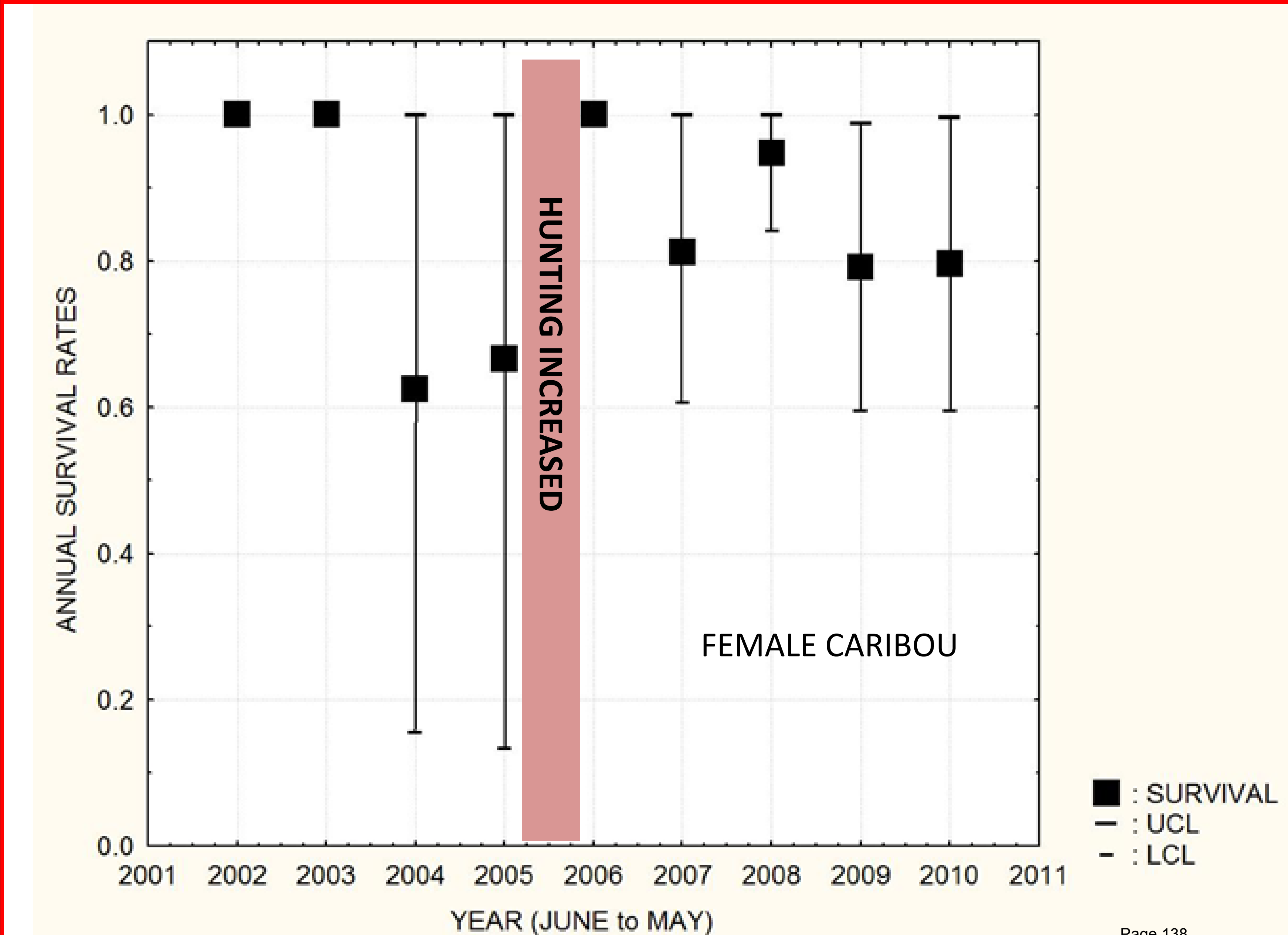
HUNTING INCREASED
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ANNUAL SURVIVAL RATES
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0.4
