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Spatial Ecology and Captive Behavior of Rehabilitated Black Bears in Utah

Patrick J. Myers
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Understanding animal behavior is critical to species life-history, community ecology, and wildlife management. One such behavior, movement, is a fundamental component that governs organismal fitness and is often shaped by the manner in which individuals utilize their habitat. Thus, spatial dynamics play a critical role in animal ecology. The study of animal space and resource use is particularly salient for the reintroduction of rehabilitated carnivores, given their wide-ranging nature, their release into habitats that are assumed to meet their needs, and human-safety which is reliant upon the expression of natural behaviors by those animals. Rehabilitated animals, however, are rarely monitored after release. I utilized GPS technology, resource selection functions, and generalized linear mixed models, to investigate the immediate post-release movements, denning chronology, release-site fidelity, and season-delineated movements, home ranges, and resource use for six, orphaned and rehabilitated black bears (Ursus americanus) – the first such study of its kind. Results indicate species-typical behaviors, with bears denning shortly after their releases, exhibiting elevated movement rates and
dispersals during late-summer, preferential selection for certain habitat types based on season, and no utilization of anthropogenic-resources.

Animal behavior that differs consistently between individuals, across time or context, is referred to as personality. Personality has been observed in a variety of taxa, in both captive and wild settings, and has even been used as an a priori technique to predict fitness, life-history traits, and, for captive animals, their success after release. Here, I present the first application of captive behavior tests for the investigation into black bear personality. To date, no studies have investigated the presence of personality in black bears. Through open field, novel object, startle object, and focal-animal sampling, we investigate the potential for personality in six black bear cubs, as well as the potential for behavior traits to relate to wild activity. Results indicate consistency in behavior: some bears were consistently bolder or more active across the series of tests, thus indicating personality. Analysis to identify correlations to wild activity metrics did not yield strong statistical support, however. Information presented here should provide a framework for future research into black bear personality, its relationship to life-history and ecology, and lend support for rehabilitation practices for orphan bear cubs.
Spatial Ecology and Captive Behavior of Rehabilitated Black Bears in Utah
Patrick J. Myers

Animal movements and space use are fundamental components of life and play integral roles in organismal fitness, population dynamics, and the ecology and evolution of species. The heterogeneous distribution of resources and the movement required to access them, results in ecology being a fundamentally spatial concept. Thus, elucidating animal-habitat relationships is a central focus of wildlife ecology and conservation. I utilized GPS technology, resource selection functions, and generalized linear mixed models, to investigate the immediate post-release movements, denning chronology, release-site fidelity, and season-delineated movements, home ranges, and resource use for six, orphaned and rehabilitated black bears (*Ursus americanus*). This study represents the first application of GPS monitoring and resource selection for rehabilitated black bears. Data from this study provide insights into the activity of released rehabilitated black bear cubs, highlight trends among the release cohort, and illustrate the variability of individual behavior. Results indicate species-typical behaviors, with bears denning shortly after their releases, exhibiting elevated movement rates and dispersals during late-summer, preferential selection for certain habitat types based on season, and no utilization of anthropogenic-resources.

One primary concern for large carnivores that have been captive-reared or had prolonged exposure to humans during rehabilitation, is whether they will exhibit natural behaviors after release. Behavior testing in other species has revealed that many traits
exhibited in captivity often translate to wild behavior, however this had not yet been investigated for black bears. This study presents the first application of captive behavior tests for the investigation into black bear personality, defined by consistency in the individual differences in behavior across time or context. Through open field, novel object, startle object, and focal-animal sampling, we investigate the potential for personality in six black bear cubs. Results indicate consistency in behavior across five metrics for the bold-shy axis, and eight sampling events measuring responses for the activity axis, thus indicating personality. Analysis to identify correlations to wild activity metrics did not yield strong statistical support, however. Information presented here may provide a framework for future research into black bear personality, its relationship to life-history and ecology, and lend support for rehabilitation practices for orphan bear cubs.
ACKNOWLEDGMENTS

Graduate degrees do not come easy. This is particularly true of those that involve raising a half dozen orphan bear cubs. Suffice it to say, I would not have been able to do this alone, so I would like to acknowledge the many people and organizations integral to this process.

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Patrick J. Myers
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CHAPTER 1
INTRODUCTION

The breadth and magnitude of anthropogenic forces on the environment are unprecedented and have resulted in human-domination of many of Earth’s ecosystems (Vitousek et al. 1997, Seto et al. 2012). This new paradigm is driven in large part by a human population that is increasing by 83 million individuals per year and is expected to reach 11 billion by the end of the century (United Nations 2015). The transformation of ecosystems to satisfy escalating human demands for food, fiber, fuel, homes, and economic development is environmentally deleterious and pervasive (MEA 2005). For instance, cropland is now one of the largest biomes, covering ~25% of Earth’s terrestrial surface (Foley et al. 2005), and urban development, considered a permanent land conversion, is a primary driver of species extinction (McKinney 2002). The United States is central to this phenomenon as, in the past half century, development in rural and exurban areas have increased by 500% and now cover approximately 25% of the contiguous states (Hansen et al. 2005). Though human actions may be short-term and localized, their effects may be permanent (Dupouey et al. 2002) and manifest at many scales, with implications for biodiversity (Sala et al. 2005, Newbold et al. 2016), ecosystem structure and composition (Haddad et al. 2015), and global abiotic processes (Karl and Trenberth 2003). As these effects escalate unsustainably and push ecosystems toward irreversible thresholds (Chapin et al. 2010, Brook et al. 2013), research has focused on the response by species from a variety of taxa, including plants (Williams et al. 2009), arthropods (McIntyre 2000), birds (Marzluff et al. 2001), herpetofauna (Hamer and McDonnell 2010), and mammals (Gehrt et al. 2009).
Wildlife species face many direct and indirect threats as humans encroach on and alter their native ranges (Wilcove et al. 1998). Principle hazards include the loss of native habitat, reduced patch size, and decreased connectivity (Wilcox and Murphy 1985). As wildlife navigate the fragmented and degraded vestiges of their former habitats, they are more likely to confront humans and human-induced dangers (Forman 2000, Theobald et al. 2011), such as lethal and nonlethal effects of roads (Trombulak and Frissell 2000, Fahrig and Rytwinski 2009), human recreation (Knight and Cole 1995), regulated hunting (Ruth et al. 2003), and other forms of human-wildlife conflict (Dickman 2010). Many of these threats are intensified for large carnivores, which have long been perceived to endanger human lives, livelihoods, and property (Treves and Karanth 2003), and, for the past several centuries, been persecuted to the point of extirpation and extinction (Linnell et al. 2001, Miller et al. 2013). Human views are slowing shifting, and the unique ecological roles carnivores play are garnering increased appreciation (Ripple et al. 2014), however, the greatest threat posed to carnivores continues to be death from humans and the hazards associated with life among human development (Woodroffe 2000, Dickman 2010). As human encroachment and human-wildlife interactions become more common, there have been increasing demands for wildlife management strategies that incorporate non-lethal techniques, and measures that promote animal welfare and coexistence (Linnell et al. 2001, Lindsey and Adams 2006). These evolving views have been central in the burgeoning field of wildlife rehabilitation.

