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The Good, the Bad and the Grizzly – assessing human impact on grizzly bears (Ursus arctos horribilis) at army cutworm moth (Euxoa auxiliaris) aggregation sites in the Shoshone National Forest, Wyoming

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Tom Henning Linden

Abstract

Successful management has saved the grizzly bear (*Ursus arctos horribilis*) from extirpation in the contiguous USA. As the population has grown, it has expanded its distribution. Grizzly bears now congregate from July to September in large numbers on alpine talus slopes in the eastern part of the Greater Yellowstone Ecosystem, Wyoming, to feed on army cutworm moths (*Euxoa auxiliaris*). This ecological phenomenon receives much attention from international film crews, permitted outfitters, and bear enthusiasts. Although the general consequences of human activities on bears has been investigated thoroughly, the impact of human use on grizzly bears at moth sites is poorly understood. In this thesis I describe the extent of human use on Franc`s Peak in the Shoshone National Forest, and its influence on grizzly bears foraging at moth aggregation sites using a resource selection function. I have also explored the spatial habitat use by grizzly bears on Carter Mountain, also using a resource selection function. We observed 72 people in 26 groups on Franc`s Peak between 13 July and 17 September 2017; 88 % of which approached the summit from the northern side. We documented 17 human-grizzly bear encounters in July and August, and the grizzly bears were displaced in 94 % of the them. We did however, not find any evidence of a permanent displacement of grizzly bears by humans. We recorded 121 grizzly bear-locations on Franc`s Peak and 22 grizzly bear-locations on Carter Mountain. Grizzly bears on both sites selected for higher elevation and less steep slopes. In addition, grizzly bears avoided herbaceous habitat on Franc`s Peak and selected for south and east aspects on Carter Mountain. These findings indicate that grizzly bears visited Franc`s Peak and Carter Mountain primarily to consume army cutworm moths. The current level of human use on Franc`s Peak appears to be too low to have a permanent impact on grizzly bears` habitat use. However, the relative high rate of encounters between grizzly bears and humans, and the bears` responses, suggests that the disturbance potential is high if the number of humans were to increase.

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Introduction

Mitigating human disturbance of wildlife is vital for the long-term conservation of species. Recreational activities, such as trekking, mountain climbing, and wildlife viewing, can displace and disturb wildlife (Boyle and Samson, 1985). Animals may, for instance, avoid quality foraging habitats (McLellan and Shackleton, 1989, Gander and Ingold, 1997, White et al., 1999) or change their activity pattern (MacHutchon et al., 1998, Loehr et al., 2005, Rode et al., 2007, Ordiz et al., 2013) in response to human use. At worst, human disturbance may even reduce the animals` survival (Boyle and Samson, 1985, Knight and Cole, 1995).

Before Europeans settled North America, the grizzly bear existed throughout the contiguous United States (Rausch, 1963). By the 1930s, the population had been reduced to less than 2% of its historical range, due to extensive human activity (Mattson et al., 1995, cited by Schwartz et al., 2002), and by the 1950s, only 3 isolated grizzly bear populations remained in the lower 48 states (Gunther et al., 2014). Consequently, the grizzly bear was listed as a threatened species under the Endangered Species Act in 1975 (USFWS, 2016). Successful management brought the bears back from the brink of extinction, and in 2017, the distinct population segment of the Greater Yellowstone Ecosystem was delisted, i.e., it was no longer considered to be threatened. The population is believed to be close to carrying capacity and is estimated at 695 individuals (van Manen et al., 2016). As a result of the delisting, the states of Idaho, Montana, and Wyoming will resume management of the GYE grizzly bear. Nonetheless, the continued monitoring of the GYE grizzly bear and its habitat will still be important for the long-term conservation of this population.

The diet of the GYE grizzly bear population is very diverse, consisting of more than 250 species of plants and animals (Gunther et al., 2014). Their food habits vary on a seasonal scale, as the availability of different food items changes. From late May through early June, elk (*Cervus elaphus*) calves serve as an important high-protein source after hibernation (van Manen et al., 2013). From mid-August through September, whitebark pine *(Pinus albicaulis*) seeds make up a substantial portion of their caloric intake (van Manen et al., 2013). Other frequently used food items are ants (*Formicidae*) and a variety of plants (Gunther et al., 2014). Grizzly bear foraging behavior also varies on a geographical scale. Not all high-caloric food sources are available to all grizzly bears within the GYE, e.g., army cutworm moths. Army cutworm moths are primarily selected by grizzly bears with home ranges on the eastern side of the GYE (French et al., 1994). This phenomenon was first observed by the Interagency

Grizzly Bear Study Team (IGBST) in 1986 (French et al., 1994). Since then, several authors have documented grizzly bears consuming army cutworm moths in the GYE (Mattson et al., 1991b, French et al., 1994, O'Brien and Lindzey, 1994, Robison, 2009).

In late spring or early summer, the army cutworm moths migrate from the Great Plains to escape the high temperatures at lower elevations (Pruess, 1967, Hardwick and Lefkovitch, 1971). They aggregate at high elevations in the Rocky Mountains, where they feed on nectar from various alpine plant species (Pruess, 1967). Because army cutworm moths are nocturnal (Pruess, 1967), they hide under rocks in the talus fields during the day to protect themselves from the sun and the frequent summer storms (French et al., 1994, O'Brien and Lindzey, 1994). Once the flowering season ends in September, the moths migrate back to the Great Plains (Pruess, 1967, White et al., 1998a). While the moths are present, grizzly bears occupy the talus fields during the day (Mattson et al., 1991a, White et al., 1998a), where they excavate and consume moths by the thousands (White et al., 1999). As of 2016, the IGBST has confirmed observations of grizzly bears at 31 unique moth sites in the GYE (van Manen et al., 2016). Previous research has shown that elevation, slope, and aspect are important descriptors of grizzly bear use at moth sites (Mattson et al., 1991b, O'Brien and Lindzey, 1994, White et al., 1998a).

Army cutworm moths are believed to be important to grizzly bears for several reasons. First, they are the richest food available in the GYE (Pritchard and Robbins, 1990, French et al., 1994). Samples of moths collected by French et al. (1994) showed that they contained approximately 72 % fat, giving a relatively high caloric value compared to other food items. White (1996, et al. 1999) estimated that a grizzly bear consuming moths can cover nearly half of its yearly needs over 30-day period. Second, the proportion of the GYE grizzly bears that visit moth sites is substantial. In 1994, it was estimated that roughly 45 % of the grizzly bears used moth sites (O'Brien and Lindzey, 1994). Similarly, in 2014, van Manen et al (2016) observed 343 grizzly bears using moth sites, more than half of the GYE population. In 2016, the number of grizzly bears using moth sites was estimated to be approximately 30 % of the GYE population (van Manen et al., 2016). Last, because moths are available during autumn, not only do they serve as an important food source during hyperphagia, but they also geographically separate bears from human activity at a time where human-caused grizzly bear fatalities are at its highest (Haroldson et al., 2006).

In recent years, public awareness of this phenomenon has increased, and backcountry travelers, permitted outfitters, and international film crews have shown great interest in these moth sites (D. Tyers, pers. comm., 10 January 2017). In the Shoshone National Forest, Wyoming, Franc`s Peak and Carter Mountain are two of the several locations accessible to people where U.S. Forest Service staff have observed large aggregations of grizzly bears consuming army cutworm moths (D. Tyers, pers. comm., 10 January 2017). Managers fear that human activity may disturb foraging bears or displace bears from feeding areas, as well as pose a risk to human safety. Assessing grizzly bear and human use at these sites is therefore necessary to establish adequate regulations to ensure human safety and the vitality of the grizzly bears in this area, but also to secure the long-term protection of these areas and ultimately contribute to the further conservation of the GYE grizzly bear population.

For my thesis research, I planned to I) describe the extent of human use, i.e. level of visitation and choice of hiking routes, and II) assess if human hikers displace grizzly bears on Franc`s Peak and Carter Mountain. I assessed the latter on two scales. First, I hypothesized that hikers would displace grizzly bears during encounters (H1). Secondly, I hypothesized that human use could cause a lasting displacement effect on grizzly bear resource selection (H2).

