Post-release activity and habitat selection of rehabilitated black bears

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Abstract: Despite the long history of wildlife rehabilitation and the abundance of empirical knowledge of the behavior and resource selection of wildlife species, rarely does research bridge these disciplines. Such investigations could be of value to wildlife managers and rehabilitators by revealing the suitability of the habitat at selected release sites, the wild activities, behavior, and fitness of the captive-reared individuals, and ultimately the efficacy of the rehabilitation process. Rehabilitated carnivores warrant specific attention, given that they are wide-ranging and may behave in ways that threaten human safety or interests. We investigated the behavior of orphan, rehabilitated black bear cubs (*Ursus americanus*) during their first year after release by utilizing GPS collars, resource selection functions, and generalized linear mixed models. To understand if rehabilitated individuals exhibited species-typical behaviors, we included metrics commonly reported in other empirical studies of this species, such as immediate post-release movements, denning chronology, release-site fidelity, and resource use. Rehabilitated bear cubs denned shortly after release exhibited late-summer dispersals, showed preferential selection for certain habitat types based on season, and displayed no inclination toward utilization of anthropogenic resources. The survival and behavior of the orphaned bears in this study suggest that welfare-based captive care and rehabilitation can be a safe and effective practice without habitation to humans or deleterious effects on fitness.

Key words: animal welfare, denning, dispersal, rehabilitation, release, resource selection, *Ursus americanus*

Wildlife rehabilitation is a global practice that involves the capture and care of displaced, injured, and orphaned animals, often with the objective of returning those individuals to the wild (Miller 2012). The imperilment of animals in need of rehabilitation is frequently a product of interactions with one of the many anthropogenic-related dangers they face in their altered habitats (Wilcove et al. 1998). American black bears (*Ursus americanus*), which possess cognitive and physiological traits that enable utilization of anthropogenic resources and persistence in human-dominated landscapes (Stirling and Derocher 1990, Larivière 2001, Beckmann and Berger 2003, Johnson et al. 2015), are particularly susceptible to deleterious conflict with humans. The extensive overlap between human and bear populations and the frequency of their interactions (Can et al. 2014) has resulted in the widespread and nearly 40-year practice of welfare-based rehabilitation of black bears (Rogers 1985, Beecham et al. 2015).

Wildlife conservation and management are furthered when rehabilitation efforts also include scientific research (Pyke and Szabo 2018), performed both in the captive setting (Bremner-Harrison et al. 2004, Myers and Young 2018) and after the individuals are released (Goossens et al. 2005, Houser et al. 2011). Despite the perception that captive-reared animals might lack the skills, intuitions, and behavior required to survive in the wild (Jule et al. 2008), monitoring of rehabilitated black bears after their release is rarely conducted or only done so opportunistically (Clark et al. 2002, Beecham et al. 2015). This is especially surprising because of the concern that human-habituated bears and other large carnivores could threaten people's safety (Herrero et al. 2005). Indeed, the majority of wildlife releases lack a research component, including post-release monitoring and formal assessments of success, leaving most outcomes unknown (Guy et al. 2013, Seddon et al. 2007). Post-release monitoring could validate or reject concerns regarding animal fitness and human safety, provide insight into the activity of

individuals and ecology of populations, and further wildlife management efforts. Moreover, extended monitoring can elucidate if the welfare or survival potential of individuals has been improved through the rehabilitation process. This would provide an examination into the efficacy and value of the program as a whole.

Understanding the fitness of rehabilitated animals and wildlife ecology, in general, is predicated upon elucidating the relationship between individuals and their habitat. Hetero-geneous resource distribution, and animal movements that are required to access those resources, results in a concept of ecology that is fundamentally spatial (Cagnacci et al. 2010). Animal behavior includes the proximate mech-anisms of foraging (Owen-Smith et al. 2010), hunting (Davis et al. 1999), dispersal (Bowler and Benton 2005), shelter-seeking (Szor et al. 2008), and other activities necessary for survival and the perpetuation of populations (Krebs and Davies 1997, Mitchell and Powell 2012). Shedding light on many of these ecological components can be challenging for black bears and other large carnivores that are wide-ranging, cryptic, rare, or otherwise difficult to monitor (Thompson 2004). High-resolution monitoring via global positioning system (GPS) is a valuable tool for overcoming such monitoring challenges (Tomkiewicz et al. 2010) and has given rise to a variety of approaches to investigate space and resource use by wildlife, with one of the most widely used and statistically rigorous methods being the resource selection function (RSF; Manly et al. 2002, McLoughlin et al. 2010).

The RSF models provide an estimate of the use of a particular unit by an individual, relative to the availability of that unit on the landscape (Boyce et al. 2002). The RSF and other spatial-ecological models have been used in a variety of systems and for many species of large carnivores (e.g., Mauritzen et al. 2003, Roever et al. 2008, Dellinger et al. 2013, Squires et al. 2013, Knopff et al. 2014). Habitat suitability indices, such as RSF models, are particularly useful for management and conservation of black bears, given that their activity and movement are largely dictated by the availability and distribution of food resources (Alt and Beecham 1984, Clark et al. 2002, Merkle et al. 2013, Baruch-Mordo et al. 2014). Monitoring

rehabilitated bears to assess the expression of species-typical behavior and for the purposes of generating habitat suitability indices, such as RSF models, would be useful for management and conservation (*sensu* Boyce et al. 2002). High-resolution spatial data would allow researchers to identify behavior that reflects upon individual fitness, reveal habitat resources of particular value, detect the propensity of the animals to engage in human–wildlife conflict, and ultimately validate the cost and effort associated with rehabilitation.