Wildlife rehabilitation is a process that provides aid to injured, sick, orphaned, or confiscated animals (Karesh 1995). Rehabilitation has been used for a variety of species (Goossens et al. 2003, Moore et al. 2007, Houser et al. 2011, Williams and Gregonis
2015), and one North American species that is a common recipient of this practice is the American black bear (*Ursus americanus*; Rogers 1985). Black bears range over much of North America and possess many cognitive and physiological traits that enable them to thrive in human-dominated regions (Stirling and Derocher 1990, Lariviére 2001, Beckmann and Berger 2003, Johnson et al. 2015); as such, human-bear interaction is common (Can et al. 2014). Bears can profit from the utilization of anthropogenic resources (Beckmann and Berger 2003, Hostetler et al. 2009), however, these benefits often do not outweigh the dangers associated with life in human-dominated landscapes (Beckmann and Lackey 2008). One direct threat is the orphanning of bear cubs caused by death or displacement of adult females. Should the orphaned cubs be too young to survive on their own, human-intervention may be required (Alt and Beecham 1984, Rogers 1985). A variety of reintroduction methods have been developed for orphaned black bear cubs (Rogers 1985), with one, captive rehabilitation, demonstrated as a safe and effective practice throughout its 40-year history (Clarke et al. 1980, Beecham et al. 2015). Despite their successes, however, rehabilitation practices still face concerns, in part because of the beliefs that human-habituated animals may pose a threat to humans after release (Herrero et al. 2005), or that captive-reared animals will lack the skills, intuitions, and behaviors required to survive in the wild (Jule et al. 2008). Monitoring could validate or reject these concerns and provide insight into the activity and ecology of rehabilitated black bears, however it is rarely employed (Clark et al. 2002, Beecham et al. 2015).

Several techniques have developed to understand space and resource use by wildlife (McLoughlin et al. 2010), with one of the most widely used and statistically
rigorous methods being the resource selection function (RSF; Manly et al. 2002). RSF and similar spatial-ecological models have been used for a variety of species and systems, including carnivore ecology (Mauritzen et al. 2003, Roever et al. 2010, Dellinger et al. 2013, Adams Knopf et al. 2014). The frequency with which human and carnivore populations overlap (Bateman and Fleming 2012), and the perceived dangers carnivores pose, necessitate a thorough understanding of carnivore space use. Habitat suitability indices, such as RSF models, are particularly useful for management and conservation of black bears (sensu Boyce et al. 2002). Black bear activity and movement is largely dictated by the availability and distribution of food resources (Alt and Beecham 1984, Clark et al. 2002, Baruch-Mordo et al. 2014, Beecham et al. 2015); this, along with the generalist foraging strategies and high food demands necessitated by their unique life-history, are reasons why human-black bear conflicts are exceedingly common (Can et al. 2014). High-resolution monitoring and resource use modeling could elucidate animal ecology, alleviate concerns regarding the dangers of large carnivores, such as black bears, and reveal human-wildlife spatial relationships in areas of potential conflict (Hebblewhite and Merrill 2008, Burton et al. 2012). However useful, monitoring is still an inherently reactionary management strategy, and researchers have become increasingly interested in methods to assess fitness a priori; one tool for doing so is behavioral testing, which may provide predictive insights into wild activity long before the animal is released (Bremner-Harrison et al. 2004, Smith and Blumstein 2010).

Animals – human and non-human, alike – possess unique behavioral profiles, often referred to as personality (Sih et al. 2004). Personality in non-human animals (hereafter, animal personality or, simply, personality) is characterized by consistency in
behavior across time or context, often measured with regard to several broad behavioral
traits, such as boldness, exploration, activity, aggression, or sociability (Réale et al.
2007). Personality is being increasingly observed across a broad range of taxa, including
insects, fish, birds, and mammals, and is a rapidly growing interest within the field of
animal behavior (Gosling 2001, Bell et al. 2009). The proximate mechanisms that govern
intraindividual variation in animal behavior are complex, interactive, and include
combinations of genetics (Dochtermann and Roff 2010), maternal effects (Dloniak et al.
2006), epigenetics (Herb et al. 2012), endocrinology (Moore 1983), and environmental
effects (Bell and Sih 2007). Garnering attention of late are the implications of personality
to organismal life-history and evolution (Wolf and Weissing 2012). For instance,
personality traits have been linked to some of the most fundamental of animal behaviors,
including reproduction (Cote and Clobert 2007), foraging (Johnson and Sih 2005), and
dispersal (Cote et al. 2010). With animal behavior so closely linked to fitness
(Dingemanse and Réale 2005), and as so many components of Earth’s biosphere are
rapidly changing from anthropogenic pressures (Chapin et al. 2010), advances to
conservation and evolutionary biology necessitate a more thorough understanding of
animal personality and phenotypic variation, including their ecological and evolutionary
implications.

Here, I present two firsts: the application of GPS monitoring and spatial
ecological modeling for rehabilitated American black bears, and an investigation into
black bear personality. Captive behavioral tests were administered to orphan black bear
cubs to assess personality along the bold-shy and activity axes. Using data from GPS
radiocollars, resource selection functions, and mixed-effects modeling, I describe post-
release movements, denning chronology, and season-delineated activity, home ranges, and habitat selection during the first year in the wild for the rehabilitated bears. Ultimately, these approaches could yield valuable insights into behavioral ecology, address gaps in the literature regarding bear personality, post-release activity of rehabilitated bears, and black bear spatial ecology in Utah, and provide a broad perspective to agencies tasked with the management of this species.

LITERATURE CITED


Houser, A., M. Gusset, C. J. Bragg, L. K. Boast, and M. J. Somers. 2011. Pre-release hunting training and post-release monitoring are key components in the


CHAPTER 2

SPATIAL ECOLOGY OF REHABILITATED BLACK BEARS IN UTAH¹

ABSTRACT

Fitness for animals is governed by the ability with which individuals are able to utilize the components of their habitat; thus, wildlife ecology and management necessitates a thorough understanding movement, space use, and resource needs for organisms. The study of animal space and resource use is particularly salient for the reintroduction of rehabilitated carnivores, given their wide-ranging nature, their release into habitats that are assumed to meet their needs, and human-safety which is reliant upon the expression of natural behaviors by those animals. Rehabilitated animals, however, are rarely monitored after release. I utilized GPS technology, resource selection functions, and generalized linear mixed models, to investigate the immediate post-release movements, denning chronology, release-site fidelity, and season-delineated movements, home ranges, and resource use for orphaned and rehabilitated black bears (*Ursus americanus*). Results indicate species-typical behaviors, with bears denning shortly after their releases, exhibiting elevated movement rates and dispersals during late-summer, preferential selection for certain habitat types based on season, and no utilization of anthropogenic-resources. The survival and behavior of the rehabilitated bears in this study suggest that captive care of orphaned wildlife can be a safe and effective practice with no apparent deleterious effects on fitness.

¹ Co-author is Julie K. Young; chapter formatted for Journal of Wildlife Management
INTRODUCTION

Movement is a fundamental component of life and plays an integral role in organismal fitness, population dynamics, and the ecology and evolution of species (Nathan et al. 2008). Proximate mechanisms surrounding the movement of animals include 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 individual survival and the perpetuation of populations (Krebs and Davies 1997, Mitchell and Powell 2012). Depending on the activity, animals exhibit a variety of different canonical movement modes (Fryxell et al. 2008) and are influenced by assorted environmental factors, such as conspecifics (Galef and Giraldeau 2001, Held et al. 2010), anthropogenic pressures (Roever et al. 2010, Stillfried et al. 2015), and predation risk (Lingle 2002, Gower et al. 2008).

At a landscape level, animal movements are collectively known as space use, which, when constrained in space and time, serve to delineate home ranges (Powell and Mitchell 2012). Home ranges represent the breadth of organismal space use, shaped by the intensity with which organisms utilize resources needed to maximize fitness (Millsapough et al. 2006, Kie et al. 2010). The heterogeneous distribution of resources and the movement required to access them, results in ecology being a fundamentally spatial concept (Cagnacci et al. 2010). Thus, elucidating animal-habitat relationships is a central focus of wildlife conservation (Morris 2011).

A variety of techniques have been developed to investigate space and resource use by wildlife (McLoughlin et al. 2010), with one of the most widely used and statistically rigorous methods being the resource selection function (RSF; Manly et al. 2002). RSF
models are defined generally as 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). Here, units represent habitat variables, while the landscape, which contains a proportion of those units, can be defined at several scales (Johnson 1980). Incumbent in this process is knowledge of the location of an animal in space and time – data which has become increasingly more accurate, instantaneous, and easily attained though technological advances in monitoring, such as global positioning systems (GPS; Hebblewhite and Haydon 2010). RSF and other spatial-ecological models have been used in a variety of systems, and are being increasingly utilized for many carnivore species (Mauritzen et al. 2003, Roever et al. 2010, Dellinger et al. 2013, Squires et al. 2013, Adams Knopff et al. 2014).

