

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

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Table of Contents

Project Background and Objectives	4
Objective 1: Habitat use of caribou and grizzly bear in relation to anthropogenic features and other habitat characteristics.....	6
Introduction	6
Study Area.....	6
Methods.....	11
Results.....	12
Discussion.....	15
Objective 2: Determine the probability of caribou mortality by grizzly bears and assess variation in gender, age class, and the reproductive status of bears, seasonality, and landscape characteristics associated with anthropogenic features and habitat type.....	17
Introduction	17
Methods.....	18
Results.....	20
Discussion.....	23
Year 2 Research Initiatives	24
Objective 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.	26
Introduction	26
Summary of Work	26
Methods.....	27
Results.....	28
Year 2 Initiatives.....	33

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 the wildlife is considered rare and/or sensitive to human activities. Both 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 help support recovery and conservation efforts. Risks of further population declines for both species are believed to be associated with human activities. For this reason, much 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). Little work has examined possible impacts and interactions grizzly bears and woodland caribou may have in Alberta and whether human activities affect these interactions.

Currently, recovery efforts for caribou in Alberta have focused on reducing wolf populations, as wolves are viewed as the leading cause of caribou mortality (James and Stuart-Smith 2000; Latham et al. 2011a). Unsustainable wolf predation on caribou populations is thought to be a result of resource extraction activities (DeCesare et al. 2012b; Peters et al. 2013). These activities create open habitats, young forests and linear features which increases 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 wolf populations. 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 increases the mortality risk to caribou (Latham et al. 2011b; Whittington et al.

2011; DeCesare et al. 2012b). Although poorly understood to date these negative interactions could also be occurring between caribou and other predators; augmented by human caused disturbance. Both 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 potentially as movement corridors (McKay et al. 2013). Although predation rates of grizzly bears on caribou are likely to be low, given the precipitous declines in caribou populations in recent years (Hervieux et al. 2014) even small levels of predations 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 related to resource extraction within caribou and grizzly bear range.

The goal of this project is to determine to what extent grizzly bear predation might be influencing caribou populations in west-central Alberta. We use existing datasets supplemented with additional data gathered to address this topic, and also investigate new techniques to measure and monitor grizzly bear predation levels on caribou populations.

We use 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 currently available GPS locations of collared caribou and grizzly bears to quantify the spatio-temporal overlap in habitat use and movements of these species in relation to anthropogenic features and other habitat characteristics.
2. Determine the probability of caribou mortality by grizzly bears and assess variation with respect to gender, age class, and the reproductive status of bears, as well as in relation to seasonality, and landscape characteristics associated with anthropogenic disturbance and habitat type.
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.

Objective 1: Habitat use of caribou and grizzly bear in relation to anthropogenic features and other habitat characteristics.

by: Karen Graham, fRI Grizzly Bear Program

Introduction

Understanding the spatio-temporal factors influencing the distribution of caribou and grizzly bear on the landscape is necessary if interactions between these two species are to be better understood. Resource selection function (RSF) models are routinely developed and used by biologists to understand factors influencing animal distribution (Manly et al. 2002), and are a useful tool for land and wildlife managers allowing high value habitats to be mapped and recognized within land use planning activities. In addition, RSFs for different species can be combined to determine their spatial and temporal overlap (Hebblewhite et al. 2005). In the case of a predator and prey, these areas of overlap could be where the prey species is at most risk of being encountered by the predator (Hebblewhite et al. 2010; DeCesare 2012).

In this chapter, we conduct a preliminary analysis with current data sets to identify areas where caribou and grizzly bears are likely to co-occur in space and time. We consider this to be a first step in examining predator-prey interactions. For this analysis, we used RSF models and a Geographic Information System (GIS) tool previously developed (Cranston 2013) to generate and combine RSFs for caribou and grizzly bears and evaluate where these species are most likely to co-occur. We focused this work on the Redrock-Prairie Creek and A La Peche caribou herds in west-central Alberta which is within the Grande Cache grizzly bear population unit (Figure 1.1).

Study Area

The study area for this analysis was in west-central Alberta where previously developed RSF models for the Redrock-Prairie Creek and A La Peche caribou herds (DeCesare et al. 2012b) overlapped with previously developed grizzly bear RSF models (Nielsen 2006, 2007) (Figure 1.1). For this analysis, we focused on areas open to resource extraction activities such as forestry and oil and gas, since it is these areas where human impacts combined with grizzly bear predation is of interest for this research project (Figure 1.1). The areas of RSF model overlap between caribou and grizzly bear encompassed approximately 3,500 km² (Redrock-Prairie Creek caribou and grizzly bear) and 5,400 km² (A La Peche caribou and grizzly bear), respectively.

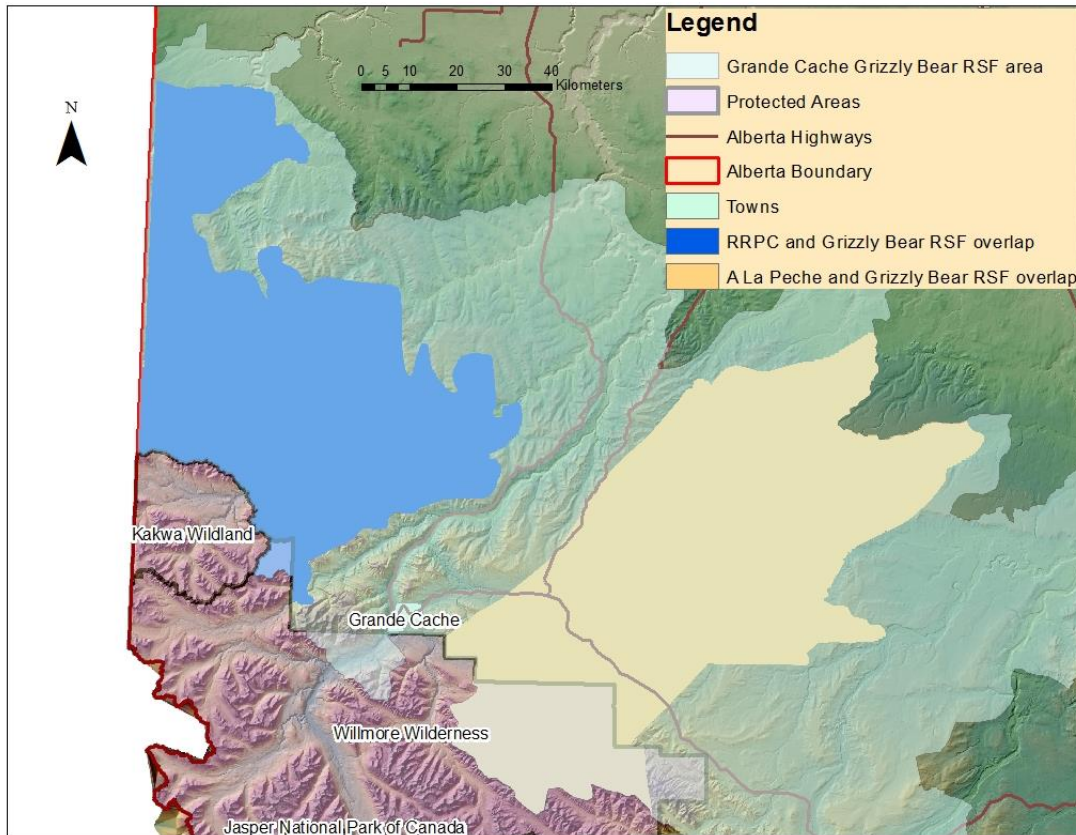


Figure 1.1. Study area for Objective 1 where the Redrock-Prairie Creek (RRPC) and A La Peche caribou RSFs overlapped with the grizzly bear RSF, within the Grande Cache grizzly bear population unit.