This study presents the first application of GPS monitoring and spatial ecological modeling for rehabilitated American black bear cubs. Using data from GPS radio-collars, and statistical approaches that include resource selection functions and generalized linear mixed-effects modeling, we describe the post-release activity and ecology of rehabilitated black bear cubs in Utah, USA. Our study highlights components of bear ecology that would be of import to wildlife managers, including immediate post-release movements, denning chronology, dispersal events, and habitat selection, and relies on the long history of extensive empirical information regarding black bear ecology to draw comparisons. Results illustrate some of the potential outcomes that may follow the release of rehabilitated black bears, reveal facets of black bear ecology in semi-arid environments, and provide a broad perspective to agencies charged with the rehabilitation and management of wildlife.

Methods

Our study was conducted at several locations in the mountains of eastern and southeastern Utah, selected as release sites by Utah Division of Wildlife Resources (UDWR) biologists based on a combination of factors that included habitat supportive of black bears and limited human presence. Areas visited by the released bears varied in elevation from approximately 1,600–3,800 m; however, the majority of used locations was between 2,200 and 2,600 m. Two rehabilitated bears were released several kilometers from one another at each of 2 sites ($n = 4$): Elk Ridge (37.7° N, -109.9° W) and Lake Canyon (40.0° N, -110.7° W). One bear was released at each of 2 other sites ($n = 2$): Book Cliffs (39.3° N, -109.6° W) and the south slope
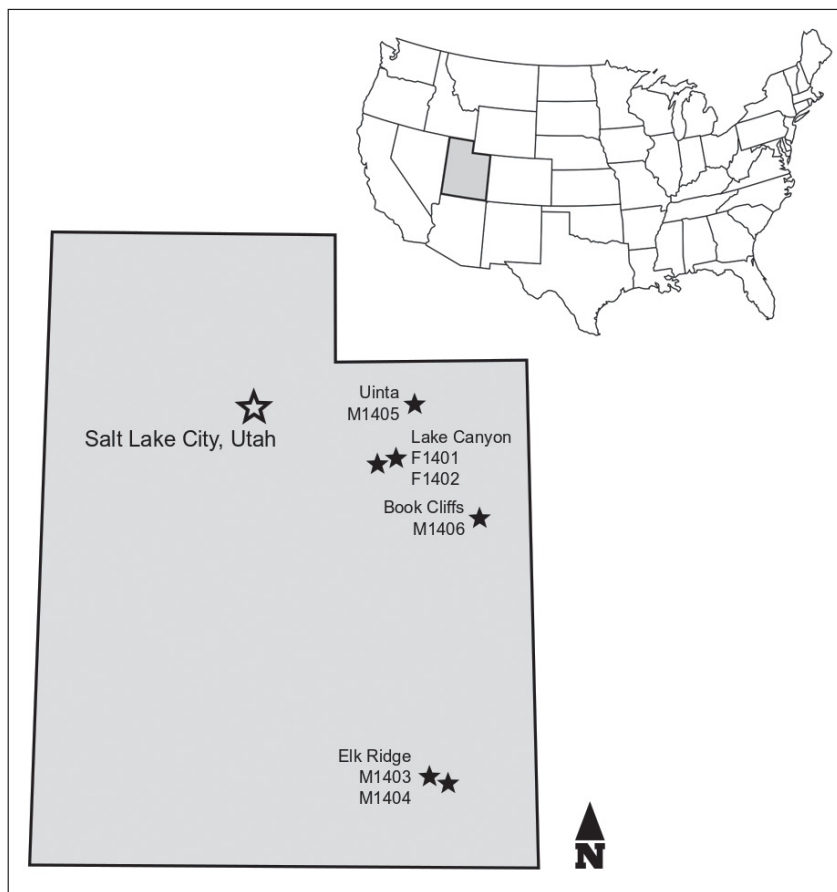
Figure 1. Release locations for 6 rehabilitated, orphan black bear (*Ursus americanus*) cubs in eastern and southeastern Utah, USA in December 2014.

of the Uinta Mountains (Uinta; 40.6° N, -110.2° W; Figure 1). Regional weather station data report that mean annual precipitation for Elk Ridge, Lake Canyon, Book Cliffs, and Uinta was approximately 51.8, 43.5, 51.7, and 77.1 cm, respectively, during the past decade (Menne et al. 2012). The variability in precipitation and topography among the sites produces a diversity of microclimates, with vegetative communities that are dominated by piñon (*Pinus edulis, P. monophylla*), juniper (*Juniperus osteosperma*), and oak (*Quercus gambelii*), and also include interspersed ponderosa pine (*Pinus ponderosa*), spruce (*Picea* spp.), fir (*Abies* spp., *Pseudotsuga menziezii*), and aspen (*Populus tremuloides*). Lower elevations and drier microclimates contain big sagebrush (*Artemisia tridentata*) and high-desert shrubland communities. A comprehensive overview of the vegetation in these regions can be found in Banner (1992).