Methods

Study area

This study area was located in the Shoshone National Forest in the eastern part of the Greater Yellowstone Ecosystem in Wyoming, USA (Fig. 1). The research was conducted above timberline (~ 3,400 m a.s.l.) on two different locations, Carter Mountain (3,755 m a.s.l.) and Franc`s Peak (4,009 m a.s.l.). These mountains are characterized by steep talus slopes and narrow ridgelines extending out from the peaks and are interspersed with deep canyons (Bonney & Bonney, 1960). The high-elevation plateaus (3,500 m a.s.l.) are mostly barren, but forbs (*Lomatium* spp., *Trifolium* spp.) and graminoids (*Carex* spp., *Poa* spp., *Agropyron* spp.*)* are not uncommon (Nünlist, *unpub. data*). The field vegetation at lower elevations is dominated by short grasses and wildflowers. Common species are forget-me-not *(Eritrichum aretioides),* snow buttercup (*Ranunculus adoneus),* and snow-lily *(Erythronium grandiflorum)* (Beidleman et al., 2000).

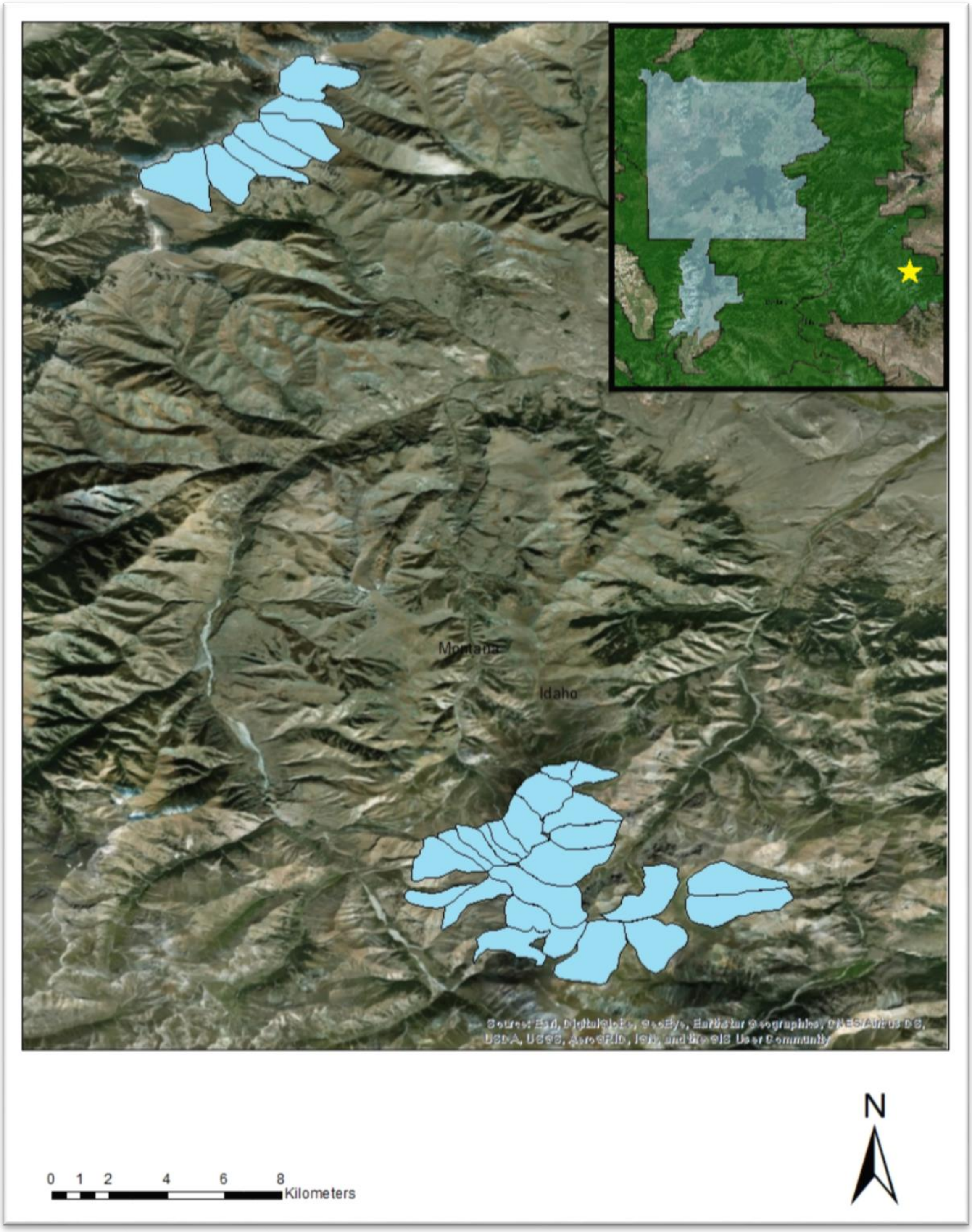

Figure 1*.Inset:Location of the study area in northeastern Wyoming, USA, southeast of Yellowstone National Park and east of Grant Teton National Park (both shown in light blue in top right corner). Main figure: the two study sites in a closer view; Franc`s Peak (bottom) and Carter Mountain (top), both depicted as blue polygons indicating the survey areas for grizzly bears.*

Summers are short and warm, with highs of +25°C, although temperatures can reach 0°C (Bonney and Bonney, 1960). Precipitation at this time of year is sparse, but hazardous afternoon lighting storms occur frequently (D. Tyers, pers. comm., 10 January 2017). Snow cover usually lasts from late September/early October until late June/early July (D. Tyers, pers. comm., 10 January 2017). Cattle grazing allotments are found in close proximity to both study sites, and depredation by grizzly bears is known to occur (A. Pils, pers. comm., 15 August 2017).

Data collection

Human data

We collected data on human use of the area by providing GPS trackers (BT-Q1300ST Sports Recorder) to hikers every Saturday and Sunday from 13 July to 17 September 2017. Challenging logistics forced the project to focus its efforts on the Phelps Mountain Road and Meadow Creek Trailhead on the north and south sides of Franc`s Peak, respectively. Based on conversations with U.S.F.S. staff prior to the fieldwork, Franc`s Peak was reported to be the most visited and therefore their main concern regarding potential human effects on bears (A. Pils, pers. comm., 9 June 2017).

To account for malfunctioning GPS units, groups with five members or less were each given a tracker and groups with six or more were given trackers equal to half their group size. The trackers recorded a GPS location every minute. The crew also recorded time, date, and number of people for each group. Hikers returned the GPS unit to a crew member, if present, or to a drop box placed at the trailheads. We also recorded opportunistic encounters between crew members and hikers by 1) giving them a GPS tracker if they had recently started their hike or 2) drawing their route on a map if they were coming back from the hike (later digitized in GIS).

We also documented potential encounters between humans and grizzly bears. To collect information on this, we handed every group a survey sheet (Appendix 1), where they could specify the location of the encounter(s), distance to the grizzly bear(s), and the bears` reaction. The crew also recorded encounters they had with grizzly bears throughout the season, with the same information. We defined encounters between humans and grizzly bears as any interaction where eye contact was made.

Grizzly bear data

We collected data on grizzly bear locations from ground observations on and around alpine army cutworm moth aggregations sites, henceforth known as moth sites, from 13 July to 17 September 2017. We visited 23 unique observation points once or twice every 14 days. A View Shed analysis performed in GIS allowed us to find optimal observations points needed to observe ~ 100 % of the focal area. The final observation points were selected based on accessibility and proximity to suspected moth sites.

Figure 2. *Observation points (red triangles) at Franc's Peak (left) and Carter Mountain (right) and the associated survey areas (blue polygons). The gold stars represent the summits.*

We made observations non-intrusively with 10x42 mm binoculars and 20-60x60 mm spotting scopes. Each observation point was associated with one, two, or three survey areas (Fig. 2), based on the View Shed analysis, resulting in 29 survey areas. We conducted 138 unique surveys between 06:00 to 13:00, with each survey lasting 20 min. However, if we had not entered the data for all the observed bears in the survey site within 20 min, we prolonged the observation time by 5-10 min. Additional bears observed during this prolonged time were also included. By changing the order at which we visited the observation sites, we ensured that the survey sites were observed at different times throughout the day. We visited all survey sites 4-7 times during the field season.

We entered the data into a field computer installed with ArcPad 10.2.4. Aerial imagery of the survey site allowed the observer to determine the approximate location of a bear, in addition to time and date. We also recorded all opportunistic sightings of bears throughout the day with the same information. To validate the bear observations, two crew members conducted the surveys simultaneously, but independently. We discussed every survey after it was complete to deal with inconsistencies in the data (e.g. correct the locations of misplaced bears). Bear detection did not vary greatly between crew members. A grizzly bear had been observed by one crew member, but not the other, in 11 of 141 surveys. I decided to include these observations to increase the sample size.