The expansive home ranges and resource requirements of carnivores, along with the frequency with which their populations overlap with humans (Bateman and Fleming 2012), and the perception that they threaten human lives and property (Treves and Karanth 2003), necessitate a thorough understanding of carnivore space use. In North America, these concerns have been compounded as, after centuries of persecution, many populations of carnivores are increasing in abundance and range (Miller et al. 2013). This is particularly relevant for American black bears (Ursus americanus), which possess a number of traits that allow persistence in human-dominated landscapes (Stirling and Derocher 1990, Larivière 2001, Beckmann and Berger 2003, Johnson et al. 2015) – areas which project innumerable anthropogenic dangers upon wildlife (Wilcox and Murphy 1985, Woodroffe 2000, Ruth et al. 2003, Beckmann and Lackey 2008, Dickman 2010, Theobald et al. 2011). One hazard black bears face is human-induced displacement and
morality of adult females that leads to the orphaning of cubs, the frequency of which has led to the development a number of reintroduction methods, such as captive rehabilitation (Rogers 1985, Beecham et al. 2015). Though used widely, and demonstrated to be safe and effective, wildlife rehabilitation still faces many concerns, including the belief that captive-rearing produces human-habituated animals which may later threaten humans (Herrero et al. 2005), and skepticism about whether captive-reared animals will possess the natural behaviors, intuition, and skills required to survive in the wild (Jule et al. 2008). Despite these concerns, however, rehabilitated black bears are often only monitored opportunistically, if at all, and little information is gathered regarding their wild activity (Clark et al. 2002, Beecham et al. 2015).

Monitoring black bears for the purposes of generating habitat suitability indices, such as RSF models, are particularly useful for black bear management and conservation (sensu Boyce et al. 2002). Black bears are wide-ranging omnivores, with generalist foraging strategies, and activity and movement largely dictated by the availability and distribution of food resources (Reynolds and Beecham 1980, Merkle et al. 2013, Baruch-Mordo et al. 2014). The spatiotemporal variability of resources has direct implications for black bear habitat use: ungulate parturition sites early in the year provide high-protein neonates (Zager and Beecham 2006), and seasonal and micro-habitat phenology offers areas of hard or soft mast (Davis et al. 2006). Further, the opportunistic and generalist diets of black bears, and their unique life-history, in which they exhibit dramatic increases in caloric consumption in late-summer and fall in preparation for denning (Nelson et al. 1983), also result in human-black bear conflicts being exceedingly common (Can et al. 2014). As such, a number of studies have investigated black bear space and
resource use along the human-wildland interface (Merkle et al. 2013, Baruch-Mordo et al. 2014, Johnson et al. 2015). High-resolution monitoring and resource use modeling has been used for elucidating animal ecology, alleviating concerns regarding the dangers of large carnivores, and revealing human-wildlife spatial relationships in areas of potential conflict (Hebblewhite and Merrill 2008, Burton et al. 2012). For rehabilitated black bears, specifically, high-resolution spatial data could expose behaviors that reflect upon individual fitness, allow for detection of resources of value, identify the propensity of the animals to engage in human-wildlife conflict, and, ultimately, validate the costs associated with rehabilitation.

Here, we present the first application of GPS monitoring and spatial ecological modeling for rehabilitated American black bears. Using data from GPS radiocollars, and statistical approaches that include resource selection functions and mixed-effects modeling, we described the post-release activity and ecology of rehabilitated black bears in Utah. We describe many components of bear ecology that would be of import to wildlife managers, including immediate post-release movements, denning chronology, and season-delineated movement rates, home ranges, and habitat selection. Results illustrate some of the potential outcomes that may follow the release of rehabilitated black bears, reveal facets of black bear ecology in Utah, and provide a broad perspective to agencies charged with the rehabilitation and management of black bears.

**METHODS**

*Capture and rehabilitation* – Between 1 July and 29 August 2014, Utah Division of Wildlife Resources (UDWR) personnel captured six orphaned black bear cubs (2
females, 4 males) deemed too young to survive without human intervention (Table 2.1). Cubs were raised at the United States Department of Agriculture (USDA) National Wildlife Research Center’s (NWRC) Predator Research Facility in Millville, Utah, until they were an appropriate age and body condition that warranted their release. The housing structure contained two enclosures, each 16.5 m long, 7 m wide, and 2.5 tall (288.8 m³), separated by a 7.5 m long, 2 m wide, and 2.5 m tall transitional pen, called a shift (Fig. 2.1). The walls and ceilings of the pens and shift were chain-link fencing. Solid-metal, guillotine-style doors, operated from an adjacent room, allowed for entrance and egress of bears between the pens and shift. Both pens were functionally identical and contained wood climbing structures, logs, a large pool of water, two den boxes, natural vegetation, and a constantly flowing source of fresh water. After an initial period that included frequent care and the provisioning of liquid formula, cubs were fed once daily, with quantities of solid food that continually increased in accordance with their body mass. In an effort to reduce familiarity with humans, the cubs had one primary caretaker, and bear-human interactions were minimal. All captive care was provided in accordance with NRWC animal care protocol, derived from widely accepted procedures (Beecham and Ramanathan 2007), administered under the authority of NWRC-SOP #ACUT-006.00, with research permitted under NWRC QA-2354 and Institutional Animal Care and Use Committee (IACUC) of Utah State University permit #2434.

Prior to release, the six cubs were immobilized, marked with uniquely numbered ear tags and subcutaneous passive integrated transponders (PIT), and assessed with regard to health and body condition. For monitoring after release, very-high-frequency (VHF) radiotelemetry collars, equipped with GPS (Advanced Telemetry Systems Inc.
[ATS], Isanti, Minnesota, USA), were affixed to the bears. To reduce the potential for injury or suffocation as a result of growth during the subsequent year, cotton spacers, designed to cause the collars to break off of the animals given sufficient pressure, were fitted to the collars (Hellgren et al. 1988). The collars were also equipped with a remotely-activated, drop-off mechanism. In early December 2014, cubs were transported for hard-release at four locations (Fig. 2.2) selected by UDWR biologists based on a combinations of factors, including habitat supportive of black bears and limited human presence. Collars were programmed to remotely detach from all males in May 2016, while the females were to retain their collars for further monitoring by UDWR. A den check was performed in February 2016 on one of the female bears to assess neck condition and overall health.

