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Predicting black bear activity at back-country campsites in Bryce Canyon National Park, Utah

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Abstract: Developing the capacity to predict black bear (*Ursus americanus*; bear) activity in a diversity of habitats will help conserve bear populations and their habitats and minimize human–bear conflicts. This capacity will be particularly important in areas that provide bear habitat and offer backcountry hiking and camping experiences. Bryce Canyon National Park (BRCA), located on the edge of the Paunsaugunt Plateau in southern Utah, USA, provides important bear habitat and offers visitors 12 backcountry campsites. To effectively manage these areas to minimize human–bear conflicts, park managers will need better information about black bear use of these campsites and other anthropogenic features in the BRCA. From 2014–2016, we studied the nature and frequency of bear activity within BRCA, with an emphasis on bear–campsite relationships, by analyzing bear activity data using radio-collared bears, remote camera monitoring of areas containing features of interest, campsite assessments, and analysis of human–bear interaction reports. We further assessed and ranked each backcountry campsite regarding its bear habitat quality, bear displacement potential, and human–bear conflict potential. Model selection showed bear preference for campsites and springs and avoidance of trails and roads. 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. Specifically, we recommend that campsites be no closer than 200 m to permanent water sources. Finally, while the park requires the use of bear-resistant food containers, we recommend backcountry visitors also be encouraged to carry bear spray.

Key words: black bears, Bryce Canyon National Park, campsite assessment, human–bear interactions, Paunsaugunt Plateau, *Ursus americanus*, Utah

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 bear (*Ursus* spp.) and visitor use patterns. 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 and to reduce disturbance to bears.

Quantitative habitat assessments are conducted 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 (Weilgus and Bunnell 1994, 2000).

The nutritional status of black bears (*U. americanus*; bear), 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 (Herrero et al. 1986, MacHutchon and Wellwood 2002), and hence estimate the bear encounter potential of a given location. 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 patterns, they have yet to be compared to actual bear activity data to test their predictive effectiveness.

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, 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, female black bears 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 affect bear habitat use, such as when black bears alter activity patterns when sympatric with grizzly bears (*U. arctos horribilis*; 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.

Increased 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 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 (Anderson et al. 2015). Landscape features such as foraging areas, springs, travel corridors, topography, and human activity levels influence levels of bear activity in a given area.

Bear habitat potential is an essential element of campsite assessment protocols (Herrero et al. 1986, MacHutchon and Wellwood 2002). While bears can be encountered nearly anywhere in the park, encounters are much more likely to occur in areas where bears are attracted to foraging opportunities. Therefore, bear foraging areas should be avoided, if possible, when selecting campsite locations. Research has indicated that black bears select vegetation and insects as mainstays in their diet, whereas mammal predation occurs opportunistically (Bates 1991).

Bear displacement potential protocols can help estimate the likelihood of bears being displaced by visitors in the campsite under evaluation (MacHutchon and Wellwood 2002). 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 (MacHutchon and Wellwood 2002, Coleman et al. 2013*a*).

Bear encounter potential protocols estimate the risk of surprise encounters with bears in campsite areas (MacHutchon and Wellwood 2002). 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.

We conducted this study to gain insight regarding bear–habitat relationships. Our study was conducted in Bryce Canyon National Park (BRCA), located on the edge of the Paunsaugunt Plateau in southern Utah, USA. The BRCA includes both natural and anthropogenic habitat features. Water is a limited resource in the arid, desert environment of BRCA. Both anthropogenic and natural water features within the park are scarce and likely present attractive temptations to foraging bears. Because visitor safety is important to the NPS, we also conducted thorough assessments for each backcountry campsite. Site assessments provide an estimate of human–bear conflict potential through both qualitative and quantitative measurements taken at each location. The primary objective of our study was to determine the degree to which characteristics at campsites are predictive of bear activity.