Between July 1 and August 29, 2014, UDWR personnel captured 6 black bear cubs (2 females, 4 males; Table 1), orphaned from a variety of circumstances and deemed too young to survive without human intervention. Causes of being orphaned included when the mother was killed by a vehicle or involved in human–bear conflict, or when a cub separated from its mother. Cubs were raised with minimal human contact at the U.S. Department of Agriculture – National Wildlife Research Center's (NWRC) Predator Research Facility in Millville, Utah, USA. Captive care and handling was administered through NWRC-Standard Operating Procedure #ACUT-006.00, with research permitted under NWRC Institutional Animal Care and Use Committee (IACUC) permit QA-2354 and Utah State University IACUC permit #2434. Details of the facility are described in Myers and Young (2018). In early December 2014, cubs were affixed with GPS radio-collars (Advanced

Telemetry Systems Inc., Isanti, Minnesota, USA) and hard-released—returned to the wild without an acclimation period (Griffith et al. 1989).

The GPS radio-collars were programmed to record locations every 2 hours during the period between release and denning in 2014, and every 6 hours during the 2015 monitoring year. Movement metrics were calculated according to an hourly movement rate (m/hr) defined by the Euclidean distance between consecutive recorded locations divided by the fix interval. Immediate post-release activity extended from the moment of a bear's release to the time at which it arrived at its den. Criteria of denning chronology were as follows: arrival dates were those on which the bears arrived at and remained within the immediate area (<100 m) of their ultimate den sites; entrance dates were calculated according to the date on which satellite communication with the GPS radio-collar was lost; and emergence dates were those on which the bear moved >100 m from their den sites without returning or re-denning elsewhere. Release-site fidelity was measured with respect to the distance between the release location in 2014 and the location of the 2015 den site. As bear activity can be influenced by seasonal vegetative phenology (Davis et al. 2006, Baruch-Mordo et al. 2014), a binary metric was used to investigate temporal variation in activity and resource use: pre-hyperphagia in spring and early summer and hyperphagia in late summer and autumn. Pre-hyperphagia began on the date the bears vacated the den area and ended on August 31 or the date on which bears dispersed. Hyperphagia began on September 1 or the first day that followed a dispersal event and ended upon den arrival. We generated seasonal home ranges via estimation of the bivariate normal utilization distribution kernels (KDE) for each season at 95% confidence, using the R package "adehabitatHR" (Calenge 2006) and the reference (*href*) bandwidth estimation. The GPS fixes that appeared spatiotemporally outside of the seasonal home ranges, with increased intermediate distances between consecutive waypoints, and which did not lead back to the original vicinity, were identified as dispersal events.

We assessed bear resource use with regard to topographic, vegetative, and anthropogenic landscape variables. Topographic covariates were derived from 1 arc-second (30 m) USGS digital elevation models (DEM), and included slope, aspect, and terrain ruggedness. Aspect and slope were generated in ArcGIS 10 (ESRI, Redlands, California, USA), with aspect coded categorically and divided into 4 classes: north (reference class), east, south, and west. Terrain ruggedness was calculated in ArcGIS 10 via the Vector Ruggedness Measure index (Sappington et al. 2007), a spatial neighborhood calculation of orthogonal topographic variation designed to be uncorrelated with slope. Vegetative covariates were sourced from the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior LANDFIRE (Landscape Fire and Resource Management Planning Tools) database, and grouped into 8 broad and ecologically relevant classifications: grasses and forbs, piñon-juniper, oak, aspen, mixed conifer, barren, shrub, and riparian (Appendix A). The TIGER/Line Shapefile, 2014, Series Information for the All Roads County-based Shapefile (U.S. Census Bureau) served as a linear representation of anthropogenic presence at the sites and included all primary, secondary, four-by-four, logging, oil field, and private roadways. Vegetation classes and roadways were incorporated as continuous, distance-based variables. This is an effective methodology for habitat use studies and one which eliminates the subjectivity of selecting reference classes (Conner et al. 2003), with values generated via the "Euclidean Distance" tool in the ArcGIS 10 Spatial Analyst toolbox.

We investigated rehabilitated black bear seasonal resource selection at Johnson's (1980) third order of selection by incorporating biophysical habitat covariates in a used-available RSF design (Manly et al. 2002). Used points consisted of bear GPS locations, and only bears that retained their collars for the entirety of the 2015 monitoring season were considered for RSF analysis. Available points were generated systematically—one per 30-m^2 pixel within each seasonal home range. We assessed the validity of the waypoint locations and retained only 3D fixes. Continuous habitat variables were standardized via z-score trans-formations, whereby covariate values were subtracted from the mean value for that

respective covariate and divided by 1 standard deviation of the distribution of that covariate. We calculated Pearson product-moment correlation coefficients for habitat covariates, considering $r_s > |0.7|$ as the threshold for collinearity (Sheskin 2007). We used generalized linear mixed models (GLMM), implemented via the R package "lme4" (Bates et al. 2015), to compare distances from used points and distances from systematic available points to the nearest representative from each habitat covariate. We estimated the relative probability of use by using a GLMM framework and logistic models with logit links that took the form:

$$ ln \left(\frac{p}{1-p} \right) = \beta_0 + \beta_{1i}x_{1i} + \beta_{2i}x_{2i} \dots \beta_{ni}x_{ni} + Y_{0i} $$