**Study Area** – This study encompassed much of eastern Utah, and included four sites where the rehabilitated cubs were released, described generally as Elk Ridge (37.7º N, -109.9º W), Lake Canyon (40.0º N, -110.7º W), Book Cliffs / East Tavaputs Plateau (hereafter, Book Cliffs; 39.3º N, -109.6º W), and the south slope of the Uinta Mountains (hereafter, Uinta; 40.6º N, -110.2º W). Regional weather station data report that mean annual precipitation for Elk Ridge, Lake Canyon, Book Cliffs, and Uinta were approximately 51.8, 43.5, 51.7, and 77.1 cm, respectively, during the past decade (Menne et al. 2012). The topography across these sites is diverse, with respect to both ruggedness and elevation; areas visited by the released bears varied in elevation from 1600 m near Canyonlands and the southern Bookcliffs, to 3800 m in the Uinta Mountains, however the majority of used locations were within the elevational range of 2200 to 2600 m. The variability in precipitation and topography among the sites produces a diversity of
microclimates and vegetative communities. The three more xeric sites – Elk Ridge, Lake Canyon, and Book Cliffs – are dominated by piñon (Pinus edulis, P. monophylla), juniper (Juniperus osteosperma, J. monosperma, J. communis), and Gambel oak (Quercus gambelii), with high ridges, plateaus, and northerly aspects supporting ponderosa pine (Pinus ponderosa), Douglas fir (Pseudotsuga menziezii), spruce (Picea spp.), and aspen (Populus tremuloides). Flat, arid expanses, lower elevations, and southerly aspects in these regions consist of mountain brush communities, including sagebrush (Artemisia spp.), and curl-leaf (Cercocarpus ledifolius) and mountain mahogany (C. montanus). Riparian corridors contain big tooth maple (Acer grandidentatum) and willow (Salix spp.). Other supported species that are of interest to bears include serviceberry (Amelanchier alnifolia), chokecherry (Prunus virginiana), squaw apple (Peraphyllum ramosissimum), cliffrose (Purshia spp.), and a variety of grasses and forbs. Semi-desert basins, steppe, and other marginal habitats surround many of the study sites and contain vast expanses of sagebrush, sparse piñon-juniper communities, rabbitbrush (Ericameria nauseosa), blackbrush (Coleogyne ramosissima) and bitterbrush (Purshia tridentata). In contrast, the more mesic Uinta site possesses montane, sub-alpine, and alpine ecological zones, and supports spruce-fir communities (Engelmann spruce, Picea engelmannii; blue spruce, Picea pungens; subalpine fir, Abies lasiocarpa; white fir, Abies concolor), lodgepole pine (Pinus contorta), vast meadows of grasses, abundant forbs such as wild geranium (Geranium spp.), and barren talus fields above treeline. A comprehensive overview of the vegetation communities in these regions can be found in Banner (1992).

Black bear populations in Utah are concentrated in the central and eastern portions of the state, primarily within the coniferous forests and high elevations of the
Wasatch, Uinta, and Manti-La Sal ranges. Black bears are managed as a game species in Utah and, depending on the management unit, may face combinations of spring, summer, and fall limited-entry hunts, including the use of dogs or bait-hunting. Secondary roads provide access throughout much of the sites, and are used for recreation, hunting, and, in some places, oil and gas extraction. The study areas are administered by the U.S. Forest Service, Bureau of Land Management, or Uintah and Ouray Reservation.

Movement and space use – GPS collars were programmed to record locations, or fixes, 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 distances traveled between consecutive fixes, divided by the fix interval. Immediate post-release activity extended from the moment of bear release to the time at which it denned. 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 collar was lost; and emergence dates were those on which the bear moved > 100 m from their den sites without returning or re-dennning 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 highly influenced by vegetative productivity (Davis et al. 2006, Baruch-Mordo et al. 2014), a binary seasonal metric was used to investigate temporal variation in activity and resource use. Seasonal delineation was as follows: pre-hyperphagia began on the date the bears vacated the den area, and ended on 31 August, or the date on which bears dispersed ($n = 2$); hyperphagia began on
1 September, or the first day that followed a dispersal event, and ended upon den arrival. Home ranges were generated by estimating 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. Distances between home ranges were calculated with respect to the centroid of each polygon. GPS fixes associated with dispersal events were those which fell spatiotemporally outside of the seasonal home ranges, with dispersal movements calculated according to the hourly movement rate methodology previously described. Comparisons between pre-hyperphagia and hyperphagia movement rates and home ranges area were achieved with two-sample t-tests.

**Biophysical Covariates** – Bear resource use was monitored 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, CA, USA), with aspect coded categorically and divided into four 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 eight broad and ecologically-relevant classifications: grasses and forbs, piñon-juniper, oak, aspen, mixed conifer, barren, shrub, and riparian (Table 2.2). Field
validation indicated that the LANDFIRE riparian class may more accurately represent the presence of water sources at several sites, particularly at the three more xeric release locations, than did most dedicated stream layers from other sources. 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, 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.

**Resource Selection Modeling** – We investigated rehabilitated black bear seasonal resource selection at Johnson’s (1980) third order of selection by incorporating biophysical 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 \( n = 5 \) were considered for RSF analysis. Available points were generated systematically – one per 30 m² pixel within each seasonal home range. Because habitat covariates were incorporated at a 30 m scale, and because the less accurate 2D fixes were largely associated with the denning period, which was not included in home range or resource selection analysis, we did not screen the GPS fixes for accuracy beyond the point of visual inspection. Continuous habitat variables were standardized via z-score transformations, whereby covariate values were subtracted from the mean value for that respective covariate and divided by one 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:

$$\ln \left( \frac{p}{1-p} \right) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} \ldots \beta_n x_{ni} + Y_{0i}$$

in which $\beta_0$ represents the fixed-effect intercept, $\beta_1$ through $\beta_n$ 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 analyses. 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 constrained from inclusion 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; and the coefficient direction for non-distance-based covariates being reversed. 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, used previously and 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. To elucidate the availability of habitat covariates, we performed compositional analyses of the vegetation types within seasonal home ranges. Analyses were conducted and summarized using Program R 3.2.3 (R Development Core Team 2016).

RESULTS

Five of six bears retained their collars for approximately 18 months – from release in December 2014 until emergence from dens in 2016. For the five bears for which home range analyses and resource selection modeling were performed, the number of GPS locations collected during non-denning periods ranged from 692 to 943 ($\bar{x} = 828$, SE = 53.49). The sixth bear shed its collar in March 2015 and is only included with regard to immediate post-release activity analysis (343 locations).

Immediate post-release activity and denning chronology – Time between bear releases and arrival to den sites varied from 3 to 20 days ($\bar{x} = 8.2$, SE = 2.7). The
distances between release sites and den sites for the six bears ranged from 0.40 to 24.85 km (\(\bar{x} = 6.53\), SE = 3.78). The activity of M1405 was anomalous and highly influential upon post-release activity statistics, as he traveled a maximum Euclidean distance of 51.45 km from the release site over the first 9 days at a rate of 336.8 m hour\(^{-1}\) (SE = 68.8), and denned 20 days after release and 24.85 km from the release site. When M1405 is excluded, cubs arrived at den sites within 5.8 days (SE = 1.6) of their releases, and the distances between release sites and den sites narrow to a range of 0.40 to 6.81 km (\(\bar{x} = 2.86\), SE = 1.15). In 2015, the mean dates for den arrival and den entrance were 24 November and 1 December, respectively (Table 2.3). Den emergence for spring 2015 and spring 2016 both occurred on the same mean Julian date: 101 (SE = 5.2 and 0.4, respectively).

**Release-site fidelity and dispersals** – Two bears – M1403 and M1406 – conducted long distance, late-summer dispersals, while three – F1401, F1402, and M1404 – exhibited strong release-site fidelity (Table 2.4). From 30 August to 3 September, M1403 traveled at an average rate of 570.1 m hour\(^{-1}\) (SE = 116.5) and resettled 43.81 km from his pre-hyperphagia range. M1406 traveled 153.0 m hour\(^{-1}\) (SE = 27.3), on average, during his 15 August to 5 September dispersal event, and resettled 46.27 km from his pre-hyperphagia range. The three non-dispersing bears remained within the general region of their release locations, with distances between their release sites and their final recorded locations (2015-16 den sites) ranging from 3.79 to 8.35 km (\(\bar{x} = 5.68\), SE = 1.37); when extended to all 5 bears, the range expands to 3.79 to 48.01 km (\(\bar{x} = 21.56\), SE = 9.79). Den sites in 2014 and 2015 for M1404 were within 100 m of each other.
*Seasonal movements* – Delineating movement rate by calendar month illustrates the similarities among bears over the course of the 2015 monitoring year (Fig. 2.3). The month after den emergence and the month before den entrance showed dramatic escalation and curtailment of activity, respectively, and an asymptote in September demonstrated the bears’ greatest levels of activity during the year. For the entire 2015 monitoring year, bears moved at a mean rate of 103.3 m hour\(^{-1}\) (SE = 1.9). Seasonal delineations of movement rate showed four bears had higher rates of movement during the hyperphagia period (Table 2.4), three of which (all males) were significantly different between seasons \(P_{M1403} = 0.029; P_{M1404} < 0.001; P_{M1406} < 0.001\) even when the high movement rates of dispersal events were excluded from analysis. Mean movement rate for all bears was 95.0 m hour\(^{-1}\) (SE = 2.3) during pre-hyperphagia and 116.3 m hour\(^{-1}\) (SE = 3.3) during hyperphagia.