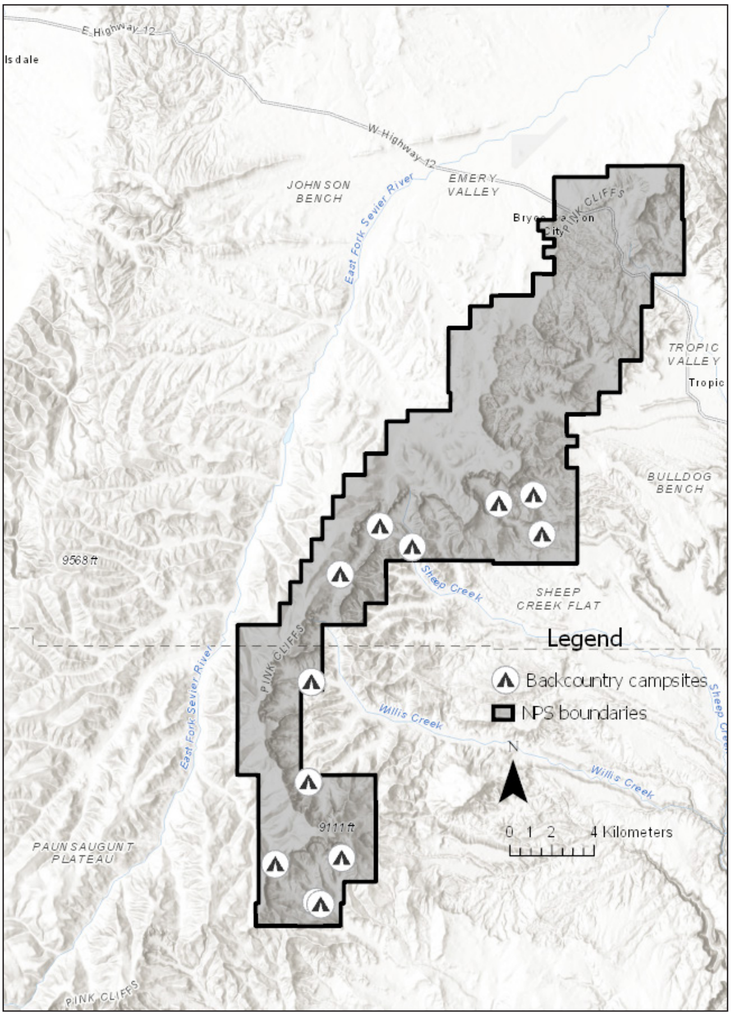

Figure 1. Boundaries for the Bryce Canyon National Park (BRCA) American black bear (*Ursus americanus*) study, BRCA, Utah, USA, 2014–2016.

Specifically, we: (1) identified bear movement and habitat use of the BRCA study area by radio-collared black bears; (2) photographed bear use of BRCA trails and spring/seep sites; (3) analyzed NPS Case Incident Reports (CIR) that involved human–bear conflicts within BRCA; (4) assessed backcountry campsites with respect to their bear habitat potential, bear displacement potential, and bear-encounter potential; (5) evaluated campsites previously closed due to repeated bear sightings and negative human–bear interactions; (6) reviewed published (peer-reviewed) literature regarding bear use of trails and campsite features; and (7) provided recommendations to NPS for backcountry camper education and human–bear conflict prevention.

Study area

The BRCA is located on the Paunsaugunt Plateau in southern Utah, USA. Approximately 16 km by 40 km, the Paunsaugunt Plateau is a southern extension of the Sevier Plateau, terminating in an area known as the Pink Cliffs at its southernmost point. Elevation ranges from 2,100–2,800 m. The plateau has several perennial streams as well as a spring that feeds into Tropic Reservoir. There are also several intermittent streams and springs that are present for parts of the year, drying up in the heat of summer (Gregory 1951). The climate on the plateau has average temperatures ranging from winter lows of -15°C to summer highs of 27°C. The plateau receives approximately 510 cm of snow per year and experiences 200 days of freeze and thaw cycles (Wikipedia 2019).

