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American Black Bears (Ursus americanus) of the Paunsaugunt Plateau: Movements and Habitat Use

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Movements and Habitat Use

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ABSTRACT

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Master of Science

Concerns over human-bear conflict and questions about the ecology of Paunsaugunt Plateau's population of black bears (*Ursus americanus*) arose due to their visitation to popular recreation sites. Greater insight about bears and their habitat use provides a foundation for conflict mitigation and effective management decisions. Between 2014 and 2017, seventeen black bears (11 female, 6 male) were fitted with global positioning system (GPS) radio-collars so that we could track their locations, daily activity patterns, and ambient temperatures. By analyzing bear locations, we calculated annual and seasonal home ranges for 16 bears, including 25 den sites. Home ranges typically consisted of three dominant vegetation types, Utah juniper, ponderosa pine and Douglas fir. I used mixed effects models to better understand den site selection and found that slope (27.87 ± 2.03) was the most significant factor ($p < 0.001$). I also used mixed effects models to understand black bear selection of annual and seasonal home ranges. Predictor variables with the greatest effect ($p < 0.001$) were elevation (2419.99 ± 1.35) and aspect (138.44 ± 0.64), with coefficients of 1.128 and -1.483 respectively. Male annual home ranges (327.20 km^2 ± 133.58 km^2) were significantly larger ($p = 0.035$) than female home ranges (175.10 km^2 ± 55.37 km^2). However, annual home ranges for both sexes were larger than those during hyperphagia ($p = 0.003$) or mating ($p = 0.004$) seasonal home ranges, between which there was no difference ($p = 0.451$). Individual home ranges overlapped for most bears, consistent with their non-territorial nature. I found that bears avoided roads and lower elevations, while showing a preference for sloping terrain throughout the non-denning period. Paunsaugunt black bear home ranges are larger than any other black bear home ranges reported in literature. We determined weekly average distances and directions for all bears. For two bears, one male and one female, we determined daily averages and directions. Nine bears provided daily averages for 12 seasonal units across all four years. Activity patterns indicate the typical crepuscular pattern noted in normal bear populations that lack human habituation. Identifying areas core use areas and potential den sites is helpful to understanding black bear ecology and useful when making decisions about how to plan infrastructure and educate the public. This research indicates that Paunsaugunt black bears avoid human activity; however, we need continued research to help determine specific interactions between bears and anthropomorphic influences.

Keywords: activity pattern, American black bear, home range, kernel density estimation, movements, Paunsaugunt Plateau, *Ursus americanus*

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CHAPTER 1

American Black Bears *(Ursus americanus)* of the Paunsaugunt Plateau, Southern Utah: Home Ranges and Habitat Relationships

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ABSTRACT

Concerns over human-bear conflict and questions about the ecology of Paunsaugunt Plateau's population of black bears (*Ursus americanus*) arose due to their visitation to popular recreation sites. Greater insight about bears and their habitat use provides a foundation for conflict mitigation and effective management decisions. Between 2014 and 2017, seventeen black bears (11 female, 6 male) were fitted with global positioning system (GPS) radio-collars so that we could track their locations, daily activity patterns, and ambient temperatures. By analyzing bear locations, we calculated annual and seasonal home ranges for 16 bears, including 25 den sites. Home ranges typically consisted of three dominant vegetation types, Utah juniper, ponderosa pine and Douglas fir. I used mixed effects models to better understand den site selection and found that slope (27.87 ± 2.03) was the most significant factor ($p < 0.001$). I also used mixed effects models to understand black bear selection of annual and seasonal home ranges. Predictor variables with the greatest effect ($p < 0.001$) were elevation (2419.99 ± 1.35) and aspect (138.44 ± 0.64), with coefficients of 1.128 and -1.483 respectively. Male annual home ranges (327.20 km^2 ± 133.58 km^2) were significantly larger ($p = 0.035$) than female home ranges (175.10 km^2 ± 55.37 km^2). However, annual home ranges for both sexes were larger than those during hyperphagia ($p = 0.003$) or mating ($p = 0.004$) seasonal home ranges, between which there was no difference ($p = 0.451$). Individual home ranges overlapped for most bears,

consistent with their non-territorial nature. We found that bears avoided roads and lower elevations, while showing a preference for sloping terrain throughout the non-denning period. Paunsaugunt black bear home ranges are larger than any other black bear home ranges reported in literature. Identifying areas core use areas and potential den sites is helpful to understanding black bear ecology and useful when making decisions about how to plan infrastructure and educate the public.

INTRODUCTION

North American black bears (Ursus americanus) are omnivores with carnivorous tendencies and are found throughout much of North America (Pelton 1982, Powell et al. 1997; Figure 1). Consequently, black bear diets consist largely of vegetation (Barnes and Bray 1967, Welch et al. 1997). Bears seek out food as it becomes available to them seasonally, with springtime vegetation being mainly grasses (Mosnier et al. 2008) and hard masts in the fall. However, bears will take advantage of any food available, including anthropomorphic sources (e.g., garbage, compost, beehives, livestock, etc.) as humans encroach into their home ranges.

Historically, humans have reduced black bear populations to small portions of their historic range (Pelton 1982, Powell et al. 1997). However, populations are currently either increasing or remaining stable, with a few exceptions, despite continual habitat loss, habitat degradation, and fragmentation (Garshelis et al. 2016, Lara-Díaz et al. 2018). As human activity within bear habitat continues to increase, human-bear conflicts will also likely increase (Herrero et al. 2011). To minimize human-bear conflict, we must have a better understanding of bear-habitat relationships (Jones et al. 2015, Seryodkin et al. 2017).

American black bears populate montane regions of Utah (Figure 2). For the past 30 years, the Utah Division of Wildlife Resources (UDWR) has radio-collared black bears for the primary purpose of estimating reproductive parameters of various Utah populations (UDWR 2011). However, black bears of the Paunsaugunt Plateau region have not been a part of UDWR's black bear studies, and their ecology is largely unknown. In recent years, sporadic problems with food-conditioned bears in Bryce Canyon National Park (BCNP) raised concerns for human safety and bear conservation, as well as a need to identify where bears were accessing anthropogenic food (S. Haas, National Park Service, personal communication). While not all food-conditioned bears are predatory towards humans, research has demonstrated that predatory bears are often food-conditioned (Herrero 2002). As a result, research was initiated in 2014 to address these information needs (Larson 2017). This work continued through 2017, and three annual progress reports were prepared (Larson and Smith 2015, Rosell and Smith 2016, Dungan and Smith 2017), as well as a graduate Master's Thesis (Larson 2017). In this document, I report on black bear research I conducted on the Paunsaugunt Plateau from 2016 to present, utilizing data collected from 2014 forward. The primary purpose of this study was to describe habitat relationships, home ranges, daily movements, and activity patterns for each radio-collared black bear to extend our understanding of how bears on the Paunsaugunt Plateau use the landscape. An analysis of bear locational data enabled: 1) calculation of home range for each bear; 2) description of den site selection; 3) identification of habitat selection factors; 4) calculation of annual and seasonal home ranges; 5) comparison of gender-related differences in 1-4. I compared these results with published findings and present those in this report.

MATERIALS AND METHODS

Study Area

The Paunsaugunt Plateau (hereafter referred to as simply 'the Paunsaugunt') is in the southwestern fringe of the American black bear's primary geographic range (Scheick and McCown 2014; Figures 1-1 and 1-3). The Paunsaugunt is in both Kane and Garfield counties. The Paunsaugunt is approximately 16 km wide and 40 km long and is a portion of the larger Sevier Plateau. It has a range of elevation from 2100—2800 m. BNCP forms the eastern border of the Paunsaugunt, and the Pink Cliffs comprise the southern border. Most of the Paunsaugunt is Dixie National Forest land, but some private inholdings exist as well (United States Forest Service 2017). The Great Basin Divide and Colorado River Watershed also form part of the Paunsaugunt. Two rivers surround the Paunsaugunt, including the East Fork of the Sevier River, to the north, and Paria River, to the east which cuts through part of the Paunsaugunt and BCNP (Wikipedia 2017).

We focused on the part of the Paunsaugunt located south of Tropic Reservoir, including portions above and below the Pink Cliffs, for bear trapping. The Paunsaugunt, as a small portion of the Colorado River watershed, has several perennial streams, as well as a spring, that feed into Tropic Reservoir. There are also many intermittent streams and springs that are present, drying up in the heat of summer (Gregory 1951, United States Forest Service 2017).

The climate on the Paunsaugunt is highly varied, with mean temperatures strongly associated with elevation. The highest average temperature recorded for the BCNP region is 26.7° C and the lowest is -9.4° C. There were frequent thunder and rainstorms during all four summers in our trapping area. In winter, the Paunsaugunt typically has snow covering the ground but it frequently melts, giving rise to thick mud. Average precipitation in the form of rain is five centimeters while snowfall is two meters (Gregory 1951, National Park Service 2018).

Vegetation on the Paunsaugunt's upper elevations is primarily coniferous forests, especially pine (*Pinus ponderosa*) and spruce (*Picea pungens*), with some Douglas fir (*Pseudotsuga menziseii*) and aspen (*Populus tremuloides*) intermixed. The foothills are typically covered with pinyon (*Pinus edulis*) and juniper (*Juniperus utahensis*), and the lower levels just off the side of the tableland turn into oak shrub (*Quercus gambelii*; Gregory 1951). This habitat provides excellent cover for black bears, with oak mast being an important food resource in fall. Shrubs found on the Paunsaugunt include manzanita (*Arctostaphylos patula*) and currant (*Ribes spp*.), as well as sagebrush (*Artemisia tridentata*).

Trap Site Selection

We deployed 10 to 17 barrel traps at a time over four years of the study (Figure 1-4). Between 2014 and 2015, W. Larson used 15 to 17 traps. In 2016, seasonal bio-technicians used 10 to 12 traps, and in 2017, we used 10 to 12 traps. All traps were placed in locations south of Tropic reservoir and south and west of the cliff edges. Traps were placed in two groups (lines) that were approximately equal in the amount of time required to travel and check.

We selected trap site locations based on local knowledge, which included United States Forest Service (USFS) cameras on guzzlers, UDWR and USFS personnel experience, and from previous work done by W. Larson (Larson 2017). The ability to access a trap site by either an ATV or truck was important because our barrel traps were heavy (~39 kg) and difficult to carry long distances and maneuver through dense brush. We also considered known bear preferences for habitat features such as food, cover and escape terrain, as well as the amount of shade available at specific trapping sites. We chose sites that were ≥ 30 meters from roads to avoid detection and human activity. Traps were not visible from roads and we placed warning signs at least 20 meters from the trap. Additionally, we avoided cattle and social trails, but placed traps near game trails. Social trails are pathways formed when people habitually access points of interest by the same route. More specifically, social trails refer to unofficial, unmaintained and destructive trails. One can easily differentiate between trail types by the large amount of erosion and lack of vegetation associated with cattle and social trails. Once in place, we anchored traps to two or more trees with 16-gauge wire to hold them in place when bears were inside. We recorded the global positioning system (GPS) location for each trap site.

Bait Usage

We used a wide array of commonly used scent baits for attracting and trapping bears, including anise oil, loganberry oil, raw rotting meat and sugary pastries. Additionally, we tried novel scents such as peanut butter, canned tuna fish in oil, canned cat food, vanilla frosting and hard candies (Appendix 1). We baited each trap site with a liquid scent, such as loganberry oil, sprayed on a 14 cm x 14 cm piece of carpet hung approximately 2 to 3 meters high from a nearby tree to draw bears into the general vicinity. We kept carpet squares within reach of bears to allow access to them. Allowing bears to reach, maneuver and explore carpet squares kept bears near the trap longer, which increased trapping success likelihood (C. Mecham, UDWR biologist, personal communications). We placed rotten meat at the back of each trap to coax bears in. We filled plastic mesh bags with an assortment of pastries, cooked bacon, hard candies and other foods (Appendix 1), then hung them from the trap's gate release mechanism. We often smeared peanut butter, bacon grease, honey, vanilla frosting and other such odorous foods on nearby trees to keep bears in the area longer. We placed a few rotten fruits and vegetables on the ground just outside the trap to attract and hold bears in the area.

Trail Camera Placement

In 2017, we placed a Reconyx PC900 covert infrared camera (Reconyx, Inc., Holmen, Wisconsin) at each trap site to document all wildlife activity at the trap. Each camera was set to take pictures when motion was detected (i.e., cameras were sensitive to motion within 12 m). Trail cameras were especially helpful for deciding when to leave traps in place and when to move them.

Live Capture

All trapping operations were conducted in accordance to protocols approved by the Brigham Young University (B.Y.U.) Institutional Animal Care and Use Committee (IACUC protocol #140602). Trapping extended from late May through late August annually. We followed immobilization procedures as outlined in Black et al. (2004). Additionally, we collected the first premolar from each bear, as well as fur and fecal samples. We collected weight data using hobbles that attached to a scale. We also measured body length and chest circumference with a tape measure.

Our work schedule consisted of 10 days of active trapping followed by four days of inactivity. We checked traps daily, leaving the Dave’s Hollow Guard Station (37°40' 34.3"N 112°12' 20.1"W) between 08:00 and 09:00, and returning in early afternoon. We added rotten meat obtained from butcher shops, typically beef and pork, to traps every other day, added more liquid scent to hanging carpet squares daily, and replaced trigger bait bags as needed. Prior to each inactive period, we deactivated traps by removing their doors and did not rebait them. We checked traps at least once every 24 hours and were able to check all traps before 12 noon. We moved traps periodically due to a lack of bear activity or if we found evidence of human activity or tampering (caught on remote camera). We moved all traps that had no bear sign present over a 14 day period. We visited den sites between February and March of the years following capture, 2015 to 2018. We visited denned bears to replace or remove radio-collars and batteries, as well as monitor the health and reproductive status of the bears. Bears were anesthetized at den sites, as outlined in Black et al. (2004).

At trap sites, we sedated captured bears with a combination of ketamine hydrochloride (100 mg/ml) and xylazine hydrochloride (100 mg/ml). We visually estimated the weight of bears inside traps and administered ketamine hydrochloride at a dosage of 4 mg/kg (2 cc per 45.4 kg) and xylazine hydrochloride at 2 mg/kg (1 cc per 45.4 kg). We administered drugs with a syringe pole or "jab stick" that was inserted through 12 cm x 12 cm ports located on both ends of the trap. We maintained chemical immobilization data sheets for each capture (Appendices 2 and 3). We carefully removed tranquilized bears from traps, placed them in the shade and applied masks to protect eyes from debris and to lower stress by limiting vision. Throughout the immobilization process, we monitored respiration by counting the number of breaths per 30 seconds, heart rate with a stethoscope, and body temperature using a rectal thermometer. Normal ranges for these data were 80-100 bpm, 7-60 breaths per minute, and 37.2-40.0 °C (A. Rouge, UDWR veterinarian, personal communications). If temperatures climbed above 40.0 °C, we applied water or ice to the bear and reversed the anesthesia. We collected these physiological data at least once every five minutes.

Radio-Collar Programming, Deployment and Data Transmission

We used ATS® Iridium GPS radio-collars for tracking bear movements (Figure 1-5). These radio-collars permitted us to adjust how frequently they collected data and how often those data were transmitted to satellites. We programmed most radio-collars to transmit data every six hours. Additionally, radio-collars collected ambient temperature at the time of each positional fix, accurate to ± 2.0º C. Collar temperature and ambient temperature sometimes differed due to the sensor's location at the time of transmission (e.g., bear was curled up sleeping, walking, resting on side, etc.). Radio-collars also recorded activity data using mercury tilt-switch sensors. These sensors log the percentage of time the switch moved during a 15-minute period just prior to each GPS fix. Radio-collar data were made accessible to researchers by way of ATS web servers.

Statistical Analysis

I downloaded location, temperature and activity data from the ATS website and entered it into Microsoft Excel (2016) to look for locational errors, duplicates, and poor accuracy. I evaluated locational accuracy using the horizontal dilution of precision (HDOP) score. This score ranges from 0 to 20, the higher the number the less accurate the horizontal component. I excluded locations with HDOP values > 5, leaving only data points that had "Ideal", "Excellent", and "Good" scores (Rempel and Rodgers 1997, Jiang et al. 2007, Person 2008, Frair et al. 2010).

Using a geographic information system (GIS; ArcMap, version 10.5, Environmental Systems Research Institute, Redlands, California), I displayed locations on a map of the study area and searched for obvious errors (e.g., locations generated in transport as well as any outside the study area) and removed them (Jiang et al. 2007, Laver and Kelly 2008). Next, I regrouped data by individual bear using their unique radio-collar serial numbers. I evaluated each bear's locations for accuracy, removing locations associated with each bear's capture day, as well as those that were recorded less than one hour apart, or that were auto-correlated (Jerde and Visscher 2005, Ganskopp and Johnson 2007, Horne et al. 2007). I determined the season and period of the day for each location using its time stamp. I divided locations by season, defined as follows: denning was November through March, mating, April through July and hyperphagia, August through October (Erickson et al. 1964, Pelton et al. 1980, Nelson et al. 1983, Gray et al. 2016). I chose to use these seasonal divisions based on remote camera data, locations, and the published literature. I divided each day into four, six-hour periods: morning (04:00-09:59), day (10:00-15:59), evening (16:00-21:59) and night (22:00-3:59; Lewis and Rachlow 2011, Karelus et al. 2016). I attached these classifications to each bear location using Microsoft Excel (2016).

I used the program QGIS ®, a free open source GIS program, to calculate 95% and 50% minimum convex polygons (MCP) and ArcMap 10.5 to generate kernel density estimates (KDE) with 95% and 50% contours to identify black bear home ranges on the Paunsaugunt (Karelus et al. 2016, Walter et al. 2011, Silverman 1986). By convention, 50% contours of both the KDEs and MCPs represent core areas of habitat which are considered habitat of critical importance (Samuel et al. 1985, Powell et al. 1997). I subdivided annual home ranges for each bear into the appropriate seasonal categories, mating and hyperphagia.

Using ArcMap, I attached additional data to each location including aspect, slope and elevation. Additionally, using ArcMap, I identified the vegetation type associated with each location, and distances to the nearest road, campsite, trail and spring. I obtained these data layers from the Utah Mapping Portal (2018) and ESRI (2018) data.

To investigate the habitat selection process, I began by generating the same number of random points as bear locations. Next, I extracted slope, aspect, elevation and habitat type for each random point as performed previously for actual bear locations. To assure that random points were distributed in proportion to available habitat, I calculated the true mean of all the pixels (10 m x 10 m) within the study area for each variable and compared those with the random sample means ± 95 percent confidence intervals (Westover et al. 2016). Because the true mean fell within the confidence interval for each variable, I concluded that our sample of random points accurately represented the availability of the habitat.

To compare black bear habitat selection and avoidance, I developed 30 *a priori* models (Table 1-2, Bertsimas et al. 1990, Casullo 2003, Mitchell and Powell 2004). I developed *a priori* models using published information regarding bear-habitat relationships, local knowledge, and personal experience with Paunsaugunt bears. I calculated the Pearson correlation coefficient for each variable (Freckleton 2010, Symonds and Moussalli 2010). Highly correlated variables ($r > |0.600|$) were not used together in the same model. Explanatory variables of distance to trails and distance to campsites were highly correlated ($r = 0.942$) so they were not included in the same model. I based two models on information provided by Larson et al. (2017) regarding bear use in the BCNP. I ran mixed effects models using the lme4 package and glmer function in RStudio (R Development Core Team 2016). I compared models using AICc criteria using MuMIN (Barton 2018). I used coefficients from the top model as predictors of bear use across the study area. I performed a resource selection function (RSF) to generate heat maps (Gaines et al. 2005, Nielsen et al. 2010, Manly et al. 2011). I calculated predictive values for each pixel within the study area in Microsoft Excel (2016), and then uploaded results in GIS to generate a heat map of annual use. To create heat maps for hyperphagia and mating seasons, I included season as a categorical variable in the top model to generate seasonal coefficients. I uploaded these values into ArcMap to generate the two seasonal heat maps. Significance threshold for all data analysis was set to ≤ 0.05 for *P* values.

I analyzed bear locations to determine den sites using GIS. For identifying den sites that we did not visit the following spring, I visually examined relocations for clustering (> 10 points in close proximity), beginning in October. If relocations were consecutive by date within the cluster, I examined movements away from these clusters. If movements away from clusters occurred, I looked for the next set of clustering. If there were no movements away from the initial cluster until February, March or April, I concluded I had a general den location. I calculated the central location of each cluster for each den using ArcMap Centroid tool, and if this location was within the distance error for GPS locations (20 m), I designated this a den location.

I downloaded GIS layers for streams, digital elevation models (DEM), dominant vegetation, and roads from the Utah GIS clearinghouse (Utah Mapping Portal 2018). I analyzed these layers in GIS to determine the distance from den sites to roads, trails, campsites and springs. I downloaded campsite and trail layers from ESRI®. I also determined the vegetation type, aspect, slope, and elevation for each den site using GIS.

To analyze den site selection by bears, I generated 250 random points (ten times the number of den sites) in ArcMap and compared them against den site characteristics. Random locations should adequately characterize the habitat available within the study area to compare available habitat to selected den sites. To verify that random points were representative of available habitat, I calculated the true mean of all pixels within the study area for each habitat variable and compared results with the random sample mean ± 95 percent confidence intervals (Westover et al. 2016). Because the true mean fell within the confidence interval in each case, I concluded that 250 random points adequately represented the availability of habitat in the study area.