*Seasonal home ranges* – The two bears that exhibited late-summer dispersals had two distinct seasonal home ranges, while the three that did not disperse had some degree of overlap between pre-hyperphagia (spring and early summer) and hyperphagia (late summer until denning) home ranges (Table 2.5). Pre-hyperphagia home ranges varied in size from 18.11 to 52.97 km\(^2\) \((\bar{x} = 42.41, \text{SE} = 6.32)\), and hyperphagia home ranges varied from 14.68 to 120.24 km\(^2\) \((\bar{x} = 51.08, \text{SE} = 18.28)\). Overlap between seasonal home ranges for the non-dispersing bears varied from approximately 32 to 36\% \((\bar{x} = 32.51, \text{SE} = 1.76)\). The change in area between seasonal homeranges varied widely and ranged from a 21\% decrease to a 133\% increase, with a mean change of +27.68 (SE = 36.29).
Third-order habitat selection – The best supported marginal model for black bear habitat selection, which later represented the base model, included all vegetation and topographic covariates, but did not include the distance to roads covariate (Group A, Table 2.6). Out of >4000 tested model combinations, the top model had a model weight of 0.42, while the second best was 0.25 (and 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, nearly 50,000 models were tested. 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 (Group B, Table 2.6). The second best marginal model for seasonal resource selection had a ΔAIC score of 12. Coefficients indicate that bears selection was strongest for northerly aspects, slightly less for east and west aspects ($\beta = -0.259$ and -0.504, respectively), and weakest for south-facing aspects ($\beta = -0.903$).

Coefficients from the fixed main effects indicate strong selection for aspen ($\beta = -1.565$), oak ($\beta = -0.322$), and mixed conifer ($\beta = -0.515$). 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 ($\beta = -1.565$ and 1.651, respectively; Fig. 2.5), and oak habitats eliciting modest selection in general, and avoided during hyperphagia ($\beta = -0.322$ and 0.893, respectively; Fig. 2.5). Grasses and forbs were strongly selected earlier in the year, and avoided during the hyperphagia period ($\beta = 0.171$; Fig. 2.5). The compositional analysis of landcover type for seasonal home ranges (Table 2.2) illustrates the preponderance of piñon-juniper, shrub, mixed conifer, and barren landscapes within the ranges of these bears. Non-linear selection of slope and
ruggedness were demonstrated (Fig. 2.6), in which selection of slope was greatest between 20 and 30 degrees (0 = flat, 90 = max), and a similar intermediate degree of ruggedness was selected (Fig. 2.8).

DISCUSSION

We used GPS collar data and generalized linear mixed RSF models to investigate the movement and resource selection of six orphan, rehabilitated black bears in Utah. We monitored bears for more than one year after release, and predicted that movement and resource selection would be influenced by season. To our knowledge, this is the first report of GPS-monitoring of rehabilitated black bears, or GPS-data-derived resource selection of black bears in Utah; as such, we provide useful information to agencies charged with the rehabilitation, release, and management of black bears.

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), are known to travel long distances after release – an unideal outcome for wildlife managers. It is believed that most dispersals are unrelated to resource requirements, but due to translocated animals being in unfamiliar or undesirable environments (Stamps and Swaisgood 2007). Our study included several factors that may have reduced post-release dispersals. Cubs were collected at young age, before they had developed a home range or habitat preferences of their own, and before they would have developed the acute homing tendencies prevalent in older bears (Rogers 1987). The cubs were also released in early winter – a time during which environmental conditions would compel them to den immediately (Beecham and Ramanathan 2007). Five of six bears denned shortly after
release, and only one bear (M1405) traveled more than 7 km from the release site before denning. Excluding M1405, bears denned 2.86 km, on average, from their respective release sites. Over the entirety of the study, the five bears that retained their collars remained near the release sites for at least eight months, and three for the duration of monitoring. Although we monitored these bears for less than two 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 release schedule for the bears undoubtedly influenced denning chronology in 2014, however, dates of den entrance for the second year were just marginally later than during the release year, particularly when omitting the atypical post-release behavior of M1405. 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, Lariviere 2001, Immell et al. 2013). Baldwin and Bender (2010) report that bears in Colorado denned later during wetter years. If the body conditions of the bears in our study, which were greatly enhanced from the rehabilitation process, serve as functional analogs to a productive food year, this may 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 release-influenced, bears arrived to their den sites approximately one week before entering.

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 which 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 five 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 five bears, some hundreds of kilometers apart, spanned just three days (100-102). While these results allude to the importance of photoperiod on bear behavior, this relationship should be explored further.

Studies have demonstrated that activity and home ranges change by season and are influenced primarily by food availability and distribution (Alt and Beecham 1984, Clark et al. 2002, Beecham et al. 2015). To test this hypothesis in our system, we divided our data by time of year, and produced results in support of a seasonal effect on space use. Four out of five bears exhibited higher rates of movement during hyperphagia ($P < 0.05$ for 3 of 5 bears), which corresponds to seasonally induced changes in bear activity from other studies (Amstrup and Beecham 1976, Garshelis et al. 1983). Because movement and home range are inherently related, it is not surprising that we report home ranges to be, on average, 28% larger during hyperphagia. Our data did not match the prevailing trend of male black bear home ranges being significantly larger than those of females (Lindzey and Meslow 1977, Alt et al. 1980, Reynolds and Beecham 1980, Koehler and Pierce 2003), however, it is possible that many studies which utilize more course, VHF-derived locations, could artificially inflate the spatial dimensions of bear space use by mistakenly identifying each of the two distinct, seasonal home ranges of the dispersing males as singular home ranges. To comparable habitats of New Mexico ($x̄ =$
43.1 km²; Costello et al. 2001) and Texas (μ = 36.2 km²; Onorato et al. 2003), we observed similarities with regard to overall home range sizes. Because smaller home range sizes have been documented in areas of increased productivity (Smith and Pelton 1990, Oli et al. 2002, Koehler and Pierce 2003), we believe that the two large, seasonal home ranges for the two female yearlings is a product of increased spatial coverage due to lower densities of food resources at their xeric sites.

The two yearling males who dispersed during late-summer, did so 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. While the mechanisms are unknown, other studies report similar results: average dispersals of 34 km for 60 released, rehabilitated black bears in Canada (Binks 2008), 13 km for yearling bears in West Virginia (Lee and Vaughn 2003), and 40 km for male yearling black bears in New Mexico (Costello 2010). In our study, late-summer movements for two bears resulted in approximately 40 km distance between pre-hyperphagia and hyperphagia ranges. M1404, a bear which did not disperse, meandered 11.39 km from its release site – a distance that some studies may report as a dispersal event – but ultimately denned, as a yearling, less than 4 km from the release site, and within 100 m of his den the previous year.