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

The BRCA encompasses 14,502 ha of the eastern edge of the plateau (Figure 1). Due to the steep escarpment for which BRCA is renowned, backcountry campsites are mostly located in forested canyon bottoms. The BRCA provides habitat for an estimated population of 20 bears

Figure 2. Example of an inactive barrel trap used in for capturing American black bears (*Ursus americanus*), Bryce Canyon National Park, Utah, USA, 2014–2016.

(S. Haas, BRCA, personal communication). The BRCA topography restricts and funnels bear movements as well as contains extensive areas of bear forage species. Consequently, backcountry campers are much more likely to observe and encounter bears than other visitors. Potentially dangerous bear encounters (involving human contact or property destruction) periodically occur in BRCA.

Methods

Bear captures and radio-collaring

We started trapping bears on June 12, 2014 and continued through July 2015. We did not conduct trapping from September to May during both years because bears were likely in hibernacula. Trapping was conducted in an area approximately 10 km by 16 km on the southern end of the Paunsaugunt Plateau. No trapping was conducted within the BRCA. We used 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 with a 4-wheel-drive pickup truck and then hand-carried them to pre-selected sites that were at least 20 m 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 week in a steel 208-liter 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 a 12 x 12-cm carpet square doped with either anise oil, banana oil, or loganberry oil from a tree. We placed traps in areas that had shade to protect bears from hyperthermia. We placed warning signs on nearby trees (within 20 m of the trap) to caution recreationists in the area. We placed a Model PC900 Reconyx® motion-activated trail camera (Reconyx, Inc., Holmen, Wisconsin, USA) to capture movement around the trap site. This provided information regarding bear activity in and around our trap sites that helped us refine our capture protocols.

We checked baited traps at 0900 hours daily. Once captured, bears were sedated with a combination of ketamine hydrochloride (100 mg/1 ml) and xylazine hydrochloride (100 mg/1 ml). 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 culvert trap. Once bears were immobilized, we removed them 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 global positioning system (GPS) collars (Advanced Telemetry Systems Inc., Isanti, Minnesota, USA), and programmed the collars to collect locational data every 4 hours throughout the day.

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 chose 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 biologists from the Utah Division of Wildlife Resources (UDWR), as these bears were previously ear tagged. 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.

Radio-collars were programmed to transmit locations every 4 hours. We considered a bear to be denned when ≥4 successive points were found in the same location following the first week of November. Denning was also inferred if only 1 point was transmitted in November, with no more successive points for at least 2 weeks. We remotely altered positional fix rates to 1 per 72 hours during the denning period to extend the collar's battery life. This research protocol was approved by the Brigham Young University (BYU) Institutional Care and Use Committee (IACUC) and operated under IACUC protocol number 140602.

GIS analysis

Bear locations were downloaded into ArcMap® 10.3 for spatial analysis. 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 study, we restricted the study area to only include the 14,502 ha 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. 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 locations with State of Utah vegetation maps and their corresponding vegetation types, and then 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 features (e.g., trails and campsites).

We employed second-order model selection, as it encompassed 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 (Johnson 1980). 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 our 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

For this study, we incorporated the findings from 2 recent studies of wildlife use of trails and springs in BRCA, including a report from 2013 (C. Wait, L. Bailey, S. Haas, and Z. Warren, National Park Service, unpublished report) and Anderson et al. (2015). These studies deployed 76 cameras in 88 different sites for varying amounts of time. Single cameras were placed on grid points roughly 1 mile apart, and at a smaller scale were placed on features of interest including trails, springs, and roads. Cameras were programmed to trip when motion-activated, and then take 5 photographs in succession with a 1-second delay between photographs and then a 15-second delay between the last photograph and a new succession. Cameras with video capabilities would take a single photo followed by a 10-second video (C. Wait, L. Bailey, S. Haas, and Z. Warren, National Park Service, unpublished

report; Anderson et al. 2015). Photographs containing bear individuals from this effort were provided to us for the purposes of our study.