I created a list of 16 *a priori* models based on experience, observation of Paunsaugunt black bears, and a review of pertinent literature (Table 1-3). I based model number 14 on previous models used by Larson (2017) to analyze the relationship between bears and anthropomorphic features of the landscape. I calculated the Pearson correlation coefficient for each variable (Freckleton 2010, Symonds and Moussalli 2010). Highly correlated variables ($r > |0.600|$) were not used together in the same model. Explanatory variables of distance to trails and distance to campsites were highly correlated ($r = 0.942$) so they were not included in the same model. I scaled all variables prior to analysis. Model ranking and the top model were determined using model.sel function in R studio with package MuMIN (Barton 2018).

RESULTS

Captures

Over four years (2014 to 2017) we captured, 17 bears (males, females, yearlings and adults). Prior to my field season of 2017, 13 unique bears were captured and radio-tagged from 2014 to 2016 (Larson et al. 2015, Rosell and Smith 2016). In 2017, we caught four bears that had not been captured previously and recaptured six from previous years that had lost their radio-collars

(Table 1-1). Seventeen radio-collars were deployed on this project with only one collar failure that provided no data. The number of bears that provided sufficient data for analysis was 16.

Home Range Size and Selection

After censoring our locational data, I generated 16 annual MCPs, 16 KDEs home ranges, and 32 KDE seasonal home ranges, comprised of 16 mating and 16 hyperphagia seasonal ranges (Table 1-4). Additionally, I generated maps of KDE and MCP home ranges for each bear (Figure 1-6). I found average male and female annual KDE home ranges to be significantly different (P = 0.035; Table 1-5). The average mating home range was 158 km^2 (SD ± 170.04 km^2; KDE) and the average hyperphagia home range was 164.1 km^2 (SD ± 164.14 km^2; KDE). Paired t-tests determined annual home ranges to be statistically different from mating and hyperphagia home ranges, with P values of 0.003 and 0.004 respectively. However, mating and hyperphagia home ranges were not statistically different (P = 0.451).

Dominant vegetation types in the study area included Douglas fir (18%), ponderosa pine (29%) and Utah juniper (52%), with only small portions consisting of Gambel oak (0.61%), greasewood (*Sarcobatus vermiculatus,* 0.64%), and sagebrush (0.26%; Figure 1-7). The proportion of dominant vegetation within each KDE annual home range was not proportional to the amount of each dominant vegetation type found throughout the study area (Table 1-6). Additionally, bears did not spend time in habitat types proportional to their availability (Table 1-7).

The top model explaining bear-habitat selection (model 27; Table 1-3), included slope, aspect, elevation, dominant vegetation, distance to trails, and distance to springs and had an

AICc weight of 1.00 (Table 1-2). All variables were highly significant (Table 1-8) except for Douglas fir (PSME). The top model positively correlated north, east and northeast aspects with bear use and negatively correlated with all other aspects. Flat areas had the highest negative factor, while elevation had the strongest positive correlation. Increased elevation and dominant vegetation type Utah juniper (JUOS) also correlated positively with bear use. Two other vegetation types, PSME and ponderosa pine (PIPO), as well as distance to springs and trails, correlated negatively with bear use. The top model variables in order of potential effect on bear use are as follows: flat aspect, elevation, southwest aspect, west aspect, distance to trails, northeast aspect, ponderosa pine vegetation type, south aspect, slope, distance to springs, northwest aspect, north aspect, southeast aspect, east aspect, Utah juniper vegetation type, and Douglas fir vegetation type. The predictive values generated from this model show a preference for higher elevations and an avoidance of roads and flat lands (Figure 1-8, Table 1-9).

Den Site Selection

Over the course of the study (2014 to 2017), we found 25 den sites belonging to 15 different bears. Males used nine of the den sites and females used 16 den sites. Four bears provided two unique den locations each, one bear used three unique dens and one bear used four different dens. The top model (model 5) accounted for 74.2% of bear den sit selection. The second-best model (model 8), explained 10.8% of the variation (Table 1-10). I performed statistical analysis of the top model using Generalized Linear Modeling in R Studio MuMln package (Table 1-11) to determine significance for each variable and the positive or negative correlations.

Data analysis indicated that the steeper the slope (≤ 44º), the more likely a Paunsaugunt black bear would be to select the area for denning. Slopes associated with den sites ranged in steepness from 1.3° to 43.3°. While not significant (P = 0.091), distances to roads were positively correlated with den site selection, indicating that the greater distance from a road, the more likely a bear was to den. We found distance to trails negatively correlated with den site selection but not significantly (P = 0.090). The top model variables in order of potential effect on den site selection are as follows: east aspect, slope, flat aspect, north aspect, northeast aspect, distance to trails, northwest aspect, west aspect, south aspect, southwest aspect, distance to roads, and southeast aspect.

DISCUSSION

Home Range Size and Selection

American black bears are not territorial, in that they do not defend home ranges, though females will defend cubs (Barnes and Bray 1967, Powell 1987, Costello 2010, Gray et al. 2016). Home ranges on the Paunsaugunt reflect this lack of territoriality creating a nearly indistinguishable web of home ranges (Figure 1-9). Average home ranges on the Paunsaugunt are among the largest home ranges reported for black bears in North America with one male home range being the largest yet reported. Earlier, unpublished data, reported home ranges in three areas of Utah north of the Paunsaugunt; the Book Cliffs, Hobble Creek, and the LaSals. Males had average home ranges of 345.00, 112.00 and 121.00 km^2 respectively and females had average home ranges of 152.00, 42.00, and 37.00 km^2 (Bates 1991, Tenney 1996). These averages were calculated using the MCP method. According to Kelt and Van Vuren (2015), the average home range of an American black bear is 39.27 km^2. More specifically, Lindzey and

Meslow (1977) reported average home range sizes of 5.05 km^2 for males and 2.35 km^2 for females in southwestern Washington. LeCount (1980) reported an average home range size of 29.00 km^2 for males and 18.00 km^2 for females in Four Peaks, Arizona. The average American black bear home range on the Paunsaugunt is 232.20 km^2. The average female American black bear home range on the Paunsaugunt is 175.10 km^2 and the average male home range is 327.20 km^2 (Table 1-5).

Black bears tend to follow the ideal free distribution theory in that they disperse and move across the landscape in a manner that matches or closely follows the distribution of needed resources (Milinksi 1979, Powell 2000, Mitchell and Powell 2012, Dugatkin 2014). Essential resources for black bears include vegetation such as spring grasses, soft and hard masts and ungulate neonates. Other important resources include maternal den sites for reproduction and winter survival and access to mates (Hiller et al. 2015). The need for Paunsaugunt black bears to range extensively suggests that the Paunsaugunt provides widely dispersed, limited resources (Powell 2000, Mitchell and Powell 2004, Dugatkin 2014). The top model indicates that of all the variables measured it is the best fit to explain selection. This does not indicate it is the best explanation for habitat selection merely that, of what we were able to measure, it is the most likely explanation.

Individual male black bear home ranges encompassed several female ranges, and I found significant differences between average Paunsaugunt male and female home range sizes (Table 1-5). Additionally, overlap is apparent for many of the female home ranges, even in the 50% MCPs and KDEs. Male home ranges typically encompass many female home ranges to maximize breeding opportunities (Dobson 1982, Costello et al. 2009). Males also tend to range farther in their explorations and movements out of their natal territories than do females (Dobson

1982, Costello et al. 2009, Costello 2010). Black bears on the Paunsaugunt hold true to this pattern in that females with dependent young tend to avoid other bears to protect their offspring (Beecham et al 1983, Gray et al. 2016). However, female home ranges overlap with both male and female home ranges on the Paunsaugunt, though they avoid being in the same areas at the same time (Figure 1-9).

The dominant vegetation of the study area was comprised mostly of trees, including various conifer species and scrub oak. Oaks provide hard masts during late summer and fall. A lack of information regarding secondary (shrubs) and tertiary (forbs and grasses) vegetation on the Paunsaugunt left us without more information regarding food resources available during spring and early summer. Manzanita and currants are extensive across the Paunsaugunt and provide berries, while sagebrush on the Paunsaugunt provides little in regards to forage resources for bears (LeCount 1980, Mitchell and Powell 2004, Baldwin and Bender 2009). American black bears on the Paunsaugunt did not distribute their home ranges in proportion to the available vegetation, nor did they utilize territory within their home ranges in proportion to availability (Table 1-6, Table 1-7). We would expect them to favor areas relative to their forage resource density and this appeared to be the case based on their habitat selection disproportionate to availability (Powell 2000, Mitchell and Powell 2012, Dugatkin 2014).

Annual home ranges include denning sites and areas of hyperphagic and mating activity. We did not analyze denning season as a seasonal home range because this is a point location without area. However, mating season, immediately following den emergence, involves extensive movement as males seek estrous females (Alt et al. 1980, Smith and Pelton 1990). Hyperphagia also involves considerable movement as bears seek the most nutritious food resources to prepare for winter survival (Pelton et al. 1980, Nelson et al. 1983). Mating and hyperphagia seasonal home ranges did not differ in size from each other and overlapped extensively (Figure 1-10). However, annual home ranges are statistically different from the two seasonal home ranges.

Den Site Selection

Black bear den sites on the Paunsaugunt were strongly correlated with slope ($P < 0.001$). When comparing the slope of den sites on the Paunsaugunt to those of previous studies, we found that 76% of Paunsaugunt dens fell into the 20° to 40° range, consistent with values reported by Mack (1990) and Baldwin and Bender (2008). Baldwin and Bender (2008) found that in the Rocky Mountain National Park, slopes from 31° to 32° were most often associated with black bear dens. Mack (1990) and Beecham et al. (1983) noted that steeper slopes prevent snowmelt from entering into dens due to rapid runoff. Soil drainage, in conjunction with the decreased likelihood of human activity, other bears, or other predators discovering them, might explain why bears select steep slopes for denning (Mack 1990). Additionally, it is energetically less costly to excavate on a slope where materials flow downhill with little effort.

The location and types of dens found on the Paunsaugunt are consistent with the significance of slope in the models. Black bears utilize a variety of structures for denning (Pelton et al. 1980, Beecham et al. 1983, Baldwin and Bender 2008, Gray et al. 2016). On the Paunsaugunt, all dens were in rock crevices, talus areas, or on steep slopes. The only exception to this was a single bear den on an essentially flat surface (slope = 1°), though the physical attributes of this den are unknown. None of the observed dens in the study area were in hollowed-out standing trees or fallen logs, as has been reported by Black et al. (2004). Instead, we found dens associated with cliffs and rocky ledges. Consequently, slope is highly important in predicting den site suitability on the Paunsaugunt, given the close association between black bear dens and naturally occurring rock crevices and talus areas.

Aspect, distance to roads, and trails were not found to be significantly associated with black bear dens in the study area ($P = 0.170$, $P = 0.090$, $P = 0.080$ respectively). Fifty-two percent of dens had a north, northwestern, or western aspect (Figure 1-11). Mean elevation for dens was 2,413 m, with a range of 1,935 to 2,744 m. The distance to roads from dens was on average 974 m, but varied between 135 to 3,337 m (Table 1-4). Den sites are critical to healthy populations of black bears (Linnell et al. 2002), and black bears on the Paunsaugunt are selective in their den site choices. Our top model demonstrates that slope, distance from trails, distance from roads and elevation are the most important of the variables we measured.

MANAGEMENT IMPLICATIONS

It is going to become increasingly difficult to avoid human-bear conflict with both species increasing across North America (Garshelis et al. 2016, North American Population 2018). Humans and their infrastructure occur on the landscape within black bear home ranges on the Paunsaugunt. The area is largely comprised of Dixie National Forest land used recreationally year-round. Additionally, the rugged cliffs that encircle the Paunsaugunt and lands below are either part of Bryce Canyon National Park or private property. This puts bears and people into close proximity though conflict to date is sporadic and rare.

The Paunsaugunt represents an edge of black bear geographic range (Scheick and McCown 2014), as evidenced by the low density of bears inhabiting the area. Despite few black bear sightings and minimal human-bear conflict in the region now, these both will likely change in the coming years as visitation increases. Documenting home range, movements, and habitat selection of a relatively undisturbed population of black bears establishes a benchmark against which the future change can be compared. Establishing average home range size for this particular population of black bears will be critical for future efforts to estimate population size using hair capture, DNA profiling, and mark-recapture analysis (Mowat and Strobeck 2000). In the absence of a known population size, the large home ranges of study animals suggests a low density (small population) of bears on the Paunsaugunt and indicates that hunting quotas should be conservative to avoid over-harvesting. Understanding black bear habitat preferences, movements and home range sizes can help guide future decisions regarding campsites, trails and other infrastructure developments (Herrero et al. 1986). Managers and developers can avoid core use areas, preferred habitats and den sites with the information presented.

American black bears on the Paunsaugunt range into Bryce Canyon National Park. To reduce potential risk of bear-human conflicts managers can avoid developments within prime habitat areas, such as campsites and trails. National Park Service interpreters for visitor education and outreach can use information about the local population of black bears to enhance visitor experiences. Human and American black bear populations are both increasing in this study area. Using information and insights gained from this research will help both species to coexist on Paunsaugunt Plateau. Additionally, the studies performed here can inform and guide other research done in areas of low-density populations in Utah and the western United States.

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FIGURES

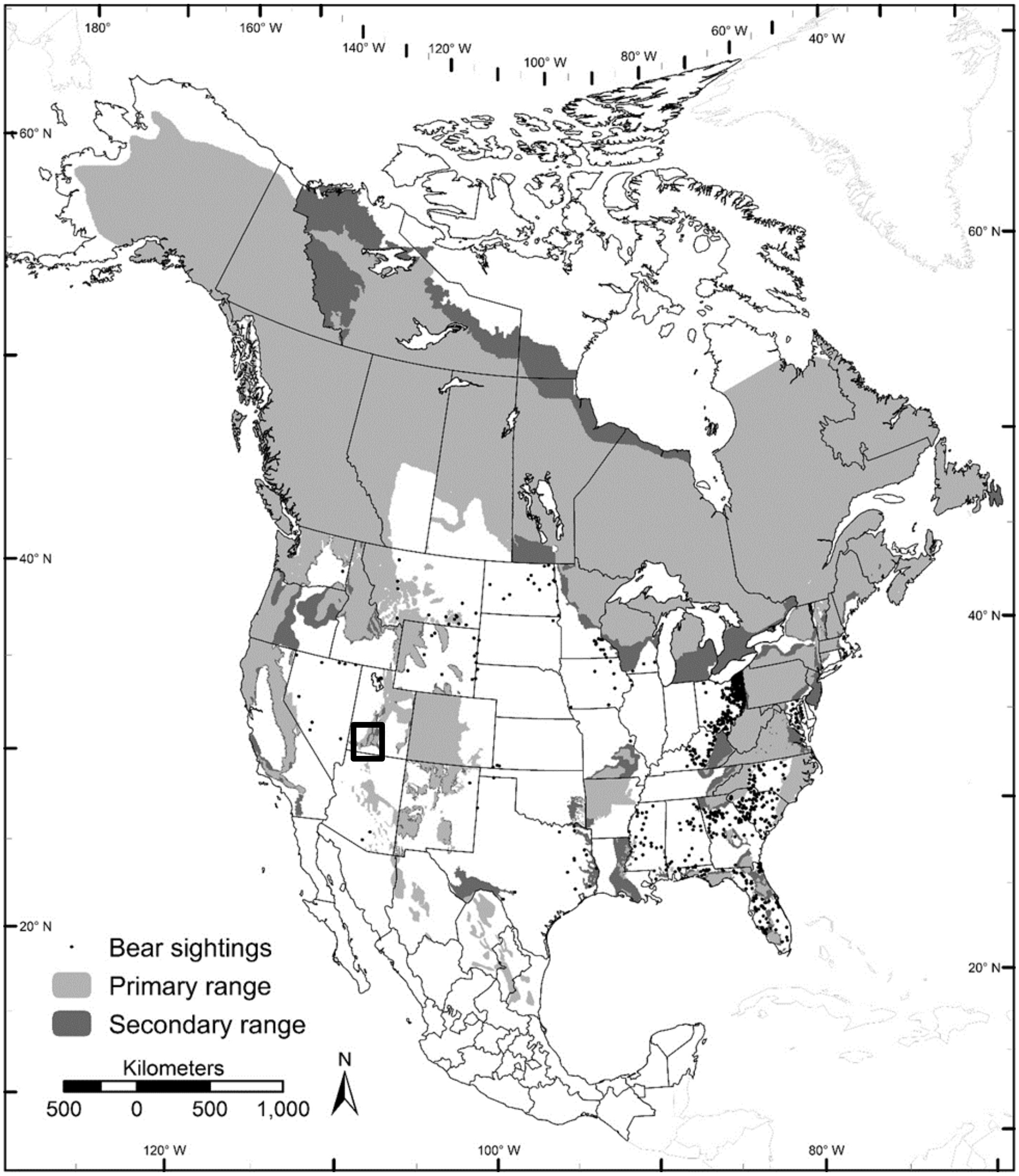

Figure 1–1: Current geographic range of *Ursus americanus* (Scheick and McCown 2014). The Paunsaugunt Plateau region and study area are located approximately within the black box.

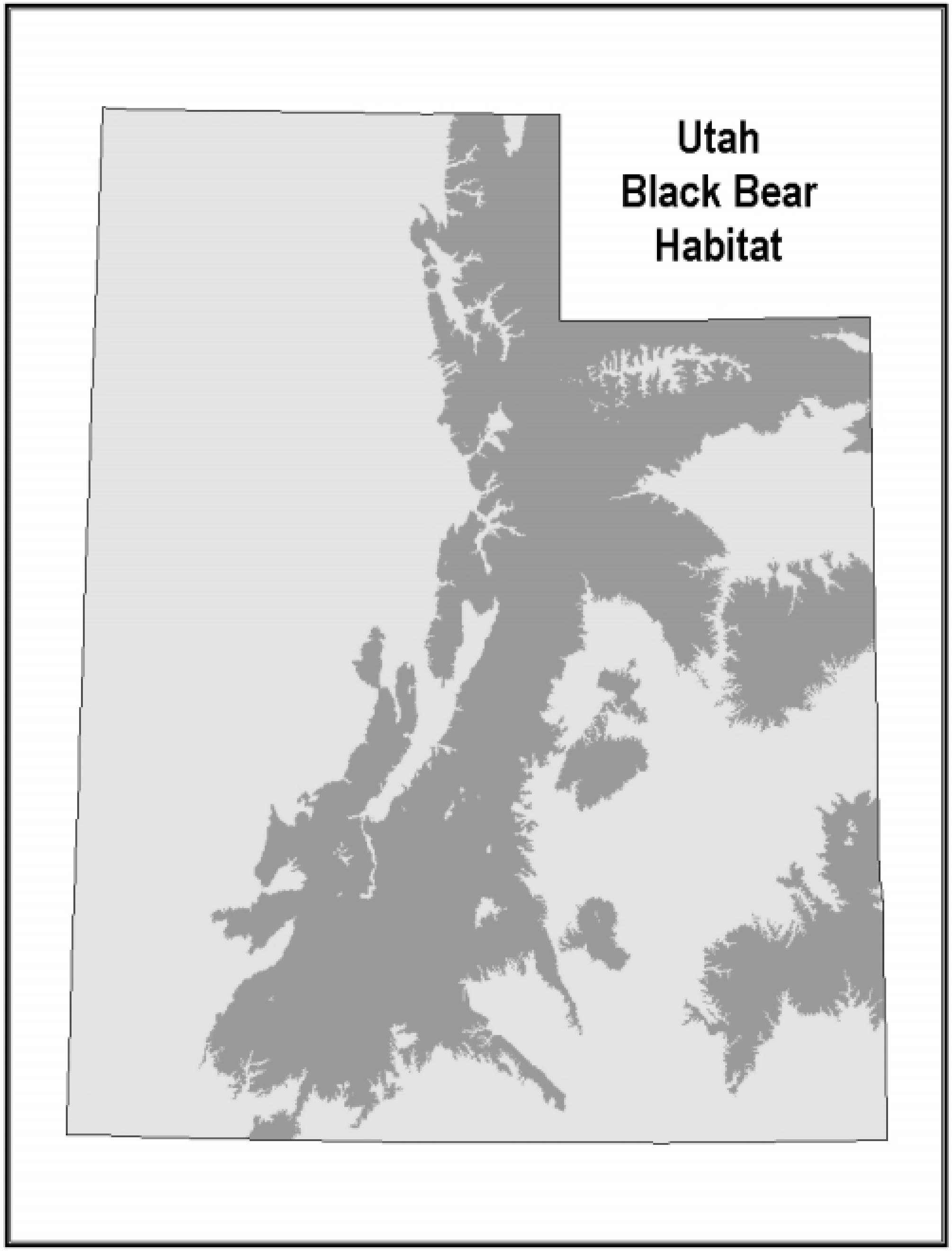

Figure 1–2: American black bear habitat in Utah as indicated by the dark gray. Light gray areas are unsuitable habitat.