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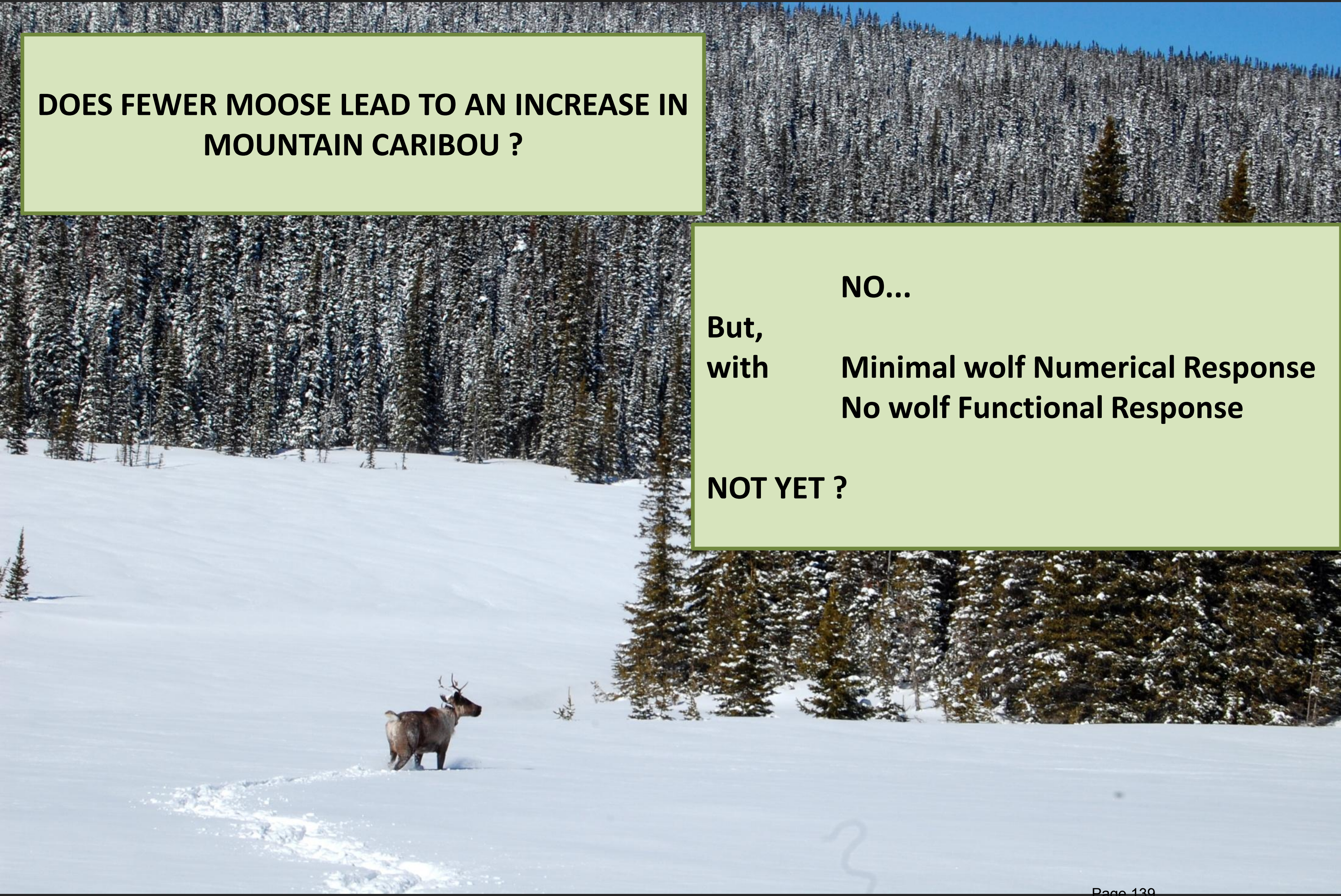
DOES FEWER MOOSE LEAD TO AN INCREASE IN MOUNTAIN CARIBOU ?



NO…

But,

with Minimal wolf Numerical Response
No wolf Functional Response

NOT YET ?


BRITISH
COLUMBIA
FISH AND WILDLIFE
COMPENSATION PROGRAM
UNBC

Background

Need to recover caribou

Here's how we're trying to do it

Context

Moose distribution sample

Caribou distribution sample of points

Point is that elevation mostly separates them and they are populations

Wolf distribution e.g., 2011

Really no other prey in system (elk, cougar, deer); other potential predators grizzly bears black bears wolverines

Human footprint; logging and roads at low elevations; nothing on caribou range.

Initial densities/numbers

Of moose ABOUT 2000 STABLE AND SO ARE CONTROLS

Of Caribou 100-150 STABLE AS "CONTROL" -> HART RANGES LAMBDA = 1.02

Could be numbers or graphs (we just want to convey trend perhaps without specific numbers) and maybe rel. to control populations

The approach/Experiment

Change hunting pressure through LEH – ref to RS's talk

What we monitored

Collared wolves (packs, movements, dens, kills, forays, numbers)

Collared moose (adult female survivorship, surveys)

Collared caribou (adult female survivorship, spring census, fall survey)

What hunters did

Change in kill

What moose did

Words and redo initial graphs

What wolf did

Numbers (trend graph of min counts on fig with pack locations, vacancies leading to an extrapolated est of total, especially of missed more in 2007 2008 than in 2011)

Forays?

Dispersal

What did this mean for caribou

Same as controls, not too exciting

Contrary to Explanations

Overall responses

Wolves selective

Hunters not selective

Caribou little change to date (caribou OK in winter; calf natality OK, calf recruitment poor)

Possible explanations (discussion)

Why didn't we detect a response in caribou (conclusions)

Not yet enough time / time lags

Magnitude of response isn't big enough to detect

No response (wolves are not major killers of caribou calves) – Gustine's stuff of bears, wolverine, golden eagles

Can reject the large-scale switch to caribou

Others that we can't separate

Other points

Unclear wolf numerical response (some suggestion of dispersal)

Fewer wolves can kill as many calves over a short period of time

Conclusions

Wolves did not switch to c with fewer moose

Lack of a c response could be because a) not enough time for wolf response b) not enough magnitude in wolf num response to detect or c) wolf pred not limiting thus change not sig

Acknowledgements

People, watts altofts eric becky dusty….

pwfwcp

bc gov

unbc

fig with study area showing cutblocks?

Does fewer moose lead to an increase in mountain caribou?

That was the question researches and biologists asked back in 2006 in hope they would find out a way to increase the numbers of mountain caribou in the Parsnip River area in central British Columbia.

The Parsnip Caribou Recovery Project, initiated by the Ministry of Environment, began by doubling the number of Limited Entry Hunting permits, which continue to be maintained at higher than pre-2006 levels, with the hope that hunters would reduce moose density.

"By liberalizing moose hunting regulations we are examining whether hunters will reduce moose numbers and decrease the moose population densities, thus supporting a smaller wolf population and reducing the predation impacts on caribou," explains Doug Heard from XXX. "To evaluate the effectiveness of this approach, moose, caribou and wolf populations have been monitored ever since."

Moose numbers have since declined from 3000 in 2005 to 1000 in 2011, but wolf numbers did not appear to change. "Unfortunately we also discovered that there were about the same number of caribou in the Parsnip herd in 2012 as in 2002," continued Heard. "And over the same time period when moose were declining, caribou numbers declined by 35% – from 200 in March 2007 to 129 in March 2012."

Why then, in spite of a 66% reduction in moose numbers, did Parsnip Herd caribou numbers not increase as hypothesized? Possible explanations are:

1. A time lag in wolf numerical response.
2. The reduction in moose numbers was insufficient to affect the numerical response of wolves.
3. As wolf numbers declined wolves also increased their predation on caribou, particularly calves.
4. Caribou survival and recruitment was more closely related to other factors (e.g., bear predation), than to moose/wolf abundance.

The Parsnip Caribou Recovery Project will continue to monitor changes in caribou numbers……

Sidebar

Mountain caribou (*Rangifer tarandus caribou*) are endangered across their range and the primary proximate cause of mortality is predation. In the Parsnip study area, mountain caribou select for high-elevation habitats, while moose (*Alces alces*) densities are highest in valley bottoms and along the Parsnip River plateau. Wolves (*Canis lupus*) spend most of their time in these valley bottoms, but occasionally make forays to high-elevation areas where caribou are present.