Campsite assessments

We assessed each of the 12 backcountry campsites from 3 perspectives: bear habitat potential, bear displacement potential, and bear encounter potential. The assessments 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 NPS 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.

Using methods developed by Herrero et al. (1986) and MacHutchon and Wellwood (2002), we assessed backcountry campsites in BRCA for their bear habitat potential, bear displacement potential, and bear encounter potentials. We conducted these assessments for all 12 backcountry campsites within the park.

Human–bear case incident reports

We reviewed CIR from BRCA for information related to aggressive backcountry bear encounters. These reports are collected by park personnel following reported encounters with bears. We also included bear sightings that occurred within 100 m 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. Using the search terms bears and habitat and anthropogenic and relationships, we searched 7 databases comprised of peer-reviewed publications, including ProQuest Science and Technology, Biological Sciences, BioOne Abstracts and Indexes, GeoRef, Materials Research, Dissertations and Theses, Environmental Science Collection, and Science and Technology. This review was performed with assistance from the BYU Life Sciences librarian.

Results

We trapped bears at 35 different sites for 72 days in 2014 and for 6 days in 2015. During 2014, we captured (n = 17) black bears (7 males and 10 females), and during 2015 we captured 1 female bear. We collared 10 individual bears (n = 4 males and 6 females). Of those bears that were collared and had a tooth extracted for aging, 1 bear was a dependent cub (<1 year old), 5 bears were subadults (1–4 years old), and 4 bears were adults (>5 years old). One bear removed her collar within a day of trapping, 1 bear was harvested by a hunter during the summer of 2015, and 1 bear left the study area. As such, we have included locations from 9 individual bears in our analysis, but sampling timeframes vary among individuals. Four-hour intervals remained the standard for our GPS data collection.

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. This combination proved to be more effective than the previously recommended use of red licorice and gumballs. In addition, we found banana oil to be an ineffective attractant and discontinued its use.

Model selection and analysis

Modeling using AIC returned 2 fixed-effects models that accounted for 83.3% of the cumulative model weight. Model weight was nearly equally distributed between the 2 models, so we used both in our analyses. Model weights represented 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.,

Table 1. Akaike's Information Criterion adjusted for small sample size (AIC_c), change in AIC_c from the most supported model, (AIC_c), model weight (w_i), and number of parameters (K), American black bear (*Ursus americanus*) study, Bryce Canyon National Park, Utah, USA, 2014-2016.

