

EVALUATION OF BROWN BEAR PREDATION ON UNGULATE CALVES IN SOUTHCENTRAL
ALASKA USING NECK MOUNTED CAMERAS, GPS, AND STABLE ISOTOPES

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Abstract

Neck mounted cameras combined with high frequency GPS and Stable Isotope Analysis (SIA) were used to resolve the feeding ecology of brown bears (*Ursus arctos*) as it pertains to consumption of moose (*Alces alces*) and caribou (*Rangifer tarandus*) calves in the spring. Over a 3-year period bears were collared with store-on-board GPS collars equipped with cameras, and tissue samples were collected for chemical analysis to characterize diet sources. Typically, each brown bear was harvesting an ungulate calf each day, while diet estimates from SIA indicated that spring diets were primarily terrestrial prey, and the proportion of meat varied throughout the summer and fall by individual. Bear locations and movement patterns deduced from GPS data did not correlate with diet compositions, but appeared to indicate patterns of ungulate calf selection based on spatial aggregation of calving areas of moose and caribou. In general, caribou calved at higher elevations than moose, indicating that elevation could be used to identify species killed in some cases. Importantly we found that ungulate kill rates in the spring are higher than previously estimated, and that bears exhibit a range of dietary preferences that vary seasonally.

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Chapter 1: General Introduction

The combination of multiple synergistic methods to investigate individual variation in the feeding ecology of brown bears.

Large mammal population dynamics and their interactions in complex systems have long been important to ecologists and wildlife managers in the development of sound management strategies. Predation has always played a controversial role and has been the focus of research in that respect (Boertje et al. 2010). Brown bears (*Ursus arctos*) have been identified as a major source of ungulate mortality throughout North America and Scandinavia (Franzman and Schwartz 1986, Ballard and Miller 1990, Gasaway et al. 1992, Boertje et al. 2010, Testa et al. 2000, Swenson et al. 2007, Rauset et al. 2012). Bears impact ungulate populations primarily by predation on calves in the spring (Zager and Beecham 2006). The extent to which brown bears harvest different ungulate species and the degree to which they harvest individual species in specific habitats across vast landscapes is unclear.

The most common method used to investigate ungulate calf mortality has been to collar neonate calves and monitor their fate, investigating kill sites and assigning cause of death (Keech et al. 2011, Swenson et al. 2007, Valkenburg et al. 2004).

Although the collaring of ungulate calves gives researchers the ability to putatively identify cause-specific mortality and assign predation to a likely predator, it does not allow researchers to assess predation at any finer scale or provide an understanding of

predation dynamics at the individual level. This project focused on understanding the intraspecific variation in brown bear diets and landscape use, specifically as they relate to predation on moose (*Alces alces*) and caribou (*Rangifer tarandus*) calves.

Continuous monitoring of large animals such as bears, caribou (*Rangifer tarandus*), and moose (*Alces alces*) in their natural habitats is very difficult. Today most big game monitoring is limited to infrequent observations from aerial surveys using very high frequency (VHF) transmitters and global positioning systems (GPS) tracking or through indirect observations by assessments of tracks and scat (Thompson et al. 2012). Recent advances in camera technology have increased the potential for using cameras attached to animals to sample their behavior. Most ungulate calf predation by bears occurs in a relatively short period from 15 May to 30 June (Ballard et al. 1981), allowing for collection of frequent observations of predation events with a neck mounted camera, within the limitations of battery life and on-board memory capacity. I used GPS collars equipped with cameras to sample both location and behavior of brown bears in spring in the Nelchina area of southcentral Alaska. This is the first time this technology has been applied to the study of predation by brown bears. In this study, identification of individual kill rates by brown bears on ungulate calves (moose and caribou) are of specific interest.

To complement the video collar study, I used stable Isotope analysis (SIA) to estimate the diets of bears captured in this study. SIA allows estimation of diet over a

specific period reflected in the tissue type sampled. SIA ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) has greatly advanced understanding of animal nutritional ecology, especially of free ranging wildlife (Tieszen and Boutton 1989, Hatch et al. 2011, Hilderbrand et al. 1996, Milakovic and Parker 2013, Robbins et al. 2004, Hopkins et al. 2012, Stanek 2014, Rogers et al. 2015) and has been successfully applied to brown bear diet ecology (Robbins et al. 2004, Hatch et al. 2011, Hilderbrand et al. 1996, 1999). My objective was to determine if brown bear diets were consistent between individuals, if they were consistent across seasons, and if the estimated diets corresponded to known landscape use patterns. In addition, I examined the use of known diets (from camera collar recordings) to guide selection of discrimination values from the literature and to evaluate model selection in regard to sources included.

Camera collars give a new perspective that allows investigation into behaviors like predation that until now have been elusive. This study combined use of cameras with SIA to provide a more refined understanding of diet estimates from SIA techniques. The addition of the landscape use complimented the other techniques, providing an ecological context to what was revealed about diet and more specifically predation of ungulate calves by brown bears in Alaska.

Chapter 2: Determining individual kill rates of ungulate calves by brown bears (*Ursus arctos*) in southcentral Alaska using neck-mounted cameras and GPS¹

Abstract

Predation of moose (*Alces alces*) and caribou (*Rangifer tarandus*) calves by brown bears (*Ursus arctos*) has been extensively studied, since it has population implications for both predator and prey species. Due to the elusive nature of brown bears in many habitats, estimation of predation rates has been limited to tracking of individual bears or monitoring prey species to estimate predation rates. Although these methods have provided population specific predation rates, they have not been available to estimate kill rates of individual bears until recently.

I fitted brown bears in the Nelchina Basin of Alaska with GPS collars equipped with cameras in the spring of 2011, 2012 and 2013, and retrieved the collars in late June of each year to download the video data and associated GPS locations. I classified the primary recorded behaviors for 7 bears that provided adequate video samples, counting individual ungulate kills and kill characteristics such as handling time to estimate the likelihood of missing kills. To compensate for incomplete sampling across time when calves are most vulnerable to predation, I constructed a calf risk model from previous

¹Brockman C. J., Collins W. B., Spalinger D. E., Welker J. M., 2015. Determining individual kill rates of ungulate calves by brown bears (*Ursus arctos*) in southcentral Alaska using neck-mounted cameras and GPS. Prepared for The Journal of Wildlife Management.

calf mortality studies and used it to predict total calf kills for each individual bear through the end of June. The mean kill rate for ungulate calves by the sampled bears was 34 calves/bear each spring. Median handling times were 40 minutes for caribou calves and 60 minutes for moose calves. These short handling times indicate why it is difficult to detect calf kills by other methods, and help explain the considerably higher kill rates that I observed.

Introduction

Ungulate population dynamics and their interactions with predators in complex ecological systems have long been important to ecologists and wildlife managers in the development of sound management strategies. Predation has always played a controversial role and has been the focus of research in that respect (Boertje et al. 2010). Predators that exert a top-down influence on ungulate populations in North America include; cougars (*Puma concolor*), bears (*Ursus sp*) and wolves (*Canis lupus*). Predation on ungulate calves in the spring by both brown bears (*U. arctos*) and black bears (*U. americanus*) has been shown to limit growth of ungulate populations at low densities (Boertje et al. 1988, Ballard et al. 1991, Gasaway et al. 1992, Reynolds et al. 1987). Most studies have focused on the impact of predation on deer (*Odocoileus sp*) (Demma et al. 2007), elk (*Cervus elaphus*) (Milakovic and Parker 2013), caribou (*Rangifer tarandus*) (Valkenburg et al. 2004), and moose (*Alces alces*) (Keech et al. 2011, Ballard et al. 1981). Brown bears, black bears, and wolves have all been shown to be important predators on ungulates in Alaska (Spraker et al. 1981, Keech et al. 2011).

The impact of predation on ungulate populations depends on a variety of factors, including the types and density of predators present, the vulnerability and density of the prey, and the season of the year (Boertje et al. 2009, Mattson 1997). Bears impact ungulate calves primarily in the spring (Zager and Beecham 2006). Wolves impact ungulates throughout the year (Boertje et al. 2009, Valkenburg et al. 2004, Keech et al. 2011), but their impact is generally greater when deep snow make ungulates of all ages less mobile and more vulnerable to predation. ADF&G (unpublished data) in south central Alaska and Keech et al. (2011) in interior Alaska found calf mortality rates as high as 80% and 60%, respectively in spring. In south central Alaska, brown bears and black bears were responsible for approximately 50% and 20% of the observed mortality, respectively, and in interior Alaska, 40% and 5%, respectively.

Monitoring the fate of collared neonate calves has been the primary tool used to investigate causes of early ungulate mortality (Keech et al. 2011, Swenson 2007, Valkenburg et al. 2004). Although the collaring of ungulate calves provides researchers the ability to identify cause-specific mortality and assign predation relatively accurately to specific predators, it does not allow researchers to assess many other important questions in predator-prey ecology.

One important aspect of predation that has been elusive in previous studies is intraspecific variation among individuals within a predator species. Spraker et al. (1981) and Boertje et al. (1988) found variable kill rates by sex class and individual bears.

Milakovic and Parker (2013) suggest that nutritional limitations of herbaceous diets indicate that large males should exhibit higher rates of prey consumption than females. However, robust methods have not been available to thoroughly evaluate the individual predation behavior and diet of bears.

Determination of predation rates and cause-specific mortality of newborn calves typically requires radio collaring large samples of calves, intensive monitoring, and examination of mortality sites. Such methods are both expensive and logistically difficult, and currently do not address the potential individual variation among predators. Boertje et al. (1988) intensively monitored collared brown bears with daily aerial observations for an entire summer, investigating kill sites and necropsying apparent prey. This method provides minimum estimates of adult ungulate kills but is likely to underestimate predation on small prey items like ungulate calves because of low detection probabilities. According to Zager and Beecham (2006) the tools to investigate predation rates and factors influencing predation rates by specific classes of bears have not been available. Thus, if a cost-effective technique can be developed to identify individuals or classes of predators responsible for the majority of ungulate calf mortality, the effectiveness and efficiency of predator research and management programs could be greatly enhanced and total costs reduced. This will be increasingly important if greater human intervention (e.g., predator control) becomes necessary to conserve or enhance prey populations.

Continuous monitoring of large animals such as bears, caribou, and moose in their natural habitats is very difficult, resulting in most monitoring being limited to infrequent observations from aerial surveys using very high frequency (VHF) transmitters and global positioning systems (GPS) tracking or indirect observations by assessments of tracks and scat (Thompson et al. 2012). These traditional methods of monitoring large terrestrial mammals are insufficient to provide fine scale (subhourly) behavior and diet selection information of their predators. However, recent advances in camera technology have increased the potential for using cameras attached to animals to sample their behavior. These cameras can be programmed to collect real-time footage at short intervals ("clips"), providing explicit sampling of individual behaviors. For bears, these behaviors could include stalking prey, sleeping, and mating, as well as quantitative characteristics of individual predation events such as search time (encounter rates) and handling time. The majority of ungulate calf predation by bears occurs in a relatively short period from 15 May to 30 June (Ballard et al. 1981), allowing for collection of frequent observations of predation events within the limitations of battery life and on-board memory capacity.

I used new camera technology to quantify ungulate calf kill rates by brown bears. For this study, I define kill rate as the rate (prey killed per day) at which an individual bear kills prey, in contrast to predation rate, which is traditionally defined as the rate that a prey species is killed by a specific predator species. The goal of this study was to examine the feeding ecology of brown bears using a new technique for quantifying their

predation on ungulate calves, and thus help guide management of bears and their prey. I used a combination of animal-borne video camera and GPS technology to quantify bear behaviors specifically related to the predation on ungulate calves during a period of high neonatal mortality. I evaluated the significance of video and GPS sampling interval on the detection of predation behaviors. I constructed a calf risk model from a cumulative predation function derived from moose and caribou calf mortality studies and proportionately applied to observed kill rates by individual bears to extrapolate total kills in the spring season, compensating for incomplete sampling. Finally, I compared results of this study to other methods of evaluating predation characteristics of bears and the utility of those methods, and I discuss limitations of the combined GPS/video technology.

Methods

Study Area

This study was conducted in the Nelchina Basin, Alaska, an area covering approximately 11,200 sq km, 70 km northwest of the town of Glennallen (Figure 2.1). Located within Alaska Department of Fish and Game (ADF&G) Game Management Unit (GMU) 13A. The climate is characterized by cold winters and warm summers (average high 19.0°C, average low -29°C) and annual precipitation averaging 28.4cm (Walton et al. 2013).

The topography is composed of high alpine habitat in the west (Talkeetna Mountains) with peak elevations exceeding 2,100 meters, and lower elevation spruce

forest in the east. Drainage is either north into the Susitna River or south into the Nelchina River. The lower elevation spruce forest has many lakes and small ponds. Plant communities along the rivers and streams are dominated by riverine willows (*Salix alexensis*, *S. hastata*). The forest is dominated by white spruce (*Picea glauca*) and black spruce (*P. mariana*) with a shrub understory of dwarf birch (*Betula nana*). The sub alpine areas are comprised of dwarf heath (*Cassiope spp.*, *Empetrum Spp.*, *Ledum spp.*, *Vaccinium Spp.*, and *Arctostaphylos spp.*) (Ballard et al. 1987). Other common vegetation types scattered throughout the study area are Alder (*Alnus crispa*), willow (*Salix spp.*), and sedges (*Cyperaceae*). The topography, climate and vegetation of the study area are described in more detail by Skoog (1968).

The most recent density estimate of brown bears in the study area was 21.3/1000km² (95%CI 18.4-25.9; Testa et al 2004). The area also supports healthy moose, caribou and sheep populations. Approximately 40,000 caribou inhabit the area from May through August, calving there in mid to late May (ADF&G unpublished data). The area has a controversial management history for moose, caribou, brown bear and wolves (Van Ballenberghe 1985), and more recently, predator control programs have been initiated (Tobey and Kelleyhouse 2007).

Bear Capture

Brown bears were captured 15-17 May by darting from a helicopter (4 in 2011, 4 in 2012 and 9 in 2013). The bears were recaptured between 17-29 June in each year, and the collars were recovered. The 4 brown bears captured in 2011 were already

collared as part of an ongoing study and were selected because they had a history of predating ungulate calves, verified by aerial observation. These bears were selected to ensure that video footage would be collected to evaluate the camera/GPS technology as a useful tool for investigating bear predation characteristics. The bears captured in 2012 and 2013 were haphazardly selected for collaring with the caveat that they were adults (at least 5 years old).

Bears were anesthetized with 5 mg/kg of Telazol[®] (Fort Dodge Laboratories, Inc., Fort Dodge, IA). The sex of the captured brown bears was determined, and they were inspected for lip tattoo identification numbers. If they were not tattooed, a tattoo (an identification number) was applied to the upper lip and a pre-molar tooth was extracted for aging. Two full 3ml (lavender cap) K₂EDTA blood vials were collected from the femoral vein and guard hair samples were collected from the shoulder. In 2013, muscle and fat biopsies were also collected from the front shoulder, anterior of the spinous process of the scapula using a 6mm biopsy punch. The bears were administered antibiotics and allowed to recover. All animal handling and sampling protocols reported in this paper complied with current law and were approved by the appropriate ethical committees (UAA IACUC -IRBNet ID #462094-1, IRBNet ID #462079-1 and ADF&G ACUC Protocol No. 2013-11) (Appendix B).

Collar Programming

Each bear was fitted with a prototype Lotek Wireless™ GPS_3300 collar equipped with a digital camera (Lotek Wireless Inc., Newmarket, Ontario, Canada). The

GPS_3300 collars had a location accuracy of 5-10m 95% of the time. The sampling interval in 2011 was selected without prior information on handling time and was chosen based on 28 hours of available camera battery life. The sampling intervals were adjusted in subsequent years to evaluate the effects of interval selection on detection of kill rate and handling time. In 2011, camera collars were programmed to record a 10-second clip every 15 minutes and a GPS location every 15 minutes. The camera programming included a duty cycle of 18 hours on and 6 hours off. The 6 hour off period was different for each collar (12:01am-6:00am, 6:01am-12:00pm, 12:01pm-6:00pm and 6:01pm-12:00am). Duty cycles were only used in 2011. In 2012, the collars were programmed to record a 10-second clip every 5 minutes and a GPS fix every 15 minutes. In 2013, four collars were programmed to record a 10-second clip every 5 minutes and a GPS fix every 10 minutes, and five collars were programmed to record a 10-second clip every 10 minutes and a GPS fix every 10 minutes (Table 2.1).

The collars were store-on-board devices for both the video and GPS data. The collared bears were recaptured at the end of the programmed life of the camera and the collars were recovered. A second set of tissue samples were collected at the time of collar recovery. The collars were returned to the manufacturer for downloading of digital video clips and GPS data. Video clips were processed by sorting into a single video montage for each day of footage using IMTOO™ video processing software. All clips were viewed and classified into behaviors based on defined criteria. Behaviors were classified into primary and secondary classes, with a primary behavior being one of

the following: feeding, hunting, traveling, standing, grooming, nursing, sniffing, socializing, aggressive, resting, and unknown. Secondary behaviors were classified (subclasses of the primary behaviors) as follows. For feeding, I identified the food: adult moose, calf moose, adult caribou, calf caribou, adult ungulate, calf ungulate, bear, mammal, bird, insect, fish, vegetation, and unknown. For hunting, I classified the secondary behavior as hunting for adult moose, calf moose, adult caribou, calf caribou, bear, mammal, other, and suspected hunting. I reviewed all clips classified as feeding or hunting for consistency in prey identification. Hunting was distinguished from traveling when the bear was determined to be stalking or subduing a prey species. If the behavior was stalking (i.e., “low crawl” or “fast rush”), but the target of the stalk was not observed; the primary behavior was classified as hunting but the secondary behavior was classified as suspected. Otherwise, all dietary items were identified to species.

Data Analysis

Activity budgets were estimated for brown bears whose collars collected sufficient video information. For analyses to investigate ungulate calf predation, sufficient video information was defined as those individuals having 6 complete days of samples after 20 May (arbitrarily selected as the date on which predation on calves began). This date was selected since it was the median date of first observed calf kill for 5 of the 7 brown bears observed to consume calves. Two brown bears were excluded from the median first kill date analysis, because 1 was collared on 25 May and therefore

was not sampled at the beginning of the calf predation season and the second bear returned to its den after collaring and did not kill a calf until 30 May. All activities were categorized at the level of an individual video clip. Behaviors were broken down to percent of time spent in that behavior, which directly relates to the percent of clips where that behavior was the primary behavior.

Each clip classified as feeding on an ungulate was further evaluated to estimate whether the bear was feeding on a fresh or old carcass (i.e., scavenging) using criteria presented in Table 2.2. Feeding clips on fresh carcasses were assumed to have been killed by the bear. Feeding clips on old carcasses were classified as scavenged or revisited kills based on GPS locations and kill location history (Figure 2.2). All clips classified as feeding on an ungulate were sorted by metadata including the time stamp (from the videography) and the associated GPS location recorded within the nearest 10- or 15-minute interval to determine that all kills were counted and that no kills were double counted. Individual kills were determined by appearance of carcass (primarily degree of consumption: Figure 2.2), time, and distance between previous kill and current kill (Figure 2.3). If subsequent clips of feeding were not distinguishable as separate kills by appearance of carcass but occurred 200m or more apart, they were classified as separate kills. To account for the 6-hour periods when cameras cycled off in 2011, the number of observed kills was adjusted by multiplying confirmed kills by 1.33, assuming that kills occurred at the same rate when the camera was off as when the camera was on.

Handling time was also evaluated using the video samples. Minimum handling time was estimated as the interval between first and last evidence of feeding at a kill site. Maximum handling time was calculated as the minimum handling time plus twice the time interval between video clips. For example, if the camera, sampled on a 10 minute interval, recorded 2 consecutive clips of feeding, the maximum handling time that could have occurred would be 30 minutes. This includes the interval before the first clip of feeding and the interval after the last clip of feeding. Maximum handling time was used because it can constrain kill detectability given the sample interval length (Cavalcanti and Gese 2010, Martins et al. 2011). The time at kill site was determined by summing the number of consecutive GPS locations at a site identified as a kill site by video samples (Cavalcanti and Gese 2010, Martins et al. 2011, Knopff et al. 2009). Time at kill site relates only to GPS locations and may be different than maximum handling time which refers to the video data, in that bears could remain at a kill site after the prey item had been consumed or because the sampling intervals between the GPS and video clips differed. GPS locations further than 100m from a kill location were not included in determination of time at a kill location.

Calf Risk Model

In this study, most of the camera collars were either removed prior to the end of the neonatal period when calves are most vulnerable to predation (June 30 in this area), or failed prior to this date. To compensate for incomplete sampling by camera collars over this period, a calf risk model was applied to the individual measured kill rates to

estimate season-long kill rates. The calf risk model is a cumulative predation function constructed from 6 calf mortality studies to predict the proportion of calf predation by date (Figure 2.4). Of the 6 studies used to build the calf risk model, 2 were from moose calf mortality studies conducted in the same study area (2003 and 2006) (ADF&G unpublished data). Two others were from moose calf mortality studies in GMU 16B south, near the village of Tyonek (2010 and 2012) (ADF&G unpublished data), and 2 were caribou calf mortality studies from GMU 17 (2011 and 2012) (ADF&G unpublished data). Timing of moose or caribou parturition was similar in all 6 studies. Wolf control programs had reduced the wolf populations in the study areas used to build the model, as well as in this study area. Accuracy of the calf risk model is supported by its similarity to moose calf mortality rates in this same study area measured in 1977-78 (Ballard et al. 1981). This model was used to extrapolate the total number of calves that individual marked bears would likely have killed each spring through 30 June. The model was not projected beyond that date because the specific cause of mortality is generally not known after 30 June due to reduced monitoring, delayed investigation of mortality sites, and subsequent inability to determine cause of death.

Results

Camera Performance

Of the 17 prototype collars deployed during this study, malfunctions resulted in 9 collars failing to collect sufficient data for analysis. Two collars failed before the scheduled removal date, due to damage caused by the bears, and one of these was not

included in the analysis. Video samples (clips) were included in the analysis if they contained at least 6 days of video samples after 20 May (Table 2.3). The earliest observed calf predation event occurred on 18 May. Of the collars whose data were analyzed, a total of 36,376 clips (2,022—8,020 per brown bear, mean 5,197 SD=2,447, n=7) (Table 2.4) were recorded. Two collars on a 5-minute clip interval produced 1 clip per interval, whereas the other 5 collars collected two consecutive clips at each interval due to programming error by the manufacturer.

Activity Budgets

The mean activity budgets of the 7 brown bears included in the study were as follows: resting 60.5%, traveling 21.3%, standing 6.3%, feeding 6.2%, unknown 2.9%, sniffing 1.3%, socializing 1.0%, hunting 0.4%, and grooming 0.1%, (Table 2.4, Figure 2.5). Of the 6.2% of clips classified as feeding, the mean diets of the 7 brown bears during the 15 May to 17 June study period were; adult moose 12.2%, calf moose 29.8%, adult caribou 3.2%, calf caribou 22.4%, adult ungulate 0.2%, calf ungulate 3.6%, brown bear 3.2%, mammal 1.6%, bird 1.7%, fish 0.4%, vegetation 19.2%, and unknown 2.5% (Table 2.5, Figure 2.6, Appendix A). Ungulates comprised 71.3% of all clips classified as feeding.