Pre-Processing

Landscape variables

I extracted landscape variables; Land Cover Data LCD (National Land Cover Dataset by State) and Digital Elevation Model DEM (National Elevation Dataset 10 METER), which I obtained from the USDA Geospatial Gateway for Park County, Wyoming (https://datagateway.nrcs.usda.gov/GDGOrder.aspx) on 20 December 2017. I calculated slope steepness (degrees) and aspect from the DEM in ArcMap 10.5.1. I converted the Land Cover dataset to dummy variables, which included Barren Land, Herbaceous, and Shrub/Scrub on Franc`s Peak, and Barren Land and Herbaceous on Carter Mountain. I also converted the Aspect dataset to dummy variables, which included North, South, West and East. The use of dummy variables requires one of the dummies to be omitted from the model (Suits, 1957).

Human variables

At Franc`s Peak, we documented 18 groups and their routes of travel. I digitized these routes and calculated the human use with the line density function in GIS (cell units = 25 m, search radius = 750 m). I assumed that most hikers followed the recommended route for ascending Franc's Peak that I found in selected books and websites (Appendix 2). I digitized this route in GIS and calculated the distance from the bears to the recommended route using the Euclidean distance function in GIS. Because we observed bears close to our observations points on Franc`s Peak on a few occasions, I included the potential effects from crew use in the analysis. I digitized all our travel routes and calculated our use with the line density function in GIS (cell units = 25 m, search radius = 750 m). Because we prioritized Franc`s Peak, there was little data on human use on Carter Mountain. Therefore, I did not include any human variables in the analysis of Carter Mountain.

Observer effort

To account for different search effort between survey areas on Franc`s Peak, I assigned the total observation time to each area. Search effort on Carter Mountain was equal between all survey areas and search effort was therefore not included in the analysis of the Carter Mountain data.

Resource selection model

I modeled bear resource selection as presence/availability with a binominal generalized linear model (GLM) (Boyce et al., 2002). Presence data consisted of 143 unique bear observations (Franc`s Peak = 121, Carter Mountain = 22), and resource availability was sampled by generating ~ 160 000 random points inside the survey sites in GIS (density = 1 point / 270 m^2). I analyzed the two study sites separately. Because I was interested in how all potential explanatory variables affected bear resource selection, I chose to focus on the full model only, without any model selection procedure (Steyerberg et al., 2000, Harrell, 2015, Boyce, 2006). I checked for correlation between all continuous variables with a correlation matrix, and removed potential correlated variables ($r \geq 0.6$) from the model. I also investigated boxplots between categorical and continuous variables to rule out potential correlations between explanatory variables.

Table 1*. A generalized linear model without model selection, was run for each location with grizzly bear habitat selection as the response variable. Explanatory variables are displayed in the table for the two sites, Franc's Peak and Carter Mountain, Wyoming.*

Model	Location	Response variable	Explanatory variable
RSF_{FP}	Franc`s Peak	Bear resource selection	Aspect:East Aspect:South Aspect:West Slope Elevation Barren Land Herbaceous Distance to recommended route Human density Crew density Observer effort
RSF_{CM}	Carter Mountain	Bear resource selection	Aspect:East Aspect:South Aspect:West Slope Elevation Barren Land

Because of small sample sizes of observations (n RSF_{FP} = 121, n RSF_{CM}= 22) in a large geographical space, RSF estimates may not be robust when sampled in a 1:1 use/availability fashion. Hence, I applied bootstrapping on Franc's Peak and Carter Mountain with 1000 repetitions (Efron and Tibshirani, 1994, Davison and Hinkley, 1997). With bootstrapping, the RSF models resampled the random points with a sample number equal to the number of bear observations, and produced 1000 estimates for each variable. I extracted the model estimates from each sample and plotted them with a Gaussian kernel density estimator (KDE). I considered the effect to be significant if the KDE distribution did not include zero (Boyce et al., 2002). I also considered distributions that did not include zero between the 2.5 and 97.5 percentiles to have a small significant effect.

I validated the models using the cv.binary function from the DAAG package in a bootstrap manner (n = 1000) (Maindonald and Braun, 2006, Maindonald and Braun, 2014), and plotted the cross-validation estimates of accuracy in a KDE (Appendix 3).

Results

Human use

Weekend visitation

We observed a total of 19 groups using the Phelps Mountain Road and Meadow Creek Trailhead on Franc`s Peak during the 10 weekends between 13 July and 17 September 2017 (Fig. 3). Of the two approaches to Franc`s Peak, the north approach from the Phelps Mountain Road was by far the most used (n=16) (Fig. 3). We also documented another 7 groups opportunistically during the week days (Appendix 4).

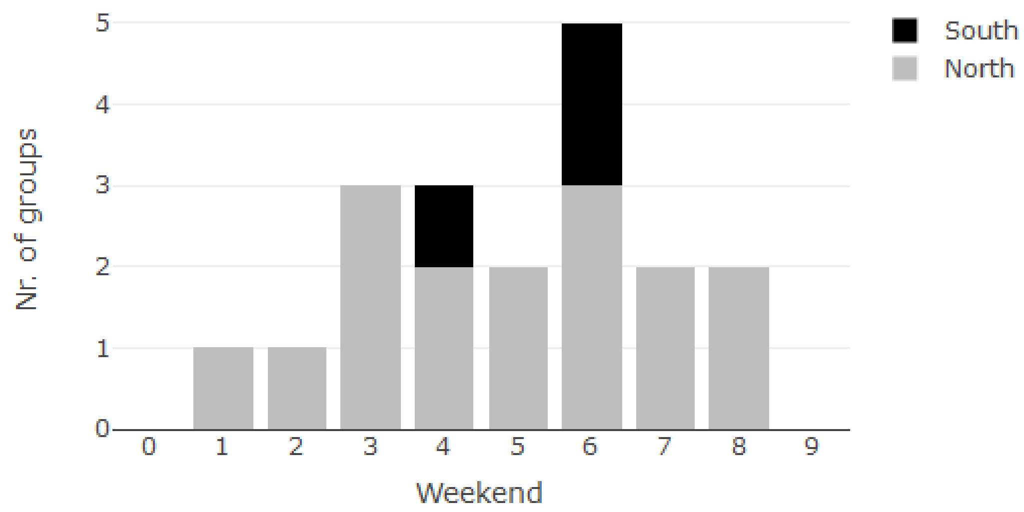

Figure 3. *Human visitation by weekend at the Phelps Mountain Road north of Franc's Peak (n = 16 groups) and the Meadow Creek Trailhead south of Franc's Peak (n = 3 groups), Wyoming, during the 2017 field season. Y-axis: Weekend 0 = 15-16 July - weekend 9= 16-17 September. NB: no crew members were present at Meadow Creek Trailhead during the first two weekends.*

Hiking routes

Based on the GPS data from the groups that participated in the study (n = 18), half of the groups (n = 9) hiked the recommended route along the northeastern ridge (Fig. 4). Multiple routes on the northwestern side were used by some groups (n = 3). Another group of people (n = 1) made a loop, going up on the western side and coming down on the eastern ridge. A few groups (n = 2) reported that they were scouting for game animals. We documented the other groups (n = 3) on the southern side of Franc`s Peak, none of which intended to climb to the peak.