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

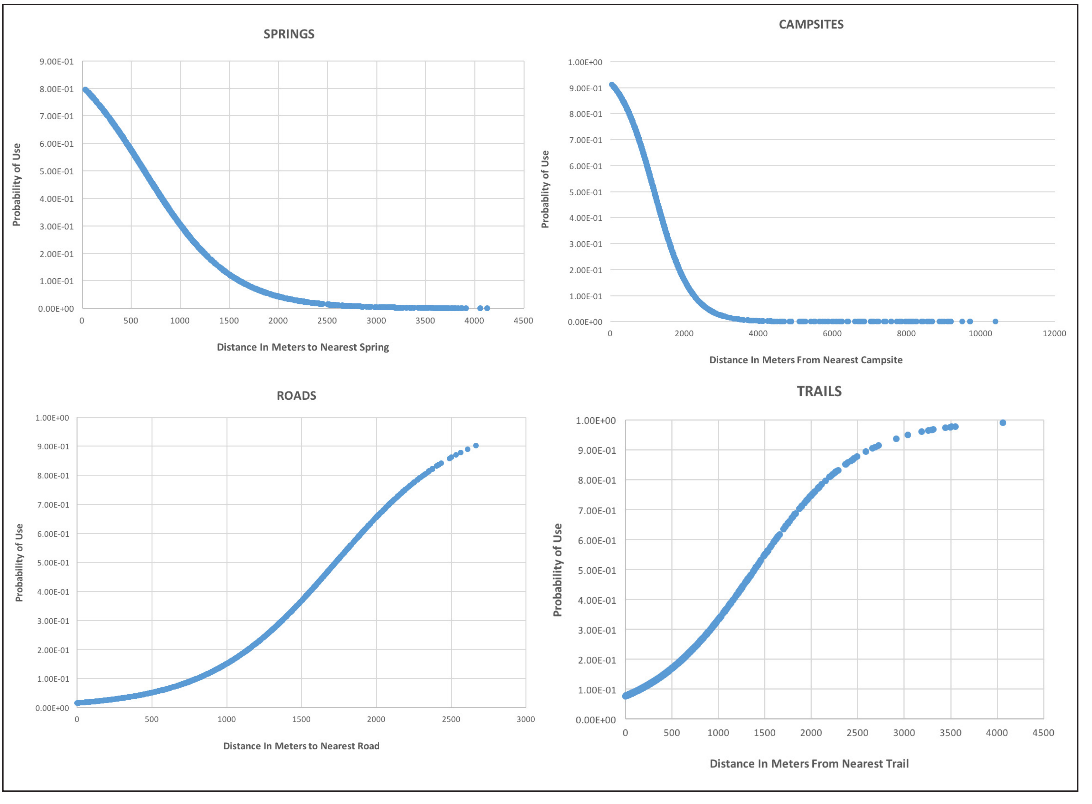

Figure 3. Relationship between radio-marked black bears (*Ursus americanus*) and back-country campsites, springs, roads, and trails, Bryce Canyon National Park, Utah, USA, 2014–2016.

trails and roads). Results from model selection have been grouped (Table 1) showing the top 2 models (w_i > 0.40), which illustrated how bears actively selected for or against different resources and features in BRCA.

Within our model analysis, relationships between bears and campsites (camp), springs (spring), trails (trail), and roads (road) were statistically significant ($P < 0.05$) when showing either selection or avoidance by collared black bears. In addition, 6 of the vegetation classes analyzed (veg) were selected for. Relationships between bears and these features (e.g., campsites, trails, roads, and springs) are presented (Figure 3).

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

GIS analysis

Vegetation composition of BRCA and bear activity per vegetation type are also presented (Table 2). The highest use occurred in the Rocky Mountain Gambel oak-mixed montane

Table 2. Utah habitat types, percentage of land cover, and associated American black bear (*Ursus americanus*) use, Bryce Canyon National Park, Utah, USA, 2014–2016.

Habitat type	% Cover	% Bear use
Rocky Mountain ponderosa pine woodland (RMPP)	36.3	32.0
Colorado Plateau pinyon-juniper woodland (CPPJ)	19.9	
Rocky Mountain cliff and canyon (RMCC)	18.4	1.4
Colorado Plateau mixed bedrock canyon and tableland (CPMB)	5.3	
Rocky Mountain subalpine dry-mesic spruce-fir forest and woodland (RMSD)	4.3	1.4
Rocky Mountain montane dry-mesic mixed conifer forest and woodland (RMMD)	4.0	<1.0
Rocky Mountain Gambel oak-mixed montane shrubland (RMGO)	3.1	56.0
Inter-Mountain Basins montane sagebrush steppe (IMBM)	3.1	
Rocky Mountain montane mesic mixed conifer forest and woodland (RMMM)	1.5	5.0
Inter-Mountain Basins big sagebrush shrubland (IMBB)	1.3	
Rocky Mountain subalpine mesic spruce-fir forest and woodland (RMSM)	1.0	<1.0
Rocky Mountain lower montane riparian woodland and shrubland (RMLM)	0.6	1.4
Colorado Plateau pinyon-juniper shrubland (CPPJ)	0.4	<1.0
Inter-Mountain West aspen-mixed conifer forest and woodland complex (IMWA)	0.3	1.8
Rocky Mountain subalpine-montane riparian shrubland (RMSM)	0.2	
Rocky Mountain alpine-montane wet meadow (RMAM)	0.1	
Inter-Mountain Basins semi-desert shrub steppe (IMBS)	0.1	
Rocky Mountain aspen forest and woodland (RMAF)	0.1	
Inter-Mountain Basins mat saltbush shrubland (IMBM)	<0.0	
Rocky Mountain subalpine mesic meadow (RMSM)	<0.0	
Inter-Mountain Basins mountain mahogany woodland and shrubland (IMBM)	<0.0	
Colorado Plateau mixed low sagebrush shrubland (CPML)	<0.0	
Inter-Mountain Basins semi-desert grassland (IMBS)	<0.0	
Open water (OW)	<0.0	
Inter-Mountain Basins shale badland (IMBS)	<0.0	