Grizzly bear RSF

Nielsen et al. (2002) created the first RSF model for grizzly bears within the Yellowhead grizzly bear population unit in west-central Alberta, approximately 150 km south of our study areas. This model was later refined with grizzly bear location data specific to the Grande Cache Population unit, to create the RSF model used for this analysis (Nielsen 2006, 2007). RSF model development involved creating models for each individual bear-season combination and averaging individual responses to create a population-level model (Nielsen et al. 2002). In this case, all sex, age, and reproductive classes were pooled. Although three seasonal RSFs (spring: 1 May-15 June; summer: 16 June-15 Aug; Fall 16 Aug-31 Oct) were available, these were combined into a RSF max that spanned all seasons to temporally match with the caribou RSF model described below.

The RSF models (Table 1.1) showed that although there was great variation among individuals and seasons (Nielsen 2007), grizzly bears generally selected habitats such as forest edges, riparian areas, forests with open tree canopies and upland herbaceous areas.

Caribou RSF

We used the female summer (16 May – 16 October) caribou RSFs developed by DeCesare et al. (2012b), specific to the Redrock-Prairie Creek and the A La Peche herds (Figure 1.1). We used the summer RSF because both calf and adult female caribou loss in the A La Peche herd is attributed to population decline (DeCesare et al. 2012a), so we did not restrict our analysis to just the calving season. DeCesare et al. (2012b)'s RSF models were created at three scales (herd range – 1st order, caribou home range- 2nd order and at individual collar locations – 3rd order) and then combined into a single scale-integrated resource selection function (SRSF) that was used in this analysis.

The results from the caribou RSF models (Table 1.2) indicated that caribou avoided areas with high cut-block density at the herd and home range scales and linear features at the individual location scale.

Table 1.1. Variable coefficients (β) and standard errors (SE) used to create the seasonal grizzly bear resource selection function (RSF) model for the Grande Cache population unit (Nielsen 2007).

<i>Variable</i>	<i>Season 1</i>		<i>Season 2</i>		<i>Season 3</i>	
	β	SE	β	SE	β	SE
wet-tree (landcover)	-1.468	0.151	-1.135	0.125	-0.148	0.113
regenerating forest (landcover)	-1.528	0.230	-2.188	0.197	-2.374	0.201
shrub (landcover)	-1.622	0.175	-2.745	0.142	-3.342	0.151
wet-herb (landcover)	-5.159	0.203	-5.762	0.193	-4.305	0.184
upland-herb (landcover)	1.224	0.225	0.713	0.191	-1.864	0.207
non-vegetated (landcover)	-3.955	0.197	0.823	0.213	-3.468	0.220
crown closure-treed sites	-0.015	0.002	-0.020	0.002	-0.029	0.002
crown closure-regenerating forest sites	-0.002	0.002	-0.003	0.002	-0.018	0.002
species composition in upland treed sites	-0.005	0.001	-0.014	0.0019	-0.010	0.0019
compound topographic index (150m average)	0.005	0.011	0.088	0.009	0.208	0.009
distance (scaled) to opening in upland-treed sites	-0.772	0.091	-1.629	0.077	-1.500	0.079
distance (scaled) to opening in wet-treed sites	-0.619	0.270	-1.687	0.262	-1.473	0.226
distance (scaled) to forest edge in upland-herb	-0.973	0.435	-0.286	0.620	-0.957	0.569
distance (scaled) to forest edge in regen. forests	0.083	0.386	1.035	0.277	-1.439	0.351
distance (scaled) to forest edge in non-vegetated	-0.746	0.263	-2.809	0.429	-1.690	0.419
distance (scaled) to stream	-0.445	0.071	-1.261	0.063	-0.997	0.060

Table 1.2. Variable coefficients (β) and standard errors (SE) used in the 3-scaled resource selection function (SRSF) model for the (A) A La Peche and (B) Redrock-Prairie Creek caribou herds (DeCesare et al. 2012b).

A) A La Peche Caribou Herd

Variable	Herd Scale (1 st order)		Home Range Scale (2 nd order)		GPS location scale (3 rd order)	
	β	SE	β	SE	β	SE
Elevation	22.09	0.739	1.03	1.73	0.748	0.573
Elevation ²	-5.33	0.181				
Slope	-0.0596	0.004	-0.020	0.007	-0.034	0.006
Slope ²	0.001	0.0001				
Aspect (S-N)			0.147	0.084	0.193	0.059
Aspect (E-W)			0.031	0.085	-0.176	0.040
Snow	1.08	0.499	-2.04	2.01		
Snow ²	-2.25	0.621				
Ndvi	0.168	0.412	0.642	0.804	0.078	0.658
Ndvi ²	-1.47	0.446				
TPI			-0.001	0.001	0.008	0.002
Distance to treeline	-0.3876	0.236	-0.737	4.35	-0.750	0.305
Distance to treeline ²	-2.872	0.237				
Distance to water			0.790	0.406	-0.177	0.118
Cutblock density	122.14	8.38	-21.74	10.55	0.666	0.256
Cutblock density ²	-240.21	24.32				
Linear feature density	5.14	0.344	-0.300	0.482	-0.033	0.007
Linear feature density ²	-0.5715	0.031				
Cutblock x elevation	-90.04	4.75				
Linear feature x elevation	-1.54	0.172				
Closed conifer (reference)						
Open conifer			0.288	0.100	0.725	0.048
Mixed/Decid			-0.214	0.131	0.071	0.125
Muskeg			0.090	0.215	0.283	0.081
Shrub			0.434	0.158	0.003	0.142
Alpine vegetated			-0.011	0.094	0.160	0.140
Rock/ice			-0.205	0.117	-1.42	0.221
Intercept	-24.79	0.761	-1.39	2.98	-1.54	0.821

Table 2 continued

B) Redrock-Prairie Creek Caribou Herd

Variable	Herd Scale (1 st order)		Home Range Scale (2 nd order)		GPS location scale (3 rd order)	
	β	SE	β	SE	β	SE
Elevation	22.09	0.709	0.252	0.869	0.416	0.257
Elevation ²	-7.03	0.199				
Slope	-0.0334	0.004	-0.007	0.005	-0.078	0.005
Slope ²	0.0003	0.0001				
Aspect (S-N)			0.037	0.034	-0.017	0.034
Aspect (E-W)			-0.011	0.037	-0.282	0.034
Snow	20.90	0.828	1.62	0.976		
Snow ²	-19.98	1.26				
Ndvi	5.06	0.439	1.40	0.333	-1.42	0.358
Ndvi ²	-6.72	0.439				
TPI			0.001	0.001	0.011	0.001
Distance to treeline	0.722	0.263	0.083	0.241	-0.372	0.136
Distance to treeline ²	-0.5703	0.299				
Distance to water			-0.155	0.189	-0.306	0.083
Cutblock density	64.18	5.79	-1.66	4.22	-0.330	0.196
Cutblock density ²	-161.48	18.71				
Linear feature density	6.41	0.585	-0.777	0.406	-0.018	0.006
Linear feature density ²	-5.19	0.277				
Cutblock x elevation	-35.65	3.18				
Linear feature x elevation	-2.56	0.311				
Closed conifer (reference)						
Open conifer			-0.173	0.099	0.302	0.074
Mixed/Decid			-0.329	0.152	0.139	0.068
Shrub			0.128	0.091	0.553	0.056
Alpine vegetated			0.042	0.124	0.897	0.070
Rock/ice			0.028	0.171	-0.106	0.1000
Cutblock			-0.359	0.183		
Burn			0.030	0.212		
Intercept	-24.16	0.640	-1.79	1.34	0.427	0.585

