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FINAL REPORT

Determining the Importance of Grizzly Bear Predation on Central Mountain Caribou Populations

fRI Research Grizzly Bear Program

December, 2016

Karen Graham[1], Gordon Stenhouse[1], Terry Larsen[1], Dr. Laura Finnegan[1], Doug MacNearney[1],
Joy Erlenback[2] and Dr. Charles Robbins[2]

[1] fRI Research; [2] Bear Research, Conservation, and Education Center – Washington State University

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This is a draft final report and further analysis may be conducted for the submission of scientific journal publications which may result in additional findings and conclusions.

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Report Summary

Both woodland caribou and grizzly bears are identified as threatened species in Alberta. Current management efforts to recover caribou populations are focused on a strategy to reduce wolf predation impacts that have resulted in low recruitment within provincial caribou herds. Wolves are seen as the primary predator impacting caribou herds although a number of other carnivores are found within recognized caribou ranges, including cougars, black bears and grizzly bears.

To gain a better understanding of possible impacts of grizzly bears on central mountain caribou populations, we investigated three separate but inter-related topics concerning grizzly bear predation activities. These included 1) gaining a better understanding of grizzly bear and caribou habitat selection patterns to determine if these species co-occur over space and time as a form of predation risk, 2) investigating grizzly bear GPS location clusters to understand predation behaviour within caribou ranges, and 3) conducting captive feeding trials with grizzly bears to determine if stable isotope analysis from bear hair could provide insights into diets pertaining to ungulate consumption.

We quantified predation risk of grizzly bear on caribou using resource selection function models. Our assumption was that predation risk was directly related to the habitat selection patterns of both species, and that caribou were responding to this form of risk. More specifically, we investigated grizzly bear predation risk relative to the habitat associations of adult female caribou when selecting 1) calving sites (May 18 – June 19); 2) habitat during the post parturition period (May 18 – July 14) where calves survived or were lost; and 3) habitat seasonally (spring [May 5 – June 19]; summer [June 20 – October 7]). We found that there was a relatively high degree of overlap between grizzly bears (males and females with cubs, not solitary females) and the habitat caribou selected during calving. During the post-parturition period, male bears tended to select habitats where caribou calves survived and avoided those habitats where caribou calves were lost. Conversely, females with cubs selected caribou habitat where calves were lost. Considering seasonal models of caribou habitat selection, female grizzly bears with cubs selected caribou habitats during spring, whereas male and female bears used these habitats at random. During summer, caribou predation risk from grizzly bears appeared to be lowest as bears tended to avoid those habitats preferred by caribou. Overall, spatial and temporal overlap was lowest between solitary (without cubs) female grizzly bears and caribou as female bears consistently avoided caribou habitat. We provide maps that show caribou predation risk as areas where the relative overlap (positive selection coefficient) between species is highest.

Over a two year period (2014 and 2015) we visited 448 GPS collar location clusters identified from collar data gathered from 6 male and 6 female adult (≥5 years of age) grizzly bears. At these clusters, we found 70 carcasses (16%), 33 scats containing hair (7%), 100 foraging sites (22%), 212 beds (47%), and 33 clusters where activity was unknown (7%). We identified the ungulate species from hair found in scats at clusters with no evidence of ungulate scavenging or feeding using morphological assessments. General habitat characteristics for each cluster type are provided. Of the 70 carcasses found at GPS clusters, 60 (86%) were moose; 2 (3%) were caribou and we identified a single mountain goat, mule deer, deer of unknown species, black bear, beaver and one unidentified animal. Of the 60 moose carcasses found, 36 were calves (51% of the total carcasses and 60% of all moose carcasses). Of the 33 scats containing hair, 15 (45%) were moose, 8 (24%) were not an ungulate species and 10 (30%) were unknown. We found scats containing hair at bed sites 91% of the time, and males were responsible for 61 (87%) of the 70 carcass clusters and 23 (70%) of the 33 hair scat clusters. Females accounted for 9 (13%) of the carcass clusters and 10 (30%) of hair scat clusters. Of the six female bears within this study we did not find carcasses at GPS clusters for three, but we did locate scats with hair for two of these females; one of which was confirmed to be a moose. We identified significant variation in estimates of meat consumption (carcasses and scats with hair combined) between individuals. During the ungulate calving season, 2 males consumed 11.4 and 3.1 moose calves/calving season, and 2 females consumed 4.3 and 0.0 moose calves/calving season. The average number of carcasses fed on by males and females were 17.2 (range 12.5-22.3, n=3) and 5.1 carcasses (range 1.9-10.7,

n=3) respectively from 15 May to 30 September. Males spent more time at carcasses (34.9 hrs, (SE=6.12, n=61) than females (18.7 hrs, SE=7.28, n=9). The two caribou carcasses found were identified as an adult male and subadult of unknown sex. Evidence at the clusters suggested that the adult caribou may have been scavenged by the bear, and it is unknown whether the collared bear killed or scavenged the subadult caribou. Using field investigations, expert opinion and duration of time that bears spent at the carcass we separated carcass clusters into scavenging versus probable kills; we suspect that 73% of adult/yearling moose carcasses were scavenging events.

Our investigations on the utility of stable isotopes to estimate the amount of caribou grizzly bears are consuming using feeding trials on captive bears revealed important findings. Blood serum isotope analysis was able to differentiate between three ungulate species (reindeer, elk and moose) within the diet of a grizzly bear following a month of feeding. However, using blood serum would require the capture and handling of many wild bears on a regular basis, which limits the utility of this approach. As non-invasive approaches are preferable, particularly when dealing with threatened species, we also investigated whether isotopic signatures within hair (obtainable via hair snagging) could be used to differentiate ungulate species. We found that the carbon and nitrogen used to synthesize bear hair may take 50 days or more to re-equilibrate after a diet shift occurs. This result was based on ~40 day trials with four adult grizzly bears. Because of this time lag effect, and the relatively few caribou carcasses observed during our field campaign, regardless of our ability to determine stable isotope value discrimination values, we believe that this technique is currently not able to help us understand grizzly bear predation on caribou in the ranges we studied.

In summary, although we found that grizzly bears will kill caribou, our study suggests that grizzly bears likely play a minor role in the dynamics of central mountain caribou populations given current densities and distributions of these two species. However, should caribou numbers decrease further, the loss of any caribou may exacerbate the effects of mortality and further hamper population recovery.

Acknowledgements

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CONTENTS

Project Background and Objectives

Alberta is home to some of Canada's most captivating ecosystems and wildlife. Some of these ecosystems are not only important habitat for woodland caribou (*Rangifer tarandus*) and grizzly bears (*Ursus arctos*), but are also rich in natural resources (oil and gas, forestry, and mining) and recreational opportunities. Human activities that occur within wildlife habitat present challenges for land use managers, especially when a wildlife species is considered to be at risk and sensitive to human activities. Both central mountain woodland caribou and grizzly bears are designated as threatened species in Alberta, which means they are "likely to become endangered if limiting factors are not reversed" (AESRD 2014) and Recovery Plans have been put in place (Environment Canada 2014, Alberta Grizzly Bear Recover Plan 2008, Alberta Woodland Caribou Recovery Team 2005) to support conservation efforts. The risk of further population declines for both species are believed to be associated with human activities. For this reason, a large body of research has been conducted on assessing the potential human impacts on caribou (Bradshaw et al. 1998; Ross 1999; Dyer et al. 2001; Latham et al. 2011a; Whittington et al. 2011) and grizzly bear (Roever et al. 2008; Graham et al. 2010; Nielsen et al. 2013; Stewart et al. 2013; Laberee et al. 2014; McKay et al. 2014). The predation of woodland caribou has also been the subject of numerous studies, with most of this work focusing on wolf predation (Bergerud and Elliot 1986; James and Stuart-Smith 2000; Seip 2008; Whittington et al. 2011), but some work has looked at grizzly bear predation on woodland caribou in British Columbia (Kinley and Apps 2001; Gustine et al. 2006; Apps et al. 2013). However, in Alberta, little work has examined possible impacts and interactions between grizzly bears and woodland caribou, and whether human activities affect these interactions.

Currently, recovery efforts for caribou in Alberta have focused on reducing wolf populations, because wolves are viewed as the leading cause of caribou mortality (James and Stuart-Smith 2000; Latham et al. 2011a; Hervieux et al. 2014). Unsustainable wolf predation on caribou populations is thought to be associated with resource extraction activities (DeCesare et al. 2012; Hervieux et al. 2013). These activities create habitat conditions that increase food supply for ungulates such as moose, elk, and deer. This increase in forage causes ungulate populations to increase, which in turn drives a numerical increase in the wolf population. In addition, wolves use linear features such as roads, seismic lines and pipelines for easy access into caribou habitat. Often linear features transect old growth forest where caribou may occur, and this increases the mortality risk to caribou because of increases in encounter rates (Latham et al. 2011b; Whittington et al. 2011; DeCesare et al. 2012b). Although poorly understood, these negative interactions could also be taking place between caribou and other predators.

Grizzly bears and cougars are known to be predators of caribou (Bergerud and Elliot 1986; Kinley and Apps 2001; Gustine et al. 2006) and recent research has found that grizzly bears are selecting for linear features as potential movement corridors (McKay et al. 2013). Although predation rates of grizzly bears on caribou are likely to be low, given low population densities and precipitous declines in caribou populations in recent years (Hervieux et al. 2013), even small levels of predation could have detrimental effects on population persistence (Kinley and Apps 2001).The focus of this research project is to assess the potential impact of grizzly bear predation upon caribou populations in west-central Alberta and whether predation is influenced by landscape conditions within caribou and grizzly bear range.

The impetus behind this research project was linked to field activities that occurred in May 2013 while our research team was conducting spring capture and collaring activities in the Kakwa area of west central Alberta. Dr. Laura Finnegan was working with our research team and at that time was receiving GPS location data from collared caribou. Over the course of two weeks she received 3 alerts of possible mortality events from collared female caribou in the general vicinity of our field station triggered by 8 hours of collar inactivity. We took this opportunity to investigate these recent mortalities and found that all 3 of these caribou mortalities were probable grizzly bear predation. These field observations and ensuing discussions led our research group to begin a collaborative project to investigate the possible impacts of grizzly bears on caribou survival and this report represents the culmination of two years of research on this topic.

The goal of this project is to determine to what extent grizzly bear predation might be influencing caribou populations in west-central Alberta.

We used existing datasets supplemented with additional data gathered to address this topic, and we also investigated new techniques to measure and monitor grizzly bear predation levels on caribou populations. More specifically, we used multiple data sources including grizzly bear GPS locations, kill site investigations, and stable isotopes from existing and newly acquired data collected as part of this project to meet the following objectives:

1. Use GPS locations of collared caribou and grizzly bears to quantify the spatio-temporal overlap in habitat use and movement patterns of these species (predation risk) in relation to anthropogenic features and other habitat characteristics. The focus of this predation risk analysis is on the caribou calving period. (Chapter 1)
2. Determine the probability of caribou mortality by grizzly bears and assess variation associated with gender, age class, and the reproductive status of bears, seasonality, and landscape characteristics associated with anthropogenic features and other habitat types. (Chapter 2)
3. Implement feeding trials with captive grizzly bears to develop and validate stable isotope techniques to quantify caribou within the diet of grizzly bears from hair. (Chapter 3)

Objective 1: Evaluating the potential risk of the grizzly bear as a predator of central mountain caribou

1.1 Introduction

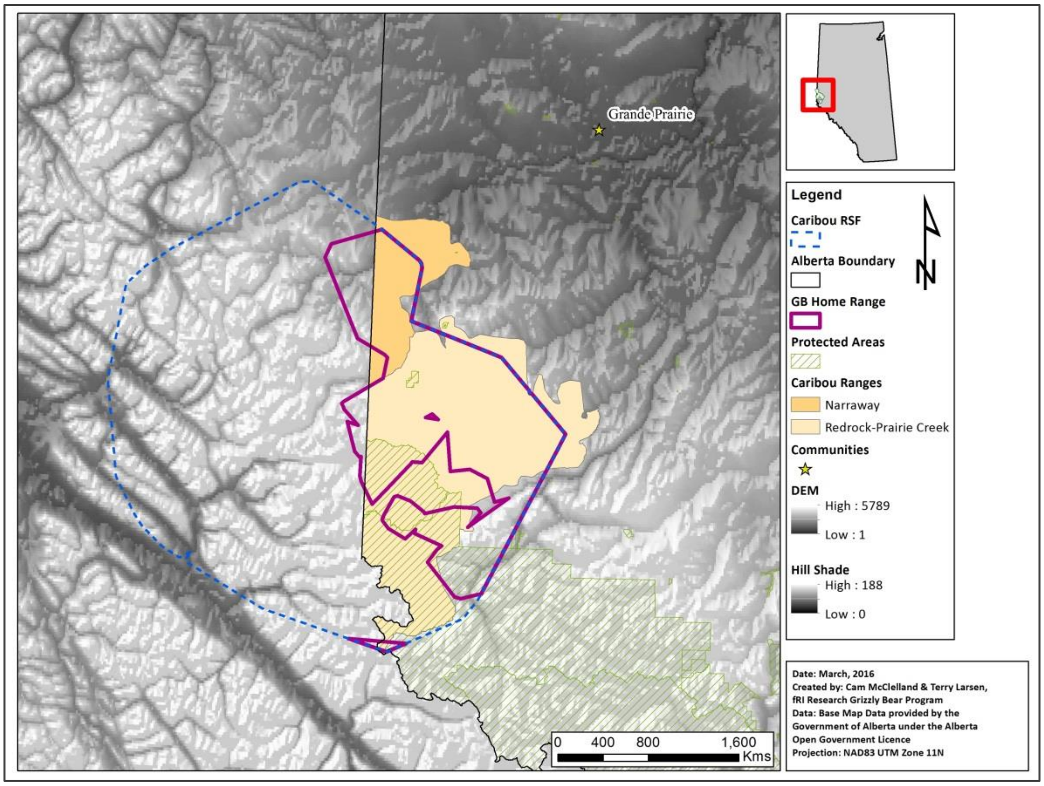
Central Mountain caribou populations are believed to have declined in recent years due to habitat mediated apparent competition associated with increases in caribou mortality from wolves (McLoughlin et al. 2005; Wittmer et al. 2005; Hervieux et al. 2013). Apparent competition is the indirect interactions among multiple prey species and a shared predator. In this case, potential increases in moose (*Alces alces*), white-tailed deer (Odeocoileus virginianus), and/or elk (*Cervus Canadensis*) populations within caribou ranges may increase predator numbers resulting in increased caribou predation rates. As a result, efforts have been made to reduce wolf numbers as a means to recover caribou population in Alberta (Hervieux et al. 2014). Because wolf control was successful in stabilizing population growth of caribou in west-central Alberta, future recommendations highlights the need to manage predators concurrently with improving caribou habitat (Hervieux et al. 2014). Although wolves do play a key role in caribou declines, other predators may also play a role, depending on their distribution and abundance. Kinley and Apps (2001) found that low calf recruitment and high adult mortality were responsible for caribou population decline. Although the reason for low recruitment was not known, cougars were found to be the main cause of adult mortality (Kinley and Apps 2001). In another study, Stotyn et al. (2007) reported that much of the adult caribou mortalities were related to grizzly and black bear predation. Bears are known to be important predators of ungulate neonates, and in northern Canada, grizzly bears are recognized as an important sources of caribou neonate mortality (Adams et al. 1995).

For caribou herds in Alberta, there is little information regarding the causes of neonate mortality, and until recently, mortality investigations of adult females were rare. However, ongoing research in west-central Alberta has revealed that multiple predators (bears, cougars, and wolves) are responsible for adult female mortality (fRI Research Caribou Program). Where data are deficient, an alternative approach to examine potential linkages between predators and caribou mortality is to model predation risk as the spatial overlap between predator and prey species estimated by a resource selection function (RSF) (Gustine et al. 2006). These models are flexible and can be tailored to examine animal or population level responses at multiple spatial and temporal scales. Because grizzly bear predation rates may vary due to biological (gender, age, reproductive status) factors (fRI Research Grizzly Bear Program unpublished data), incorporating these effects into models can yield important information for managers.