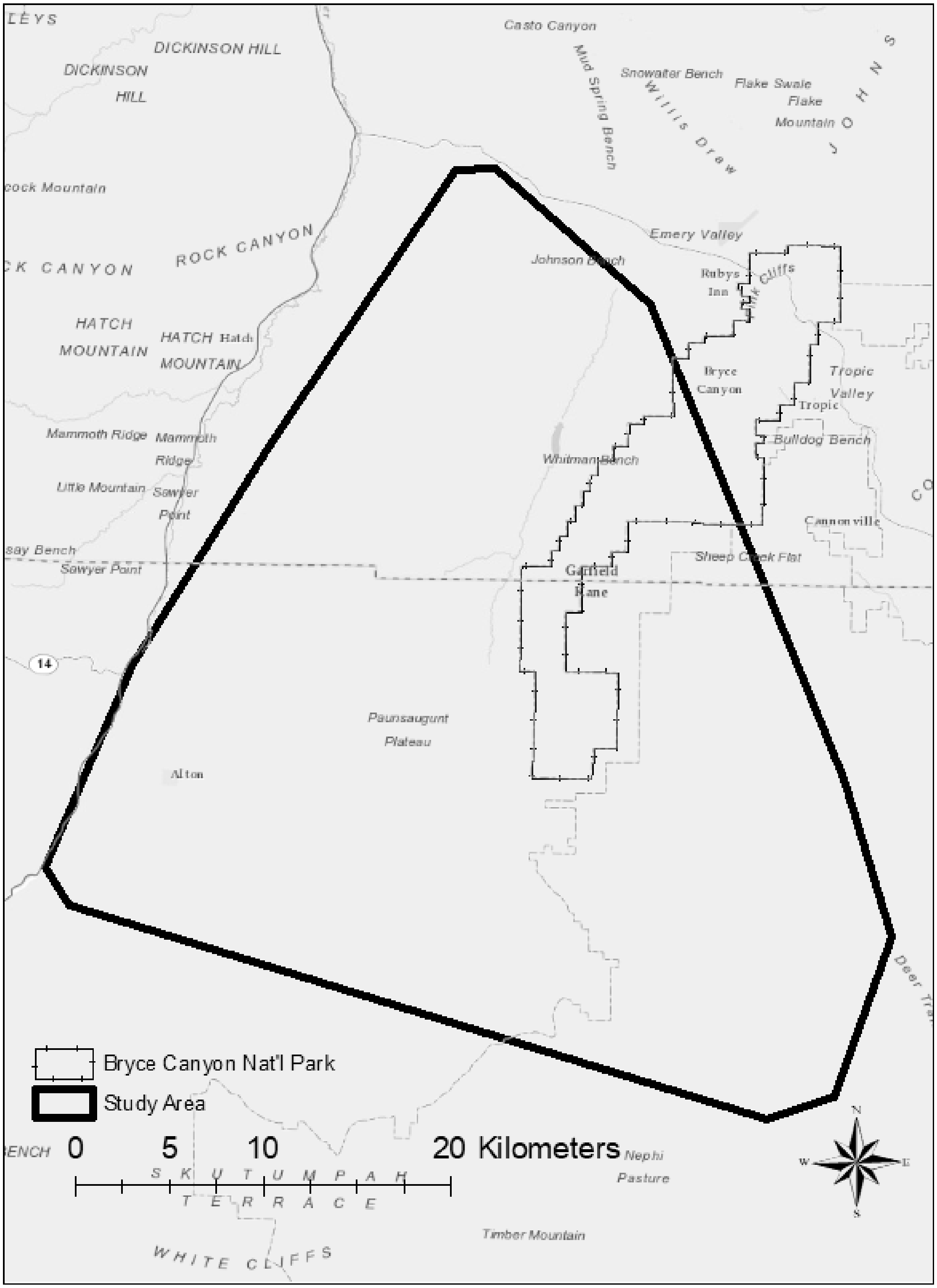

Figure 1–3: American black bear study area, Paunsaugunt Plateau, UT 2017-18.

Figure 1–4: A yearling sits outside an activated barrel trap on the Paunsaugunt Plateau, UT summer 2017.

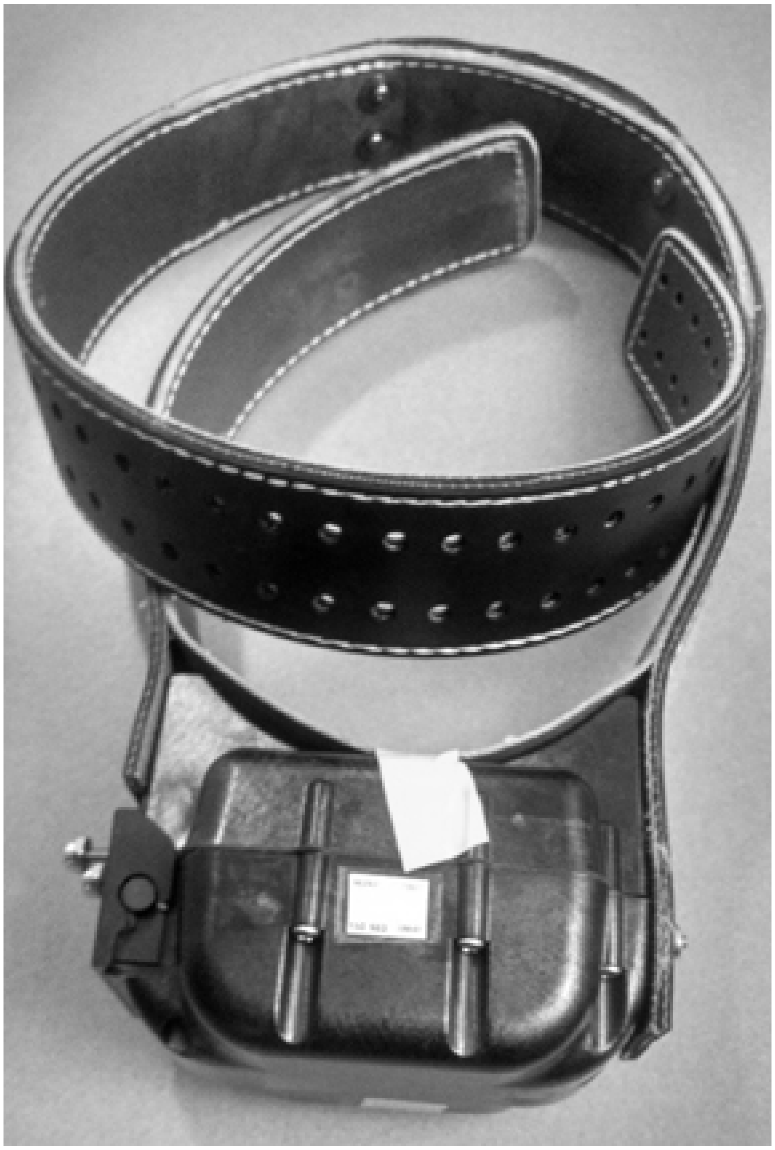

Figure 1–5: ATS® Iridium GPS bear radio-collar.

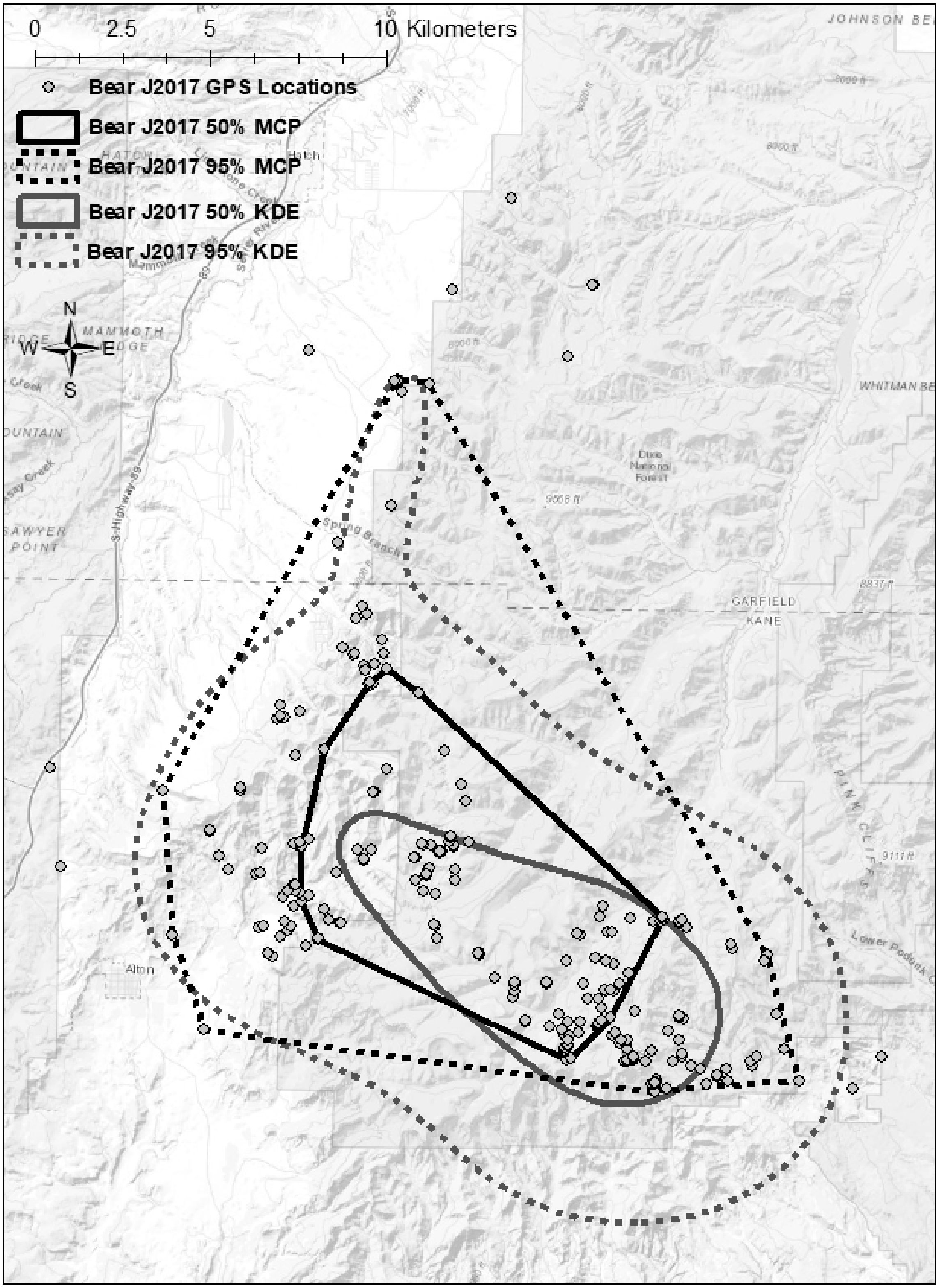

Figure 1–6: Home ranges for bear #J2017 and the GPS locations used to generate both the MCP and KDE home range on the Paunsaugunt Plateau, UT 2017-18.

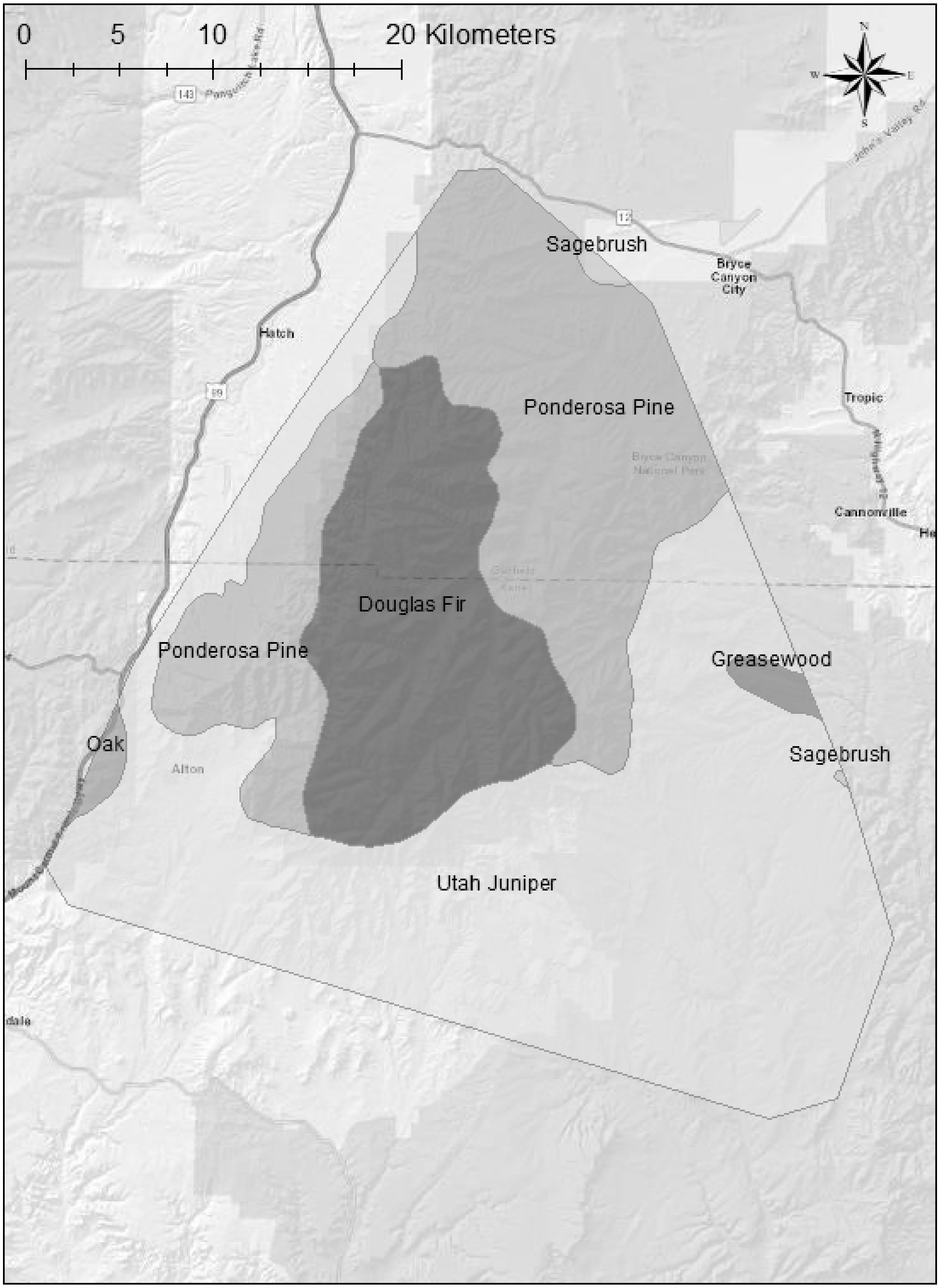

Figure 1–7: A map of the study area on the Paunsaugunt Plateau Utah divided by the dominant vegetation/habitat types.

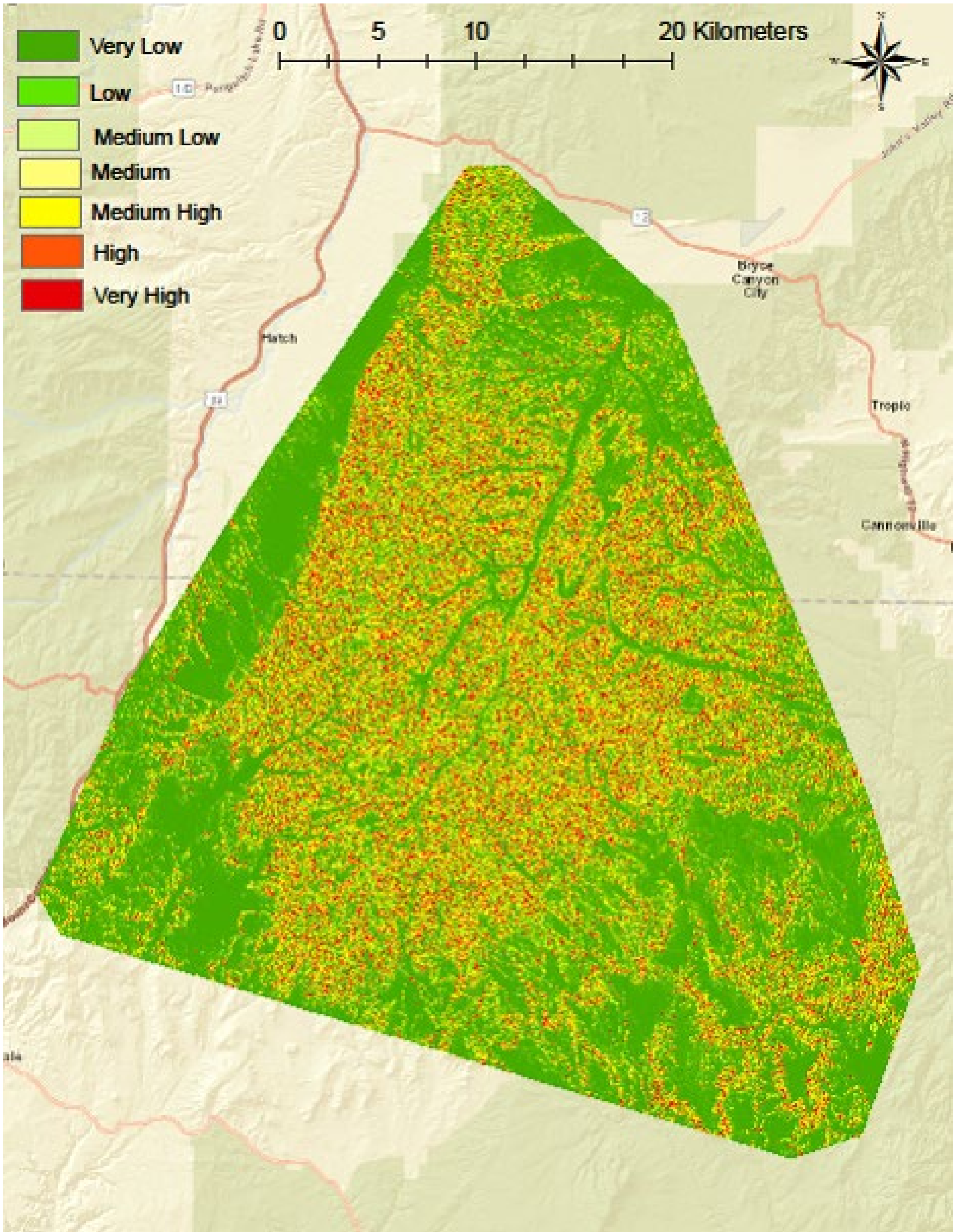

Figure 1–8: A heat map indicating areas of high and low potential bear selection in our study area on the Paunsaugunt Plateau, UT 2014-18.

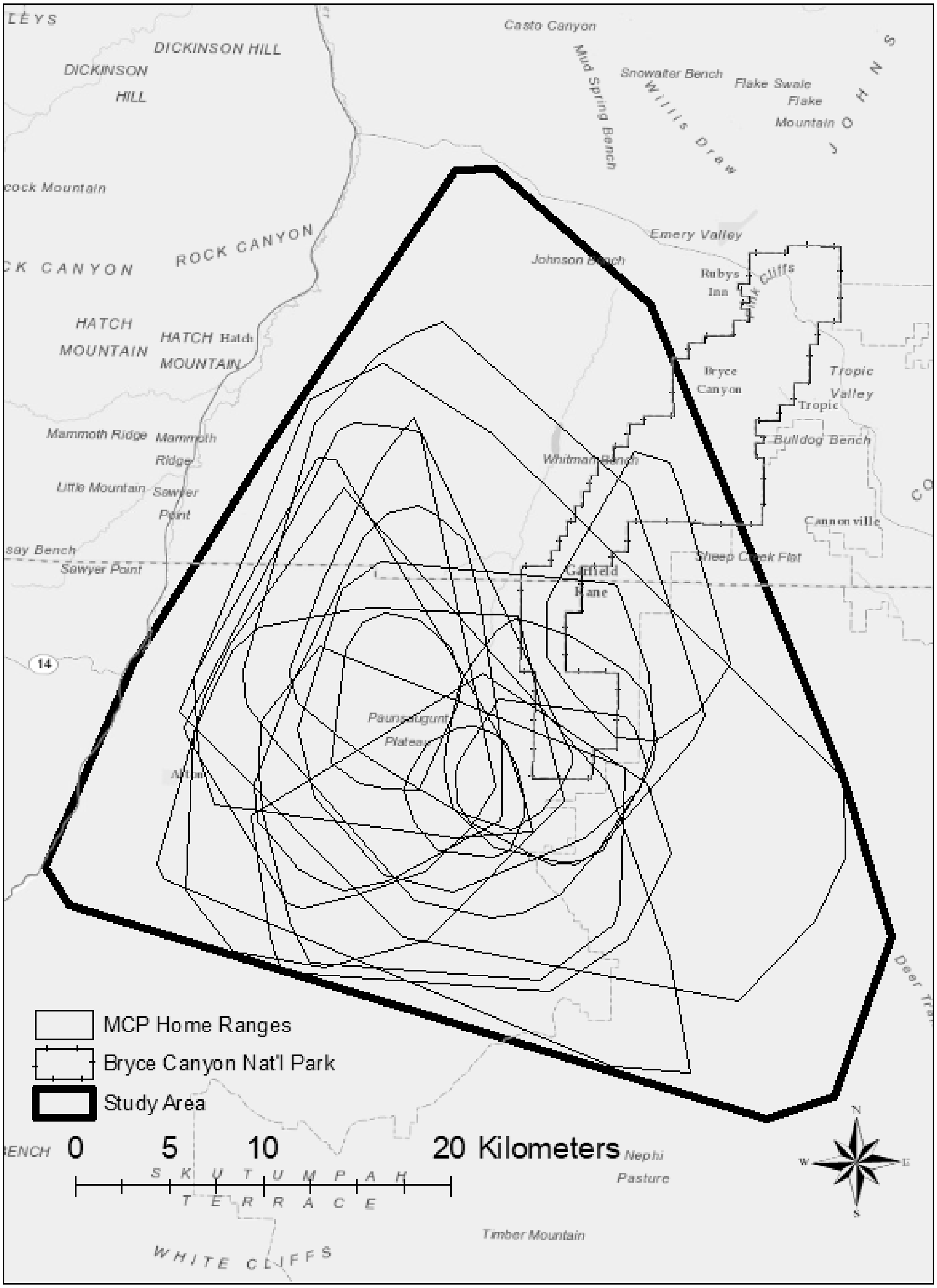

Figure 1–9: All 95% minimum convex polygon home ranges for the 16 American black bears radio-collared on the Paunsaugunt Plateau UT 2014-18.