Methods

Habitat Maps

To run the grizzly bear and caribou RSF models on the current landscape, it was necessary to obtain all the required spatial layers such as land cover, terrain, and anthropogenic features. Forest and vegetation variables were derived using remotely-sensed imagery from the Landsat 5 and Landsat 7 ETM+ satellites in 2006 (Franklin et al. 2001, 2002). Terrain surfaces were created from a Digital Elevation Model (DEMs). Landscape conditions after 2006 were updated annually by hand-digitizing using 2012 SPOT imagery or 2013 Landsat 8 imagery, or were provided by forest companies and included features such as roads; pipelines, well sites, mines and cutblocks.

Caribou: Grizzly Bear Interactions

We used the Caribou Grizzly Bear RSF tool developed by fRI (Cranston 2013) to apply the coefficients from the caribou and grizzly bear RSF models to the updated landscape. This process created separate RSF surfaces for both caribou and grizzly bear on the 2013 landscape. The tool then reclassified the caribou and grizzly bear RSF values into low, medium, and high classes. RSF values from the caribou model between 0-0.055 were reclassified into class 1, representing Low caribou RSF, 0.0551-0.263 were reclassified into class 2, representing Medium caribou RSF and 0.2631-1 were reclassified into class 3, representing High caribou RSF. Similarly, grizzly bear RSF values between 1-4 were reclassified into class 5, RSF values between 5-7 were reclassified into class 6 and RSF values between 8-10 were reclassified into class 7 to represent low, medium and high grizzly bear RSF respectively. . These new RSF classes for caribou and grizzly bear were multiplied together to form unique combinations of low, medium and high RSF values for caribou and grizzly bear combined and displayed in a GIS. For example, when an area of caribou class 3 representing high caribou RSF overlapped with grizzly bear class 6, represented medium grizzly bear RSF, the result for that area became an 18 representing high caribou and medium grizzly bear RSF combined.

Affiliation with known caribou mortalities

As part of our field component for Objective 2, grizzly bear were collared in order to locate grizzly bear carcass feeding sites (See Objective 2 for further information on capture, collaring and locating carcasses). We mapped the caribou carcasses visited by collared grizzly bears during our 2014 field season to determine where they occurred with respect to the caribou-grizzly interaction matrix results.

Results

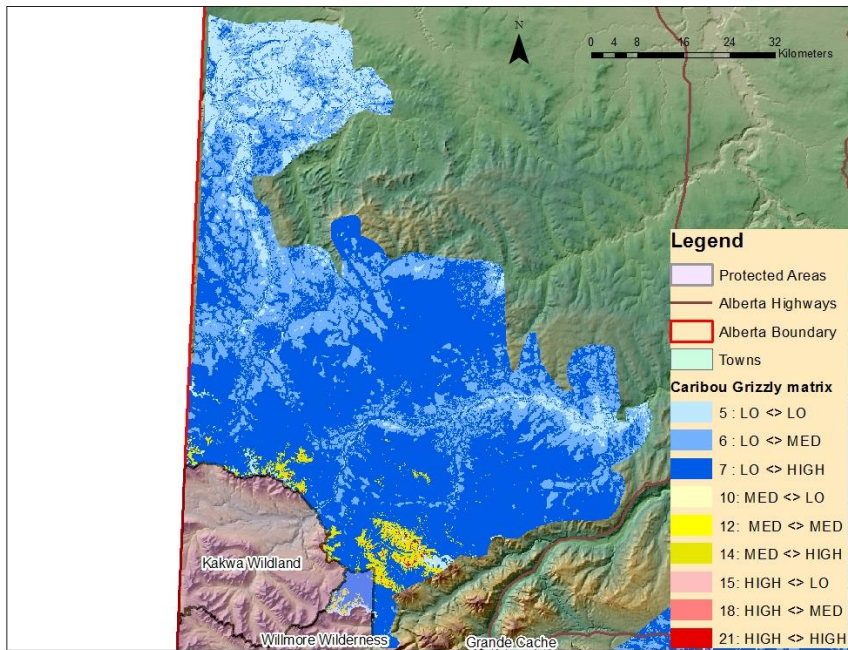
The results of combining caribou and grizzly bear RSF values (Table 1.4, Figure 1.2) indicated that the Low: High category (low RSF for caribou and high RSF for grizzly bear) made up the largest percentage of the area for the two herds, followed by Low: Med, Low: Low, Med: High and the remaining categories were < 1% of the study area. Areas with a caribou: grizzly result of medium or high RSF for both species concurrently were either in alpine meadows that occurred mainly within protected lands or in wetlands on provincial lands (Figure 1.3).

We found 3 caribou carcasses visited by collared grizzly bears in 2014. All three were in areas considered low RSF for caribou and either Medium or High RSF for grizzly bears (Figure 1.2).

Table 1.4. Results from combining the caribou and grizzly bear RSFs showing the percentage of area in each caribou herd study area for each unique RSF combination.

Caribou:Grizzly RSF values	Percent of Study Area	
	Redrock-Prairie Creek	A La Peche
Low:Low	11.21	7.26
Low: Med	27.14	29.85
Low: High	58.92	59.71
Med: Low	0.04	0.06
Med: Med	0	0.01
Med: High	2.57	2.99
High: Low	0	0
High: Med	0	0
High: High	0.12	0.11
Total	100	100

a)



b)