Measured Kill Rates

Bears collared in 2011 were equipped with duty-cycled cameras and their kill estimates were extrapolated by multiplying observed kills by 1.33. Of the 7 brown bears, 4 were documented consuming adult ungulates. The mean adult ungulate kills/bear for

all 7 brown bears while the cameras were working (15 May -17 June) was 1.4 (0-5.3); 0.6 adult moose, 0.6 adult caribou, and 0.2 unknown adult ungulates (either moose or caribou). Of the 7 brown bears, the mean number of calf kills/bear observed was 28.4; 13.3 moose calves (0-30.6), 11.9 caribou calves (0-30), and 3.3 unknown calves (either moose or caribou) (0-8.0) (Table 2.6). The number of sample days (1 day post collar deployment until camera failure or removal) ranged from 11 to 31 (mean of 23.4) per brown bear. The mean calf kills/day was 1.2 (range 0.3-1.8; Table 2.6).

Handling Time

Median maximum handling times were 45 minutes for adult caribou, 40 minutes for calf caribou, 795 minutes for adult moose, and 60 minutes for calf moose (Table 2.7). Handling times were poisson distributed and were log transformed for analysis. Handling time for calves differed significantly by prey type ($P < 0.001$), by sex * prey type ($P < 0.001$), by bear ($P = 0.048$), and by bear * prey type ($P < 0.001$). Median time spent at a kill was 45 minutes for adult caribou, 20 minutes for calf caribou, 1619 minutes for adult moose, and 60 minutes for calf moose (Table 2.8).

Modeled Kill Rates

The calf risk model estimated that 82.6% of summer calf mortality occurred by 30 June. Based on the kill rates of calves by bears from the calf risk model, during the interval from 15 May to 30 June, individual kill rates were extrapolated to be 34.4 calves

per bear, including 16.2 moose calves killed per bear (0-33.4), 14.1 caribou calves per bear (0-35.1), and 4.1 unidentified calves per bear (0-12.7).

Discussion

Estimates of ungulate calf kill rates reported in this study are considerably higher than estimates reported in other studies of brown bear calf predation (Ballard et al. 1981, Boertje et al. 1988, Swenson et al. 2007, and Rauset et al. 2012). Boertje et al. (1988), using daily aerial observations of individual collared brown bears, reported that each adult bear killed 5.4 (± 0.8) moose calves annually but recognized that this estimate was biased low. Spring (30 April- 10 June) kill rates (1 moose calf/7 bear days) were significantly greater ($p < 0.02$) than summer (9 July- 10 August) rates (1 moose calf/23 bear days) in his study. Ballard et al. (1981) studied moose calf mortality and brown bear predation using daily and twice daily aerial observations of individual collared brown bears, monitored the fate of collared neonate calves, and monitored the survival of calves of radio-collared cow moose in a study area partially overlapping my study area. They reported the mean brown bear kill rate for the period of 26 May-1 November was 1 ungulate kill/6.1 bear days based on observation days. When adjusting for moose calf kills the rate is 1 moose calf/11.8 bear days. They also reported that the predation rates varied by individual from 0 ungulates to 1 ungulate/2.2 bear days and that 94% of calf mortality occurred by 19 July.

In Sweden, Swenson et al. (2007) calculated predation rates based on population parameters of moose and bear and bear-specific calf mortality by monitoring marked moose calves and investigating mortality sites to determine cause of death. They reported that moose calf predation rates by brown bear were 6.8 calves/bear annually or 1 calf/6 bear days during the 6-week period when calves were effectively preyed on by brown bears (approximately 15 May-30 June). Rauset et al. (2012) estimated an average individual kill rate of 7.6 (± 0.71) calves/calving season (15 May- 30 June) or 1 calf/6.2 bear days by observing GPS clusters of collared female brown bears and kill site evidence to predict predation events and estimate kill rates. Estimates of average ungulate calf kills in this study using the calf risk model for the 7 bears that killed calves were 16.2 moose calves (0-33.4), 14.1 caribou calves (0-35.1) and 4.1 unidentified calves per bear (0-12.7). For the period 20 May-30 June this equates to 1 ungulate calf/1.2 bear days (1 moose calf/2.5 bear days; 1 caribou calf/2.9 bear days). These rates are substantially higher than rates reported in other studies (Table 2.9).

Estimates of moose and bear densities within this study area are within the range of estimates from comparative studies, suggesting that neither difference in moose nor bear densities are responsible for the considerably higher kill rates measured in this study. Boertje et al. (1988) reported moose and brown bear densities of 86/1,000km² and 16/1,000km², respectively in east central Alaska. Moose and brown bear densities in the Nelchina Basin were 750/1,000km² and 24/1,000km², respectively, in earlier studies (Ballard et al. 1981, 1991, Testa et al. 2000,). Swenson et al. (2007)

and Rauset et al. (2012) reported moose and brown bear densities of 920/1,000km² and 30/1,000km², respectively, in 2007, and 500/1,000km² and 30/1,000km², respectively, in 2012 in a study area in Sweden (Table 2.9). Kill rates were similar in these 4 studies, even though moose/bear estimates varied six-fold. The most recent published estimates of moose and brown bear densities in my study area are 560/1000 km² and 21.3/1000km² respectively (Testa 2004). Boertje et al. (1988) likewise reported that kill rates by brown bears remain relatively constant across variable moose densities.

The vastly greater kill rates of ungulate calves observed in this study are likely due to our ability to more accurately detect predation events. Camera collars are likely to capture more predation on calves than the once or twice-a-day monitoring of marked brown bears from the air as used by Ballard et al. (1981) and Boertje et al. (1988). Daily monitoring from the air relies on the assumption that monitored bears spend enough time on kills that each kill will be detected. This assumption is violated when bears kill multiple calves in a single day or move away from a kill without consuming the majority of the carcass, or simply if the handling time is too short. The median maximum handling times estimated from this study were 60 minutes for moose calves and 40 minutes for caribou calves. With median handling times of one hour or less, the detection of many calf kills would be unlikely with sampling intervals that are much greater than one hour. Seventy-five percent of moose calves were handled in 150 minutes or less, indicating that even the twice-daily observations employed by Ballard et al. (1981) were insufficient to accurately quantify daily calf kill rates. In this study,

decreasing the sampling interval reduced the proportion of kills that were detected in only a single clip (Figure 2.7). However, even on a five-minute sample interval, 9% of moose and 19% of caribou calf predation events were only observed in a single video clip (i.e., a maximum handling time of approx. 10 minutes).

This analysis suggests that the guidelines proposed by Rauset et al. (2012) for the assessment of calf predation rates estimated from GPS locations may not be appropriate for many studies. By use of 30-minute intervals for GPS location fixes and activity sensors, Rauset et al. (2012) found that clusters of 12 locations and ≥ 4 active periods produced the best model to predict moose calf kill sites. Based on the estimate of median time at kill site of 60 minutes for moose calves and 20 minutes for caribou calves, there would be no location cluster for half of the caribou calf kill sites in my study if the fix interval was 30 minutes and 2 GPS fixes at most for half of the confirmed moose calf kill sites. Twenty five percent of the moose calf kills were attended for 15 minutes or less and would not have created any cluster with a 30 minute fix interval (Figures 2.8 and 2.9). When the parameter of 12 fixes at 30-minute intervals is applied to the data collected by the camera collars only 25% of moose calf predation events would have been detected in this study (Table 2.8). This would have resulted in a spring kill rate estimate of 4.8 bear days/ungulate calf kill and 8.8 bear days/moose calf kill. Importantly, these adjusted rates are then comparable to those estimated by Rauset et al. (2012): 6.2 bear days/moose calf kill.

The considerably lower kill rates reported by Swenson et al. (2007) may indicate that there is a high degree of variation in kill rates for individual bears. This is supported by Rauset et al. (2012) who found a range of kill rates from 2-15 for female brown bears in the same study area. Swenson et al. (2007) estimated per bear kill rates for moose calves by dividing the number of moose calves killed by the estimated bear population to derive a rate of kill by individual bears. However, mean kill rates determined in this manner ignore the considerable and important implications of variation among individuals in their effectiveness as predators. Variation in kill rates by demographic class has been documented in Alaska (Ballard et al. 1990, Boertje et al 1988), although other studies failed to document specific sex or age classes as having significantly different kill rates on ungulate calves (Ballard et al. 1981). When the methods used to calculate kill rates by Swenson et al. (2007) are applied to moose and brown bear demographic information from Testa (2004) in the Nelchina Study Area, the calculated kill rates are 8-11.25 moose calves/brown bear. This is lower than the 16.2 moose calves/brown bear estimated in this study. Due to the low sample sizes in my study it would be inappropriate to apply the mean kill rate to the entire bear population. Low sample sizes in this study prevented testing for differences in kill rates by age or sex but handling time differences were significant for sex by prey type.

Although all bears whose cameras functioned sufficiently were documented killing calves, the kill rates varied substantially. For example, one sow killed 7 caribou calves; in contrast, one of the boars killed 44 moose and caribou calves as well as other

prey items such as beaver and hare. This high degree of variability in kill rates has important implications in relation to predation ecology and therefore population management. The differences in kill rates between bears in this study indicates that indiscriminate bear removal may do little to lower predation rates at the population level until the majority of the population of bears has been removed. Alternatively, the selective removal of “high value” predators might effectively reduce predation rates without significantly altering bear populations.

The ability to identify individual variation in kill rates within a bear population has been somewhat elusive. Many studies have attempted to address this by identifying kill rates of collared bears with VHF or GPS technology or calculating kill rates from predation rates determined from calf mortality studies (Ballard 1992). These methods have not been sufficient, primarily due to the lack of information on handling time. The collection of high frequency video samples combined with GPS is a new tool that, based on the results of this study, is better suited to evaluate the factors affecting kill rates, such as handling time. The comparison of methods to determine kill rates is important in determining the appropriate direction of future studies. Assessment of bias is essential to interpreting data and increasing comparability to future and past studies of bear kill rates on ungulates.

Biases associated with the neck mounted video/GPS method of data collection include the inability to sometimes identify the primary behavior and the difficulty of

determining the item being consumed. Inability to accurately categorize behavior from video clips can be caused by darkness, obscured lens, positioning of the bear's chin in relation to what it is consuming, and positioning of items being consumed in relation to the camera. Early in the study period, darkness prevented accurate identification of the primary behavior (3 hours and 45 minutes of darkness on 15 May). As the sampling period progressed, the darkness was reduced until 1 June when no sampling periods were lost due to darkness. Snow, water, dirt, and blood sometimes obscured the camera lens preventing determination of the primary behavior. The angle of view due to positioning of the bear relative to the prey item occasionally prevented determination of the prey species. In most situations, it was possible to determine the prey if the prey item was an ungulate calf or adult by considering contrasts in bone size and hair texture. All of the above biases resulted in underestimation of kill rates because the clips classified as unknown are included in non-feeding activity. However, the relatively low proportion of unknown primary behaviors (2.9%) and unknown prey type (2.5%) indicate that the GPS\video technology is robust compared to other methods of detecting and quantifying predation behaviors. Indeed, in spite of these difficulties, I conclude that this technology is far superior to current alternative technologies.

Other sources of bias in estimating kill rates from non-continuous monitoring of brown bears have been identified and discussed by Ballard et al. (1990) and Boertje et al. (1988). These additional sources of bias include the displacement of bears by other

bears, scavenging, and kill sharing. When considering scavenging and displacement by other bears, the method of high frequency (15 minute interval or less) behavior sampling using the video cameras and the associated GPS locations allows for the identification of fresh kills by signs of consumption or decomposition (Table 2.2) and how that relates temporally to arrival at the kill site. With the longest interval between clips having been 15 minutes the bias associated with this method is less than with previous methods of once or twice a day monitoring flights to observe VHF collared bears (a sampling interval of 12-24 hours). Relative to scavenging, Ballard et al. (1981) monitored abandoned moose calf carcasses and partially consumed predated calves and noted that scavenging by bears did not occur within a 30 hour period following death. Kill sharing is difficult to assess with neck mounted cameras, since the image provided by the camera while the bear is feeding would require that another bear sharing the kill be located directly in front of the collared bear to be detected. Of the camera-equipped bears without cubs, 568 clips of other bears were recorded, but only 8 clips classified as feeding contained other bears. Aerial observation is better for assessing kill sharing because it allows the observer to view the marked bear from a distance and see what is in the vicinity of the subject.

In this study, camera collars were deployed at the beginning of the calving season but were either removed or failed by 16 June. This short time frame does not document the entire period of calf vulnerability to predation. Previous studies have demonstrated that ungulate calf mortality is relatively high for the first 6 weeks of life

(Ballard et al. 1981, 1987, Larsen et al. 1989, Boertje et al. 1988, Gasaway et al. 1992, Zager and Beecham 2006, Reynolds et al. 1987, Swenson et al. 2007). The 7 cameras that captured calf mortalities recorded an average of only 23.4 days of footage (11-31), missing any mortalities that occurred later in the season. Expected kill rates on ungulate calves by brown bears were estimated for the spring period ending 30 June, using the calf risk model I developed here. However, brown bears have been documented killing ungulate calves throughout the summer (Boertje et al. 1988), and therefore mortality through 30 June will still underestimate annual calf kill rates.

Conclusions

Predation of ungulate calves by brown bears has been demonstrated to be a limiting factor on ungulate populations (Ballard et al. 1981, Ballard 1992, Van Ballenberghe and Ballard 1994, Boertje et al. 1988, Testa et al. 2000, Franzmann and Schwartz 1986). As such it is important to understand rates at which individual bears kill calves and the variability between individual kill rates. Until recently our ability to detect behaviors of elusive animals has been limited to infrequent observations, radio-telemetry, and GPS location data. These types of observations are not sufficient to provide fine-scale information on diet selection or time allocation of behaviors (Thompson et al. 2012). The method of animal-borne video combined with GPS location data appears to be a robust method to estimate predation rates. The ability to observe the behaviors and associated location information on a short time interval for the entire sample period allows for the assessment of prey handling time and time at kill site,

something previous methods could not do. The ability to detect predation events lasting only minutes appears to be essential, as half of the ungulate calves in this study were handled in less than one hour. The additional behavior and movements data obtained by this method allow researchers to understand mechanisms that relate to ungulate kill rates, such as the time spent feeding on alternative food sources, distribution of food sources, and social interaction with other bears. As this technology evolves and becomes more reliable it will contribute to our understanding of brown bear ecology especially as it relates to diet selection and predation.

The bears in this study were estimated to kill an average of more than 34 ungulate calves in a single spring, which is substantially higher than previous estimates of kill rates. The range of estimated kill rates (8-51) is very large indicating individuals within the population have highly variable predation efficiencies. These factors are important when considering population management of bears and ungulates. Bears in this area clearly impact the ungulate populations; however, the variability in kill rates indicates that indiscriminate bear removal may have variable results on recruitment of ungulate calves, but if high efficiency predators are removed, calf recruitment may increase substantially.

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Figures

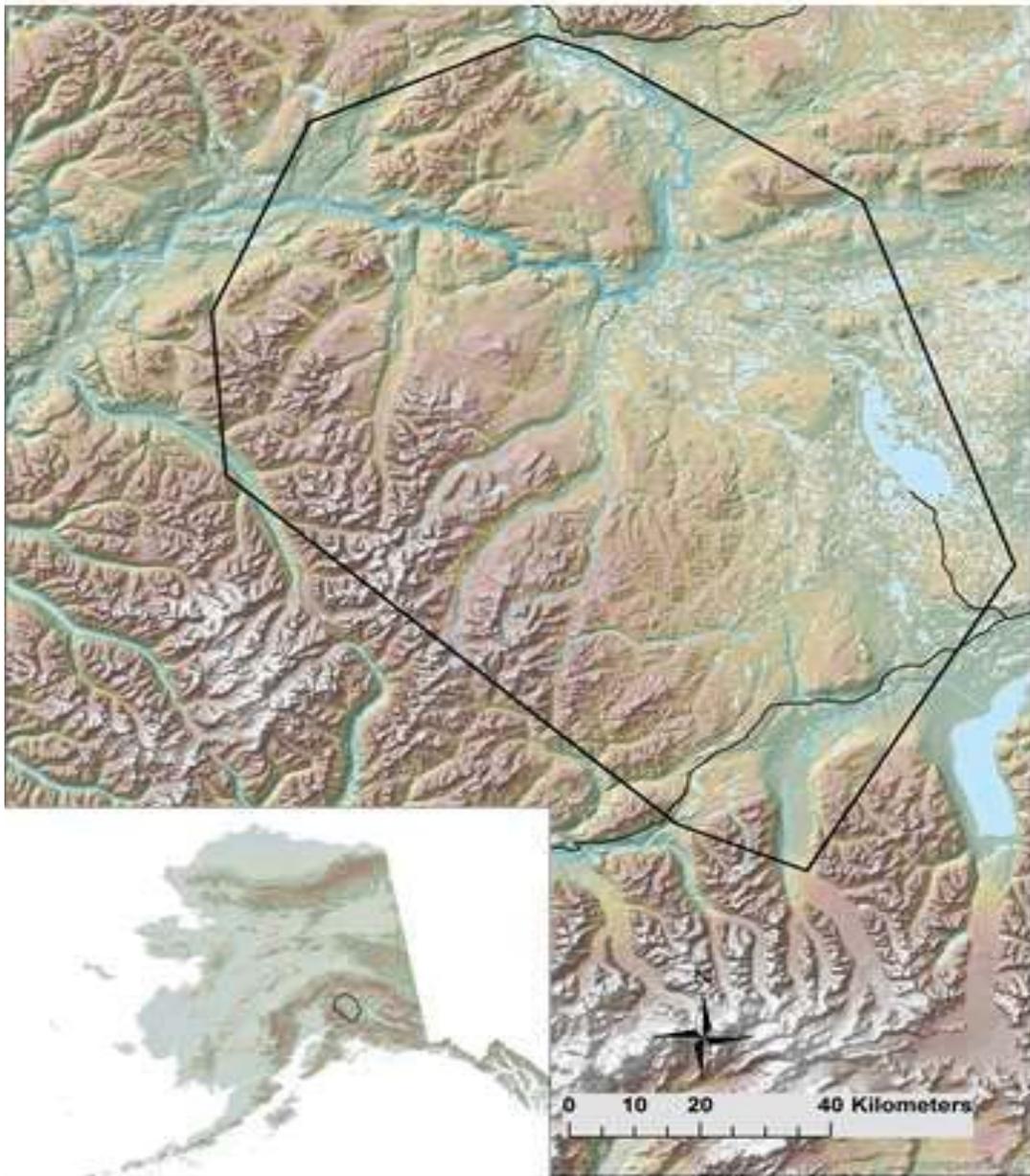


Figure 2. 1. The location and extent of the study area in the Nelchina Basin. The boundary includes the range of all brown bears collared and monitored during the spring of 2011, 2012 and 2013.

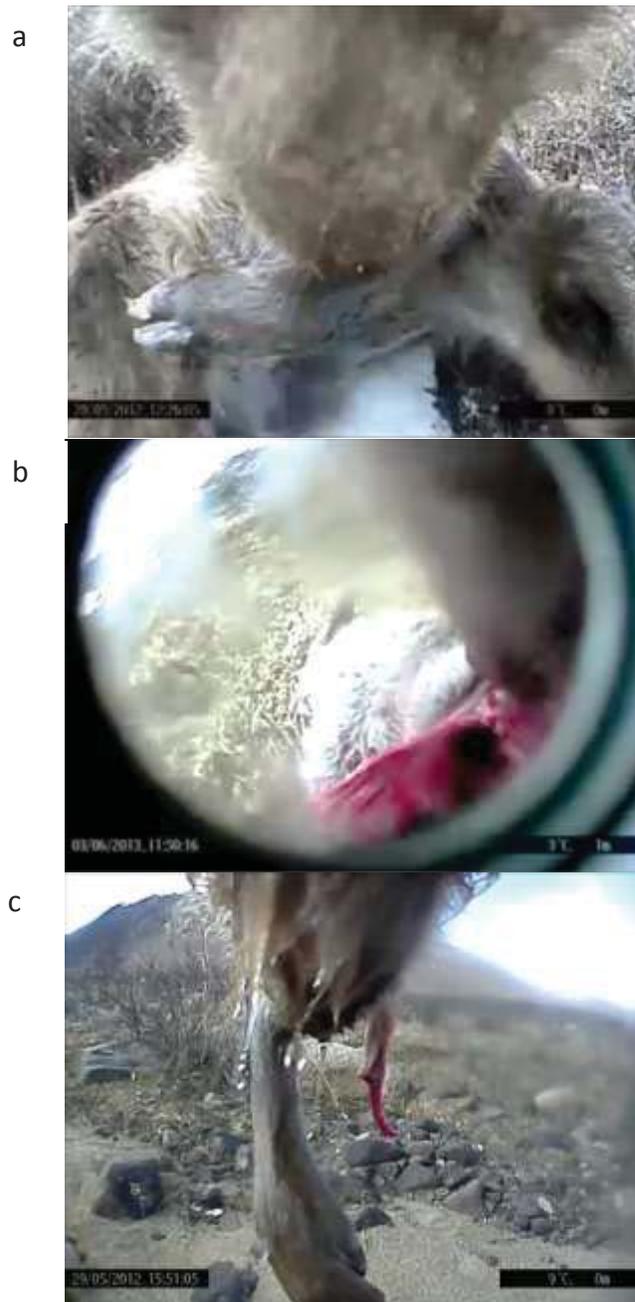


Figure 2. 2. Examples of video images taken during predation events: (a) a live caribou calf soon after capture, (b), a partially consumed caribou calf, and (c), the consumption of a caribou calf leg.

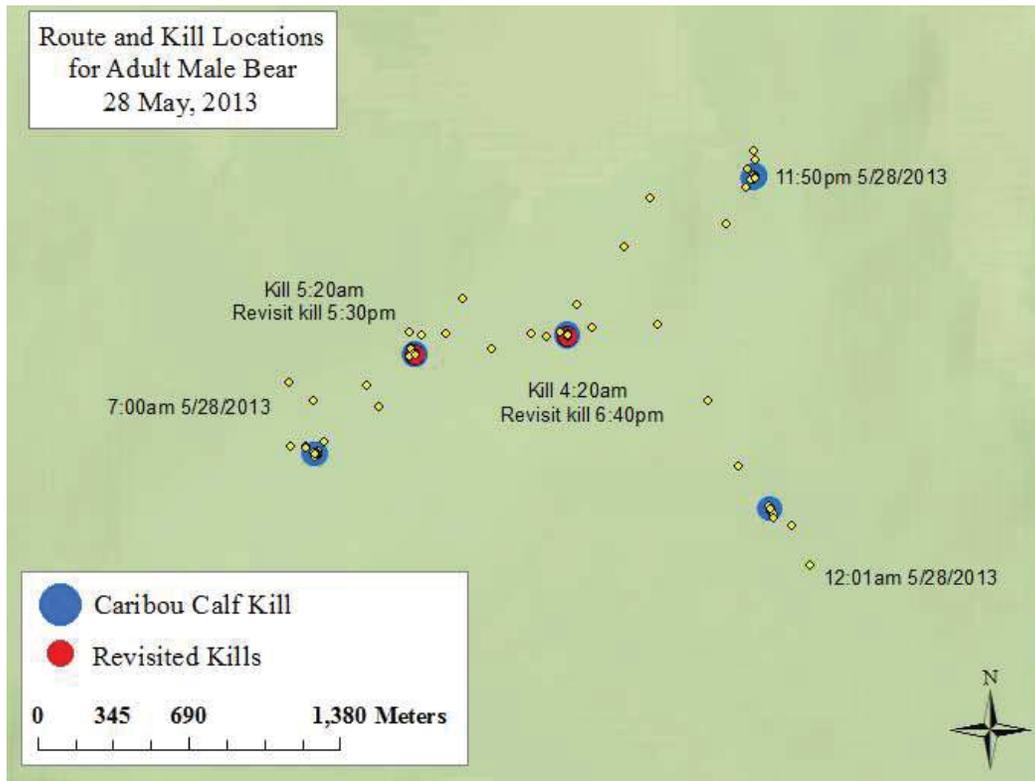


Figure 2. 3. An example of a GPS track of a male brown bear on 28 May, 2013, and the location of calf kills verified by video images. Blue circles indicate ungulate calf kill locations, red circles indicate kill sites that were revisited.