in which β_0 represents the fixed-effect intercept, β_1 through β_n are the fixed-effect coefficients for selection of the respective X_1 and X_n biophysical covariates, and Y_{0i} is the random intercept for individual i. Random intercepts for individuals were incorporated into each model to account for sampling inconsistencies between animals and any potential lack of independence between GPS fixes (Gillies et al. 2006). We ran univariate models to ensure that selection for individual vegetation types were significant across all bears for their respective ranges. Vegetation covariates were combined to form a base model, which was included in all subsequent analysis. The base model was combined with all possible combinations of the fixed effects of topographic and anthropogenic covariates using the "MuMIn" package in R (Bartoń 2016). We tested the hypothesis that black bear response to habitat covariates is temporally variable by including an interaction of season with all fixed main effects. We sought to improve model fit by testing for nonlinearities using quadratic terms for topographic covariates and distance to roads. To avoid confounding effects, a nonlinear term and interaction of season for the same parameter were never included in the same model. The estimated probability of selection or avoidance was based on the strength and direction of coefficients: negative coefficients for the main effects of distance-based metrics indicated selection; negative coefficients for the interaction of distance-based metrics and season indicated selection during hyperphagia;

coefficient values close to zero indicated little to no effect, unless a seasonal effect was at play. Coefficients for non-distance-based covariates were reversed, with positive values indicating the relativity of selection. Models were ranked using corrected Akaike's Information Criterion (AICc) for small sample sizes (Burnham and Anderson 2002). For clarity, the terms selection and avoidance, aforementioned and used hereafter, represent the estimated probability of selection or avoidance as defined by a resource being used significantly more or less, respectively, relative to its availability within each individual's seasonal home range. Analyses were conducted and summarized using Program R 3.2.3 (R Development Core Team 2016).

Results

Five bears retained their collars for approximately 18 months, from release in December 2014 until emergence from dens in 2016, while 1 bear shed its collar in March 2015 and is only included with regard to immediate post-release activity analysis (Table 1). The interval between bear releases in December 2014 and arrival to den sites varied from 3–20 days ($\bar{x}$ = 8.2, SE = 2.7), and the distances between release sites and den sites ranged from 0.4–24.9 km ($\bar{x}$ = 6.5, SE = 3.8). The activity of 1 male cub, 1405, was anomalous and influential upon overall post-release activity statistics; this bear traveled a straight-line distance of 51.5 km from the release site at a rate of 336.8 m hour^{-1} (SE = 68.8) during the first 9 days and denned 20 days after release, approximately 25 km from the release site. When 1405 is excluded, cubs arrived at their den sites an average of 5.8 days (SE = 1.6) after release and the distance between release sites and den sites narrows to a range of 0.4–6.8 km ($\bar{x}$ = 2.9, SE = 1.2). For the 5 bears that retained their collars for the duration of the study, the mean dates for 2014 den arrival and den entrance were November 24 and December 1, respectively, and the mean date of den emergence for spring 2015 and spring 2016 both occurred on the 101st day (April 11 and April 10, respectively) of the calendar year (SE = 5.2 and 0.4).

Two bears, 1403 and 1406, conducted long-distance, late-summer dispersals, while the 3 others, 1401, 1402, and 1404, exhibited strong release-site fidelity. From August 30 to

Table 1. Details of the 6 black bear (*Ursus americanus*) cubs that were rehabilitated at the USDA-Predator Research Facility in Millville, Utah, USA, and released in Utah by the Utah Division of Wildlife Resources after being orphaned in 2014.

Bear ID	Sex	Capture weight (kg)	Release weight (kg)	Time in captivity (days)	Release location	GPS waypoints for analysis
1401	Female	4.0	43.5	155	Lake Canyon	885
1402	Female	5.6	47.1	141	Lake Canyon	990
1403	Male	13.6[a]	66.4	132	Elk Ridge	744
1404	Male	13.6[a]	64.3	132	Elk Ridge	989
1405	Male	15.9[a]	62.2	105	Uinta	344
1406	Male	15.9[a]	57.1	98	Book Cliffs	840

[a] Estimated

Table 2. Fixed effects model structures, negative log-likelihood (LL), and model selection results (AIC, ΔAIC) for the top 5 models, and base model, for generalized linear mixed-models of habitat selection, anthropogenic influence (distance to roads), and seasonal effects (pre-hyperphagia and hyperphagia) in 2015 by rehabilitated and released black bears (*Ursus americanus*) in eastern Utah, USA.

Model structure	K	LL	AIC	ΔAIC
Base+GR:S+OA:S+AS:S+BA:S+RI:S+DR+DR^2+S^2+R^2	23	-12176	24401	-
Base+GR:S+OA:S+AS:S+MC:S[a]+BA:S+RI:S+DR+DR^2+S^2+R:S[a]	24	-12182	24413	12
Base+GR:S+OA:S+AS:S+MC:S[a]+BA:S+RI:S+S^2+R:S[a]	22	-12186	24417	16
Base+GR:S+OA:S+AS:S+MC:S[a]+BA:S+SH:S[a]+RI:S+DR+DR^2+S:S[a]+R^2	25	-12183	24418	17
Base+GR:S+OA:S+AS:S+MC:S[a]+BA:S+SH:S[a]+RI:S+R^2	22	-12188	24424	23
Base	14	-12541	25112	711

[a] MC:S, mixed-conifer by season; R:S, ruggedness by season; SH:S, shrubland by season; S:S, slope by season.