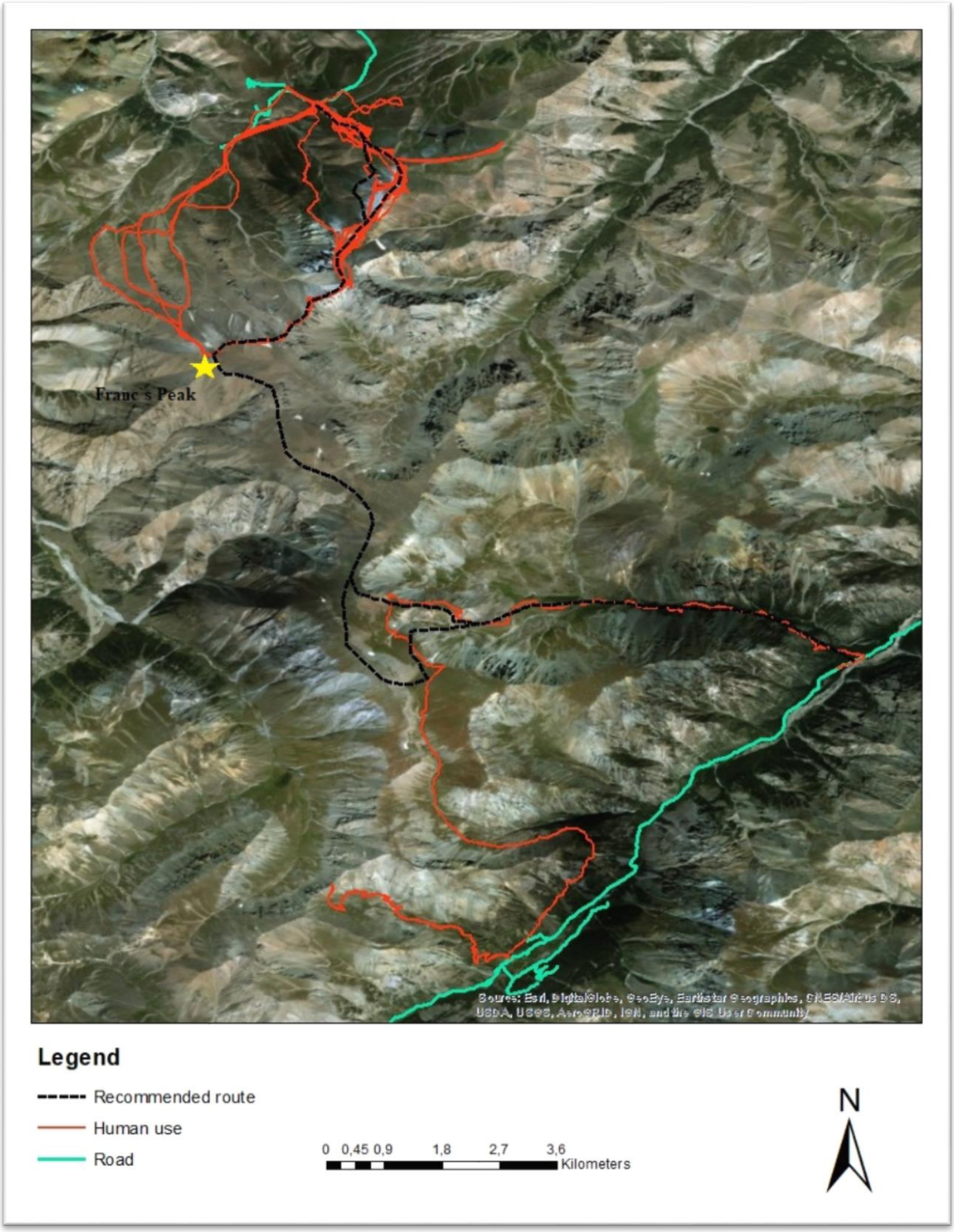

Figure 4. *Observed human use on Franc`s Peak, Wyoming, based on 18 groups of people and the routes they used from 13 July to 17 September 2017. Routes were documented from GPS units (n=16) and opportunistic interviews (n=2). The recommended route (black line) was the most travelled, with 9 out of 18 groups using it.*

Human – grizzly bear encounters

We recorded 17 human-grizzly bear encounters on Franc`s Peak from 13 July – 17 September (Fig. 5). Four of these encounters involved crew members during field work, 3 of which took place on the southeastern plateau below the peak. We also documented 4 encounters just below the peak on the northwestern ridge and 8 more encounters in a large area along the northeastern ridge. One encounter occurred at the peak. The encounters occurred in July and August, and the grizzly bears were displaced in 16 of the 17 encounters. The distance from the group of people to the bear(s) when first encountered varied from 50 m to 500 m (Appendix 5). Although American black bears (*Ursus americanus*) occur in the area, we did not observe any during our study, nor did the hikers.

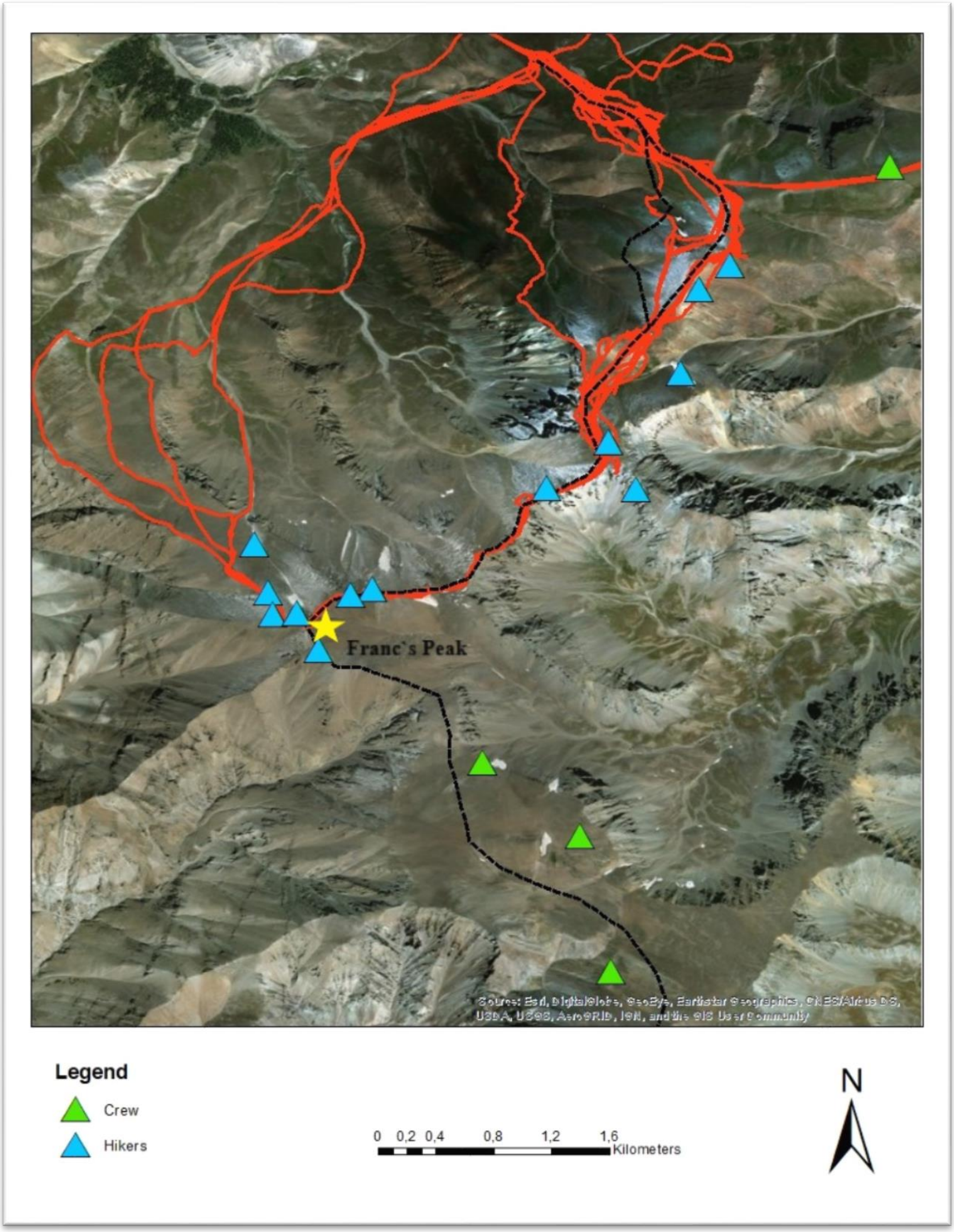

Figure 5. *Human – grizzly bear encounters (n = 17) on Franc`s Peak, Wyoming, between 13 July – 17 September 2017 involving hikers (blue triangles, n = 13,) and crew members during field work (green triangles, n = 4).*

Grizzly bear resource selection

Franc`s Peak

I included 121 unique grizzly bear positions in the analysis. After correcting for observer effort (β ± se; 0.023 ± 0.0002), bears selected for higher elevations (0.009 ± 0.00004), tended to select for less steep slopes (-0.037 ± 0.0005), and avoided herbaceous habitat (-1.023 ± 0.0154) (Fig. 6). I considered all other model terms as not significant (Appendix 6).