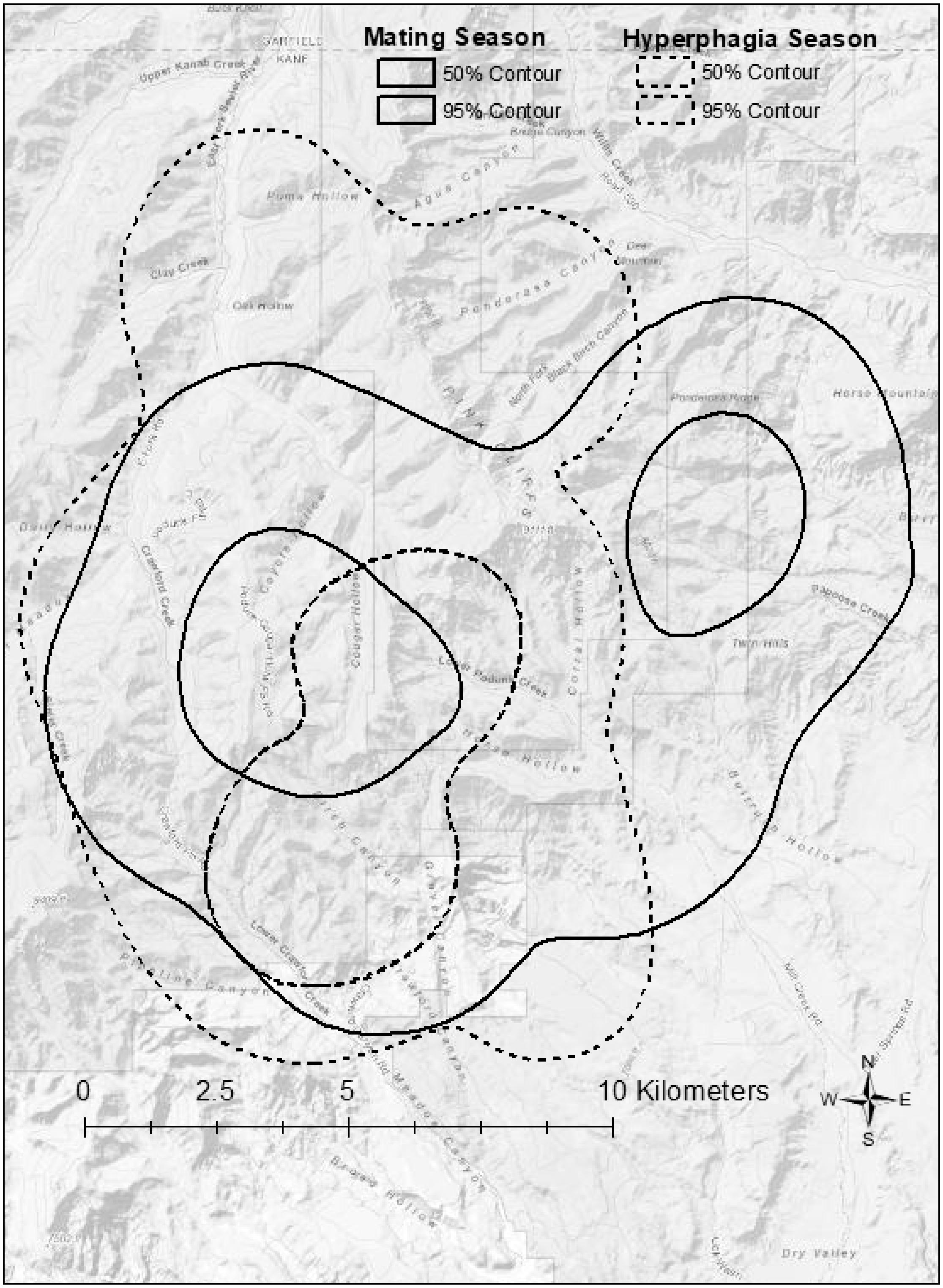

Figure 1–10: Hyperphagia and mating home ranges, 95% and 50% contours, for bear #A2016 on the Paunsaugunt Plateau UT 2016-18.

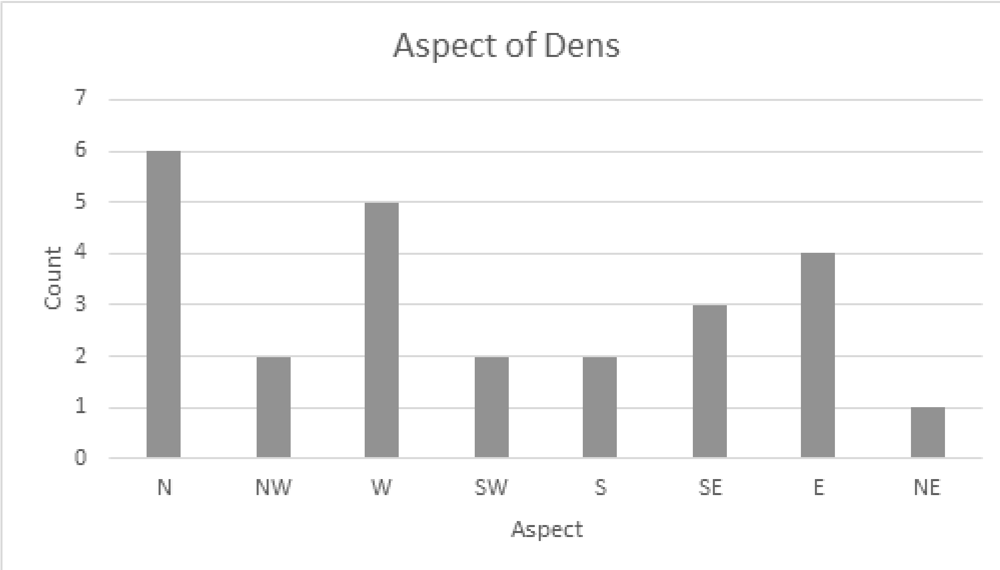

Figure 1–11: Number of dens per aspect. 25 total den sites were identified on the Paunsaugunt Plateau, UT 2014-17.

TABLES

Table 1–1: A complete list of collared bears, sex, date of initial collar deployment and age class at time of capture.

Bear ID	Sex	Collar Deployment	Age Class
A2016	F	6/28/2016	Adult
C2014	M	6/27/2014	Yearling
C2-2014	F	7/23/2014	Adult
D2016	F	5/23/2016	Adult
G2014	M	7/9/2014	Adult
G2-2014	M	7/12/2014	Adult
H2014	M	7/10/2014	Adult
J2017	M	8/8/2017	Yearling
JG2016	M	7/13/2016	Adult
L2015	F	7/21/2015	Yearling
M2014	F	8/9/2014	Adult
M2-2014	F	8/10/2014	Adult
P2014	F	7/30/2014	Adult
S2017	F	7/9/2017	Yearling
T2017	F	7/9/2017	Yearling
T2-2017	F	8/2/2017	Yearling
V2016	F	5/9/2016	Adult

Table 1–2: *A priori* models for habitat selection on the Paunsaugunt Plateau, Utah 2014-18. Includes the null (1) and global models (30).

1. 1 + (1|bearID)
2. aspect + dominantveg + elevation + roads + season + (1|bearID)
3. aspect + dominantveg + elevation + roads + season + season*dominantveg + (1|bearID)
4. aspect + season + season*dominantveg + (1|bearID)
5. aspect + slope + elevation + season + slope*season + (1|bearID)
6. aspect + slope + elevation + season + aspect*season + elevation*season + (1|bearID)
7. aspect + dominantveg + elevation + roads + springs + season + season*dominantveg + springs*season + (1|bearID)
8. aspect + slope + elevation + season + (1|bearID)
9. trails + slope + dominantveg + roads + season + season*roads + (1|bearID)
10. trails + slope + elevation + roads + dominantveg + (1|bearID)
11. trails + roads + dominantveg + season + roads*season + trails*season + (1|bearID)
12. springs + camps + season*camps + slope + (1|bearID)
13. season*dominantveg + season*slope + (1|bearID)
14. season + elevation + season*elevation + (1|bearID)
15. season*dominantveg + elevation*season + season + elevation + dominantveg + (1|bearID)
16. season + (1|bearID)
17. season + season*dominantveg + camps + (1|bearID)
18. season + camps +roads + (1|bearID)
19. season + trails + season*trails + (1|bearID)
20. season + roads + elevation + dominantveg + season*roads + season*elevation + season*dominantveg + (1|bearID)
21. season + trails + slope + elevation + season*trails + slope*season + elevation*season + (1|bearID)
22. season*slope + (1|bearID)
23. season*camps + season*dominantveg + slope*season + season*elevation + (1|bearID)
24. slope + season + elevation + dominantveg + (1|bearID)
25. slope + season + (1|bearID)
26. slope + elevation + dominantveg + camps + aspect + springs + (1|bearID)
27. slope + elevation + dominantveg + trails + aspect + springs + (1|bearID)
28. slope + elevation + trails + springs + roads + (1|bearID)
29. camps + dominantveg + elevation + springs + roads + (1|bearID)
30. aspect + slope + elevation + trails + springs + roads + dominantveg + season + season*dominantveg + springs*season + season*roads + camps*dominantveg + elevation*season + slope*season + (1|bearID)

Table 1–3: *A priori* models for den site selection on the Paunsaugunt Plateau, Utah, 2014-18.

1	slope + elevation + trails + dominantveg + springs + roads + (1|Bear_ID)
2	roads + camps + springs + (1| Bear_ID)
3	roads + camps + dominantveg + (1| Bear_ID)
4	roads + trails + elevation + (1| Bear_ID)
5	roads + trails + slope + aspect + (1| Bear_ID)
6	elevation + slope + aspect + dominantveg + (1| Bear_ID)
7	elevation + slope + aspect + (1| Bear_ID)
8	elevation + slope + aspect + roads + (1| Bear_ID)
9	elevation + springs + camps + dominantveg + (1| Bear_ID)
10	dominantveg + springs + aspect + trails + (1| Bear_ID)
11	dominantveg + slope + roads + (1| Bear_ID)
12	dominantveg + roads + camps + springs + (1| Bear_ID)
13	aspect + elevation + (1| Bear_ID)
14	camps + dominantveg + elevation + springs + roads + (1|Bear_ID)

Table 1–4: Table of home range sizes in km^2 on the Paunsaugunt Plateau, Utah.

BearID	M/F	Annual 95% KDE	Mating 95% KDE	Hyperphagia 95% KDE	MCP 95%	h-value	# Points
A2016	F	108.51	99.30	102.54	144.91	3.00	2123.00
C2014	M	350.15	245.06	297.51	366.81	7.00	1148.00
C2-2014	F	31.64	26.00	28.15	41.71	1.50	785.00
D2016	F	68.35	47.96	63.08	73.95	2.50	6244.00
G2014	M	197.49	184.47	164.12	375.37	6.00	2654.00
G2-2014	M	354.41	343.67	170.62	333.65	7.00	1799.00
H2014	M	193.77	82.30	189.38	223.96	10.50	1230.00
J2017	M	241.47	82.56	269.09	280.62	8.00	330.00
JG2016	M	626.11	667.48	330.6	1141.03	13.00	1058.00
L2015	F	407.67	377.73	260.88	736.02	7.50	3345.00
M2014	F	119.70	76.15	70.57	229.05	2.50	2874.00
M2-2014	F	247.48	141.28	198.89	306.02	8.50	1639.00
P2015	F	395.67	97.13	272.78	527.88	8.50	1949.00
S2017	F	62.28	17.92	49.96	92.61	2.00	383.00
T2017	F	52.30	38.75	40.10	60.35	2.00	792.00
V2016	F	257.54	192.92	118.09	343.60	4.00	386.00
Mean		232.16	170.04	164.15	329.85		
St. Dev		163.59	170.96	100.45	283.06		
St. Error		40.90	42.74	25.11	70.76		

Table 1–5: Male and female home range averages on the Paunsaugunt Plateau, Utah, 2014-18.

Annual KDE 95%	Female	Male
Mean	175.114	327.233
St. Dev	142.229	162.845
St. Error	44.977	66.481

P-value = 0.035

Table 1–6: Results of the Chi-square test on the observed vs. the expected proportion of dominant vegetation within each home range for each bear on the Paunsaugunt Plateau, Utah, 2014-18.

Bear I.D.	Chi-Square	D.F.	*P*-value
A2016	2.318	2	0.314
C2014	68.397	2	< 0.001
C2-2014	24.582	1	< 0.001
D2016	547.824	1	< 0.001
G2014	19.421	2	< 0.001
G2-2014	206.225	2	< 0.001
H2014	214.063	2	< 0.001
J2017	1.516	2	0.469
JG2016	203.795	4	< 0.001
L2015	25.294	2	< 0.001
M2014	41.548	2	< 0.001
M2-2014	268.410	2	< 0.001
P2014	413.175	2	< 0.001
S2017	24.849	2	< 0.001
T2017*	X	X	X
V2016	5.858	2	0.053

* Comprised of a single dominant vegetation habitat type

Table 1–7: Results of the Chi-square test on the observed vs. the expected use of dominant vegetation for each collared bear on the Paunsaugunt Plateau, Utah, 2014-18.

Bear I.D.	Chi-Square	D.F.	W	*P*-value
A2016	364.294	5	0.441	< 0.001
C2014	172.756	5	0.403	< 0.001
C2-2014	347.706	5	0.672	< 0.001
D2016	3778.966	5	0.914	< 0.001
G2014	904.410	5	0.597	< 0.001
G2-2014	895.404	5	0.722	< 0.001
H2014	806.476	5	0.816	< 0.001
J2017	84.129	5	0.505	< 0.001
JG2016	9.179	5	0.104	0.108
L2015	1126.321	5	0.637	< 0.001
M2014	2613.620	5	0.961	< 0.001
M2-2014	838.489	5	0.757	< 0.001
P2014	419.525	5	0.510	< 0.001
S2017	33.789	5	0.317	< 0.001
T2017	1098.117	5	1.180	< 0.001
V2016	45.49	5	0.343	< 0.001

Table 1–8: Comparison between the top two models for habitat selection on the Paunsaugunt Plateau, Utah 2014-18.

Model	Intercept	Aspect	Domveg	Elev	Slope	Trails	Springs	Camps	D.F.	LogLik	AICc	Δ	Wt
27	0.154	+	+	1.013	0.224	-0.631	-0.221		16	-27532.26	55096.50	0.00	1
26	0.171	+	+	1.015	0.232		-0.236	-0.547	16	-27920.52	55873.10	776.53	0

Table 1–9: Habitat selection top model results for habitat selection on the Paunsaugunt Plateau, Utah, 2014-18.

	Estimate	Std. Error	Z value	*P*-Value
Intercept	0.154	0.190	0.815	0.415
Slope	0.224	0.011	20.557	< 0.001
Elevation	1.013	0.024	42.825	< 0.001
DomvegPIPO	-0.558	0.032	-17.470	< 0.001
DomvegPSME	-0.044	0.047	-0.938	0.348
Trails	-0.631	0.013	-50.514	< 0.001
AspectFlat	-1.483	0.123	-12.067	< 0.001
AspectN	0.190	0.046	4.153	< 0.001
AspectNE	0.583	0.037	15.779	< 0.001
AspectNW	-0.195	0.037	-5.207	< 0.001
AspectS	-0.439	0.042	-10.415	< 0.001
AspectSE	-0.162	0.039	-4.144	< 0.001
AspectSW	-0.678	0.044	-15.358	< 0.001
AspectW	-0.678	0.044	-15.501	< 0.001
Springs	-0.220	0.012	-18.821	< 0.001

Table 1–10: Comparison between the top two models for den site selection on the Paunsaugunt Plateau, Utah 2014-18.

Model	Intercept	Domveg	Aspect	Roads	Trails	Slope	D.F.	Loglik	AICc	Δ	Wt
5	-3.362		-0.3221	0.2369	0.7012	1.256	6	-57.173	126.7	0.00	0.742
11	-3.447	+		0.5138		1.122	6	-59.103	130.5	3.86	0.108

Table 1–11: Den site selection top model results on the Paunsaugunt Plateau, Utah, 2014-18.

	Estimate	Std. Error	Z Value	*P*-value
Intercept	-3.374	0.709	-4.761	< 0.001
Roads	0.244	0.207	1.179	0.091
Trails	-0.877	0.314	-2.793	0.090
Slope	1.206	0.261	4.615	< 0.001
AspectFlat	-21.319	1024.000	-0.021	0.983
AspectN	0.935	0.850	1.100	0.271
AspectNE	-0.916	1.231	-0.744	0.457
AspectNW	-0.677	1.066	-0.635	0.526
AspectS	-0.468	1.067	-0.437	0.662
AspectSE	-0.172	1.071	-0.190	0.849
AspectSW	-0.368	0.906	-0.350	0.726
AspectW	0.649	0.845	0.769	0.442

Table 1–12: List of dominant vegetation by scientific name, common name and vegetation forestry code.

Scientific Name	Common Name	Code
Juniperus osteosperma	Utah juniper	JUOS
Pinus ponderosa	ponderosa pine	PIPO
Pseudtsuga menzesii	Douglas fir	PSME

APPENDICES

Appendix 1–1: A complete list of baits used on the Paunsaugunt Plateau, Utah, during the 2017-trapping season. Baits in gray indicate use in trigger bags.

Anise Oil	
Bacon - cooked	gray
Bacon - raw	gray
Bear Spray	
Bread - moldy	
Candied Fruit - assorted	gray
Cantaloupe	
Cat Food - canned, assorted	gray
Cooking Oil - used	
Corn Cobs - boiled and buttered	
Doughnuts - assorted	gray
Doughnuts - Hostess coconut crunch	gray
Enchilada filling	
French Fries - cooked, old	gray
Ham - moldy	gray
Ham Hocks - uncooked	gray
Hamburgers - cooked, old	gray
Hard Candy - assorted	gray
Honey	gray
Honeybuns	gray
Licorice Ropes	gray
Loganberry Oil	
Marshmallow Jet Puff	
Marshmallows	gray
Meat - raw, rotting	
Melons - unknown, assorted	
Milk - sour, clotted	
Peaches	
Peanut Butter	gray
Peanut Butter Cookies	gray
Peppermint Oil	
Potatoes - rotting	
Sardines - canned in oil	
Sharp Cheddar	
Spearmint Oil	
Squash - unknown, assorted, rotting	
Strawberries	
Strawberry Licorice Ropes	gray
Strawberry Shortcakes - Lil Debbie	gray
Tuna - canned in oil	gray
Vanilla frosting	
Vegetables - assorted, rotting	
Watermelon	

Appendix 1–2: An example of our Xylazine administration drug log. This is not a comprehensive log. All drugs and logs were accounted for and turned in to the University veterinarian.

Xylazine Administration Log (Protocol 16-0201)

Concentration: 100mg/ml Volume: 50ml

Date	Vial Number	Description (Animal ID)	Beginning Amount	Amount Given	Balance Left	Initials
6/9/2017	3	Black Bear	50ml	1.6ml	48.4ml	RACD
6/11/2017	3	Black Bear	48.4ml	1ml	47.4m	RACD
6/21/2017	3	Black Bear	47.4ml	2ml	45.4ml	RACD
6/21/2017	3	Black Bear	45.4ml	2ml	43.4ml	RACD
7/9//2017	4*	Black Bear	50ml	1ml	49ml	RACD
7/9/2017	4*	Black Bear	49ml	1.25ml	47.75ml	RACD
		*Vial #3 expired & Utah state wildlife Veterinarian Annette Roug took vial #3				

Appendix 1–3: An example of our Ketamine administration log. All drug logs recorded in situ were typed up and recorded neatly. All drugs and logs were accounted for and turned in to the University veterinarian.