September 3, 1403 traveled at an average rate of 570.1 m hour^{-1} (SE = 116.5) and resettled 43.8 km from his pre-hyperphagia range. Bear 1406 traveled an average of 153.0 m hour^{-1} (SE = 27.3) during his August 15 to September 5 dispersal event and resettled 46.3 km from his pre-hyperphagia range. The 3 non-dispersing bears remained within the general region of their release locations, with distance between their release sites and their final recorded locations (2015–16 den sites) ranging from 3.8–8.4 km ($\bar{x}$ = 5.7, SE = 1.4).

The best supported marginal model for third-order black bear habitat selection, which later represented the base model (Table 2), included all vegetation and topographic covariates but did not include the distance to roads covariate (Table 3, Group A); the top model had a model weight of 0.42, while the second best was 0.25 (also excluded distance to roads). Incorporating the top base model with season-interactions of vegetation covariates and quadratic terms

for topographic covariates and distance to roads, the most parsimonious model included seasonal effects of grasses and forbs, oak, aspen, barren, and riparian vegetation classes, and quadratic terms for distance to roads, slope, and ruggedness (Table 3, Group B). Coefficients indicate that bears' selection was strongest for north aspects, slightly less for east and west aspects (β = -0.259 and -0.504, respectively), and weakest for south aspects (β = -0.903). Coefficients from the fixed main effects indicate strong selection for aspen (β = -1.565), oak (β = -0.322), and mixed conifer (β = -0.515; Table 3, Group B). The strongest seasonal effects included aspen and oak, in which aspen habitats were strongly selected during spring and early summer and strongly avoided during hyperphagia (β = -1.565 and 1.651, respectively; Figure 2), and oak habitats, which elicited modest selection in general but were avoided during hyperphagia (β = -0.322 and 0.893, respectively; Figure 2). Utilization

Table 3. Fixed-effects coefficients, represented by the negative log-likelihood, from the top model of habitat selection, anthropogenic influence (distance to roads), and seasonal effects (pre-hyperphagia and hyperphagia) in 2015 by rehabilitated and released black bears (*Ursus americanus*) in eastern Utah, USA.

Biophysical covariate	Code	β	SE	*P*
GROUP A.[a]				
Intercept		-2.514	0.270	<0.001
Slope	S	0.114	0.024	<0.001
Ruggedness	R	0.282	0.029	<0.001
Aspect (North reference)				
East	AE	-0.259	0.045	<0.001
South	AS	-0.903	0.065	<0.001
West	AW	-0.504	0.049	<0.001
Grasses and forbs	GR	-0.054	0.024	0.027
Piñon-juniper	PJ	0.050	0.019	0.008
Oak	OA	-0.322	0.090	<0.001
Aspen	AS	-1.565	0.124	<0.001
Mixed conifer	MC	-0.515	0.089	<0.001
Barren	BA	-0.073	0.031	0.017
Shrub	SH	0.094	0.020	<0.001
Riparian	RI	0.084	0.027	0.002
GROUP B.[b]				
Grasses and forbs by season	GR:S	0.171	0.039	<0.001
Oak by season	OA:S	0.893	0.104	<0.001
Aspen by season	AS:S	1.651	0.125	<0.001
Barren by season	BA:S	-0.126	0.053	0.018
Riparian by season	RI:S	-0.126	0.041	0.002
Distance to roads	DR	0.019	0.034	0.586
Distance to roads quadratic	DR^2	-0.052	0.018	0.003
Slope quadratic	S^2	-0.165	0.021	<0.001
Ruggedness quadratic	R^2	-0.068	0.013	0.002

[a]Variables included in the base model.
[b]Additional fixed effects, including interactions of season and quadratic terms, which improved model fit.

of grasses and forbs also exhibited a strong seasonal effect, with greater selection earlier in the year (Figure 2). Nonlinear selection of slope and ruggedness were observed, in which selection of slope was greatest between 20 and 30 degrees; a similar intermediate degree of ruggedness was selected.