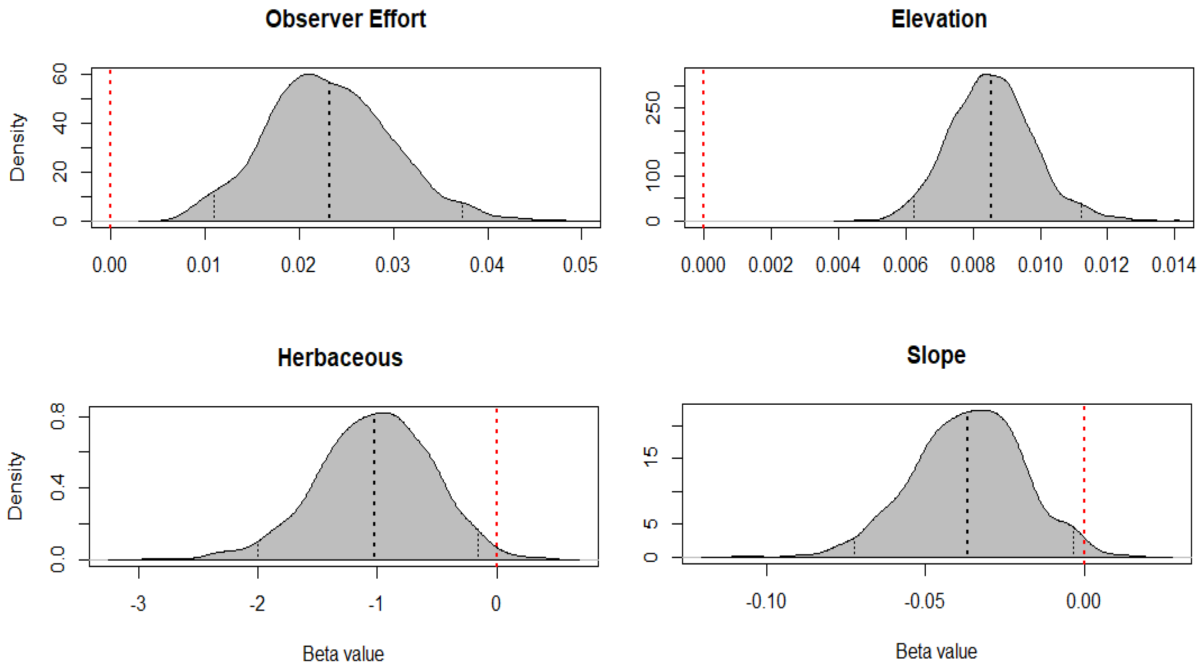

Figure 6. *Grizzly bear resource selection on Franc`s Peak, Wyoming, during July – September 2017. Kernel density estimation plot for; Observer Effort (kernel bandwidth = 0.1183, Elevation (kernel bandwidth = 0.0002), Herbaceous vegetation (kernel bandwidth = 0.1058) and Slope (kernel bandwidth = 0.00369). X-axis: beta estimates (n = 1000), y-axis = kernel density. Distribution mean (black dotted line) and zero-line (red dotted line) are displayed in each plot.*

Carter Mountain

I included 22 unique bear positions in the analysis. Bears selected for higher elevations (0.0097 ± 0.00006), relatively less steep slopes (-0.0542 ± 0.0007), and were oriented to the south (1.6733 ± 0.0165) and east (1.2207 ± 0.0151). All other model terms were not significant (Appendix 7).

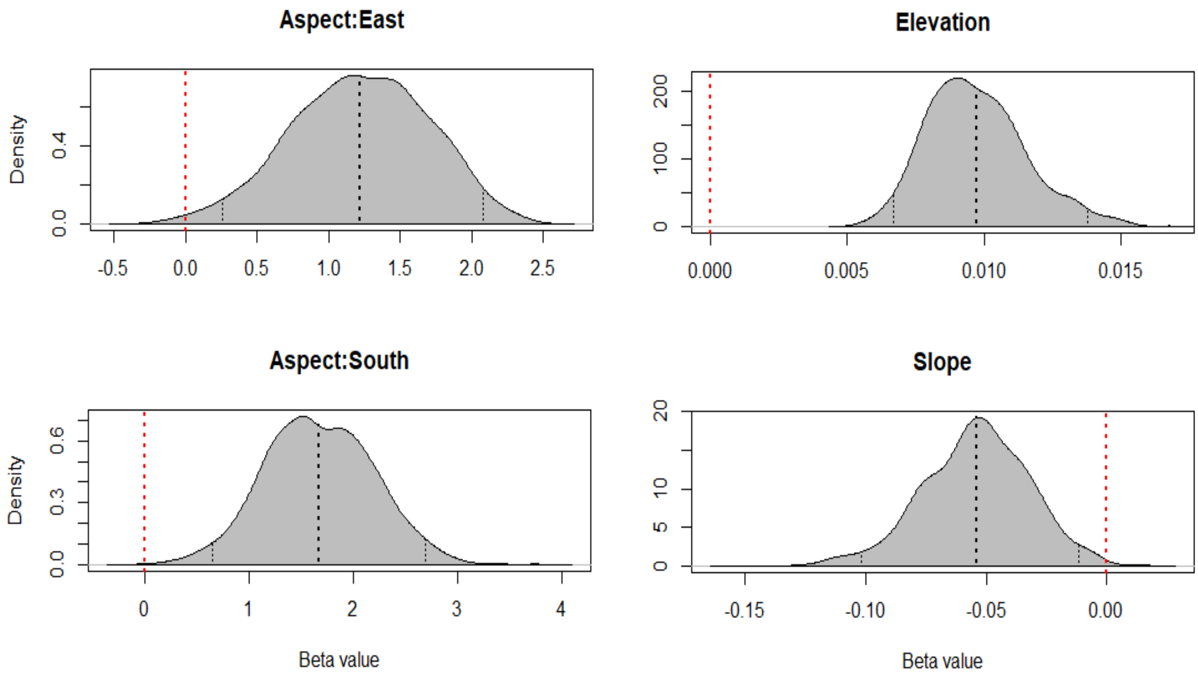

Figure 7. *Grizzly bear resource selection on Carter Mountain, Wyoming, from 13 July – 17 September 2017. Kernel density estimation plot for Elevation (kernel bandwidth = 0.0004), Slope (kernel bandwidth = 0.0049) and aspects; east (kernel bandwidth = 0.1077) and south (kernel bandwidth = 0.1181). X-axis = beta estimates (n = 1000), y-axis = kernel density. Distribution mean (black dotted line) and zero-line (red dotted line) are displayed in each plot.*

Discussion

Our data showed that the current level of human use on Franc`s Peak is low, and that most hikers approached the summit from the northern side. Encounters between humans and grizzly bears were common, and the bears were displaced in nearly all (94 %) of them, which supports H1. However, the RSF_{FP} showed no evidence of a permanent displacement of grizzly bears by human use on Franc`s Peak, which do not support H2. Additionally, the RSF_{FP} and the RSF_{CM} indicated that grizzly bears visited both study locations primarily to forage at the moth sites. Elevation and slope were both significant descriptors of grizzly bears use. However, aspect was only significant on Carter Mountain.

Human use

Human use on Franc`s Peak had not been documented previously, therefore we had no expectations with regards to how many visitors there would be throughout the season. In total, we documented 26 groups of people over the course of 10 weeks, 19 of which occurred on the weekends (Fig. 3). This number is probably an underestimation. Because we also observed human use during the weekdays, it is very likely that we missed groups of hikers on the days we were not in the field. Nevertheless, assuming that people primarily use weekends for recreational activities, I believe that we captured most of the human use on Franc`s Peak, based on our weekend efforts at the Phelps Mountain Road and Meadow Creek Trailhead. Franc`s Peak is remotely located, approximately 2 hours from the closest small town (Meeteetse, population 327), and can only be accessed with four-wheel drive vehicles. In perspective, 26 groups of people during the two-month period of 13 July – 17 September is a low number of visitors, but not surprising given the remoteness and poor accessibility of the area.

The level of human use on the northern side of Franc`s Peak was much greater than we observed on the southern side (Fig. 3). Although we were not present on the southern side during the first two weekends of the field season, I doubt this explains the difference. The southern approach to Franc`s Peak is a 2-day hike, as described in books and on websites (Appendix 2). By contrast, climbing Franc`s Peak from the northern side is only a 1-day hike and thus offers easier access to the summit (Appendix 2). I believe this is the primary reason why people chose to approach Franc`s Peak from the northern side. This is also consistent with our data on the hiking routes. I confirmed that that the recommended route on the northern side was the most used (Fig. 4). As opposed to the southern side, where no people were documented using the recommended route, or any other route, to climb the peak (Fig. 4). Although we may have missed a few groups on both sides of Franc`s Peak, I believe our data strongly indicate that the northern side in general, and especially the recommended route, is the most used by people for recreational purposes.