Ketamine Administration Log (Protocol 16-0201)

Concentration: 100mg/ml   Volume: 5ml   Total: 500mg

Date	Vial Number	Description (Animal ID)	Beginning Amount	Amount Given	Balance Left	Initials
6/9/2017	26	Black Bear	5ml	3.25ml	1.75ml	RACD
6/11/2017	26	Black Bear	1.75ml	1.75ml	0	RACD
----------	27	--------------------------	5ml	.25ml	4.25ml	RACD
6/21/2017	27	Black Bear	4.25ml	4.25ml	0	RACD
6/21/2017	28	Black Bear	5ml	4ml	1ml	RACD
7/9/2017	28	Black Bear	1ml	1ml	0	RACD
7/9/2017	29	Black Bear	5ml	1.25ml	3.75ml	RACD

Appendix 1–4: An example of our in-situ data sheet. Each bear has its own sheet. Drug information was taken from these sheets and typed into a drug log. Ear tags were often cut into unique shapes to help differentiate bears. These unique shapes and other identifying features were noted.

CHEMICAL IMMOBILIZATION FIELD FORM

Date:________________

Species:______________ Animal ID:______________ Personnel:_________________________________

Location:_____________________ Ambient Temp(F):___ Cloud Cover (%)___ Bait Type:______________

Drugs Administered	Amount(mg)	Time(24 hours)	Notes
1________________________	______	___________	_________________________________
2________________________	______	___________	_________________________________
3________________________	______	___________	_________________________________
4________________________	______	___________	_________________________________

Reaction	Time
Head Down	______
Unresponsive	______
Relaxed	______
Responsive	______
Head Up	______
Walked/Ran	______
Other______________	

Physical

Body Condition: Poor( ) Fair( ) Good( ) Excellent( )
Weight(lbs): Estimate_______ Actual_________
Gender: Male( ) Female( )
Mouth Examined( )___________________
Markings/Color:_____________________________
Scars/Injuries:_______________________________
Length(cm)__________ Chest(cm)___________

Procedures

Hair Sample( )
Tooth Remove( )
Ear Tag( )__________
Collar( )#__________
Photographed( )
Blood Sample( )
Fecal Sample( )

VITAL SIGNS

Resp/Min	Time	Temp(F)	Time	Pulse/Min	Time	Oxygen	Time

Other Notes/Observations:

CHAPTER 2

Movements and Activity Levels of the American Black Bear *(Ursus americanus)* on the Paunsaugunt Plateau, Utah

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ABSTRACT

American black bears on the Paunsaugunt Plateau region of Utah are a previously unstudied population, apart from a few females checked annually for reproductive status. Due to this population's proximity to Bryce Canyon National Park (BCNP) and other popular recreation sites, concerns over human-bear conflict arose. Greater insight about bears and their activity patterns and movements provides a foundation for improved mitigation and management decisions. Between 2014 and 2017, seventeen black bears were fitted with GPS collars to collect their locations and movement patterns. We determined weekly average distances and directions for all bears. For two bears, one male and one female, we determined daily averages and directions. Nine bears provided daily averages for 12 seasonal units across all four years. Activity patterns indicate the typical crepuscular pattern noted in normal bear populations that lack human habituation. This research indicates that Paunsaugunt black bears avoid human activity; however, we need continued research to help determine specific interactions between bears and anthropomorphic influences.

INTRODUCTION

American black bears (*Ursus americanus*) are omnivores with carnivorous tendencies and are found throughout much of North America (Pelton 1982, Powell et al. 1997; Figure 2-1). Consequently, black bear diets consist largely of vegetation (Barnes and Bray 1967, Welch et al. 1997). Bears seek out food as it becomes available to them seasonally, with springtime vegetation being mainly grasses (Mosnier et al. 2008) and hard masts in the fall. However, bears will take advantage of any food available, including anthropomorphic sources (e.g., garbage, compost, beehives, livestock, etc.) as humans encroach into their home ranges.

Since the European colonization of North America, humans have reduced black bear populations to small portions of their historic range (Pelton 1982, Powell et al. 1997). However, populations are increasing, or remaining stable, with a few exceptions, despite continual habitat loss, habitat degradation, and fragmentation (Garshelis et al. 2016, Lara-Díaz et al. 2018). As human activity within bear habitat continues to increase, human-bear conflicts will also likely increase (Herrero et al. 2011). A clearer understanding of bear-habitat relationships is key to minimizing human-bear conflict (Jones et al. 2015, Seryodkin et al. 2017).

American black bears populate montane regions of Utah (Figure 2-2). For the past 30 years, the Utah Division of Wildlife Resources (UDWR) has radio-collared black bears for the primary purpose of estimating reproductive parameters of various Utah populations (UDWR 2011). However, black bears of the Paunsaugunt Plateau region have not been a part of UDWR's black bear studies and their ecology is largely unknown. In recent years, sporadic problems with food-conditioned bears in Bryce Canyon National Park (BCNP) raised concerns for human safety and bear conservation, as well as a need to identify where bears were accessing anthropogenic food (S. Haas, National Park Service, personal communication). While not all food-conditioned bears are predatory towards humans, research has demonstrated that predatory bears are often food-conditioned (Herrero 2002). As a result, research was initiated in 2014 to address these information needs (Larson 2017). This work continued through 2017, and three annual progress reports were prepared (Larson and Smith 2015, Rosell and Smith 2016, Dungan and Smith 2017), as well as a graduate Master's Thesis (Larson 2017). In this document, I report on black bear research I conducted on the Paunsaugunt Plateau from 2016 to present, utilizing data collected from 2014 forward.

The primary purpose of this chapter is to describe movements and activity patterns for radio-collared black bears to extend our understanding of how bears on the Paunsaugunt Plateau use the landscape. An analysis of global position system (GPS) locational data and associated activity data enabled: 1) determination of diel activity patterns; 2) determination of annual activity patterns; 3) determination of annual movements; 4) determination of weekly movements; 5) determination of daily movements. These results were then compared to published findings regarding 1-5 and are reported here.

MATERIALS AND METHODS

Study Area

The Paunsaugunt Plateau (hereafter referred to as 'the Paunsaugunt') is in the southwestern fringe of the American black bear's primary geographic range (Scheick and McCown 2014; Figures 2-1 and 2-3). The Paunsaugunt is in both Kane and Garfield counties. The Paunsaugunt is approximately 16 km wide by 40 km long and is an extension of the larger Sevier Plateau. It ranges in elevation from 2100-2800 m. BNCP forms the eastern border of the Paunsaugunt, and the Pink Cliffs comprise the southern border. Most of the Paunsaugunt is Dixie National Forest land, but some private inholdings exist as well (United States Forest Service 2017). The Great Basin Divide and Colorado River Watershed also form part of the Paunsaugunt. Two rivers surround the plateau, including the East Fork of the Sevier River to the north, and Paria River to the east, which cuts through part of the Paunsaugunt and BCNP (Wikipedia 2017).

We concentrated bear trapping efforts south of Tropic Reservoir, including portions above and below the Pink Cliffs. The Paunsaugunt, as a small portion of the Colorado River watershed, has several perennial streams, as well as a spring, that feed into Tropic Reservoir. There are also many intermittent streams and springs scattered throughout, drying up in the heat of summer (Gregory 1951, United States Forest Service 2017).

The climate on the Paunsaugunt is highly varied, with mean temperatures strongly associated with elevation. The highest average temperature recorded for the BCNP region is 26.7° C and the lowest is -9.4° C. There were frequent thunder and rainstorms during all four summers in our trapping area. In winter, the Paunsaugunt typically has snow covering the ground but it frequently melts, giving rise to thick mud. Average precipitation in the form of rain is five centimeters while snowfall is two meters (Gregory 1951, National Parks Service 2018).

The dominant vegetation on the Paunsaugunt's upper elevations is primarily coniferous forests, particularly Ponderosa pine (*Pinus ponderosa*) and blue spruce (*Picea pungens*), with some Douglas fir (*Pseudotsuga menziseii*) and quaking aspen (*Populus tremuloides*) intermixed. The foothills are typically covered with pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus utahensis*), and the lower levels adjacent to the tableland are dominated by Gambel oak (*Quercus gambelii*; Gregory 1951). This habitat provides excellent cover for black bears, with oak mast being an important food resource in fall. Shrubs found on the Paunsaugunt include Greenleaf manzanita (*Arctostaphylos patula*), currant (*Ribes spp*.), and big sage (*Artemisia tridentata*).

Trap Site Selection

We deployed 10 to 17 barrel traps at a time over four years of the study (Figure 2-4). Between 2014 and 2015, W. Larson used 15 to 17 traps. In 2016, seasonal bio-technicians used 10 to 12 traps, and in 2017, we used 10 to 12 traps. All traps were placed in locations south of Tropic Reservoir, south, and west of the cliff edges. Traps were placed in two groups (lines) that were approximately equal in the amount of time required to visit them daily.

We selected trap sites based on local knowledge, which included United States Forest Service (USFS) cameras that monitored wildlife activity at guzzlers (water storage and catchments), UDWR and USFS personnel experience, and from previous experience trapping in the area (Larson 2017). The ability to access a trap site by either an ATV or truck was important because our barrel traps were heavy (~39 kg) and difficult for two persons to carry long distances and maneuver through dense brush. In selecting trap sites, we also considered known bear preferences for habitat features such as food, cover, and escape terrain, as well as the amount of shade available. We chose sites that were ≥ 30 meters from roads to avoid detection and human interference. Traps were not visible from roads and we placed warning signs ~ 20 meters from each trap. Additionally, we avoided cattle and human foot trails, but placed traps near game trails. Once traps were in place, we anchored them to two or more trees with pliable16-gauge wire to anchor them when bears were captured. We recorded the global positioning system (GPS) location for each trap site.

Bait Usage

We used a wide array of scent baits to attract bears to our traps, including anise oil (licorice scent), loganberry oil (fruity scent), raw rotting meat and sugary pastries. Additionally, we tried peanut butter, canned tuna fish in oil, canned cat food, vanilla frosting and hard candies (Appendix 1). We baited each trap site with a liquid scent, such as loganberry oil, sprayed on a 14 cm x 14 cm piece of carpet hung approximately 2 to 3 meters high from a nearby tree to draw bears into the general vicinity. We hung carpet squares so that bears could explore the scent, thus keeping bears near the trap longer, which increased trapping success (C. Mecham, UDWR biologist, personal communications). We placed rotten meat at the back of each trap to coax bears in. We filled plastic mesh bags with an assortment of pastries, cooked bacon, hard candies and other foods (Appendix 1), and then hung them from the trap's gate release mechanism situated at the back of the trap. We often smeared small amounts of peanut butter, bacon grease, honey, vanilla frosting and other such odorous foods on nearby trees, as well as scattered rotten fruits and vegetables, to attract and hold bears in the area.

Trail Camera Placement

In 2017, we placed a Reconyx PC900 covert infrared camera (Reconyx, Inc., Holmen, Wisconsin) at each trap site to document all activity at the trap. Each camera was set to take pictures when motion was detected (i.e., cameras were sensitive to motion within 12 m). Trail cameras were useful for deciding when to leave traps in place and when to move them.

Live Capture

All trapping operations were conducted in accordance to protocols approved by the Brigham Young University (B.Y.U.) Institutional Animal Care and Use Committee (IACUC protocol #140602). Trapping extended from late May through late August annually. We followed immobilization procedures as outlined in Black et al. (2004). Additionally, we collected the first premolar from each bear, as well as fur and fecal samples. We weighed each bear using hobbles that were attached to a scale. We also measured each bear's body length and chest circumference with a tape measure.

Our work schedule consisted of 10 days of active trapping followed by four days of inactivity. We checked traps daily, leaving the USFS Dave's Hollow Guard Station (37°40' 34.3"N 112°12' 20.1"W) between 08:00 and 09:00, and returning in early afternoon. We added rotten meat obtained from butcher shops, typically beef and pork, to traps every other day, added more liquid scent to hanging carpet squares daily, and replaced trigger bait bags as needed. Prior to each inactive period, we deactivated traps by removing their doors and did not rebait them. We checked traps at least once every 24 hours and were able to check all traps before 12 noon. We moved traps periodically due to a lack of bear activity or if we found evidence of human activity or tampering (as recorded by our trail cameras). We moved all trap that had no bear activity over a 14-day period. We visited den sites between February and March of the years following capture, 2015 to 2018. We visited denned bears to replace, or remove, radio-collars and batteries, as well as monitor the health and reproductive status of the bears. Bears were anesthetized at den sites, as outlined in Black et al. (2004).

Specifically, at trap sites we sedated bears with a combination of ketamine hydrochloride (100 mg/ml) and xylazine hydrochloride (100 mg/ml). We estimated the trapped bear's weight and administered ketamine hydrochloride at a dosage of 4 mg/kg (2 cc per 45.4 kg) and xylazine hydrochloride at 2 mg/kg (1 cc per 45.4 kg). We administered drugs with a syringe pole or "jab stick" that was inserted through 12 cm x 12 cm ports located on both ends of the trap. We maintained chemical immobilization data sheets for each capture (Appendices 2 and 3). We removed tranquilized bears from traps, placed them in the shade and applied masks to protect their eyes from debris as well as to lower stress by limiting visual stimulation. Throughout the immobilization process, we monitored respiration by counting the number of breaths per 30 seconds, heart rate with a stethoscope, and body temperature using a rectal thermometer. Normal ranges for these data were 80-100 bpm, 7-60 breaths per minute, and 37.2-40.0 °C (A. Rouge, UDWR veterinarian, personal communications). If temperatures climbed above 40.0 °C, we applied water or ice to the bear and reversed the anesthesia. We collected these physiological data at least once every five minutes.

Radio-Collar Programming, Deployment and Data Transmission

We attached ATS® Iridium GPS radio-collars to bears to track movements (Figure 2-5). These radio-collars permitted us to adjust data collection and transmittal rates to satellites. We programmed most to collect data every six hours and transmit to satellites every 24 hours. Additionally, radio-collars collected ambient temperature at the time of each positional fix, accurate to ± 2.0º C. Radio-collars also recorded activity data using mercury tilt-switch sensors. These sensors log the percentage of time the switch moved during a 15-minute period just prior to each GPS fix. Radio-collar data were made accessible to researchers by way of ATS web servers.

DATA ANALYSIS

Activity Patterns

I analyzed all bear movement, activity and temperature data using Microsoft Excel ® 2016 and ArcMap 10.5 (ESRI 2018). Activity data were recorded as the percent of time a bear was “active,” or activating the tilt switch, for 15 minutes prior to each GPS fix (John Roth, ATS technician, personal communication). The GPS fix is the time at which the collar determines its 2-D location. The activity data are a number that correlates to a percent; hence, all activity data collected ranges from 0 to 100. I never had a GPS fix with 100% activity associated with it. For analyzing activity levels, I removed all data, GPS fixes and their associated activity levels, during the denning season. I defined denning season on the Paunsaugunt as November through March.

To determine daily patterns, I summed activity levels for each hour of the day and then averaged the sum by the number of bears that contributed for each hour. To create proportions rather than percentages, I calculated the total potential activity levels for each hour and divided the actual activity level sums by the potential activity level totals (i.e. for 7 fixes there would be a potential activity level sum of 700 and if the actual activity level sum were 600 the proportion would be 600/700 = 0.857). I averaged proportions across all bears that contributed to each hour. I did the same for annual activity levels, determining activity proportion averages for each month.

Prior to examining any relationship between collar temperature or ambient temperature and activity levels, I determined the relationship between the collar temperature and ambient temperature. To attempt the best approximation of actual temperatures possible I derived our ambient temperatures for this analysis from several sources and averaged monthly data across these sources. I used data collected by the US Historical Climate Network (HCN) and the national cooperative network, which includes snowpack telemetry (SNOTEL), data collected by the Global Historical Climatology Network and the Applied Climate Information System (ACIS), maintained by the NOAA Regional Climate Centers (National Oceanic and Atmospheric

Administration, National Snow and Ice Data Center, Regional Climate Centers). To reflect the varied elevation and microclimates I used data from 15 different weather stations from the previously noted data sources. I accessed these data layers from ESRI ®, downloaded them into Microsoft Excel ®, and averaged them to get averaged maximum, minimum and mean temperature values for each month.

In order to determine if collar and ambient temperatures could be used as indicators of potential activity levels, I performed the following: I used regression analysis to see if there was a correlation between ambient monthly averages reported by weather stations in the area and average values recorded by collars monthly. Next, I performed a regression analysis comparing activity levels to both ambient and collar temperature levels to determine the degree of correlation.

Movements

I examined movement data for each radio-collared bear, checking for date gaps and consistency in time stamps. I determined that across all bears, a weekly analysis would best represent the data for all bears, keeping the sample size of bears at 16 for an initial movement analysis. However, two bears provided sufficient data for daily movement analysis from den-out to den-in during 2015 and nine bears provided enough data for six hyperphagia and six mating seasons during the four years (2014-2017). I began week for each bear starting with the earliest data point during the mating season (April-July), rather than beginning on a specific day of the week.

I used the ArcMap 10.5 tool “XY to Lines” to generate movement vectors between the successive points. This created a file containing the distances traversed by each bear for each week and for each bear that provided daily data across each day. I attached season, week number, year, bear ID and starting and ending points in ArcMap because the newly created line files did not contain this additional information. I used “Add Geometry Attributes” in ArcMap to calculate the length of each weekly and daily movement vector of travel. This process was repeated for the hyperphagia season (Aug-Oct), starting at the earliest locational data point recorded in that season. The denning season (Nov-March) was excluded from movement analysis because bears did not move much during this period.

I compared the distance moved on a weekly basis between mating and hyperphagia seasons using a paired t-test in Microsoft Excel ®. I determined the annual weekly movement distance averages for four years, 2014-2017, by summing the distance moved during mating and hyperphagia seasons, then dividing those totals by the number of contributing bears. I did this process for daily movements as well. Additionally, I analyzed the differences between male and female weekly movements during hyperphagia and mating seasons using t-tests in Microsoft Excel ®. Individual weekly average distances were also calculated. For daily movement vectors, I calculated male and female means for both hyperphagia and mating, as well as annual daily means. I compared these means using t-tests in Microsoft Excel ®.

A bear's direction of travel was determined for each movement vector using the ArcMap tool “Add Geometry Attributes”. This tool determined the bearing degree of each movement vector, which I manually converted to the cardinal directions of east (E = 67.50-112.49), southeast (SE = 112.50-157.49), south (S = 157.50-202.49), southwest (SW = 202.50-247.49), west (W = 247.50-292.49), northwest (NW = 292.50-337.49), north (N = 337.50-22.49) and northeast (NE

= 22.50-67.49). I generated graphs demonstrating the average direction of traveled by bear and by season using Microsoft Excel ®. I also generated graphs depicting the distances traveled in each direction for each bear individually, seasonally and annually. I inspected each bear's weekly movements in search of movement patterns associated with home ranges and den sites. Significance threshold for all data analysis was set to ≤ 0.05 for *P* values.

RESULTS

Captures

Over 4 seasons of study (2014-2017) we captured 17 bears (10 males and 11 females, yearlings and adults). Prior to our field season of 2017, Wes Larson and others caught 13 unique bears from 2014-2016 (Larson et al. 2015, Rosell and Smith 2016). In 2017, we caught four bears that had not been captured previously and recaptured six bears from previous years that had lost their radio-collars (Table 2-1). Seventeen radio-collars were deployed on this project with only one collar failure.

Activity Patterns

Averaged daily activity levels demonstrated a bimodal pattern throughout a 24-hour period: with one activity peak during the early morning (05:00-08:00) and another during evening hours (17:00-21:00; Figure 2-6). Activity was lowest at night and marginal during the late morning and afternoon. Throughout the year, activity levels were highest during the months of June and July, (the mating season), and lowest during December, January and February (denning; Figure 2-7). Collar and ambient temperatures were highly correlated (r^2 = 0.78). Additionally, the relationships between collar temperature and activity level, and ambient temperature and activity level, were highly correlated ($r^2 = 0.82$ and 0.96 respectively; Figure 2-8).

Bear Movements

The average weekly distances traveled during mating season was 4.31 km (SE ± 2.50 km), hyperphagia season was 4.64 km (SE ± 2.74 km), and the annual average movement per week was 4.49 km (SE ± 18.80; Table 2-2). Female bears averaged 4.25 km (SE ±2.24 km) of movement per week, whereas male average was 4.92 km (SE ± 3.34 km) per week (Table 2-2). There were no significant differences between male and female weekly movement averages during either season or between annual weekly movement averages (Table 2-3). In addition, there were no differences between weekly mating, hyperphagia or weekly annual means (Table 2-3).

The primary direction of travel during both seasons and annually was south (Figure 2-9). A south direction accounts for 31% of the weekly movement vectors of direction annually, across all bears. The second-ranked direction of travel was southwest, accounting for 22% of the annual directions. For hyperphagia, south accounts for 35% and southwest accounts for 23%. During the mating season, south and southwest again comprised the majority of the direction traveled with 26% and 24% respectively. The least traveled direction was northwest during hyperphagia (1%) and north during mating (3%). Annually, north and northwest both accounted for 4% each (Table 2-6). This pattern was consistent with individual bears' weekly movement results (Figure 2-10).

Two bears provided daily movements continuously for a year. A male bear, G2-2014, had a daily mean movement distance of 2.75 km (SE± 0.21). Annually, his daily primary direction of movement was northeast (19%), followed by southwest (18%). During the mating season, this male's primary direction traveled was southwest (20%) and during hyperphagia it was northeast (20%; Figure 2-11). The adult female bear, M2-2014, provided daily movement data for 2015 but no ending den site, only the starting den site. Her daily distance traveled was 2.13 km (SE ± 0.13). Primary direction traveled annually was southeast (17%), whereas the mating season was dominated by two directions, west and east, 18%, and hyperphagia was southeast (19%; Figure 2-11).