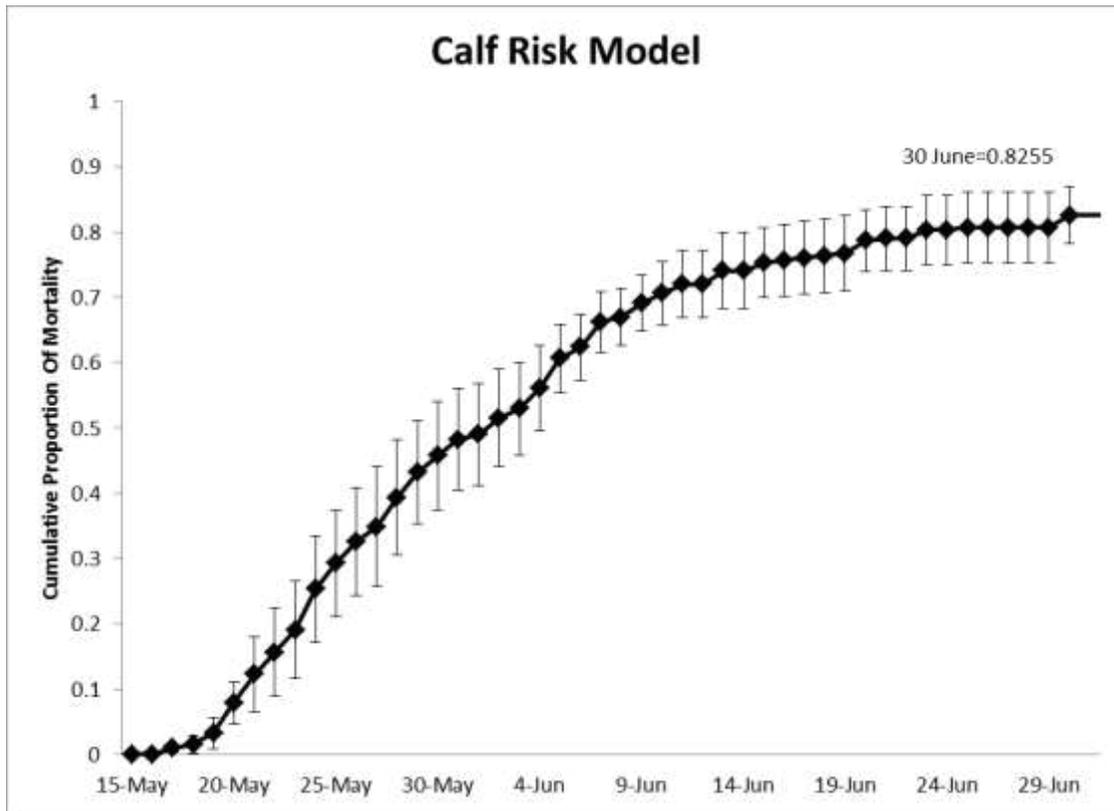


Figure 2. 4. Calf Risk Model describing the cumulative frequency distribution of calf mortality by date for 4 moose calf mortality studies (ADF&G unpublished data) and 2 caribou calf mortality studies (ADF&G unpublished data) with standard errors.

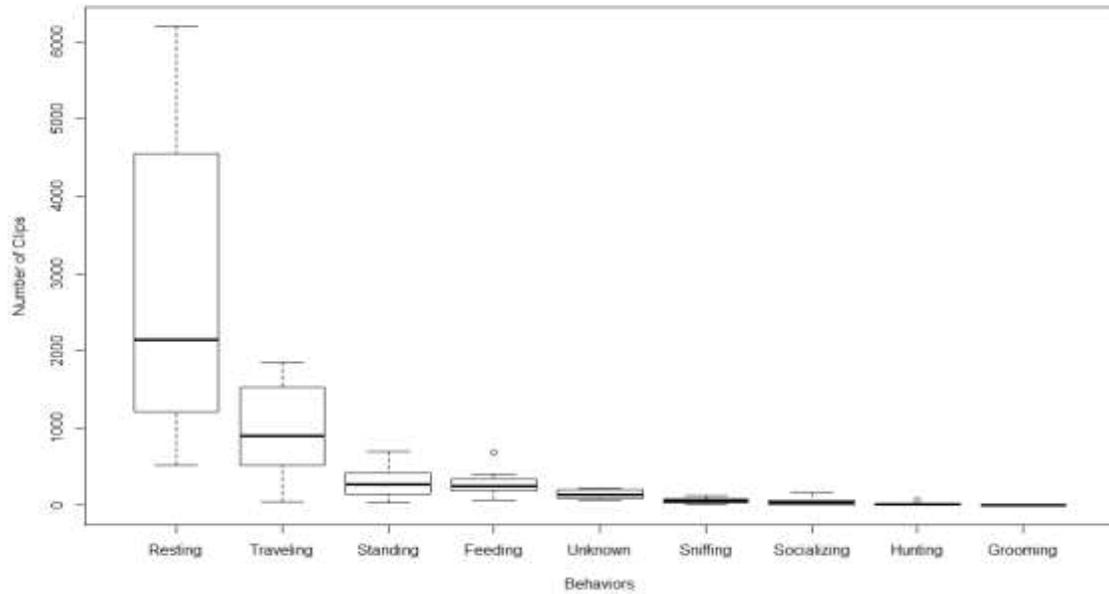


Figure 2. 5. The frequency of each primary behavior for all collared bears that provided adequate clips.

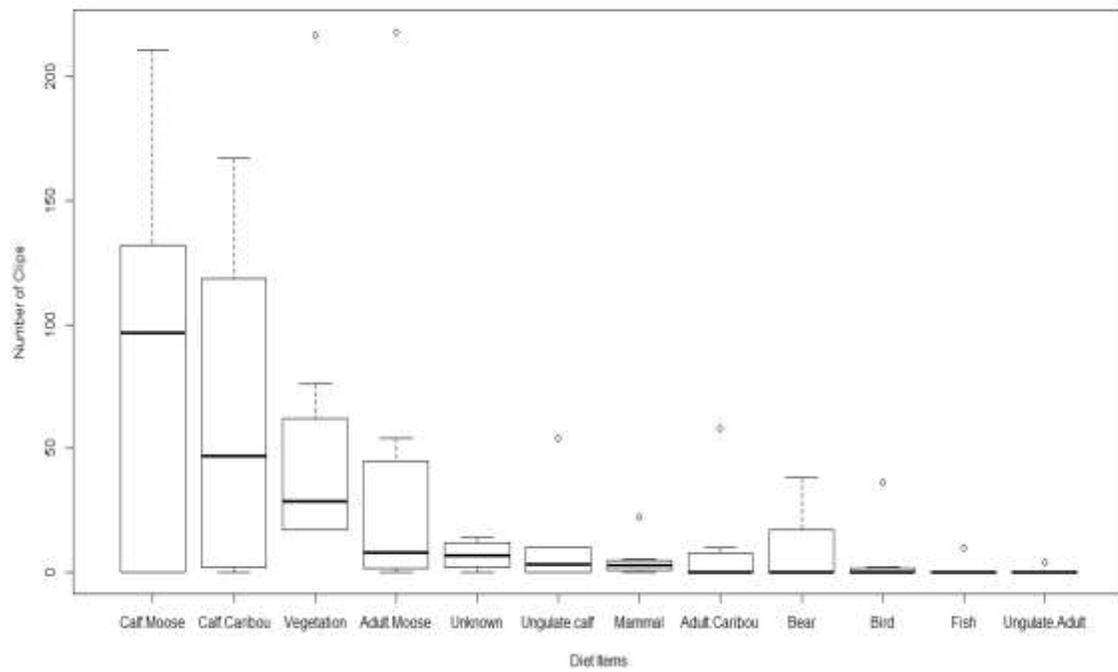


Figure 2. 6. Frequency of feeding behaviors by prey category for all bears.

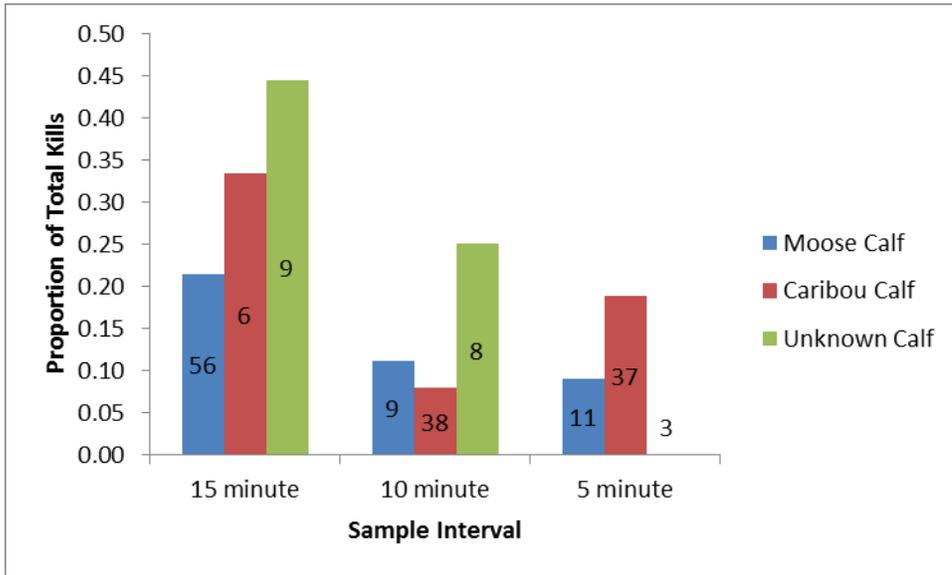


Figure 2. 7. Proportion of kills identified in a single video clip, by species. Number within each bar represents the total number of kills for that species/camera interval.



Figure 2. 8. Image of bear feeding on fresh moose calf carcass. At this kill site, only one GPS point was recorded (15 min. interval between GPS locations) as seen in figure 2.9.

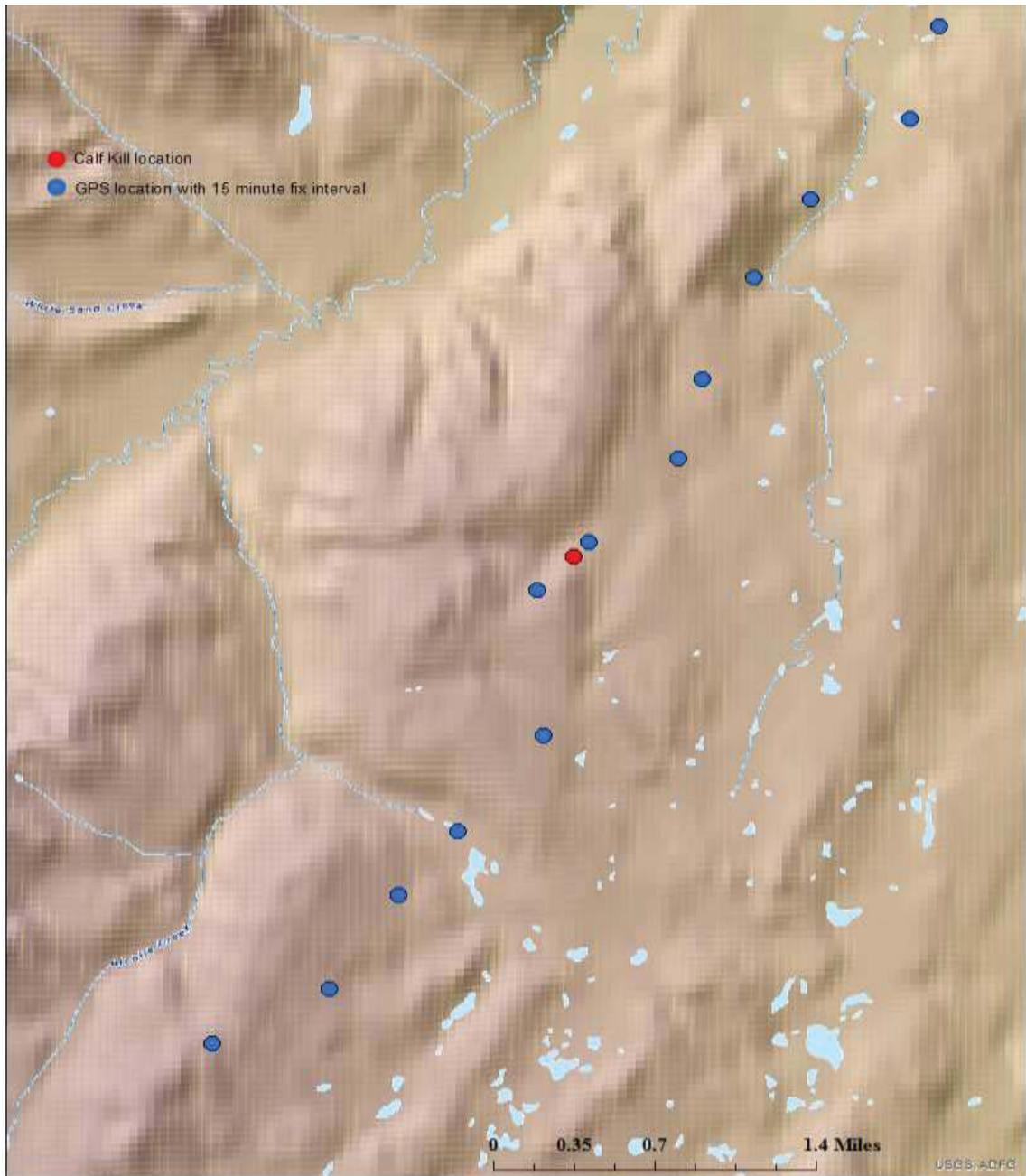


Figure 2. 9. Map of 14 locations (3.5 hours) depicting a lack of any cluster at a kill site. The red dot indicates the kill site from figure 2.8. GPS fix interval was 15 minutes.

Tables

Table 2. 1. The number of camera/GPS collars deployed per year, and their programmed sampling intervals.

Interval	2011	2012	2013
15 Minute	4 (Camera, GPS)	4 GPS	
10 Minute			5 Camera, 9 GPS
5 Minute		4 Camera	4 Camera

Table 2. 2. Visual characteristics used to determine if a carcass was fresh or old from the video clips.

Fresh Carcass	Old Carcass
Live prey	Muscle tissue appears dark maroon
Dead intact carcass no rigormortis	Blood is coagulated and dark
Muscle tissue and blood appears bright pink	Hair is matted, dirty or loose
Bones clean of dirt and wet. Fur clean and unmatted	Bones covered in dirt appear dry
Connective tissue clean and white in appearance	

Table 2. 3. The number of clips recorded and the duration of camera recordings by bear.

	2011_0.950	2011_0.960	2011_0.980	2012_0.950	2013_0.900	2013_0.950	2013_0.970
Date of first clip	5/19/2011	5/17/2011	5/17/2011	5/16/2012	5/15/2013	5/15/2013	5/28/2013
Date of last clip	6/2/2011 ^a	6/17/2011	6/17/2011	6/10/2012 ^b	6/12/2013 ^b	6/11/2013 ^b	6/5/2013 ^b
Total Clips	2022	4436	4456	7261	8020	7587	2594

^a camera failed due to damage caused by bears. ^b cameras failed due to manufacture defect.

Table 2. 4. The number of clips of each primary behavior for each collared bear that provided useable data.

Bear ID	Feeding	Hunting	Traveling	Standing	Grooming	Sniffing	Socializing	Resting	Unknown	Total
2011_0.950	199	0	459	344	0	67	73	778	102	2022
2011_0.960	243	1	799	694	2	95	1	2390	211	4436
2011_0.980	257	22	1687	175	2	127	81	1899	206	4456
2012_0.950	268	29	1850	489	4	34	39	4390	158	7261
2013_0.900	407	14	1008	245	4	53	0	6194	95	8020
2013_0.950	684	69	1358	308	4	76	162	4705	221	7587
2013_0.970	187	10	583	38	2	51	0	1652	71	2594
total	2245	145	7744	2293	18	503	356	22008	1064	36376
Mean	561.25	36.25	1936	573.25	4.5	125.75	89	5502	266	5196.57143
Porportion	6.17%	0.40%	21.29%	6.30%	0.05%	1.38%	0.98%	60.50%	2.93%	100%

Table 2. 5. The number of clips of feeding for each bear by food item.

Feeding Bear ID	Adult Moose	Calf Moose	Adult Caribou	Calf Caribou	Ungulate Adult	Ungulate calf	Bear	Mammal	Bird	Fish	Vegetatio	Unknown	Total
2011_0.95	0	138	5	4	0	10	0	3	0	0	35	4	199
2011_0.96	0	212	0	0	0	4	0	5	0	0	22	0	243
2011_0.98	36	108	10	16	4	2	34	4	2	10	17	14	257
2012_0.95	14	85	0	78	0	0	0	1	1	0	76	13	268
2013_0.90	0	0	0	155	0	0	0	22	0	0	219	11	407
2013_0.95	218	126	58	167	0	54	0	0	36	0	17	8	684
2013_0.97	0	0	0	82	0	10	38	2	0	0	50	5	187
													2245
Mean	38.29	95.57	10.43	71.71	0.57	11.43	10.29	5.29	5.57	1.43	62.29	7.86	320.71
Proportion	11.9%	29.8%	3.3%	22.4%	0.2%	3.6%	3.2%	1.6%	1.7%	0.4%	19.4%	2.4%	100%

Table 2. 6. The number of ungulates killed per bear documented in the video clips. For 2011 the total is corrected for duty cycled cameras by multiplying observed by 1.33.

	2011_0.950	2011_0.960	2011_0.980	2012_0.950	2013_0.900	2013_0.950	2013_0.970
Moose calf Kills	17.29	25.27	30.59	11	0	9	0
Caribou Calf Kills	1.33	0	6.65	30	7	27	11
Unknown Calf	7.98	0	3.99	3	0	6	2
Total calves	26.6	25.27	41.23	44	7	42	13
Adult Moose Kills	0	0	1.33	1	0	2	0
Adult caribou Kills	1.33	0	2.66	0	0	0	0
unknown Adult	0	0	1.33	0	0	0	0
Total Adults	1.33	0	5.32	1	0	2	0
Kill Days	16	31	28	25	27	26	11
Calf Kills/Bear Day	1.66	0.82	1.47	1.76	0.26	1.62	1.18
Adult Kills/bear day	0.08	0.00	0.19	0.04	0.00	0.08	0.00

Table 2. 7. The estimated maximum handling time, measured as the time interval between first clip of a kill and last clip of a kill plus the interval before the first clip and after the last.

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	sample size
Adult Caribou	30	37.5	45	50	60	75	3
Adult Moose	20	95	795	1170	1870	3069	4
Caribou Calf	10	20	40	58.8	60	855	81
Moose Calf	10	32.5	60	201.7	150	2280	75

Table 2. 8. Time at kill site. Represents the time between the first and last GPS locations at a kill site.

	Min	1st Quartile	Median	Mean	3rd Quartile	Max	sample size
Adult Caribou	30	37.5	45	45	52.5	60	3
Adult Moose	105	400	1619	2474	1800	8445	5
Caribou Calf	0	0	20	75.7	60	880	81
Moose Calf	0	15	60	271.8	385	2250	75

Table 2. 9. Average kill rates from 4 published studies of brown bear predation on moose. The average kill rate for this study presented for modeled kill rate through 30 June for calves plus observed adult ungulate kills.

Study	Location	Method	Moose calf kills/Bear	Ungulate Kills/Bear	Moose/Bear Estimate
Boertje 1987	East central AK	Aerial Observation of Bears	5.4 ^a		5.4
Ballard 1981	South Central AK (Nelchina)	Aerial Observation of Bears	1.6 ^b	3.1 ^b	31.3
Swenson 2007	Sweden	Monitored Calves	6.8 ^a		30.7
Rauset 2012	Sweden	GPS clusters from Collared Bears	7.6 ^a		16.6
Brockman	South Central AK (Nelchina)	GPS/Camera Collars	16.2 ^a	35.9 ^a	26.7

^a spring period approximately 20 May-30 June. ^b summer period approximately 20 May-31 October.

Chapter 3: Diversity in brown bear (*Ursus arctos*) diets and landscape use in the Nelchina Basin, south-central Alaska: implications for ungulate predation¹

Abstract

Predator-prey ecology is a central focus of research and management of wildlife in northern systems, especially in Alaska, Canada, and Scandinavia. Brown bears (*Ursus arctos*) have been identified as a major predator on ungulates and especially their calves, possibly exerting a top-down influence on ecosystem function and structure. Delineating the degree of diet variation in the consumption of ungulate prey between individual bears and for individual bears between seasons is important in understanding population processes and the implications of alternative management strategies.

I conducted stable isotope analyses (SIA-¹³C and ¹⁵N) of hair, muscle, fat, and blood taken from radio-collared bears in the Nelchina Basin of southcentral Alaska over a three year-period. I then compared their chemistry to possible prey isotope chemistry to investigate the extent to which individual bears exhibit divergent or similar foraging behavior and the degree to which prey use varies by season and by landscape use patterns. In general, bears in this region extensively utilized the ungulate resources that were available in spring. These bears appear to fall into three different categories of

¹Brockman C. J., Collins W. B., Spalinger D. E., Welker J. M., 2015. Diversity in brown bear (*Ursus arctos*) diets and landscape use in the Nelchina Basin, south-central Alaska: implications for ungulate predation. Prepared for The Journal of Wildlife Management.

feeding behavior: a) those that use primarily ungulates (moose calves or caribou calves), b) bears that consume very little ungulate prey but consume other resources such as vegetation and c) bears that appear to switch and use both ungulate calves and other resources between seasons. Spatial information on habitat and area used by individuals could further refine diet selection information to separate predation on caribou and moose calves, prey which do not appear to be isotopically distinct. SIA could be used to identify individual variation in diet preference and therefore individuals with a propensity to feed on ungulates.