Human – grizzly bear encounters

Of 12 groups that provided information about grizzly bear encounters, 7 groups reported having one or more encounters. In total, we documented 13 encounters between grizzly bears and hikers and another 4 encounters between crew members during field work and grizzly bears (Fig. 5). In 16 of 17 of the documented encounters, the bear(s) ran or walked away from the source of disturbance (Appendix 5). How bears react to humans on foot is influenced by many factors. McLellan and Shackleton (1989) found that grizzly bears reacted more strongly to people on foot (e.g. displaced more often and moved farther) in open areas, compared to areas with cover. They also observed that the grizzly bears` reactions were strongest in areas of low human use (McLellan and Shackleton, 1989). In Glacier National Park (GNP), grizzly bears displayed more aggression towards hikers in areas of low human use than in areas of high human use (Jope, 1985). These studies and other researchers argue that habituation can occur in areas that humans visit frequently, and consequently reduce the strength of the animals` reactions to humans (Thorpe, 1956, Kimmel, 1973, Knight and Cole, 1995).

Franc`s Peak is an open mountainous habitat and has a relatively low level of human use, which likely is too low to develop habituation. These two factors may explain why grizzly bears on Franc`s Peak reacted strongly to humans. Another important factor to consider in human-bear encounters is group size. Gunther and Hoekstra (1998) found that most bear-inflicted injuries to humans in Yellowstone National Park happened to single individuals or pairs. In Denali National Park, grizzly bears behaved more aggressively towards smaller groups of people than large groups (Albert and Bowyer, 1991). During our study, 14 of the 17 encounters involved a group of ≥ 3 people (Appendix 5). This may partly explain why no bears displayed aggression towards any of the hikers, but rather moved away. Although the Scandinavian brown bear was not found to display any aggressive behavior towards people, regardless of group size, in the experimental approaches carried out by Moen et al (2012), it is believed that North American brown bears (*Ursus arctos*) are generally more aggressive (Swenson et al., 1999).

The potential energetic effects of human disturbance of bears feeding at moth sites have been quantified by White et al. (1999). Although their sample size was small, they estimated that bears spent 53 % less time foraging in a single day after being disturbed, compared to when undisturbed (White et al., 1999). They also estimated that bears can consume more than 40,000 kcal per day from eating army cutworm moths (White et al., 1999). Although many have studied bears` immediate reactions, few have been able to document any lasting effects on bears after human encounters. In Sweden, however, Ordiz et al. (2013) recorded the behavior of brown bears in the days following experimental encounters with a human. The bears changed their daily movement patterns for the two succeeding days, becoming more active during the night and less active at daytime (Ordiz et al., 2013). Similar responses have been found in Alaskan and Canadian brown bears, where the bears became more night-active after being disturbed by humans (MacHutchon et al., 1998, Rode et al., 2007). Although bears can alter their activity pattern to accommodate human use, grizzly bears at moth sites are unable to adopt a nocturnal feeding strategy. When army cutworm moths feed in the alpine meadows at night, they become unavailable to grizzly bears. Hence, grizzly bears must forage at moth sites during the day and therefore do not have the option to avoid humans at daytime.

The importance of army cutworm moths as a food source for grizzly bears in the GYE is unknown, and how bears use moth sites in relation to other food sources when moths are abundant or scarce, has not yet been explored (Robison, 2009). Other foods, such as the whitebark pine, is an important food source for bears in the GYE. Abundant seed crops have been positively correlated with increased bear fecundity, lower human-cause grizzly bear mortality, and reduced numbers of management actions (Mattson et al., 1992, Gunther et al., 2014). It is believed that moths may have the same influence on a segment of the GYE grizzly bears (Schwartz et al., 2006). White (1996, et al. 1999) also suggests that undisturbed bears at moth sites are well fed and thus less inclined to depredate on livestock. Given the caloric value of army cutworm moths and the disturbance potential at Franc`s Peak, the grizzly bears' energy intake could be reduced significantly if they were to be disturbed repeatedly by humans. Consequently, this could potentially negatively affect the grizzly bears` survival and reproduction, and possibly increase nearby livestock depredations.

Grizzly bear resource selection

In my analyses of grizzly bear observation data from Franc`s Peak, I did not find any evidence of a permanent displacement of grizzly bears by the current level of human use (Appendix 6). I confirmed that the recommended route from the northern side was the most commonly used approach by hikers (Fig. 4), but the results did not indicate that grizzly bears were displaced from this route (Appendix 6). Nor did I find any indication that the crew`s field work affected the grizzly bears` habitat use (Appendix 6).

In this study, we surveyed areas with an altitude ranging between 3,000 – 4,000 m that included potential moth sites and their surroundings. My results showed that grizzly bears on Franc`s Peak (Fig. 6) and Carter Mountain (Fig. 7) selected for higher elevations. Grizzly bears were generally at elevations between ~ 3,700 – 4,000 m on Franc`s Peak and at elevations between ~ 3,550 – 3,750 on Carter Mountain (Appendix 8). In addition, I found a tendency towards a selection for less steep slopes in both study sites (Figs. 6 and 7). When I compared the distribution of the observed bear locations to the random points (Appendix 8), I found that grizzly bears occurred less frequently on the very steep slopes, > 43°, and on flatter areas, < 27°, and more frequently on intermediate slopes, between 27-42°. These findings are consistent with the literature on grizzly bear use at moth sites, where researchers generally observed more bears at higher elevations and at slopes between 31 – 45° (Mattson et al., 1991b, O'Brien and Lindzey, 1994, White et al., 1998a).

Army cutworm moths aggregate at high elevations in talus on slopes between 13 - 60°, which are usually found below large headwalls (French et al., 1994, O'Brien and Lindzey, 1994, White et al., 1998b). O'Brien and Lindzey (1994) investigated moth abundance and grizzly bear use in talus slopes in the Absaroka Mountains, in which the study area is located, and suggested that grizzly bears preferred foraging for moths on the intermediate slopes. The very steep slopes may contain too little talus accumulation to support moths and therefore are avoided by the bears. In the flatter areas, slopes may not be steep enough for bears to cost-effectively dig through talus to catch moths. Hence, intermediate slopes would be favored by bears, because they can support moths and they allow bears to cost-effectively forage on them (O'Brien and Lindzey, 1994).

Grizzly bears on Carter Mountain showed a tendency to select for areas oriented to the south and east (Fig. 7). I believe this result can in part be explained by the topography of the mountain. Our survey sites on Carter Mountain included four different cirques, with their headwalls facing either south or east. Talus dominated these headwalls and, based on our observations of grizzly bears and moths at these sites, we suspected that these sections of the cirques supported moth populations that were visited by grizzly bears. We also surveyed the two sides of every ridge that separated the different cirques. The sides were oriented in north/south or east/west directions, and were either vegetated or too steep to allow an accumulation of talus. The presence of moths in these areas was unlikely, which may be why we observed few grizzly bears here. If grizzly bears visited Carter Mountain primarily to feed on moths, I would expect them to select for the south- and east-facing headwalls, which is what my analysis indicated.

Although research suggests that grizzly bears prefer moth sites at south and west aspects (Mattson et al., 1991b, O'Brien and Lindzey, 1994, White et al., 1998a), grizzly bears have been documented using moth sites at all aspects (Mattson et al., 1991b, French et al., 1994, O'Brien and Lindzey, 1994, White, 1996, White et al., 1998a). The apparent selection of south and west aspects by grizzly bears is merely a result of moth habitat selection (Robison, 2009). Preuss (1967) explained that moths are temperature sensitive and therefore will select for warmer areas. A warmer microenvironment reduces the moths` energy cost related to flight and maintenance of body temperature (Heinrich, 1974).

On Franc`s Peak, I also found that grizzly bears tended to avoid herbaceous habitat (Fig. 6). Because our survey sites covered areas adjacent to the potential moth sites, nearly 40% of our study area on Franc`s Peak was herbaceous. Although we commonly observed grizzly bears foraging for vegetation, we observed fewer bears on herbaceous land than expected. Because we found that grizzly bears selected for higher elevations and intermediate slopes at Franc`s Peak (Fig. 6), I conclude that grizzly bears probably visited Franc`s Peak primarily to forage on moths. The land cover variable barren land, which is where potential moth sites would be, covered 50% of the study area on Franc`s Peak. However, barren land included all unproductive surfaces (e.g. rocks, talus, scree), and therefore probably performed poorly as a descriptor of grizzly bear selection at moth sites.