Third-order habitat selection modeling revealed strong selection for several vegetation types. The most pronounced effects involved a seasonal response to aspen, which could be explained by a number of factors. Spring and early summer aspen habitats often contain sources of water and serve as parturition sites for mule deer (Odocoileus hemionus) and other ungulates (Pojar and Bowden 2004, Latham et al.
the offspring of which are reliable, protein-rich resources for bears (Zager and Beecham 2006). Young and Ruff (1982) showed bears in Alberta selecting aspen sites for their seasonally available resources, while in Utah, aspen habitats in summer accounted for 21.7% of bear locations (Pederson et al. 2008). We predicted oak habitats to be strongly selected for by black bears, but were not certain in which direction that selection would fall when an interaction of season was implemented. For instance, in spring, the availability of overwintered hard mast can be of great import to bears (McDonald and Fuller 2005), however plant phenology is often highly variable and difficult to predict. Pederson et al. (2008) detected the greatest abundance of insects in oak species, with ants having been demonstrated as an important food source for bears (Auger et al. 2004). Presumably, the avoidance of oaks in later months may be, in part, the open and exposed nature of many oak communities in Utah, which might not provide suitable protection during the heat of summer. 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. Juniper is another overwinter mast species of interest, in that fall production 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. These results might be reflective of the ubiquity of piñon-juniper on the landscape, which may have masked true selection or avoidance. Similar to other studies (Reynolds and Beecham 1980, Servheen 1983, Pederson et al. 2008), 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. The importance of grass-forb habitats is further demonstrated by the fact that it was the least represented landcover type, as illustrated in the compositional analysis, yet it elicited such a pronounced selection response. 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. Similarly, 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 and higher vegetative productivity 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 a combination of predator and conspecific defense strategies, vegetation structure, and ease of locomotion contributed to the non-linear, intermediate selection of slope and ruggedness.

The post-release behavior of M1405 was atypical, but serves as an example for what could happen after releasing a black bear or other wide-ranging animal. Clark et al. (2002) surmised that there may be a negative relationship between the success of releases and regional black bear population densities. The immediate post-release activity of M1405 may reflect this. The mesic, montane, and subalpine habitat in which M1405 was released was the most productive of all sites. Following his release in 2,700 m (8,800 ft) elevation, mixed-conifer habitat, M1405 traveled more than 50 km to the crest of the Uinta Mountains and denned at 3,760 m (12,336 ft) in a talus field. If the habitat conditions at the release site correlate to a higher population of black bears, it is possible
that M1405 encountered, and was displaced by, a conspecific in the days subsequent to release. Tietje and Ruff (1980) reported that bears which abandoned one or more dens experienced a significantly greater body mass loss than did those that maintained a single den for the entire period. Here, not only did M1405 appear to den several times throughout the winter, as informed by several clusters of GPS locations, but the dens that were selected appeared to not provide ample protection from the elements, as evidenced by the GPS collar maintaining daily satellite communication throughout the denning season. We surmise that the high elevation winter exposure resulted in a substantial reduction in body mass for M1405, and facilitated the shedding of the collar in spring 2015.

Given widely-held concerns about the potential for unnatural behaviors by captive-reared animals, we were broadly interested in how the activities of these bears related to those of wild bears from previous studies. The comparisons we make, however, are done with caution for several reasons. First, we acknowledge the small sample size for this study, and although this is not unique among those involving carnivores, particularly those which are captive-reared, it does hinder us from making robust population-level inferences (Leban et al. 2001). Second, because black bear cubs and yearlings in natural circumstances travel with and are highly influenced by their mothers (Reynolds and Beecham 1980), wild bears of this age might make for poor comparisons. Third, there is a discrepancy between the xeric habitat of our study sites, and those of most bear studies, including the resource-rich landscapes of the Canadian Rockies (Hebblewhite et al. 2003), upper Midwest (Noyce and Garshelis 2011), Appalachia (Garshelis et al. 1983), or Pacific Northwest (Koehler and Pierce 2003) – an issue of
import, given that availability of resources is a primary driver for bear activity (Jonkel and Cowen 1971, Amstrup and Beecham 1976, Baruch-Mordo et al. 2014). Thus, comparisons should be judiciously drawn. However, the reasons that cause our cautious extrapolation, highlight the importance of this data to fill gaps in the literature for rehabilitated or translocated bears, and for spatiotemporal dynamics of black bear ecology in Utah.

Success for released, rehabilitated black bear cubs and yearlings is frequently measured according to bear survival and bears not engaging in human-conflict situations, with many studies setting short-term goals, sometimes as few as 30 days. According to these standards, we report a high degree of success for the cubs in our study. All six bears established den sites during their first winter and, for the five bears who retained their collars, survived through their second den season, more than one year after release. Further, for the duration of the study, we report no nuisance behaviors or any indication that these bears were inclined to utilize anthropogenic resources or approach human-use areas. The success of our bears was undoubtedly a product of release site locations that were selected because of their reduced human influence. Roads and human-traffic were not uncommon 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 which increase the availability of available anthropogenic resources and the potential for interactions with humans (Alt and Beecham 1984, Linnell et al. 1997).

Management Implications – Data from this study provide insight into the activity of released rehabilitated black bear cubs, and highlight the variability of individual
behavior. Most orphan black bear rehabilitation efforts release the animals during their second year of life, as yearlings, despite the positive relationship between time in captivity and probability of human-bear conflict (Beecham et al. 2015). Here, cubs were captured at approximately 6 months of age and released within 5 months – a methodology which is much less common and even less documented, despite the fact that is considered to be effective, advisable, and greatly reducing on rehabilitation time and effort (Beecham and Ramanathan 2007). The cubs quickly adapted to life in the wild, denning shortly after release and showing no inclinations to utilize anthropogenic resources. As the results of this study demonstrate, female black bears are often philopatric and uninclined to disperse, so managers should feel comfortable that those released in suitable habitat will remain in the immediate area. For released males, dispersals should not be unexpected, with the potential likelihood reduced if the release area is productive, but not overly saturated with wild conspecifics. If movement, home range size, and resource use of animals is important to wildlife managers, we suggest GPS devices, which provide high-resolution spatiotemporal information that vastly outperform, and alleviate the logistical limitations associated with, VHF monitoring (Garshelis et al. 1983, Millspaugh and Marzluff 2001, Hebblewhite and Haydon 2010).

Results from this study also highlight how prior knowledge regarding species-specific ecology should be used to tailor monitoring efforts. For example, resource selection modeling would not have indicated selection or avoidance of several important habitat types without a delineation by season – in essence, the effects of one season would have masked that of the other. In this way, exploring wild activity data at different scales may yield valuable insights as compared to coarser approaches. Because state
wildlife management agency personnel recognize that, like many western states, Utah is experiencing losses of aspen habitats (UDWR 2008), and that aspen is of critical import to numerous species (UDWR 2011), efforts to restore these vegetation communities are paramount to ensure the well-being of black bear and other wildlife populations.

Ultimately, we contend that short-term captive rehabilitation of orphan black bear cubs is an effective practice to aid the long-term survival of imperiled individuals, a management strategy that would appeal to and have support from the growing social contingents concerned for animal welfare. We submit that this practice should be undertaken by wildlife managers in the state of Utah and throughout the range of the black bear.

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Table 2.1. Details surrounding the orphaning and capture of the six American black bear cubs rehabilitated at the USDA-NWRC Predator Research Facility in Millville, Utah, in 2016. The sex of each bear is denoted by the prefix to their alphanumeric identification.

<table>
<thead>
<tr>
<th>Bear</th>
<th>Capture date</th>
<th>Orphaning and capture details</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1401</td>
<td>07/01/16</td>
<td>Inadvertently captured as state biologists attempted to trap her mother</td>
</tr>
<tr>
<td>F1402</td>
<td>07/15/16</td>
<td>Orphaned after her mother was killed for predating on a domestic goat</td>
</tr>
<tr>
<td>M1403</td>
<td>07/26/16</td>
<td>Sibling of M1404; mother was killed in a vehicle collision</td>
</tr>
<tr>
<td>M1404</td>
<td>07/26/16</td>
<td>Sibling of M1403; mother was killed in a vehicle collision</td>
</tr>
<tr>
<td>M1405</td>
<td>08/20/16</td>
<td>Found in a dog kennel at a private residence</td>
</tr>
<tr>
<td>M1406</td>
<td>08/29/16</td>
<td>Captured after utilizing anthropogenic resources within city limits</td>
</tr>
</tbody>
</table>
Table 2.2. Reclassified vegetation covariates used within the resource selection function and GLMM framework. Results of compositional analysis are represented by the area (km²) of seasonal home ranges (*Pre-hyperphagia* and *Hyperphagia*) occupied by each of the vegetation types.

<table>
<thead>
<tr>
<th>Landcover class</th>
<th>Description of vegetation classification</th>
<th>Pre-hyperphagia</th>
<th>Hyperphagia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasses and forbs</td>
<td>Annual and perennial graminoid grassland and forbs</td>
<td>2.38</td>
<td>2.02</td>
</tr>
<tr>
<td>Piñon-Juniper</td>
<td>Colorado Plateau piñon-juniper woodland and savanna</td>
<td>80.54</td>
<td>96.91</td>
</tr>
<tr>
<td>Oak</td>
<td>Gambel oak shrubland and Gambel oak mixed-montane shrubland</td>
<td>8.08</td>
<td>5.92</td>
</tr>
<tr>
<td>Aspen</td>
<td>Aspen forest, woodland, and parkland</td>
<td>14.69</td>
<td>18.10</td>
</tr>
<tr>
<td>Mixed conifer</td>
<td>Mixed conifer forest, woodland, and savannas; ponderosa and lodgepole pine woodlands</td>
<td>37.93</td>
<td>24.36</td>
</tr>
<tr>
<td>Barren</td>
<td>Barren; rocks, rock outcrops, and talus fields; sparsely vegetated</td>
<td>37.88</td>
<td>56.36</td>
</tr>
<tr>
<td>Shrub</td>
<td>Sagebrush, blackbrush, and desert scrub alliances; Colorado Plateau and foothill shrublands</td>
<td>25.05</td>
<td>46.31</td>
</tr>
<tr>
<td>Riparian</td>
<td>Riparian systems; wetland herbaceous zones and floodplains</td>
<td>3.74</td>
<td>3.94</td>
</tr>
</tbody>
</table>
Table 2.3. Release schedule and denning chronology, according to Julian date, for rehabilitated, orphan black bear cubs in winter 2014-15 and 2015-16. Distance from release site (km) for 2014-15 dens reflects post-release movements, while distance from release site for 2015-16 dens reflects release-site fidelity.

<table>
<thead>
<tr>
<th>Bear</th>
<th>Release</th>
<th>Arrival</th>
<th>Entrance</th>
<th>Emergence</th>
<th>Distance from release site</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 - 2015 Den</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1401</td>
<td>337</td>
<td>340</td>
<td>346</td>
<td>116</td>
<td>0.40</td>
</tr>
<tr>
<td>F1402</td>
<td>337</td>
<td>348</td>
<td>350</td>
<td>104</td>
<td>6.81</td>
</tr>
<tr>
<td>M1403</td>
<td>339</td>
<td>342</td>
<td>351</td>
<td>98</td>
<td>2.52</td>
</tr>
<tr>
<td>M1404</td>
<td>339</td>
<td>343</td>
<td>348</td>
<td>84</td>
<td>3.72</td>
</tr>
<tr>
<td>M1405</td>
<td>338</td>
<td>358</td>
<td>358</td>
<td>68</td>
<td>24.85</td>
</tr>
<tr>
<td>M1406</td>
<td>338</td>
<td>346</td>
<td>346</td>
<td>103</td>
<td>0.85</td>
</tr>
<tr>
<td>mean:</td>
<td>338 (4 Dec)</td>
<td>346 (12 Dec)</td>
<td>350 (16 Dec)</td>
<td>101(^a) (11 Apr)</td>
<td>6.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bear</th>
<th>Arrival</th>
<th>Entrance</th>
<th>Emergence</th>
<th>Distance from release site</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 - 2016 Den</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1401</td>
<td>348</td>
<td>363</td>
<td>100</td>
<td>4.89</td>
</tr>
<tr>
<td>F1402</td>
<td>343</td>
<td>343</td>
<td>102</td>
<td>8.35</td>
</tr>
<tr>
<td>M1403</td>
<td>303</td>
<td>304</td>
<td>101</td>
<td>42.77</td>
</tr>
<tr>
<td>M1404</td>
<td>332</td>
<td>343</td>
<td>100</td>
<td>3.79</td>
</tr>
<tr>
<td>M1406</td>
<td>313</td>
<td>323</td>
<td>101</td>
<td>48.01</td>
</tr>
<tr>
<td>mean:</td>
<td>328 (24 Nov)</td>
<td>335 (1 Dec)</td>
<td>101(^b) (10 Apr)</td>
<td>21.56</td>
</tr>
</tbody>
</table>

\(^a\) Excludes M1405 whose collar was shed during denning season

\(^b\) Leap year
Table 2.4. Mean movement rates (m/hr) of rehabilitated bears during the entirety of 2015 (*Full-year*), as delineated by the two seasons (*Pre-hyperphagia* and *Hyperphagia*), and during dispersal events for two bears. Four of five exhibited greater late-year movement rates, three of which were significant (bold text).

<table>
<thead>
<tr>
<th>Bear</th>
<th>Full-year SE</th>
<th>Mean (m/hr)</th>
<th>Maximum (m/hr)</th>
<th>SE</th>
<th>Mean (m/hr)</th>
<th>Maximum (m/hr)</th>
<th>SE</th>
<th>Mean (m/hr)</th>
<th>Maximum (m/hr)</th>
<th>SE</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1401</td>
<td>124.6 4.7</td>
<td>128.0 733.0</td>
<td>6.5</td>
<td></td>
<td>121.1 982.3</td>
<td>6.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.450</td>
</tr>
<tr>
<td>F1402</td>
<td>100.7 4.0</td>
<td>95.0 558.9</td>
<td>4.7</td>
<td></td>
<td>108.4 602.2</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.112</td>
</tr>
<tr>
<td>M1403</td>
<td>111.0 5.7</td>
<td>93.7 756.6</td>
<td>4.9</td>
<td></td>
<td>117.7 715.8</td>
<td>9.8</td>
<td></td>
<td>117.7</td>
<td>715.8</td>
<td></td>
<td>0.029</td>
</tr>
<tr>
<td>M1404</td>
<td>93.7 3.5</td>
<td>82.2 596.7</td>
<td>3.9</td>
<td></td>
<td>116.0 626.0</td>
<td>6.8</td>
<td></td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1406</td>
<td>99.4 5.0</td>
<td>78.1 662.7</td>
<td>5.0</td>
<td></td>
<td>118.4 573.3</td>
<td>8.4</td>
<td></td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean:</td>
<td>103.3 95.0</td>
<td></td>
<td></td>
<td></td>
<td>116.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5. Home range area (km²) by season for bears in 2015. Two bears had distinct seasonal home ranges, as denoted by percent overlap, and three bears increased their utilization distribution later in the year, represented by percent change.

<table>
<thead>
<tr>
<th>Bear</th>
<th>Pre-hyperphagia</th>
<th>Hyperphagia</th>
<th>Overlap (%)</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1401</td>
<td>45.49</td>
<td>35.78</td>
<td>36</td>
<td>-21</td>
</tr>
<tr>
<td>F1402</td>
<td>51.60</td>
<td>120.24</td>
<td>30</td>
<td>133</td>
</tr>
<tr>
<td>M1403</td>
<td>43.86</td>
<td>52.07</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>M1404</td>
<td>18.11</td>
<td>32.66</td>
<td>32</td>
<td>80</td>
</tr>
<tr>
<td>M1406</td>
<td>52.97</td>
<td>14.68</td>
<td>0</td>
<td>-72</td>
</tr>
<tr>
<td>mean:</td>
<td>42.41</td>
<td>51.08</td>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>