An additional nine bears provided daily movements for the two seasons. We combined these results with the two previously mentioned bears for a more comprehensive analysis for annual and seasonal daily movements. Average daily distance means for males was 2.63 km (SE ± 0.11) and for females was 1.70 km (SE ± 0.05). During mating, males traveled an average of 2.23 km (SE ± 0.09) daily and females traveled an average of 1.86 km (SE ± 0.06) while during hyperphagia males' daily distance was 2.24 km (SE ± 0.14) and females' was 1.76 km (SE ± 0.11; Table 2-4). T-test results showed no difference ($P > 0.05$) between any of the means for season, male or female, or annual except for the comparison between male and female annual daily averages (Table 2-5). The primary direction of travel during mating was tied between southwest and northeast (14% for both). The primary direction of travel during hyperphagia was northeast and southwest (16%) while the primary direction traveled during mating was southwest (14%; Figure 2-12).

Inspection of movement vectors provided two general patterns: 1) den sites tended to serve as central locations for annual movements, or 2) dens were not the center activity while bears ranged away from them (Figures 2-13 and 2-14). Males ranged farther from den sites and had more long-distance movements. Females tended to stay closer to den sites throughout the year and exhibited fewer far ranging movements.

DISCUSSION

Activity Patterns

There are many opportunities for human-bear conflicts and exposure to anthropogenic food sources on the Paunsaugunt. Black bears are hunted with both baits and trained pursuit dogs. There are ATV trails, trails, paved and unpaved roads traversing the study area. Activities, such as camping or hiking occur frequently on the Paunsaugunt during summer. Food conditioned bears are active mostly at night (Ayers et al. 1986), when human activity is minimal. Conversely, bears minimize activity during the middle of the day when human activity is at its highest (Reimchen 1998, Beckmann and Berger 2003, Kaczensky et al. 2006). The activity patterns of bears that are not food conditioned are crepuscular with two peaks, one in the early morning and one in the evening. Natural activity patterns of black bears are typified by some activity during the afternoon and minimal activity during the night (Aschoff 1966, Lindzey and Meslow 1977, Garshelis and Pelton 1980, Ayres et al. 1986, Lariviére et al. 1994, Maehr 1997, Holm et al. 1999, Beckmann and Berger 2003, Bridge et al. 2004, Lewis and Rachlow 2011).

Based on activity data transmitted by radio-collars Paunsaugunt bears exhibit normal activity patterns, with clearly defined peaks during the morning and evening hours (Figure 2-6). Human-bear conflicts and bear sightings on the Paunsaugunt are infrequent (J. Schoppe, USFS biologist, personal communications and M. Graham, BCNP biologist, personal communication). Despite unsecured, and easily entered, garbage dumpsters being present within the study area, we did not observe black bears using these food sources, nor has there been evidence of bear raiding (e.g., tracks, scats, scattered trash and garbage). These observations are suggestion of a lack of conditioning to anthropogenic food sources. Anecdotally, locals are surprised whenever bear sightings occur. Many stated to us that there are no bears on the Paunsaugunt, as well as BCNP.

Seasonal activity patterns for mammals are highly dependent on available resources (Bridges et al. 2004, Gaines et al. 2005, Manly et al. 2011, Dugatkin 2014, Karelus et al. 2016, Lara-Díaz et al. 2018). For black bears on the Paunsaugunt, as with all black bear populations, the immediate needs following den exit include seeking food and potential mates (Nelson et al. 1983, Nielsen et al. 2010, Lewis and Rachlow 2011, Manly et al. 2011). Consistent with other studies of American black bears (Garshelis and Pelton 1980, Ayres et al. 1986, Bridges et al. 2004, Munro et al 2006, Lewis and Rachlow 2011), bears on the Paunsaugunt have relatively lower activity levels immediately following den emergence in April. Activity peaked during June and July, which on the Paunsaugunt is the height of mating season (Figure 2-7). During hyperphagia, bears seek out food and begin locating potential den sites (Erickson et al. 1964, Pelton et al. 1980, Nelson et al. 1983, Gray et al. 2016). We observed bears denning on the Paunsaugunt as early as September and some males never denned during the winter of 2015 based on GPS fixes. They never stopped moving during winter (Nelson et al. 1983, Hellgren and Vaughn 1989). Additionally, den abandonment occurred (n = 3), though the reasons for the abandonment we observed are unknown, abandonment does occur when environmental conditions warrant it, cubs are not carried to full term or a den is disturbed. Abandonment is not uncommon in bear populations (Pelton et al. 1980, Tietje and Ruff 1980, Amstrup 1993, Gray et al. 2016, Olsen et al. 2017). These can account for some of the activity that we observed during denning season. Temperature is also highly correlated with activity levels with warmer temperatures indicating more activity on the Paunsaugunt.

Movements

American black bears travel as much as necessary to fulfill their basic needs. They travel to find food, mates, den sites, and to explore the landscape (Alt et al. 1980, Pelton et al. 1980, Nelson et al. 1983, Smith and Pelton 1990, Mitchell and Powell 2012). Young bears, especially sub-adult males, often disperse from their natal grounds to access mates and resources (Alt et al. 1980, Dobson 1982, Schwartz and Franzmann 1992, Bull et al. 2001, Costello et al. 2009, Costello 2010). Additionally, like males in many mammal species, distant dispersal lowers the chances of inbreeding and introduces hybrid vigor into those populations they settle in (Dobson 1982). These dispersal journeys can be quite long, with Costello 2010 reporting males traveling 22-68 km away from natal ranges while Schwartz and Franzmann 1992 reported dispersal distances of 1.6-3.2 km. While we did not observe any young bears we radio-tagged dispersing, we did observe several adult males leave previously established territories and seemingly establish new territories over 140 km away. These long-range movements occurred early in the mating season (May of 2016 and 2017). Females occasionally travel great distances as well, but they do not tend to disperse as males do and we did not observe any females moving off the Paunsaugunt. The average weekly distance of more than 4 km suggests the Paunsaugunt is habitat with foods spread broadly across the landscape (Table 2-2). For the two bears we calculated daily distances, their averages were both greater than 2 km. This indicates that resources are widely distributed across the Paunsaugunt, thus necessitating much travel.

Many species exhibit movements away from human activity (Gibeau et al. 2002, Ordiz et al. 2011, Longshore et al. 2013, Dugatkin 2014). They are pushed out of areas they normally occupy because of human activity in order to avoid humans. American black bears also demonstrate this effect of being displaced by human activity (Amstrup 1993, Gibeau et al. 2002, Ordiz et al. 2011, Smith et al. 2012, Simek et al. 2015). However, despite relatively high recreational use of the Paunsaugunt during summer months bears did not exhibit these displacements, as indicated by lack of differences between the average seasonal and annual movements (Table 2-3). Bear movement patterns on the Paunsaugunt suggest that den sites anchor bear home ranges and that human activity plays a minor role (Figures 2-12 and 2-13). Additionally, the fall mast crop, a primary food source, is located below the Paunsaugunt rim with a large concentration of oaks to the south. This may explain the tendency for bears to move in a primarily southern direction (Figure 2-10). The male bear for which we calculated daily movement patterns tended to follow a northwest/southeast movement trend, regardless of season or annual weekly totals and the female followed a northeast/southwest trend (Figure 2-11).

MANAGEMENT IMPLICATIONS

It is going to become increasingly difficult to avoid human-bear conflict with both species increasing across North America (Garshelis et al. 2016, North American Population 2018). Humans and their infrastructure occur on the landscape within black bear home ranges on the Paunsaugunt. The Paunsaugunt represents an edge of black bear geographic range according to Scheick and McCown (2014). This is supported by the apparent low density of bears inhabiting the area. Despite few black bear sightings, and minimal human-bear conflict in the region now, these will likely increase in the coming years. The area is largely comprised of Dixie National

Forest land used recreationally year-round and logged. Additionally, the rugged cliffs that encircle the Paunsaugunt and lands below are either part of BCNP or private property. This puts bears and people into close proximity in this region and many stakeholders share an interest in human-bear interactions.

The National Park Service's mission, in part, is to educate park visitors about the ecosystem and its components. While BCNP is not known as a bear park like Yosemite, Yellowstone, or many others, black bears play a role in the BCNP ecosystem. Information derived from this study that are of value to the park includes:

- Black bears in the Paunsaugunt region have some of the largest home ranges in North America. This is reflective of low-quality home ranges for these bears.
- Both sexes travel large distances during mating and hyperphagia to find food. Males must travel great distances to find mates, making this a metapopulation, or subpopulation linked to others through juvenile dispersal and annual movements.
- Cliffs and rocky bluffs are predominantly used for denning and for passage to and from areas, but bears do not spend significant time in cliffs during mating and hyperphagia.
- The preferred habitat type for bears in the Paunsaugunt region is Utah juniper, with bears using it more than Douglas fir and ponderosa pine habitats despite the greater prevalence of these two habitats.
- Black bears in the region have a crepuscular activity cycle. They are most active during the morning and evening hours and least active during the night. This finding is consistent with wild populations of bears throughout North America.

- Bears in the region avoid roads and trails, however, these areas serve as contact points with people. Additionally, bears occasionally visit campsites. Bear safety best practices should be emphasized in the region.
- If and when the park considers the placement of new trails and campsites, rough areas and Utah juniper should be avoided as possible as these are preferred use areas for Paunsaugunt bears.

The USFS maintains several campsites on the Paunsaugunt within home ranges used by bears in this study. Portions of the Paunsaugunt are logged during the summer and bears utilize guzzlers maintained by the USFS (B. Barnhurst USFS maintenance personal communications, Larson 2017). Camera images show them drinking and wallowing at these sites. Information important to the USFS regarding these bears includes:

- Consideration of Utah juniper as positively correlated with bear use should be taken when considering projects such as logging, as logging roads through Utah juniper will reduce the habitat for bears, further reducing the quality of their home ranges.
- Guzzlers likely serve to improve habitat quality for these bears.
- Projects that may reduce bear habitat quality significantly, may increase conflict with humans in the region.
- Habitat improvements that increase bear forages (e.g., oak, manzanita, berry producing plants, etc.) may positively affect population size while reducing the distances traveled by bears in the region.

While the USFS and BCNP control the majority of the land these bears utilize, the UDWR manages the black bear population in this region and establish hunting quotas. New research regarding the density and population size of these bears is needed, however, some information important presented in this study includes:

- This population uses rough areas as travel corridors and for denning purposes.
- Roads and logging reduce already limited habitat for black bears in the region.
- Great distances traveled indicate a wide area for dispersal and low resources.
- Crepuscular activity cycles suggest a lack conditioning to anthropogenic food sources.
- Habitat improvements would be required to increase the regional black bear population.
- While we did not conduct a bear population estimate for the Paunsaugunt, intense trapping over a four year period suggests that the adult population is comprised of < 20 individuals. Hunting quotas that increase, decrease or keep the population stable could reasonably be based on that number.
- Pursuit of bears by dogs was infrequent during the four year study period and research investigating the effects of this activity could profitably be conducted since the population is largely unperturbed.

As human and bear populations both increase and continue to enter into conflict, this study can be used as a baseline against which other bear populations can be compared.

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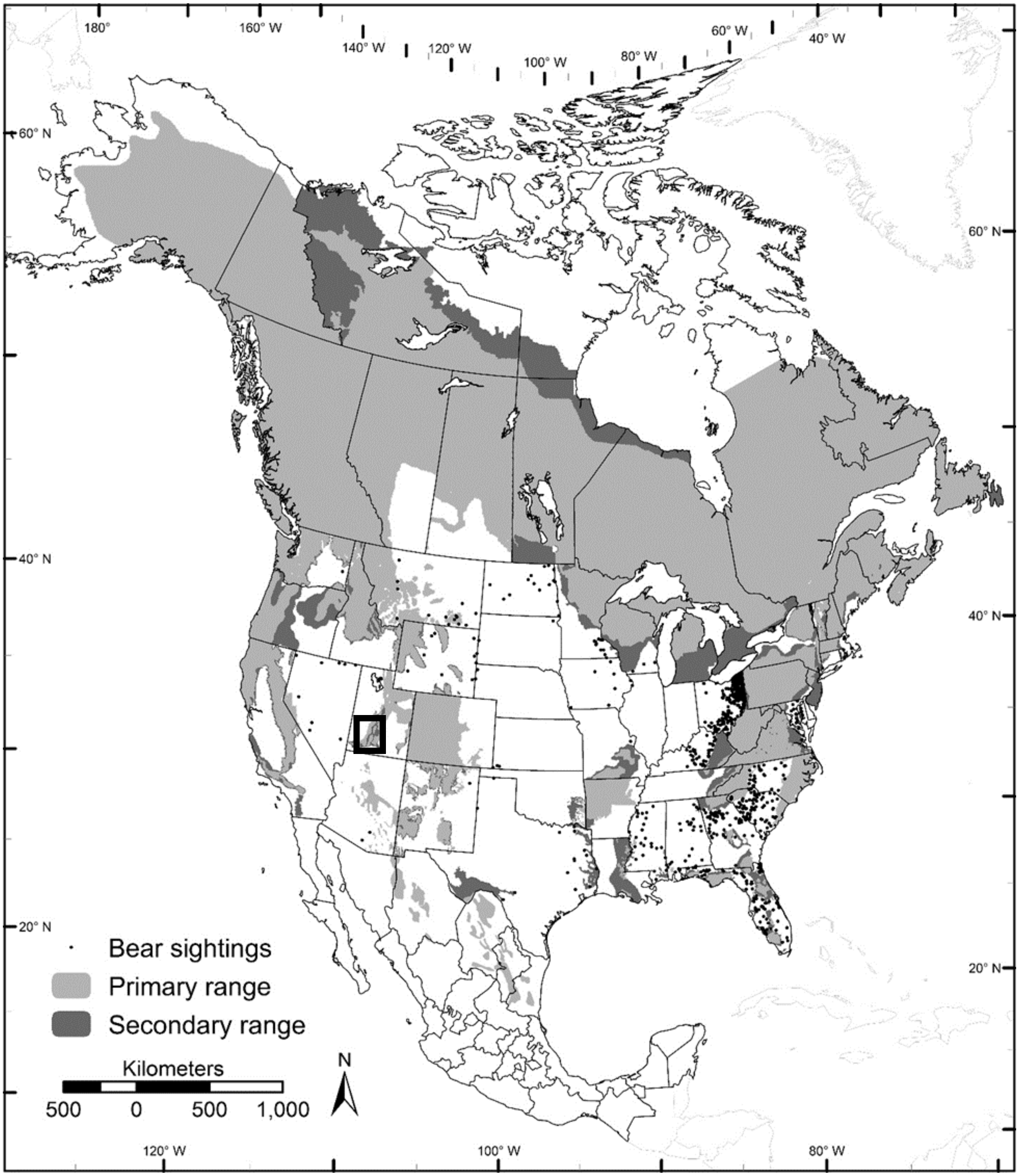

Figure 2–1: American black bear geographic range and location of the Paunsaugunt plateau in relation to that range.

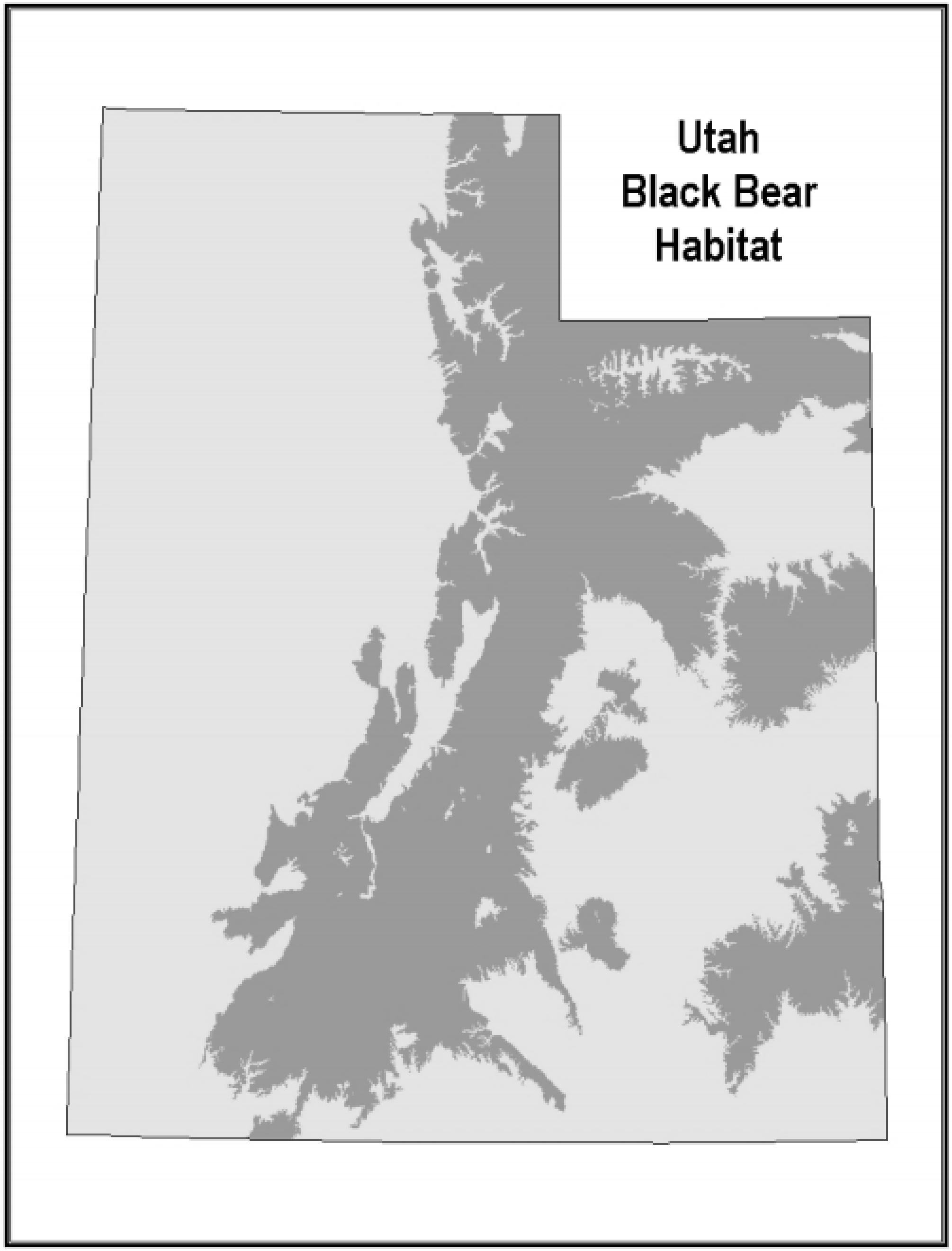

Figure 2–2: American black bear habitat in Utah as indicated by the dark gray. Light gray areas are unsuitable habitat for American black bears.

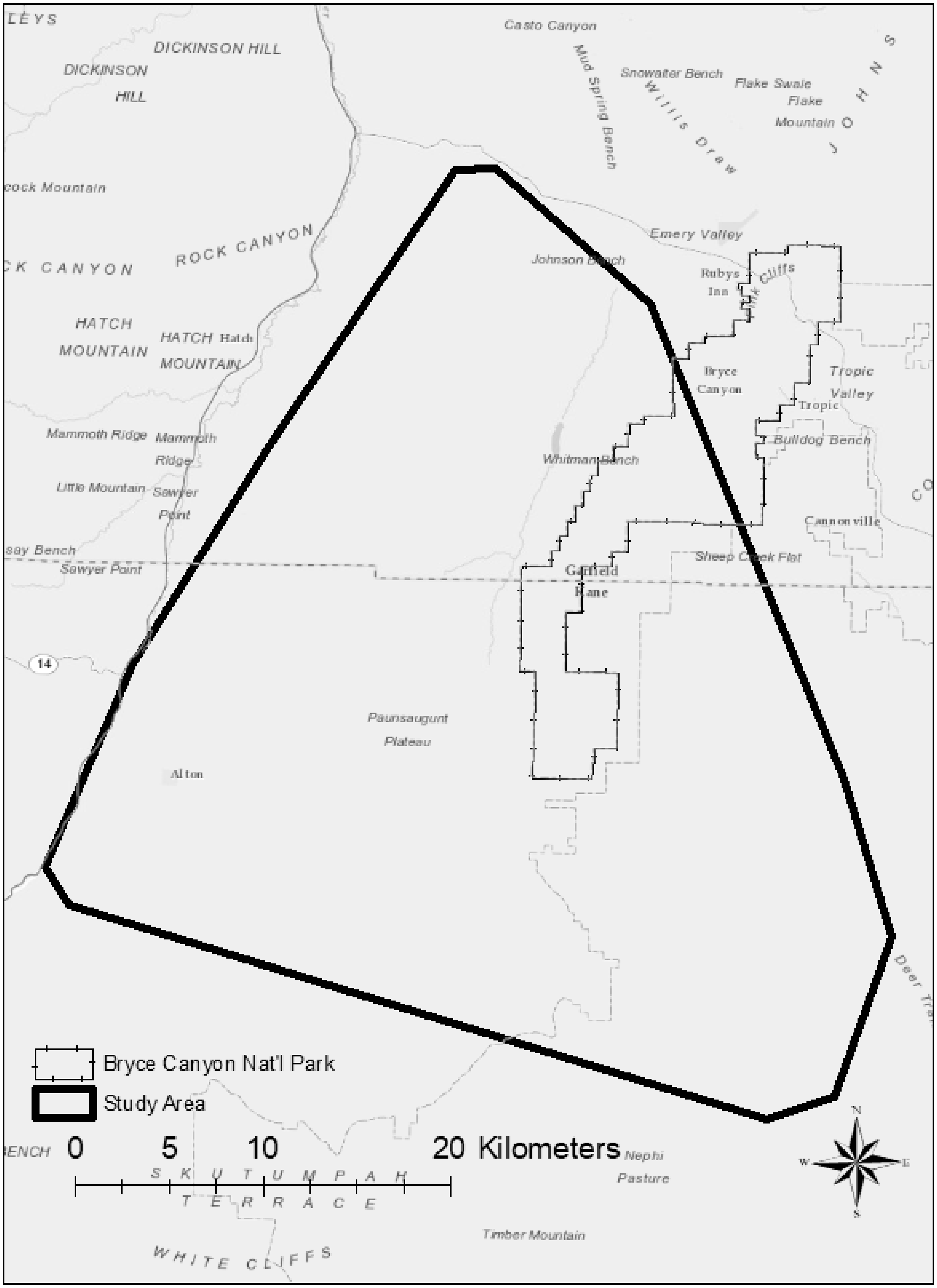

Figure 2–3: American black bear study area on the Paunsaugunt Plateau, UT, 2017.