Management recommendations

Franc`s Peak offers great opportunities for bear enthusiasts, as well as for peak baggers and other recreational activities. It is the highest mountain in the Absaroka Range, and it can be easily accessed from the Phelps Mountain Road. Although the present rate of human visitation on Franc`s Peak is low, managers have expressed concerns about an increasing trend. Considering the relatively high rate of encounters between humans and grizzly bears that we documented, their concerns are legitimate. Even though the bears were not being permanently displaced by humans at the level of human use documented in 2017, their behavioral responses in encounters suggest that such a potential exists. Exacerbated by the open landscape, increased and predictable human use may displace bears from moth sites on Franc`s Peak in the future.

Establishing the relative importance of moth sites for grizzly bears on Franc`s Peak and Carter Mountain is central to the management of these areas. Army cutworm moths can provide grizzly bears with large amounts of energy from July through September, and consequently keep grizzly bears away from human activities in the lowlands. Regulating human use at these locations to prevent further disturbance of grizzly bears may therefore be necessary, not only to protect the vitality of the grizzly bears in the area, but also to ensure human safety and minimize livestock depredations.

To my knowledge, there has been only one instance where human access has been regulated to protect grizzly bears and humans at a moth site. In 1981, the Confederated Salish and Kootenai Tribal Council enforced a seasonal closure, restricting all human use on Macdonald Peak in the Mission Mountains, Montana (Klaver et al., 1986). Such a measure, may however not be attainable on U.S. Forest Service public lands. A more realistic approach involves directing human activities to reduce conflict and bear displacement while attending to human recreational interests (White et al. 1999; Knight & Gutzwiller 1995). There are essentially three ways to climb Franc` Peak; the recommended routes from the northern and southern sides, and the alternative route on the northwestern side. Restricting the human access to only one of these routes could potentially reduce conflict between humans and grizzly bears in the other frequently travelled areas.

A supplement to this could be to create bear “observation zones”, as suggested by White et al (1999). Numerous high-points on the northern side of Franc`s Peak offer good views of the moth sites from a safe distance. This combination will allow access to the summit, but also provide bear enthusiasts with great bear viewing opportunities, all while limiting the disturbance on grizzly bears. Public outreach should also be implemented to inform about grizzly bear use at already popular moth sites, such as Franc`s Peak.

Regarding Carter Mountain, additional research must be conducted to collect data on human and bear use, so that managers can decide upon an adequate strategy. In general, effort should be made to find and document human use at other accessible moth sites, and evaluate the conflict-potential between bears and humans. Doing so, managers will have an opportunity to implement proactive management in what is likely crucial habitat for the grizzly bears in the GYE, and thus contribute to the long-term conservation of the GYE grizzly bear population.

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Appendices

Appendix 1

Thanks for participating in the GPS tracking portion of our study! We would greatly appreciate additional participation in the following survey. Please return in the drop box with your GPS unit. If you forget, you can email a copy of the completed form to erikanunlist@gmail.com or send a photo to 406-407-2297.

THANK YOU!!

Date:__________ Name:______________________ Groupsize:___________________

Reason for visiting peak:____

How did you hear about Francs peak?____

Number of bears seen:_______________

Any bear interactions and how many (i.e. ~4 bears looked up at us, 2 bears ran away, 1 stood up, etc.)

____

____

____

Appendix 2

Table A1. List of websites and books used to define the recommended hiking route on Franc`s Peak.

Websites	Books
www.summitpost.org	Guide to the Wyoming Mountains and Wilderness Areas
www.listsofjohns.com	Select Peaks of Greater Yellowstone
www.peakbagger.com	Hiking Wyoming`s Teton and Washakie Wilderness Areas

Appendix 3

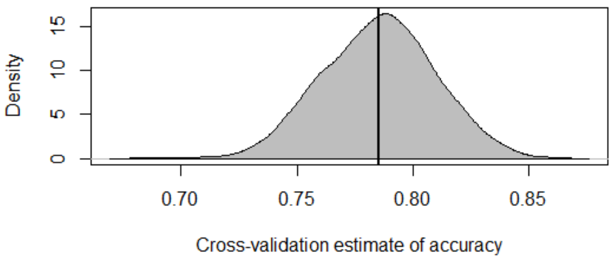

***Figure A1**. Cross-validation estimates of accuracy for RSF - Franc` Peak, Wyoming (n = 1000, bw = 0.012). The estimates were plotted in a Gaussian kernel density estimator. Distribution mean indicated by black line. X-axis: cross-validation estimates of accuracy, y-axis: kernel density.*

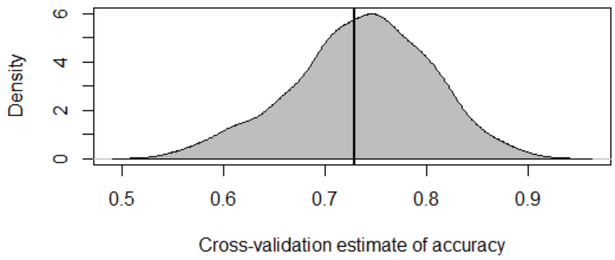

Figure A2. *Cross-validation estimates of accuracy for RSF – Carter Mountain, Wyoming (n = 1000, bw = 0.018). The estimates were plotted in a Gaussian kernel density estimator. Distribution mean indicated by black line. X- axis: cross-validation estimates of accuracy, y-axis: kernel density.*

Appendix 4

Tabell A2. List of the 26 groups of people that visited Franc`s Peak, Wyoming, on the northern (Phelps Mountain Road) and southern side (Meadow Creek Trailhead) respectively, between 13 July and 17 September.

Area	Date	Group size	Documented how
Meadow Creek Trailhead	20.07.2017	2	Opportunistically
Phelps Mountain Road	22.07.2017	4	Weekend
Phelps Mountain Road	28.07.2017	1	Opportunistically
Phelps Mountain Road	29.07.2017	3	Weekend
Phelps Mountain Road	05.08.2017	3	Weekend
Phelps Mountain Road	06.08.2017	2	Weekend
Phelps Mountain Road	06.08.2017	4	Weekend
Meadow Creek Trailhead	08.08.2017	2	Opportunistically
Meadow Creek Trailhead	12.08.2017	2	Weekend
Meadow Creek Trailhead	13.08.2017	1	Weekend
Phelps Mountain Road	13.08.2017	12	Weekend
Phelps Mountain Road	18.08.2017	1	Opportunistically
Phelps Mountain Road	19.08.2017	1	Weekend
Phelps Mountain Road	19.08.2017	3	Weekend
Meadow Creek Trailhead	22.08.2017	4	Opportunistically
Phelps Mountain Road	25.08.2017	1	Opportunistically
Meadow Creek Trailhead	26.08.2017	3	Weekend
Meadow Creek Trailhead	26.08.2017	3	Weekend
Phelps Mountain Road	26.08.2017	2	Weekend
Phelps Mountain Road	27.08.2017	1	Weekend
Phelps Mountain Road	27.08.2017	2	Weekend
Phelps Mountain Road	02.09.2017	3	Weekend
Phelps Mountain Road	02.09.2017	2	Weekend
Phelps Mountain Road	04.09.2017	3	Opportunistically
Phelps Mountain Road	09.09.2017	1	Weekend
Phelps Mountain Road	10.09.2017	2	Weekend

Appendix 5

Table A3. We documented 17 human-grizzly bear encounters on Franc`s Peak, Wyoming, between 13 July and 17 September 2017.

Who	Date	Group size	Distance (m)	Cohort	Displaced
Hikers	13 July	5	100	Subadult	Yes
Hikers	13 July	5	100	Sow w/cubs	Yes
Hikers	22 July	4	NA	Sow w/cubs	Yes
Hikers	22 July	4	NA	Subadult	Yes
Hikers	22 July	4	NA	Adult	Yes
Hikers	1 August	3	200	Subadult	Yes
Hikers	1 August	3	180	Subadult	Yes
Hikers	1 August	3	500	Subadult	Yes
Hikers	5 August	3	NA	Subadult	Yes
Hikers	6 August	3	NA	Sow w/cubs	Yes
Hikers	6 August	4	300	Sow w/cubs	Yes
Hikers	6 August	2	50	Adult	Yes
Hikers	6 August	2	250	Sow w/cubs	Yes
Crew	9 August	3	150	Adult	Yes
Crew	9 August	3	50	Adult	Yes
Crew	9 August	3	200	Adult	Yes
Crew	23 August	2	200	Adult	No