shrubland habitat type (RMGO), which comprised only 3.1% of the entire study area. The second highest used vegetation type was the Rocky Mountain ponderosa pine woodland (RMPP) habitat type, with bear relocations occurring 32% of the time in that habitat. To a much lesser extent, bears used the Rocky Mountain montane mesic mixed conifer forest and woodland (5%). Several other habitat types were also used by bears, but for short enough durations so as to account for <1% of overall fix locations. Bear locations for each habitat type within BRCA are presented (Figure 4), as well as habitat types that were associated with the top 2 models (Table 3).

Remote camera trapping

Twenty-four trail camera images of black bears in BRCA were recorded in the 2013 study (C. Wait, L. Bailey, S. Haas, and Z. Warren, National Park Service, unpublished report) and by Anderson et al. (2015). Of those images, we identified 15 photographs of bears using both trails and water resources within the park. Camera traps placed in 2013 by researchers from Colorado State University and BRCA staff recorded 4 bears using trails and 6 bears accessing springs. In 2015, a similar effort by NPS staff photo-captured 3 bears on trails and 1 bear at a spring (Figures 5 and 6). Remotely captured images from these studies

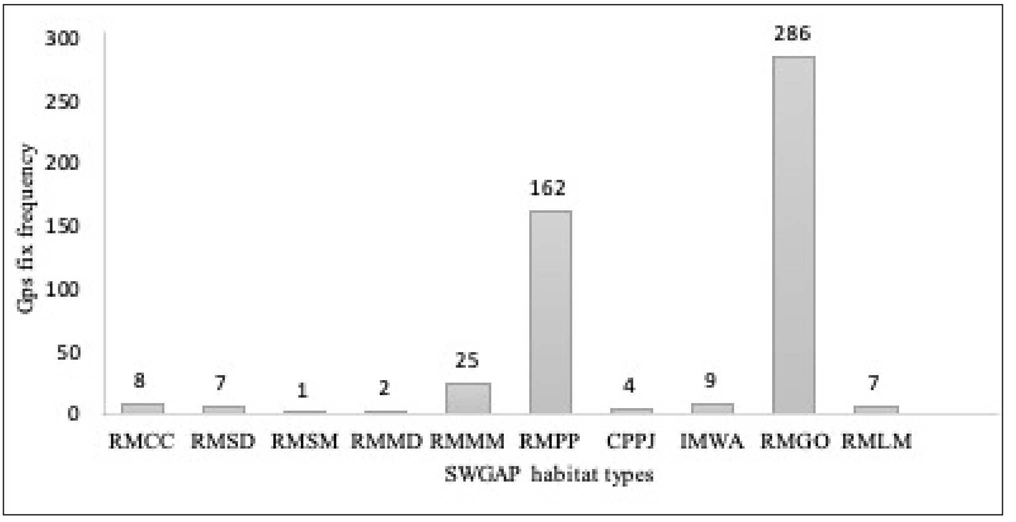

Figure 4. Southwest Gap Analysis Project (SWGAP) habitat types found within the Bryce Canyon National Park (BRCA), Utah and the total number of radio-marked American black bear (*Ursus americanus*) relocations within each used habitat type, American black bear study, BRCA, Utah, USA, 2014-2016. See Table 2 for definitions of habitat acronyms.

Figure 5. Photograph of an unmarked American black bear (*Ursus americanus*) using the Bryce Canyon National Park (BRCA) trail system near the Yellow Creek campsite, BRCA, Utah, USA, 2014–2016.

Table 3. Top 2 mixed-effects models and corresponding *P*-values for habitat types selected for by radio-marked American black bears (*Ursus americanus*), Bryce Canyon National Park, Utah, USA, 2014–2016.

Habitat type[a]	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

[a] See Table 2 for definitions of habitat type acronyms.

Figure 6. An unmarked female American black bear (*Ursus americanus*) with cubs accessing Iron Springs campsite, Bryce Canyon National Park, Utah, USA, 2014–2016.

provide supporting evidence that black bears periodically use BRCA trails, springs, and other features that were of interest in our assessment.

Campsite assessments

We visited the 12 backcountry campsites of BRCA and assessed them with respect to bear habitat potential, bear displacement potential, and bear encounter potential according to study protocols (Table 4). These campsites were located in ponderosa pine/Gambel oak, ponderosa pine/greenleaf manzanita, and ponderosa pine/bitterbrush habitat types. While ponderosa pine was the most prevalent conifer at campsites, Utah juniper and Rocky

Table 4. Campsite assessment surveys, American black bear (*Ursus americanus*) study, Bryce Canyon National Park, Utah, USA, 2014–2016.

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

[a] Bear habitat potential
[b] Bear displacement potential
[c] Bear encounter potential

Mountain juniper were also often present.

We assigned each campsite a human–bear interaction ranking of low, moderate, or high (Table 5). 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 4 of these sites are known as relatively high-use bear areas.

Through the campsite assessments, we documented a wide variety of forages used seasonally by bears. 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 BRCA. More bear encounters were reported that occurred 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 articles published in scientific journals. We refined our search results by eliminating publications that did not have information specifically relevant to human–bear relationships, specifically anthropomorphic landscape features such as roads, trails, and campsites. This refinement left 39 publications that provided information regarding bear use of trails, campsites, and other anthropogenic features.

Discussion

Our models indicated bears selected for campsites and springs and avoided trails and roads. Campsites in BRCA were typically located adjacent to trails (<10 m), often close (<100 m) to water sources, and in canyon bottoms that contained more vegetation cover and provided bear forage items. While

Table 5. Utah backcountry campsite rankings, American black bear (*Ursus americanus*) study, Bryce Canyon National Park, Utah, USA, 2014–2016.

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
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
Corral Hollow campsite	Low	Low	Low	Low	Low	Moderate

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. Herrero et al. (1986) recommended avoiding habitats selected by bears to minimize human–bear interactions for a proposed recreational development in Kananaskis Provincial Park, Canada.

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 this food-conditioning. Of those incidents reported to the NPS involving human–bear interactions at campsites, anthropogenic foods were involved in several. Whereas the park provided information regarding the proper handling and storage of food by hikers and campers, park officials voiced frustration over bears obtaining food from unsecured sources outside

of park boundaries, then returning to the park with bad habits (S. Haas, BRCA, personal communication). 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 human food-conditioning.

The bears we studied showed preference for spring locations, which was somewhat 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 followed the same response curve (Figure 3, upper left graph). As such, wildlife managers in BRCA should continue to expect higher levels of bear activity in areas that include reliable sources of water. These observations suggest that relocating campsites away from water sources would lower the probability of human–bear interactions in these areas.

Although our models showed that bears avoided trails (Figure 3), bear use of trails in the BRCA has been well documented. Bears can be expected to avoid trails as predictable thoroughfares of human activity, 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 a literature review all indicated that trail use occurs in black bear populations, as trails pose an obstacle-free movement corridor (Mattson et al. 1987, Coleman et al. 2013*b*). 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 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 vehicle 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 rare (C. Anderson, BRCA, personal communication).

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.

Rocky Mountain Gambel oak-mixed montane shrubland habitat was the most frequented habitat type by bears. Within this habitat type, Gambel's oak and other co-dominant species are important food sources for bears, especially in the late summer and early fall (Bates 1991). Our models indicated a strong preference for this habitat type. Bunnell (2000) documented that bears prefer RMGO habitat due to the numerous food species found therein. Rocky Mountain ponderosa pine woodland 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 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, Brigham Young University, personal communication).

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 (Welch et al. 1997, Rode and Robbins 2000). 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 and Robbins 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 animal protein include insects, such as bees (*Apis* spp.), wasps (*Vespinae* spp.), and ants (*Formica* spp.; Auger et al. 2004). Research beyond Utah indicated 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. 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

Trail cameras captured bears using trails within BRCA, but not enough for meaningful comparisons between seasons, time of day, or locations. However, the limited quantity of camera data, as well as collar data, reflected crepuscular bear activity typical to black bears (Smith 2002), with bear activity primarily occurring at dawn and dusk.

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. Among these changes is the relocation of campsites farther off-trail to avoid bears using trails. Campsites that were 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 m off trails and away from water sources can be expected to reduce the likelihood of human–bear interactions. The distance of 100 m would eliminate both visual and auditory cues that campers were present at the site.

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*b*) 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 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.

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 human–wildlife interactions but also provide wildlife with unrestricted access to water. For these reasons, we recommend that campsites be no closer than 200 m to permanent water sources.

Backcountry camper education

The NPS administered parks occupied by bears, including BRCA, require campers and hikers to receive information regarding proper conduct in bear country. This information is intended to educate the public on food storage and proper responses to bears when encountered. The NPS has extensive experience with bear education, and these resources should be made available to visitors of BRCA. While BRCA requires the use of bear-resistant food containers, encouragement of campers to carry 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 5). 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. Among park personnel, all 4 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 of which influence bear use of an area. Nonetheless, this ranking should provide useful guidance when park staff consider future management actions.

Closure area 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. An analysis of area closures in Yellowstone National Park confirmed their value for minimizing human–bear conflict (Coleman et al. 2013*a*). Our assessment of BRCA area closures revealed that 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. One common variable was the presence of a reliable water source, which is likely to contribute to human–bear interactions. These sites also showed signs of recent bear activity, including bear tracks, rub trees, and other bear sign. For these reasons, NPS mandated closures appear to be justified for reducing human–bear conflicts.

Improper food storage and handling, as well as irresponsible behavior in bear country, can result in human–bear conflict that has little or nothing to do with a given campsite's condition (Herrero et al. 1986). 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. While our subjective campsite ranking system is useful for the general assessment of human–bear interactions, proper education and appropriate human behavior are key to minimizing human–bear conflict.

This study provided insights 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 12 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-collared locations, remote camera data,

bear sign analysis, human–bear interaction reports, etc.) lends support to our assessments and conclusions. Our work indicated that while BRCA does not have a chronic problem with human–bear conflicts and interactions, there are a few actions, if taken, that would further reduce the likelihood of human–bear interaction and conflict.

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

1. Relocate campsites to >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. Relocate campsites to >100 m from the main trail system. Creating this minimum distance will likely decrease the potential for bears, which occasionally use trails as movement corridors, to enter 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.

Management implications

Implementation of our recommendations will help minimize the risk of negative human–bear interactions within the park. These findings are consistent with those of other studies, in that directing human activity away from high-use bear areas can minimize human–bear conflict, as well as human activity displacing bears from essential resources. 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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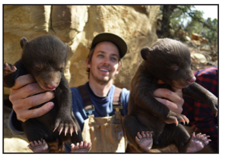

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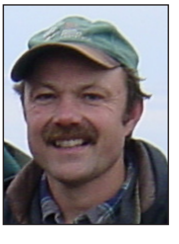

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