In this chapter, we evaluate the habitat use patterns of grizzly bears in relation to two central mountain caribou herds to assess predation risk by bears where these species overlap. Our approach was to use grizzly bear GPS location data and predictive maps of caribou occurrence defined by a RSF to model grizzly bear predation risk as a function of caribou habitat selection. We incorporated spatial predictions of caribou habitat use (RSFs) as covariates in grizzly bear RSF models that represent adult female caribou habitat associations relative to A) calving sites, B) habitats where calves were lost or survived during the post parturition period, and C) seasonality. Our rationale for considering these caribou RSFs was to determine if spatial overlap with bears is associated with the calving or post-calving period as caribou neonates tend to die within days or weeks of parturition (Guistine et al. 2006). We compared results from the calving season to a more general seasonal caribou RSF to contrast predation risk associated with calving and habitat conditions overall. Our specific objectives were to: 1) develop population level RSF models for grizzly bears by gender and reproductive status (solitary females vs. females with cubs) that correspond with caribou RSFs spatially and temporally; 2) evaluate grizzly bear responses (selection or avoidance) to caribou habitat that could lead to elevated predation risk; and 3) map grizzly bear predation risk associated with caribou habitat.

Study Area

The study area included areas of home range overlap between grizzly bear and the Redrock-Prairie Creek and Narraway caribou central mountain herds in west-central Alberta (Figure 1.1). Part of the area is public land where timber is managed for commercial production under a Forest Management Agreement between the crown and Weyerhaeuser Company (Grande Prairie). Forest harvesting since the 1970s has created a mosaic of seral stages of regenerating forest, however, because harvesting is limited within caribou zones, these areas are dominated by large tracts of mature conifer forest. Parks and protected areas occur in the western and rugged mountain portion of the area. Climate, topography, soils and vegetation are characteristic of the Rocky Mountain Natural Region. Other land use activities such as the energy sector (oil and gas) also contribute to the human footprint and recreational (i.e. hunting, fishing, trapping, and off-highway vehicle use) users also occur throughout the study area.



Date: March, 2016
Created by: Cam McClelland & Terry Larsen, fRI Research Grizzly Bear Program
Data: Base Map Data provided by the Government of Alberta under the Alberta Open Government Licence
Projection: NAD83 UTM Zone 11N

Figure 1.1. Study area (Objective 1) map depicting the Redrock-Prairie Creek and Narraway caribou herd ranges in Alberta, the spatial extent of caribou RSF models across Alberta and British Columbia, and grizzly bear home ranges where there is overlap.

1.2 Methods

Grizzly bear GPS location data

We used a GPS location dataset from the fRI Research Grizzly Bear Program as part of ongoing and long-term research. Between 2006 and 2015, grizzly bears were captured via heli-darting, snares, or culvert traps following protocols accepted by the Canadian Council of Animal Care (University of Saskatchewan animal use protocol number 20010016). Snares were not used after 2009 because of animal welfare concerns (Cattet et al. 2008). Captured animals were fit with a Televilt or Followit (Lindesberg, Sweden) Global Positioning System (GPS) collar programmed to collect locations at a pre-determined interval (0.5, 1, or 2 hours) over a two year period. A premolar tooth was extracted to estimate the age of each animal from cementum annuli analysis (Stoneberg and Jonkel 1966) and to partition grizzly bears into age classes for data analysis (Graham and Stenhouse 2014). Efforts were made to track the presence and survival of cubs by observing adult females following monthly relocation flights to download GPS location data (2006-2012). After 2012, observations were limited to periodic encounters during capture or other field work.

Caribou resource selection function models

Calf site and Post Parturition RSF models – We used a calf site and post parturition RSF models described in detail in Norbert et al. (2016) to assess the spatial overlap between grizzly bears and habitats selected by female caribou for calving and during the post parturition period. In brief, GPS location data (1998-2014) were collected from adult female caribou collared within the ranges of the Redrock-Prairie Creek and Narraway herds as part of a long-term collaring program by Weyerhaeuser Co. Ltd and Alberta Environment and Parks. Data analysis was limited to GPS locations taken from May 1 to July 14, which is the expected calving season of the Redrock-Prairie Creek and Narraway populations (Gustine et al. 2006). Breakpoints in caribou movement rates (Demars et al. 2013) were used to identify calving and mortality sites of neonates. This approach identified the state of female caribou during the calving season as: 1) calved and the calf survived for four weeks; and 2) calved and calf lost within four weeks. Logistic regression was then used to model caribou calf site selection as well as caribou habitat selection during the post parturition period where calves survived or where calves were lost. Variables representing topography (elevation, slope steepness, topographic position), aspect (northness, eastness), land cover (snow cover, vegetation, and vegetation productivity), and landscape disturbance (fire, cutblocks, roads and well sites) were used as model predictors. Predictions were then mapped in ArcGIS 10.2 using the logistic equation minus the intercept and rescaled between 0 and 1.

Seasonal models – We used a long-term dataset of GPS (use) locations from adult female caribou (Redrock-Prairie Creek n=104; Narraway n=64) collared between 1998 and 2015 to estimate seasonal RSF models and map the relative probability of habitat selection by Redrock-Prairie Creek (spring [May 10 – June 19], summer [June 20 - October 7]) and Narraway (spring [May 5 – June 19], summer [June 20 - October 7]) caribou using mixed effect binomial logistic regression models. We obtained RSF model coefficients by contrasting distributions of use and available locations representing natural (elevation, slope, topographic position index, aspect, wildfire) and anthropogenic landscape (landcover, roads, seismic lines, well sites, and forestry cutblocks) covariates (Manly et al. 2002). Habitat availability was defined for each animal by year and season using minimum convex polygons; random points were generated at a ratio of 10 (availability) to 1 (use) (Northrup et al. 2013). For each seasonal model, we included individuals where GPS locations were collected on at least 70% of the unique days over the course of the season. We fit a global model for each season and herd, and removed covariates that did not improve model fit according to Akaike's Information Criterion and the principle of parsimony (Burnham and Anderson 2002). To account for differences in sample size and variation in selection between individuals and years, we included a random effect for each individual-year combination (Gillies et al. 2006). RSF equations minus the intercept were then used to map caribou habitat as the relative probability of selection scaled between 0 and 1.

Grizzly bear predation risk models

We generated a polygon to define the area of caribou RSF overlap. Grizzly bear GPS (use) locations that fell within this area and that corresponded to the temporal period used to estimate caribou RSFs were considered in our analysis. Habitat availability for each bear was defined by a multi-annual MCP and random locations generated at a point density of 10/km^2. Three use-available datasets were created that corresponded to the 1) calving period (May 18 – June 19); 2) post parturition period (May 18 – July14); and 3) spring (May 5 – June19) and summer (June 20 – October 7) caribou seasons. We then used a GIS to extract the mapped predictions of caribou calf site (CS), post parturition (PP), and seasonal (SL) RSF models to each of the corresponding grizzly bear use-available datasets. RSF values were then multiplied by 100 (rounded up) to obtain integer values, thus, scaling the predictor variables appropriately. For those animals with a minimum of 50 GPS locations, we estimated population level RSF models using mixed effects binomial logistic regression for male, female, and females with cubs (cubs-of-the-year, yearlings, and ≥ 2 years of age) to define grizzly bear predation risk as a function of those covariates representing caribou habitat selection. We used bear as a random effect in each model to account for differences in sample size and the precision of estimated coefficients. We checked that collinearity ($|r| > 0.6$) or multicollinearity ($VIF > 3$) was not an issue for models (PP, SL) with more than one covariate. Our interpretation of our fitted models follows that if grizzly bear responses (coefficients) were significantly positive (95% confidence intervals do not overlap zero), there was habitat overlap between caribou and grizzly bears, suggesting a possible increase in predation risk for caribou. Conversely, a negative response would indicate habitat overlap between the two species was not occurring and thus there was a low predation risk for caribou by grizzly bears.

Mapping grizzly bear predation risk

We applied the regression coefficients (minus the intercept) obtained from our grizzly bear RSF models describing predation risk of caribou (CS, PP, and SL RSF maps) in relation to bear gender and reproductive status (females with or without cub). The predicted values of the rasters were then reclassified into 10 ordinal bins using Natural Breaks (Jenks), which represent a gradient of low (1) to high (10) predation risk.

1.3 Results

We used 42,980 grizzly bear GPS locations from male (n=11), female (n=14), and female & cub (n=6) to create RSF models. The results of our RSF analysis suggested that both male and female bears with cubs selected habitats that adult female caribou used for calving (Figure 1.2). However, considering the post-parturition habitat selection of caribou in relation to the loss or survival of calves, male bears selected habitat where calves survived, and avoided habitat where calves were lost (Figure 1.3). Conversely, female bears with cubs selected caribou habitat where calves were lost (Figure 1.3). During spring females with cubs selected habitats similar to caribou, whereas males and single females used these same habitats at random (availability) (Figure 1.4). During summer, grizzly bears tended to avoid caribou habitat (Figure 1.4). Overall, female grizzly bears tended to avoid caribou habitat across all seasons, and caribou predation risk from males and females with cubs tended to be associated with the calving period or spring. For males and female grizzly bears with cubs we mapped areas of high predation risk within Alberta's central mountain caribou ranges that were associated with habitats selected by adult female caribou during the calving period, post-parturition period, and spring (Figure 1.5).

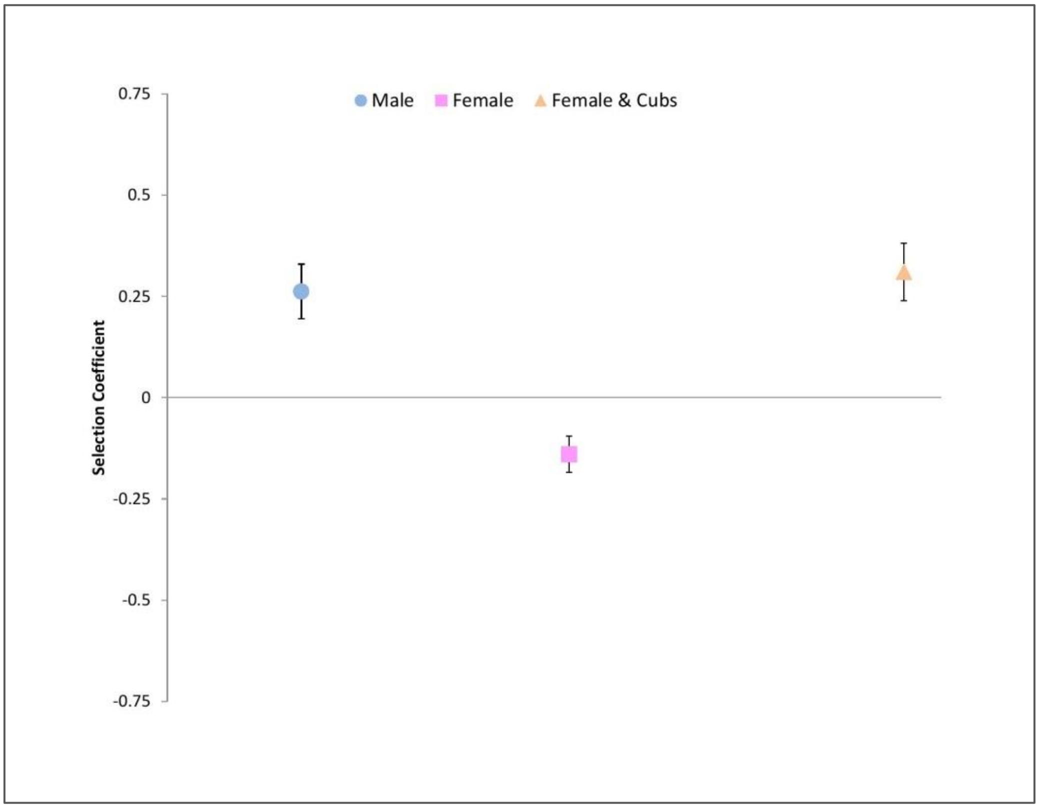


Figure 1.2. Resource selection function (RSF) model estimates (beta coefficient and 95% confidence intervals) describing the response (predation risk) of grizzly bears (male, female, and female with cubs) to habitats adult female caribou selected for calving (Norbert et al. accepted.)

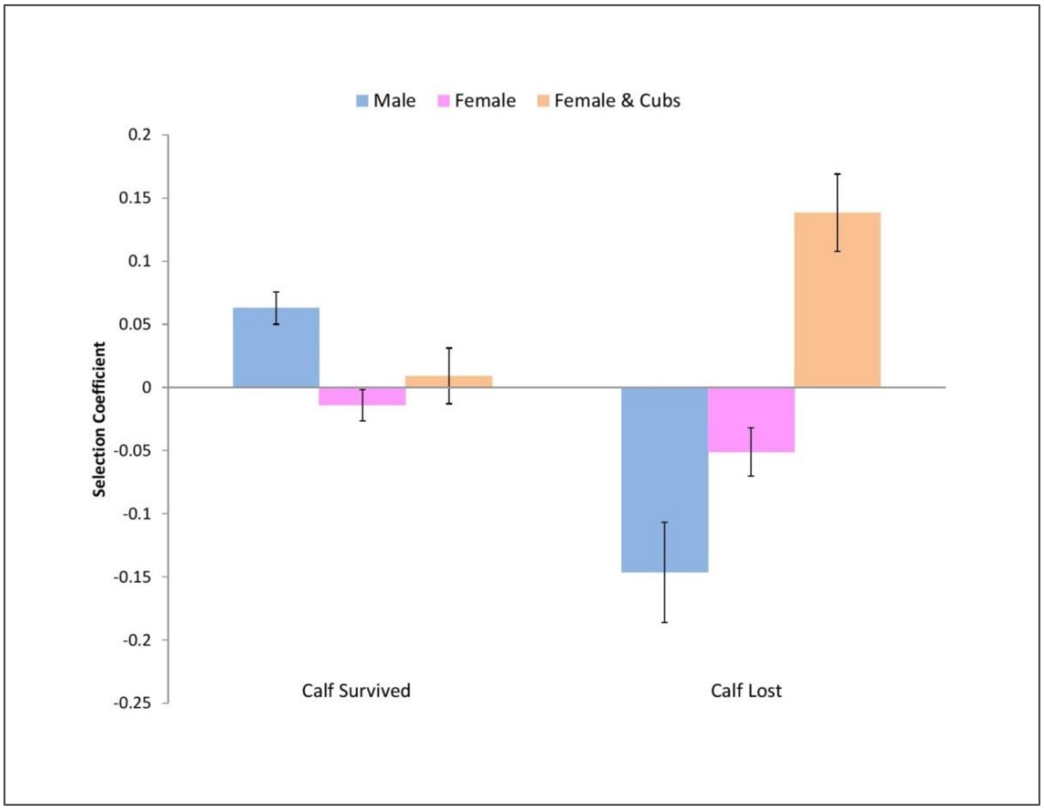


Figure 1.3. Resource selection function (RSF) model estimates (beta coefficient and 95% confidence intervals) describing the response (predation risk) of grizzly bears (male, female, and female with cubs) to habitats selected by adult female caribou during the post parturition period where calves either survived or were lost (Norbert et al. accepted).

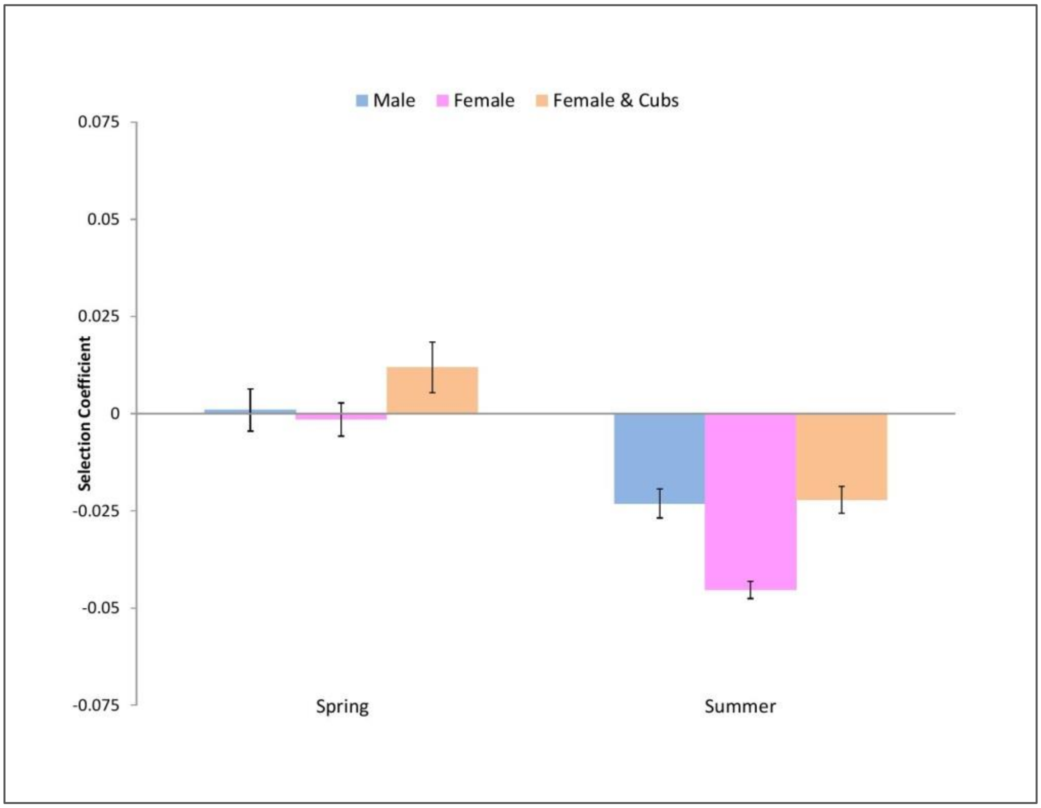


Figure 1.4. Seasonal (spring, summer) resource selection function (RSF) model estimates (beta coefficient and 95% confidence intervals) describing the response (predation risk) of grizzly bears (male, female, and female with cubs) to habitats selected by adult female caribou during spring and summer seasons (fRI Caribou Program unpublished data).

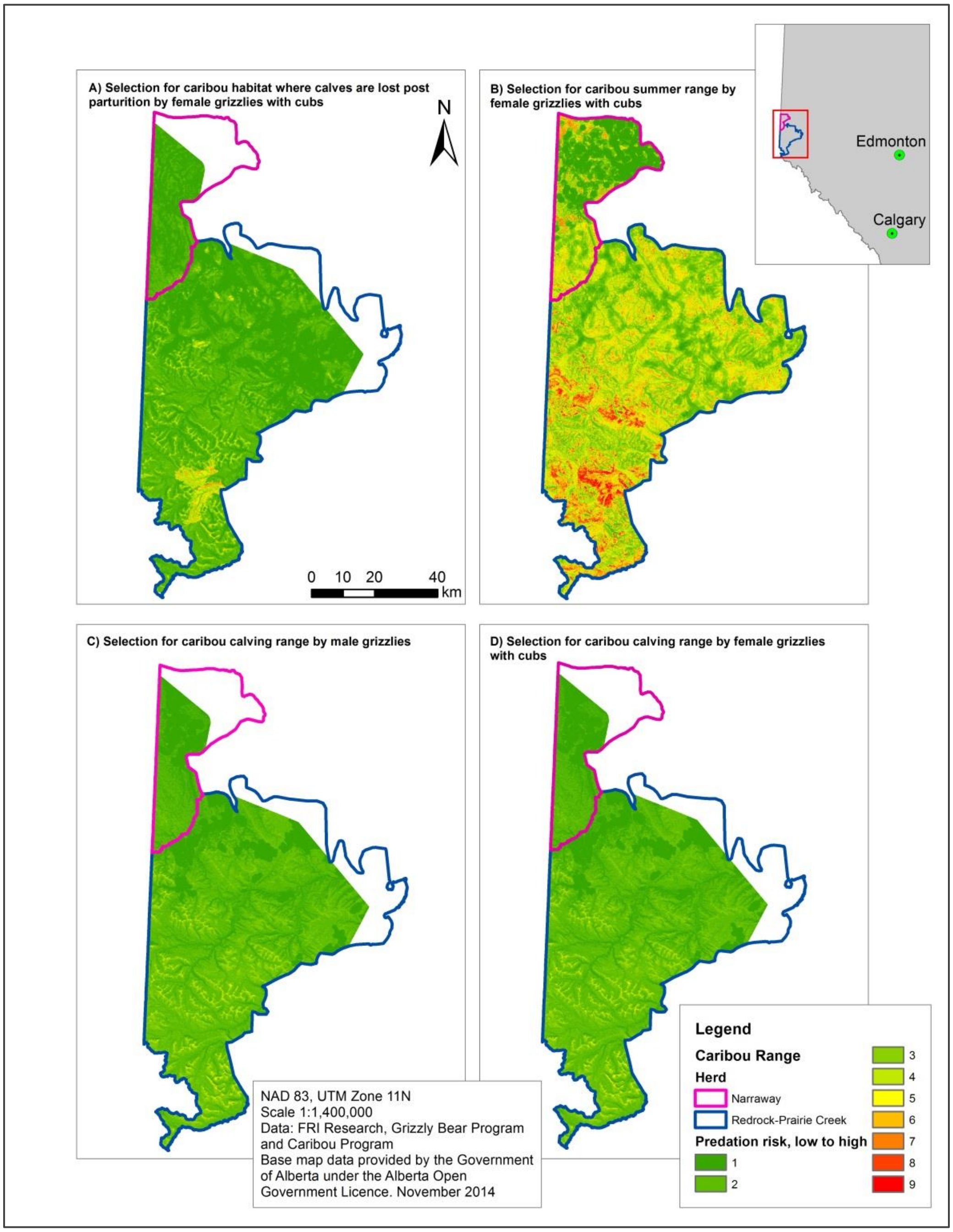


Figure 1.5. Maps depicting grizzly bear predation risk relative to A) the post-parturition period where caribou lost their calves (female grizzly bears with cubs), B) summer caribou habitat (female grizzly bears with cubs), c) caribou calving habitat (male grizzly bears), and D) caribou calving habitat (female grizzly bears with cubs).

1.4. Discussion

This component of the study showed that caribou RSF models that were specific to the calving, post-parturition, and spring seasons predicted (positive habitat selection coefficient) the occurrence of grizzly bears. Spatial overlap between these species, particularly adult female grizzly bears with cubs during the calving and post calving period, suggests that the risk of neonate predation by grizzly bears may be higher in these areas. Research from other jurisdictions that suggests most caribou calves die as neonates (< 15 days) due to predation, and that grizzly bears can be a major player (49% of the neonatal deaths) (Reynolds and Hechtel 1985; Adams et al. 1995; Valkenburg et al. 2004). Adult caribou may also be at risk of predation during the calving period, thus, minimizing risk associated with grizzly bears may be important relative to caribou selection of calving sites (Gustine et al. 2006). Boertje et al. (1988) found that predation rates of moose were highest during spring, and that grizzly bears killed cow moose during the calving period, which is also supported by research in Alberta (Munro et al. 2006). Although we do not know if female grizzly bears with cubs are predating caribou neonates, our finding that females with cubs tended to be associated with caribou habitat could be due to the high energetic demands of females given the costs associated with reproduction even though male bears tend to have more meat in their diet (Mowat and Heard 2006; López-Alfaro et al. 2013). Young and McCabe (1997) found that female grizzly bears with cubs had higher predation rates than males and solitary females. However, females with cubs may also be avoiding interactions with male grizzly bears, which could also explain the observed differences in habitat selection.

We found spatial overlap between caribou and grizzly bear, particularly during the spring, when caribou are more likely to be killed. However, whether or not grizzly bears are actively searching for adult and neonate caribou is unclear. Central mountain caribou are known to have an antipredator strategy whereby they seek out high slopes in the mountains to have their calves, which likely reduces the predation success of species such as grizzly bears given that they have to search larger areas (Bergerud et al. 1984). Adult female caribou in this study appear to also be selecting similar habitats for calving (high elevation and gradually south sloping ridgetops), and research has also found that calves were more likely to survive when adult females used higher elevation habitats (Norbert et al. 2016). Other research has also shown that predation risk by grizzly bears was dependent on landscape conditions such as topography and forest age structure (Apps et al. 2013), and that the occurrence and abundance of alternative food resources could put grizzly bears in close proximity to caribou. Bastille-Rousseau et al. (2011) found that black bears did not select areas with a high probability of encountering neonates, but instead selected area with abundant vegetation. Because bears tended to have relatively high inter patch movement, this could result in greater encounters with neonates even if they are not actively searching for them (Bastille-Rousseau et al. 2011). As industrial development associated with forestry and oil and gas continues within caribou habitat, which generally improves habitat conditions for grizzly bears (Nielsen et al. 2004; Boulanger et al. 2013; McKay et al. 2014), spacing away from predators may be increasingly challenging for caribou.

Objective 2: Investigations of grizzly bear predation events to detect caribou mortalities.

2.1 Introduction

Predation is believed to be the proximate cause of caribou population declines throughout their range (ASRD and ACA 2010, Hervieux et al. 2013). Wolves have been implicated as the main predator of caribou (Courbin et al. 2009). However, predation by grizzly bears, black bears, cougars and wolverines have also been documented (Bergerud and Elliot 1986; Wittmer et al. 2005; Gustine et al. 2006; Apps et al. 2013). Predator prey relationships are complicated, especially in multiple predator-prey systems (Sih et al. 1998). Prey evolve strategies to elude their predators, and predators evolve to kill their prey in a dynamic balance (Lima and Dill 1990). Relatively large and sudden changes to their habitats could potentially shift the balance in favour of one or the other (Gorini et al. 2012). Declining caribou populations and suspected high predation rates throughout much of their range suggests that the balance may have shifted in favour of the predators as a result of anthropogenic landscape change. Forest harvesting and oil and gas developments make openings and change the age distribution of forests on the landscape that produces food for alternate prey, resulting in an increase in predator numbers and potentially increased risk of predation (Courtois et al. 2007; Wittmer et al. 2007).

Although the limited data from mortalities in Alberta seem to suggest that wolves are the dominant predator, much of this data is based on kill site investigations well after the mortality event occurred (weeks to months later). Thus, it cannot be determined with any great level of certainty what predator was responsible for the specific mortality event. Research in the ranges of other woodland caribou populations have revealed that predators such as wolverines, cougars and grizzly bears may play a role (Bergerud and Elliot, 1986; Gustine et al., 2006), and could be under represented relative to predation impacts on caribou in Alberta. Management and recovery of caribou populations could benefit from further investigation of alternate predators. This project investigated predation by grizzly bears on caribou so that land and wildlife managers have a better understanding of the role grizzly bears may play in caribou survival.

Predation has been described as a series of events, with each event associated with a different probability. A predator must first encounter and detect the prey, followed by an attack, a kill and finally consumption (Lima and Dill 1990). In Chapter 1, we showed that grizzly bear predation risk was highest for caribou during the calving or spring period, and that male bears and females with cubs tended to show greater overlap in habitat compared to females without cubs. Our next objective was to determine whether this elevated predation risk corresponds to increased mortality, i.e. are grizzly bears killing caribou? Since a carcass is the final culmination of predation behaviour, finding caribou carcasses and determining plausible cause of death was necessary to confirm whether or not grizzly bear predation on caribou was occurring within our study area. However, determining how prey died based on signs at a carcass is often difficult to interpret because other predators may visit the carcass (scavenging), and prey animals can die from other causes (disease, old age, and/or injury etc.) and are then scavenged after death. Distinguishing a kill made by a collared grizzly bear from a kill made by a different predator, and subsequently scavenged by a bear may not always be possible. However, collecting detailed and standardized information at carcass sites could reveal patterns that may be useful in teasing apart probable grizzly bear kills from scavenging events. In this chapter we report our findings from visiting the GPS location clusters of collared grizzly bears that were used to locate ungulate carcasses and to evaluate whether carcasses were associated with predation or scavenging events.

2.2 Methods

We used collar data from grizzly bears captured in 2014 and 2015 for cluster visits. Collars were programmed to obtain a location every 30 minutes from 15 May to 30 September, every hour in early spring (1 April-14 May) and fall (1 Oct – 30 Nov) and once a day during denning (1 Dec-31 March). Grizzly Bear locations and movement data were accessed via a website, typically once a month, for GPS location cluster identification.

During May and June 2014, 3 adult male grizzly bears and 4 adult female grizzly bears were captured and collared for this study. All four females (G290, G293, G294, and G297) and one male (G298) spent the majority of their time in protected areas in the mountains. One male lived partly in the mountains and partly in the foothills (G299) and another male lived entirely in the foothills where resource extraction activities occurred (G295). In addition, one adult female grizzly bear collared in 2013 (G288) in the mountains, also became part of the study but her collar was programmed to obtain a location every hour, rather than every 30 minutes (Figure 2.1 and 2.2). During May and June of 2015, 2 adult male grizzly bears were fitted with collars programmed to obtain a location every 30 minutes and both lived outside protected areas in the foothills (G302 and G303). In 2015, an adult female (G275) and an adult male (G289) that lived in the foothills northeast of Grande Cache were added to the study (Figure 2.1 and 2.2). The female and male wore an hourly and 30 minute programed collar respectively. No subadult bears (< 5yrs old) were collared in this study

We suspect one of the females (G288 in 2014) may have had cubs of the year in the spring (May 1 to June 15) based on her small spring MCP (Sorensen 2016, unpublished data), but this was not visually confirmed. One female (G293) was captured in 2014 with yearlings but her reproductive status in 2015 was not confirmed. Therefore all females were considered to be without cubs of the year for the analysis.

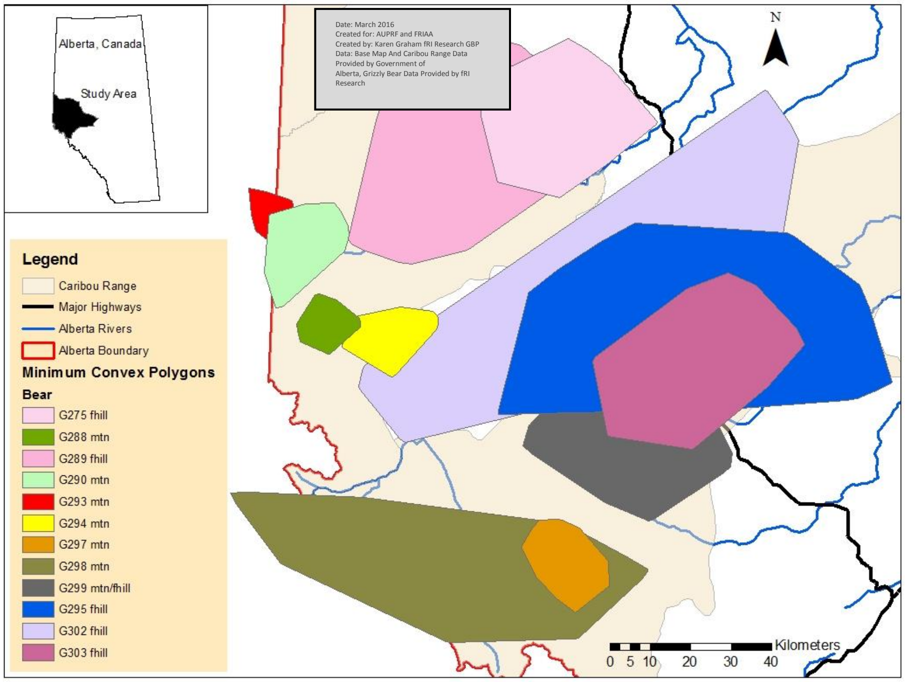


Figure 2.1. The MCP for each grizzly bear used in the study using all collar location data. "Fhills" indicates bears living predominately in the foothills and "Mtn" indicates bears living predominantly in the mountains. See Figure 2.2 for cluster locations.

Cluster Identification and Selection

We defined a cluster as a group of consecutive GPS collar locations for an individual bear within a specified distance from one collar location to the next. Clusters were identified using two methods. First, we used a python script which identified clusters from collar locations based on criteria provided by the user. In 2014, we used a 100m distance criteria between sequential points following (Metz et al. 2012). We reduced the distance criteria from 100m to 50m in 2015 to reduce the number of berry or herbaceous foraging sites visited. The python script output included 2 text files. The first file provided the bear ID and each location that made up the cluster with its Universal Transverse Mercator (UTM), date, time and distance in meters from the prior consecutive location. The second file summarized each cluster and gave the bear Id, the total number of locations that made up the cluster, the date and time the cluster began and the midpoint of the cluster in UTM.

As it was not feasible to visit every cluster due to cost, accessibility and time constraints, we created a system for cluster selection. We categorized clusters into 5 classes (A-E) based on duration (Table 2.1), and in 2014 into time of day (day or night clusters). We used time of day because previous research showed that grizzly bears in this area typically rested at night (Graham and Stenhouse 2014), so we predicted that most kills would occur during daytime hours. However, field data from cluster visits in 2014 indicated that kills did occur at night so we did not stratify clusters by time of day in 2015. We attempted to visit all clusters in Classes A and B as large clusters are often associated with ungulate carcasses (Sand et al. 2005; Zimmermann and Wabakken 2007). If there were too many clusters in Classes C through E to visit, these clusters were randomly selected for site visits using a random number table. For Class C, three day and two night clusters were randomly selected for visits in 2014 and at least 3 were selected in 2015. For class D and E, one random day and night cluster was selected in 2014 and at least three in each class were randomly selected in 2015. However, clusters in the E class were only selected if the cluster occurred in May, June or Julybecause the time required to kill and consume an entire ungulate calf would be relatively short. After July, we focused on classes A to D only.

Table 2.1. Cluster classes based on duration of cluster.

Cluster Class	Description
A	Top three longest duration clusters
B	>11 hrs
C	8-10.5 hrs
D	5-7.5 hrs
E	2-4.5 hrs

Second, we selected clusters using a manual process. We sorted locations for each bear by date and time, and a single researcher viewed locations in a GIS in sequence; noting patterns in each bear's movements such as when the bear typically rested (i.e. movement appeared to stop). We chose clusters of GPS locations to visit based on movements outside of the bear's "normal" pattern (i.e. the bear rested when it usually would be moving, or the bear had been moving when it usually would be resting). In addition, we selected clusters if a bear visited the same cluster more than once, or if a bear appeared to make a sudden change in direction that ended in a cluster. These "clusters of interest" were matched to a cluster identified using the script method by date and time, and were selected to visit if it was not already selected using the script method.

For bears collared during the spring of 2014, we initially visited clusters that were at least 3 days post capture because recovery from a capture event may cause atypical change in movements (Cattet et al. 2008). However, because one cluster visited 3 days post capture was unusual (12 hours spent at a bed in very dense alpine fir which was not usual for this bear) we extended the criterion to at least 5 days post capture. Finally, because we initially identified the 2014 clusters using a 100m distance criteria, we reran the 2014 collar locations using the 50m distance criteria so the cluster outputs would be comparable between 2014 and 2015 data.

Cluster Visit Data Collection

We accessed clusters by foot, ATV, from a helicopter, or with a 4x4 truck. We accessed all mountain bear clusters by helicopter (Figure 2.1). Upon arrival at the cluster midpoint, we meandered through an area encompassing a 20-50m radius around the cluster midpoint, searching for bear and other carnivore sign. After this focused search, crews extended the search area, and navigated to the remaining GPS locations within the cluster to record any additional evidence of bear or other predator/prey presence. Because cluster visits in 2014 identified most of the evidence observed from a predation event within 20m of the cluster midpoint, in 2015 we modified field investigations to only focus on the midpoint and a 20-50m search radius around the midpoint.

At each cluster we classified the main bear activity as one of 5 categories: carcass, hair scat, non-carcass related foraging, bed and unknown. If more than 2 activities were evident at a cluster, then categories were prioritized using the following criteria: carcass > hair scat > non-carcass related foraging > bed. Hair scat clusters were those clusters where scats containing hair were found at the cluster but no carcass was identified and the bear had not just left a known carcass 15 hours prior (15 hours is the mean time for the last defecation after feeding on meat by grizzly bears (Elfström et al. 2013). Because caribou and moose calves are small (caribou average 10 kg (Gustine et al. 2006); moose average13 kg (Swenson et al. 2007)), remains at kill sites may be absent (Rauset et al. 2012). As well, consumption of these calves can occur within minutes (Young and Mccabe 1997), and thus time spent at calf kills may not be long enough for a cluster to form. Hair scats can provide valuable information on a meat eating events that could be missed by just focusing on carcasses. Therefore we collected hair scats located at clusters to identify the remains in hair, and to augment our detection rates of caribou calf predation. We stored hair scats frozen (-20ºC) until laboratory analysis. Non-carcass related foraging sign included digs (for roots or insects), or cow parsnip (*Heracleum lanatum*) feeding, both of which leave quite obvious foraging signs. If no obvious bear sign was observed, crews noted any ripe berries or missing flowers or seed heads that the bear may have eaten. When bear sign was observed, we recorded the distance from the bear sign to the cluster midpoint.

If a carcass was found at a cluster, field crews took pictures of the site and carcass, and collected any bones or hair that could aid in species and age identification. Other predator sign was documented such as scat, tracks or a mat of hair typical of cougar kills. Field crews also documented characteristics of the carcass site, including torn up ground from burial activities, cracked femur, shattered skull, and whether remains were scattered or confined to a relatively small area. Maggots or beetles seen on the carcass were also noted to corroborate with approximate time of death. Bones collected in the field were compared with bones of a reference collection to confirm age and/ species. If there was still some uncertainty as to the prey species, we consulted with a wildlife veterinarian.

We recorded general habitat characteristics at each cluster. These included any water sources classified as streams, lakes or fens, and general habitat classes that included alpine, conifer, deciduous, mixed (conifer and deciduous), regeneration (young open cutblocks), scree slopes, shrub lands (includes cutblocks with significant shrub cover). We estimated the canopy cover by eye and classified as dense, moderate or open. In addition we noted the presence of any anthropogenic features within 50m of the cluster including cutblocks, pipelines, railway, roads, seismic lines/trails and well sites.

In the laboratory we thawed the hair scats; then removed and cleaned the hair by hand. We determined species by comparing the hair medulla and scale patterns with those from a reference library and through comparison with the literature (Deedrick and

Koch 2004; Marinis and Asprea 2006) . To further verify our findings from morphological assessments of hair samples, we sent 11 samples to a genetic lab for species identification (Wildlife Genetics International – Nelson B.C.).

Analysis

We assessed differences among clusters visited by bear activity, duration of time the bear spent at the cluster, gender and bear age. We used nonparametric tests (Mann Whitney and Kruskal Wallace) for comparisons as data were not normally distributed. We defined a meat feeding event as an occurrence in which a bear fed on an animal and included scavenging, kills, and hair scats. We determined the mean number of moose calves and carcasses fed on be grizzly bears during the calving season and summer season respectively for bears in which we were able to visit > 90% of the clusters selected. The mean number of moose calves fed on by grizzly bears during the calving season (Mc) was calculated as

$$M_c = (C + H / d) * S$$

Where C is the number of moose calf clusters and H is the number of moose hair scat clusters by bear-year found during the calving season and d is the total number of days the bear was monitored during the calving season. S is the total number of days in the calving season determined as the first day that a moose calf carcass was found up until 30 June. We calculated the average number of carcasses fed on by grizzly bears during the summer similarly except C was the number of carcass clusters, d was the number of days the bear was monitored during the summer and S was the total number of days we considered to be the summer which was 139 days (15 May-30 Sept).

We summarized habitat attributes at carcass clusters and provide descriptive details specifically for clusters where caribou remains were found. The small number of clusters with caribou remains (n = 2) prevented more detailed statistical analysis. Finally, we estimated the number of adult and yearling moose carcasses we suspected to be scavenged.

2.3 Results

Between 20 June and 9 October, 2014 we visited a total of 173 clusters (16%) out of a total of 1089 clusters from 3 males and 5 females; clusters ranged in dates from 26 May and 29 September 2014. Nine of the clusters visited in 2014 were no longer identified as clusters when using the modified 50m distance criteria in 2015. In addition, we opportunistically visited 7 clusters from two male grizzly bears (G289, G291) that lived on the edge of the caribou range. In 2015, between 2 June and 21 October we visited 275 clusters (24%) out of a total of 1142 clusters from 6 males and 4 female grizzly bears; clusters occurred between 1 May and 14 October 2015. Out of a total of 2231 clusters in 2014 and 2015 combined, we selected 529 (24%) random or required clusters to visit and were unsuccessful at getting to 141 (27%) due to lack of helicopter landing sites and 95 (18%) due to lack of time or helicopter availability. We visited an additional 58 clusters in lieu of clusters that were missed and 39 that were "clusters of interest". In total we visited 448 clusters; 296 from 8 males and 152 from 6 females.

In both years, we were restricted from visiting clusters because of permit restrictions and events outside of our control (forest fire). In both years we were unable to visit clusters in Wilmore or Kakwa Wildlands Provincial Parks after 22 August due to perceived concerns with sheep hunters and helicopter disturbance. This permit restriction resulted in missing a potential 307 clusters for 4 females in 2014, and 157 clusters for 2 females in 2015. In 2014 and 2015, a female in the Kakwa Wildlands Provincial Park frequently moved into British Columbia (G293), which was outside of the area included in our research permit. Also in 2014 a forest fire within the study area restricted aerial access, and also usurped helicopters.

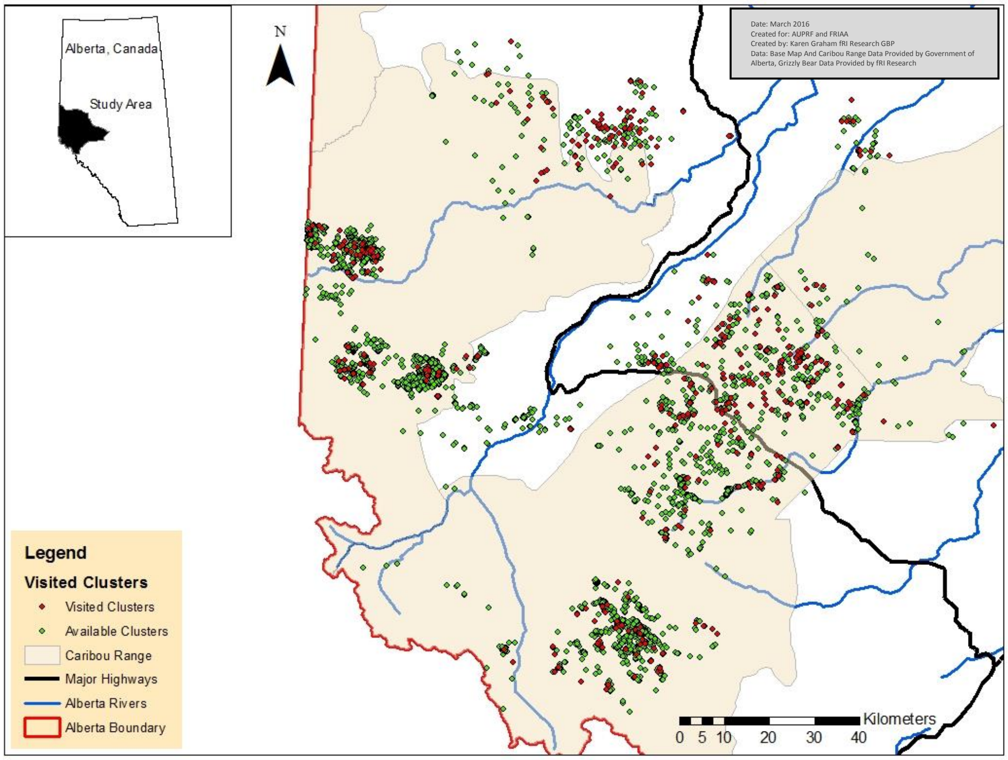


Figure 2.2. The locations of all the clusters detected using the python script (green) and the locations of all visited clusters (red) from 2014-2015 for 12 grizzly bears.

The main bear activity found at 448 clusters visited were 70 carcasses (16%), 33 hair scats (7%), 100 foraging (22%), 212 beds (47%) and 33 of unknown activity (7%). The average number of days between the cluster start date and the crew's visit was 28 days (min 3 days, max 116 days, n=441). The average distance bear sign was seen from the GPS cluster midpoint was 13m (min 0m, max 247m, n=438). There was a significant difference between the mean distance between consecutive locations in a cluster by bear activity (Kruskal Wallace X^2=22.47, df=4, p=0.0002; Figure 2.3), with foraging clusters having the longest distance (22.9m), compared with beds (16.9m), carcasses (17.3m), hair scats (18.5m) and unknowns (19.2m).

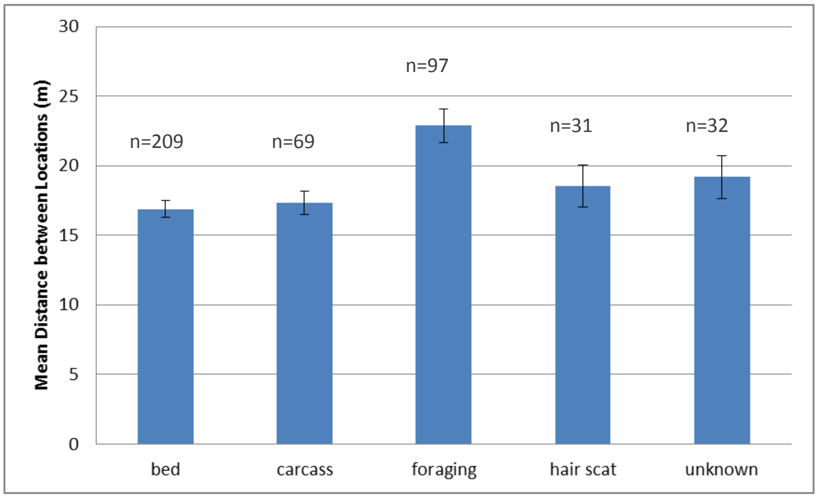


Figure 2.3. The average distance between consecutive locations at a grizzly bear cluster by bear activity. Standard error bars are shown.

Out of a total of 296 clusters visited for male bears we found carcasses at 61 (21%), and at 22 sites (7%) there were hair scats present. There were carcasses found at 9 (6%) of the clusters from female bears, and also 9 (6%) had hair scats present (Figure 2.4). Combined, we documented grizzly bears feeding on meat at 28% of male clusters and 12% of female clusters.

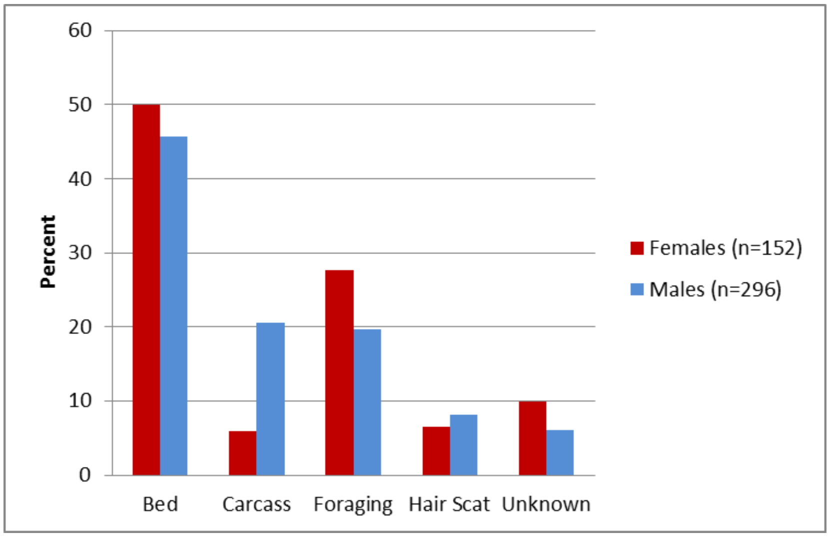


Figure 2.4. Percent of clusters categorized by bear activity and gender from 2014-2015.

Cluster duration varied by bear activity (Kruskal-wallis X^2=87.435; df=4; P=0.0001; Figure 2.4) and gender (Mann-Whitney Z=2.314; P=0.02; Figure 2.5). Carcass clusters had the longest mean duration at 19 hours and 35 hours for females and males respectively but also showed the largest variation among individuals (Figure 2.5). Mean duration a bear spent at beds, foraging, hair scats or unknown bear activity clusters ranged between 6-8 hours for both males and female bears (Figure 2.5).

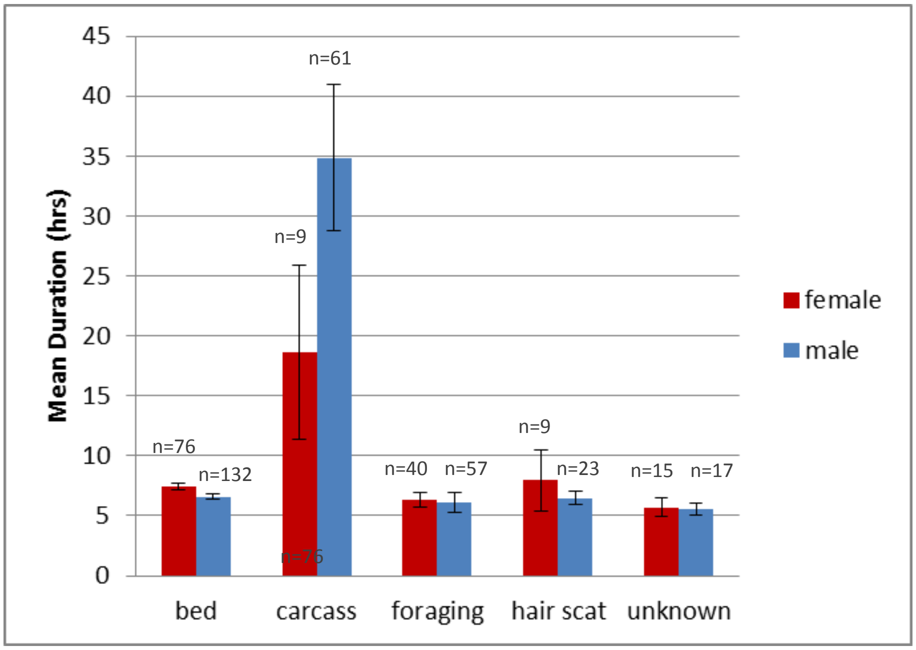


Figure 2.5. Mean cluster duration in hours for male and female grizzly by cluster activity. Standard error bars are shown.

Habitat

More than 60% of carcasses occurred within 50m of waterbodies (Figure 2.6a). In comparison, < 35% of beds, foraging, hair scat and unknown clusters occurred within 50m of water bodies. Foraging occurred most often in open canopy habitats (Figure 2.6b), while beds, carcasses, hair scats and unknown clusters occurred more commonly in moderate canopied habitats. Only one carcass occurred in the alpine (Figure 2.6c), whereas foraging often occurred in the alpine. Carcasses occurred within 50m of all types of anthropogenic features (Figure 2.6d) but all bear activities, including carcasses, occurred most often > 50m away from human features on the landscape.

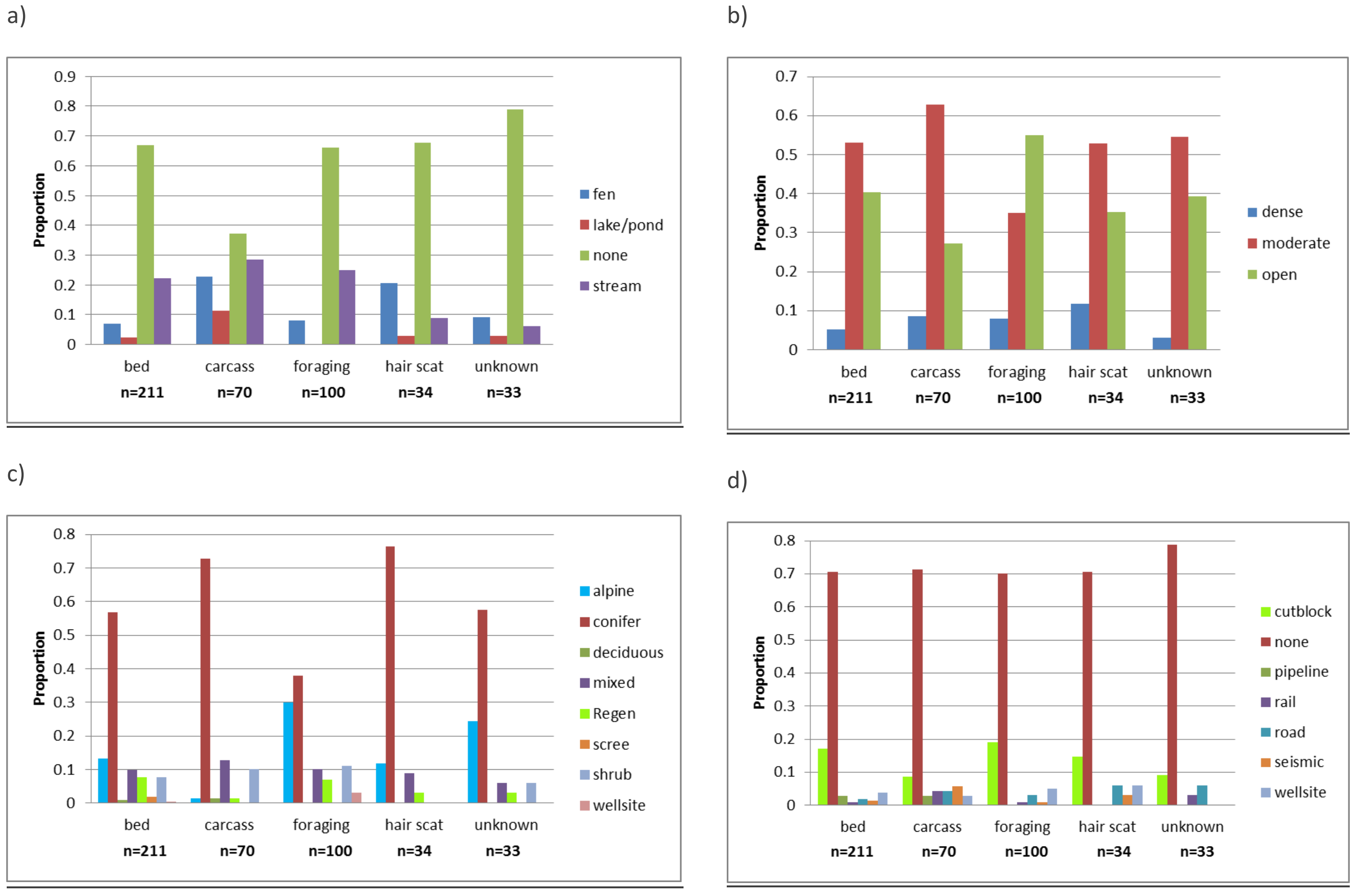


Figure 2.6. The proportion of clusters by bear activity in relation to waterbodies (a), canopy cover (b), habitat class (c), and anthropogenic features (d).

Carcasses and Hair Scats

Of the 70 carcasses found at clusters, 60 (86%) were moose; 2 (3%) were caribou and 1 each (1%) were mountain goat (*Oreamnos americanus*), mule deer (*Odocoileus hemionus*), deer of unknown species, black bear (*Ursus americanus*), beaver (*Castor canadensis*) and unknown animals respectively. There were 36 moose calves (51% of all carcasses, and 60% of all moose carcasses). Evidence of a burial occurred at 36 (51%) of all carcasses and a hair mat was found at 11 (16%).

Out of 11 ungulate hair scats sent for DNA species confirmation, 3 did not produce results. Of the 8 remaining, we had a 100% match between genetic identification and ungulate species identification using hair characteristics. Of the 33 hair scats collected, 15 (45%) were moose, 8 (24%) were non-ungulate species and 10 (30%) remained as unknown. Hair scats were found at bed sites 91% of the time.

Males were responsible for 61 (87%) of the 70 carcass clusters and 23 (70%) of the 33 hair scat clusters, while females accounted for 9 (13%) of the carcass clusters and 10 (30%) of hair scat clusters. We did not find carcasses for three female bears but we did find hair scats for 2 of these females; one of which was confirmed as a moose (Figure 2.7).

The first moose calf carcass we found on 22 May so the calf season was calculated to be 40 days (22 May-30 June). There were 2 male and 2 female bears with > 90% of the selected clusters visited during this time for use in the meat feeding estimate. The estimates for the males ranged between 11.4 and 3.1 moose calves/calving season for G295 and G303 respectively, and 4.3 and 0.0 moose calves/calving season for females G275 and G290 respectively. The average for all 4 bears was 4.9 moose calves/calving season, and the average number of days these 4 bears were monitored during the calving season was 34 days (range 23-39 days). There were 3 males and 3 females with < 90% of the selected clusters visited for the annual meat feeding estimates. The averages were 17.2 (range 12.5-22.3, n=3) and 5.1 (range 1.9-10.7, n=3) meat feeding events/day on an annual basis for males and females respectively. The average number of days these 6 bears were monitored for the year was 101 days (range 73-145 days).

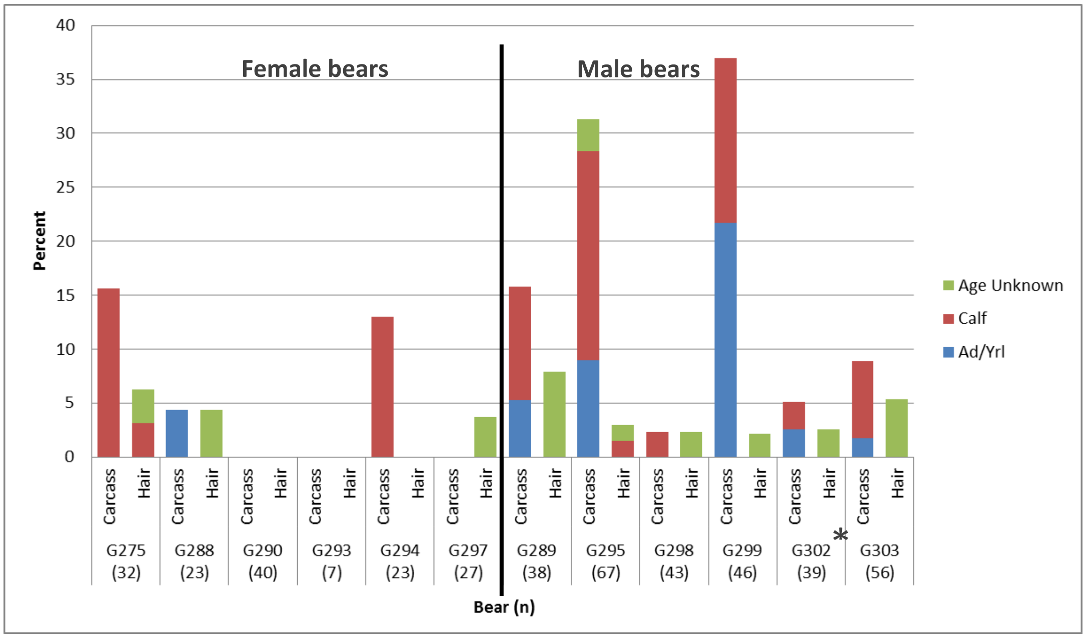


Figure 2.7. The percent of hair scat and ungulate carcass clusters out of the total number of clusters visited by staff for each bear (n) over 2 years, by ungulate age class. Male and female bear IDs are shown.

We pooled adult and yearling moose carcasses into one age class (adult/yrl) because the average weights of yearling and adult moose are similar (330 kg and 370-500 kg respectively; Jensen et al. 2013) compared to the average weight of a moose or caribou calf and we found no significant difference in duration of time spent by bears at adult (mean=59.9 hrs; SE=9.48, n=22) yearling (mean=32.8 hrs; SE=19.4, n=5) moose carcasses (Mann-Whitney z=1.717; P=0.086). Bears spent on average 32.7 hours at a carcass (n=70; SE=5.44). Males and females spent on average 34.9 hours (SE=6.12, n=61) and 18.7 hours (SE=7.28, n=9) respectively. Duration of time spent at adult/yearling carcasses (mean=54.9 hrs, SE=8.61, n=27) was significantly longer than time spent at calf carcasses (mean=12.9 hrs; SE=1.37, n=38; Mann Whitney; z=4.823; p=0.000). The duration of time spent at calf carcasses by males (mean=13.1 hrs, SE=1.48, n=30) and females (mean=12.1 hrs, SE=3.62, n=8) did not differ (Mann Whitney: z=0.467; p=0.641). No female bear clusters were found at adult/yrl moose carcasses.

All collared grizzly bears were adults that ranged in age from 6-15 years. There was no relationship between the mean duration of time spent by bear age at adult/yrl (Kruskal-Wallace: X^2=4.116, df=4, p=0.3905) or calf (Kruskal-Wallace: X2=8.135; df=4; p=0.08) carcasses (Figure 2.8).

Collared grizzly bear GPS clusters showed 83% of all calf carcasses occurred from mid May to the end of June (Figure 2.9). The first confirmed bear cluster centered on a calf carcass occurred on 22 May and the last on 5 September. Adult and yearling ungulate carcasses were visited throughout the summer and early fall months. Carcass clusters began at all times of the day but 77% of bed clusters began between 20:00 and 02:00 (Figure 2.10).

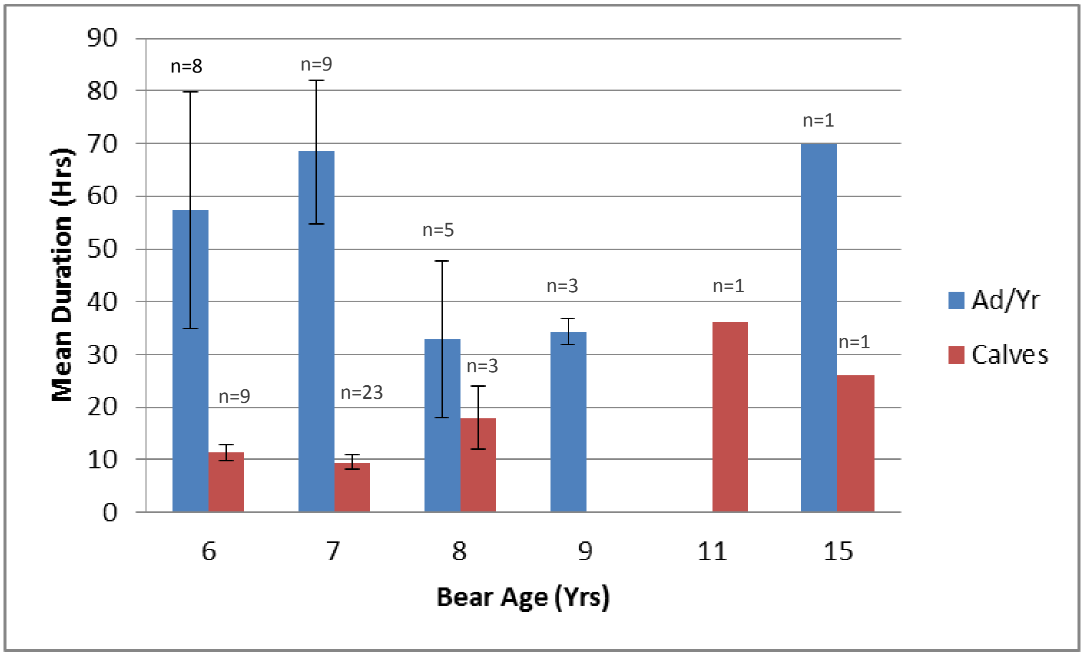


Figure 2.8. Grizzly bear age by cluster duration in hours at ungulate adult and yearling (pooled) and calf carcasses. Standard error bars are shown when the number of clusters (n) is greater than 1.

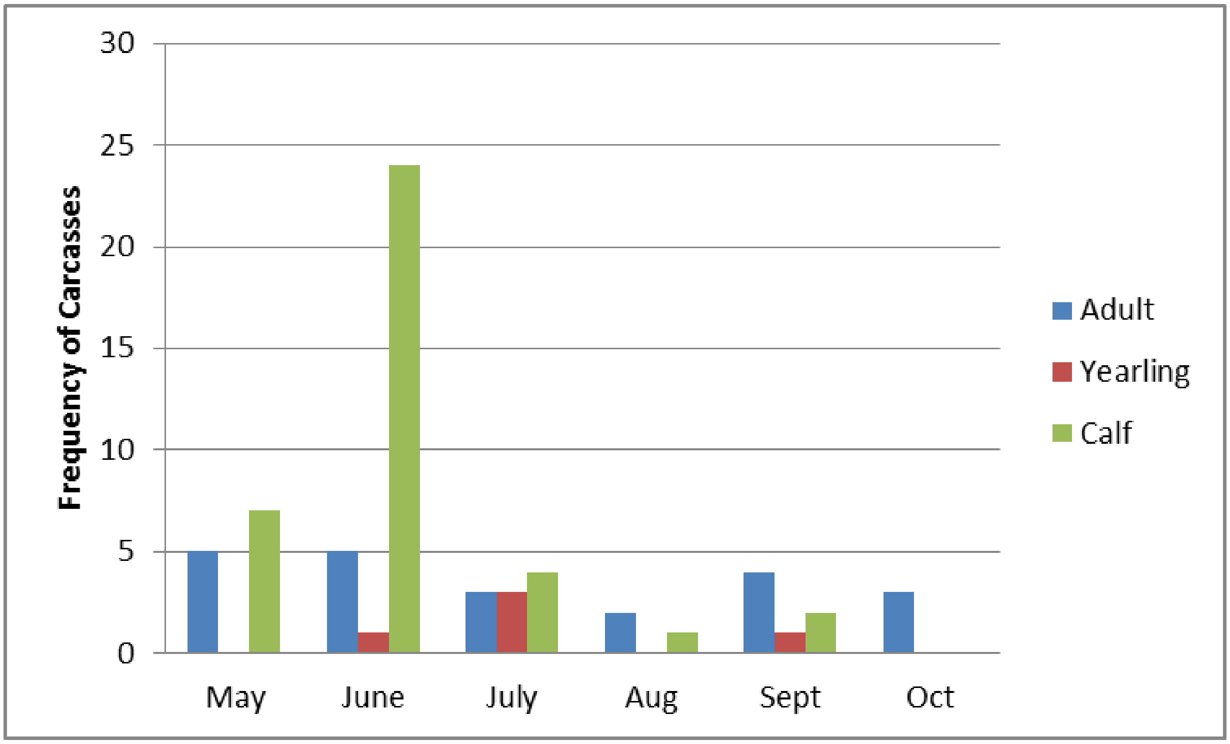


Figure 2.9. Frequency of carcasses by ungulate age class and month from 2014 -2015 for 12 grizzly bears.

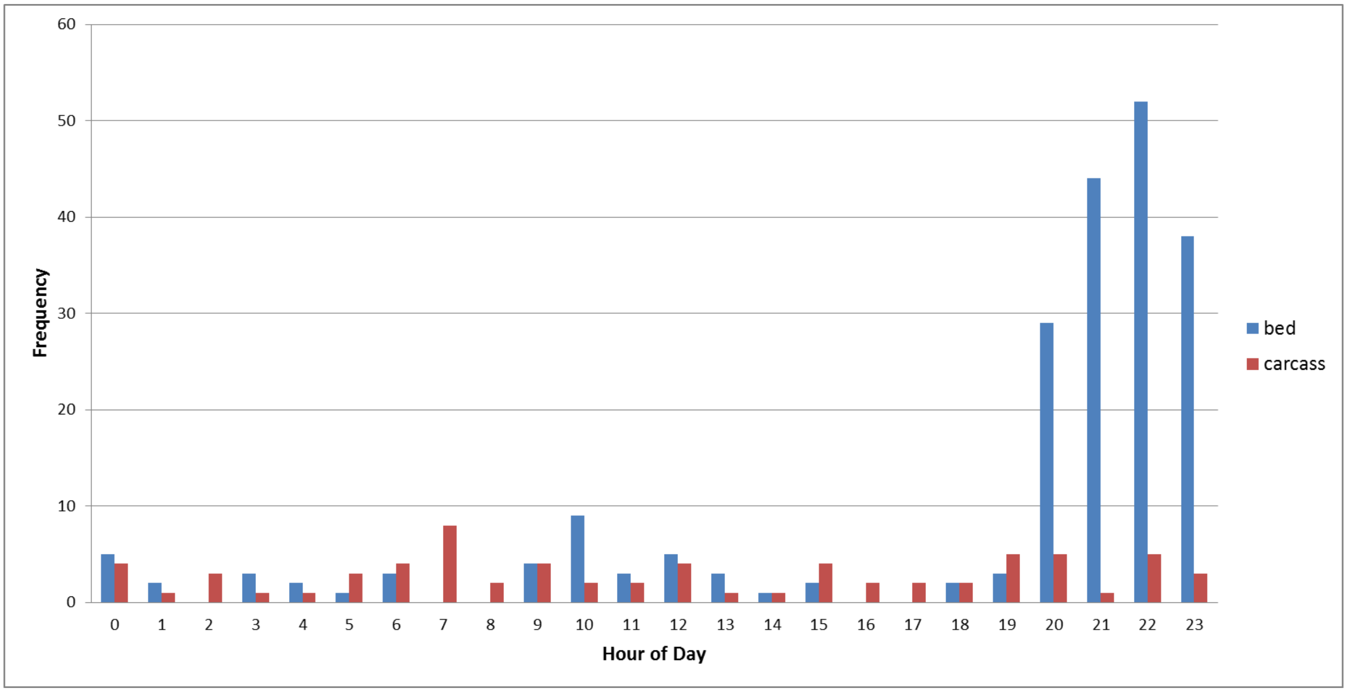


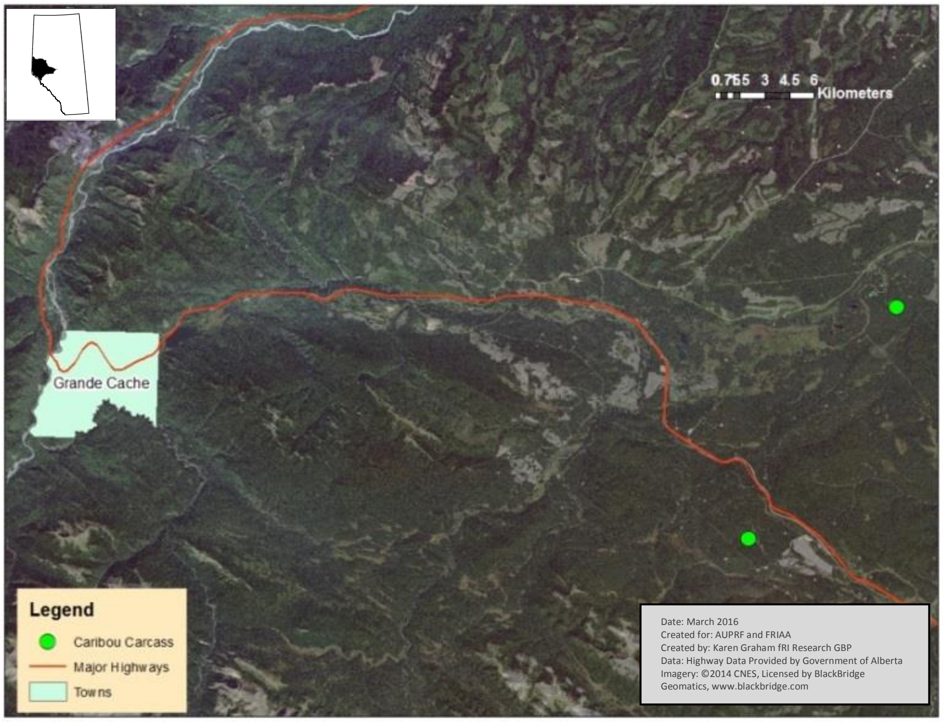
Figure 2.10. The frequency of cluster start times by hour of the day for bed and carcass clusters of 12 grizzly bears from 2014-2015.

We documented one carcass visited by two of our collared bears at different times. G303 visited an adult moose carcass for 12 hours, followed by G299 who visited the same carcass a day later for 18 hours. Two sites had remains from more than one animal. A moose calf and yearling were found at one site where the bear had spent 110 hours, and the second site had an adult moose tooth and spinal column, a section of hide from a non-ungulate, and a pelvis too small to belong to the adult moose. The bear spent 8 hours at this site.

Three carcasses had evidence of humans either injuring or killing the moose. Two of these occurred during the fall ungulate hunting season. An arrow shaft was found at one adult moose carcass that the bear had visited for 30 hours; no hide was found but a burial was evident as well as numerous bear scats and other carnivore scats. At a different adult moose carcass, we found a scalpel blade. There was no burial, other carnivore scat was present, and clean cut edges of the hide indicated the animal had been skinned by humans. The leg bones were missing (except for part of one lower leg) and this was the only adult moose carcass where we did not find the skull. The bear spent 50 hours at this site. The third site was found prior to the start of the ungulate hunting season and did not appear to be a recent kill site. There was an adult moose skull with antlers sawed off, along with a deer skull and leg bones. The bear was at this site for 4 hours. No bear scat or other carnivore sign was present.

Caribou Carcass Details

Of the 448 clusters we visited only two contained remains from caribou, both in the foothills of the study area, within the A La Peche caribou herd (Figure 2.11). Statistical analysis on caribou predation by grizzly bears was not possible due to the low sample size (n=2) in our dataset, so a descriptive summary follows.



Date: March 2016
Created for: AUPRF and FRIAA
Created by: Karen Graham fRI Research GBP
Data: Highway Data Provided by Government of Alberta
Imagery: ©2014 CNES, Licensed by BlackBridge Geomatics, www.blackbridge.com

Figure 2.11. Overview of the of the two caribou carcass locations visited by collared grizzly bears found within the A La Peche caribou range in 2014 with respect to Grande Cache and Hwy 40 (red line). No caribou carcasses were found in 2015.

The remains of an adult male caribou were found on 25 Sep 2014, which included most of its skeleton and a large mat of fur. The large mat of fur (Figure 2.12a and 2.12b) suggested that either a cougar killed the animal, as they tend to pluck or sheer the hair prior to feeding (Anderson and Lindzey 2003; Knopff et al. 2009b), or that the animal died and was scavenged. Hair will fall off a carcass hide within 3 days of death, depending on the weather (Gonder 2008). The mandibles showed the teeth were in poor condition (Figure 2.12c). The collared bear (G299) was at the carcass for 44 hrs; beginning 27 August 2015 at 20:00. We suspect that G299 likely scavenged this caribou. Adult barren ground caribou, which are smaller than woodland caribou (Gauthier and Farnell 1986), take 2-3 days for a grizzly bear to consume (Boertje et al. 1988; Young and Mccabe 1997) so 44 hours seems reasonable for a bear to have scavenged this adult male woodland caribou. There was no obvious burial site but a trampled area was observed (Figure 2.12d). Cougar and/or wolf scat was also observed at the scene (Figure 2.12e) along with bear scats. The carcass was located (Figure 2.13a) on the edge of a fen, surrounded by lodgepole pine. It was within 140m of a seismic line and 970m of a pipeline. It was within 2 km of the railroad, 2.2 km of Hwy 40 and 2.1 km of a cutblock (<20yrs old).

We found the second caribou on 13 August 2014. Based on remains it was classified as a subadult caribou (Dr. Helen Schwantje, Wildlife Veterinarian; personal communication), whose remains included one metatarsus bone and one tooth (Figure 2.12f) found at a bed site from G295, dug into a squirrel midden. Whether this caribou was a calf or yearling is unknown The bear was at this site for 6 hours beginning 23 July 2014 at 11:00.which is sufficient time for a bear to consume a caribou calf (Gunther and Roy 1990), but likely not long enough to consume a yearling (Boertje et al. 1988). Scat at this bed was full of vegetation. We also found a second bear bed within 20m of the first bed. Bear scat at this bed was full of ants. None of G295's locations occurred at this second bed so it is unlikely that the bed was made by G295. We can't be sure if G295 killed and consumed this animal but it is plausible, especially if it was a calf. The carcass was located in a mature lodgepole pine stand, 40m from a pipeline (or deactivated road) and within 1.5 km from a truck trail (Figure 2.13b). Motorized access onto the pipeline from the truck trail was not possible because the ground surface of the pipeline at the pipeline-road intersection had been mounded to effectively restrict motorized access. A major gravel road (Little Smoky haul road) was within 2.8 km of the carcass, with Joachim Lakes and Joachim creek meandering between this major road and carcass. A cutblock (< 20 yrs old) was within 1.7 km of the carcass. The carcass was within 750m of a small tributary of Joachim creek and within 400m of a fen.

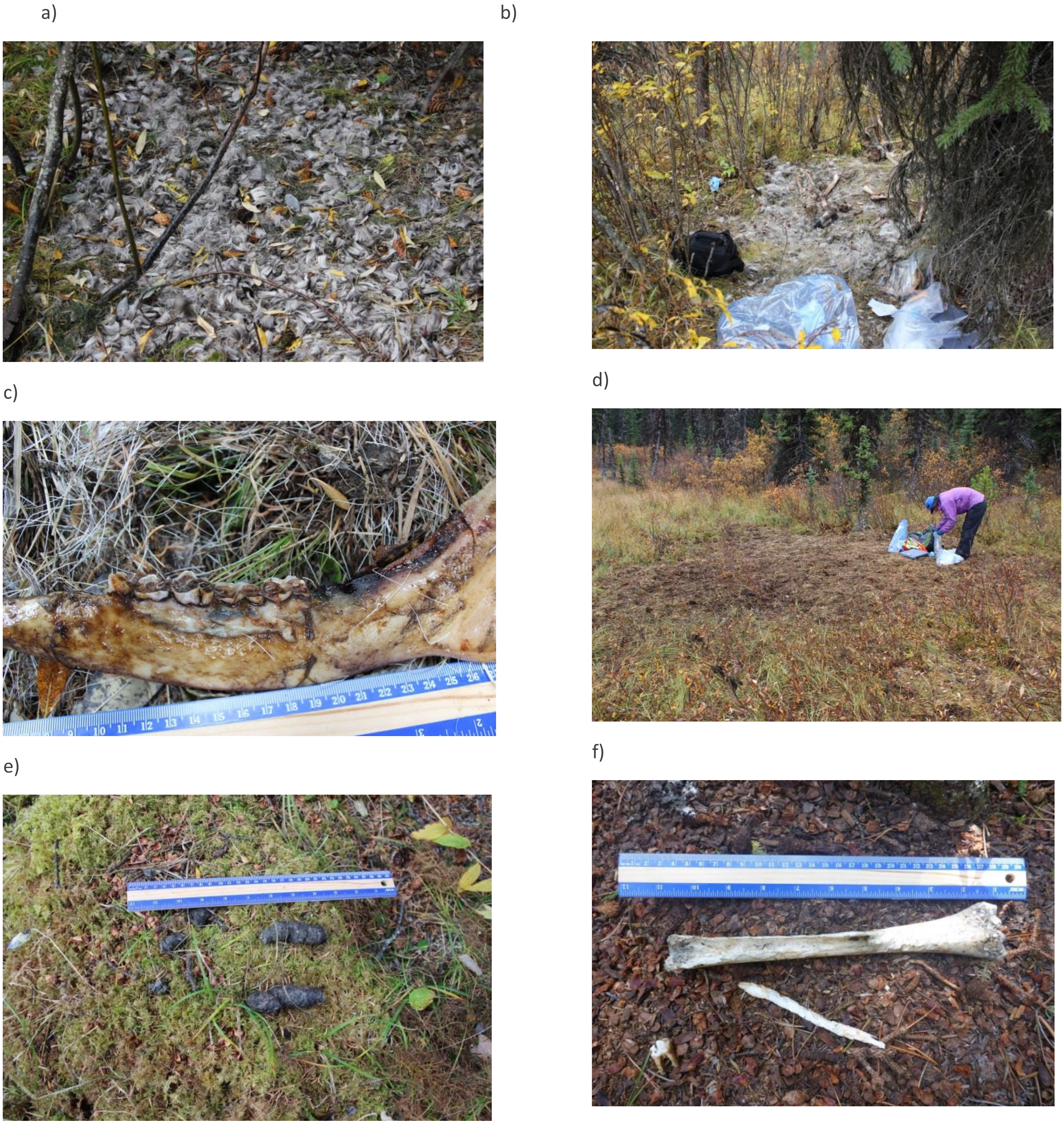


Figure 2.12. Photos of the adult (a-e) and subadult (f) caribou remains found at two grizzly bear clusters visited in 2014 (adult) and2015 (sub-adult). Shown are: the hair mat (a &b), mandible (c), trampled area (d) and cougar and/or wolf scat (e) found at the adult male caribou carcass, and (f) the metatarsus bone and tooth found at the subadult caribou remains.

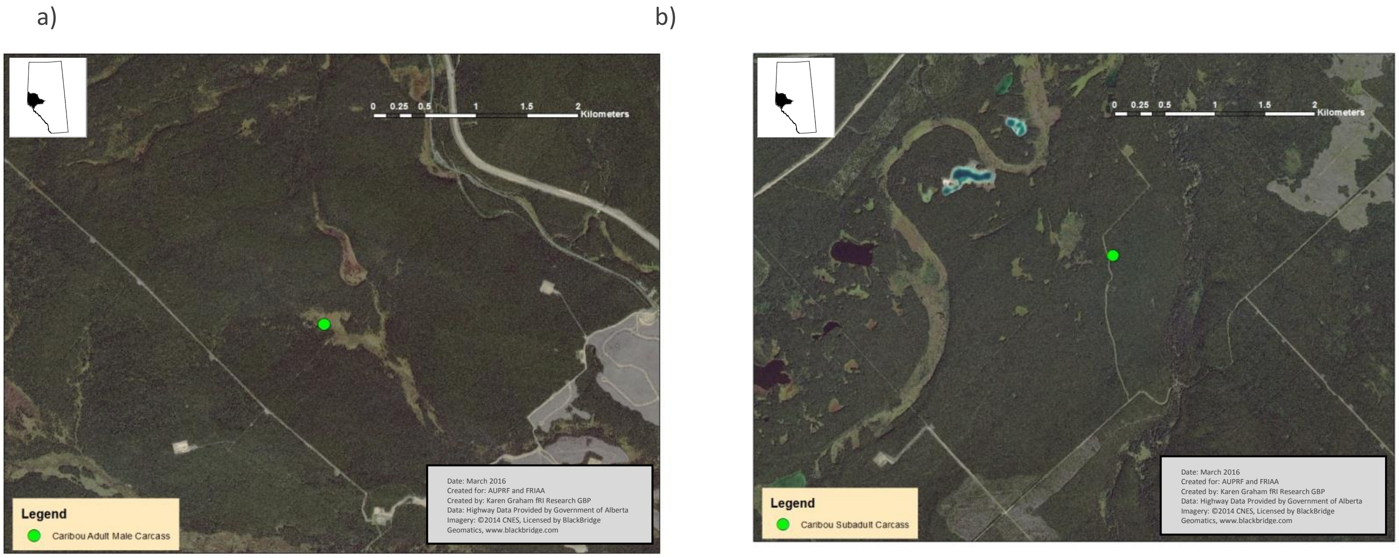


Figure 2.13. The location of an adult male caribou carcass (a) and a subadult caribou carcass (b) visited by collared grizzly bears in 2014 showing the landscape features and human footprint of the surrounding areas.

Scavenging

To distinguish scavenging events from kills we focused on adult and yearling moose carcasses because these were the largest prey (> 330 kg) available in our study, would take the longest time to consume and therefore had the greatest likelihood of being scavenged. Boertje et al. (1988) reported that it took 7-14 days (168-336 hours) for grizzly bears to consume an Alaskan moose ≥ 1 year old. In our study, only one bear spent >168 hours at a moose carcass. Because moose at more northern latitudes tend to be larger than those further south (Sand et al. 1995), we arbitrarily selected 100 hours as a conservative estimate of the minimum duration that an adult moose could be consumed by a grizzly bear. Out of 22 adult or yearling moose carcasses in our study (the adult moose visited by two collared bears was counted once), 73% (n = 16) had a duration < 100 hours (Figure 2.14). We cannot be sure if the collared bear killed the moose and was chased away by a more dominant animal or pack of animals. However, since all the collared bears involved were adult male grizzly bears, we feel this would be a rare event. Also, it is possible that a bear may kill a moose and not completely consume it before it departs. Boertje et al. (1988) reported that the bears always consumed a carcass before leaving the area. Therefore we suspect that at least 73% of the adult or yearling moose carcasses were scavenged by our collared bear. Included in this “scavenged’ category were 3 moose likely killed by hunters and the single moose carcass visited by two different collared bears. The remaining 27% (6 carcasses) adult or yearling moose carcasses may or may not have been scavenged since a bear could come across a fairly intact carcass and feed on that carcass for ≥ 100 hrs.

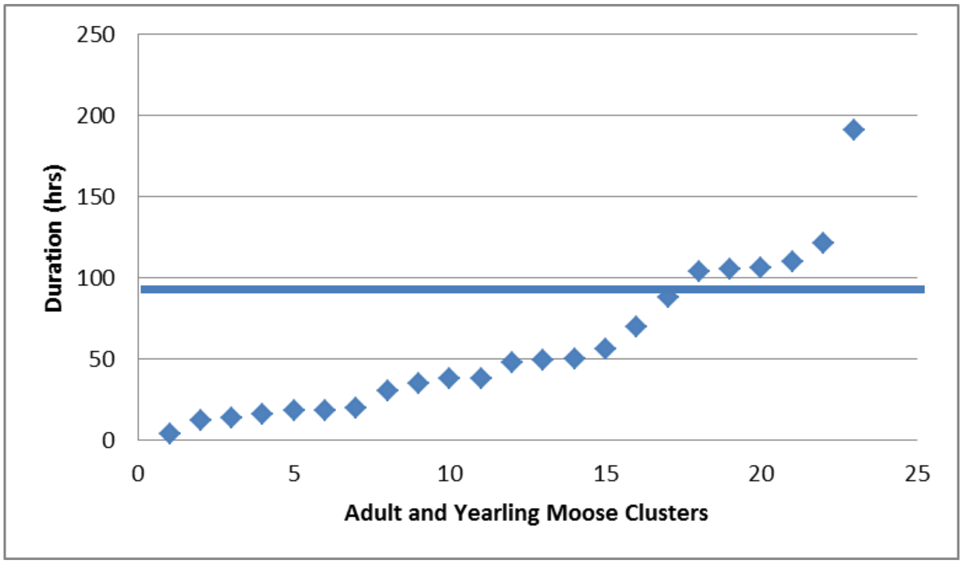


Figure 2.14. The duration in hours that collared male grizzly bears spent at an adult or yearling moose carcass. Those carcasses in which the grizzly bear spent < 100 hours (below the blue line) were considered probable scavenging events.

For those 6 carcasses ≥ 100 hours in duration, we used field data collection to confirm scavenging versus predation events. There were signs of a burial at 5 of the 6 carcasses. The single site with no burial signs was where both a yearling and calf moose carcass was found, and the bear had spent 110 hours there. The hide of the yearling was neatly piled against a tree and no leg bones were found. Although we found no evidence that humans were involved with the animal's death, it is possible that a hunter killed and skinned the yearling and taken its front and hind quarters. The location was 250m from the end of a seismic line that connected to a well used gravel road, and ended where the topography dropped down into the drainage. If we include this clusters in the "scavenged" category, then grizzly bears likely scavenged 17 of 22 (77%) adult or yearling moose carcasses.

2.4 Discussion

Our data suggests that grizzly bears were not common predators of caribou in our study. Out of 448 clusters visited, we identified caribou remains at only 2 (0.4%). One was an adult male caribou suspected of being scavenged by the collared bear, and the other was a subadult that may have been killed by the bear or scavenged. It must be noted that we collected data from only 12 bears from a population of approximately 388 estimated within our study area (Alberta Grizzly Bear Inventory Team, 2008). Previous studies have found that a few bears may "specialize" in killing certain animals such as ungulate calves (Boertje et al. 1988; Bastille-Rousseau et al. 2011; Rauset et al. 2012). In British Columbia where 12-13% of woodland caribou mortalities were attributed to grizzly bear predation (Kinley and Apps 2001; Gustine et al. 2006; Apps et al. 2013), and preliminary mortality site investigations within west-central Alberta had revealed similar predation rates by grizzly bears on caribou (Finnegan et al. 2016). Therefore, it is possible that some grizzly bears in the population may specialize in finding and killing caribou and caribou calves, and our collaring efforts failed to capture these specialist bears. We documented an additional 33 suspected animal feeding events by collared grizzly bears by collecting hair scats and identifying the species based on the physical characteristics of the hair. The predation or scavenging of animals as small as caribou calves (8-9 kg; Bergerud and Page 1987) may occur within minutes (Young and McCabe 1997) and therefore unlikely to form a cluster using a 30 minute collar location acquisition rate. In addition, there may not be any evidence at the feeding site because the entire animal may be consumed (Bergerud and Elliot

1986; Rauset et al. 2012). By visiting bed clusters and collecting hair scats we were able to detect feeding on small animals and scavenging events that may have otherwise been missed. However, it was not feasible to visit every bear bed made by the collared grizzly bears so some hair scats were likely missed and therefore it is possible that caribou hair scats were not recovered.

Moose calves were the most common prey item for grizzly bears in our study. Conservative estimates of moose calf feeding rates for 2 female bear were 0 and 5 moose calves/calving season; within the range of kill rates reported in Scandinavia for female grizzly bears (mean= 7.6 moose calves/season; range 2-15; Rauset et al. 2012). The average kill rate reported in Alaska was 5.4 moose calves (Boertje et al. 1988); very similar to our conservative estimate of 4.9 moose calves for both sexes combined. One male grizzly bear in our study (G295) may have specialized in killing moose calves, or it is also possible that the density of moose calves was highest within his home range, which increased his probability of encounter with moose. However, because the home ranges of three other collared male bears overlapped with parts of the range of G295 and did not have as many calf carcasses as G295 so we believe G295 may have specialized in killing moose calves.

Adult moose were eaten throughout the summer but 83% of moose calves were consumed in June, likely within their first 4-5 weeks of life with only 2 eaten in September. This is similar to Sweden where over 90% of moose calves that died, died within 4 weeks of life and none died after 13 weeks (Swenson et al. 2007). Caribou calves were also most likely to die within the first 8 weeks of life in Alaska (Reynolds et al. 1987).

Our mean duration time estimates at carcasses of 35 hours and 19 hours for males and females respectively were similar with those reported by Cristescu et al. (2014) of 40 hours for males and 24 hours for females. The longer duration of time spent by males at carcasses is likely because males killed larger prey. We did not find any female bears GPS clusters at adult moose carcasses. We do not know whether this is because males are larger and can kill larger prey, or can usurped carcasses from smaller animals.

If we are correct in our estimation that it takes ≥100 hours for a grizzly bear to consume a moose and that an adult male grizzly bear will not leave a carcass until it is finished (Boertje et al. 1988), then it is possible that up to 77% of adult and yearling moose carcasses were scavenged by grizzly bears in our study. Scavenging by grizzly bears is well documented (Boertje et al. 1988; Green et al. 1997) and can be attributed to their keen sense of smell that allows them to find a carcass within 2 days after its death (Green et al. 1997). Both wolves and cougars occurred within our study area at unknown densities. Cougars in Alberta will kill approximately 1 ungulate/week on average (Knopff et al. 2010) and take up to 3 days to consume it (Knopff et al. 2010). This long handling time provides the opportunity for a grizzly bear to find and displace the cougar from the carcass. In Yellowstone, 14-33% of cougars kills were scavenged by grizzly bears (Murphy et al. 1998). In our study, 11% of the carcasses had a hair mat present and hair mats can be a sign of a cougar kill (Knopff et al. 2009a). As well, wolves have been reported to kill almost 2 moose/week (Sand et al. 2005) and may leave their kill before it is entirely consumed (Sand et al. 2005). Both cougars and wolves could provide amply scavenging opportunities for grizzly bears.

We were able to show that grizzly bears were likely not important predators of caribou in our study area. In doing so, we were able to examine meat feeding events on other prey species and how these events varied by bear age and gender, time of year and time of day. We also attempted to discern predation from scavenging events using the time spent at adult and yearling moose carcasses. We believe this project provides the first detailed data on grizzly bear meat eating events in caribou range in Alberta. We are able to conclude that although grizzly bears do feed on caribou, it is a rare event and within this study we determined that moose are an important component within the diet of some grizzly bears within caribou range in west central Alberta.

Objective 3: Captive feeding trials to quantify and validate a stable isotope approach to measure caribou in the diet of grizzly bears

3.1 Introduction

To better understand and identify grizzly bear predation on woodland caribou, moose, and elk in Alberta, a feeding study utilizing stable isotope analysis was undertaken using captive grizzly bears at Washington State University (WSU).

Primary goals of the collaboration include: 1) documenting isotopic values of ungulates and grizzly bear blood and hair while on various ungulate diets, developing stable isotope discrimination values for grizzly bears feeding on ungulate diets, and determining which isotopes (carbon, nitrogen, or sulfur) could be used in mixing models to reconstruct assimilated diets of wild bears and 2) understanding how a pulse of meat consumption in the bear's diet is expressed in bear hair many months after consumption.

This work is essential for translating isotopic values of blood and hair samples collected from wild grizzly bears into meaningful information regarding bear feeding patterns. Bear tissue, including blood and hair, can be collected from wild bears and analyzed for carbon, nitrogen, and sulfur stable isotope composition. Because isotopic values of consumer tissues are similar to the values of items in their diet, isotopic values of bear tissue can be compared to isotopic values of potential diet items to determine the proportion of various foods that compose bear diets. However, metabolism by consumers slightly alters the isotopic composition of the food items, such that accurate diet estimation cannot be made without knowing the value of this alteration (isotopic discrimination). The discrimination value can only be elucidated through captive feeding trials using the species of interest on controlled diets.

SUMMARY OF WORK

Three ungulates—reindeer (*Rangifer tarandus)*, moose (*Alces alces*), and elk (*Cervus elaphaus*)—were fed to captive grizzly bears for approximately 28 days during May-July 2014 to determine stable isotope discrimination of bears on ungulate diets.

3.2 Methods

Ungulate Feeding

Free-range Alaskan reindeer meat + bone (adult animals) and road-killed moose and elk (all ages; meat + hide) from Alberta were fed to grizzly bears at Washington State University (WSU). Meat was stored frozen and fed twice daily for 28 days, or as long as the meat supply would allow.

Sample Collection and Processing

Small samples of reindeer, moose, and elk tissues were collected daily, frozen, freeze-dried for 72 hrs, ground using dry ice in a Wiley Mill (Thomas Scientific, Swedesboro, NJ), and re-dried prior to analysis. Daily diet samples of each ungulate were combined and homogenized to represent diet over the entire trial. Subsamples of each diet were analyzed for protein (crude protein; N x

6.25) and fat content (ether extract) at the WSU Wildlife Habitat and Nutrition Laboratory (Pullman, WA) and for stable isotopic content at the WSU Stable Isotope Core Laboratory (Pullman, WA).

Blood samples were collected weekly from two bears trained for voluntary blood draws without anesthetization (Luna fed reindeer and Peeka fed elk). These bears were used to evaluate how quickly serum or plasma isotope values equilibrated with the diet. Bears that are not trained for voluntary blood draws (Roan fed reindeer and Pacino fed moose) were anesthetized and blood-sampled at the beginning and end of each trial. Bears were anesthetized using dexmedetomidine-tiletimine-zolazepam (DexDomitor, Orion Corporation, Espoo, Finland; Telazol, Fort Dodge Animal Health, Fort Dodge, Iowa) and reversed using atipamezole.

Plasma was collected in 10 ml sodium-heparin vacutainer tubes and serum was collected in 10 ml no-additive vacutainer tubes (BD, Franklin Lakes, New Jersey). Blood was spun at 1750 RPM for 20 min at 4°C and the supernatant was pipetted into vials and frozen. Frozen samples were freeze-dried for 48 hrs and ground to fine powder.

Powdered meat and serum/plasma samples were weighed into tin cups for isotopic analysis (~ 0.7 mg carbon/nitrogen; 2.5-3 mg sulfur). All analyses were performed on non lipid-extracted tissues. Isotopic analyses were conducted using an ECS 4010 Elemental Analyzer (Costech Analytical, Valencia, CA) and Delta PlusXP GC mass spectrometer (Thermo-Finnigan, Bremen, Germany). Reported isotope values of δ^{13}C, δ^{15}N, and δ^{34}S are measured in parts per thousand (‰) relative to Vienna Peedee Belmnite (carbon-C), N^2 in air (nitrogen-N), and Vienna Cañon Diablo Troilite (sulfur-S). C and N samples were normalized using acetanilide and keratin internal running standards and S samples were normalized using BBOT, Ag2S, BaSO4, and elemental S internal running standards. Running standards were previously calibrated to NBS 19, RM 8542, and IAEA-CO-9 for carbon; USGS 32, USGS 25, and USGS 26 for nitrogen; and IAEA-S-1,2,3,4, IAEA-S05, 06, and NBS 127. Analytical error, estimated based on known standard samples, was ± 0.01 ‰ for C, ± 0.05 ‰ for N, and ± 0.39 ‰ for S.

Isotopic discrimination factors (Δ values) were calculated as the δ value of bear serum on the final day of the trial minus the average δ value of the diet.

3.3 Results

Nutrient Composition of Ungulates Fed to Grizzly Bears

All diets were quite lean and typical of wild ungulates in late winter. Protein and fat accounted for 75% of the dry matter in reindeer and 90 to 91% of the dry matter in moose and elk (Table 3.1). The difference is largely mineral matter created by the moose and elk being deboned whereas the reindeer was fed with the included bone.

Table 3.1. Nutrient content of diets

Diet Item	Dry Matter (%)	Protein (% DM)	Fat (% DM)
Reindeer	30	63	12
Moose	27	79	12
Elk	29	82	8

Isotopic Values of Ungulates Fed to Grizzly Bears

The carbon and nitrogen isotope signatures of the ungulates were typical of a herbivore consuming C_3 plants (Table 3.2, Figure 3.1). **While we recognize that the reindeer were not from Alberta, the differences in the isotope values of the three ungulates**

suggest that we may be able to distinguish between ungulate meat sources when using mixing models to estimate assimilated diets of grizzly bears (Milakovic and Parker 2011). However, further analyses of food items collected in the field, and examination of their associated variation in isotopic signatures are necessary for validation.

Table 3.2. Carbon, nitrogen, and sulfur isotope values of grizzly bear diets (± SD, n=3)

Ungulate	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$	C:N
Reindeer	-22.5 (0.1)	3.0 (0.1)	16.6 (0.3)	3.8 (0.2)
Moose	-26.5 (0.5)	2.1 (0.2)	2.0 (0.1)	3.7 (0.1)
Elk	-26.0 (0.1)	5.2 (0.2)	6.7 (0.1)	4.2 (0.2)

Figure 3.01 Captive feeding trials at Washington State Bear Centre

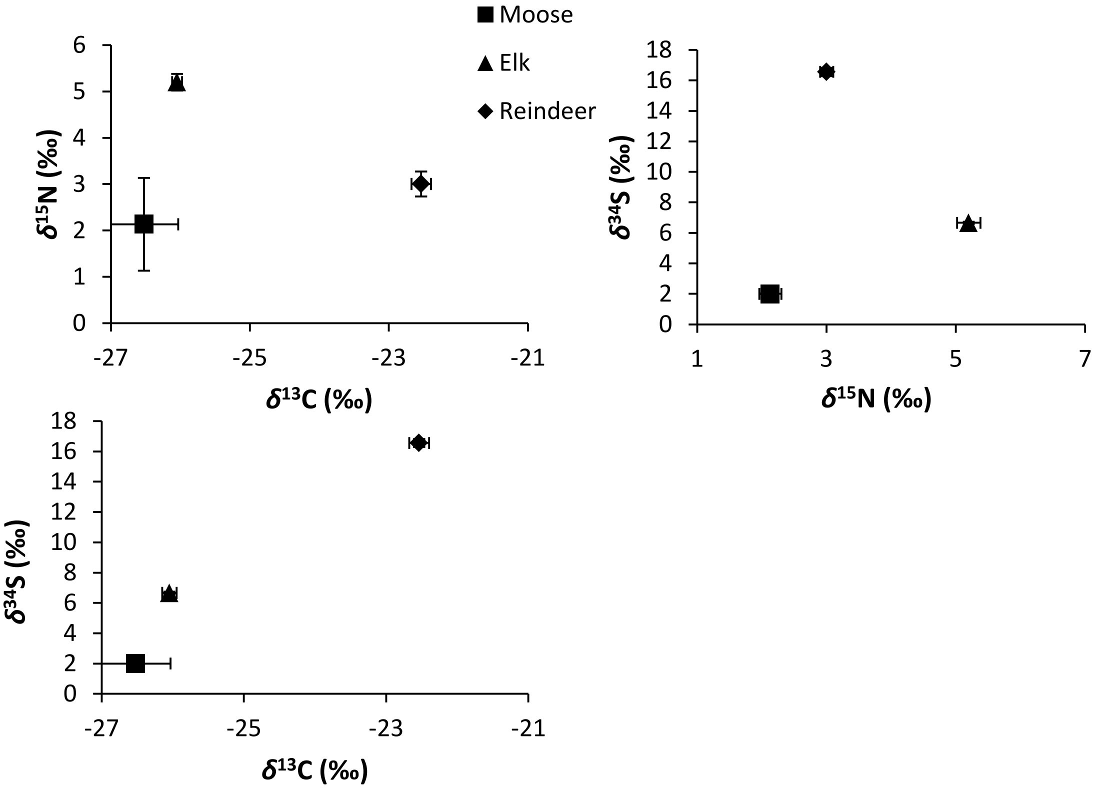


Figure 3.1. δ^{13}C, δ^{15}N, and δ^{34}S values of moose, elk, and reindeer fed to grizzly bears

Isotopic Equilibration of Grizzly Bear Tissue on Ungulate Diets

Grizzly bear plasma and serum carbon, nitrogen, and sulfur equilibrated with the diet by 28 days when bears either maintained or gained weight (Figure 3.2). Equilibration was less clear when bears lost weight or gained very little (Figure 3.3).

The serum half-life of carbon was 6.9 days, nitrogen was 5.3 days, and sulfur was 4.6 days for a bear gaining weight. Differences between serum and heparinized plasma isotope values were small when bears gained weight (carbon- 0.1 ± 0.1 ‰, nitrogen- 0.1 ± 0.1 ‰, and sulfur- 0.2 ± 0.3 ‰; Figure 3.2).

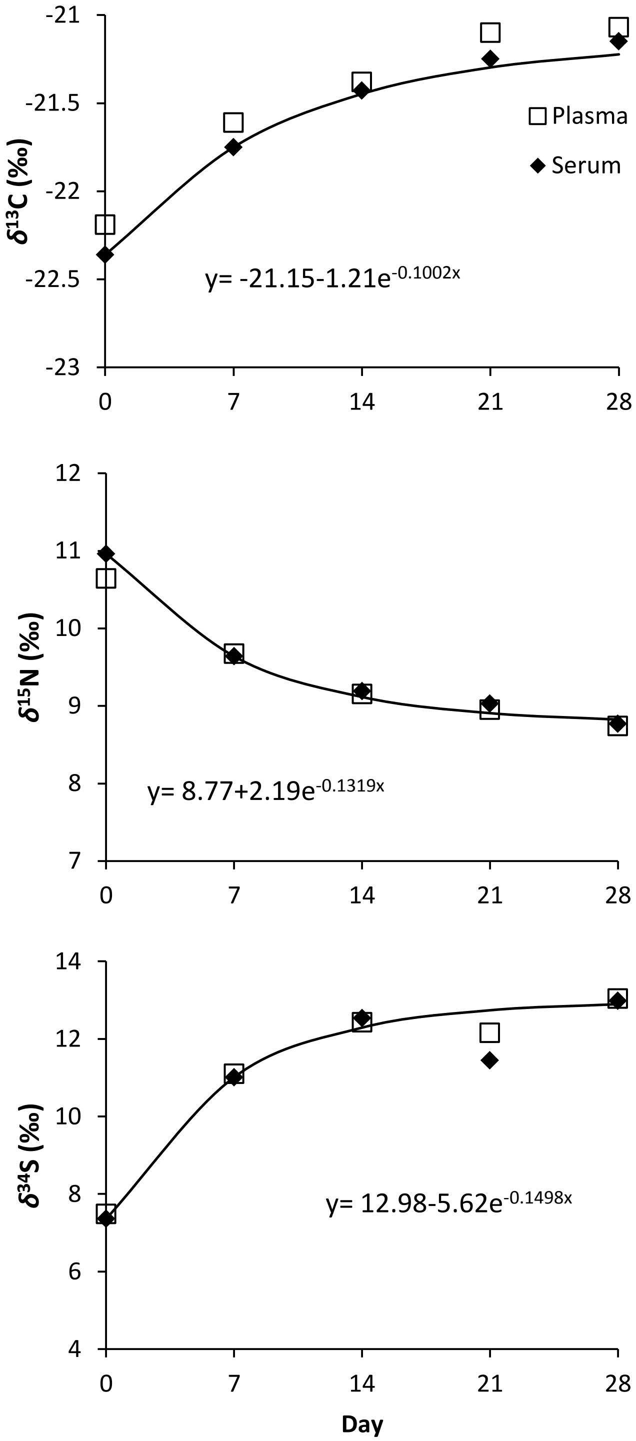


Figure 3.2. Equilibration of bear blood (Luna, Reindeer)

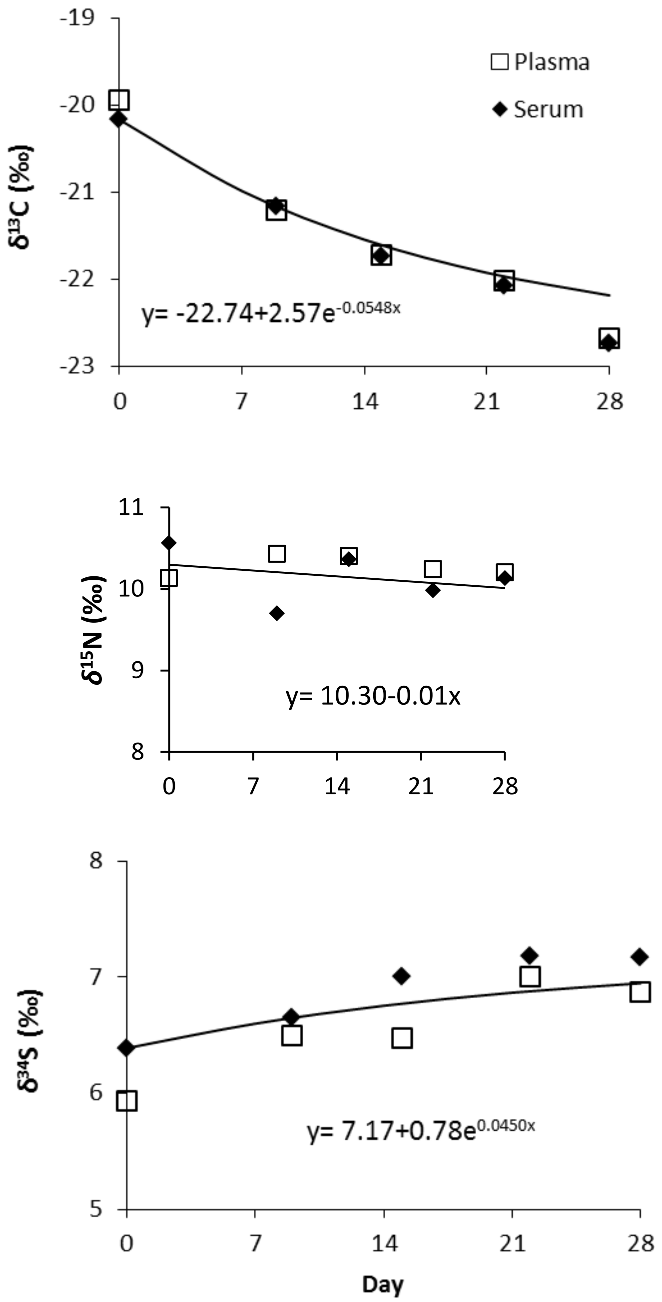


Figure 3.3. Equilibration of bear blood (Peeka, Elk)

Discrimination Values of Bear Blood (Serum)

Discrimination values of bear serum differed among bears for carbon and sulfur, but were generally similar for nitrogen (5.3 ± 0.3; Table 3.3). This value is higher than previously determined when black bears were fed mule deer (4.1; Hilderbrand et al. 1996). In grizzly bears, ^{15}N discrimination has been observed to vary widely—from as little as 0 ‰ on high-fat, low protein diets, to beyond 5 ‰ on high-protein, low fat diets (unpublished data and this study). One potential reason for the higher nitrogen discrimination in the current study is the very low fat content of the meat relative to previous studies (Robbins et al. 2005), which would lead to increased use of dietary protein to meet energy requirements. This would elevate nitrogen excretion and turnover, which should elevate the nitrogen discrimination as observed. Nitrogen discrimination in a mixed natural diet would likely be lower than what we observed in this study, and could also vary by season. For example, when bears feed on ungulates in good body condition discrimination might be lower than when ungulates are in poor body condition due to changes in the protein: fat ratio of the ungulate prey. Sulfur discriminations determined for a wide range of other animals have decreased from +3 when dietary sulfur values are more negative to -3 and the dietary values are more positive (Florin et al. 2011). That is the trend shown by the current values, which are within 1 unit of what would be predicted by previous predictive equations. Carbon has always been quite variable, and thus far no one has provided a comprehensive, biologically-based predictive equation to which the current values could be compared.

Table 3.3. Isotope discrimination of bears on ungulate diets

Diet	Δ^{13}C (‰)	Δ^{15}N (‰)	Δ^{34}S (‰)	Bear	Age	Sex	Days	Mass change (kg)
Reindeer	1.4	5.8	-3.6	Luna	11	F	28	11.3
Reindeer	3.1	5.2	-6.2	Roan	3	M	28	-13.2
Elk	3.3	4.9	0.5	Peeka	9	F	28	-0.5
Moose	4.9	5.2	0.8	Pacino	3	M	23	1.4

Isotopic Values in Hair

It has typically been assumed that because hair is a biologically inert tissue that stable isotopes in hair are reflective of diet during growth (Hobson 1999). During the course of this research project our team was able to collaborate with USGS polar bear researchers who were investigating stable isotope signatures in polar bear diets. A combined analysis of both grizzly bear and polar bear hair samples found that carbon and nitrogen isotopes in hair did not immediately reflect diet during growth but rather may take 50 days or more to represent current diet. (Rhodes et al. 2016 in press). These results are very important for our work as it suggests that even with major and complete diet shifts (e.g. full caribou diet) it would not be able to be measured for at least 50 days after the diet altered.

3.4 Conclusion

This work has shown that the blood serum isotope analysis is able to differentiate various ungulate species within the diet of a grizzly bear following a month of feeding on meat from reindeer, elk and moose. This result was from trials where the entire diet for the feeding trial was the specified meat only which would not be the case with the diet of a wild bear even during the peak ungulate calving period. Using blood serum would require the capture and handling of many bears on a regular basis and our research team would prefer to employ methods that are more non-invasive.

Our goal was also to then determine if stable isotope value discrimination would be possible from grizzly bear hair analysis and the finding of the time lag for detection leads us to believe that this technique is currently unable to identify different ungulate meats in hair samples. Further with the small number of caribou carcasses found from our GPS cluster investigations (section 2) the identification of a very small amount of caribou meat within the annual feeding period of a grizzly bear would further hamper the utility of this approach.

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