Appendix 6

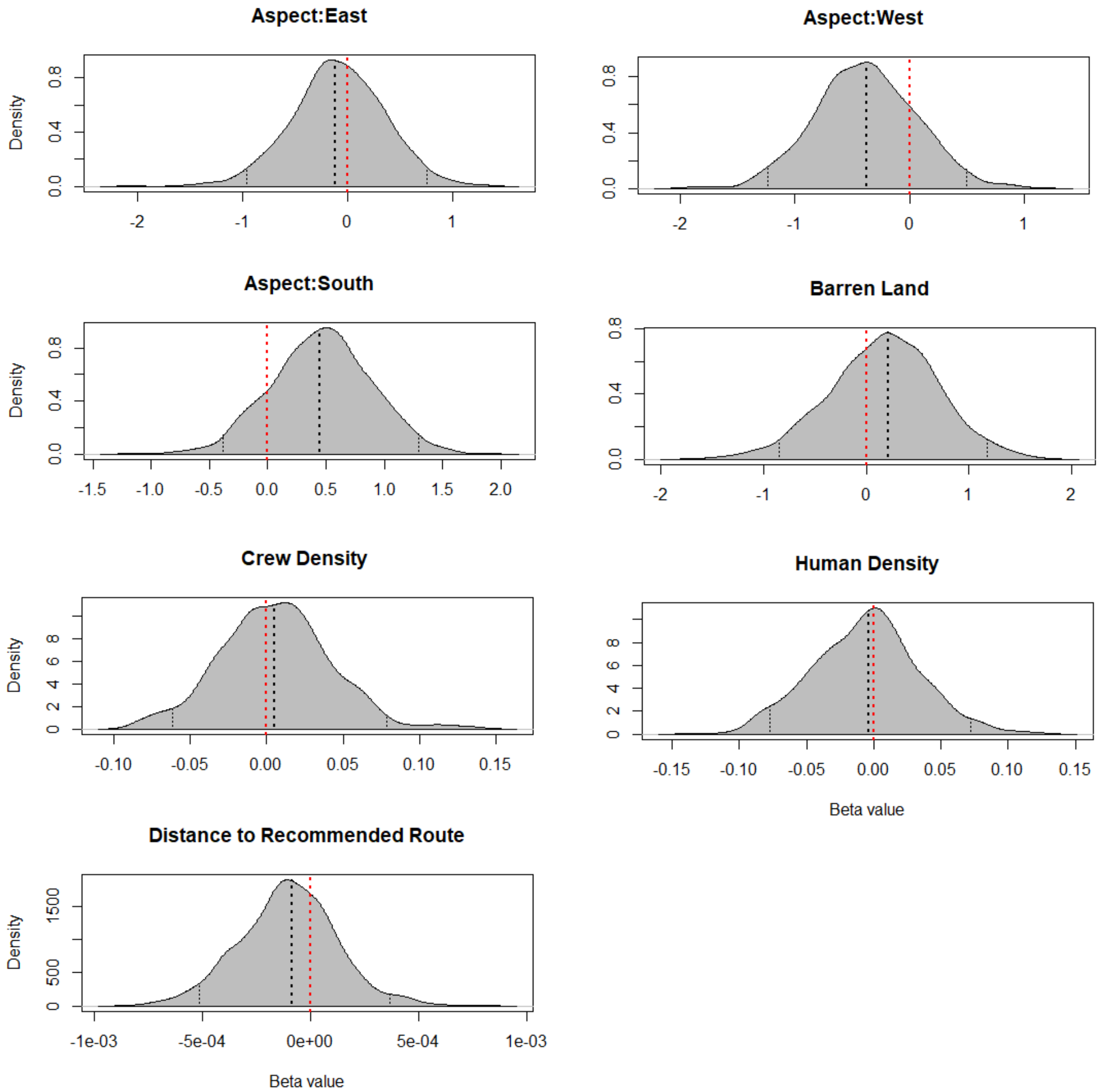

Figure A3. *Franc`s Peak; KDE plot for aspects; east (Kernel band width, bw = 0. 0936), west (bw = 0. 09300936) and south (bw = 0.0912), Barren Land (bw = 0.1183), Crew Density (bw = 0.007623), Human Density (bw = 0.0064) and Distance to Recommended Route (bw = 0.00004). X-axis = beta estimates (n = 1000), y-axis = kernel density.*

Appendix 7

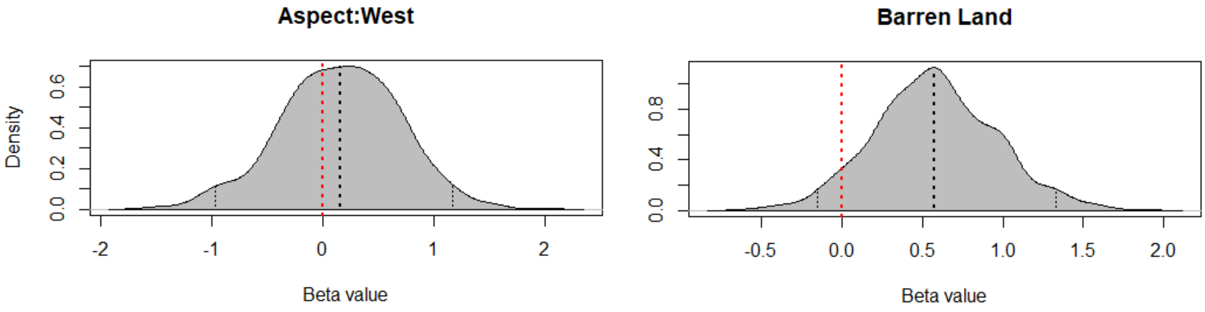

Figure A4. *Carter Mountain; KDE plot for Aspect:West (Kernel band width, bw = 0.1207) and Barren Land (bw = 0.08307). X-axis = beta estimates (n = 1000), y-axis = kernel density.*

Appendix 8

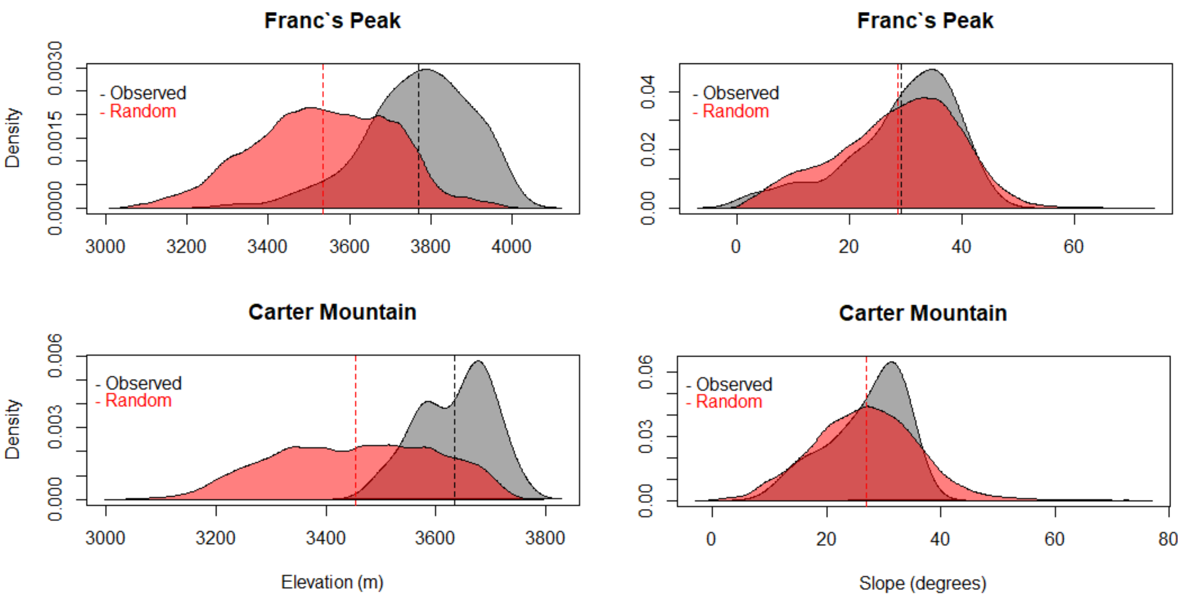

Figure A5. *Distributions of the observed and random grizzly bear points according to elevation (left) and slope (right), on Franc`s Peak (top) and Carter Mountain (bottom), Wyoming, plotted in a Kernel Density estimator. Y-axis: kernel density.*

Appendix 9

Table A4. Crew effort and observations of hikers at Franc's Peak and Carter Mountain, Wyoming, including the northern and southern approaches to Franc's Peak.

	Total crew effort (%)	*Groups of people observed*	*People observed*	*Travel routes documented*
Franc`s Peak (north)	45 %	20	58	15
	38 %	6	14	3

Franc`s Peak (south)				
Carter Mountain	17 %	3	7	1
Total	100 %	29	79	19

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