Introduction

Predator-prey interactions are central to the ecology and management of northern systems, especially those in Alaska, Canada and Scandinavia (Adams et al. 2010, Gervasi et al. 2012, Hervieux et al. 2014). Predation on ungulates has consistently been viewed as “top-down” control on ecosystem function and structure as opposed to a “bottom-up” perspective that recognizes the role of habitat in controlling ungulate populations (McArt et al. 2009) and subsequently affecting predators as well. For instance, brown bears (*Ursus arctos*) have been identified as major source of ungulate mortality throughout North America and Scandinavia (Franzman and Schwartz 1986, Ballard and Miller 1990, Gasaway et al. 1992, Boertje et al. 2010, Testa et al. 2000, Swenson et al. 2007, Rauset et al. 2012). While these generalities as to the role of predators in regulation and ecosystem function and structure have elicited considerable discussion and controversy (Graves et al. 2007), research into the individualistic

behavior, landscape use, and diet of predators is only now becoming realized with studies that combine camera, GPS and stable isotope analyses. However, leveraging all three research approaches in the study of large predator ecology has seldom been attempted (Adams et al. 2010, Stanek 2014, Stanek et al. 2015).

Brown Bears are the largest living terrestrial carnivore on earth (Walker 1968). As such they are considered to be dominant factors in population dynamics of their ungulate prey (Reynolds et al. 1987, Boertje et al. 1988, Larsen et al. 1989, Gasaway et al. 1992). The omnivorous nature of brown bears allow them to inhabit a range of habitats from mountainous tundra to lower elevation spruce forests in interior Alaska, and they commonly inhabit coastal zones such as those on Kodiak Island and in Southeast Alaska (Atwell et al. 1980, Johnson 1980). These habitats provide a diversity of diet resources, which include herbaceous material (e.g. berries and tubers), as well as high density protein sources from adults, juveniles and calves of ungulates, primarily caribou and moose in Alaska. In many regions in Alaska, salmon are a temporally abundant but spatially limited prey base (Adams et al. 2010, Stanek et al. 2015). The proportional uses of these prey resources by brown bears have often been uncertain, and seasonal patterns of variability in diet remain to be documented, especially for brown bears in south central Alaska.

Characteristics of a herbaceous diet have been suggested as limiting to the productivity of brown bears (Rode et al. 2001), especially in light of their simple, short

gastrointestinal tract characteristic of carnivores, and their limited ability to digest fiber, as compared to true herbivores (Pritchard and Robbins 1990). Foraging efficiency additionally constrains energy intake by bears consuming berries, roots, and other plant matter (Welch et al. 1997). The temporal and spatial availability of protein rich meat (i.e. caribou and moose in spring and salmon in summer and fall) has been linked to bear size and population density; typically the higher the prey density, the larger the individual bear size and the higher their population densities (Hilderbrand et al. 1999). However, the extent to which individual bears within a population exhibit diet similarities or differences is poorly understood and may be more complex than previously expected, since sex, size, and age may all control predatory behavior. These characteristics may also influence their access to the landscape, and thus affect the temporal and spatial availability of their prey. Therefore quantifying the proportions of terrestrial meat and other possible items in bear diets is important to understanding the population dynamics of both bears and ungulates (Mattson 1997).

Traditionally dietary analysis of free ranging animals has been studied by means of gross fecal analysis, stomach content analysis, and foraging observation (Hatch et al. 2011). Fecal analysis was a common method of nutritional research in quantifying diets of various bear species prior to the late 1990's (Murie 1981, Mattson et al. 1991, McLellan and Hovey 1995). However, fecal analysis misrepresents diet due to the differential disappearance of food items during digestion, especially meat versus vegetation (Hilderbrand et al. 1996, Robbins et al. 2004).

Stable isotope ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) analysis has greatly advanced our understanding of animal nutritional ecology, especially of free ranging wildlife (Tieszen and Boutton 1989, Hatch et al. 2011, Hilderbrand et al. 1996, Milakovic and Parker 2013, Robbins et al. 2004, Hopkins et al. 2012, Stanek 2014, Rogers et al. 2015). It has been successfully applied to brown bear diet ecology (Robbins et al. 2004, Hatch et al. 2011, Hilderbrand et al. 1996, 1999). Stable isotope analysis is a diet forensic tool based on the assumptions that: a) the isotope chemistry of consumers reflects the isotope geochemistry of their diet sources (DeNiro and Epstein 1978); b) prey resources can have markedly different fundamental $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, differences in prey isotope ratios can indeed be a reflection of their trophic level (terrestrial or marine), and the isotope signature in the carnivore will reflect their foraging behavior (Hopkins et al. 2012, Bentzen et al. 2014, Darimont et al. 2009, Stanek 2014) and c) tissues with different turnover times can provide an “isotopic clock” allowing one to estimate the seasonality of diets (Ben-David et al. 1997).

SIA measures the ratio of heavy to light atoms of ($^{13}\text{C}/^{12}\text{C}$; $\delta^{13}\text{C}$), ($^{15}\text{N}/^{14}\text{N}$; $\delta^{15}\text{N}$), and ($^{34}\text{S}/^{32}\text{S}$, $\delta^{34}\text{S}$) in parts per thousand (‰) and reports those relative to a standard (Ben-David and Flaherty 2012). The $\delta^{15}\text{N}$ of animal tissue becomes isotopically enriched (increases) with each trophic level due to the preferential excretion of the lighter ^{14}N in urine and assimilation of the heavier ^{15}N into tissues (DeNiro and Epstein 1981, Peterson and Fry 1987, Mingawa and Wada 1984, Hobson 1992, Gannes et al. 1998). The $\delta^{13}\text{C}$ of an animal’s tissue should reflect the sources of primary productivity, and can be used to

distinguish between marine and terrestrial diet sources (DeNiro and Epstein 1978, Ramsey and Hobson 1991, Hobson and Clark 1992) and may distinguish between browsers and grazers that use C₃ or C₄ plant types (Ambrose and DeNiro 1986, Gannes et al. 1998).

Today there are several other important advances involving the use of stable isotopes in the diet ecology of free ranging animals. First, studies delineating discrimination factors for large carnivores based on captive animals and feeding trials are becoming more abundant (Hilderbrand 1996, 1999, Ben-David 1996, Stanek 2014). Second, these detailed physiological studies have included assessment of tissue turnover time estimates that have led to predictable patterns of isotopic incorporation and the ability to examine wildlife diets over different time scales [i.e. by sampling tissues with different turnover rates (Hobson and Clark 1992, Hilderbrand 1996, Jacoby et al. 1999)]. Third, diet proportion estimates using statistical models are rapidly progressing from simple linear mixing models to Bayesian models that estimate diet proportions when more than two diet sources are possible (Phillips 2012). And forth, the new Bayesian mixing models allow for the inclusion of concentration dependence between prey resources and the use of prior diet estimates from observations and stomach contents (Phillips and Koch 2002).

Dietary reconstruction using mixing models is sensitive to the variance in diet to tissue discrimination values, which can vary by species and tissue type (e.g., hair, serum,

blood clot) (Wolf et al. 2009, Martinez del Rio et al. 2009). Tissue-diet discrimination values can also be prey type dependent (i.e. meat vs. fish) (Caut et al. 2008a). Assigning with confidence a tissue-diet discrimination factor is one of the most important parameters in an isotope mixing model, as it defines the proximity of predator isotope values to that of their prey (Ben-David and Schell 2001). However, even though there have been a range of tissue-diet discrimination factors applied to diet estimates in mixing models, no single value for each species and each tissue type exists today. This leaves some ambiguity in model estimates of prey proportions in carnivore diets (Caut et al. 2009, Milakovic and Parker 2013, Hilderbrand et al. 1996, Felicetti et al. 2003). This ambiguity in discrimination value assignments in diet proportion estimates of free ranging carnivores has, however, been minimized in some instances where feeding trials with captive animals have been undertaken to determine species-specific discrimination factors (Hilderbrand et al. 1996, Stanek 2014). These values can then be used in wild carnivore diet estimates, as did Stanek et al. (2015) with gray wolves in south central Alaska. Using discrimination values from captive animals applied to free-ranging carnivores is likely more robust than using the mean values applied across taxa. However, it is recognized such values may still be in error since captive and wild animals may have different metabolic rates and may be in different physiological condition (Hobson and Clark 1992, Post 2002, Caut et al. 2008b, Vanderklift and Ponsard 2003) thus possibly influencing discrimination. Discrimination values in brown bear plasma can vary more than 3 fold depending on diet (Robbins et al. 2005).

Use of SIA to reconstruct diet relies on understanding the rate at which consumed foods are incorporated into a tissue (i.e. turnover). The turnover rate of a tissue is influenced by the physiological state of the animal, whether the animal is growing or losing weight (Martinez del Rio et al. 2009). Therefore, determining diet from SIA can be complicated if the metabolic or physical state of the animal is changing. For example, after den emergence, brown bears in some areas have been documented to lose fat mass until July (Farley 2003); endogenous fat may thus serve as a pseudo diet source in estimating diet composition in tissues being assimilated (e.g., blood cells). Recognizing the metabolic state of carnivores may be critical to accurately estimating diet composition using stable isotopes.

This study sought to answer four questions about brown bear diet composition:

- a) Are the proportions of terrestrial prey (ungulates) in spring brown bear diets consistent between individuals based on blood $\delta^{15}\text{N}$ & $\delta^{13}\text{C}$ values?
- b) Is there evidence that diet estimates using SIA are consistent in spring, summer and fall based on the $\delta^{15}\text{N}$ & $\delta^{13}\text{C}$ values of sectioned hair samples?
- c) Do the diets of bears with known landscape use patterns and predatory behavior correspond to diets estimated by blood and hair SIA?
- d) Can known diet proportions (i.e. based on video camera footage) be used to guide the selection of sources for inclusion in mixing models, including endogenous sources and the evaluation of discrimination value selection?

Methods

Study Area

This study was conducted in the Nelchina Basin, Alaska, an area covering approximately 11,200 sq km, 70 km northwest of the town of Glennallen (Figure 2.1). Located within Alaska Department of Fish and Game (ADF&G) Game Management Unit (GMU) 13A. The climate is characterized by cold winters and warm summers (average high 19.0°C, average low -29°C) and annual precipitation averaging 28.4cm (Walton et al. 2013).

The topography is composed of high alpine habitat in the west (Talkeetna Mountains) with peak elevations exceeding 2,100 meters, and lower elevation spruce forest in the east. Drainage is either north into the Susitna River or south into the Nelchina River. The lower elevation spruce forest has many lakes and small ponds. Plant communities along the rivers and streams are dominated by riverine willows (*Salix alexensis*, *S. hastata*). The forest is dominated by white spruce (*Picea glauca*) and black spruce (*P. mariana*) with a shrub understory of dwarf birch (*Betula nana*). The sub alpine areas are comprised of dwarf heath (*Cassiope spp.*, *Empetrum Spp.*, *Ledum spp.*, *Vaccinium Spp.*, and *Arctostaphylos spp.*) (Ballard et al. 1987). Other common vegetation types scattered throughout the study area are Alder (*Alnus crispa*), willow (*Salix spp.*), and sedges (*Cyperaceae*). The topography, climate and vegetation of the study area are described in more detail by Skoog (1968).

Bear Capture

Brown bears were captured by darting from a helicopter (4 in 2011, 4 in 2012 and 9 in 2013) 15-17 May, a time period when bears have recently emerged from winter hibernation. The bears were recaptured and the collars recovered between 17-29 June in the same year as deployment. Bears were anesthetized with 5mg/kg of Telazol[®] (Fort Dodge Laboratories, Inc., Fort Dodge, IA). The sex of the captured brown bears was determined, and they were inspected for lip tattoo identification numbers from previous captures. If they were not tattooed, a tattoo identification number was applied to the upper lip and a pre-molar tooth was extracted for aging. Two full 3ml (lavender cap) K²EDTA blood vials were collected from the femoral vein and guard hair samples were collected from the shoulder. Blood samples were centrifuged for 15 minutes within 48 hours of collection. Plasma and red blood cells were pipetted into separate vials. All collected tissues were kept frozen until processing for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values.

In 2013, muscle and fat biopsies were also collected from the front shoulder, anterior of the spinous process of the scapula using a 6mm biopsy punch. Blood and hair samples from an additional 21 bears were collected as part of an ongoing ADF&G project in the same area and provided for stable isotope analyses. Bears were administered antibiotics and allowed to recover. All animal handling and sampling protocols reported in this paper complied with the current law and was approved by the

appropriate ethical committees (UAA IACUC -IRBNet ID #462094-1, IRBNet ID #462079-1 and ADF&G ACUC Protocol No. 2013-11) (Appendix B).

Each bear was fitted with a Lotek Wireless™ GPS_3300 collar equipped with a digital camera (Lotek Wireless Inc., Newmarket, Ontario, Canada). The GPS_3300 collars had a location accuracy of 5-10m 95% of the time. The sampling interval in 2011 was selected without prior information on handling time and was chosen based on 28 hours of available camera battery life. The sampling intervals were adjusted in subsequent years to evaluate the effects of interval selection on estimates of kill rate and handling time. In 2011, camera collars were programmed to record a 10 second clip every 15 minutes and a GPS location every 15 minutes. The camera programming included a duty cycle of 18 hours on and 6 hours off. The 6 hour off period was different for each collar (12:01am-6:00am, 6:01am-12:00pm, 12:01pm-6:00pm and 6:01pm-12:00am). Duty cycles were only used in 2011. In 2012, the collars were programmed to record a 10 second clip every 5 minutes and a GPS fix every 15 minutes. In 2013, four collars were programmed to record a 10 second clip every 5 minutes and a GPS fix every 10 minutes, and five collars were programmed to record a 10 second clip every 10 minutes and a GPS fix every 10 minutes (Table 2.1).

The collars were store-on-board devices for both the video and GPS data. The collared bears were recaptured at the end of the programmed life of the camera and the collars were recovered. A second set of tissue samples were collected at the time of collar recovery. The collars were returned to the manufacturer for downloading of

digital video clips and GPS data. Video clips were processed by sorting into a single video montage for each day of footage using IMTOO™ video processing software.

Isotope Analysis

Identifying brown bear prey using stable isotopes requires measurements of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of potential prey resources. Prey muscle from spring moose (*Alces alces*) and caribou (*Rangifer tarandus*) calves was provided by the Alaska Dept. of Fish & Game (ADF&G) and was collected as part of ongoing calf mortality projects. Adult moose and caribou muscle samples were collected from hunters who harvested animals in the fall throughout the eastern region of the Nelchina Basin (10 August – 25 September). Three willow ptarmigan (*Lagopus lagopus*) and 1 arctic ground squirrel (*Spermophilus parryii*) were also donated by hunters and processed for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements. Blueberries (*Vaccinium uliginosum*), crowberries (*Empetrum nigrum*) and low bush cranberries (*V. vitis-idaea*) were collected in early October 2013.

Blood samples were freeze-dried and were ground into a fine powder and homogenized using a bead beater. Berries were air dried and ground to a fine powder using a bead beater. Muscle and fat samples were washed with distilled water; freeze dried, ground into a fine powder and homogenized using a bead beater (Ben-David et al. 1997). Hair samples were cleaned of surface oils and contaminants using 2:1 chloroform: methanol solution and placed on a shaker plate for 24 hours. Samples were then rinsed with distilled water, and oven dried at 50 °C (Hobson et al. 2000). Hair

samples were sectioned into thirds (3mm per section), where the tip portion represents growth contributed in spring (i.e., the spring diet) (May-June), the middle section represents the summer (July-August) and the base represents the fall (September-August) assuming constant growth rates typical of healthy bears (Jacoby et al. 1999).

All samples were weighed (1mg of hair, blood, muscle and fat; 5.5-6.5mg vegetation) into tin capsules (5 mm X 8 mm; Costech, Valencia, CA, USA) for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were determined using a Costech ECS 4010 (Costech Inc., Valencia, CA, USA) coupled to a Thermo-Finnigan Delta V Advantage mass spectrometer (Thermo Fisher Scientific Inc, Waltham, MA., USA) at the Environment and Natural Resources Institute Stable Isotope Facility at the University of Alaska Anchorage, Anchorage, AK, USA. Standards were included in each batch run of 40 unknowns that were comprised of peach leaves, methionine, BWBII (baleen), and moose blood. Values for the standards were -25.89, -34.58, -18.37 and -28.24 $\delta^{13}\text{C}$, 1.9, -0.94, 14.44, and 2.22 $\delta^{15}\text{N}$ respectively. Standard deviations for $\delta^{13}\text{C}$ were 0.1 per mil and 0.3 per mil for $\delta^{15}\text{N}$.

The mixing model, Stable Isotope Analysis in R (SIAR), described by Parnell et al. (2008) was used to determine the most likely (mode) proportions of vegetation and terrestrial meat in diets of brown bears (Table 3.1). Salmon was not included as a source due to the lack of available of salmon in the spring season, extremely limited salmon spawning in the study area, and neither camera footage or bear isotopic

signatures indicating its use. Included in the model for blood samples was endogenous fat as a source with no discrimination. Mobilization of fat may incur some discrimination after triglycerides are processed in the liver; however, estimates of this discrimination were not available from the literature. Endogenous fat was used as a C source for blood isotope values as it would be transported in the plasma and incorporated in the blood clot. Endogenous fat was not considered a source for hair because hair is composed almost entirely of keratin (after the methanol: chloroform wash). The mixing model SIAR uses Bayesian inference to determine probability distributions for a given set of diet sources. Diet proportion models were run for each individual bear for blood serum, blood clots and hair.

Multiple iterations of the model were run on samples from bears with dietary information from the cameras to evaluate the choice of discrimination values found in the literature (Hilderbrand et al. 1996, Post et al. 2002, Ben-David et al. 1997, Caut et al. 2009). Discrimination values that produced diet proportion estimates most closely matching the diet proportions observed in the video footage (n=7) were selected as the most appropriate values and were applied to the samples from the bears that did not have any associated prior diet selection information (i.e. no cameras).

Landscape Use

GPS data were recovered from the collars after collar removal from the bears, and the data were entered into ArcMap for spatial analysis. The high frequency location

data were analyzed for each bear to determine spring home range by use of minimum convex polygon (MCP) (Dahle and Swenson 2003). Ungulate calf kills were determined from the video footage and linked to the associated GPS locations (Chapter 2). Ungulate calf kill locations were sorted by species and examined for habitat parameters such as elevation that could be used to identify species by location.

Results

Source Isotope Values

Isotopically characterized prey resources, including the most prevalent ungulate species available in the area (--adult and calf moose and caribou) -- as well as other terrestrial prey (--arctic ground squirrel, willow ptarmigan, etc.)-- that may have comprised a portion of the bears' diets (Table C 1). In the Nelchina area moose calves were enriched in $\delta^{13}\text{C}$ values and depleted in $\delta^{15}\text{N}$ values compared to adult moose, while caribou calves were enriched in $\delta^{15}\text{N}$ values compared to adult caribou (Figure 3.1). The enrichment in $\delta^{15}\text{N}$ for caribou calves has been reported in the literature but the depletion for moose calves has not (Jenkins et al. 2001). Because sample sizes for all terrestrial prey were small, isotopic differences between species and prey types could not be tested for significance. Hence, all terrestrial prey isotope values were grouped into one category 'terrestrial prey' for diet analysis. Terrestrial prey (n=22) values ranged from -0.07 to 2.6‰ for $\delta^{15}\text{N}$ (mean \pm SD: $1.5 \pm 0.85\%$) and from -25.75 to -23.52 ‰ for $\delta^{13}\text{C}$ (mean \pm SD: $-24.53 \pm 0.57\%$). Plant foods (n=30) were depleted in both $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ relative to terrestrial prey. Vegetation values ranged from -9.16 to -0.15‰ for

$\delta^{15}\text{N}$ (mean \pm SD: $-5.19 \pm 2.13\text{‰}$) and from -29.68 to -25.60‰ for $\delta^{13}\text{C}$ (mean \pm SD: $-27.34 \pm 1.01\text{‰}$). Although terrestrial prey and vegetation were not distinguishable by species, vegetation and terrestrial prey were isotopically distinct from each other $\delta^{13}\text{C}$ (Welch t-test: $t=-11.8$, $p=6.172 \times 10^{-16}$) and $\delta^{15}\text{N}$ (Welch t-test: $t=-15.6$, $p=2.2 \times 10^{-16}$). These sources are also distinct from potential marine sources (salmon) $\delta^{15}\text{N}$ (mean \pm SD: $-12.43 \pm 0.10\text{‰}$) and $\delta^{13}\text{C}$ (mean \pm SD: $-20.67 \pm 0.12\text{‰}$) (Stanek 2014).

Consumer Isotope values

Isotopic values for bear tissue varied by tissue type and by sampling date. Overall, May plasma and blood clot $\delta^{15}\text{N}$ values (plasma mean \pm SD: $6.5\text{‰} \pm 0.8\text{‰}$, Blood Clot mean \pm SD: $5.6\text{‰} \pm 0.6\text{‰}$) were not significantly different when compared to June $\delta^{15}\text{N}$ values (plasma mean \pm SD: $6.5\text{‰} \pm 0.9\text{‰}$, Blood Clot mean \pm SD: $5.3\text{‰} \pm 0.7\text{‰}$). May plasma and blood clot values (plasma mean \pm SD: $-24.6\text{‰} \pm 0.8\text{‰}$, Blood Clot mean \pm SD: $-24.1\text{‰} \pm 0.4\text{‰}$) were depleted in $\delta^{13}\text{C}$ when compared to June samples (plasma mean \pm SD: $-23.3\text{‰} \pm 0.4\text{‰}$, Blood Clot mean \pm SD: $-23.6\text{‰} \pm 0.4\text{‰}$). Mean 2011 $\delta^{15}\text{N}$ values for June plasma (7.0‰) were significantly enriched from mean June plasma samples from 2012 and 2013 combined (5.9‰) (Welch t-test: $t=3.82$, $p<0.002$). Stable isotope values of hair varied between the tip, middle, and base of the hair. Mean values of all sampled bears hair were as follows: hair tip mean \pm SD: $4.7\text{‰} \pm 0.5\text{‰}$ $\delta^{15}\text{N}$ and $-22.0\text{‰} \pm 0.4\text{‰}$ $\delta^{13}\text{C}$, hair middle mean \pm SD: $4.5\text{‰} \pm 0.6\text{‰}$ $\delta^{15}\text{N}$ and $-22.4\text{‰} \pm 0.6\text{‰}$ $\delta^{13}\text{C}$, and hair base mean \pm SD: $4.7\text{‰} \pm 0.5\text{‰}$ $\delta^{15}\text{N}$ and $-22.3\text{‰} \pm 0.4\text{‰}$ $\delta^{13}\text{C}$ (Figure 3.2). Bear fat values were depleted in $\delta^{13}\text{C}$ in May samples (mean \pm SD: $-28.1\text{‰} \pm 1.8\text{‰}$)

compared to June samples (mean \pm SD: $-25.7\text{‰} \pm 2.8\text{‰}$) but did not differ significantly in $\delta^{15}\text{N}$ values between May (mean \pm SD: $5.6\text{‰} \pm 0.4\text{‰}$) and June (mean \pm SD: $5.4\text{‰} \pm 0.5\text{‰}$). Bear muscle values did not differ significantly between May (mean \pm SD: $5.8\text{‰} \pm 0.4\text{‰}$ $\delta^{15}\text{N}$, $-25.0\text{‰} \pm 1.2\text{‰}$ $\delta^{13}\text{C}$) and June (mean \pm SD: $5.6\text{‰} \pm 0.30\text{‰}$ $\delta^{15}\text{N}$, $-23.5\text{‰} \pm 0.4\text{‰}$ $\delta^{13}\text{C}$).