Discussion

We investigated the movement and resource selection of orphan, rehabilitated black bear cubs in Utah using GPS-collar data and generalized linear mixed RSF models. Although our sample size is small, results from this study have key implications for wildlife ecology and management, as it is likely the first to implement GPS-monitoring and spatial analysis for rehabilitated black bears. We recorded data for these bears for >1 year after release, anticipated the likelihood of dispersal events, predicted that resource selection would be influenced by season, and acknowledged the potential for
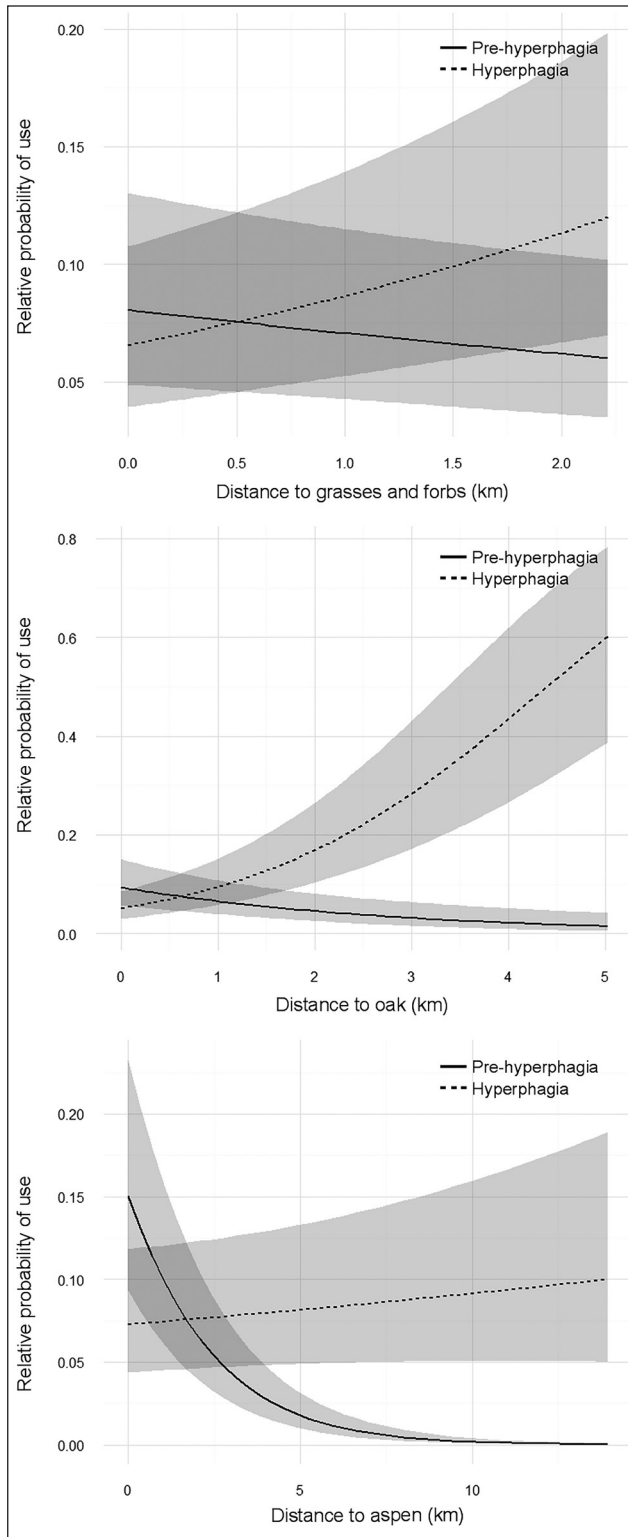
Figure 2. Habitat covariates (distances to grass-forb, oak, and aspen), which elicited a strong marginal response for selection by rehabilitated black bears (*Ursus americanus*) following their release in 2015 in eastern Utah, USA, with shaded bands representing 95% confidence limits.

atypical behaviors, given that bears of this age would normally be traveling with and influenced by the behavior of their mothers. We found that these rehabilitated black bear cubs selected resources similarly to wild-raised bears, established home ranges in areas proximate to release sites, and were not predisposed to immediately seek out or utilize anthropogenic resources post-release.

Black bears, whether rehabilitated yearlings (Binks 2008, Beecham et al. 2015) or translocated sub-adults and adults (Linnell et al. 1997, Clark et al. 2002, Wear et al. 2005), occasionally travel long distances immediately after release. This is an undesirable outcome, given that release sites are often carefully selected and because of the innumerable anthropogenic dangers that may be encountered and the potential for human–bear conflict. In this study, 5 of 6 bears denned shortly after release and only 1 bear (1405) traveled >7 km from the release site before denning. Excluding 1405, bears denned an average of 2.9 km from their respective release sites. Over the entirety of the study, the 5 bears that retained their collars remained near the release sites for at least 8 months, and 3 bears remained for the duration of monitoring. We believe that several factors may have reduced the potential for immediate post-release dispersals. Here, bears were collected and released as cubs, before they had developed a home range, and before they would exhibit the acute homing tendencies common in older animals (Rogers 1987, Linnell et al. 1997). The cubs were also released in early winter when environmental conditions would compel them to den immediately (Beecham and Ramanathan 2007). Although we monitored these bears for <2 years, the fact that both females remained proximal to their release sites reflects the philopatric tendencies of female bears reported in previous studies (Swenson et al. 1998, Beckmann

and Berger 2003, Costello et al. 2008).

The approximately 40 km, late-summer dispersal events of the 2 yearling males in our study occurred at a time when bear forays are common. Noyce and Garshelis (2011) reported that about half of all bears in Minnesota engaged in late-summer movements that averaged 10 km for females and 26 km for males. Other studies report similar results: average dispersals of 34 km for 60 rehabilitated black bears in Canada (Binks 2008), 13 km for wild yearling bears in West Virginia (Lee and Vaughan 2003), and 40 km for wild male yearlings in New Mexico (Costello 2010). Given the similarities in topography and vegetation structure between New Mexico and Utah, it is not surprising that the dispersal distances are also comparable. While the proximate mechanisms for the dispersal events are unknown, the hyperphagia regions selected by the 2 dispersing bears were considerably more remote, with fewer road features and human access, and third-order modeling did not include selection for roads, which suggests that utilization of anthropogenic resources was not of influence.