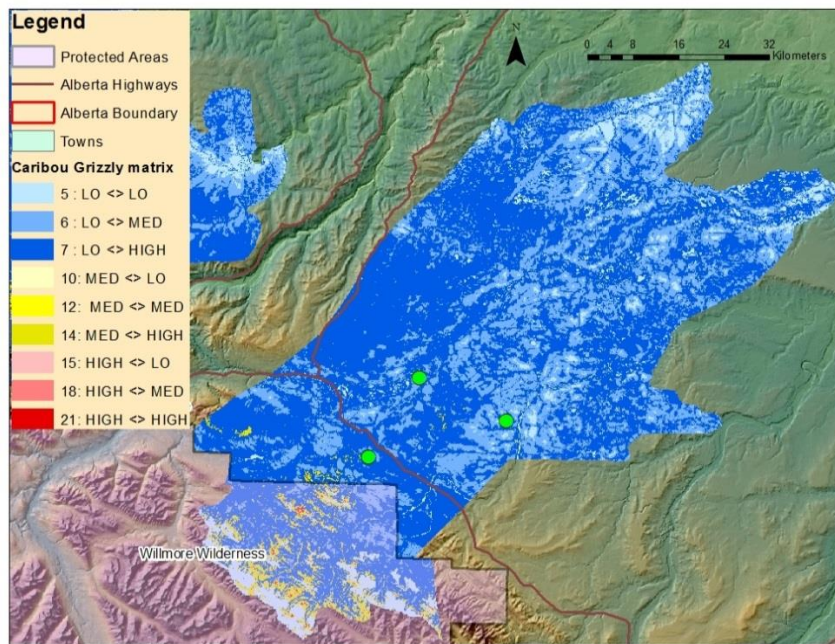
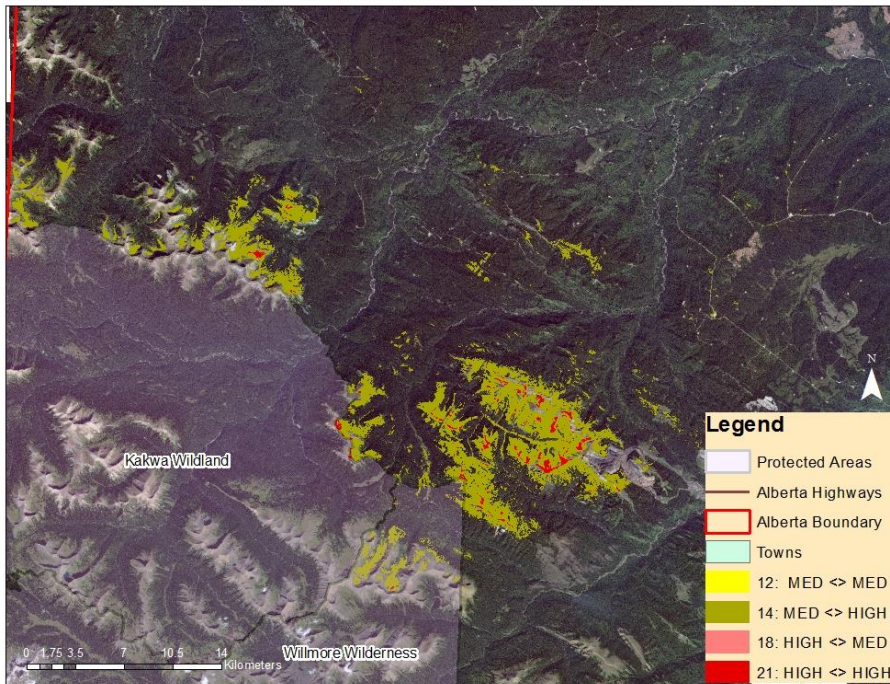


Figure 1.2. Results of combining the caribou and grizzly bear RSFs for a) Redrock-Prairie Creek study area and b) A La Pêche study area, showing the percentage of area for each unique RSF combination. For example, dark red shows areas where high RSF for caribou and grizzly bear overlap. The green circles represent locations of dead caribou visited by collared grizzly bear in 2014 (see Objective 2 for details).

a)



b)

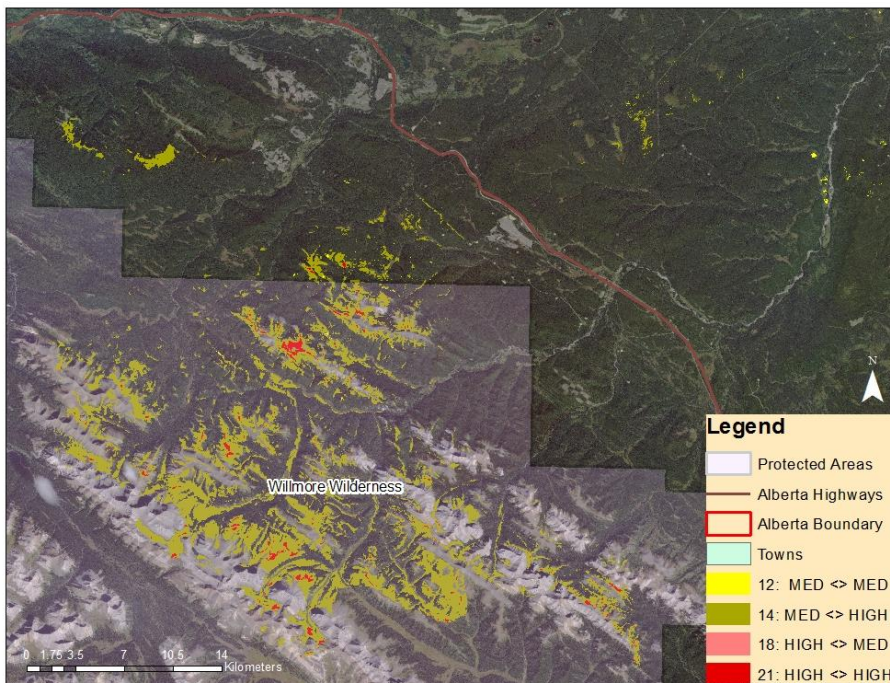


Figure 1.3. Results of combining the caribou and grizzly bear RSF values showing only the medium and high values with the SPOT 2013 image beneath for a) Redrock-Prairie Creek study area and b) A La Peche study area. For example, dark red shows areas where high RSF for caribou and grizzly bear overlap.

Discussion

Our results revealed little overlap between areas of high RSF values for caribou and grizzly bear in our study area. Hebblewhite et al. (2010) and Neufeld (2006) also found that high caribou RSF areas often did not overlap with areas of high wolf RSF. This may be expected since caribou have evolved to spatially separate themselves on the landscape from predators (Bergerud and Elliot 1986; Seip 1992; Smith et al. 2000). Risk of caribou predation may in fact be higher in areas of low caribou RSF with high predator RSF because, although the encounter probability may be low in those areas, if an encounter does occur, the probability of a kill could be high (DeCesare 2012). For example, terrain or vegetation characteristics could make the caribou more vulnerable to a successful attack by a grizzly bear. The three caribou mortalities visited by collared grizzly bears in 2014 did occur in low caribou RSF areas. In collaboration with the fRI Caribou Program during the second year of this project, we plan to examine more caribou mortalities to determine spatial attributes associated with grizzly bear predation sites (See Objective 2).

It should be noted that the caribou RSFs used in our analysis were developed using data from adult females (DeCesare et al. 2012b), since it is the survival and reproductive success of females that is most important for population growth (DeCesare et al. 2012a). It is possible that male caribou could be using the landscape differently from females. We know one of the three caribou mortalities visited in 2014 was an adult male. We do not know where spatial overlap between grizzly bears and adult male woodland caribou may occur because female caribou are collared and tracked, whereas males generally are not.

The reclassification of the RSF values into low, medium and high classes were arbitrarily assigned. Therefore the percentages by RSF value presented in Table 1.4 would change if different cutoffs were used. However, regardless of the cutoffs, the overall conclusions would be similar showing little overlap between high caribou RSF and grizzly bear. This is because areas of high caribou RSF was small despite including a wide range of RSF values from the original model (RSF values 0.2631-1 were classified as high RSF). High caribou RSF values were associated with areas away from resource extraction activities and linear features (Decesare et al. 2012b), features common within our study area and likely why high caribou RSF areas were rare in our analysis.

Although examining the spatial/temporal overlap of a predator and prey is an obvious first step to better understand interactions, there are many other factors to consider, especially in a multi-predator

and multi-prey system such as ours (Sih et al. 1998). Extrinsic factors such as predator and prey densities (Solomon 1949; Messier 1994), climate (Griffin et al. 2011) and habitat (Gorini et al. 2012) as well as intrinsic factors such as predator and prey age, sex, reproductive status and individual behaviour (Creel 2011) contribute to a complicated and poorly understood community ecology.