Figure 2–4: A yearling sits outside an activated barrel trap on the Paunsaugunt Plateau, UT during summer 2017.

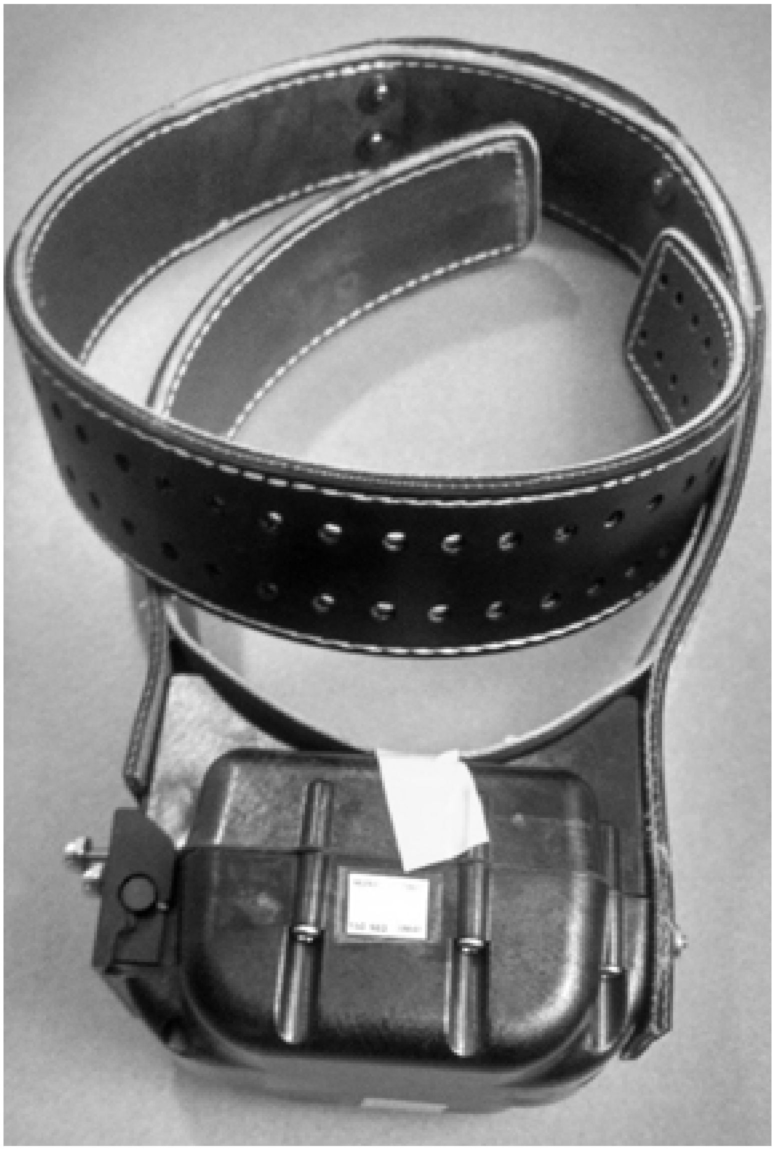

Figure 2–5: ATS® Iridium GPS bear radio-collar.

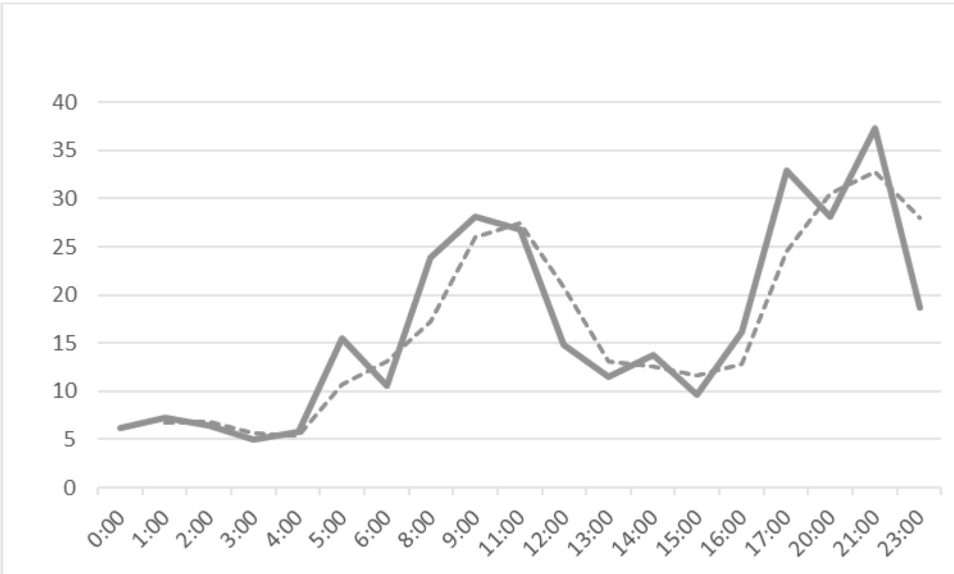

Figure 2–6: Black bear daily activity patterns on the Paunsaugunt Plateau, UT, 2014-2017.

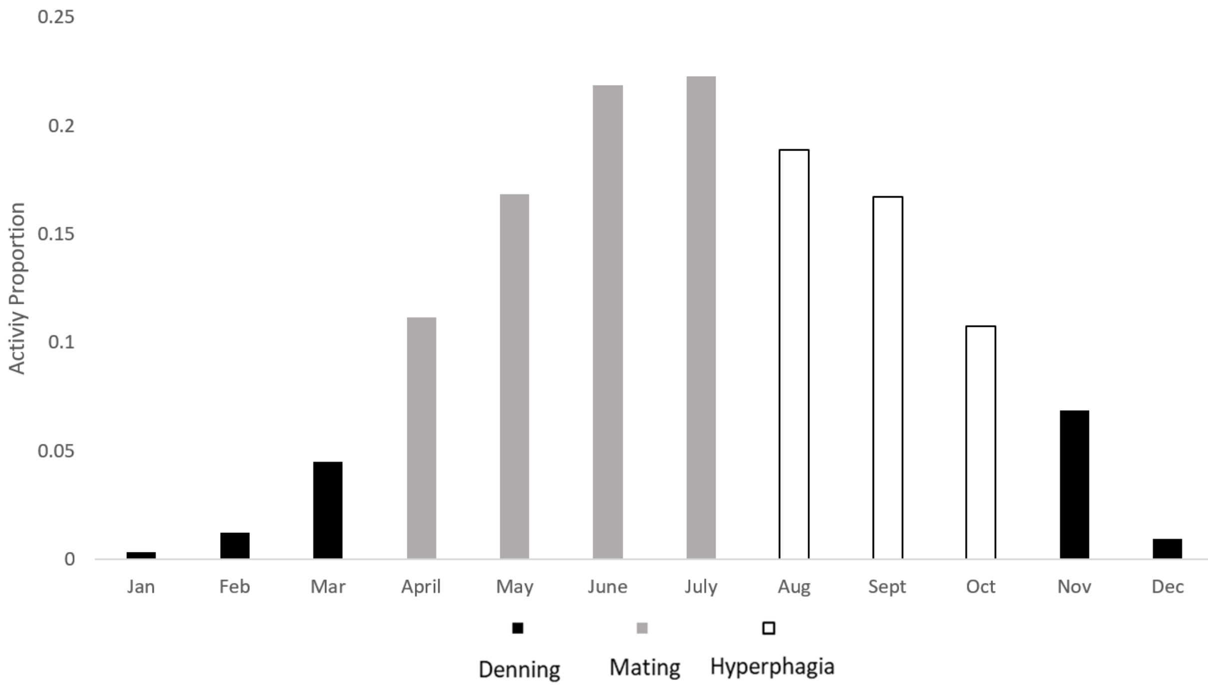

Figure 2–7: Black bear annual activity patterns on the Paunsaugunt Plateau, UT, 2014-2017.

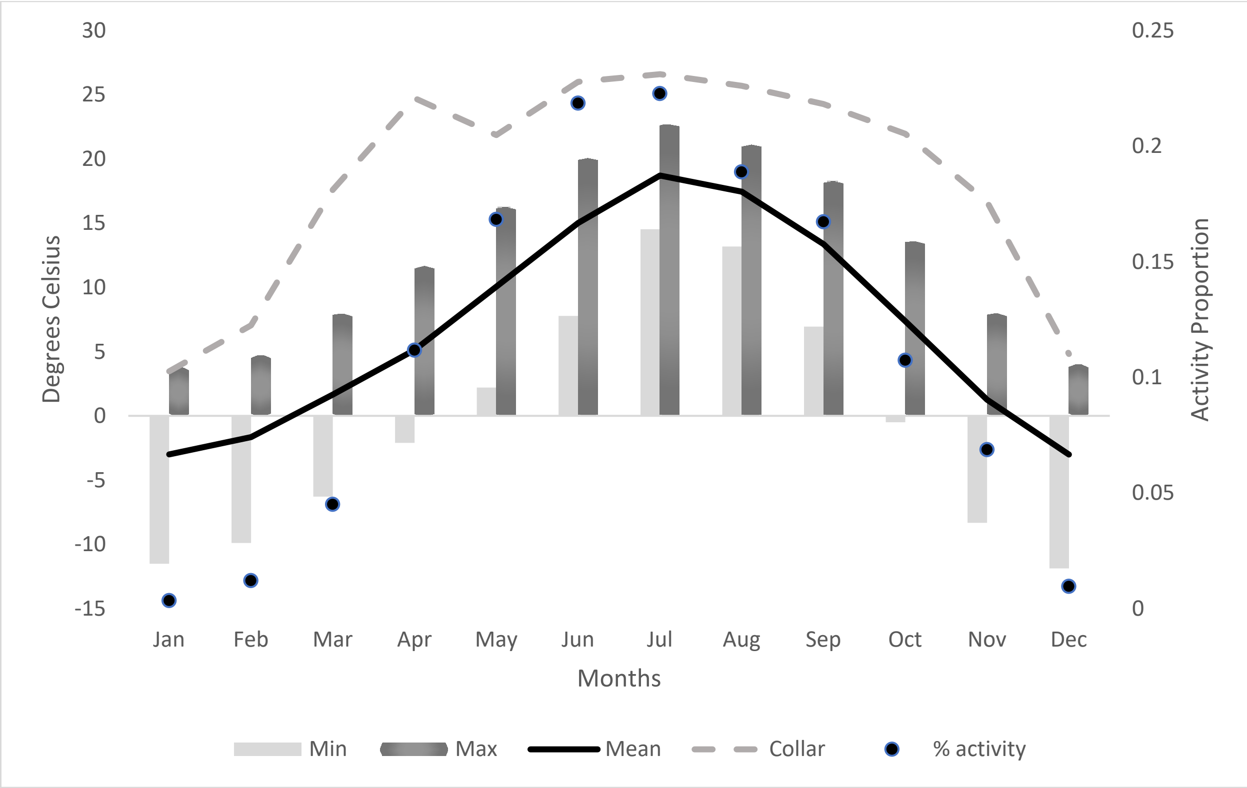

Figure 2–8: Annual temperature relationships with activity levels on the Paunsaugunt Plateau, UT, 2014-2017.

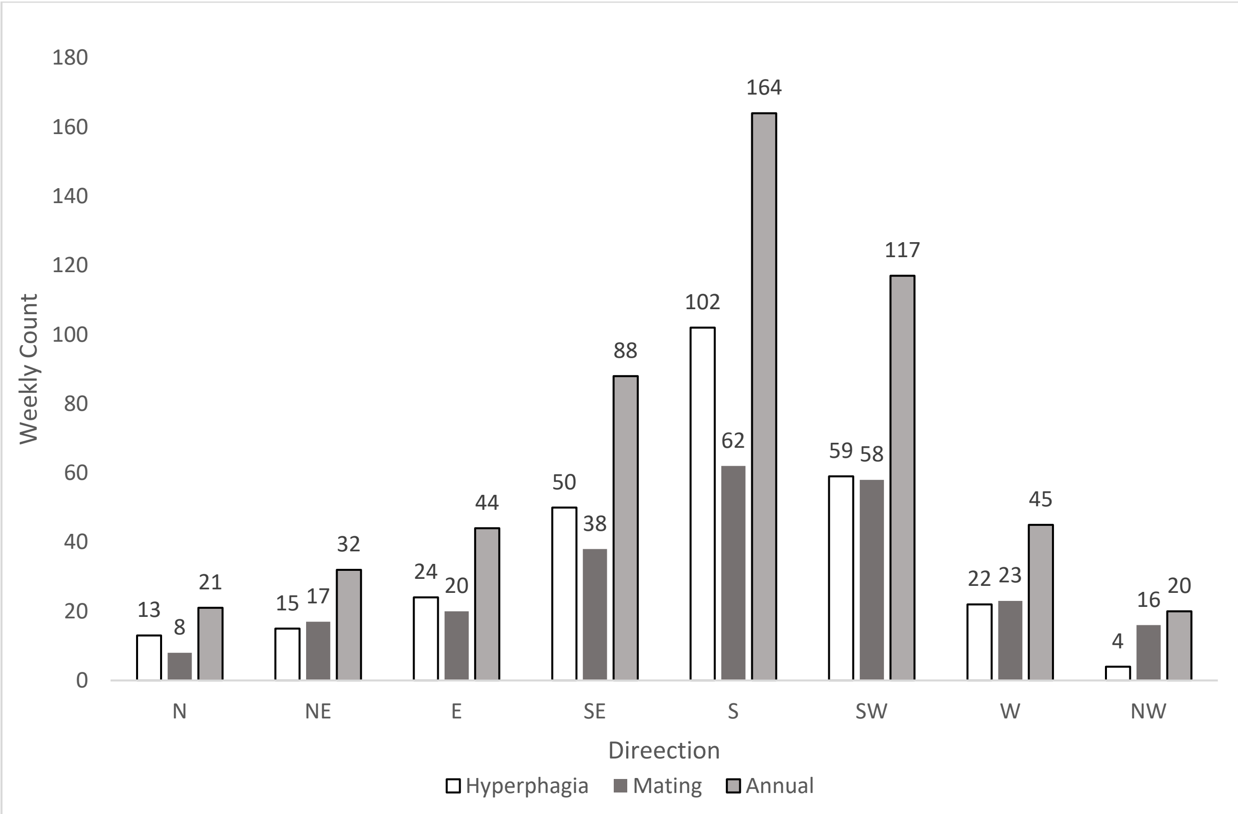

Figure 2–9: Count of weekly directions traveled annually and by season on the Paunsaugunt Plateau, UT, 2014-2017.

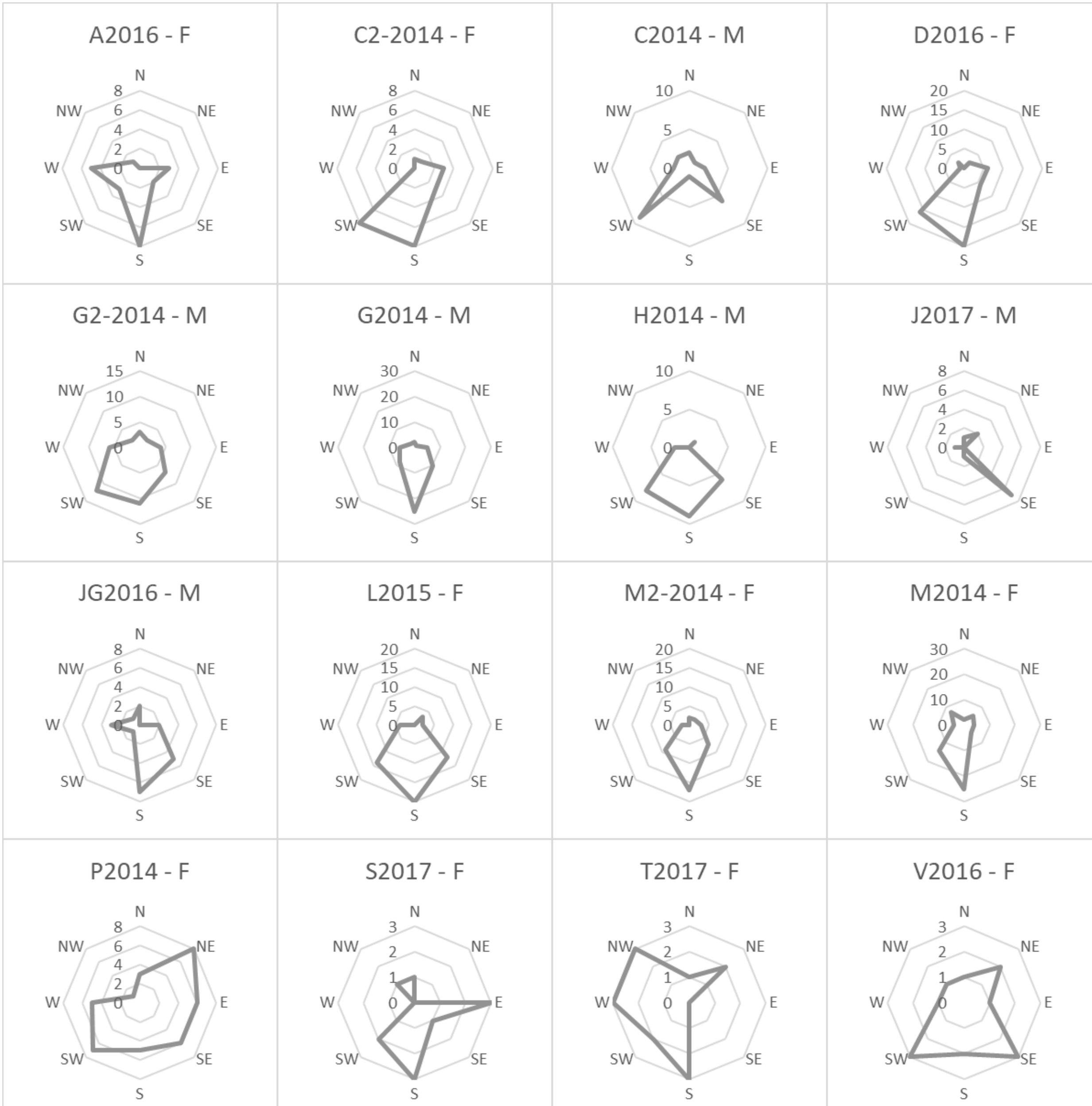

Figure 2–10: Count of weekly directions traveled by each bear on the Paunsaugunt Plateau, UT, 2014-2017.