Denning chronology for the bears in 2014 was influenced by the release schedule, but dates of den entrance for the second year were just marginally later than during the release year. Den entrance and emergence for both years were within normal ranges for black bears, although with a slightly later entrance than some (Beecham et al. 1983, LeCount 1983, O'Pezio et al. 1983, Larivière 2001, Immell et al. 2013). Baldwin and Bender (2010) report that bears in Colorado arrived at dens later in wetter years. A den check of 1401 in spring 2016 revealed a high body condition score, with body mass similar to the time of release a year earlier and likely greater than a wild bear of the same age. The greatly enhanced body condition of the bears in our study—a typical product of the rehabilitation process—may have served as a functional analog to a productive food year and provide an explanation for den entrances in 2015 that seemed somewhat late. Similar to Beecham et al. (1983), we report that for the second year, during which denning chronology was not influenced by release date, bears arrived at their den sites approximately 1 week before entering. A study of black bear denning

behavior in Utah from 2011 to 2013 (Miller et al. 2017) reported that bears left the den approximately April 8, which coincides closely to our reported April 10–11 average.

It is presumed that photoperiod and circadian rhythm are predominant drivers for many species life-history processes (Dibner et al. 2010), including the denning chronology of black bears (Johnson and Pelton 1980, Schooley et al. 1994)—a phenomenon that may have been demonstrated by our results. Interestingly, despite the differences between sites with regard to latitude, microclimates, and landscape-level biophysical components, the den emergences for the 5 bears in spring 2015 and spring 2016 fell on the same mean Julian date (101). Moreover, the range of spring 2016 den emergence for the 5 bears, some hundreds of kilometers apart, spanned just 3 days. These results add to the evidence of the influence of photoperiod on bear denning behavior, though these relationships should be explored further.

Because black bear activity is hypothesized to change by season and be influenced primarily by food availability and distribution (Alt and Beecham 1984, Clark et al. 2002, Beecham et al. 2015), we evaluated our data by time of year, with results in support of a seasonal effect on space use. The most pronounced effects involved a seasonal response to aspen, which could be explained by a number of factors. Spring and early summer aspen-dominated habitats often contain sources of water, productive understory vegetation, and serve as parturition sites for mule deer (*Odocoileus hemionus*) and other ungulates (Pojar and Bowden 2004, Latham et al. 2011), the offspring of which are reliable, protein-rich resources for bears (Zager and Beecham 2006). Prior research by Young and Ruff (1982) demonstrated that bears in Alberta selected aspen sites for their seasonally available resources. Good hard mast production in 2014 and poor production in 2015 (D. Mitchell, UDWR, personal communication), helped explain the bears in our study occupying oak habitats in spring 2015 rather than fall. McDonald and Fuller (2005) demonstrated that overwintered hard mast, such as acorns, can be of great importance to bears in spring months. In eastern Utah, which can be hot and dry in late summer, avoidance of oak habitat during this time may allude to the exposed nature of these vegetation communities, with cover

having been demonstrated as an important habitat characteristic for black bears (Lindzey and Meslow 1977, Young and Beecham 1986). The strong seasonal effect for aspen and oak communities witnessed here may be a product of the generalist and season-specific diet of black bears in which ungulates neonates, insects, and hard and soft mast are temporally available. Fall production by junipers has been linked to black bear fitness during the following spring (Costello et al. 2003); however, we did not witness a strong selection for piñon-juniper, either as a main effect or with an interaction of season. Further, the ubiquity of piñon-juniper on the landscape may have masked true selection or avoidance.

Similar to previous research (Reynolds and Beecham 1980, Servheen 1983), bears in this study showed a strong, early-season selection for grasses and forbs. In spring and early summer, these lower-quality food sources are often the only readily available forms of green vegetation. By the time the moisture associated with the spring season passes and grasses and forbs cease production and become less palatable, other forms of vegetation are then available for bear consumption. Although seasonal selection of barren regions and riparian vegetation appeared in the top model, their coefficients, and a visual inspection of their seasonal effects, do not indicate biologically significant effects. Previous research has documented that road use by humans is negatively related to bear presence (McLellan and Shackleton 1988, Mace et al. 1996, Switalski and Nelson 2011). A quadratic term for distance to roads improved model fit, but this was likely a product of landscape structure and not biologically significant. Mesic microhabitats, higher vegetative productivity, and greater cover accompanied north facing slopes in our system; thus, it was not surprising to witness selection for northerly aspects and reduced use of south-facing slopes. We believe that vegetation structure and ease of locomotion contributed to the nonlinear, intermediate selection of slope and ruggedness.

The post-release behavior of 1405 was atypical but serves as an example for what could happen after releasing a black bear or other wide-ranging animal. Following his release at 2,700 m (8,800 ft) elevation, mixed-conifer habitat, 1405 traveled >50 km to the crest of the Uinta Mountains and denned at 3,760 m (12,336 ft) in a talus field. Clark et al. (2002) surmised that there may be a negative relationship between the success of releases and regional black bear population densities. The montane and subalpine habitat in which 1405 was released was the most productive of all sites; should those habitat conditions correlate to a higher population of black bears, it is possible that 1405 encountered and was displaced by a conspecific in the days subsequent to release. Although the release sites used in this study may have been selected to enhance bear populations, there were no data available on population estimates of black bears specific to these areas. Alternatively, J. Beecham (Idaho Department of Fish and Game [retired], personal communication) has witnessed multiple cases of failed attempts at denning by rehabilitated bears, resulting in individuals being above ground and facing exposure for the remainder of winter. Not only did 1405 appear to attempt to den several times, as informed by clusters of GPS locations, but the dens that were selected likely did not provide ample protection from the elements, as evidenced by the GPS collar maintaining daily satellite communication throughout the denning season. Tietje and Ruff (1980) reported that bears which abandoned ≥1 den experienced a significantly greater decline in body mass than those that maintained a single den for the entire period. We surmise that 1405 was unable to find or excavate a suitable den, which led to high elevation, winter exposure, and a substantial reduction in body mass, thus facilitating the shedding of its collar in spring 2015.