This analysis was our first step in examining grizzly bear predation on caribou. The RSF models factored in caribou and grizzly bear habitat use associated with anthropogenic features and by combining the two models we could simultaneously assess the probability of overlap of caribou and grizzly bears in space and time. The next step is to examine caribou carcasses visited by grizzly bears to determine if any relationship exists between where caribou are dying as a result of grizzly bear predation and environmental and anthropogenic attributes. This work is presented in Objective 2.

Objective 2: Determine the probability of caribou mortality by grizzly bears and assess variation in gender, age class, and the reproductive status of bears, seasonality, and landscape characteristics associated with anthropogenic features and habitat type.

By: Karen Graham, FRI Grizzly Bear Program

Introduction

Predation is believed to be the proximate cause of declining caribou populations throughout their range (ASRD and ACA 2010, Hervieux et al. 2013). Wolves have been implicated as the main predator on caribou (Courbin et al. 2009). However, predation by grizzly bears, black bears, cougars and wolverines have also been documented (Bergerud and Elliot 1986; 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 high predation throughout much of their range suggests that the balance may have shifted in favour of the predators as a result of human activities on the landscape. Forestry and oil and gas developments make openings and change the forest seral stage distribution on the landscape which produces food for alternate prey, resulting in an increase in predator numbers and an increased risk of predation (Wittmer et al. 2007, Courtois et al. 2007).

Predation has been described as a series of events that occur, with each event associated with a different probability. A predator must first encounter and detect their prey followed by an attack, a kill and finally consumption (Lima and Dill 1990). Carcass sites where an animal has been killed are a culmination of all these events with a final result being a dead and eaten animal. Our results from Objective 1 suggest that the encounter probability between woodland caribou and grizzly bears may be low because of the small geographic overlap between areas with a high probability of both caribou and grizzly bear use. Yet grizzly bears have been observed near caribou (K.Graham, personal observation), and observed feeding upon dead caribou in our study area (G.Stenhouse, personal observation), hence encounters between these species are known to occur. By visiting grizzly bear feeding sites, identified from cluster analysis of GPS locations, we hope to determine if, when, and how often grizzly bears are

killing are/or feeding on caribou and if certain terrain, habitat or anthropogenic features are associated with carcass locations.

Previous studies assessing grizzly bear predation have shown great variation in predatory behaviours across individuals. Preliminary results from work investigating grizzly bear predation on reindeer in Sweden indicated a few individual bears were responsible for the majority of caribou calf deaths (Stoen et al. 2013). Similarly Rauset et al. (2012) found high variability among female grizzly bear predation rates on moose calves, with certain individuals appearing to specialize in calf killing. Our goal is to determine if age, sex and/or reproductive status of both grizzly bears and their prey are important in predicting predation risk.

Methods

Grizzly bears were captured and radio-collared by FRI staff in the spring 2014. Capture methods included the use of culvert traps and aerial darting from a helicopter. Capture protocols were approved by the Canadian Council on Animal Care for the safe handling of bears and approved annually by the University of Saskatchewan and the Government of Alberta Environment and Sustainable Resource Development animal care committees. Captured grizzly bears were collared with Followit GPS Satellite collars. Collars were programmed to obtain a location every 30 minutes. Data was accessed via a website typically once a month for cluster identification.

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 location to the next. Clusters were identified using two methods. First we used a python script which identified clusters from the collar locations based on criteria provided by the user. We used a 100m distance criteria between > 2 sequential points because this distance was used in other similar studies (Metz et al. 2012) and was a reasonable value to use until evidence collected during the summer suggested otherwise. The script output included 2 text files. The first file provided the bear ID and each location in a cluster with its Universal Transverse Mercator (UTM), date, time and distance in metres from the prior consecutive location. The second file summarized each cluster and gave the bear ID, the number of locations in 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 across our study area, due to cost, accessibility and time constraints, we created a system to select clusters to visit. Clusters were categorized into 5 classes

based on duration (Table 2.1). The time of day that the cluster began was also used to split each class into day or night clusters. Previous work suggested that grizzly bears in this area typically rested at night (Graham and Stenhouse 2014), so we predicted that most kills would occur during the daytime hours. 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). Clusters in Classes C through E were randomly selected for site visits. For Class C, 3 day and 2 night clusters were randomly selected for visits. For class D and E, one random day and night cluster was selected. Clusters in the E class were only selected if the cluster occurred in May, June or July when ungulate calves were small. 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	3-4.5 hrs

The second method used to select clusters was a manual process. Locations for each bear were sorted by date and time and viewed in a GIS in sequence. This method documented patterns in each bear's movements such as when the bear typically rested (i.e. movement appeared to stop). Clusters of GPS locations chosen to visit were those associated with movements out of that 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). As well, clusters were selected if a bear visited the same cluster more than once, or if a bear appeared to make a sudden change in direction that cumulated in a cluster. These "clusters of interest" were matched to a cluster identified using the script method by date and time and identified as clusters to visit based on subjective selection if the cluster was not already selected as one to visit using the script method.

For bears collared in 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, one cluster 3 days post capture was visited and appeared unusual (12 hours spent at a bed in very dense alpine fir which was not usual for this bear) so we extended the criterion to at least 5 days post capture.

Cluster Data Collection

All collar locations in a cluster as well as the midpoint of the cluster were uploaded into a GPS. Cluster sites were accessed using helicopter, 4x4 truck or ATVs. Once near the cluster location crews navigated to the cluster midpoint and recorded the distance walked from either the truck or helicopter. Upon arrival at the cluster midpoint an area encompassing a 20-50 m radius, depending on terrain and visibility, was searched for bear and other carnivore sign. After a focused search near the midpoint of the clusters, crews extended the search area and meandered through remaining bear GPS locations to record any additional evidence of bear or other predator/prey presence. Bear sign included: a bed, carcass, digs (for roots or insects), cow parsnip (*Heracleum lanatum*) feeding or scat. If no obvious bear sign was observed, crews looked for ripe berries or missing flowers or seed heads that the bear may have eaten. If there was no obvious carcass at the cluster, any bear scat observed with hair or bone fragments was collected. When bear sign was seen, the distance from the bear sign to the cluster midpoint was recorded.

If a carcass was found at a cluster, 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 sheared hair typical of cougar kills. Crews also documented characteristics of the carcass, including: torn up ground from burial, 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 reference collections to confirm age and/ species. If there was still some uncertainty we consulted with a wildlife veterinarian.

Results

During May and June 2014, 3 adult male grizzly bear and 4 adult female grizzly bear were captured and collared within our study area. All four females spent the majority of their time in protected areas in the mountains. One male's home range was also in protected areas in the mountains; one male was partly in and outside protected areas and one male lived entirely in the foothills where resource extraction activities occurred. In addition, an adult female grizzly bear collared in 2013, whose home range was in the mountains also became part of the study and her collar was programmed to obtain a location every hour (Figure 2.1).

From June 20, 2014 to Oct 9, 2014, we visited a total of 175 clusters out of a total of 983 potential clusters detected using the python script. We were restricted from visiting clusters for four females located in Wilmore or Kakwa Wildlands Provincial Parks after 22 Aug, 2014 due to perceived concerns with sheep hunters and helicopter disturbance. In addition, one of the females in the Kakwa Wildlands Provincial Park frequently moved into British Columbia. Clusters in British Columbia were not visited because of permitting restrictions.

The average distance travelled by field crews to the cluster was 349m (min 4m, max 2000m). The average number of days between the cluster start date and when crews visit was 29.8 days (min 3 days, max 107 days; Figure 2.2). The average distance bear sign was seen from the cluster midpoint was 10m (min 1m, max 44m). Out of the 175 clusters visited, we identified carcass remains at 14.3%, beds at 37.1% (excluding carcass sites and foraging sites), suspected foraging activity at 17.7% (does not include carcass sites) and 30.1% clusters with unknown activity.

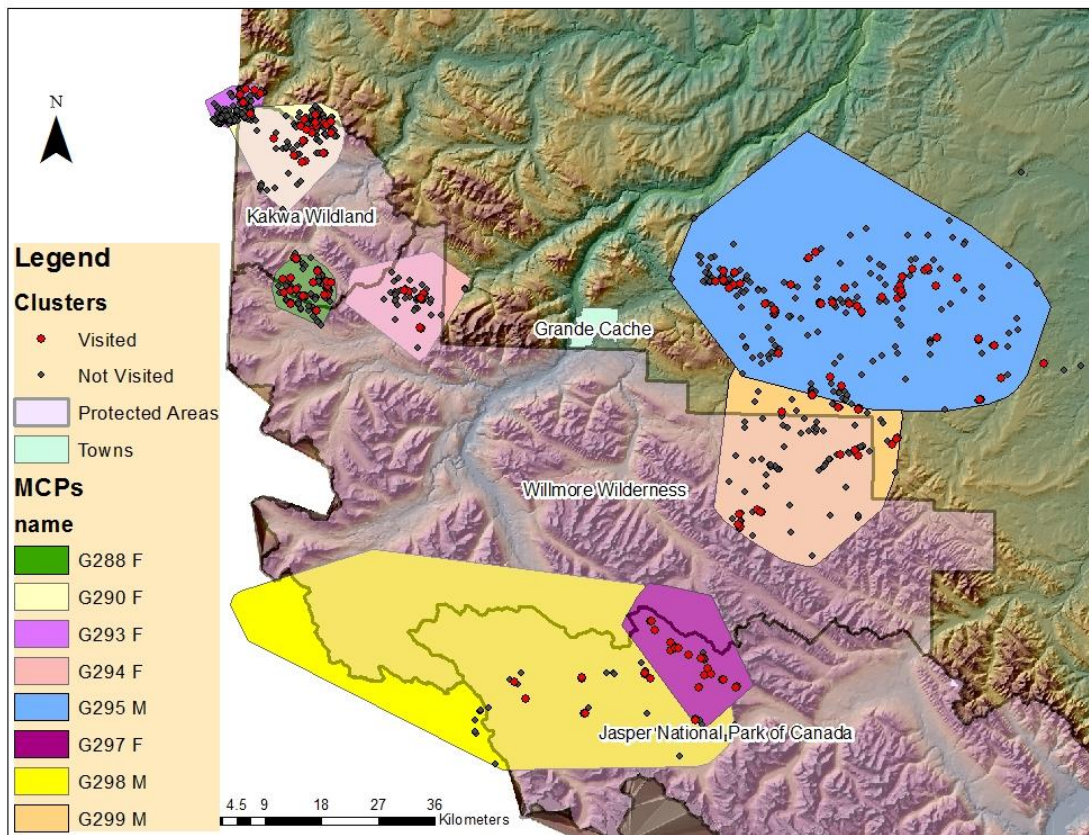


Figure 2.1. MCPs of all 8 grizzly bears with their sex (F or M) and locations of all clusters from GPS collar locations and those clusters visited.

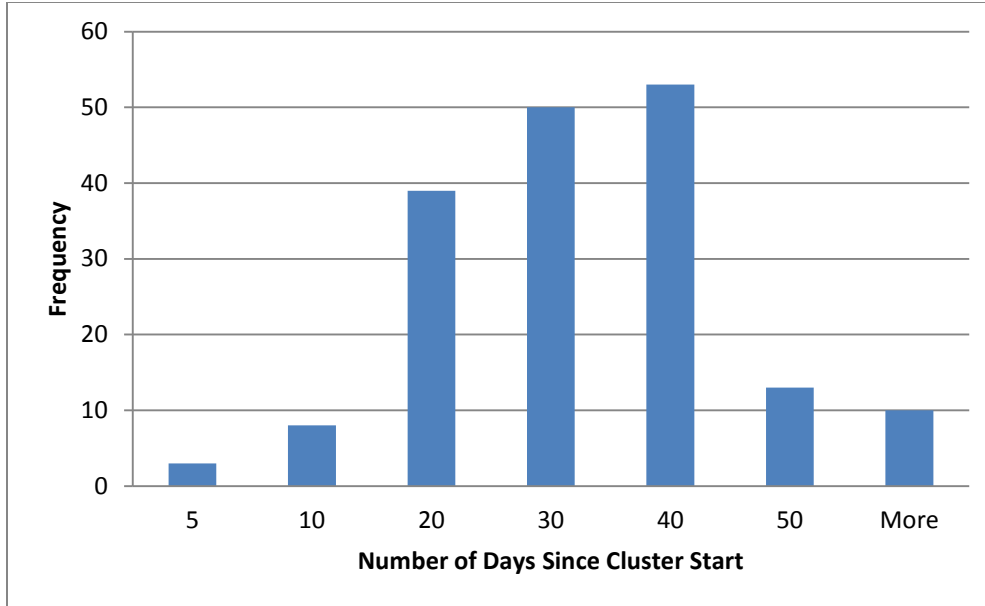


Figure 2.2. The number of days from the start of the cluster to when crews visited the cluster.

Examining the 7 bears with 30 minute locations, the average distance travelled by a bear between consecutive points in a cluster was similar for bed and carcass clusters (18-21m) and longer for foraging clusters (38m) (Table 2.2). The average number of locations in a cluster was highest for carcasses at 74 locations (min 15, max 237 locations), followed by beds at 17 locations (min 3, max 35 locations) and shortest for foraging clusters at 13 locations (min 3, max 28 locations) (Table 2.3).

Of the 25 carcasses found 80% were moose, 12% were caribou and 4% were mule deer or mountain goat (Table 2.4). Over half (52%) were moose calves born in the spring of 2014; with the majority (61%) killed in June, 2014. Four of the eight bears did not have any carcasses found at clusters. However, there were an additional 12 clusters where no carcass was found but where scats containing hair and/or bones were collected. Hair from these scat samples will be examined in detail to determine if any ungulates were ingested by the bear.

Table 2.2. Average distance travelled between consecutive locations by cluster type for 7 grizzly bears with 30 minute location data.

Activity	Average (m/30min)(n)	Min (m/30min)	Max (m/30min)
Bedding	20.7 (57)	7.1	39.2
Carcass	18.2 (24)	9.5	39.8
Foraging	37.6 (23)	17.2	60.4

Table 2.3. Average number of locations within each cluster type for 7 grizzly bears with 30 minute location data.

Activity	Average Count(n)	Min (count)	Max (count)
Bedding	16.8 (57)	3.0	35
Carcass	74.0 (24)	15.0	237.0
Foraging	13.2 (23)	3.0	28.0

Table 2.4. Species of carcasses detected at grizzly bear location clusters.