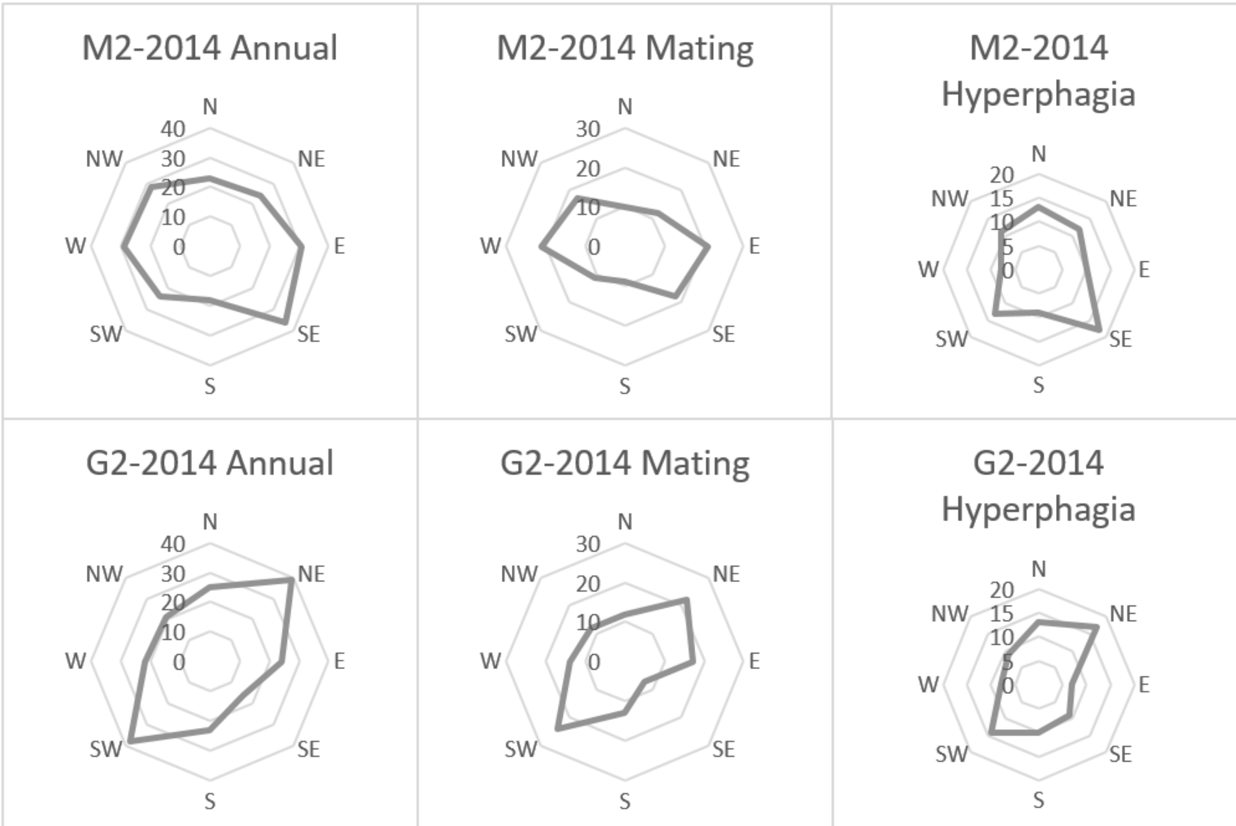

Figure 2–11: Daily directions traveled annually and seasonally on the Paunsaugunt Plateau, UT, 2015.

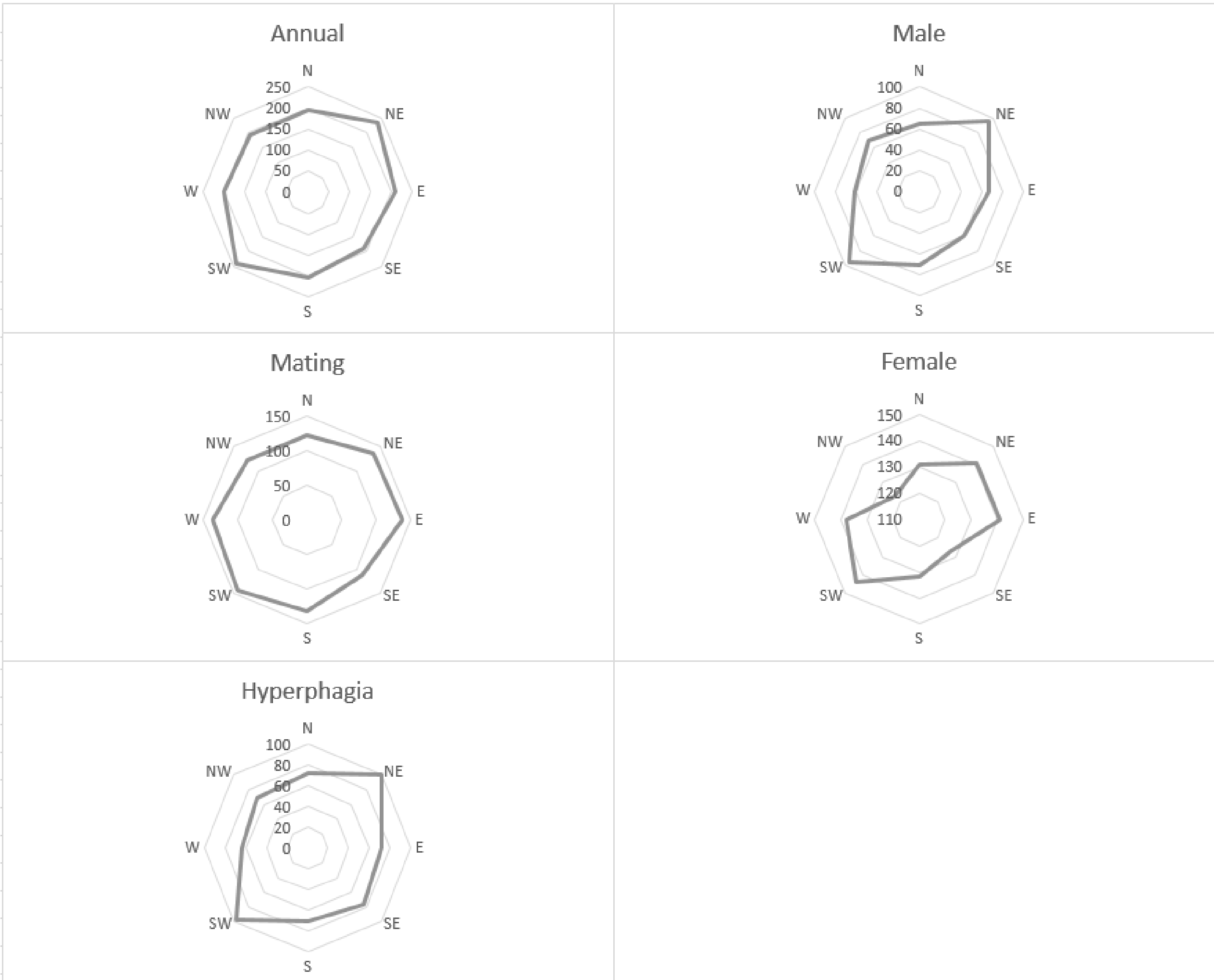

Figure 2–12: Daily directions traveled by a subset of our sample of American black bears on the Paunsaugunt Plateau, UT, 2014-2017.

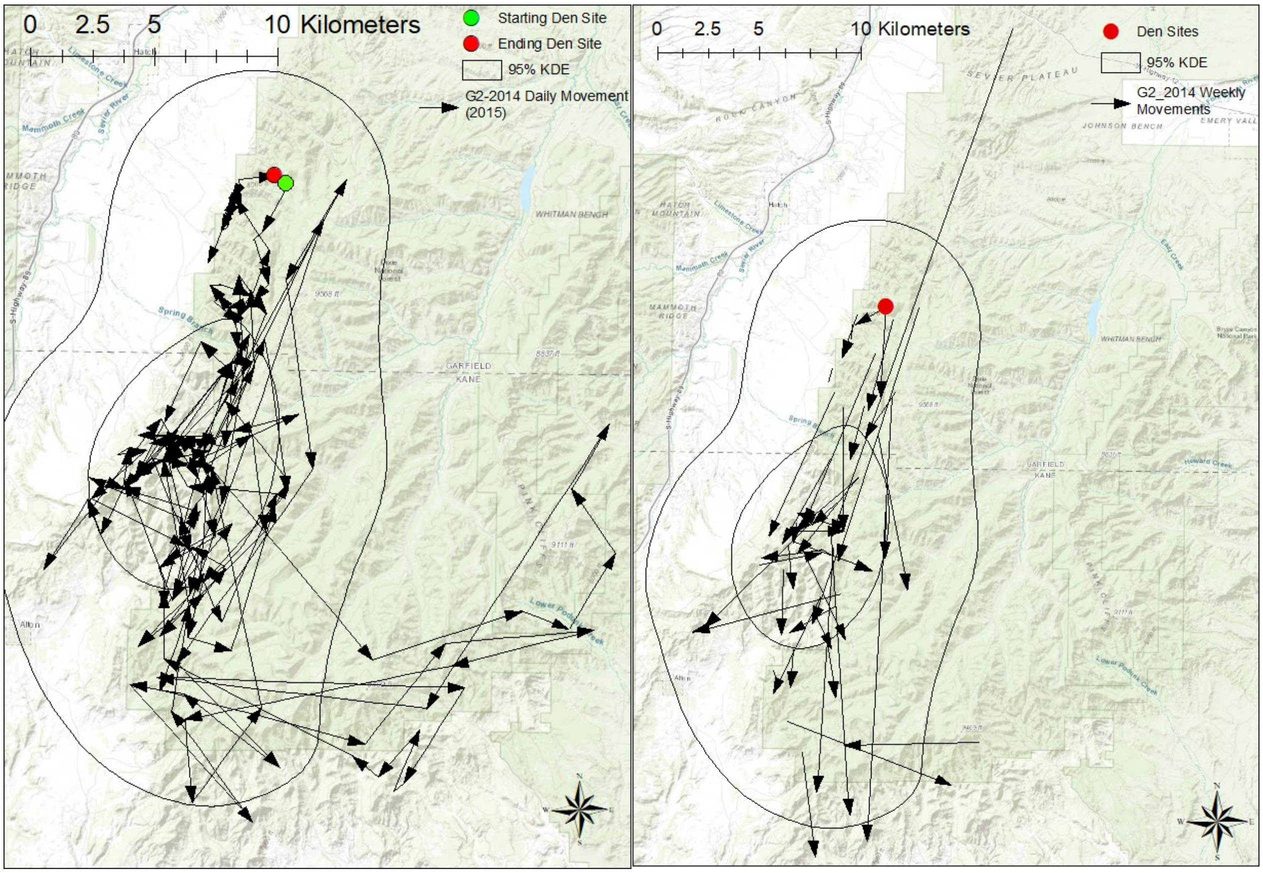

Figure 2–13: G2-2014 daily and weekly movements in relation to the appropriate den sites and the 95% KDE home range on the Paunsaugunt Plateau, UT.

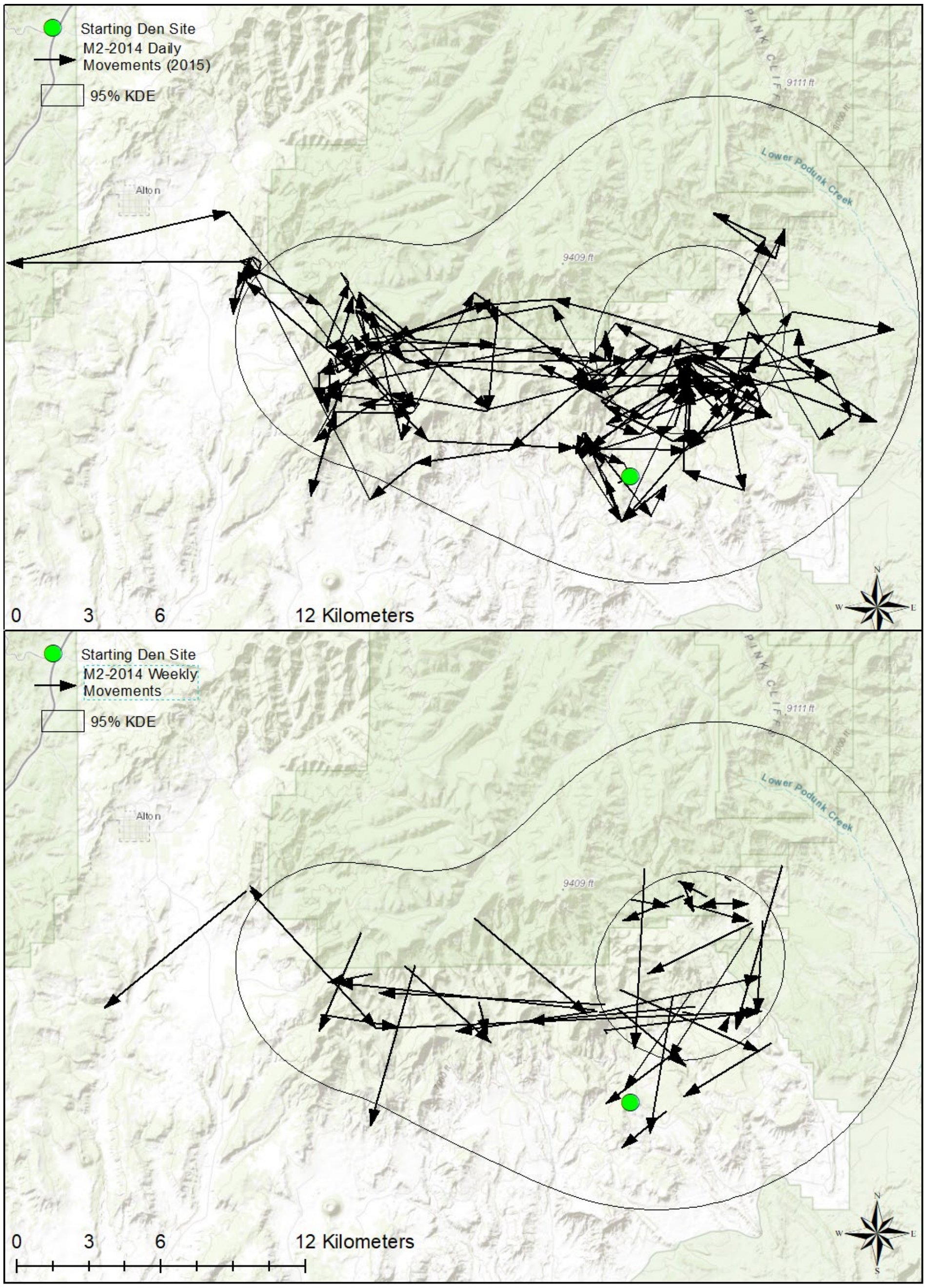

Figure 2–14: M2-2014 daily and weekly movements in relation to the appropriate den sites and the 95% KDE home range on the Paunsaugunt Plateau, UT.

TABLES

Table 2–1: A complete list of collared American black bears, sex, date of initial collar deployment and age class at time of capture on the Paunsaugunt Plateau, UT, 2014-2017.

Bear ID	Sex	Collar Deployment	Age Class
A2016	F	6/28/2016	Adult
C2014	M	6/27/2014	Yearling
C2-2014	F	7/23/2014	Adult
D2016	F	5/23/2016	Adult
G2014	M	7/9/2014	Adult
G2-2014	M	7/12/2014	Adult
H2014	M	7/10/2014	Adult
J2017	M	8/8/2017	Yearling
JG2016	M	7/13/2016	Adult
L2015	F	7/21/2015	Yearling
M2014	F	8/9/2014	Adult
M2-2014	F	8/10/2014	Adult
P2014	F	7/30/2014	Adult
S2017	F	7/9/2017	Yearling
T2017	F	7/9/2017	Yearling
T2-2017	F	8/2/2017	Yearling
V2016	F	5/9/2016	Adult

Table 2–2: The average distance moved weekly by American black bears on the Paunsaugunt Plateau, UT, 2014-2017.

	Male (km)	Female (km)	Mating (km)	Hyperphagia (km)	Annual (km)
Means	4.92	4.25	4.31	4.64	4.49
S.E.	3.34	2.24	2.50	2.74	1.88
St. Dev	4.56	4.15	3.88	4.65	4..32

Table 2–3: T-test results from comparing the weekly average distances traveled by American black bears on the Paunsaugunt Plateau, UT, 2014-2017 for the categories listed.

	Mate vs Hyp	Mate vs Annual	Hyp vs Annual	M vs F Mate	M vs F Hyp	M vs F Annual
D. F.	16	16	16	16	16	16
P - value	0.245	0.337	0.376	0.435	0.140	0.371

Table 2–4: The average distance moved daily by a subset of our samples of American black bears on the Paunsaugunt Plateau, UT, 2014-2017.

	Male (km)	Female (km)	Hyperphagia (km)	Mating (km)	Annual (km)
Means	2.64	1.84	2.03	2.16	2.11
S. E.	0.11	0.05	0.91	0.64	0.53
St. Dev.	2.72	1.70	2.26	2.07	2.15

Table 2–5: T-test results from comparing the daily average distances traveled by a subset of our sample of American black bears on the Paunsaugunt Plateau, UT, 2014-2017 for the categories listed.

	Mate vs Hyp	Mate vs Annual	Hyp vs Annual	M vs F Mate	M vs F Hyp	M vs F Annual
D. F.	14	22	22	16	6	14
P - value	0.329	0.400	0.392	0.435	0.225	0.028

Table 2–6: Directional counts and percentages for total weeks for American black bears on the Paunsaugunt Plateau, UT, 2014-2017.

Direction	Mating	Mating %	Hyperphagia	Hyperphagia %	Annual	Annual %
N	8	3.31	13	4.50	21	3.95
NE	17	7.02	15	5.19	32	6.03
E	20	8.26	24	8.30	44	8.29
SE	38	15.70	50	17.30	88	16.57
S	62	25.62	102	35.29	164	30.89
SW	58	23.97	59	20.42	117	22.03
W	23	9.50	22	7.61	45	8.47
NW	16	6.61	4	1.38	20	3.77
Totals	242		289		531	

APPENDICES

Appendix 2–1: A complete list of baits used on the Paunsaugunt Plateau, Utah, during the 2017-trapping season. Baits in gray indicate use in trigger bags.

Anise Oil
Bacon - cooked
Bacon - raw
Bear Spray
Bread - moldy
Candied Fruit - assorted
Cantaloupe
Cat Food - canned, assorted
Cooking Oil - used
Corn Cobs - boiled and buttered
Doughnuts - assorted
Doughnuts - Hostess coconut crunch
Enchilada filling
French Fries - cooked, old
Ham - moldy
Ham Hocks - uncooked
Hamburgers - cooked, old
Hard Candy - assorted
Honey
Honeybuns
Licorice Ropes
Loganberry Oil
Marshmallow Jet Puff
Marshmallows
Meat - raw, rotting
Melons - unknown, assorted
Milk - sour, clotted
Peaches
Peanut Butter
Peanut Butter Cookies
Peppermint Oil
Potatoes - rotting
Sardines - canned in oil
Sharp Cheddar
Spearmint Oil
Squash - unknown, assorted, rotting
Strawberries
Strawberry Licorice Ropes
Strawberry Shortcakes - Lil Debbie
Tuna - canned in oil
Vanilla frosting
Vegetables - assorted, rotting
Watermelon

Appendix 2–2: An example of our Xylazine administration drug log. This is not a comprehensive log. All drugs and logs were accounted for and turned in to the University veterinarian.

Xylazine Administration Log (Protocol 16-0201)

Concentration: 100mg/ml   Volume: 50ml

Date	Vial Number	Description (Animal ID)	Beginning Amount	Amount Given	Balance Left	Initials
6/9/2017	3	Black Bear	50ml	1.6ml	48.4ml	RACD
6/11/2017	3	Black Bear	48.4ml	1ml	47.4m	RACD
6/21/2017	3	Black Bear	47.4ml	2ml	45.4ml	RACD
6/21/2017	3	Black Bear	45.4ml	2ml	43.4ml	RACD
7/9//2017	4*	Black Bear	50ml	1ml	49ml	RACD
7/9/2017	4*	Black Bear	49ml	1.25ml	47.75ml	RACD
		*Vial #3 expired & Utah state wildlife Veterinarian Annette Roug took vial #3				

Appendix 2–3: An example of our Ketamine administration log. All drug logs recorded in situ were typed up and recorded neatly. All drugs and logs were accounted for and turned in to the University veterinarian.

Ketamine Administration Log (Protocol 16-0201)

Concentration: 100mg/ml Volume: 5ml Total: 500mg

Date	Vial Number	Description (Animal ID)	Beginning Amount	Amount Given	Balance Left	Initials
6/9/2017	26	Black Bear	5ml	3.25ml	1.75ml	RACD
6/11/2017	26	Black Bear	1.75ml	1.75ml	0	RACD
----------	27	--------------------------	5ml	.25ml	4.25ml	RACD
6/21/2017	27	Black Bear	4.25ml	4.25ml	0	RACD
6/21/2017	28	Black Bear	5ml	4ml	1ml	RACD
7/9/2017	28	Black Bear	1ml	1ml	0	RACD
7/9/2017	29	Black Bear	5ml	1.25ml	3.75ml	RACD

Appendix 2–4: An example of our in situ data sheet. Each bear has its own sheet. Drug information was taken from these sheets and typed into a drug log. Ear tags were often cut into unique shapes to help differentiate bears. These unique shapes and other identifying features were noted.

CHEMICAL IMMOBILIZATION FIELD FORM

Date:________________

Species:______________ Animal ID:______________ Personnel:_______________________________

Location:_____________________ Ambient Temp(F):___ Cloud Cover (%)___ Bait Type:______________

Drugs Administered	Amount(mg)	Time(24 hours)	Notes
1			
2			
3			
4			

Reaction Time
Head Down ______
Unresponsive ______
Relaxed ______
Responsive ______
Head Up ______
Walked/Ran ______
Other_____________

Physical
Body Condition: Poor( ) Fair( ) Good( ) Excellent( )
Weight(lbs): Estimate_______ Actual_________
Gender: Male( ) Female( )
Mouth Examined( )___________________
Markings/Color:______________________________
Scars/Injuries:______________________________
Length(cm)___________ Chest(cm)___________

Procedures
Hair Sample( )
Tooth Remove( )
Ear Tag( )__________
Collar( )#__________
Photographed( )
Blood Sample( )
Fecal Sample( )

VITAL SIGNS

Resp/Min	Time	Temp(F)	Time	Pulse/Min	Time	Oxygen	Time

Other Notes/Observations: