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Human-Bear Interactions Among Black Bears in Bryce Canyon National Park, Utah, and Polar Bears on Alaska's North Slope

Wesley G. Larson

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

Tom S. Smith, Chair
Randy Larsen
Mark Jackson

Department of Plant and Wildlife Sciences

Brigham Young University

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ABSTRACT

Human-Bear Interactions Among Black Bears in Bryce Canyon National Park, Utah, and Polar Bears on Alaska's North Slope

Wesley G. Larson
Department of Plant and Wildlife Sciences, BYU
Master of Science

Human-bear interactions are an important consideration of bear biology, as interactions can lead to destruction of property as well as injury or death for both human and bear. Successful analysis of why these interactions occur can lead to appropriate preventative measures and mitigation of further conflict. Bryce Canyon National Park (BRCA) is comprised of relatively poor bear habitat, but a black bear population exists on the Paunsaugunt Plateau, on which the park occupies the eastern edge. Park managers expressed interest in learning more about bear movements and, specifically, bear use of anthropogenic features following a number of human-bear incidents located at backcountry campsites within park boundaries. By analyzing data from GPS radio-collared bears, trail cameras, existing literature, park incident reports and in-depth campsite assessments, we were able to show how bears are using both natural and anthropogenic features on the Bryce landscape. Campsites were assessed for bear habitat, displacement and encounter potential in order to establish an overall human-bear conflict potential. AIC model selection and resource selection functions using GPS collar data showed that bears selected for some anthropogenic features (campsites, springs), while actively avoiding others (trails, roads). Trail camera data, existing literature and park incident reports all pointed toward use of trails. We then considered all data sources used in the analysis and compiled rankings of human-bear conflict potential for each of the backcountry campsites within BRCA, and submitted a detailed report of findings, conclusions and recommendations to NPS personnel.

Second, we investigated human-bear interactions at polar bear dens sites on Alaska's North Slope. As parturient female polar bears in the Southern Beaufort Sea subpopulation increasingly construct maternal dens on coastal land features rather than sea ice, they become more likely to interact with industry and other human activity. We wanted to understand what levels of human interaction could lead to disturbance of denning polar bears, and what types of responses were being exhibited by bears following those interactions. We subdivided potential disturbance stimuli into groups based on their size, motion and sound and the used AIC model selection techniques and multinomial logistic regression to analyze records of human-bear interactions at den sites ranging from 1975 through the present day. We found significant probabilities of varying levels of bear disturbance response among a number of stimuli and intensities. However, denning bear families were overall more tolerant of human activity near den sites than expected. Den abandonments were rare, and we documented no cases of reproductive failure following a disturbance event. We hope that our results from the analysis can be used to further enhance management of industry when operating in polar bear denning habitat.

Keywords: Alaska, anthropogenic stressors, black bears, Bryce Canyon National Park, campsite assessment, human-bear conflict, polar bears, *Ursus americanus*, *Ursus maritimus*

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Most of all I want to thank my family who has been patient with me and my obsession with all things wild since I was a toddler. I love them and am grateful for everything they do.

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CHAPTER 1

Black Bear Activity at Backcountry Campsites in Bryce Canyon National Park, Utah

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ABSTRACT

A number of efforts in recent years have sought to predict bear activity in a diversity of habitats to minimize human disturbance and human-bear conflicts. The Paunsaugunt Plateau, including Bryce Canyon National Park (BRCA), provides important habitat for black bears (*Ursus americanus*) in Southern Utah. BRCA has 12 backcountry campsites and park officials can effectively manage these areas to minimize human-bear conflict when they know more about black bear use of these campsites and other anthropogenic features in the park. This study provides insight regarding the nature and frequency of bear activity within BRCA, with an emphasis on bear-campsite relationships. We attained a clearer understanding of bear-habitat relationships within the park by analyzing bear activity data through radio-collaring bears, remote camera monitoring of areas of interest, campsite assessments, and analysis of human-bear interaction reports. Each backcountry campsite was assessed with regard to its bear habitat quality, bear displacement potential, and human-bear conflict potential. Although not all of our radio-tagged bears visited campsites, agreement among measures of activity (e.g., radio-tagged locations, camera data, etc.) lends support to our qualitative site assessments. We found that radio-collared bears selected several anthropogenic features (campsites and springs), while actively avoiding others (trails and roads). Remote camera images, BRCA Case Incident Reports, and an extensive literature review documented trail use among black bears. We completed assessments for each campsite and ranked them from low to high according to three

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site assessment criteria. Finally, we offer recommendations that can be used to minimize the likelihood of human-bear interactions at BRCA backcountry sites.

INTRODUCTION

The Paunsaugunt Plateau in Southern Utah provides habitat for black bears (*Ursus americanus*). BRCA is comprised of 14,502 hectares (35,835 acres, 56 square miles), and occupies the eastern edge of the plateau and contains large areas of black bear habitat (Figure 1). Given both the mandate to interpret the natural environment to the public and provide for the protection of nature (National Park Service Organic Act 1916), the National Park Service (NPS) has a stake in better understanding black bear use within BRCA. Due to the steep escarpment for which BRCA is renowned, backcountry campsites are mostly located in forested canyon bottoms. These areas include topography that restricts and funnels bear movements, as well as contain extensive areas of bear forage species. Consequently, backcountry campers are much more likely to observe and encounter bears than most visitors high on Bryce's rims. Potentially dangerous bear encounters (involving contact or property destruction) periodically occur in BRCA (BRCA Case Incident Reports). Therefore, to minimize human-bear conflict, park officials will benefit from information regarding bear habitat use, as well as bear use of anthropogenic park features (trails, roadways, campsites), as they strive to enhance visitor safety as well as to reduce disturbance to bears. This report provides our findings from research conducted from 2014—2016.

The primary objective of this study was to gain insight regarding bear-habitat relationships in BRCA, including both natural and anthropogenic features. Insuring visitor safety is important to the NPS, so we conducted thorough assessments for each backcountry

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campsite. Site assessments provide an estimate of human-bear conflict potential through both qualitative and quantitative measurements taken at each location. Our approach was to assess each of the 12 backcountry campsites from three perspectives: bear habitat potential, bear displacement potential, and bear encounter potential. Each assessment enabled us to make informed recommendations for each campsite, as well as broad recommendations to reduce the risk of human-bear conflict in BRCA. In addition to campsite assessments, an increased understanding of bear-habitat relationships in the BRCA area provides important information for managers. The national park system is designed to provide a wilderness experience for visitors while preserving wildlife habitat, and the proper placement and management of campsites is important for achieving that goal in BRCA.

Bear habitat potential is an essential element of our site assessment protocols. While bears can be encountered nearly anywhere in the park, it is much more likely to occur in areas where bears are attracted to foraging opportunities. Research has indicated that Utah black bears select vegetation and insects as mainstays in their diet, whereas mammal predation occurs opportunistically (Bates et al. 1991). Therefore, bear foraging areas should be avoided, as possible, when selecting campsite locations.

The nutritional status of black bears, particularly females, affects population productivity (Samson and Huot 1995, Hilderbrand et al. 1999). Consequently, seasonal differences in bear habitat use generally track the temporal-spatial variation in nutrient availability. There are several ways to evaluate bear habitat quality (MacHutcheon and Wellwood 2003), and hence estimate a given location's bear encounter potential. The assumption underlying these methods is that as habitat quality increases, bear use increases, as does the probability of human-bear encounters. Although qualitative measures may prove appropriate for evaluating bear use

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patterns, they have yet to be compared to actual bear activity data to test their predictive effectiveness.

Quantitative habitat assessment has also been used to evaluate bear-habitat relationships (Hamilton and Bunnell 1987, Tredick et al. 2016). These quantitative efforts can be useful for monitoring habitat selection and the activity of individual animals, but may not directly reflect activity patterns on a population level. Habitat selection, particularly among females, varies as a function of an individual bear's age/sex cohort. A female's reproductive status, as well as other factors such as the presence of other bears and the variable quality and quantity of forage across habitats, also influences habitat selection (Weilgus and Bunnell 1994, Weilgus and Bunnell 2000). For example, females may forgo optimal foraging opportunities in an effort to protect offspring by avoiding other bears. During a 2-year study in Kenai Fjords National Park, black bear females with dependent offspring were encountered in beach habitats only twice in areas with high black bear densities (Smith et al. 2012). Interspecific interactions can also effect bear habitat use, such as when black bears alter activity patterns when sympatric with grizzly bears (Holm et al. 1999, Jacoby et al. 1999). Given the complex nature of bear-habitat relationships, monitoring productive areas for overall bear use can provide valuable insight in addition to using individual animals whose habitat selection may be highly variable between years. This habitat-centric approach also aligns more fully with current information needs as management activities are generally focused on specific sites and not on individual animals. Regardless, we have included results from individually monitored animals, as well as data from areas that we assessed for their overall bear use.

Clearly, an understanding of bear habitat use patterns can be used to reduce risks associated with camping in bear habitat. Due to the relatively low densities and the cryptic

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nature of bears, remote trail cameras have proven to be a valuable tool for documenting bear activity (Mace et al. 1994, MacHutchon et al. 1998). Trail cameras triggered by movement can provide a crude index of overall use and activity rates (Anderson et al. 2015). Besides trails, other landscape features may affect bear use. For example, foraging areas, travel corridors, topography and human activity levels influence levels of bear activity in a given area.

Bear displacement potential protocols estimate the likelihood of bears being displaced by visitors in the campsite under evaluation. A campsite located in an area that represents productive habitat, a movement corridor, or a reliable water source is likely to have a higher than average amount of bear use when not occupied by people, and those individuals may be displaced when such campsites are occupied.

Bear encounter potential protocols estimate the risk of surprise encounters with bears in campsite areas. Site visibility, topography, ambient noise levels and proximity to bear movement corridors are factors that contribute to the likelihood of human-bear encounters. A surprise encounter with a black bear may put humans within the overt reaction distance of the animal and lead to defensive-aggressive behaviors (Herrero et al. 2011). These defensive-aggressive behaviors rarely lead to physical contact and injury with humans, but could be mistaken for aggression by visitors and lead to inappropriate responses, such as dispatching the bear with a firearm. While extremely rare, a predatory black bear can also use cover to stalk human prey (Herrero 2002), and understanding the encounter potential is important for avoiding conflict.

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RESEARCH OBJECTIVES

The primary objective of our study was to determine the degree to which abiotic and biotic characteristics at campsites are predictive of bear activity. We addressed this research objective through accessing and analyzing six activities:

1. Identification of bear movement and habitat use of the BRCA study area through the capture and radio-tagging of black bears.
2. Photo-trapping of bear use of BRCA trails and spring/seep sites.
3. Analysis of NPS Case Incident Reports that involved human-bear conflicts within BRCA.
4. Assessment of backcountry campsites with respect to their bear habitat potential, bear displacement potential, and bear-encounter potential.
5. Evaluation of previously closed campsites due to repeated bear sightings and negative human-bear interactions.
6. Review of published (peer-reviewed) literature regarding bear use of trails and campsite features.

METHODS

Bear Capture and Radio-tagging

Black bear trapping started 12 June 2014 and continued through July 2015. We did not attempt any trapping efforts from the months of September-May. Trapping was conducted in an area approximately 10 km by 16 km (6 mi by 10 mi) on the southern end of the Paunsaugunt Plateau. No trapping was conducted within Bryce Canyon National Park. We used barrel traps (also known as culvert traps, Figure 2) in both years. We chose trap locations based on their proximity to water, forage resources, and likely bear movement corridors. We transported traps

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with a 4WD pickup truck and then hand-carried them to pre-selected sites that were at least 20 meters from the road. We secured traps to trees using 14-gauge wire so that trapped bears could not roll them over and inadvertently cause the gate to open. Initially, we baited traps according to procedures reported by Black et al. (2004). We placed a layer of soil in the bottom of each trap to soak up any urine or feces, then baited traps with raw meat that had been aged for > 1 wk in a steel 208 liter (55 gallon) drum. Bears were captured when a trigger opposite the entry point was pulled by the bear, thus causing the steel gate to drop at the other end. To entice bears to pull triggers, we loaded small plastic mesh bags with red licorice and gumballs. To attract bears to our trap sites, we hung from a tree a 12 cm by 12 cm carpet square, doped with either anise oil, banana oil, or loganberry oil. We placed traps in areas that had shade to protect bears from hyperthermia. We placed warning signs on nearby trees (within 20 meters of the trap) to caution recreationists in the area. Model PC900 Reconyx® motion-activated trail cameras captured movement around the trap site. This provided information regarding bear activity in and around our trap sites that helped us fine-tune capture protocols.

We began checking baited traps at 9:00 AM daily. Once captured, bears were sedated with a combination of ketamine hydrochloride (100mg/1ml) and xylazine hydrochloride (100mg/1ml). We estimated the weight of the animal and administered ketamine hydrochloride at a dosage of 4 mg/kg (2 cc per 45.4 kg (100 lbs)) 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 ports located on either end of the barrel trap. Once immobilized, we removed bears from the trap, placed them in the shade and provided eye protection. Throughout the immobilization process, we monitored respiration, heart rate and body temperature. We fitted bears with ATS® Iridium GPS collars, and programmed collars to collect locational data every four hours

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throughout the day. Additionally, ambient temperature is transmitted with each location upload and is accurate to ±2 degrees Celsius. Activity sensors report the percentage of time that tilt switch movement was detected since the last GPS fix attempt, or during a 15-minute period prior to the GPS fix.

As needed, we were able to alter the locational sampling rate remotely via satellite link. Additionally, collars were configured to allow us to remotely drop a collar. For example, if a bear wandered beyond our study area boundaries and established a new home range outside of the area of interest we might choose to drop and retrieve the collar for reuse. We weighed bears using methods established by LeCount (1986), and placed an ear tag in the right ear, with the only exception being bears that were previously handled by the Utah Division of Wildlife Resources (UDWR). We assigned each bear a unique 6-digit identifier that represented the serial number of their respective GPS collar. Upon completion of all handling procedures, we placed bears sternally recumbent in the shade to recover, which normally took 10-15 minutes before bears were up and mobile once again.

Typically, radio-collars were programmed to transmit bears' locations every four hours. We considered a bear "denned" when four or more successive points were found in the same location following the first week of November. Denning was also inferred if only one point was transmitted in November, with no more successive points for at least two weeks. We remotely altered positional fix rates to one per 72 hours during the denning period to extend the collar's battery life.

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GIS Analysis

Bear locations were downloaded into ArcMap® 10.3 for spatial analysis. For this report, we included locations from June 2014 to November 2015. Using the minimum convex polygon tool in ArcGIS®, we calculated the home range for each bear, then combined all home ranges to define a study area for analysis. However, for the purposes of this report, we restricted the study area to only include the 14,502 ha (35,835 ac, 56 mi^2) that exist within the borders of BRCA. Elevation, slope and aspect values were extracted for each bear's locations using digital elevation models (DEM) provided by the United States Geological Survey (USGS). A DEM consists of 10 x 10 m grid cells with 1 m vertical accuracy. We used the ArcMap® "near" tool to establish the distance of each bear location to the nearest spring, stream, trail, road and campsite. We intersected bear relocations with State of Utah vegetation maps, and their corresponding vegetation types and extracted those values. Using the random point generator in ArcGIS®, we created random points that were intersected with study area attributes (i.e., elevation, slope, aspect, vegetation, and distance to springs, streams, roads, trails and campsites). We selected the number of random points (n = 12,136) using the following steps. First, we calculated true averages for the elevation, slope, and aspect for each pixel within the study area. We then added varying quantities of random points and averaged the same values for each of those points. Once averages for random points fell within a 95% confidence interval of the true averages for each pixel, we felt we had an appropriate number of random points. The resulting points, both random and actual, and their associated features, were exported to Microsoft Excel®, reformatted and analyzed in Program R (R Development Core Team 2008). We used model selection and analysis to determine which habitat types were selected, for and against, by bears. We also determined bear responses to a variety of anthropomorphic features (e.g., trails and

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campsites). We employed second-order model selection, as it addresses the study population (i.e. bears within BRCA). First order selection can be used to gain insight into the entire population of black bears, and third order selection is used to analyze individual animals. We used mixed effects logistic regression, and model candidates were compared using the Akaike Information Criterion selection, adjusted for small sample size in program R (AIC_C; Akaike 1973). Due to small sample size, we did not include interactions between variables (Peduzzi et al. 1996). Following model selection, statistically significant variables within the top models were individually analyzed to determine how they influenced the movements and behavior of bears within the study area.

Remote Camera Trapping

Due to the relatively low densities and the cryptic nature of bears, trail camera photography has proven to be a valuable tool for documenting bear activity (Mace et al. 1994, MacHutchon et al. 1998, Steenweg et al. 2015, Miller et al. 2016). Trail cameras set to capture photos when sensing motion can provide a measure of overall use and activity rates. For this study, we incorporated the findings from two recent studies of wildlife use of trails and springs in BRCA (Wait et al. 2013 and Anderson et al. 2015). Remotely captured images from these studies provide supporting evidence that black bears periodically use BRCA trails, springs and other features that were of interest in our assessment.

Campsite Assessments

Using methods developed by Partridge et al. (2009) and MacHutchon et al. (2003), we assessed backcountry campsites in BRCA for their bear habitat potential, bear displacement

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potential and bear encounter potentials. We conducted these assessments for all 12 backcountry campsites within the park (see Appendix 1). Complete protocols are presented in Appendix 2, and completed data sheets can be found in Appendix 3.

Human-Bear Case Incident Reports

We reviewed BRCA Case Incident Reports (CIR) for information related to aggressive backcountry bear encounters. We also included bear sightings that occurred within 100 meters (328 feet) of a campsite or on a major trail corridor. Data from these reports had been previously entered in a human-bear conflicts database (Miller et al. 2016). We included this information to determine where and when bear incidents have occurred in the park, and what factors might have contributed to them.

Literature Review

We conducted a thorough review of the scientific literature to learn about black bear use of trails and other anthropogenic features that exist on the landscape in BRCA. This review was performed with assistance from the Life Sciences Librarian (Dr. M. Goates) at Brigham Young University.

RESULTS

Bear Radio-Tagging

We trapped bears for 72 days in 2014 and for only six days in 2015. To enhance trap success rates, we modified the Black et al. (2004) protocol so that trigger bags contained a combination of pastries (strawberry shortcake and donuts), cooked bacon, honey and gumballs.

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This combination proved to be more effective than the previously recommended use of black licorice and gumballs. In addition, we found banana oil to be an ineffective attractant and discontinued its use. During the summer of 2014, we trapped at 35 different sites, captured 17 black bears, collared 10 different individuals, including six females and four males. Trapping efforts in 2015 added a single female bear to the study. Bears experienced no complications from immobilizations during trapping. Unfortunately, Bear #033300 removed her collar within one day of trapping. Bear #033297 was harvested by a hunter during the summer of 2015. In addition, bear #033299 left the study area to the Mount Dutton area to the north of Highway 12. As such, we have included locations from nine individual bears in our analysis, but sampling timeframes vary among individuals. Four-hour intervals remained the standard for our GPS data collection.

Model Selection and Analysis

Modeling using AIC returned two fixed-effects models that accounted for 83.3% of the cumulative model weight, with that weight being nearly equally distributed between the two models, so we used both in our analyses. Model weight represents the probability that model x is the best-fit model among those being considered. These top models identified several habitat features relevant to black bear habitat selection, including campsites, springs, trails, roads, and several vegetation types. We found that some of these variables were positively correlated with bear use (e.g. campsites, springs, specific vegetation types), whereas the remainder were negatively correlated (e.g. trails and roads). Results from model selection have been grouped into Table 1, showing the top two models ($w_i > 0.40$) which illustrate how bears actively selected for, or against, different resources and features in BRCA. Within our model analysis,

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relationships between bears and campsites (camp), springs (spring), trails (trail), roads (road) proved to be statistically significant (p-value < 0.05) when showing either selection or avoidance by collared black bears. In addition, six of the vegetation classes analyzed (veg) were selected for. Relationships between bears and these features (e.g., campsites, trails, roads and springs) are presented in Figure 3.

Analysis shows that bears selected campsites and springs while avoiding roads and trails. Graphs presented in Figure 3 indicate the probability of bears occurring at a given distance from the feature of interest. For example, for the graph displaying bear-campsite relationships (graph in the upper right), radio-collared bears have a 92% probability visiting campsites at some point during the sampling period.

GIS Analysis

The *Rocky Mountain Gambel Oak-Mixed Montane Shrubland* (RMGO) habitat type was the most widely associated with bear GPS fix locations, with bear relocations occurring 56% of the time in that habitat type. The RMGO habitat type represents only 3% of total available habitat in BRCA. The *Rocky Mountain Ponderosa Pine Woodland* (RMPP) habitat type was the second-most widely utilized habitat, with bear relocations occurring 32% of the time in RMPP habitat. The *Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland* (RMMM) was utilized 5% of the time. *Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex* (IMWA) was used approximately 1.8% of the time in relocations. *Rocky Mountain Cliff and Canyon* (RMCC) was used 1.6% of the time in relocations. *Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland* (RMSD) and *Rocky Mountain Lower Montane Riparian Woodland and Shrubland* (RMLM) were both used during 1.4% of the time. Several

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other habitat types were also used by bears, but for short enough durations so as to account for less than 1.0% of overall fix locations, and these included *Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland* (RMSM), *Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland* (RMMD), and *Colorado Plateau Pinyon-Juniper Woodland* (CPPJ). Bear locations for each habitat type within BRCA are presented in Figure 4. The vegetation composition of BRCA is presented in Table 2. Finally, Table 3 presents habitat types that were associated with the top two models.

Remote Camera Trapping

A review of BRCA's catalog of images collected by Wait et al. (Wait et al. 2013) and Anderson et al. (Anderson et al. 2015), identified 15 instances of black bears using either trails or springs within the park.

Campsite Assessments

We visited BRCA's 12 backcountry campsites and assessed them with respect to bear habitat potential, bear displacement potential, and bear encounter potential according to protocols found in Appendix 2. Results from the assessments are presented in Table 4. Generally, Ponderosa Pine/Gambel Oak (*Pinus ponderosa/Quercus gambelii)*, Ponderosa Pine/Greenleaf Manzanita (*Pinus ponderosa/Arctostaphylos patula)* and Ponderosa Pine/Bitterbrush *(Pinus ponderosa/Purshia tridentate)* were the three main habitat types encountered in campsites by the survey crew. While Ponderosa Pine was the most prevalent conifer at campsites, Utah Juniper *(Juniperus osteosperma)* and Rocky Mountain Juniper *(Juniperus scopulorum)* were also often present.

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Through the campsite assessment process, we documented a wide variety of forages used seasonally by black bears. We present those forages in Table 5 and a complete list of potential bear forage items in BRCA can be located in Appendix 5.

We encountered minimal bear sign (tracks, rubs, scratch marks, scat, foraged vegetation and insect removal from trees or logs) during campground assessments. However, some sign was observed, such as where bears tore logs apart for ants, scats and tracks. The small amount of sign we encountered is likely due to a combination of factors including heavily used hiking trails, loose sandy soil which poorly preserves tracks, and a low-density bear population. Additionally, we visited each campsite just once, whereas repeated visits would likely identify more sign.

Human-Bear Case Incident Reports

We examined all CIR on file at the park and list relevant human-bear incidents in Table 6. The majority of bear encounters reported occurred at along Sheep Creek (n = 7), near Riggs Springs (n = 4), and along Yellow Creek (n = 2). Other than these observations, a few additional encounters were reported to officials but lacked sufficient information for inclusion in this report.

Literature Review

Our review of scientific publications pertaining to bear use of, and association with, anthropogenic features, (specifically trails, roads and campsites) yielded 473 peer reviewed scientific articles. We further delimited search results by eliminating publications that did not have information specifically relevant to our interests. The remaining 39 publications provided

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useful insight regarding bear ecology, as well as bear use of trails, campsites and other anthropogenic features.

DISCUSSION

Resource Selection

Model selection showed bear preference for campsites and springs and avoidance of trails and roads. Campsites in BRCA are typically located adjacent to trails (< 10 m), often close (< 100 m) to water sources, and in canyon bottoms that contain higher amounts of vegetation and bear forage items. While these features make campsites appealing to visitors, they are also attractive to bears and other wildlife. Therefore, it is likely that bears are not specifically selecting campsites as indicated by our models (Figure 3, upper right graph), but rather are selecting for the areas in which campsites occur. The exception to this would be when a bear has encountered human food in a campsite and has associated the location with the food reward, a phenomenon referred to as food conditioning (Herrero 2002). The strong relationship between radio-collared bears and campsites could possibly be attributed to food-conditioning. Third order selection analysis, or analysis of individual animals rather than study populations, would be necessary to learn if individuals among the study population had higher campsite visitation rates due to food-conditioning.

Bears in the study population also showed strong selection for spring locations. This is expected as water sources are scarce in BRCA and springs provide a reliable source of water throughout the year. The close proximity of springs to several campsites (n = 4) may also explain why bear selection for springs and campsites follows the same response curve (Figure 3, upper left graph). As such, wildlife managers in BRCA should expect to have higher levels of bear activity in areas that include reliable sources of water.

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While model results showed that bears avoid trails (Figure 3), bear use of trails in the Park has been documented. As predictable thoroughfares of human activity, bears can be expected to avoid trails, yet they will use them opportunistically, particularly during lulls in human activity (e.g., dawn, dusk, nighttime; Costello et al. 2013). Camera imagery, incident reports and literature review all indicate that trail use occurs in black bears populations, as trails pose an obstacle-free movement corridor (Mattson et al. 1987, Coleman et al. 2013). So while bear trail use appears infrequent in BRCA, it does occur, and trails likely funnel bears into campsites where they may come in contact with park visitors, their property, and/or anthropogenic foods.

Our analysis revealed that roads were generally avoided by bears (Figure 3, bottom left graph). The road network in BRCA is not extensive but sustains steady vehicular traffic throughout the day. It is well documented that bears avoid roadways (Kasworm and Manley 1990, Gibeau et al. 2002), and there is no reason to expect otherwise at BRCA. Consequently, roadside sightings of bears at BRCA are extremely rare (C. Anderson, personal communications, BRCA biologist).

RMGO habitat was the most frequented habitat type by bears. Within this habitat type, Gambell's Oak and other co-dominant species are important food sources for bears, especially in the late summer and early fall (Bates 1991). Model analysis revealed a strong preference for this habitat type and published literature indicates that bears prefer RMGO due to the numerous food species found therein (Bunnell 2000). Secondly, RMPP was also frequently used by bears. While bears seek forage items within this habitat type, it may also be that bears utilize RMPP habitat for resting cover, as day beds were often observed adjacent to large Ponderosa Pines,

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which periodically function as escape terrain for bears. It has been observed in Utah's Book Cliffs that bears occasionally den at the base of large trees, presumably as escape cover from potential predators (H. Black personal communications, BYU biologist).

Campsite assessments, as well as analysis of bear fix locations, provided a sample of potential bear forages throughout the study area. Although there is relatively little variation in the gross energy and crude protein content of most above ground vegetation, other plant components (e.g., nuts, berries, seeds) change throughout the year and have a substantial effect on the overall nutritional value (Partridge et al. 2001). The overall nutritional value of a plant for bears depends on its size, phenology and the nutritional values of its individual components. While most plants increase in size through the growing season, which can increase the intake rate per plant for bears, the fiber content also increases, which reduces digestibility and decreases the overall nutritional value. Flowers are generally low in fiber and are highly digestible, while seeds are high in fiber but also high in digestible protein, fats and carbohydrates. The stems and stalks of plants are generally more digestible early in the season when less fiber is required to support the plant, while roots and tubers can be high in energy early in the season before energy stores are mobilized for growing, and high late in the season when energy is being stored for the next growing season. Berry producing shrubs and plants can achieve high fruit densities and provide higher intake rates for bears, but due to the low protein content of most fruits, bears must continue to consume food items with higher levels of digestible protein (Welch et al. 1997, Rode et al. 2000). Berries that contain oils, such as juniper and elderberry, have higher gross energy content and are sought after by bears (Partridge et al. 2001).

Meat sources, such as ungulates, can be an important source of nutrition for bears (Bates 1991, Mattson 1997, Hilderbrand et al.1999, Jacoby et al. 1999). Other potential sources of

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animal protein include insects, such as bees (*Apis spp)*, wasps (*Vespinae spp)*, and ants (*Formica spp)* (Auger et al. 2004). Research beyond Utah indicates that where large insect colonies exist, bears can achieve high intake rates (Noyce et al. 1997, White et al. 1998), and that they actively seek them.

Third-order selection for statistical analysis may be a more effective way to investigate resource selection in BRCA bears. In this study, however, we used second-order selection to understand habitat use among bears that frequent the park. However, small sample sizes are often better candidates for third-order analysis which shows resource selection trends among individual animals rather than the study population as a whole. This is because individuals may vary widely in their use of specific habitat components; something lost when doing second order analyses.

Remote Camera Data

Twenty-four trail camera images of black bears in BRCA were recorded by Wait et al (2013) and Anderson et al (2015). Of those images, we identified 15 photos of bears using both trails and water resources within the park. Camera traps placed in 2013 by researchers from Colorado State University and park staff recorded four bears using trails and six bears accessing springs. In 2015, a similar effort by NPS staff photo-captured four bears on trails and one bear at a spring (Figures 5 and 6).

Trail cameras did not record high amounts of bear activity in BRCA, thus rendering comparisons between seasons, time periods, and camera locations pointless. However, the limited quantity of camera data reflected crepuscular bear activity typical to black bears (Smith 2002).

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Campsite Assessments

Campsite assessments were an effective method for gathering and organizing information that can aid wildlife managers in making decisions that minimize human-bear conflict. During site assessments, we identified a number of modifications to existing campsites that may help minimize human-bear interactions. Foremost among these changes is the relocation of campsites farther off-trail to avoid bears using trails. Campsites that are located in close proximity to springs or streams heighten the chances of human-bear interactions as these are foci of bear activity within the BRCA landscape. Moving campsites at least 100 meters off trails and away from water sources can be expected to reduce the likelihood of human-bear interactions. The following discussion presents aspects of campsites that could be modified to decrease the potential for conflict.

Distance of Campsite from Trails

All campsites (n = 12) were located < 10 m from established trails. Although our collar data showed avoidance of trails, remote camera data, BRCA human-bear incident reports, and existing scientific literature show that bears occasionally use trails for movement (Reimchen 1998, Coleman et al. 2013), and that placing campsites close to trails directs bears into potential conflict with humans. Bears are among some of the most curious of mammals (Burghardt 1982), so it should not be surprising that when encountering a tent or other camping gear, bears investigate it with their claws and teeth. Such activity does not represent an aggressive, but rather an inquisitive, bear. Pitching tents close to bear travel corridors, hiking trails in this instance, presents an attractive nuisance for bears, with novel sights, scents and sounds that pique their curiosity. In addition, while bear sightings and encounters are rare in BRCA, the majority

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of those reviewed in this study occurred near trails. Based on the existing literature we assume that bears likely avoid trails during high periods of human use, but use them for movement when humans are not present or less active. Therefore, it is our recommendation that campsites be > 100 m from major trails. When considering alternate campsite locations, avoiding areas of concentrated bear forage (e.g., manzanita patches, wet meadows with lush vegetation, etc.), and poor visibility (dense brush) will lower the odds of surprise encounters. Relocating campsites away from trails will also provide campers and hikers increased privacy and a more solitary wilderness experience.

Distance of Campsites from Water

Water is a limited resource in BRCA, hence radio-collared bears showed a strong selection for water. Additionally, trail cameras monitoring springs documented a variety of wildlife, including bears. While springs provide campers with a source of water for drinking, cooking, and washing, allowing people to camp nearby likely excludes wildlife. Relocating campsites away from the immediate vicinity of springs will not only reduce the likelihood of wildlife-human interactions, but also provide wildlife with unrestricted access to water. For these reasons, we recommend that campsites be no closer than 200 meters to permanent water sources.

Backcountry Camper Education

Park units with bears require campers and hikers to receive information regarding proper conduct in bear country. This information is intended to inform persons regarding food security and proper responses to bears when encountered. The NPS has extensive experience with bear

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education, and these resources should be made available to visitors to BRCA. While BRCA requires the use of bear resistant food containers, encouragement of campers carrying bear spray is also recommended (Smith et al. 2008).

Campsite Ranking by Bear Activity

Ranking of campsites based on their habitat, displacement and encounter potentials provided a useful means for evaluating potential for bear conflict. Campsites were assigned a ranking of low, moderate, or high for each assessment (Table 7).

Campsites located near perennial water sources were those that ranked highest for the likelihood of human-bear interaction. These sites included Yellow Creek, Swamp Canyon, Riggs Springs, and Iron Springs. All four of these sites are known as relatively high-use bear areas. Unfortunately, we could not address the availability of alternative foraging areas and visitor use numbers, both which influence bear use of an area. Nonetheless, this ranking should provide useful guidance when park staff consider future management actions.

Closure Areas Evaluations

One objective of this project was to evaluate campsites at Yellow Creek, Sheep Creek, Yovimpa Pass and Riggs Springs, as there have been periodic closures to camping in recent years due to human-bear interactions. The average ranking of these sites with respect to overall bear concern was moderate, based on a simplified scale (low to high), with a number of different factors being considered. Although our assessment of bear habitat potential at these sites was moderate, all had in common reliable water sources. These sites also showed signs of bear activity, including bear tracks, rub trees and other bear sign.

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Improper food storage and handling, as well as inappropriate behavior towards bears, can result in human-bear conflict that has little or nothing to do with a given campsite's condition. When visitors in bear country do not store food properly, leave food scraps in campsites, or act inappropriately when confronted with a bear, the likelihood of conflict increases. So while our subjective campsite ranking system is useful for the general assessment of human-bear interactions, proper education and appropriate human behavior is key to minimizing human-bear conflict.

CONCLUSIONS AND RECOMMENDATIONS

This study provides insight regarding the nature of bear activity at backcountry campsites within BRCA. We were able to obtain a better understanding of bear-habitat relationships within the park by radio-collaring black bears on the Paunsaugunt Plateau, tracking their movements via satellite, and by analyzing resource selection by bears, both natural and anthropogenic. Additionally, we visited each of twelve campsites to generate an assessment of bear conflict potential. Data previously collected with remote cameras, human-bear incident reports, and existing literature provided a more thorough understanding of human-bear relationships and of bear activity within the park. Although we did not specifically assess levels of bear activity at campsites, agreement among measures of activity (e.g., radio-tagged locations, remote camera data, bear sign analysis, human-bear interaction reports, etc.) lends support to our assessments and conclusions. Our work indicates that while BRCA does not have a chronic problem with human-bear conflicts and interactions, there are a few actions, if taken, which would further reduce the likelihood of human-bear interaction and conflict.

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While showing that bears only occasionally use trails and springs within the park, the colocation of campsites at or near these features unnecessarily increases the likelihood of problems. We suggest the NPS consider a few modifications to the current situation in the BRCA backcountry that may minimize human-bear interactions:

1. Relocation of campsites > 200 m from water sources. Both camera and GPS data show bear use at spring and streams, and removing campsites from those areas will decrease conflict potential between visitors and wildlife.
2. Relocation of campsites > 100 m from the main trail system. Creating this minimum distance will likely decrease the potential of bears, which occasionally use trails as movement corridors, entering campsites.
3. If not relocated, campsites with an overall conflict potential rating of moderate or high should be monitored with remote cameras. Documenting the frequency and timing of bear use could be used to either justify site relocation or seasonal closures.
4. Visitors to BRCA backcountry should receive bear safety information regarding safe conduct in bear country and should be encouraged to carry bear spray.

Implementation of these guidelines will minimize the risk of negative human-bear interaction within the park. In recent work done by T. S. Smith and S. Herrero (manuscript in review), it was shown that human-bear conflict rates in Alaska were strongly correlated with human population growth in the state. Therefore, as human activity increases in bear country, more human-bear interactions can be expected. Changes made now to decrease the potential for future conflict can help to ensure the safety of both humans and bears during this period of visitation growth.

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TABLES

Table 1-1: AIC model selection. Included is model structure, Akaike's Information Criterion adjusted for small sample size (AICc), change in AICc from the most supported model, (AICc), model weight (wi), and number of parameters (K).

Model Structure	AIC_c	ΔAIC_c	w_i	K
camp+veg+elevation +spring+ trail+road	456.4	0.0	0.43	24
slope+elevation+trail+veg+spring+camp+road+stream	456.5	0.095	0.41	26

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Table 1-2: BRCA habitat types and the overall percentage of land cover for each habitat type within BRCA.

Count	Percentage	Description
58754	36.3	Rocky Mountain Ponderosa Pine Woodland
32137	19.9	Colorado Plateau Pinyon-Juniper Woodland
29773	18.4	Rocky Mountain Cliff and Canyon
8569	5.3	Colorado Plateau Mixed Bedrock Canyon and Tableland
6940	4.3	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
6494	4.0	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
5088	3.1	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
5041	3.1	Inter-Mountain Basins Montane Sagebrush Steppe
2370	1.5	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
2155	1.3	Inter-Mountain Basins Big Sagebrush Shrubland
1572	1.0	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
901	0.6	Rocky Mountain Lower Montane Riparian Woodland and Shrubland
603	0.4	Colorado Plateau Pinyon-Juniper Shrubland
405	0.3	Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex

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340	0.2	Rocky Mountain Subalpine-Montane Riparian Shrubland
171	0.1	Rocky Mountain Alpine-Montane Wet Meadow
135	0.1	Inter-Mountain Basins Semi-Desert Shrub Steppe
128	0.1	Rocky Mountain Aspen Forest and Woodland
76	<0.0	Inter-Mountain Basins Mat Saltbush Shrubland
27	<0.0	Rocky Mountain Subalpine Mesic Meadow
26	<0.0	Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland
11	<0.0	Colorado Plateau Mixed Low Sagebrush Shrubland
11	<0.0	Inter-Mountain Basins Semi-Desert Grassland
8	<0.0	Open Water
6	<0.0	Inter-Mountain Basins Shale Badland

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Table 1-3: Habitat types selected for by collared bears in our top two mixed-effects models and corresponding p-value.

Habitat Type	Beta Coefficient	p-value	SE
RMMD	1.92	0.04	1.17
RMLM	2.62	0.04	1.47
IMWA	4.75	0.02	2.15
RMPP	1.72	0.01	6.76
RMGO	5.15	< 0.00	7.75
RMMM	3.99	< 0.00	8.56

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Table 1-4: Results from campsite assessment surveys.

Site Number	Site Name	BHP[a]	BDP[b]	BEP[c]
1	Yellow Creek Group Site	Low	Low	Low
2	Yellow Creek Campsite	Moderate	Low	Moderate
3	Right Fork Yellow Creek Site	Moderate/High	Moderate	High
4	Swamp Canyon Campsite	Moderate	Moderate	Moderate
5	Right Fork Swamp Canyon Site	Low	Low	Low
6	Yovimpa Pass Campsite	Low	Low	Low
7	Riggs Springs Campsite	Moderate	High	Moderate
8	Riggs Springs Group Site	Low	Moderate	Low
9	Natural Bridge Campsite	Low	Low	Low
10	Sheep Creek Campsite	Low	Moderate	Moderate

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11	Iron Springs Campsite	Moderate	Moderate	Moderate
12	Corral Hollow Campsite	Low	Low	Moderate

BHP[a] = Bear Habitat Potential,

BDP[b] = Bear Displacement Potential,

BEP[c] = Bear Encounter Potential

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Table 1-5: Forage items identified by survey crew while performing campsite assessments.

Type	Common Name	Scientific Name	Season	Relative Abundance at Campsites
Berry	Greenleaf Manzanita	*Arctostaphylos patula*	Summer	Moderate-High
Berry	Currant	*Ribes spp.*	Summer	Low
Berry	Elderberry	*Sambucus racemose*	Summer	Low
Berry	Juniper	*Juniperus spp.*	Summer	Moderate-High
Berry	Snowberry	*Symphoricarpos spp.*	Summer	Low
Berry	Chokecherry	*Prunus virginiana*	Fall	Low
Berry	Wild Rose	*Rosa woodsia*	Fall	Moderate
Berry	Serviceberry	*Amelanchior utahensis*	Fall	Low
Berry	Oregon Grape	*Mahonia repens*	Fall	Moderate
Seed	Acorns	*Quercus spp.*	Fall	Moderate-High
Seed	Pine Nuts	*Pinus edulis*	Fall	Low-Moderate
Grass	Bluejoint Grass	*Calamagrostis canadensis*	Spring	Low

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Grass	Indian Rice Grass	*Stipa hymenoides*	Summer-Fall	Low
Sedges	Various	*Carex spp.*	Spring-Summer	Low-Moderate
Forbs	Stinging Nettle	*Urtica dioica*	Spring-Summer	Low
Forbs	Cow Parsnip	*Heracleum lanatum*	Spring-Summer	Low
Forbs	Miners Lettuce	*Claytonia spp.*	Spring-Summer	Low
Forbs	Sweet Cicely	*Osmorhiza spp.*	Summer	Low
Trees	Aspen Buds	*Populus tremuloides*	Spring	Low
Trees	Willow Buds	*Salix spp.*	Spring	Low

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Table 1-6: BRCA bear incident reports that involve both bears using campsites, and other anthropogenic features within the park, and bears acting aggressively towards humans.

Year	Date	Time	Location	Bear Cohort	Description	Injuries
1975	August 7	19:30	Riggs Springs	Juvenile	While setting up camp, camper saw light brown bear running through the trees away from the spring	None
1982	June 3	AM	Riggs Springs	Adult	Large brown phase black bear seen browsing on vegetation near Riggs Spring. Ran off upon being approached by hiker	None
1988	July 3	15:00	Sheep Creek Campground	Adult	Curious bear. Took an empty can, came back and circled	None

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					campsite. Hung around for about 10-15 minutes.	
1988	July 3	16:30	Sheep Creek Connecting trail	Adult	Large adult bear followed and circled hikers for 2 hours. Hikers ran up the hill and threw rocks at the bear	None
1990	Sept. 18	Night	North Campground	NA	Bear entered their campsite 3 times, ate their bread and scratched their tent	None
1991	May 21	19:00	Riggs Springs Campground	NA	Black bear brown in color was moving south on eastern side of campground.	None

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2003	June 23	8:00	Right Fork Swamp Canyon	N/A	Bear observed moving around area next to campsite	None
2009	May 12	6:00-20:30	Yovimpa area, Rainbow Point	N/A	Smaller bear seen eating trash out of trash cans in several areas of the park. Was hazed by BRCA personnel.	None
2009	June 3	18:30	Rainbow Point	N/A	Bear seen looking into car windows and pit toilets	None
2009	June 5	18:30	Iron Spring	N/A	Bear scared away from spring and watched hikers at a distance as they filled up their water bottles	None

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2009	August 21	19:00	Yellow Creek Campground	Juvenile	Young bear visited campsite while occupied. Non-aggressive	None
2009	Sept 15	12:30	Sheep Creek Campsite	Juvenile	Bear followed person while he collected water samples.	None
2009	Sept 29	14:30	Sheep Creek Campsite	N/A	Visitors stopped for lunch and fixed freeze dried meat. Bear approached and burnt nose on coffee and left, then returned for food soon after	None
2009	Oct 7	AM	Yellow Creek Campsite	Juvenile	Bear came near tent so visitors got out of tent; tried charging, yelling, throwing rocks at bear but	None

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					it stayed within 20ft of campsite	
2009	Oct 23	22:00	Swamp Canyon Campsite	N/A	Smaller bear approached campsite, inspected stove, and then returned half hour later.	None
2010	June 14	19:00	Sheep Creek Campsite	N/A	Bear seen about 40 ft. from tent. Likely smelled dinner and came to investigate	None
2010	June 15	13:40	Sheep Creek Campsite	N/A	Bear seen on trail and ran when seen by visitor.	None
2010	June 15	14:00 - 18:00	Sheep Creek Campsite	N/A	Bear came to tent in afternoon and ate food; moved camp over 1 mile and	Bear was killed by

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					bear followed campers - aggressive, ate tent and sleeping pad and all food	wildlife officers
2014	May 22	4:30	Riggs Springs	Adult	Bear tore into tent while campers slept inside and one was hit by the paw.	Contact with little to no injury
2015	July 4	3:00	Yovimpa Campsite	Adult	Campers woke at 3 am to see bear standing next to a tree about 200 feet away.	None

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Table 1-7: Campsite Rankings. Each campsite was assigned a ranking of low, moderate or high based on their encounter, displacement and habitat potentials.

Site Name	Overall Human-Bear Concern	Spring Bear Habitat Potential	Summer Bear Habitat Potential	Fall Bear Habitat Potential	Bear Displacement Potential	Bear Encounter Potential
Yellow Creek Group Site	Low	Low	Low	Moderate	Low	Low
Yellow Creek Campsite	Moderate	Low	Moderate	Moderate	Low	Moderate
Right Fork Yellow Creek Site	High	Moderate	Moderate	High	Moderate	High
Swamp Canyon Campsite	Moderate	Low	Moderate	Moderate	Moderate	Moderate
Right Fork Swamp Canyon Site	Low	Low	Low	Low	Low	Low

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Site Name	Overall Human-Bear Concern	Spring Bear Habitat Potential	Summer Bear Habitat Potential	Fall Bear Habitat Potential	Bear Displacement Potential	Bear Encounter Potential
Yovimpa Pass Campsite	Low	Low	Moderate	Low	Low	Low
Riggs Springs Campsite	Moderate	Moderate	Moderate	Moderate	High	Moderate
Riggs Springs Group Site	Low	Low	Low	Low	Moderate	Low
Natural Bridge Campsite	Low	Low	Low	Low	Low	Low
Sheep Creek Campsite	Moderate	Moderate	Low	Low	Moderate	Moderate
Iron Springs Campsite	Moderate	Low	Moderate	Moderate	Moderate	Moderate

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Site Name	Overall Human-Bear Concern	Spring Bear Habitat Potential	Summer Bear Habitat Potential	Fall Bear Habitat Potential	Bear Displacement Potential	Bear Encounter Potential
Corral Hollow Campsite	Low	Low	Low	Low	Low	Moderate

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FIGURES

Figure 1-1: Bryce Canyon National Park outlined in green on the eastern flank of the Paunsaugunt Plateau.

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Figure 1-2: Example of an inactive barrel trap

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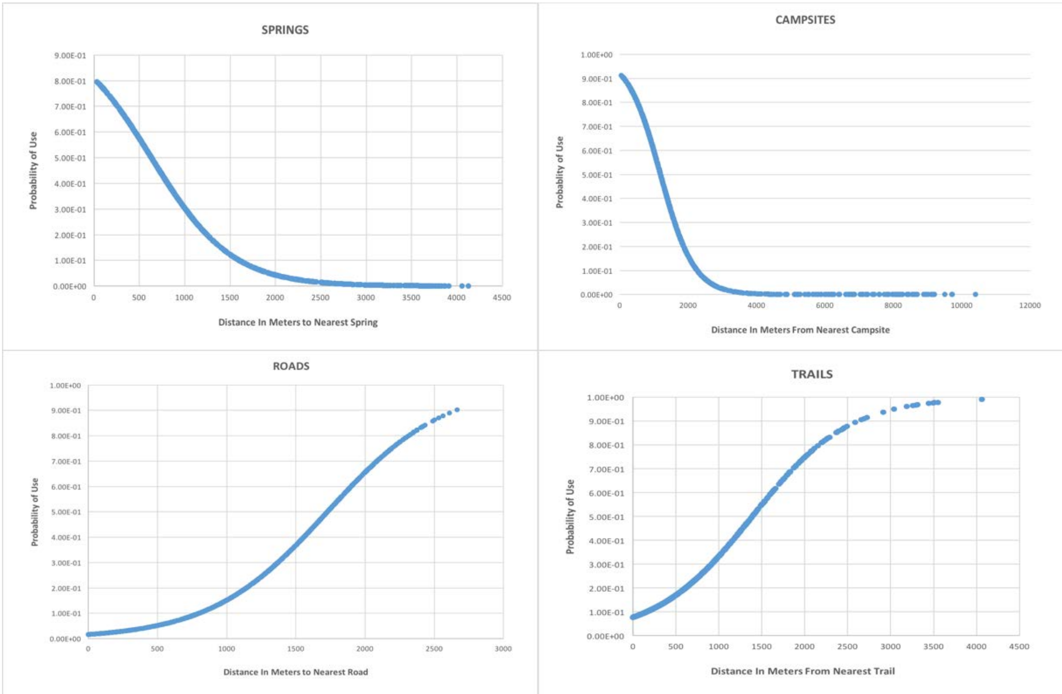

Figure 1-3: Graphs illustrating the relationship between radio-collared bears and campsites, springs, roads and trails within BRCA. Probability (y-axis) of a bear selectinlocation that is x meters (x-axis) from the measured feature at some point during the sampling period is displayed.

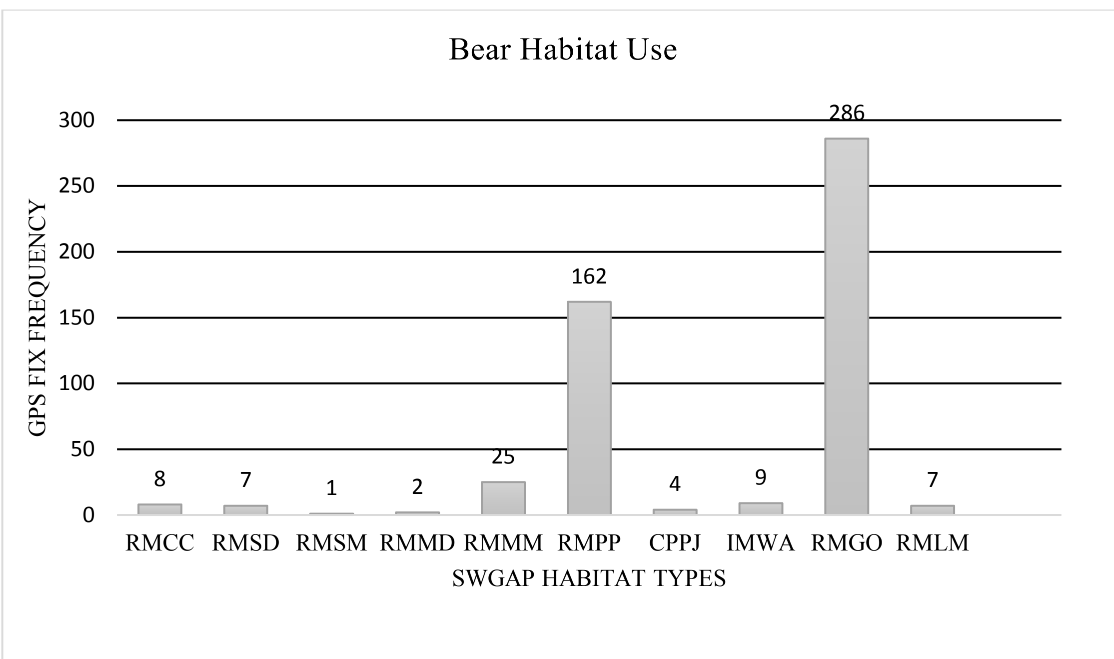

Figure 1-4: Habitat types found within the BRCA study area and the total number of radio-collared bear GPS fixes for each used habitat type. Total availability can be located in Table 2.

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Figure 1-5: An example of an unmarked bear using the BRCA trail system near the Yellow Creek campsite

Figure 1-6: An unmarked female with cubs accessing Iron Springs near a BRCA campsite.

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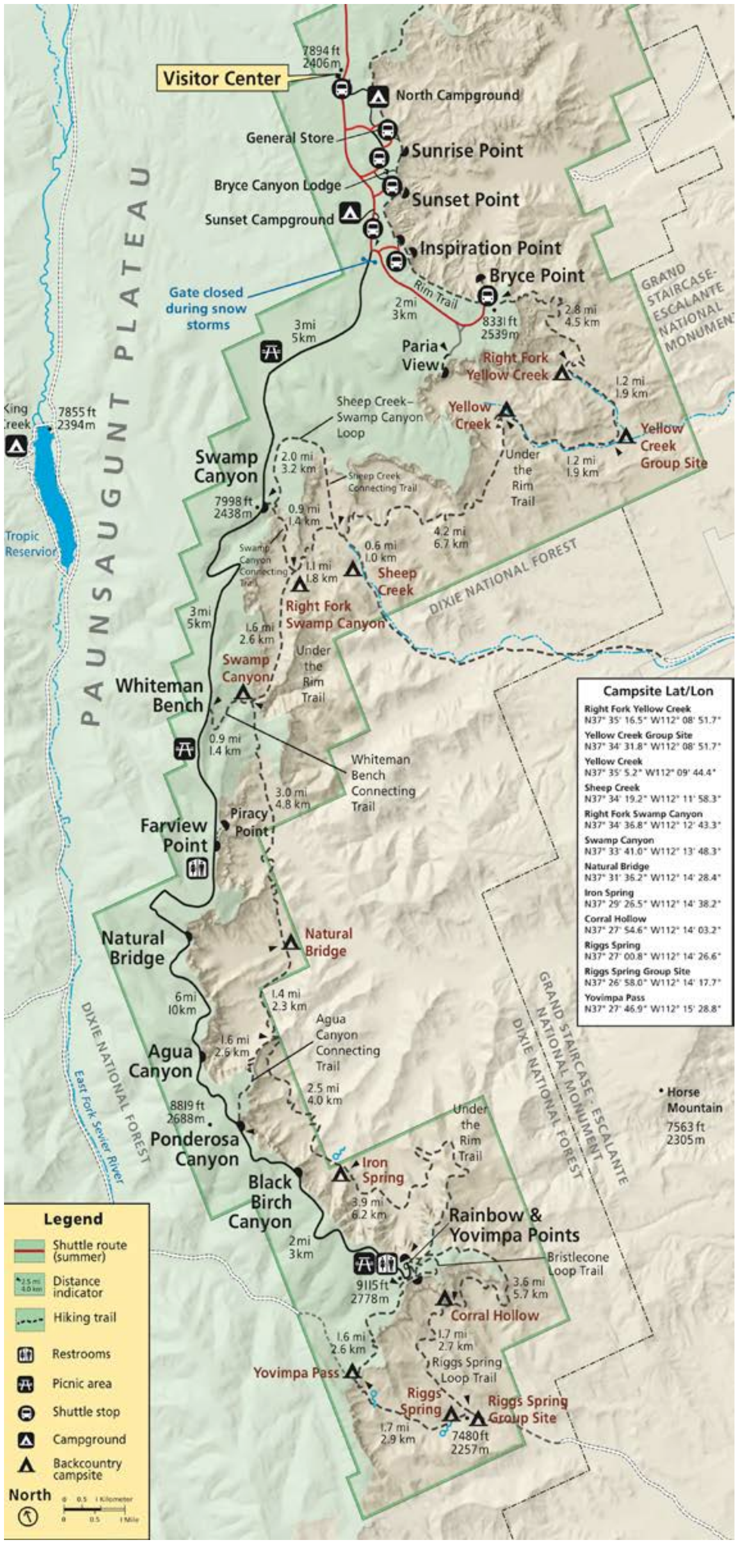
APPENDIX

Appendix 1-1: Map of Locations and Names of Campsites Within BRCA



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Appendix 1-2: Campsite Assessment Protocols

Campsite surveys produce data that are entered on the Campsite Assessment Form (CAF). The purposes of the CAF include: 1) specifies site variables most useful for estimating bear habitat, displacement, and encounter potentials, 2) enables field personnel to make preliminary estimates of bear habitat, displacement, and encounter potentials, and 3) provides data which will be used for the development of predictive models regarding human-bear conflicts.

In order to develop an effective site assessment protocol, an effort was made to strike a balance between a wholly qualitative approach and one that is quantitative. Qualitative assessments are fast, but results are subjective and highly dependent upon the experience and judgment of those conducting them. On the other hand, though an entirely quantitative site assessment protocol would eliminate the need for experts but would be slow and cumbersome. Hence, this site evaluation protocol utilizes both quantitative and qualitative measures of site variables. To minimize subjectivity, quantitative values are recorded for site variables that lend themselves to actual measurement: visibility, distances to important geographic features (e.g., fresh water, high water line, nearest available food sources, etc.), campsite width, etc. Qualitative data are recorded for less easily quantifiable variables. The CAF has been structured to guide data collection so that by the time a crew has completed the form they will have developed a well-informed opinion regarding the site's qualities with regard to its habitat potential, bear displacement potential and encounter potential. Hence, the final task on the CAF is to provide preliminary estimates of site's potential habitat, displacement and encounter values. These preliminary 'on-site estimates' are subjective but important. For one, these estimates provide closure to the field assessment process and represent our best estimate until more analyses are conducted. These field assessments also provide a baseline against which site potentials calculated by other means can be compared. An effort will be made to create a quantitative model for determining site potential values (e.g., habitat quality, displacement and conflict) using data from the CAF. Model results will be compared to field crew estimates as a means of verifying model outputs. Similarly, a *resource selection function* approach will be used to create a predictive model for human-bear conflict. Outputs of this model will be compared, in part, to site potentials estimated by field crews. For these reasons, it is important for field crews to make estimates on-site even though rigorous analysis of field data is forthcoming.

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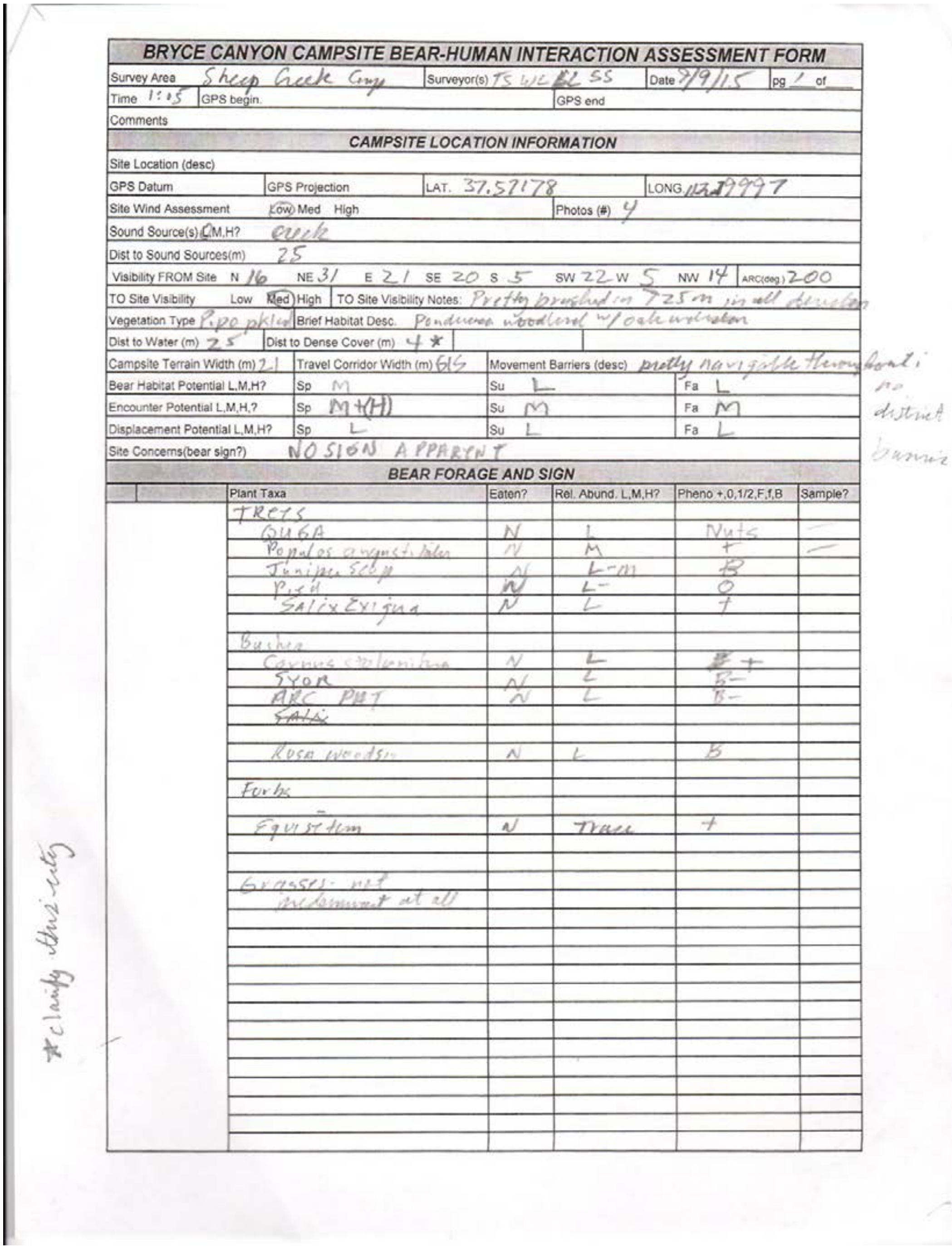
Appendix 1-3: Completed Campsite Assessment Data Sheet Example



BRYCE CANYON CAMPSITE BEAR-HUMAN INTERACTION ASSESSMENT FORM

Survey Area Sheep Creek Camp	Surveyor(s) TS WL BL SS	Date 9/9/15	pg 1 of
Time 1:05	GPS begin	GPS end	
Comments			

CAMPSITE LOCATION INFORMATION

Site Location (desc)

GPS Datum | GPS Projection | LAT. 37.57178 | LONG. 112.19997

Site Wind Assessment (Low) Med High | Photos (#) 4

Sound Source(s) L,M,H? creek

Dist to Sound Sources(m) 25

Visibility FROM Site N 16 NE 31 E 21 SE 20 S 5 SW 22 W 5 NW 14 ARC(deg) 200

TO Site Visibility Low (Med) High | TO Site Visibility Notes: Pretty brushed in ~25 m in all direction

Vegetation Type Pipo pklw | Brief Habitat Desc. Ponderosa woodland w/ oak understory

Dist to Water (m) 25 | Dist to Dense Cover (m) 4 *

Campsite Terrain Width (m) 21 | Travel Corridor Width (m) 615 | Movement Barriers (desc) pretty navigable throughout; no distinct barriers

	Sp	Su	Fa
Bear Habitat Potential L,M,H?	M	L	L
Encounter Potential L,M,H,?	M+(H)	M	M
Displacement Potential L,M,H?	L	L	L

Site Concerns(bear sign?) NO SIGN APPARENT

BEAR FORAGE AND SIGN

Plant Taxa	Eaten?	Rel. Abund. L,M,H?	Pheno +,0,1/2,F,f,B	Sample?
TREES				
QUGA	N	L	Nuts	—
Populus angustifolia	N	M	+	—
Juniper scop	N	L-M	B	
Pied	N	L-	O	
Salix Exigua	N	L	+	
Bushes				
Cornus stolonifera	N	L	B +	
SYOR	N	L	B—	
ARC PAT	N	L	B—	
~~SALIX~~				
Rosa woodsii	N	L	B	
Forbs				
Equisetum	N	Trace	+	
Grasses - not predominant at all				

* clarify this entry

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Appendix 1-4: Individual Campsite Assessment Form Example

Yellow Creek Group Campsite:

Overall Bear Concern: Low

Seasonal Bear Habitat Potential:
April-June: Low
July-August: Low
September-November: Moderate
Bear Encounter Potential: Low
Bear Displacement Potential: Low

Campsite Description: The Yellow Creek Group site is located in a remote area with a reliable stream nearby. Mountain Maple, Utah Juniper and Ponderosa Pine can all be found in the vicinity of the site. It is the lowest BRCA campsite with an altitude of 6865 feet (2092 m). It is 4.2 miles from the Bryce Point parking lot.

Bear Habitat Concerns: Both Gambel Oak and Juniper are found in moderate abundance throughout the general area of the site. However, both of these species are plentiful throughout overall area and the campsite itself poses no particular attraction as far as forage is concerned.

Bear Travel Concerns: The travel corridor width is well over 200 meters and offers moving bears a number of options that allow them to easily avoid the campsite.

Visibility Concerns: Visibility is relatively poor over roughly 280°

Bear Sign Within 100m of the Campsite: None

Bear Displacement Concerns: While the Yellow Creek Group site is situated close to a water source, chances of displacement are low, as bears using the stream are more likely to access it at points that have better cover and are less barren.

Recommendations: Yellow Creek Group site is a generally low-risk campsite with poor habitat and multiple options for movement corridors. This campsite can remain as is and will present a generally safe environment for campers in black bear country.

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Appendix 1-5: Potential Seasonal Forages Utilized by Black Bears at Bryce Canyon National Park

Pre-Greenup
rotted logs (ripped & chewed...grubs & ants?) .... *Pinus spp, Populus spp, etc*

Spring (Late April-May)
Grasses
bluejoint .... *Calamagrostis canadensis*
Sedges
Various .... *Carex sp.*
Forbs
Stinging nettle .... *Urtica diociai*
Utah angelica .... *Angelica wheeleri*
Cow parsnip .... *Heracleum lanatum*
Miners lettuce .... *Claytonia spp.*
Wild sweet pea .... *Lathyrus spp.*
Plantain .... *Plantago spp.*
Dandelion .... *Taraxacum officinale*

Trees
Aspen buds .... *Populus tremuloides*
Willow buds .... *Salix spp.*

Summer (June-July)
Forbs
Utah angelica .... *Angelica wheeleri*
Dandelion .... *Taraxacum officinale*
Cow parsnip .... *Heracleum lanatum*
Horsetail .... *Equisetum spp.*
Lupine (roots) .... *Lupinus spp.*
Field locoweed .... *Oxytropis campestris*
Sweet cicely .... *Osmorhiza spp.*

Other Plants
Lady fern .... *Athyrium filix-femina*

Insects
Ants .... *Formica, Tapinoma, Camponotus, Lasius*
Wasps .... *Vespula spp.*

Mammals
Porcupine .... *Erethizon dorsatum*
Mule deer .... *Odocoileus hemionus*
Elk .... *Cervus elaphus*
Ground squirrels .... *Spermophilus variegatus*

Summer (August)
Berries
Elderberry .... *Sambucus racemosa*
Highbush cranberry .... *Viburnum edule*
Raspberry .... *Rubus spp.*
Mountain ash .... *Sorbus spp.*
Currants .... *Ribes spp.*

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Manzanita .... *Arctostaphylos patula*
Juniper .... *Juniperus spp.*
Skunkbush (Squawbush).. *Rhus aromatica*
Wild crab apple (Squaw apple).. *Peraphyllum ramosissimum*
Snowberry.. *Symphoricarpos spp.*
Canadian dogwood .... *Cornus canadensis*

Fall (September-October)
Berries & Seeds
All listed above should be continually visited
Chokecherry.. *Prunus virginiana*
Wild rose .... *Rosa woodsii*
Serviceberry.. *Amelanchior utahensis*
Oregon grape .... *Mahonia repens*
Pinenuts .... *Pinus edulis*
Acorns.. *Quercus spp.*

Mammals
Porcupine.. *Erethizon dorsatum*
Mule deer.. *Odocoileus hemionus*
Elk .... *Cervus elaphus*
Domestic cattle .... *Bos taurus*
Ants .... *Formica, Tapinoma, Camponotus, Lasius*
Wasps .... *Vespula spp.*
Insects
Ants .... *Formica, Tapinoma, Camponotus, Lasius*
Wasps .... *Vespula*

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CHAPTER 2

Human Interaction and Disturbance of Denning Polar Bears on Alaska's North Slope

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ABSTRACT

Across the central coast of Alaska's North Slope, human-polar bear (*Ursus maritimus*) interactions concern both industry and wildlife managers alike. In response to sea ice reductions due to climate change, parturient polar bears in the Southern Beaufort Sea subpopulation are increasingly accessing coastal topography for suitable denning habitat. Land-denning bears are more susceptible to anthropogenic stressors, chiefly in areas with high levels of energy exploration, extraction and production. For over 30 years, denning polar bears in the Southern Beaufort Sea subpopulation have been monitored directly or through opportunistic observations. Scientists have opportunistically recorded polar bear responses to aircraft, snowmachines, track-vehicles, heavy machinery, trucks, dog teams, and humans afoot within the denning area. Concurrent studies have provided important information regarding the interaction between polar bears and anthropogenic stressors. However, the long-term nature of this work and associated human-bear interaction observations represent a unique dataset that provides wildlife managers insight into the way polar bears have responded to anthropogenic stimuli in active oil fields. Our objective here is to analyze the different disturbance stimuli at den-sites and the associated bear responses. To do so, we subdivided potential stimuli into four groups based on the size, noise levels, and motion of each. Both field notes and video recordings of interactions were analyzed and ranked by response intensity where available. We found significant probabilities for

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disturbance among all stimulus classes, with aircraft showing the highest potential for initiating den abandonment. However, while all human activities elicited varying degrees of response, the overall response intensity was less than anticipated, even under high use scenarios. It is our hope that these data will provide both wildlife managers and industry with information that can be used to promote polar bear conservation through minimizing disturbance, and informing alternative actions for dealing with bears denned near industrial activity.

INTRODUCTION

The response of wildlife to human activities is a well-studied component of wildlife management and conservation. Understanding the effect that human-wildlife interactions have on different species is key to effective management. While any co-occurrence of humans and wildlife could constitute an interaction (Hopkins et al. 2010), not all interactions result in disturbance. However, anthropogenic stressors that lead to changes in reproductive success, behavior and physiology are classified as disturbance (Tarlow and Blumstein 2007). To understand how disturbance may lead to biologically significant effects, information regarding the following is needed: 1) type of stimulus, 2) context of the encounter, and 3) the behavioral and physiological strategies the animal uses when threatened (Frid and Dill 2002). Additionally, when disturbance studies are conducted, it is equally important to document when no apparent response occurs. Because a non-response to a stimulus can be difficult to identify, they are often under-reported. Failure to document non-responses, as well as overt responses, may lead to the inaccurate conclusion that a species is sensitive to a particular type or intensity of human activity, when in fact it is not.

In many carnivore species, the most energetically efficient response to a perceived threat

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is to move from the area of concern (Linnell et al. 2000). However, denned, parturient bears are an exception, and less likely to abandon a den site due to the negative consequences for reproductive success (Linnell et al. 2000). Nonetheless, polar bear den abandonment due to human disturbance has been documented (Belikov 1976, Lentfer and Hensel 1980, Amstrup 1993, Lunn et al. 2004). When considering den abandonment in polar bears, it is important to make a distinction between "abandonment," which is an early departure from a maternal den, often as a result of disturbance, and "departure", which is the undisturbed, normal departure from the maternal den. Additionally, the theory of residual reproductive value (Frid and Dill 2002) predicts that young female bears should have a higher likelihood of abandoning a den and their offspring than older females, as younger bears have a higher residual reproductive value and much more to lose. A number of studies have sought to determine the flight initiation distance (FID) and factors leading to flight initiation for a variety of species (Walther 1969, Frid and Dill 2002). While some studies have addressed FID in bear species (Andersen and Aars 2007, Smith et al. 2012), disturbance thresholds and FID in polar bears have been largely unstudied. We would predict, however, that the younger the parturient bear, the more risk-averse they would be with respect to perceived disturbance, as evidenced by larger FIDs.

In late fall and early winter in the Southern Beaufort Sea (SBS), parturient polar bears construct dens in a matrix of snow and ice which provides protection from predators and insulation from outside noise, low temperatures, and other weather conditions (Blix and Lentfer 1993, MacGillivray et al. 2009). Altricial polar bear cubs are born from late December through early January (Ramsay and Stirling 1988), and require >2 months of den protection post-partum before emerging in late March or early April (Ramsay and Stirling 1988, Amstrup and Gardner 1994, Smith et al. 2007). Historically, a majority of dens constructed in the Southern Beaufort

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Sea population occurred on offshore pack ice, near pressure ridges where deep snow accumulates. However, the proportion of dens constructed on pack ice declined from 62% (1984—1994) to 37% (1998—2004); (Fischbach et al. 2007). This increase in terrestrial denning was likely in response to reductions in multi-year ice pack and a lengthening of the ice-free season (Fischbach et al. 2007). With a higher percentage of terrestrial denning activity, polar bears are at a higher risk of conflict with humans, particularly along the central part of Alaska's North Slope where petroleum industry activity is widespread.

Polar bears may be particularly vulnerable to den disturbance among the bear species, as fasting periods can last up to eight months (Ramsay and Dunbrack 1986, Atkinson and Ramsay 1995, Derocher and Stirling 1998), during which time females may lose up to 43 percent of their body weight (Atkinson and Ramsay 1995). Increased nutritional stress and subsequent decreases in cub survival, litter size and reproductive periods have been documented and correlated to losses in sea ice (Stirling et al 2004, Regehr et al 2006, Rode et al. 2007, Molnar et al 2011). Human-bear interactions add to denning females' stress and can lead to den abandonment and reproductive failure. Premature den abandonment is particularly costly for denned (fasting) female bears and subject offspring to exceptionally harsh weather conditions, thus lowering their chances of survival. As such, it is important that stress be minimized for denned bears along Alaska's North Slope.

In an effort to strengthen protections for marine mammals, the U.S. Congress passed the Marine Mammals Protection Act (MMPA) in 1972 (MMPA 1972). Along with various habitat and harvest related guidelines, the MMPA clearly specifies the types of disturbance that must be reported to U.S. management authorities. All disturbance events fall under the MMPA classification of a "take". The MMPA defines two types of "takes" as follows: Level A is "to

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harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" and Level B is "any act that has the potential to injure a marine mammal or marine mammal stock, or has the potential to disturb a wild marine mammal or marine mammal stock by causing disruption of behavioral patterns (MMPA 1972).

Non-sanctioned "takes" can lead to the suspension of work and associated financial burdens for commercial activities. Commercial operators, such as Alaska's oil and gas industry, can request Letters of Authorization (LOA) from the FWS that allow incidental "takes" of polar bears during specified activities. When working in polar bear denning habitat, LOA permittees are required to make an effort to locate polar bear dens and avoid exclusion zones around known polar bear dens. To locate polar bear dens within areas of operation, forward-looking infrared (FLIR) cameras (which detect denned bears' heat through the snow), polar bear scent-trained dogs, or radio-telemetry of collared bears are used. Once identified, observed or suspected polar bear dens must be reported to the FWS prior to initiation of industrial activity. Additionally, industry must observe a 1.6-km (one mile) exclusion zone around all known polar bear dens during the denning season (November–April), or until the female and cubs leave their dens, unless otherwise directed by FWS. The FWS evaluates newly discovered dens on a case-by-case basis to determine the best mitigation options and conservation outcomes (FWS Marine Mammals; Incidental Take During Specified Activities; Final Rule 2016). To implement the Incidental Take Program without placing an undue burden on industry, FWS managers need to understand bears' responses to the various types and intensities of human activities that may occur near den sites.

From 1975 to the present, researchers from the United States Geological Survey (USGS), FWS, Brigham Young University (BYU), and Polar Bears International (PBI) have conducted

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polar bear research or monitoring activities within the Prudhoe Bay Operations Area and adjacent habitats. During that time, human-polar bear interactions at den sites have been opportunistically observed and documented. The purpose of this report is to present those interactions and accompanying bears' responses in an effort to contribute to our understanding of polar bear response to human activity within the context of denning (Ramsay and Stirling 1986, Amstrup 1993, Lunn et al 2004, Perham 2005, Andersen and Aars 2007). Our hope is that this information will aid managers in their efforts to minimize negative human-bear interactions as industry and others operate in polar bear habitat. Specifically, we will examine whether available data support the 1.6 km (one mile) buffer guideline currently in place for oil industry operators in denning habitat. In addition, our results will help to direct future research efforts so we can better understand the effects of anthropogenic stressors on polar bear denning.

STUDY AREA

The study area encompasses the Prudhoe Bay Operations Area, extending 111 km east of Prudhoe Bay to the Arctic National Wildlife Refuge, and 133 km west to the Eskimo Islands (Figure 1). Within this area, small bluffs (< 4 m) on barrier islands, riverbanks and the coastal plain provide topographical relief where snow drift accumulation is sufficient for polar bear denning sites (Benson 1982, Durner et al. 2003). Habitat across the North Slope has been analyzed for suitable polar bear denning habitat and subsequently mapped (Durner et al., 2006).

METHODS

Dens were located through a combination of VHF telemetry and GPS radio collar relocation, from results of both aerial and ground surveys using FLIR camera technology

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(Amstrup et al. 2004, Robinson et al. 2014), direct observation by local observers, and from polar bear scent-trained dogs (Perham and Williams 2003). Human interactions at these locations were opportunistically recorded by personnel working for the USGS, FWS, BYU and PBI on a variety of polar bear research projects. Along with long term capture and tracking research, the USGS initiated a polar bear den emergence study in 2002, which was subsequently led by BYU and PBI to present (Smith et al. 2007 and 2013). For the first two years of the study, researchers used observation blinds to directly observe bears at den sites. However, these small tent camps occasionally elicited increased vigilance and other responses by bears to human activities, so in 2005, autonomous video systems were deployed to reduce the potential for human-bear interaction (Smith et al. 2013). Autonomous video capture proved to be a more effective, and less intrusive, means for documenting denning behavior (Smith et al. 2013).

For the purposes of this study, we compiled all human-bear interactions observed at den sites in a database (Figure 2). For each human-bear interaction we recorded the date, time, location, type of anthropogenic stimulus (e.g., human afoot, snowmachine, truck, etc.), distance from bear to stimulus, bear cohort, response intensity, and other ancillary data (e.g., weather, number of persons involved, etc.). For analysis, each human-bear interaction was assigned to a specific distance category, stimulus group, response intensity ranking, and response intensity group. We describe each of these categories as follows: distances from stimulus to bear were often estimated. To account for the lack of precise distance measurements, we used the following broad groups: Distance Group One (DG1) included all interactions that occurred between 0 and 150 meters, Distance Group Two (DG2) contained interactions that occurred between 151 and 300 meters, and Distance Group Three (DG3) which contained all interactions that occurred at distances > 301 meters.

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We assigned each interaction to a stimulus group based on the physical size of the stimuli (e.g., a human on foot was considered a small stimulus whereas a Rolligon® vehicle a large stimulus), the motion (speed), and noise level associated with it. Stimulus Group One (SG1) included all aircraft involved in human-bear interactions (both fixed and rotary wing). Stimulus Group Two (SG2) included large industrial machinery (Rolligon®, Tucker Sno-Cat®, snowplow, semi-truck etc.) Stimulus Group Three (SG3) included smaller machinery (4-wheel drive pickup truck, snowmachine), and Stimulus Group Four (SG4) included only humans on foot. Table 1 presents the different anthropogenic stressors observed near polar bear den sites and associated group identifiers.

Human-bear interactions were subdivided into three groups based on the estimated noise level, motion of stimuli, distance from stimulus, duration of interaction, and directionality of approach associated with each incident. Directionality of approach is important when considering bear responses to stimuli, as bears are likely to respond differently to a direct approach as opposed to a more angled, indirect approach. Intensity of interaction was more difficult to quantify, as we did not have data for all variables affecting intensity rankings for every interaction. To insure consistency, however, we carefully reviewed all notes associated with each interaction, and then evaluated each individually. We classified stimulus intensity on a scale of one to three, with a score of one representing a low intensity interaction that involved quiet, slow-moving stimuli, with shorter interaction times and less direct approaches at greater distances (> 301 meters). A score of two represented a moderate intensity stimulus that occurred with faster, louder stimuli for a longer duration and more direct approaches at shorter distances (151 – 300 meters). A score of three was assigned to high intensity interactions that occurred with rapid moving, loud stimuli for longer durations, direct approaches, and at relatively close

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distance (< 151 meters).

Bear responses to each interaction were grouped by intensity, on a scale of one to four. A score of one represented an apparent "non-response" following an interaction, a two represented a low intensity response (increased vigilance, change from sitting to standing posture), a three represented a moderate intensity response (rapid movement, retreat to den) and a score of four represented a high intensity response (den abandonment). While a bear may have responded internally to a given stimulus (i.e., changes in heart rate, respiration, and/or release of stress hormones), our 'non-response' category means that observers were unable to visually detect an overt change in behavior as a result of a particular human-bear interaction.

Finally, we examined each stimulus group, distance, cohort, intensity of interaction, and resulting bear reactions for trends. To accomplish this, we built and compared models in Program R (R Development Core Team, 2008) with the Akaike Information Criterion selection (AIC; Akaike 1973). Given multiple categorical variables, we used multinomial logistic regression, then ran a post-hoc Tukey comparison using the lsmeans package to analyze top models. Within our top model we compared each variable against all others and associated polar bear responses to construct probabilities of observing categorized bear response intensities (1-4), when approached by categorized stimulus classes (1-4), at varying disturbance intensities (1-3).

RESULTS

We collected 138 human-bear interactions that spanned a 42-year period (1975—2017). Interactions involving aircraft (SG1) accounted for 26.1 percent (n = 36) of interactions, large machinery (SG2) comprised 17.4 percent (n = 24) of all interactions, smaller machinery (SG3) accounted for 37.0 percent (n = 51) of interactions, and people afoot (SG4) accounted for 19.6

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percent (n = 27) of all interactions. Of all interactions, 23.2 percent (n = 32) elicited no discernible response (level one) from bears, 39.6 percent (n = 55) led to a change in posture or increase vigilance response (level two), 29.0 percent (n = 40) elicited a rapid movement response (level three), and 8.0 percent (n = 11) led to a den abandonment response (level four). We present counts of each bear response level for all stimulus groups in Figure 3. Additionally, we present counts of bear response levels by distance for each stimulus group in Figure 4.

Model selection and comparison with AIC identified a top model that accounted for 90% of the cumulative model weight and was therefore the only model which received enough support to be included in our analysis. This model contained 'bear reaction to stimuli' as the response variable, with intensity level and stimulus group as explanatory variables. Table 2 presents the top model, as well as the second highest-ranked model in our AIC analysis.

Multinomial logistic regression and post-hoc Tukey comparison returned statistically significant probabilities (95% confidence interval that does not cross zero) in multiple (n = 17) comparisons of variables. The top model for bear response contained both stimulus group and stimulus intensity level as important explanatory variables, but our sample size was too small for specific combinations of the response variable with both explanatory variables. Consequently, combinations with response as the dependent variable and stimulus group and stimulus intensity as dependent variables with fewer than six data points ($n < 6$) were removed from analysis. The following discussion includes only those stressors for which adequate sample size allowed statistical analysis.

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Low Intensity Stressors

Low intensity stimuli was our most robust data set. Large machinery had a 27.5% probability (95% CI = 7.38 - 47.5) of eliciting no response from denning bears, a 42.0% probability (95% CI = 20.1 - 64.0) of eliciting increased vigilance, and a 30.5% (95% CI = 10.0 - 51.0) probability of eliciting a rapid movement response. Small machinery had a 51.5% probability (95% CI = 33.8 - 69.2) of eliciting no response, a 26.9% probability (95% CI = 11.7 - 42.1) of eliciting increased vigilance and a 21.6% probability (95% CI = 07.6 - 35.7) of initiating a rapid movement response. People afoot had a 91.9% probability (95% CI = 80.0 - 100) of eliciting increased vigilance in denning polar bears. All other low intensity stimulus group interactions were not statistically significant, or did not have a large enough sample size ($n > 6$) to be included.

Moderate Intensity Stressors

The majority of moderately intense stimuli were associated with stimulus group three, or small machinery, including pickup trucks and snowmachines. We identified a 36.6% probability (95% CI = 11.7 - 61.5) of moderate intensity interactions by small machinery eliciting no response from denning polar bears, and a 39.1% probability (95% CI = 15.1 - 63.1) of initiating increased vigilance. We did not have sufficient sample sizes for other stimulus groups to merit inclusion for analysis at moderate levels of stimuli.

High Intensity Stressors

While a number of high intensity stimuli interactions with polar bears were included in the dataset, those that had a sample size large enough for analysis ($n > 6$) were all in the aircraft

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stimulus group (SG1). High intensity stimuli associated with aircraft showed a 20.0% probability (95% CI = 05.1 - 34.9) of eliciting increased vigilance, a 57.4% probability (95% CI = 38.9 - 75.9) of initiating rapid movement, and a 22.6% probability (95% CI = 06.8 - 38.4) of causing den abandonment. All other high intensity stimulus group interactions did not have large enough sample sizes to be included.

Polar bear response probability data for each of the stimulus groups and interaction intensities are presented in Table 3.

DISCUSSION

Our data show that denned polar bears on Alaska's North Slope are overtly unreactive (i.e., largely tolerant) of human activity near den sites (< 1.6 km), and that den abandonment did not occur when bears were exposed to low levels of disturbance. We found that bears responded differently to each stimulus type as shown in Figure 3. However, a better understanding regarding which stimuli and intensity levels result in den abandonment is of chief importance, as premature polar bear den abandonment could lead to failed recruitment. Within the data available to this study, den abandonment events were rare (n = 11), and almost all abandonments (n = 10) occurred following high intensity interactions involving females without dependent young. Most abandonment events (n = 7) were caused by high intensity interactions (longer duration with distances < 150 meters) of low-flying aircraft (both helicopter and fixed-wing aircraft). The majority of these interactions were associated with capture and radio-collaring operations of females at open den sites that had not yet produced cubs (n = 6). In addition, it should be noted that each of these radio-collaring events occurred in the fall when den construction was ongoing, and females had less to lose by abandoning those sites following

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disturbance. From an energetics standpoint, an incomplete den (i.e. a hole in the snow as opposed to a sealed den) likely does not represent a great energetic cost for parturient females and, as such, were more readily abandoned than a bear within a closed den. While radio-collaring operations represent intense interactions, work by Ramsay and Stirling (1986), as well as that by Rode et al. (2014), reported that fall captures of pregnant females did not appear to negatively affect reproduction or cub survival. Ramsay and Stirling (1986) handled 13 pregnant bears at den sites, and all successfully re-denned, with a mean den relocation distance of 17.8 km from the handling location. Results from their study, as well work by Amstrup (1993), showed no significant effect of handling and subsequent increased movement prior to denning on cub survival and weight. Conversely, Lunn et al. (2004) showed that handling pregnant polar bears in the fall may lead to lighter female cub weights, but found no change in male cub weights. In a closed den (i.e., the entrance is filled with snow), polar bear cubs are not likely to survive a forced abandonment event, and therefore collaring operations are not carried out prior to normal den breakout and abandonment when cubs are healthy enough to leave the den site. In all of our den site interactions, we documented only one den abandonment involving cubs. This occurred after USGS researchers excavated a den believed to be abandoned (family groups at 11 other known dens had departed), but was still occupied. Following a high intensity interaction with researchers at this den site, the female fled the den when the nearby helicopter was restarted and was immobilized nearby. Her cubs were removed from the den and brought to her. It is unknown if the female and cubs re-denned, though one of the two cubs was recently been captured as a healthy adult bear (USGS, Todd Atwood pers comm).

The distance between anthropogenic stressor and polar bear dens is an obvious factor which influences the outcome of an interaction. A bear approached directly to within 10 meters

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by a snowmachine is almost certainly going to react differently than one approached no closer than 300 meters. Within our observations, some distances were estimated which may explain why the ‘distance to stressor’ variable was not in the top model. However, we included distances between stimuli and bears when assigning intensity rankings for each interaction, and ‘intensity of interaction’ was a potential explanatory variable that was included in the top model. The ‘distance to bear’ variable was of particular importance when we analyzed human-polar bear interactions on the North Slope. The 1.6 km buffer guideline was established to mitigate the potential for unnecessary stress imposed on denning polar bears through human activity in oil development areas. Our data indicate that the 1.6 km buffer represents adequate protection for denned bears from aircraft disturbance. All other stimulus groups elicited markedly lower bear responses at the distances for which we had data (all interactions occurred < 1.6 km). Figure 4 shows the distribution of bear responses for each stimuli type within our three distance categories. Non-responses were shown to occur at larger distances for most stimuli groups, with 81% of interactions resulting in no response from bears occurring at distances > 300 meters (n = 25). Conversely, the large majority of human-bear interactions that led to abandonment occurred at close distances, with 91% occurring < 150 meters of a den site (n = 10). Within the response groups we created for analysis, groups 3 (rapid response movement) and 4 (den abandonment) fit criteria for FWS’ level B “take” responses, or a disruption of behavioral patterns. Within our analysis, we noted significant probabilities for “take” levels of disturbance for both large and small machinery at low intensities and for aircraft at high intensity. Low intensity interactions associated with large machinery were more likely to initiate a rapid movement in polar bears than a non-response, with probabilities of 30.5% and 27.5% respectively. However, low intensity interactions associated with small machinery were more likely to lead to a non-response

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than a rapid movement response with probabilities of 51.5% and 21.6% respectively. Understanding the probability for each stimulus group to cause a "take" level of disturbance is key to implementation of current industry rules when dealing with den sites in operating areas.

Although our data were opportunistically collected and not evenly distributed (frequency and distance of occurrence for each stimuli group), several trends among the den sites monitored are evident: 1) the majority of dens subjected to intense disturbance (n = 38) stimuli were not abandoned (n = 27), 2) bears that relocated as a result of disturbance did not suffer reproductive losses, 3) dens abandoned near areas of intense industrial activity were still vacated within the expected normal range for undisturbed bears, 4) individual bears reacted differently to the same stimuli on different occasions, and 5) non-responses to activity are difficult to quantify. Following is a discussion of each of these findings.

1) We found that polar bear dens were not abandoned, even when subjected to intense stressors, such as persons' digging into them or snowmachines parked atop them. Every den site observed in the den monitoring study was approached to within 60 meters, and occasionally closer, with snowmobiles, track vehicles and humans afoot. No bears in closed dens (i.e., entrances snow-filled) abandoned them, which may be due to the high costs of abandonment (energy and loss of reproductive effort), or the fact that bears in sealed dens are less susceptible to anthropogenic stressors and associated noise and vibration levels (MacGillivray 2009, Blix and Lentfer 1992). Acoustically, closed dens represent a highly insulated environment, and sound levels from industrial activities >100m from den sites have not been shown to penetrate the snow and disturb denning polar bears (Blix and Lentfer 1992, Owen and Bowles 2011).

2) During the multi-year den monitoring study, we did not observe any premature den abandonments that may have led to reproductive failure, as females were observed leaving den

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sites with offspring and no remains of young were observed in dens when examined following abandonment.

3) While den sites near chronic human activity in 2002, 2006 and 2009 were departed within three days of den breakout (i.e., first emergence in spring from a sealed den), these abandonments fell within established norms for bears at undisturbed dens (3—13.2 d) as reported by Smith et al. (2007). While human activity may have been a factor in these den departures, we do not have sufficient evidence to determine its potential contribution. In each of these instances, cubs were observed leaving the den site with the female.

4) Individual bears responded differently to the same stimuli on numerous occasions. We noted a range of responses to the same stimuli by single bears, underscoring the difficulty in making conclusions based on limited observations. In its pilot year, the den monitoring project monitored two groups of polar bear dens, some near industrial activity (n = 2) and some not (n = 4). Researchers found that bears exposed to frequent industrial activity (e.g., heavy trucks on ice roads near the den) spent less time scanning their surroundings (i.e., vigilant behavior) than bears at den sites in undisturbed areas (Smith et al. 2007). This difference was attributed to habituation, a waning of wariness, as prolonged exposure resulted in no negative consequences. This varying level of response between individual bears could be explained by a number of factors, including age, life experience, the process of habituation, and den site location.

5) A change in posture, increased vigilance, rapid movement and abandonment all represent a behavioral change that is easily recognizable. A non-response is much more problematic to document, as there is no clear start or stop point to the non-interaction. Response group one (non-response) included observations of interactions with bears at open den sites that elicited no overt behavioral response. While we recorded a number of these non-responses (n =

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31), there were likely many more that went unrecorded, and denning polar bears may actually be far more tolerant to anthropogenic interaction than shown here.

It is possible that polar bears denning within the Greater Prudhoe Bay area are more tolerant of disturbance than those denning in areas with a reduced human presence, and results from this study may not be applicable in areas where bears have not been conditioned to human activity. Increased tolerance of human activity may even lead to bears denning near anthropomorphic features to utilize them as a type of human shield to discourage predators. Berger (2007) showed that parturient moose (*Alces alces*) in the greater Yellowstone Ecosystem increasingly selected birth sites closer to paved roads where traffic-averse grizzly bears (*Ursus arctos*) were less likely to be found. Other animals have been shown to adopt similar strategies to use human presence as a type of predation shield, and it is possible that female polar bears in the Southern Beaufort Sea are employing a similar tactic when denning close to industrial activity. Male polar bears represent the main den predator on the North Slope (Amstrup et al. 2006), and if males actively avoid industrial areas, females could possibly select those same areas to heighten den security. A comparison of male polar bear movement patterns within industrially active areas with those in areas devoid of human activity may address this question (i.e. if males are more likely to actively avoid human activity).

CONCLUSIONS AND RECOMMENDATIONS

These findings demonstrate that the 1.6 km buffer rule has been effective for minimizing den disturbance in industrially active areas on the North Slope. Additionally, we found that occupied dens are less vulnerable to disturbance than previously thought, and complete cessation of industrial activity in proximity to den locations may not be necessary. A recent case

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demonstrates how informed mitigation can result in success for managers, industry and polar bears. In March 2017, BYU and PBI deployed an autonomous camera unit near a confirmed den site adjacent to a bridge with vehicular traffic to a nearby oil and gas facility. The bear had denned within 10 meters of this bridge, and rather than completely suspend all traffic, the den was continuously monitored by remote camera for emergence activity. When bears were within the den, vehicles were permitted to cross the bridge. When the adult female emerged from the den on March 18, all use of the roadway was temporarily suspended until the family group departed their den on March 3, two weeks later. Work by Smith et al (2007) shows that after den breakout, bears remain largely in den, with only brief periods of out of den activity. As such, human activity could be coordinated rather than halted all together, particularly at night when bears have not been observed outside of dens (Smith et al. 2007). In locations where real-time den monitoring is not possible, the 1.6 km buffer is an effective means of avoiding potential disturbance during periods when den sites may be open.

Because our data provide limited insight regarding polar bear response to human activity at den sites, inferences are limited as stressor distances and frequencies were not replicated nor adequacy of sample size achieved. Future research at den sites with experimentally controlled distances and stimuli would provide a much clearer understanding of denned polar bear responses to human activity.

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TABLES

Table 2-1: Anthropogenic stressors observed interacting with polar bears on Alaska's North Slope, 1975-2017.

Group Number	**Stimulus Type**	**Stimulus Examples**
1	Aircraft	Helicopter, Fixed-Wing Plane
2	Large Machinery	Semi-Truck, Tucker Sno-Cat®, Cat Train, Tractor, Gravel Truck
3	Small Machinery	Pickup Truck, Snowmachine
4	Humans on foot	Survey Teams, Researchers in Tents

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Table 2-2: AIC model selection. Included is model structure, Akaike's Information Criterion adjusted for small sample size (AICc), change in AICc from the most supported model, (AICc), model weight (wi), and number of parameters (K).

Response Variable	Model Structure	AIC_c	ΔAIC_c	w_i	K
Bear Response	Stimulus Group + Intensity	282.5	0.0	0.90	18
	Stimulus Group + Distance + Intensity	289.0	6.5	0.03	24

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Table 2-3: Significant probabilities of categorized bears responses (1-4) for low, moderate and high intensity disturbance events involving categorized stimulus groups (1-4). A response of 1 represents a non-response, a response of 2 represents increased vigilance or a change in posture, a response of three represents rapid movement or escape to the den, and a response of 4 represents den abandonment.

	Low Intensity			Moderate Intensity			High Intensity		
Stimulus Group	Response	Probability	95% CI	Response	Probability	95% CI	Response	Probability	95%CI
1: Aircraft							2	20.0%	0.05-0.35
							3	57.4%	0.39-0.76
							4	22.6%	0.07-0.38
2: Large Machinery	1	27.5%	0.07-0.47						
	2	42.0%	0.20-0.64						
	3	30.5%	0.10-0.51						
3: Small Machinery	1	51.5%	0.34-0.69	1	36.6%	0.12-0.61			
	2	26.9%	0.12-0.42	2	39.1%	0.15-0.63			
	3	21.6%	0.08-0.36						
4: People Afoot	2	91.9%	0.80-1.00						

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FIGURES

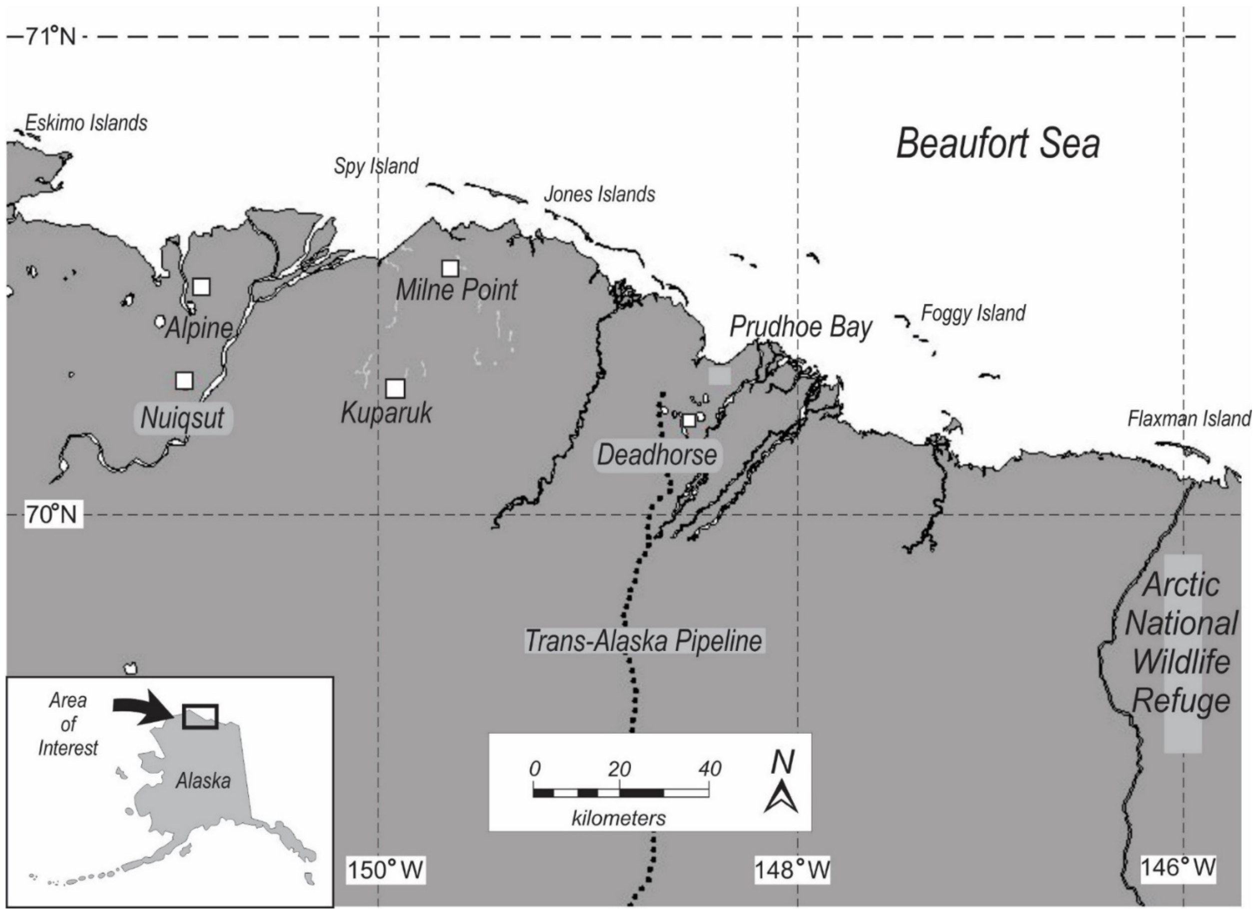

Figure 2-1: The Southern Beaufort Sea study area where polar bear den site observations were made (2002-2016).

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Location	Stimulus	Stimulus Gro	Clarification	Intensity	Distance	Cohort	Date	Duration	Result	Notes	Gen_Notes			
2	Bullen Point	Track Vehicle	2	Tucker	1	2	2	2002		1	No apparent	Tucker started up but sow showed no response			
3	Bullen Point	Track Vehicle	2	Tucker	1	2	2	2002		1	No apparent	Tucker engine started for warmth; no apparent response			
4	Bullen Point	Track Vehicle	2	Tucker	1	2	2	2002		1	No apparent	Tucker door was slammed			
5	Bullen Point	Track Vehicle	2	Tucker	1	2	2	2002		1	No apparent	Tucker engine started for warmth; no apparent response			
6	Bullen Point	Track Vehicle	2	Tucker	1	2	2	2002		1	No apparent	Tucker fired up			
7	Bullen Point	Large Vehicle	2	Snowblower	1	3	2	2002		1	No apparent	Blade and snowblower rumble by			
8	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Bear sleeps as truck drives by			
9	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	2 Trucks drive by, bear scans in general direction...			
10	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck drives by with no apparent response			
11	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	2 Trucks drive by, bear scans in general direction...			
12	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck drives by with no apparent response			
13	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck drives by with no apparent response			
14	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent response				
15	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
16	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
17	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
18	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
19	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
20	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
21	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck comes by			
22	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck comes by			
23	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
24	Bullen Point	Pickup	3		1	3	2	2002		1	No apparent	Truck passes by			
25	Bullen Point	Pickup	3		2	3	2	2002		1	No apparent	3 trucks rumble by			
26	Bullen Point	Pickup	3		2	3	2	2002		1	No apparent	2 more trucks come by			
27	Bullen Point	Pickup	3		2	3	2	2002		1	No apparent	2 more trucks come by			
28	Bullen Point	Pickup	3		2	3	2	2002		1	No apparent	2 more trucks come by			
29	Bullen Point	Pickup	3		2	3	2	2002		1	No apparent	2 more trucks come by			
30	Bullen Point	Fixed Wing A	1		2	3	2	2002		1	No apparent	Small aircraft flies overhead			
31	1038822922	Fixed Wing A	1		2	3	2	3/23/02	0.2	1	Fixed wing recon of den with radio tracking. Observed female out of den.				
32	Ice Road	pickup	3		2	1	2	1-Apr	0:00	1	cubs played outside den while pickup took photos				
33	Ice Road	Large Vehicle	2	snowblower	1	2	2	1-Apr	9:58	2	pulled head in den				
34	Bullen Point	Track Vehicle	2	Tucker	1	2	2	2002		2	Sow scans to	Will got out of tucker...			

Figure 2-2: A sample of the dataset used in the analysis

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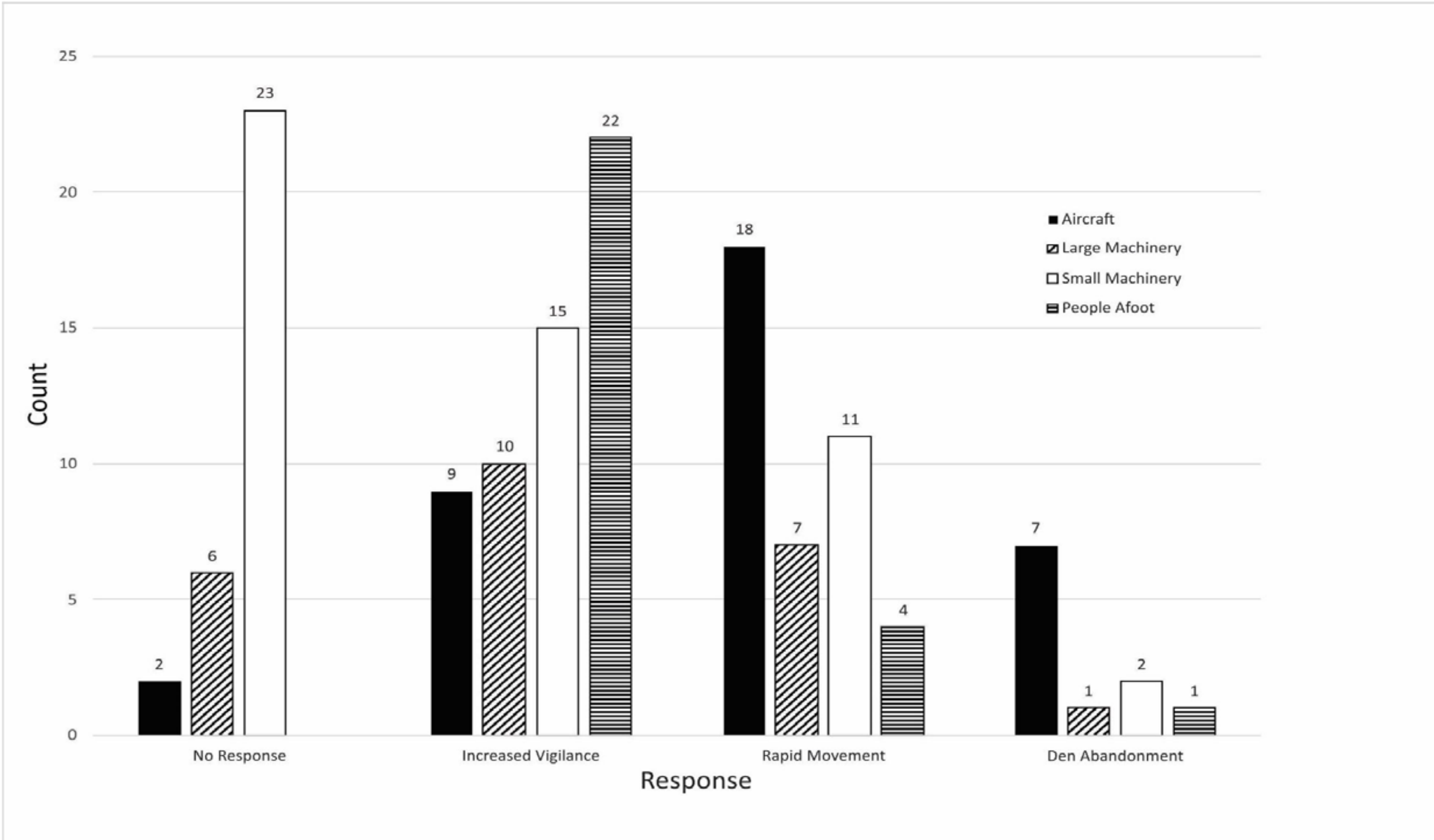

Figure 2-3: Counts of bear responses at all response levels for each stimulus class

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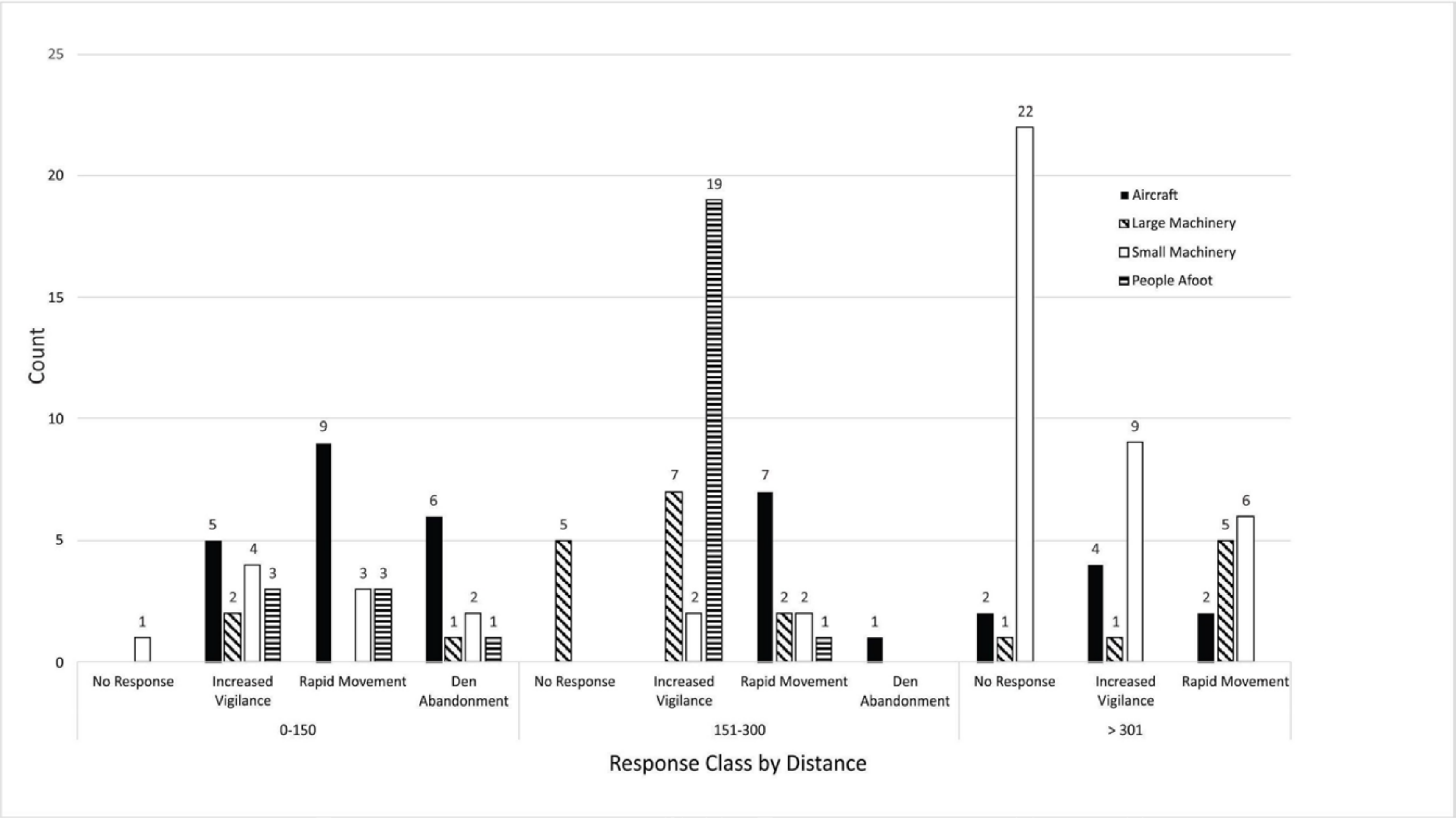

Figure 2-4: Counts of bear responses by distance group at all response levels and for each stimulus class. Distance groups are 0-150, 151-300 and >301 and all distances are given in meters

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Figure 2-5: A Tucker Sno-Cat® (Stimulus Group 2) approaches a polar bear at a den entrance on Flaxman Island, North Slope, Alaska.

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