Spring Dietary Proportions

The most likely (mode) dietary proportions of terrestrial prey for the camera-collared bears estimated from the blood clot, ranged from 42% to 65% (Figure 3.3). The 95% credible intervals ranged from 21% to 91% (Figure 3.3). The remaining dietary proportions of vegetation and endogenous fat had 95% credible intervals that ranged from 0 to 56% for all bears except one whose credible interval for endogenous fat ranged from 5% to 56% (Figure 3.3). There was no difference in most likely proportion of terrestrial prey in the diet between sexes (Welch t-test: $t=1.06$, $p=0.32$) based on the June blood clot samples.

Seasonal Dietary Proportions

Seasonal diets determined from segmented hair indicated that overall terrestrial prey was highest in the spring (mean: 86%) and lower in the summer (mean: 74%) and fall (mean: 74%) (Figure 3.4). Contrasts of seasonal diet selection for individuals are however, demonstrated by three bears (ID 1, 12, and 13) (Figure 3.4). Bear 1's diet was estimated to be more than 90% terrestrial prey in spring and summer and 86% for fall.

The most likely proportion of terrestrial prey in the diet of bear 12 varied between seasons: 70% in spring, 89% in summer and 70% in fall. The diet of bear 13 is indicative of bears with "low" terrestrial meat in their diets, with terrestrial prey being only 58% in spring 53% in the summer and 58% in the fall. Bear 1 and 2 are the same bear, sampled in 2011 and 2013. Although this is only a single measure of the variance in inter-annual diets, it indicates that diet selection is relatively consistent between years; approximately 90% of the diet of this bear was terrestrial prey in all seasons (Figure 3.4) in both years. Collectively, bear diets exhibit three main patterns: a) bears with consistently high terrestrial prey consumption, b) bears that show diet switching between spring, summer and fall and c) bears with consistently low terrestrial prey consumption across all three seasons.

Landscape Use

Daily movement patterns and landscape use were summarized for each GPS-collared bear using the MCP estimator. In spring, the area used/day by an individual averaged 34.5 km²/day and ranged from 8.5-111.2 km²/day (Figure 3.5-3.12). There was a significant difference in average area used/day by sex; male=58.5 km²/day and female =17.7km²/day, Welch t-test: t=2.89, p=0.032, (Figure 3.13). There was no correlation between area used/day and the estimated proportion of terrestrial prey in the diet for all bears combined, (Figure 3.14), or bears by sex (Figure 3.15).

Nelchina moose and caribou generally calve in different habitats, with caribou calving at higher elevations. Thus, I expected that kill sites for the two prey would likely differ in elevation. Indeed, elevation of caribou calf kills between 2011-2013 was significantly greater than that of moose calf kills (Welch t-test: $t=-5.03$, $p<0.001$), with mean elevation of moose calf kills occurring at 949 meters and mean elevation of caribou calf kills occurring at 1124 meters. The highest elevation of a confirmed moose calf kill occurred at 1201 meters and the highest caribou calf kill occurred at 1709 meters, the median kill elevation for caribou calves was 1090 meters and the 3rd quartile for moose calf kills was 1090 meters (Figure 3.16). Low sample sizes prevented the testing of year as a factor for elevation of kill.

Comparison of SIA vs Camera Diet Compositions

Patterns of diet selection observed in camera footage were reflected in dietary estimates from SIA (Figure 3.17, 3.18, and 3.19). Excluding bear #6 (due to mismatch in diet sampling periods) in Figures 3.17 and 3.18 from the regression (Figure 3.19) the correlation between the two methods was 0.88. Although the general pattern was coherent, estimates of terrestrial prey composition from SIA were consistently lower than observed in camera footage. Stable isotope values for bear blood fell to the left of the mixing space created by sources from terrestrial meat and vegetation (Figure 3.20) indicating an additional isotopic source to the blood. Both of these discrepancies can be explained by the inclusion of endogenous fat as this source.

Discussion

Diets and landscape use by the brown bears sampled and collared in this study indicate that the diets of Nelchina bears can be quite different among individuals (Figure 3.4). In addition to variability in diet, the landscape use of these bears was quite different among individuals as well (Figure 3.5-3.15). While some individuals exhibit very consistent diets among seasons, collectively the bears from this study depict classic omnivory (Terrestrial Prey mean \pm SD: spring = $86\% \pm 12\%$, summer = $74\% \pm 17\%$, fall = $73 \pm 14\%$) which likely reflects the population (Mowat and Heard 2006). Approximately 30% of the sampled bears in this region were consistently consuming (>80%) terrestrial prey (caribou and moose calves) in spring, summer and fall and hardly deviated from this pattern and behavior between years. However, other bears (~8%) exhibited diet preferences that consistently included a large proportion of vegetation (>40%), and most bears (60%) were diet switchers, exhibiting seasonally divergent diet preferences (Figure 3.4).

Terrestrial prey could not be distinguished at the species level by SIA because of low sample sizes of isotopic values of the primary meat resources (moose and caribou). Bears that were consistently terrestrial meat eaters were exploiting the abundance of caribou and moose calves in this region of Alaska, in agreement with conclusions about prey selection from past and recent studies (Ballard et al. 1990, Testa 2004,) and from our video camera observations (Chapter 2). Similar patterns in diet proportions of terrestrial meat were seen in camera footage and SIA. These similarities provide

corroboration for the methods as independent tools for assessing diet. Further use of the cameras in conjunction with SIA could be used to refine these estimates possibly to the species level, particularly if the species are isotopically distinct.

There is ample documentation of brown bears feeding extensively on ungulate calves in the spring period when calves are highly vulnerable to predation, supporting our findings here (Ballard et al. 1981, Ballard et al. 1990, Ballard 1992a, 1992b, Van Ballenberghe and Ballard 1994, Boertje et al. 1988). In addition, summer predation by brown bears on moose and caribou adults and calves has been documented, but reported kill rates are relatively low (Ballard 1992a, Boertje et al. 1988). Separating the terrestrial meat source of brown bears into diet proportions consisting of moose or caribou may be possible in the future using compound specific approaches (Fogel and Tuross 2003) combined with additional behavior from camera collars and location data or inclusion of fatty acid analyses to accompany the stable isotope information (Williams and Buck. 2010, Iverson et al. 2004). Separating brown bear terrestrial prey into moose and caribou may provide important insight about diet preferences and how predators may respond to inter-annual variation in the timing, the location, and the density of caribou and moose in this region.

Significant differences in the size of spring use areas existed between males and females (Figure 3.13) but there was no significant difference in the estimated proportions of terrestrial prey in their diets in comparison to landscape use. Size of area

used did not correlate to proportion of prey consumed (Figure 3.14) even within a sex (Figure 3.15). This suggests that distance traveled or area covered did not increase consumption of terrestrial prey. Given that the MCPs often overlapped (Figure 3.5, 3.7, 3.9, and 3.11) the density of prey should not have been the driving factor in increasing area used. The lack of increase in prey consumption with larger area coverage indicates that searching for prey is not the motivation for movement by these bears. Other factors such as the search for mates or avoidance of neighboring territories may be what drives landscape use by bears.

The spatial analysis of kill locations revealed that caribou and moose calf kills overlapped in elevation but there was a tendency for brown bear kills at the higher elevations to be of caribou whereas kills at lower elevations tended to be of moose (Figure 3.16). Therefore elevation information for bear movement and kill locations could possibly guide the interpretation of dietary analysis in regards to source species assignment (i.e. caribou or moose). For example the western portion of the study area is higher elevation alpine-dominated habitat and the eastern portion of the study area is lower elevation spruce forest with many small lakes and ponds. Bears using elevations primarily over 1200m are likely focusing on hunting caribou, and bears who occupy the eastern lower elevation portion of the study area may be more generalist or focused on hunting moose calves.

In addition to moose and caribou, other terrestrial meat sources exist in the Nelchina Basin, including Dall's sheep (*Ovis dalli*), beaver (*Castor canadensis*), arctic ground squirrels (*Spermophilus parryii*), three species of ptarmigan (*Lagopus spp*), snowshoe hare (*Lepus americanus*), insects, and many species of migratory birds, which could contribute to the terrestrial prey proportions of the diets in all seasons. This area (GMU13A) also supports heavy human harvests of moose (5yr average 265) and caribou (5yr average 655) each fall (ADF&G unpublished data) providing the potential for scavenging of carcasses by brown bears in the fall. Marine food sources are not likely to contribute significantly to bear diets in this study area as salmon runs are limited (ADF&G 2011).

Bears that switched diets seasonally (5, 6, 7 & 8) exhibited a very high proportion of terrestrial prey in their spring diet (Figure 3.4), but meat in their diets declined in summer. However, meat consumption increased in fall for several of these individuals (5, 7 & 8), while one individual's diet (6) further decreased its consumption of meat in the fall. Diet switching may be in response to several facets; (1) the vulnerability of prey such as moose and caribou calves declines as these individuals age and become much more mobile (Ballard et al. 1981), (2) the abundance of alternative food resources increases as vegetation growth reaches its maximum in mid-summer (Nielson et al. 2004, Elgmork and Kaasa 1992) and becomes more accessible across the landscape as snow bed patches become completely snow free (Borner et al. 2008), (3) the abundance of

berries increases in late summer, and (4) carcasses of hunter killed moose and caribou increase in the fall.

The methods used in this study to examine diet, landscape use and behavior provide a means by which we can, for the first time, cross-calibrate foraging behavior (camera footage) with integrative measures of diets for a free-ranging carnivore in Alaska. In this study, the selection of discrimination factors from the literature was guided by using the values that produced diet estimates most closely matching diet proportions for the same bears as recorded on camera (Chapter 2). This cross-calibration provided a higher level of confidence in the modeled diet estimates for those bears that did not have camera data but did have GPS collars and were sampled for isotopic analysis (~50% of the total bears sampled in the study).

Proportional diets determined from SIA of blood clot reflect general patterns seen in the camera footage (Figure 3.17, 3.18, and 3.19). Terrestrial prey consumption of individuals 1-3 in Figure 3.18 appear elevated relative to individuals 4-7. This is likely a result of sampling bias, as bears 1-3 were captured in 2011 and sampled on 17 June, while bears 4-7 were captured in 2012 and 2013 and sampled on 29 and 26 June, respectively. This shift in the sampling date of the latter bears away from the period of peak calf vulnerability could result in reduction in the estimated proportion of terrestrial prey in the diet. The disagreement in the diet estimates of bear #6 in Figures 3.17 and 3.18 is likely due to an additional problem associated with temporal mismatch of

camera and isotopic data. In this case, bear #6's camera prematurely failed on 10 June but was not samples for SIA until 26 June. The June blood clot samples should reflect the diet of the previous 45-60 days (Hilderbrand et al. 1996 Roth and Hobson 2000) - similar but not identical to the period of sampling from the cameras. In addition, the camera footage reflects what the bears consumed in proportions of clips, which does not necessarily correspond precisely with volume consumed or more importantly digested (Chapter 2). These factors likely influenced the relationship between SIA dietary proportions and those obtained from the camera footage. An additional factor that could cause mismatch in camera versus SIA estimates is a significant switch in diet that was not captured by the camera due to premature failure of the camera. This may explain bear #6 from Figures 3.17 and 3.18.

The cameras sampled consumption of prey, and obviously could not provide information regarding endogenous resource use (fat or protein). Blood isotope values fit within the mixing space when endogenous fat was included as a potential source (Figure 3.20). We did not take any measures of body fat or weights of bears but did notice that bears appeared generally thinner in June captures than they had in May captures. In 2013 bear fat isotope values shifted in their $\delta^{13}\text{C}$ values between May and June. Additionally, Farley (2003) found that brown bears in GMU 13 lose fat mass between den emergence and the end of June, further suggesting the importance of an endogenous source to the spring blood sample isotope signatures. The use of endogenous fat and incomplete sampling may explain the discrepancy in the very high

use of terrestrial prey (>90% in the camera footage for bears 2, 3, and 6) versus the lower estimates of most likely prey consumption (<70% in the SIA for bears 2, 3, and 6) (Figure 3.17 and 3.18).

There were several nuisances in our data of diets, landscape use, and behavior that are worthy of discussion. In particular, the June plasma samples of three of the brown bears sampled in 2011 were significantly enriched ($p < 0.05$) in $\delta^{15}\text{N}$ (mean: 8.31‰) compared to the remaining bears sampled in June of 2011 (mean: 6.6‰) and significantly enriched ($p < 0.04$) in $\delta^{15}\text{N}$ from all other bears (mean: 6.2‰), sampled in June 2011, 2012, and 2013 combined (Figure 3.20). The bears included a 10-year-old male equipped with a camera collar (7.5‰ $\delta^{15}\text{N}$), a 22 year old female (8.45‰ $\delta^{15}\text{N}$), and a 7 year old male (8.99‰ $\delta^{15}\text{N}$). These enriched values of $\delta^{15}\text{N}$ produced estimates of very high consumption of terrestrial prey in the mixing model SIAR, and fell outside of the mixing polygon of terrestrial prey, vegetation, and endogenous fat. From the camera footage, we determined that the 10-year-old male (bear #3 in Figure 3.18) consumed very high proportions of terrestrial meat. However, similar levels of terrestrial prey consumption were observed in other camera collared bears and their $\delta^{15}\text{N}$ values were not significantly enriched.

One item that was observed in the diet from camera footage, and sampled but not included as a source in the model was brown bear muscle and fat. Fat was included as an endogenous source, and as such, no discrimination factor was applied.

Cannibalism has been documented in brown bears (Bellemain et al. 2006, Swenson et al. 2001) and was observed as the sole dietary source for 2 days for bear #3. If bear muscle was included as a source and corrected for discrimination, it would have an estimated value of 9.1 ‰ $\delta^{15}\text{N}$ and -21.7 ‰ $\delta^{13}\text{C}$, and the outlier would then fall within the mixing polygon. Therefore it is likely that the diet of individuals in this system with elevated $\delta^{15}\text{N}$ values is partially composed of their own species. This cannibalism is likely a temporally limited diet source as the resulting enrichment in $\delta^{15}\text{N}$ is seen in the plasma samples but not to the same extreme in the blood clot samples.

Conclusions

Brown bear foraging ecology in the Nelchina Basin of south-central Alaska conforms as a population to exhibit characteristics of classic omnivory, utilizing an array of terrestrial resources including multiple ungulate species as well as vegetation, and with little evidence of marine dietary components more typical of coastal brown bears. Bears within this region do however, exhibit a suite of seasonal foraging patterns: a) almost exclusively ungulate consumers in spring, summer and fall, b) ungulate-vegetation switchers between seasons and c) low ungulate consumers across all seasons. The consumption of specific ungulate calf species, either moose or caribou, while difficult to resolve with isotope data only, are more reliably resolved when camera and GPS data are simultaneously considered. Bears using higher elevation regions likely consumed primarily caribou calves and those bears who spend most of their time in low elevation forests may be preying primarily on moose calves. Exogenous resources are,

however, periodically supplemented with endogenous resource (fat) catabolism to meet energetic needs, while in some instances, cannibalism is also a part of brown bear feeding behavior.

Though ungulate calves are sometimes considered to be an alternative prey for brown bears, in some regions they may actually be a primary food source in spring. As such it is likely that brown bear survival and productivity is linked to ungulate populations and their productivity. Future management decisions of bears and ungulates in this region should consider the implications of bear reliance on ungulate prey in spring and how manipulations of either of these populations will affect the other.

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Figures

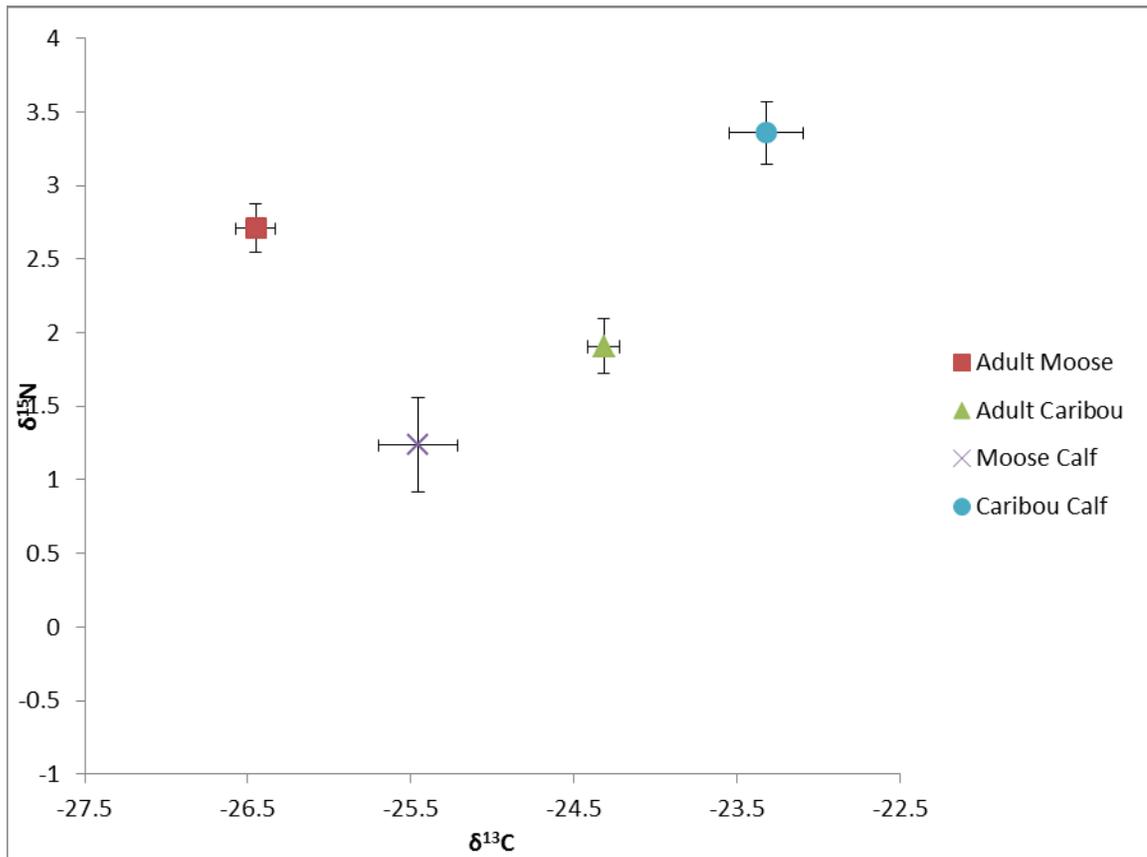


Figure 3. 1. Co-isotope plot of primary observed prey in the Nelchina area, determined from muscle tissue. Ungulate calves differ in isotopic signatures from the ungulate adults.

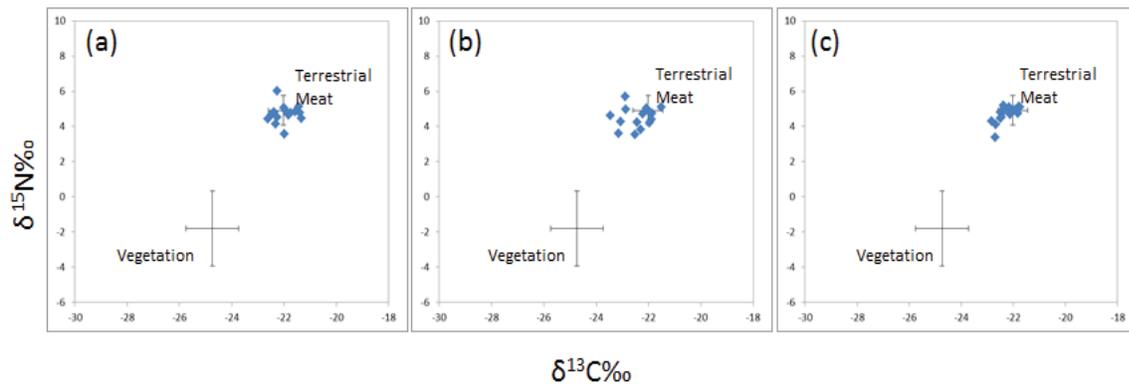


Figure 3. 2. Co-isotope plots for brown bear (*Ursus arctos*) hair, (a) tip, (b) middle, and (c) base collected in mid May 2011-2012 in the Nelchina area southcentral Alaska. Discrimination factors were applied to each source.

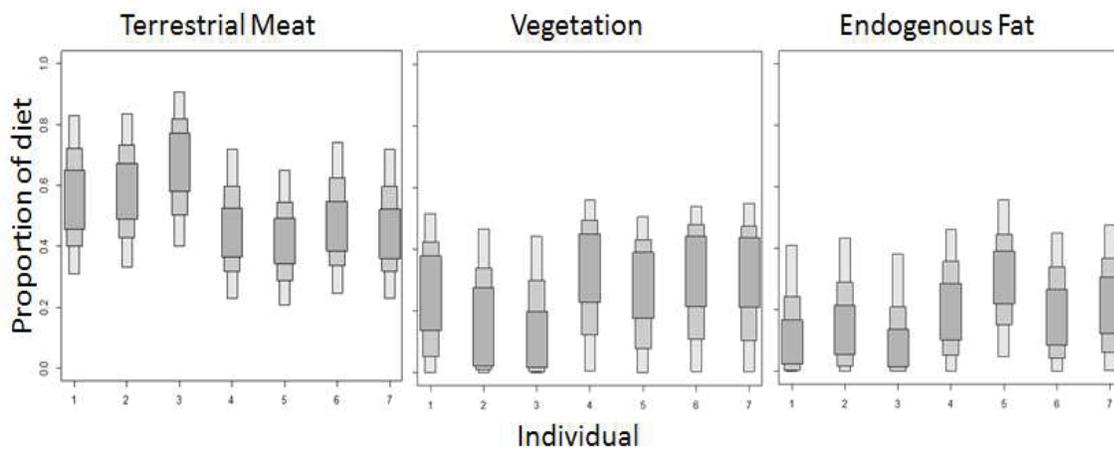


Figure 3. 3. Source proportions for blood clot collected in mid to late June from brown bears (*Ursus arctos*) in the Nelchina area in southcentral Alaska 2011-2013. Vegetation and terrestrial prey are both dietary sources and endogenous fat is a potential source due to the metabolic condition of the bears in this area in spring.

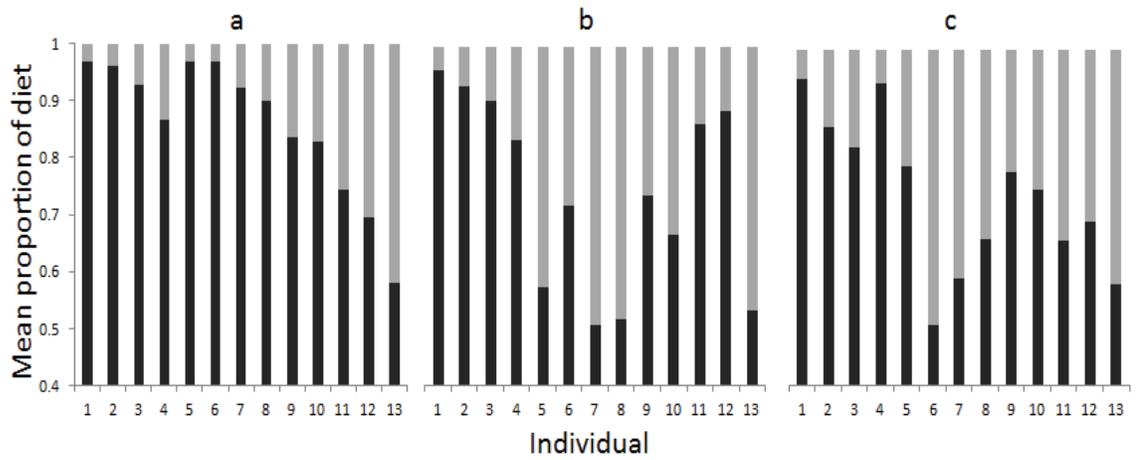


Figure 3. 4. Most likely (mode) proportional contributions of terrestrial prey ■ and ■ vegetation to the seasonal diets ((a) spring, (b) summer, and (c) fall) of brown bears (*Ursus arctos*) in the Nelchina basin, Alaska, 2010-2012. Individual #1 and #2 are the same bear sampled in both 2011 and 2013 respectively.

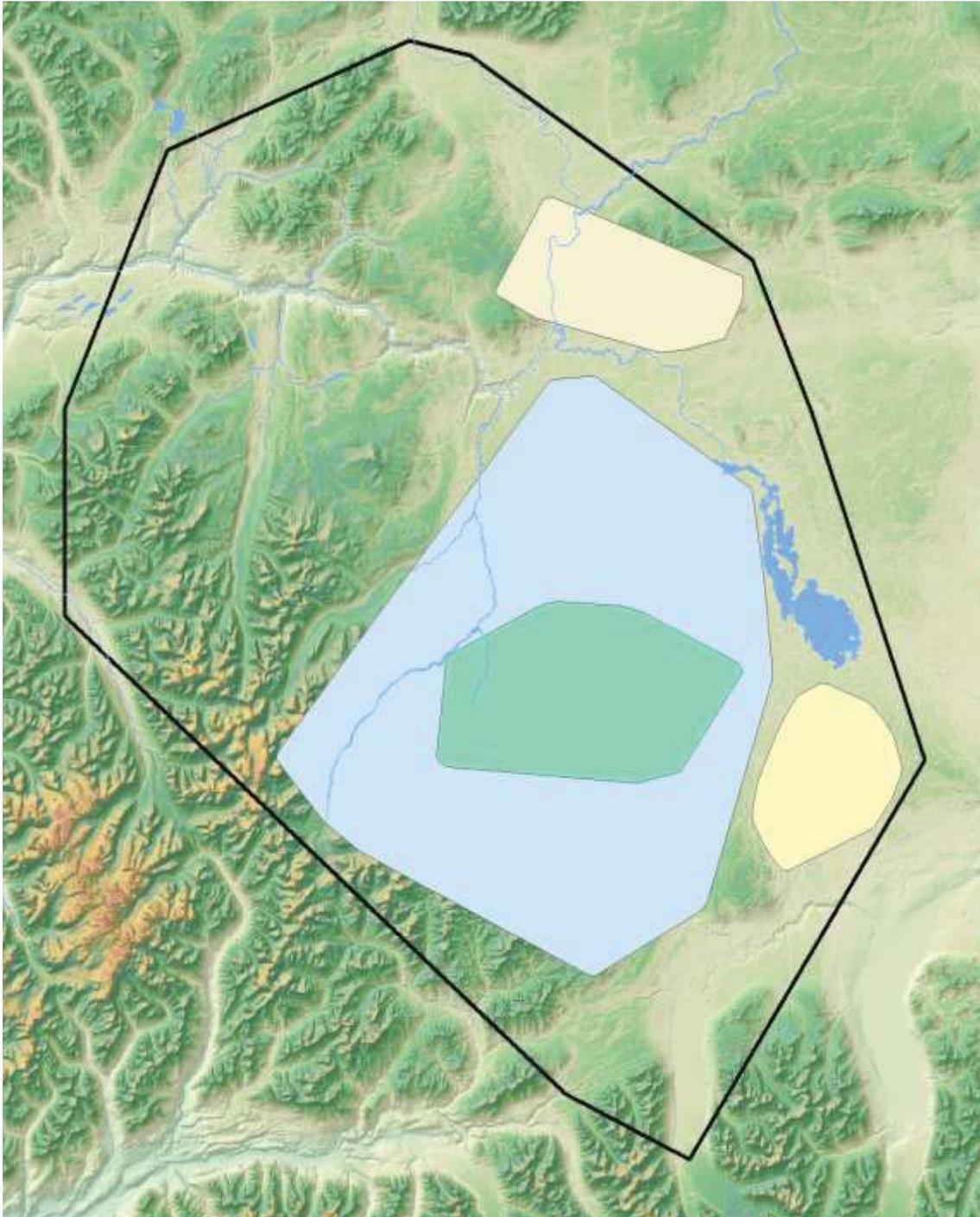


Figure 3. 5. Polygon estimates of landscape use within the study area (outer polygon) for the four collared bears 17 May – 17 June in 2011.

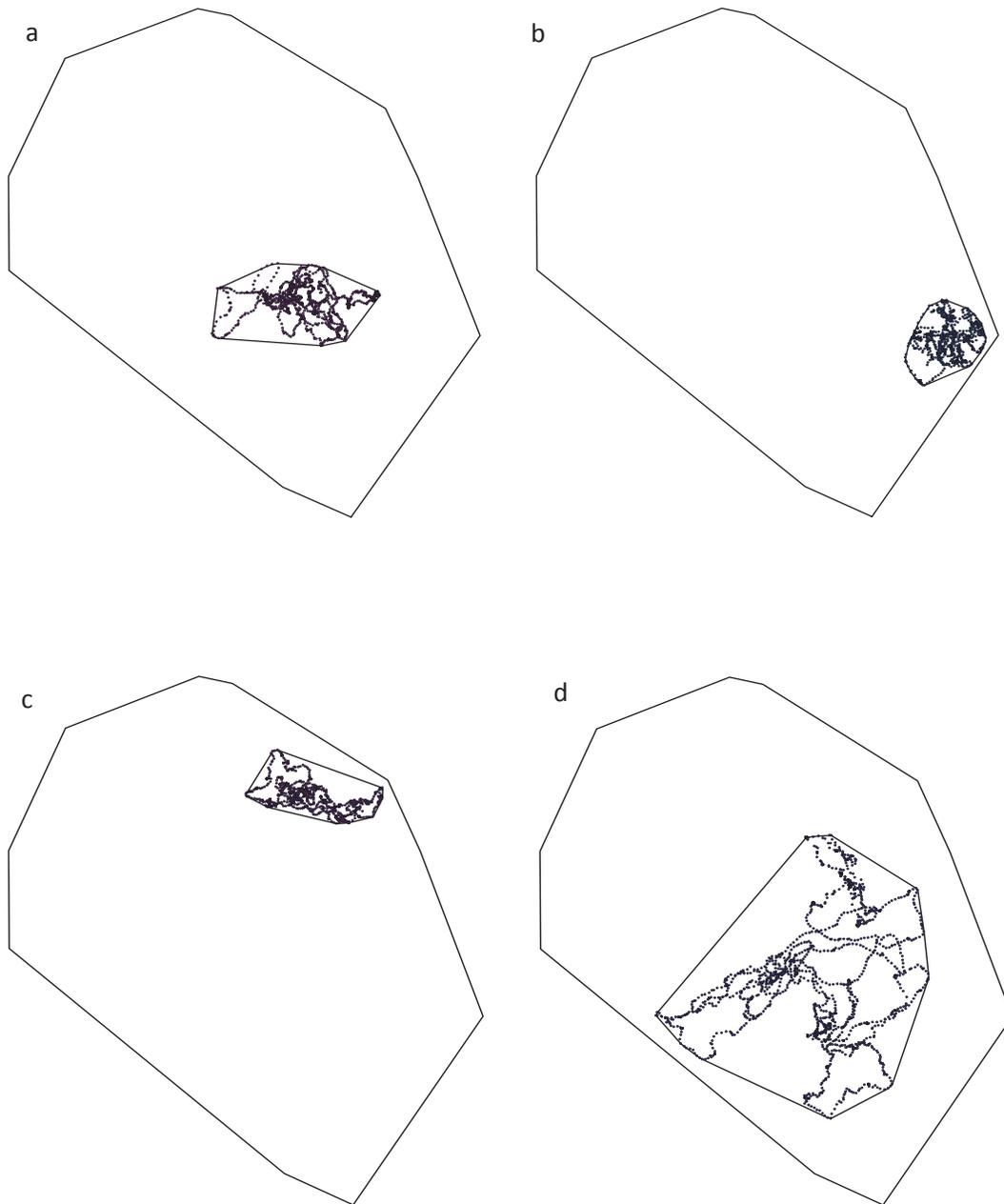


Figure 3. 6. Polygon estimates of landscape use and tracks within the study area for the four collared bears 17 May – 17 June in 2011: a). 2011_0.950 (female with 2 year old cub), b). 2011_0.960 (female), c). 2011_0.970 (female with yearling cub), and d). 2011_0.980 (male).

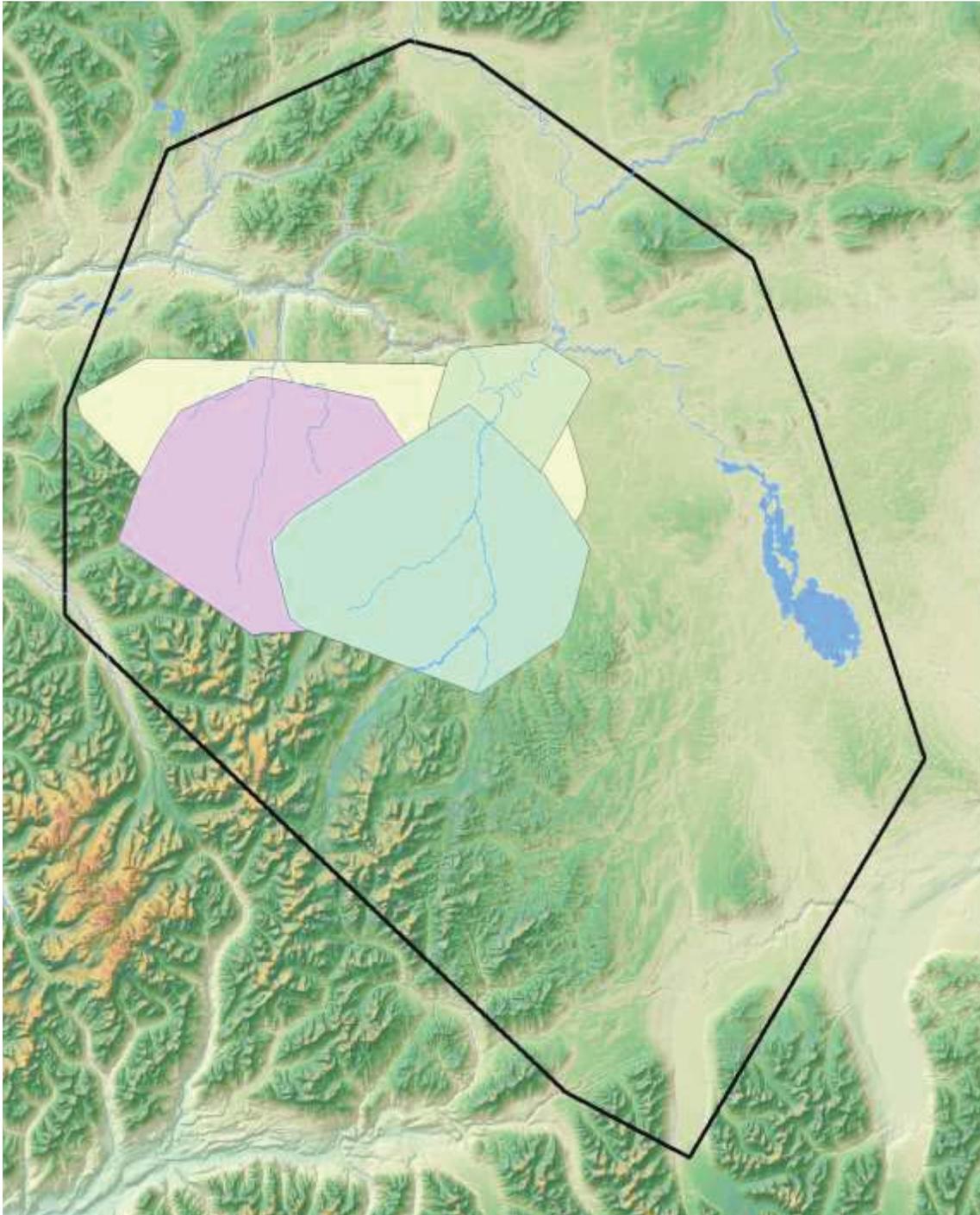


Figure 3. 7. Polygon estimates of landscape use within the study area (outer polygon) for the four collared bears 16 May – 29 June in 2012.

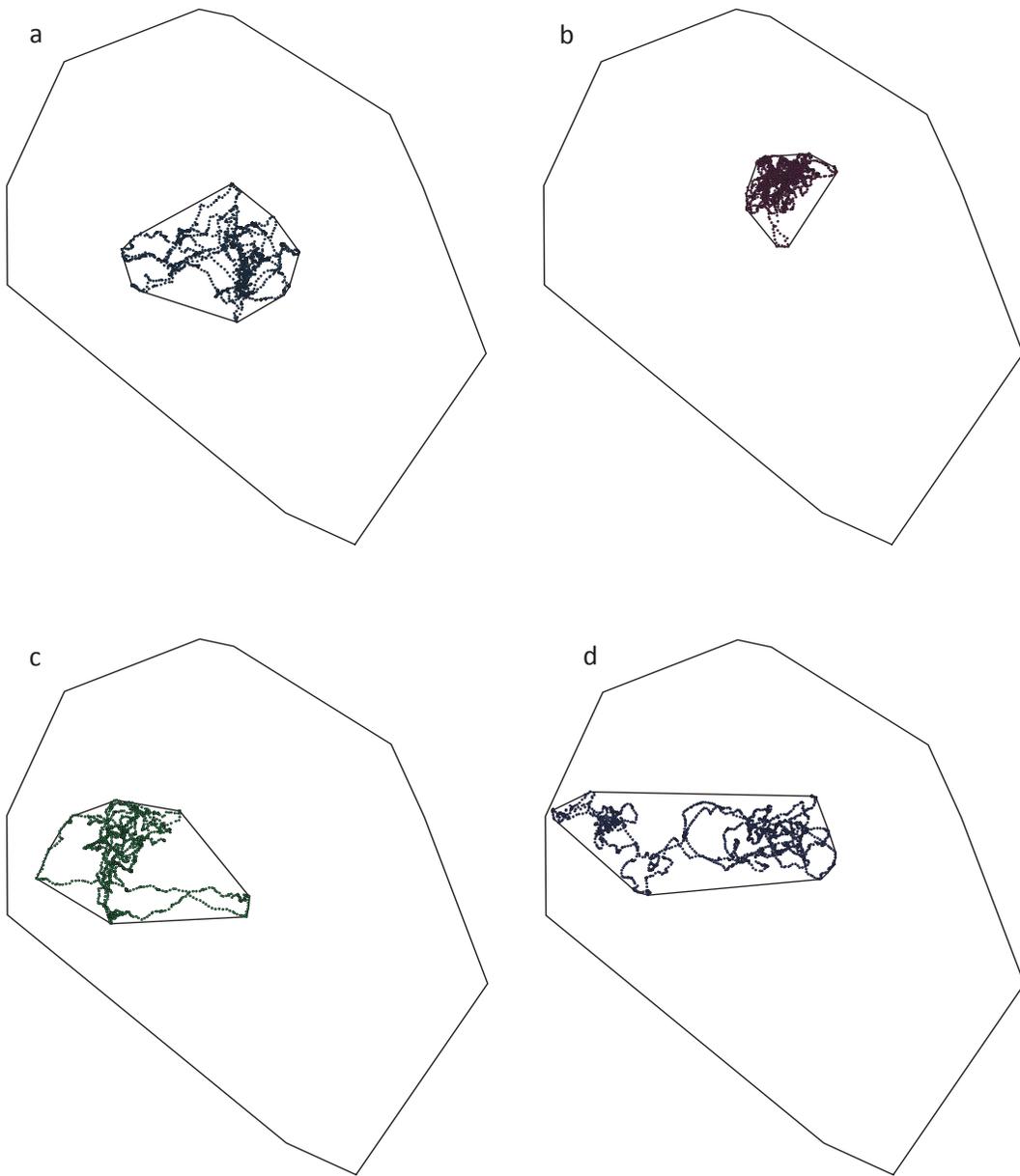


Figure 3. 8. Polygon estimates of landscape use and tracks within the study area for the four collared bears 16 May – 29 June in 2012: a) 2012_0.950 (female), b). 2012_0.960 (female), c). 2012_0.970 (male, dropped collar on 13 June), and d). 2012_0.980 (male).

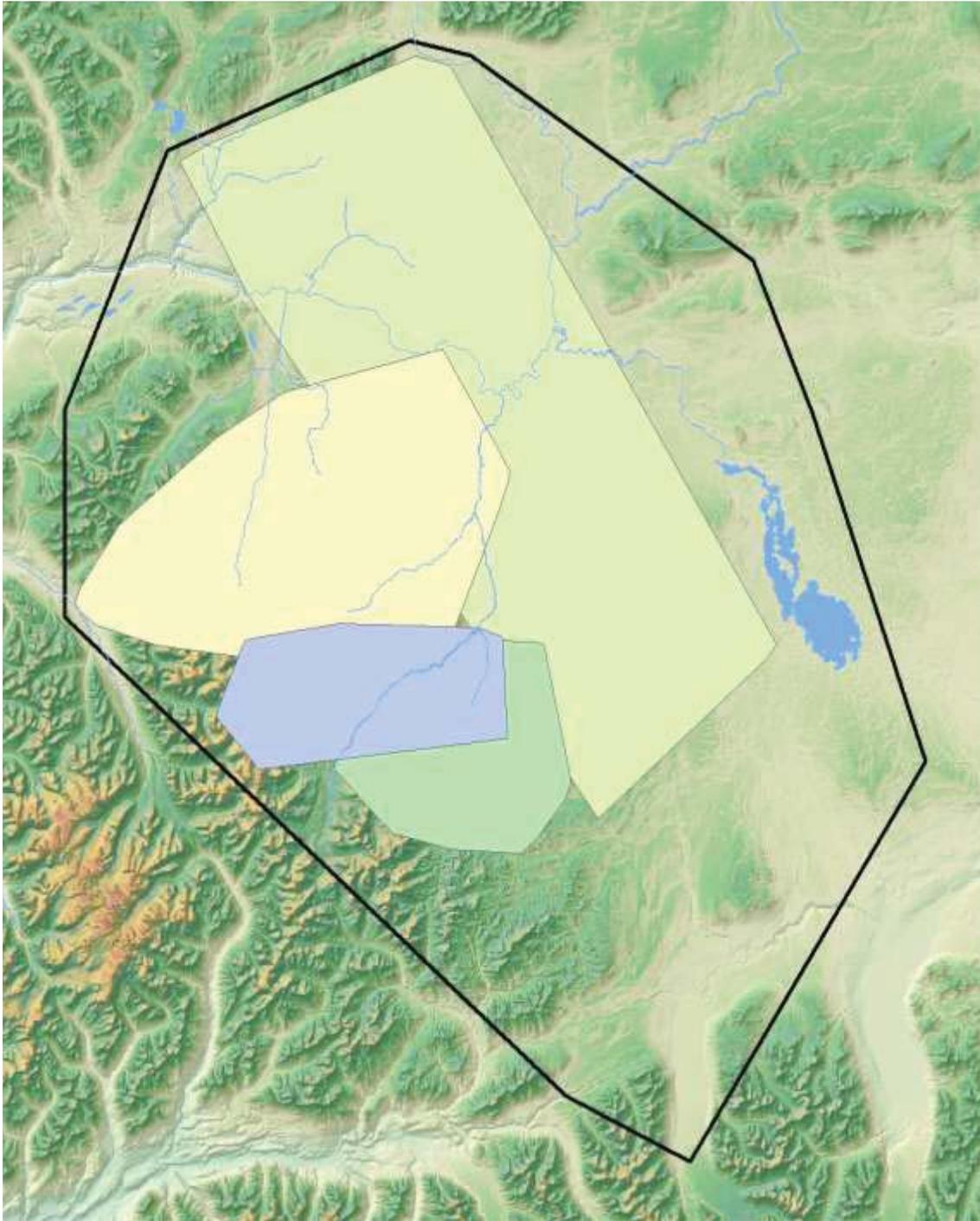


Figure 3. 9. Polygon estimates of landscape use within the study area (outer polygon) for four collared bears 15 May – 26 June in 2013.

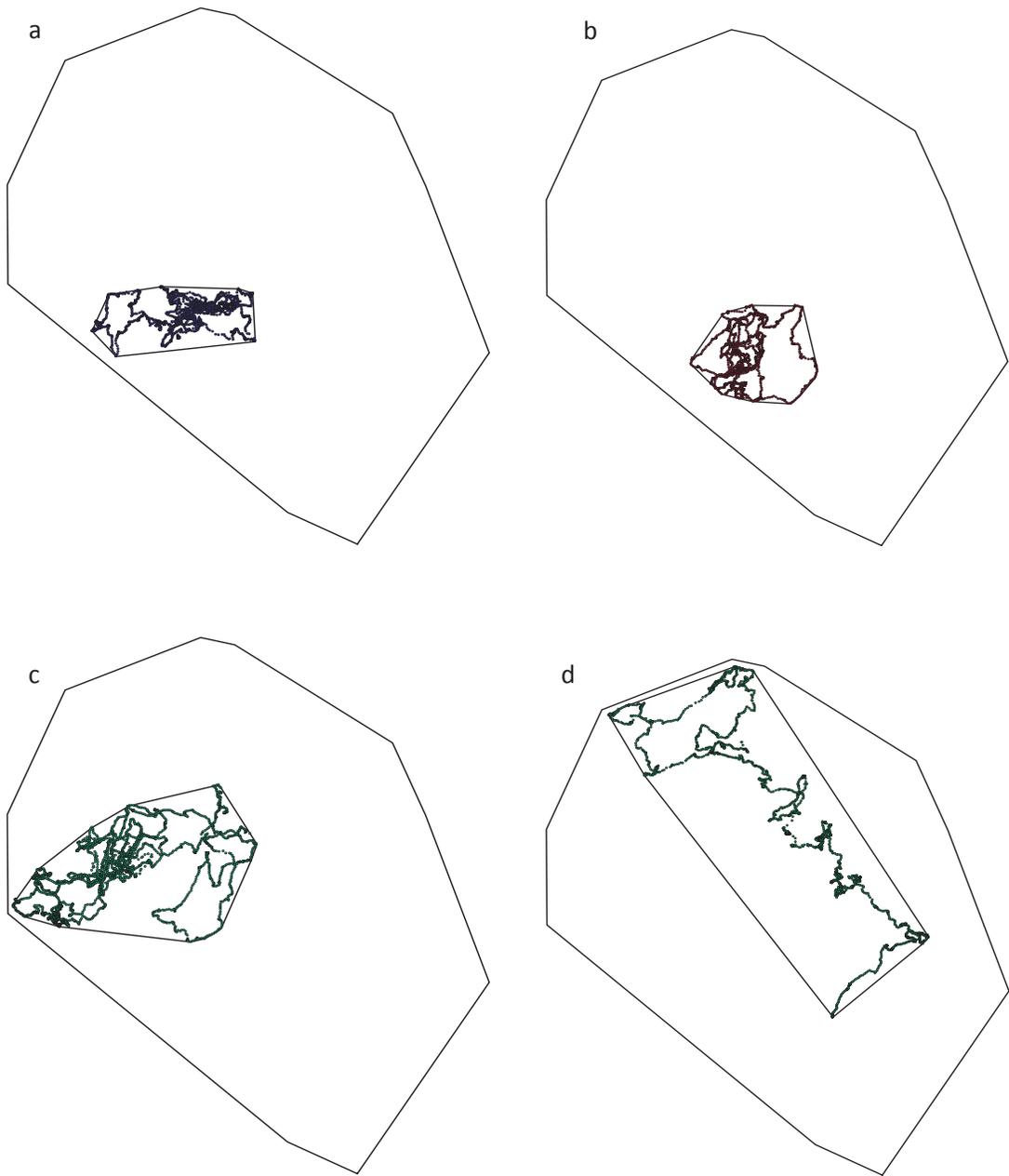


Figure 3. 10. Polygon estimates of landscape use and tracks within the study area for four collared bears 15 May – 26 June in 2013: a). 2013_0.890 (female), b). 2013_0.900 (female), c). 2013_0.940 (male), and d). 2013_0.950 (male).

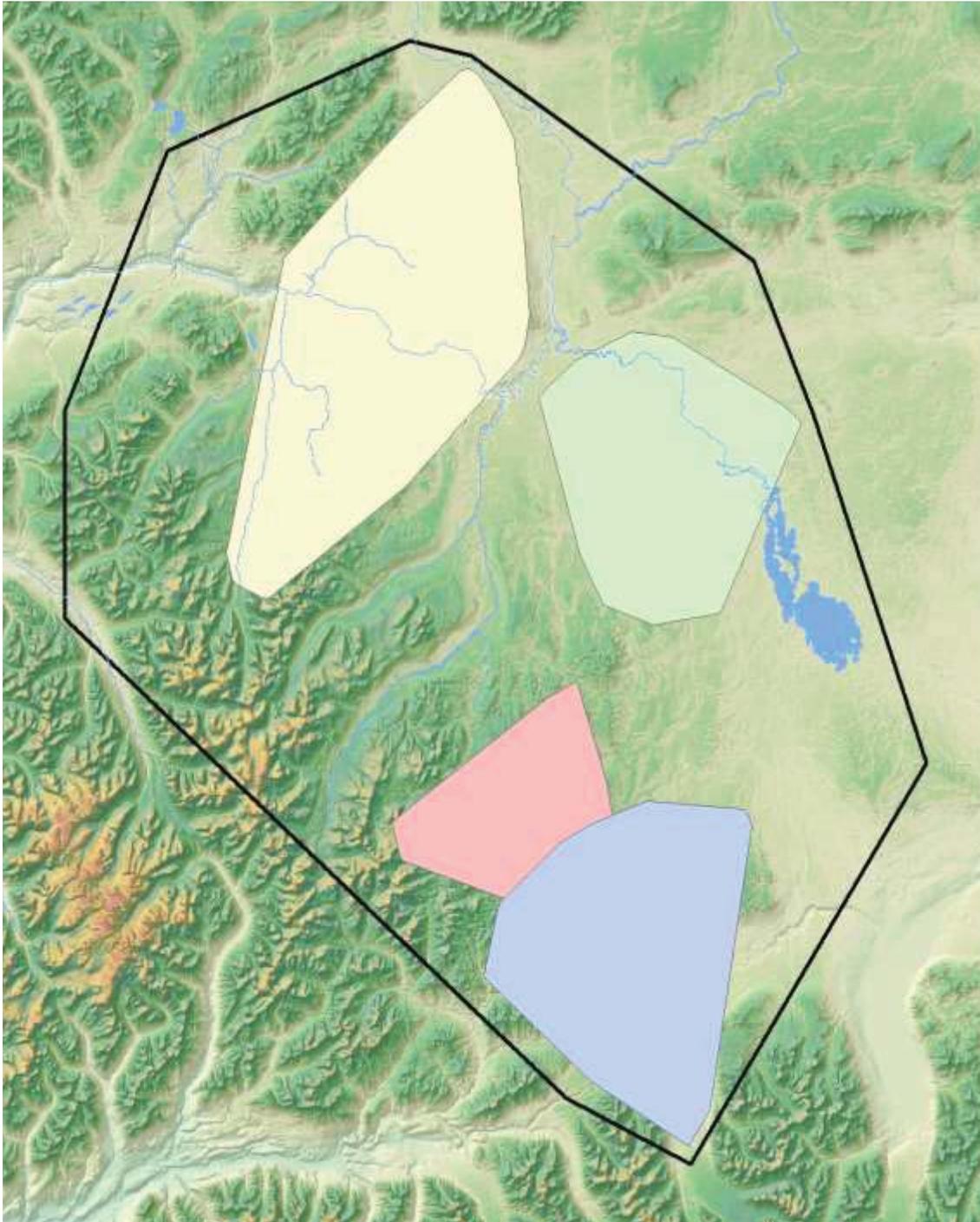


Figure 3. 11. Polygon estimates of landscape use within the study area (outer polygon) for four collared bears 15 May – 26 June in 2013.

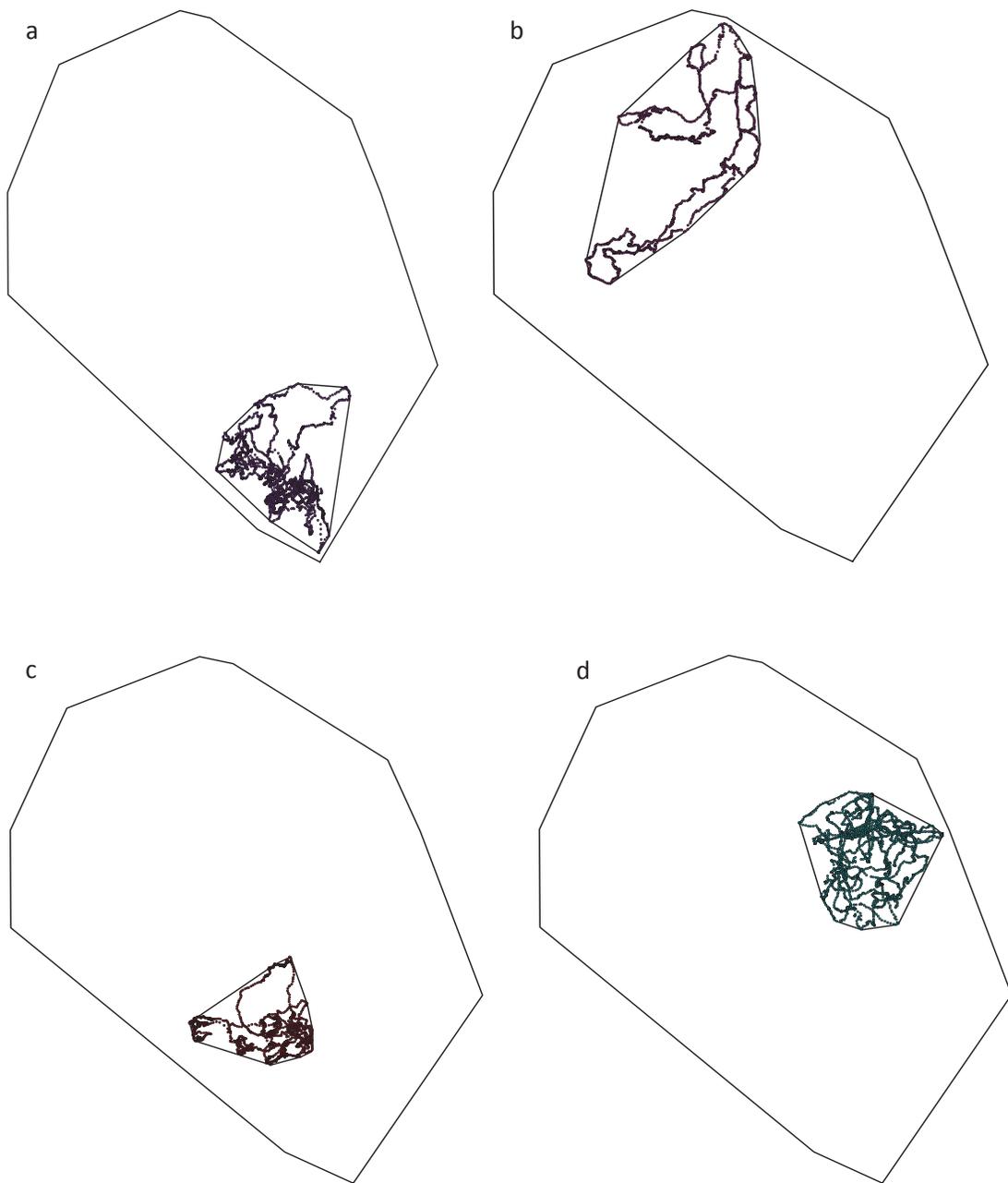


Figure 3. 12. Polygon estimates of landscape use and tracks within the study area for four collared bears 15 May – 26 June in 2013: a). 2013_0.960 (female), b). 2013_0.970 (female), c). 2013_1.350 (male), and d). 2013_1.370 (male).

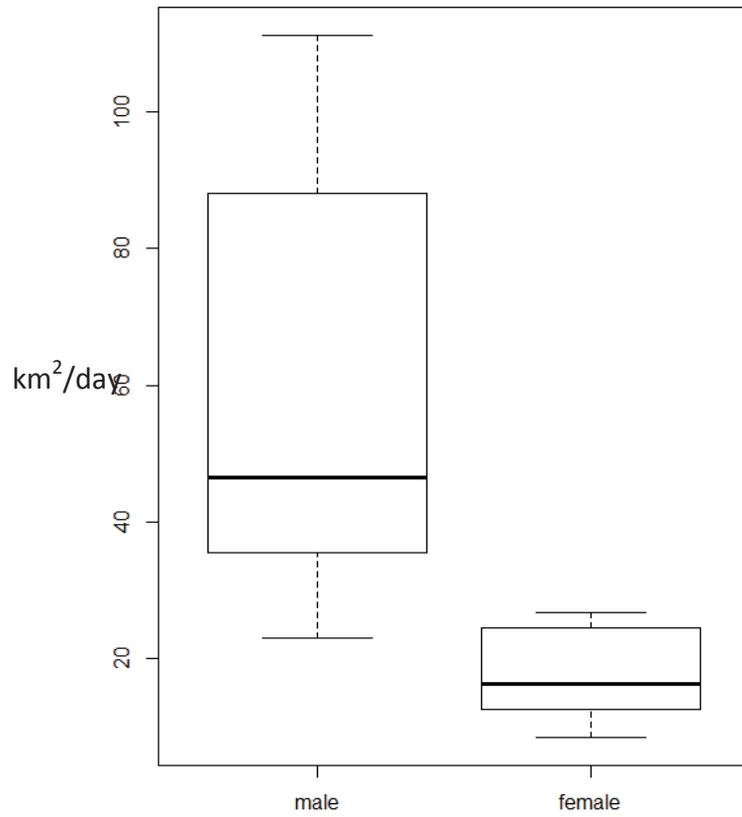


Figure 3. 13. Boxplot of mean area in km²/day used by brown bears in the Nelchina area in the spring; male (n=6), female (n=8).

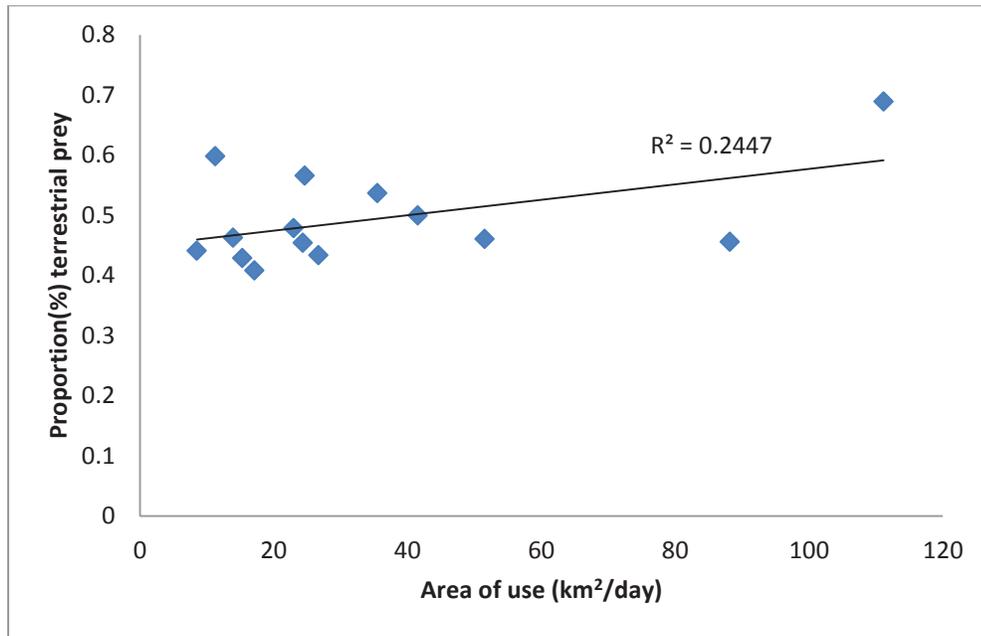


Figure 3. 14. Regression of proportion of terrestrial prey in the spring diet of brown bears (*Ursus arctos*) estimated from SIA of June blood clot samples against mean area used per day (MCP/days of monitoring).

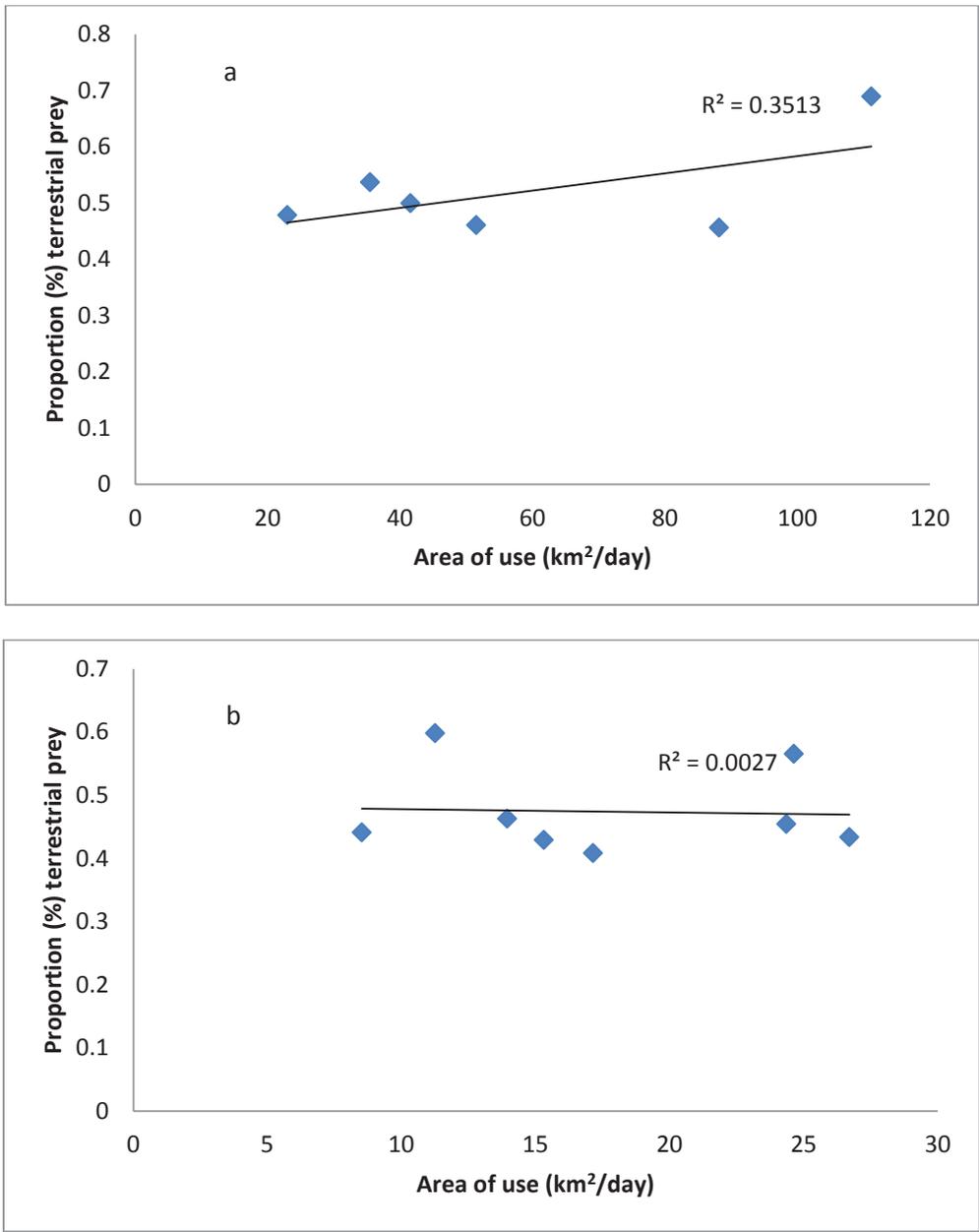


Figure 3. 15. Regression of proportion of terrestrial prey in the spring diet of brown bears (*Ursus arctos*) estimated from SIA of June blood clot samples against mean area used per day (MCP/days of monitoring) for a.) males and b.) females.

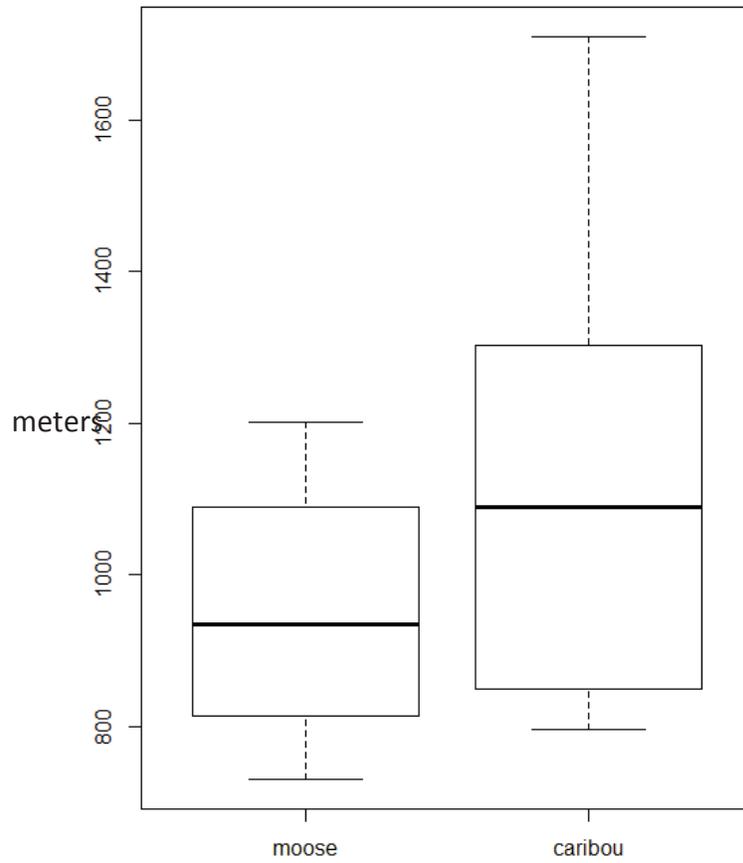


Figure 3. 16. Elevations in meters of ungulate calf kills by collared bears in the Nelchina area in 2011 -2013; moose (n=74), caribou (n=80).

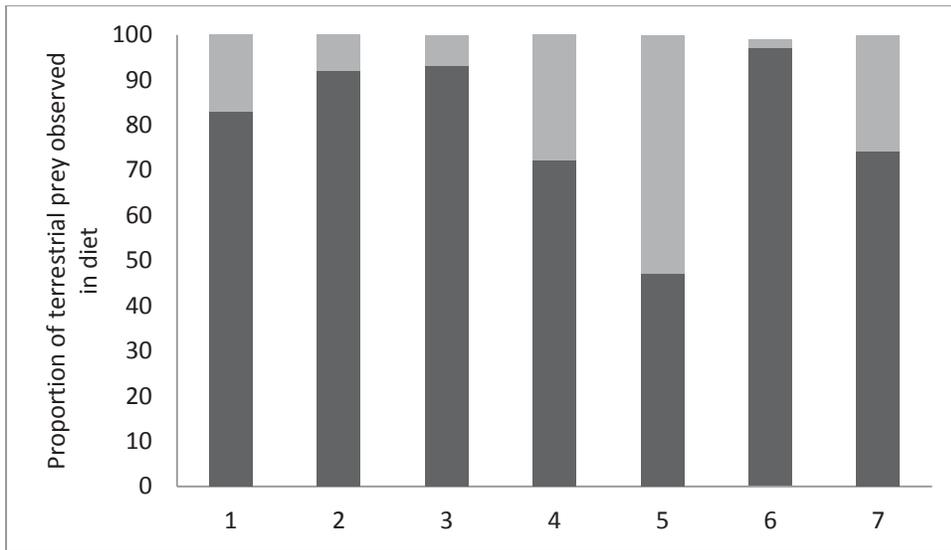


Figure 3. 17. Proportions of video clips where terrestrial prey was observed for brown bears (*Ursus arctos*) equipped with neck mounted cameras in the Nelchina area southcentral Alaska 2011-2013.

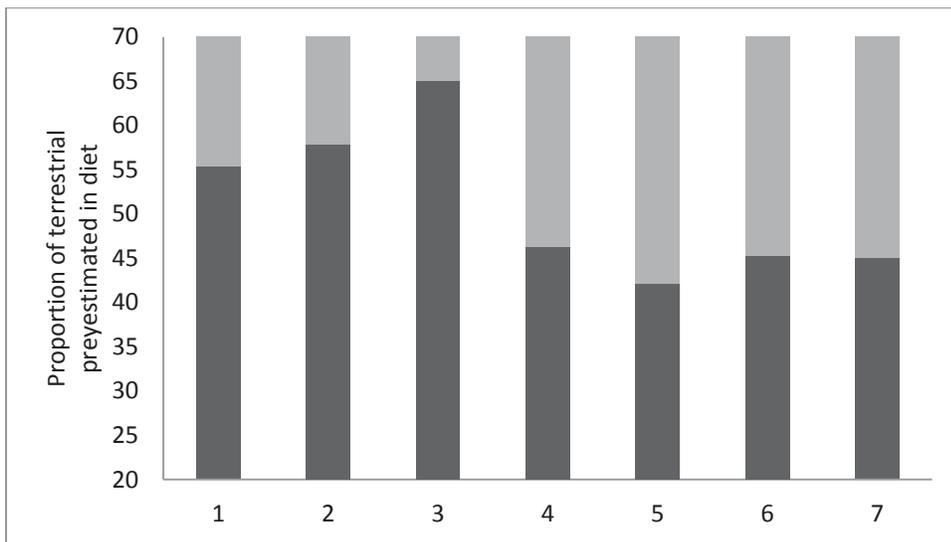


Figure 3. 18. Most likely proportions of terrestrial prey estimated in diet using SIA for brown bears (*Ursus arctos*) that were equipped with neck mounted cameras in the Nelchina area southcentral Alaska 2011-2013.

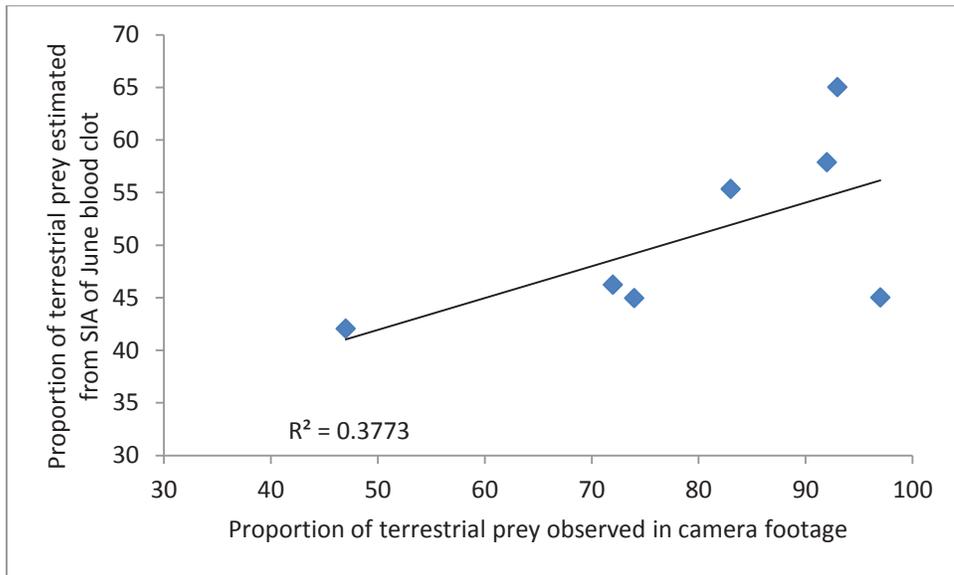


Figure 3. 19. Regression of proportion terrestrial prey in diet observed in the camera footage versus proportion of terrestrial prey in diet estimated from SIA of June blood clot.

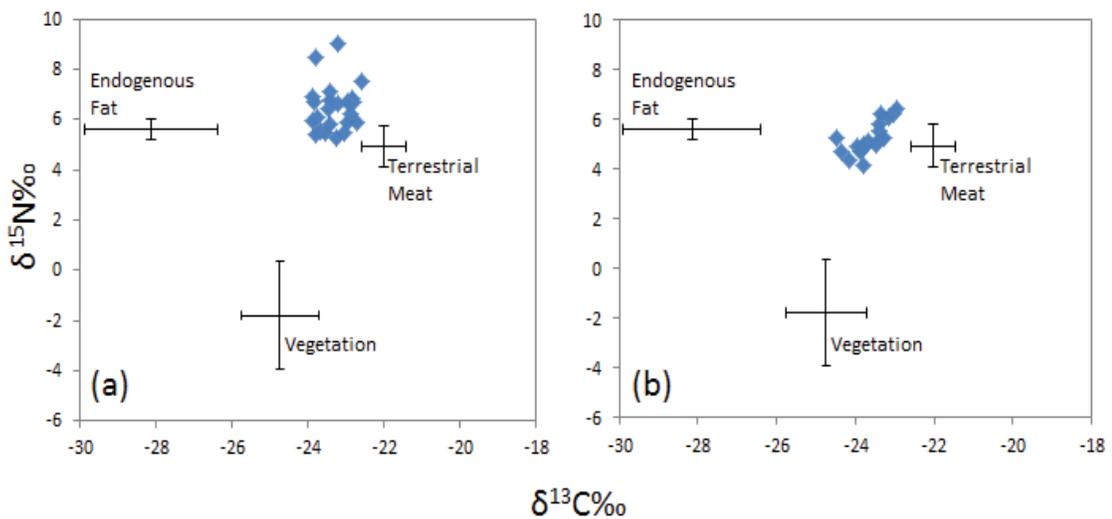


Figure 3. 20. Co-isotope plots for brown bear *Ursus arctos* blood, (a) Plasma and (b) clot collected in mid-late June 2011-2013 in the Nelchina area southcentral Alaska. Discrimination factors were applied to each dietary source, but not endogenous fat.

Tables

Table 3. 1. Isotopic values ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) \pm standard error (SE) and discrimination factors ($\Delta\delta^{15}\text{N}$ and $\Delta\delta^{13}\text{C}$) \pm standard deviation (SD) measured from samples collected in the Nelchina area. These values were used to estimate proportional contributions of the three major sources to bear blood samples and the two major food categories contributing to hair of brown bears (*Ursus arctos*), in the Nelchina area, southcentral Alaska, 2011-2013.

Food category	$\delta^{15}\text{N}$ (‰) \pm SE	$\Delta\delta^{15}\text{N}_{\text{tissue-diet}}$ (‰) \pm SD	$\delta^{13}\text{C}$ (‰) \pm SE	$\Delta\delta^{13}\text{C}_{\text{tissue-diet}}$ (‰) \pm SD
Terrestrial prey	1.5 ± 0.19^a	$3.4^d \pm 0.64^e$	-24.62 ± 0.14^a	$2.6^d \pm 0.26^e$
Terrestrial vegetation	-5.19 ± 0.39^b	$3.4^d \pm 0.64^e$	-27.34 ± 0.18^b	$2.6^d \pm 0.26^e$
Endogenous fat	5.61 ± 0.14^c	0^f	-28.14 ± 0.58^c	0^f

^a Terrestrial meat values measured from muscle samples collected from the study area and surrounding GMU n=22, 4 adult moose, 2 calf moose, 10 adult caribou, 2 calf caribou, 3 willow ptarmigan, 1 arctic ground squirrel.

^b Measured isotopic values from berries sampled in the study area n=30.

^c Measured isotopic values of bear fat collected mid May 2013 n=9.

^d Tissue to diet discrimination values averaged from Hilderbrand et al. 1996 reported in Caut et al. 2009.

^e Standard deviations around discrimination values for C and N from Milakovic and Parker 2013 are doubled for a conservative representation of uncertainty in discrimination values.

^f No diet to tissue discrimination was assumed for endogenous sources.

Chapter 4: Conclusions

This study provides evidence that individual kill rates of ungulate calves can be estimated accurately using a combination of animal-borne video and GPS techniques. These combined methods revealed that handling time for ungulate calf kills can be very short and therefore require sampling intervals as short as five minutes to attain high accuracy in detecting kills. This very short handling time explains discrepancies between kill rates measured in this study and previous studies using different techniques. Kill rates of ungulate calves reported in this study are higher (34/spring) than any other kill rates found in the literature (2-8/spring). This is likely influenced by the healthy populations of ungulates in the area, the lack of anadromous resources, and a new methodology that provides high temporal resolution of activity patterns of bears. Additionally, individual variation in kill rates was high indicating differences in foraging ecology at the level of the individual. Consequently, these aspects of brown bear foraging ecology should be considered and accounted for when assessing brown bear-ungulate dynamics.

Addition of stable isotope techniques to the study of predation using cameras and GPS allowed for application of detailed diet selection information to guide the interpretation of SIA mixing models. Expansion of detailed information collected on a few individuals can then be applied to a broader sample of the population. My results indicated that the brown bears in the Nelchina area employ diverse behaviors in

seasonal diet selection, except in spring when most bears rely heavily on terrestrial prey. Though SIA signatures correlated well to terrestrial prey consumption from video footage, it is not possible to estimate kill rates from SIA alone. The diet selection of brown bears can be further guided by landscape use information in identifying prey down to the level of species.

Combination of these three methods in the same study provided a synergistic approach to understanding brown bear ecology and bear-ungulate dynamics. Further work using the combination of these methods in other systems is clearly warranted given the management implications of bear-ungulate interactions.

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Appendix A
Brown Bear Diet Items Observed in Footage From Camera Collars
in the Nelchina Area in Spring 2011-2013.

Moose, adults and calves (*Alces alces*)

Caribou, adults and calves (*Rangifer tarandus*)

Dall Sheep (*Ovis dalli*)

Brown Bear (*Ursus arctos*)

Arctic ground squirrel (*Spermophilus parryii*)

Snowshoe Hare (*Lepus americanus*)

Beaver (*Castor canadensis*)

Ptarmigan (*Lagopus spp*)

Ptarmigan eggs (*Lagopus spp*)

Swan (*Cygnus spp*)

Winter kill Fish (*Coregonus, Prosopium, Stenodus, or Thymallus spp*)

Appendix B

IACUC Approval Form

STATE OF ALASKA
DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION

2013-11
SEAN PARNELL,
GOVERNOR

1300 College Road
Fairbanks, Alaska 99701-1551
PHONE: (907) 459-7213
FAX: (907) 459-7332

ASSURANCE OF ANIMAL CARE FORM
FOR NEW PROTOCOL REVIEW THROUGH THE
DWC ANIMAL CARE AND USE COMMITTEE

Office Use Only:

ACUC PROTOCOL NO. 2013-11

DATE RECEIVED:

12 April 2013

DATE APPROVED:

4 May 2013

RENEWAL MONTH:

March

I. GENERAL INFORMATION

Principal Investigator or Project Leader: Christopher Brockman

Phone #: (907) 746-6338

e-mail: christopher.brockman@alaska.gov

Office Location: Palmer

Title of Project: Evaluation of brown bear predation on moose calves in south central Alaska using neck mounted cameras, GPS, and stable isotopes.

Approx. Starting Date: May 15, 2013

Completion Date: June 30, 2014

DECLARATION: Read the following statement and affirm your willingness to comply by signing and dating at the bottom of the page. Email a scanned copy of the signed page and the electronic form of this document to the DWC Animal Care and Use Committee (ACUC).

The information on this Assurance of Animal Care Form is an accurate description of the animal care and use protocol(s). All people handling animals have been properly trained to use appropriate methods and have read and agree to comply with this protocol. All individuals working under this Assurance will comply with the procedures and approved methods in the DWC Animal Welfare Policy, DWC Drug Policy, DWC Wildlife Capture and Restraint Manual, DWC Guidelines for the Handling and Marking of Wildlife, and applicable Department Policies. All animal use proposed herein is the most refined possible to avoid or minimize discomfort, distress, and pain to the animals; does not unnecessarily duplicate previous experiments; and non-animal alternatives have been considered.

Signature of Principal Investigator or Project Leader

Date

Signature of Regional Supervisor or Designate granting project approval Date

Approved, Chairman of the DWC ACUC

Date

Christopher Brockman 4 May 2013

PERSONNEL: List the PI and all individuals who will be working directly with live animals. PI shall rate the experience levels as **E** (Extensive), **I** (Intermediate), or **N** (Novice). If Novice, indicate which personnel will act as mentor or attach training plan.

Name and position <i>(affiliation if not DWC staff)</i>	Duties/Responsibilities on Project. <i>List specific activities (e.g. net-gunner, anesthesia monitoring, sample and data collection). If the person will be involved in all aspects of the protocol, put "ALL" in the space provided.</i>	Recent experience level with duties. <i>(E, I, or N)</i>	Chemical immobilization training course, mentorship or refresher (if drugs are to be administered) <i>Year/type</i>	Attended DWC or University Animal Welfare training <i>(yes/no)</i>
Chris Brockman	All	E	May 2011	Yes
Lem Butler	All	E	Mar 2010	Yes

II. USE OF ANIMALS

ANIMAL SPECIES <i>(Scientific and Common name)</i>	NUMBER USED (YEAR 1)	NUMBER USED (YEAR 2)	NUMBER USED (YEAR 3)
Ursus arctos Brown Bear	UP TO 20	UP TO 20	
	LIKELY ONLY 9		

CLASSIFICATION OF PROJECT: *Check all that apply.*

- RESEARCH ON FREE-RANGING ANIMALS RESEARCH IN A CAPTIVE SETTING
MANAGEMENT PROJECT (e.g. population monitoring)
TEACHING/TRAINING/EDUCATIONAL DIAGNOSTIC

RESEARCH STUDY SITE LOCATION AND/OR GAME MANAGEMENT UNIT:

GMU 13A

CAPTIVE ANIMAL HOUSING AREA *(only applicable to captive >12 hrs):*

- MOOSE RESEARCH CENTER PALMER AGRICULTURAL STATION
OTHER (PLEASE DESCRIBE LOCATION, CONDITIONS AND LENGTH OF HOLDING):

IS THIS PROJECT BEING REVIEWED BY ANOTHER IACUC? YES NO

If yes, please provide us with a copy of Protocol as submitted, the final letter of approval, and a contact person for that committee

PERMITS: ARE PERMITS OUTSIDE OF ADF&G NEEDED? YES NO

LIST PERMITS APPLIED FOR PENDING OR ACQUIRED

Please append copies of all relevant permits to the ACUC chairperson prior to starting this project.

III. JUSTIFICATION & METHODS:

OBJECTIVES: In **500 words or less**, please explain, as though speaking to the non-scientist members of the ACUC, the specific project objective(s). If this is a research project, explain how the proposed animal use procedures or activities will accomplish the objectives; and how this project will benefit wildlife populations, human or animal health, and/or provide knowledge or understanding applicable to the animals under study. If the project is a wildlife management project, describe the management objectives and measurable goals.

This project will evaluate brown bear predation patterns during the moose calving season in the vicinity of the Oshetna River drainage, south central Alaska using camera collars to record predation behavior of various age and sex class bears relative to landscape use (resource selection) and diet composition (stable isotopes). Predation of moose calves by bears is compressed into a relatively short period allowing for the collection of a lot of data in relatively little time. I will evaluate the new combination of technologies for quantifying predation characteristics, provide new information on feeding ecology of bears, and help guide ADF&G's management of bears and ungulates. I plan to correlate the results of the camera collar data with isotope testing to develop a method for sampling harvested bears and determining what proportion of their sprig diet is composed of moose.

JUSTIFICATION:

Use of live animals in research: *Have you considered if the project objectives could be accomplished without the use of live animals (e.g. computer models, molecular techniques on naturally shed tissues, hunter harvest carcass sampling). YES NO*

If live animals are to be used when other methods are available, please explain why those methods are not acceptable for this project. (Note: In nearly all cases, ADFG projects must use the specific species of live animal because that is the species of interest (e.g., need to capture moose for a management or applied research project), so a surrogate is not tenable). If so, the author should explain that as a justification.

This project is evaluating camera collars as a tool to determine predation characteristics of free ranging Brown bears, so a surrogate is not tenable.

Appropriateness of species to be used: *Could a lower taxa (e.g. cold-blooded or invertebrate) be substituted and still meet project objectives? YES NO*

If yes explain why the lower taxa are not utilized in this case. {overwrite here}

REPLACEMENT, REFINEMENT AND REDUCTION:

- 1) Have you consulted colleagues, the scientific literature and reports (gray literature) to determine that this work does not unnecessarily duplicate research? YES NO
- 2) Have you consulted with the attending veterinarian, colleagues, DWC handling manuals and the literature to ensure the procedures are the most refined possible? YES NO
- 3) Have you considered alternatives to procedures that may cause more than momentary or slight pain or distress to the animal? YES NO

If you answered [No] to any of the above please provide a narrative description of your planned sources and methods to address the above three topics.

SCIENTIFIC METHODOLOGY/ PROJECT DESIGN: *For nonroutine, technique development, or novel capture studies and/or management programs please describe the basic scientific methodology, research design or management objectives. Include how numbers of animals to be used was determined and describe any control groups. Do not include detailed procedures in this section.*

Minimum bear size - The smallest bears that will be used in this project will be a minimum of 250 lbs. The collar weight is slightly heavier than a standard bear VHF radio collar but still less than 1% of the animal's total weight. The collars will be deployed for no more than 45 days at which time the bears will be recaptured, samples collected and the collars removed.

IV. ANIMAL HANDLING PROCEDURES & CARE:

VETERINARY CARE OF ANIMALS:

NOTE NEW PROCEDURE FOR CONSULTATION AND APPROVAL OF VETERINARY PROCEDURES INCLUDING IMMOBILIZING DRUG ADMINISTRATION AND BLOOD/TISSUE SAMPLING: **The DWC attending veterinarian should be consulted regarding procedures potentially requiring veterinary supervision during development of your protocol and prior to submission of this form. Particularly when you are planning to use drug protocols, blood collection or tissue sampling techniques that are not previously approved in the DWC wildlife capture and handling manuals or that personnel are not very experienced with, consult the DWC attending veterinarian prior to submission of this form for refinement and approval of veterinary techniques. The ACUC will accept attending veterinarian approved drug doses and veterinary procedures without requiring further review.**

Fat/muscle BIOPSY Procedure:

Using sterile gloves locate the site of biopsy between the base of the tail and the ischium. Trim hair in a 2 inch square around site. Scrub site with betadine and clean with isopropyl alcohol until betadine has been removed. Make 8-10mm incision (large enough to introduce the biopsy punch without stretching the incision edges) using sterile scalpel parallel to the spine. Hold open the incision and using a 6-8mm punch cut through the fat layer and into the muscle with a rotating motion. Place a finger over the punch as it is removed. If the biopsy is retained within the incision remove it with sterile forceps. Treat the sample site by applying gauze and direct pressure for 2 minutes. Monitor the incision area during the tenure of the capture operation and avoid rolling the bear over, so as to avoid contact of the area with the ground.

If you plan to use a different individual/organization than the DWC attending veterinarian to ensure adequate veterinary care of animals please provide the name(s) of veterinarian(s) providing medical care to your animals (emergencies, illness, preventive medicine, field surgery). This section may not be applicable to unless invasive procedures are planned.

ANIMAL HANDLING AND USE PROCEDURES: *Check all that apply. Provide detailed descriptions whenever DWC ACUC approved handling techniques are not utilized, not established (non-routine or novel), or your protocol will differ significantly such as new technique development.*

Planned? (ck if yes)	Proposed Animal Use	Approved technique/procedure numbers or Details
<input checked="" type="checkbox"/>	1. Chemical capture	Helicopter Darting (IACUC 09-16)
<input type="checkbox"/>	2. Net-capture	
<input type="checkbox"/>	3. Trapping/snaring	
<input type="checkbox"/>	4. Underwater/dive capture	
<input type="checkbox"/>	5. Other physical capture	

<input checked="" type="checkbox"/>	6. Tagging & marking	Standard lip tattoo for brown bear.
<input checked="" type="checkbox"/>	6. Radio-collar or transmitter	Collaring (IACUC # 09-16)
<input checked="" type="checkbox"/>	7. Blood collection	Blood draw from femoral vein (IACUC # 09-16)
<input type="checkbox"/>	8. Urine or fecal collection	
<input checked="" type="checkbox"/>	7. Tissue sample via biopsy	Tissue collection for Isotope Analysis (see above Veterinary Care).
<input type="checkbox"/>	8. Necropsy/ lethal collection*	
<input type="checkbox"/>	9. Use of drugs or chemicals other than initial capture	
<input type="checkbox"/>	10. Catheterization	
<input type="checkbox"/>	11. Manipulation of feed or foraging	
<input type="checkbox"/>	12. Surgery	
<input type="checkbox"/>	13. Invasive procedure	
<input type="checkbox"/>	14. Technique development	
<input type="checkbox"/>	15. Novel techniques	
<input type="checkbox"/>	16. Use of approved techniques in a new species or condition	
<input type="checkbox"/>	17. Transport from capture site	
<input type="checkbox"/>	18. Translocation and release	
<input type="checkbox"/>	19. Euthanasia or humane killing*	Gunshot to head if euthanasia is required (IACUC #05-06)
<input type="checkbox"/>	20. Nuisance wildlife	
<input type="checkbox"/>	21. Non-target/bycatch handling	
<input type="checkbox"/>	22. Disturbance without capture	
<input checked="" type="checkbox"/>	23. Other	Hair collection for Isotope Analysis.

VI. EUTHANASIA AND DISPOSAL

*Methods of euthanasia and humane killing must follow the AVMA Guidelines on Euthanasia 2007 or the Guidelines for Euthanasia of Nondomestic Animals, 2006, American Association of Zoo Veterinarians. Humane killing (e.g. gunshot to the heart/lung area rather than the head) is acceptable in lieu of euthanasia in emergency situations such as remote areas or where euthanasia methods are

not feasible or likely to result in wounding/pain prior to death. Any deviations from acceptable methods from the above references must be scientifically justified.

Even if you do not intend to euthanize animals as a part of your project, a method of euthanasia should be listed in cases of emergency, injury that would cause severe pain or make survival unlikely.

Please describe the method planned in the Section 19 above. If by gunshot, describe where shot placement and ammunition. If by chemical agent you must identify the compound, dose (mg/kg) and route of administration. If barbiturate euthanasia solution is employed, describe carcass disposal to prevent secondary toxic exposure to scavengers.

Appendix C

Isotope Values for Prey Animals

Table C 1. Isotope values for all prey items sampled.

Species (tissue)	Sample size	Location (GMU)	$\delta^{15}\text{N}$ vs air	SD	$\delta^{13}\text{C}$ vs VPDB	SD
Adult Moose (muscle) ^a	4	13	1.48	0.7	-25.35	0.43
Adult Moose (muscle) ^a	24	14	2.91	0.74	-26.64	0.48
Adult Caribou (muscle) ^a	10	13	1.91	0.59	-24.32	0.31
Moose Calf (muscle) ^b	2	13	-0.03	0.05	-24.13	0.44
Moose Calf (muscle) ^b	8	16	1.55	0.86	-25.79	0.34
Moose Calf (ground) ^{b,c}	2	13	-0.14	0.12	-24.33	0.56
Caribou Calf (muscle) ^b	2	13	2.46	0.08	-24.65	0.15
Caribou Calf (muscle) ^b	8	17	3.58	0.54	-22.99	0.19
Caribou Calf (ground) ^{b,c}	2	13	2.61	0.13	-24.67	0.26
Willow Ptarmigan (muscle)	3	13	0.6	0.25	-24.11	0.62
Arctic Ground Squirrel (muscle)	1	13	1.49		-25.18	

^a Adult samples collected in the fall.

^b Calf samples collected in the spring.

^c Ground samples were composed of whole frozen calves cut through perpendicular to the spine with a band saw at 2 inch increments. The saw dust was then mixed and sampled. Samples reflect whole body isotope signatures.