Given widely held concerns about the potential for unnatural behaviors by captive-reared animals, we cautiously draw comparisons to data from other empirical investigations of black bear ecology. The first is that it is not possible to study wild-reared cubs or yearlings, or indeed most large carnivores, in this way because under natural circumstances, cubs travel with and are dependent on their mothers, with movement largely dictated by her (Reynolds and Beecham 1980). The second is due to the small sample size of this study. While this is certainly not unique among studies involving carnivores, particularly

those including captive-reared individuals, it does hinder us from making robust population-level inferences (Leban et al. 2001). However, the reasons that cause our cautious extrapolation highlight the importance of this data to fill gaps in the literature for rehabilitated or translocated wildlife.

Management implications

The results of this study provide insight into the variability of individual behavior of released rehabilitated black bear cubs and highlight effective strategies for rehabilitation and release efforts. For instance, most orphan black bear rehabilitation programs release the animals during their second year of life, despite the positive relationship between time in captivity and probability of human–bear conflict (Beecham et al. 2015). Here, cubs were orphaned and captured at approximately 6 months and released 3–5 months later—a methodology much less common and even less documented, despite its efficacy and the reduction of rehabilitation time and effort (Beecham and Ramanathan 2007).

Because the success of this rehabilitation effort was measured in large part by the ability of the bears to survive and exhibit species-typical behaviors, it was vital to select release sites with limited human presence. Rural roadways, both developed and unimproved, were prevalent within the bear home ranges; however, resource selection modeling indicated that habitat selection was not influenced by them. What was lacking within the vicinity of the sites, however, was human habitation and its associated development—features that increase the availability of anthropogenic resources and the potential for interactions with humans (Alt and Beecham 1984, Linnell et al. 1997). As opportunities to utilize anthropogenic resources were limited, so too was the potential for atypical behaviors, human–wildlife conflict, and threats to human or bear well-being.

Results also highlight how monitoring and analytical approaches similar to those of this study can inform wildlife and ecosystem conservation objectives. Prior knowledge regarding species-specific ecology, for instance, should be used to tailor monitoring and management efforts, and varying monitoring regimes and data analysis to explore wild activity at different temporal or spatial scales may yield new and valuable insights. Further, studies like this are able to reveal habitats of import to specific wildlife populations. For example, we provide additional evidence of the important role of aspen habitats, which are critical for innumerable wildlife species and which may be threatened without appropriate management. Thus, protecting and restoring these vegetative communities could enhance black bear and other wildlife populations.

Ultimately, we contend that wildlife rehabilitation is an effective practice to facilitate the long-term health and survival of orphaned, sick, or injured black bears. If conducted short-term and with restricted human contact, the rehabilitation process should not detrimentally affect the future behavior or fitness of the animal, but allow it to live self-sufficiently in its natural habitat. Indeed, because the principle goal of rehabilitation is to better the lives of imperiled animals, it is imperative that rehabilitators are able to monitor and assay the individuals during their time in captivity. Moreover, should the behavior or health of an individual indicate that their greatest welfare may not exist in a wild setting, alternate humane options should exist, such as permanent placement in an accredited captive facility. Post-release monitoring of rehabilitated animals that provides data on movement and landscape-level behavior is vital to understanding the efficacy of the rehabilitation process, the validity of captive behavioral assessments, and alleviate concerns over post-release welfare and fitness. We believe that rehabilitation of orphan black bear cubs is an advisable practice for wildlife practitioners in the state of Utah and throughout its range.

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Appendix A. Reclassified vegetation covariates used within the resource selection function and GLMM framework for global positioning system radio-collar data from 6 orphaned black bear (*Ursus americanus*) cubs after they were released in December 2015 in Utah, USA. Results of compositional analysis are represented by the area (km^2) of seasonal home ranges (pre-hyperphagia and hyperphagia) occupied by each of the vegetation types.

Landcover class	Description of vegetation classification	Pre-hyperphagia	Hyperphagia
Grasses and forbs	Annual and perennial graminoid grassland and forbs	2.38	2.02
Piñon-juniper	Colorado Plateau piñon-juniper woodland and savanna	80.54	96.91
Oak	Gambel oak shrubland and Gambel oak mixed-montane shrubland	8.08	5.92
Aspen	Aspen forest, woodland, and parkland	14.69	18.10
Mixed conifer	Mixed conifer forest and woodland; ponderosa and lodgepole pine woodlands	37.93	24.36
Barren	Barren; rocks, rock outcrops, and talus fields; sparsely vegetated	37.88	56.36
Shrub	Sagebrush, blackbrush, and desert scrub; Colorado Plateau and foothill shrublands	25.05	46.31
Riparian	Riparian systems; wetland herbaceous zones and floodplains	3.74	3.94

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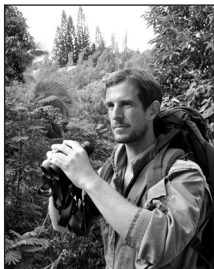
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