Bear	Moose			Caribou		Mule Deer	Mt Goat
	calf	yearling	adult	subadult	adult	adult	adult
G288	0	0	0	0	0	0	1
G295	8	3	0	1	1	1	0
G298	1	0	0	0	0	0	0
G299	4	0	4	0	1 (male)	0	0

None of the randomly selected clusters were carcass sites. All carcass sites were in classes A or B or were subjectively selected during the manual process. Of the 25 carcass clusters, 10 began in the morning (6am-11am), 5 in the afternoon (12-6pm), 4 in the evening (8-10 pm), and 7 at night (10:30pm-3:30am).

Discussion

We found the remains of three caribou at grizzly bear clusters. However, we were unable to determine with certainty whether the collared bear killed the animal, or scavenged the carcass. We plan to collect additional data at carcass sites during the second year of the study to help us class carcasses as those likely killed and consumed by the collared bear based on duration of cluster, number of bear scat present, presence of other predators, and carcass characteristics. However, we acknowledge that we will never know with certainty if the bear actually killed the animal even if all evidence suggests this to be true. Evidence of a bear killing a caribou or coming across a recently dead (within a day or two) but intact caribou would likely be similar. For example cluster duration, number of bear scat, carcass characteristics, and insect species present would likely show similar patterns.

Information obtained during this project reinforced the belief that each bear was unique in terms of predation behavior and feeding patterns. One bear (G295) appeared to specialize in either killing or finding dead moose calves at seven clusters that spanned 21 days in June resulted in finding six moose calf carcasses and one moose yearling. In comparison, only one of five females appeared to have eaten an ungulate (a mountain goat). Additional female collared grizzly bears may be added to this list after

hair from their scat is identified. We were unable to visit clusters for four females when they occurred in British Columbia or after 22 August in Wilmore or Kakwa Wildlands Provincial Parks, so it is possible that some carcasses were missed for these bears.

Year 2 Research Initiatives

We will continue to visit clusters that we suspect are carcass sites throughout the 2015 field season. Additional grizzly bears will be captured and collared in the A la Pêche caribou range in the spring of 2015 to increase our sample size for this area. We plan to use the information obtained in 2014 to further refine our selection of clusters to visit. We will focus on clusters with small distances traveled by the bear between consecutive points to filter out foraging clusters. We do not plan to stratify GPS clusters by day or night as bears arrived at carcasses at all times of the day or night.

We plan to focus more efforts in June on clusters that span a short time frame (eg. 2-8 hrs) in an attempt to document any caribou calf mortalities. In Alaska, barren ground caribou calves were targeted by grizzly bears just days after birth, compared with wolves that generally killed caribou calves weeks after birth (Adams et al. 1995). Woodland caribou calves weigh 8-9 kgs at birth (Bergerud and Page 1987) as compared to moose calves that weigh about 13 kg at birth (Rauset et al. 2012). Evidence from our 2014 field season indicated that a moose calf may 'hold' a bear at a location for at least 8 hrs. Since caribou calves are almost half as small as moose calves we anticipate that clusters at caribou calf kills could be as short as or shorter than 3-4 hrs in duration. We plan to visit more clusters of short durations in late May and June in an attempt to find caribou calf carcasses.

In addition to grizzly bears spending only a few hours at a caribou calf carcass, it is possible that little evidence of a caribou calf kill may be left as grizzly bears are apt to eat the entire caribou calf (Bergerud and Page 1987). Fortunately, hair can be identified under the microscope using medulla and scale characteristics (Marinis and Asprea 2006) as well as through DNA. Therefore, we plan on visiting spring bed sites where scat is typically deposited. Data from 2014 indicated that bears will remain at a bed site on average 6-8 hrs and since meat meals typically take 6-17 hrs to pass through a bear (Elfström et al. 2013), there is a good chance that after a grizzly bear eats a caribou calf, scat deposited at the subsequent bed site may contain hair evidence of that consumption. A reference library of ungulate and predator hair samples is currently being collected to aid with identification. We also plan to send a number of hair samples to a genetics lab for species and gender identification and to verify our species hair identification using the microscope.

We will use the detailed information collected at carcass sites to create rules to assign whether the collared bear likely killed and consumed the animal. We will use information such as number of bear scats at the carcass, time spent by the bear at a carcass, other carnivore sign, and characteristics of carcass etc. This will be used to estimate predation versus scavenging events for individual bears as well as information on predation or scavenging by other carnivores. We acknowledge that discerning a kill made by a collared grizzly bear versus scavenging a recently dead but intact caribou would be virtually impossible without using a more frequent (e.g. every minute) but unrealistic (collar battery would last a few weeks vs 1.5 years) GPS location acquisition schedule that would allow the detection of a chase event that likely occurs prior to a kill.

In the second year of this project we will create a predictive model to show areas where caribou predation risk is high. This model may be specific to grizzly bear predation or may include other predators such as cougar. The model will show whether anthropogenic features are associated with high caribou mortality risk.

Objective 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.

by:

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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 elaphus*)—were fed to captive grizzly bears for approximately 28 days during May-July 2014 to determine stable isotope discrimination of bears on ungulate diets.

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 $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ are measured in parts per thousand (‰) relative to Vienna Peedee Belmnite (carbon-C), N² 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.

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 C₃ 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. This work may be undertaken during the second year of the study when visiting collared grizzly bear location clusters.

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

Ungulate	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{34}\text{S}$	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)

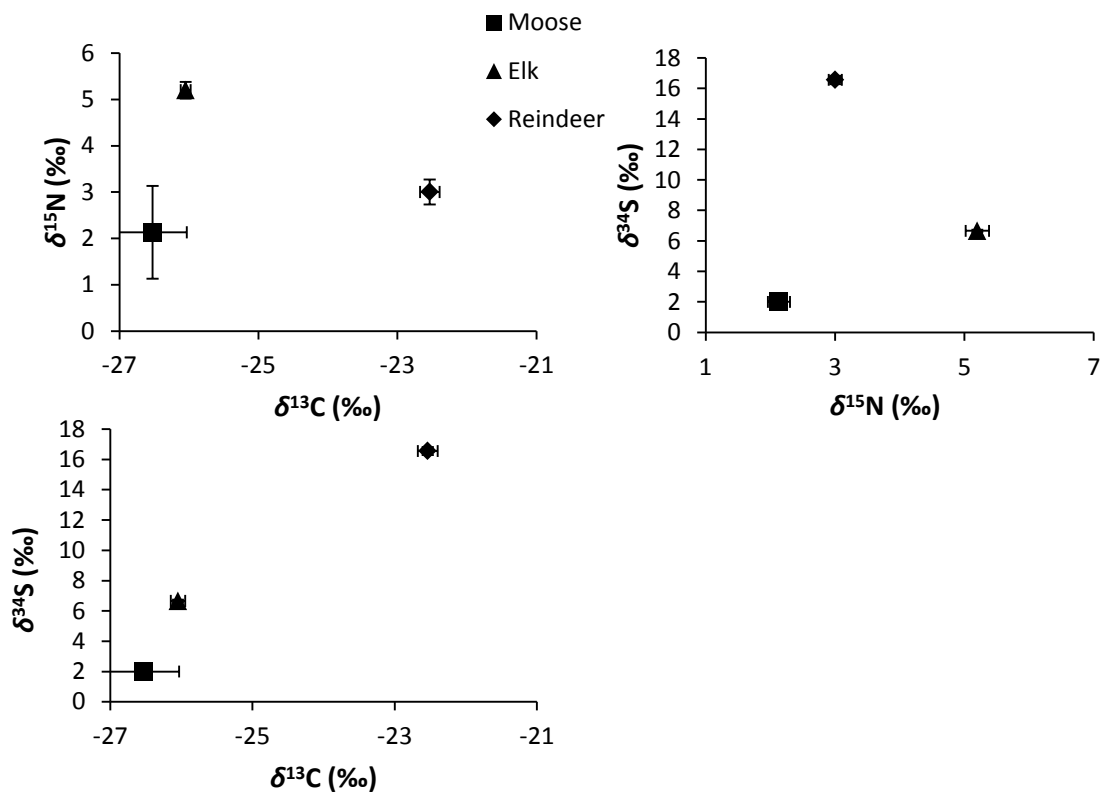


Figure 3.1. $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ values of moose, elk, and reindeer fed to grizzly bears

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).

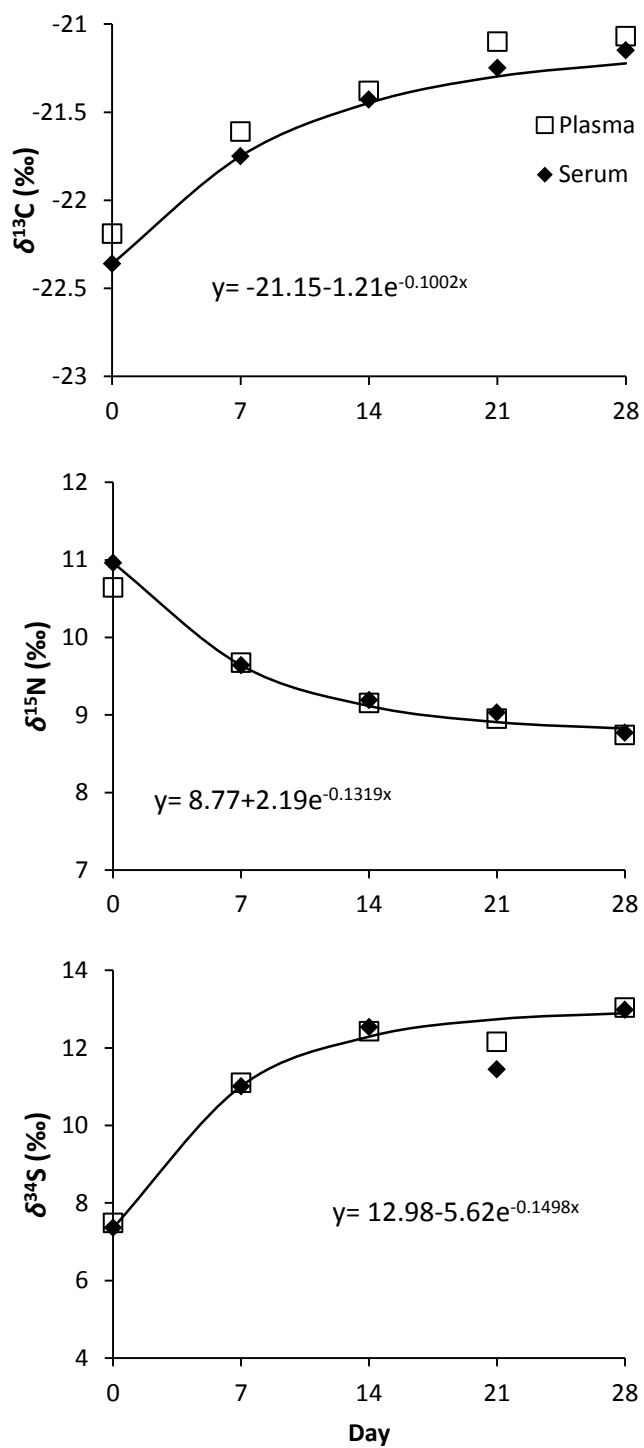


Figure 3.2. Equilibration of bear blood (Luna, Reindeer)

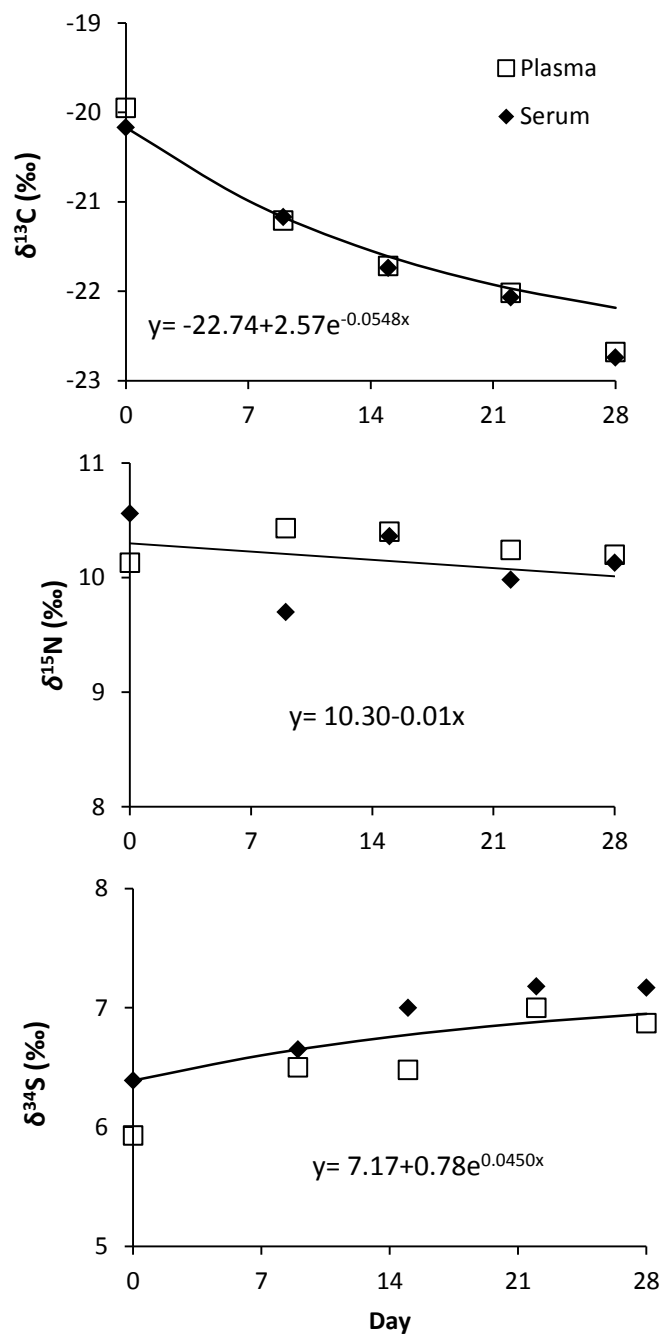


Figure 3.3. Equilibration of bear blood (Peeka, Elk)

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	$\Delta^{13}\text{C}$ (‰)	$\Delta^{15}\text{N}$ (‰)	$\Delta^{34}\text{S}$ (‰)	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 polar bear researchers with the USGS 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. in prep). 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.

Year 2 Initiatives

In the second year of this component of the research program we will undertake stable isotope analysis of grizzly bear hair samples from the study animals that were fed reindeer meat in 2014. These hair samples were collected prior to denning (December 2014) and upon den emergence (March 2015) to determine if we can see any evidence of this one month forced diet shift in 2014. These analyses will provide the needed results for us to confirm the utility of this technique to measure and monitor hair samples from bears to understand possible caribou consumption.

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