Table 2.6. Fixed-effects coefficients, represented by the negative log-likelihood, from the top model of black bear habitat selection, anthropogenic influence (distance to roads), and seasonal effects (pre-hyperphagia and hyperphagia) in 2015, in eastern Utah, USA. Group A represents the variables included in the base model. Group B represents additional fixed effects, including interactions of season and quadratic terms, which improved model fit.
<table>
<thead>
<tr>
<th>Biophysical covariate</th>
<th>Code</th>
<th>β</th>
<th>SE</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP A.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td>-2.514</td>
<td>0.270</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Slope S</td>
<td>S</td>
<td>0.114</td>
<td>0.024</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Ruggedness R</td>
<td>R</td>
<td>0.282</td>
<td>0.029</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Aspect (North reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East AE</td>
<td>AE</td>
<td>-0.259</td>
<td>0.045</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>South AS</td>
<td>AS</td>
<td>-0.903</td>
<td>0.065</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>West AW</td>
<td>AW</td>
<td>-0.504</td>
<td>0.049</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Grasses and forbs GR</td>
<td>GR</td>
<td>-0.054</td>
<td>0.024</td>
<td>0.027</td>
</tr>
<tr>
<td>Piñon-Juniper PJ</td>
<td>PJ</td>
<td>0.050</td>
<td>0.019</td>
<td>0.008</td>
</tr>
<tr>
<td>Oak OA</td>
<td>OA</td>
<td>-0.322</td>
<td>0.090</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Aspen AS</td>
<td>AS</td>
<td>-1.565</td>
<td>0.124</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Mixed Conifer MC</td>
<td>MC</td>
<td>-0.515</td>
<td>0.089</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Barren BA</td>
<td>BA</td>
<td>-0.073</td>
<td>0.031</td>
<td>0.017</td>
</tr>
<tr>
<td>Shrub SH</td>
<td>SH</td>
<td>0.094</td>
<td>0.020</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Riparian RI</td>
<td>RI</td>
<td>0.084</td>
<td>0.027</td>
<td>0.002</td>
</tr>
<tr>
<td>GROUP B.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasses and forbs by season GR:S</td>
<td>GR:S</td>
<td>0.171</td>
<td>0.039</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Oak by season OA:S</td>
<td>OA:S</td>
<td>0.893</td>
<td>0.104</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Aspen by season AS:S</td>
<td>AS:S</td>
<td>1.651</td>
<td>0.125</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Barren by season BA:S</td>
<td>BA:S</td>
<td>-0.126</td>
<td>0.053</td>
<td>0.018</td>
</tr>
<tr>
<td>Riparian by season RI:S</td>
<td>RI:S</td>
<td>-0.126</td>
<td>0.041</td>
<td>0.002</td>
</tr>
<tr>
<td>Distance to roads DR</td>
<td>DR</td>
<td>0.019</td>
<td>0.034</td>
<td>0.586</td>
</tr>
<tr>
<td>Distance to roads quadratic DR^2</td>
<td>DR^2</td>
<td>-0.052</td>
<td>0.018</td>
<td>0.003</td>
</tr>
<tr>
<td>Slope quadratic S^2</td>
<td>S^2</td>
<td>-0.165</td>
<td>0.021</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Ruggedness quadratic R^2</td>
<td>R^2</td>
<td>-0.068</td>
<td>0.013</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Table 2.7. Fixed effects model structures, negative log-likelihood (LL), and model selection results (AIC, ΔAIC) for the top five models, and base model, for generalized linear mixed-models of black bear habitat selection, anthropogenic influence (distance to roads), and seasonal effects (pre-hyperphagia and hyperphagia) in 2015, in eastern Utah, USA. Refer to Table 2.6 for variable codes.

<table>
<thead>
<tr>
<th>Model structure</th>
<th>K</th>
<th>LL</th>
<th>AIC</th>
<th>ΔAIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base + GR:S + OA:S + AS:S + BA:S + RI:S + DR + DR^2 + S^2 + R^2</td>
<td>23</td>
<td>-12176</td>
<td>24401</td>
<td>-</td>
</tr>
<tr>
<td>Base</td>
<td>14</td>
<td>-12541</td>
<td>25112</td>
<td>711</td>
</tr>
</tbody>
</table>

*MC:S, mixed-conifer by season; R:S, ruggedness by season; SH:S, shrubland by season; S:S, slope by season*
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CHAPTER 3
PERSONALITY IN BLACK BEARS AND THE RELATIONSHIP TO WILD ECOLOGY

ABSTRACT

Personality is defined by consistency in the individual differences in organismal behavior across time or context, a phenomenon which is growing in interest within the field of animal behavior. Empirical data has revealed an ever-increasing number and diversity of taxa that display these phenotypic patterns, in both wild and captive settings. Moreover, these behavioral traits are frequently linked to wild behavior, life-history strategies, and measures of individual fitness. To date, no studies have investigated the presence of personality in black bears (*Ursus americanus*). Through open field, novel object, startle object, and focal-animal sampling, we investigate the potential for personality in captive black bears. Results indicate the presence of personality, with consistency in behavior across five metrics for the bold-shy axis, and eight sampling events measuring responses for the activity axis. Analyses to identify correlations between personality and wild activity metrics did not yield statistical support, however. Information presented here may provide a framework for future research into black bear personality and its relationship to life-history and ecology.

INTRODUCTION

An ever-growing body of empirical data demonstrate that animals, human and non-human alike, display consistency in behavior across time or context – a phenomenon

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1 Co-author is Julie K. Young; chapter is formatted for Behavioral Ecology and Sociobiology
referred to as personality (Bell et al. 2009; Stamps and Groothuis 2010). Although the concept of personality has existed for more than a century within the discipline of human psychology (Caspi et al. 2005), only of late has it drawn attention in studies of non-human animal behavior (Gosling 2001; Bell et al. 2009; Réale et al. 2010). Influenced in large part by the seminal work of Wilson et al. (1994), the study of personality in non-human animals (hereafter, *animal personality* or, simply, *personality*) often includes measurements along continua within one of several broad behavioral traits, such as boldness, exploration, activity, aggression, or sociability (Réale et al. 2007). Observations of behavioral consistency within individual animals provides an alternative to the long-standing perspective that organisms are phenotypically plastic in response to repeated stimuli (West-Eberhard 1989). The between-individual differences in behavior have also garnered interest, as they are now recognized as indicative of individuality and no longer considered mere deviations from the population mean (Wolf and Weissing 2012).

Additionally, many studies have identified that personality traits are not always expressed in isolation, but as suites of correlated behaviors called behavioral syndromes (Sih et al. 2004); for example, an organism may consistently display aggression in one context and boldness in another (Kortet and Hedrick 2007).

As the study of animal personality grows, the phenomenon has been documented in individuals across a variety of taxa, including arthropods, fish, lizards, mollusks, birds, and mammals, and in both field and laboratory settings (Gosling 2001; Bell et al. 2009). Studies have included species recognized for their cognitive abilities, such as primates, canids, and cephalopods (Gosling 2001), however, despite their large brain size and demonstrated cognition (Vonk et al. 2012; Benson-Amram et al. 2016; Johnson-Ulrich et
al. 2016), bears (family Ursidae) have been largely unexamined with regard to personality (Gosling 2001; Bell et al. 2009; but see Fagen and Fagen 1996). Understanding bear behavior is critical, given that they often spatially overlap with human populations (Bateman and Fleming 2012), are known to utilize anthropogenic resources (Beckmann and Berger 2003; Hostetler et al. 2009), and threaten, in ways both real and perceived, human lives and property (Treves and Karanth 2003). This is particularly relevant for the American black bear (*Ursus americanus*), which is the most widely-distributed North American bear, possessing of a number of traits that allow persistence in human-dominated landscapes (Stirling and Derocher 1990; Lariviére 2001; Beckmann and Berger 2003; Johnson et al. 2015), and frequently involved in human-wildlife conflict (Can et al. 2014).

When conflicts lead to orpaning of black bear cubs, rehabilitation efforts are met with concerns over bear behaviors, including an unease that captivity produces human-habituated animals that may pose a threat to humans after release (Herrero et al. 2005), and skepticism about whether captive-reared animals will possess the skills, intuitions, and behaviors required to survive in the wild (Jule et al. 2008). Primary objectives of rehabilitation facilities are to improve the potential for individual survival after release, and incumbent in this process is the ability to assess animal behavior (Guy et al. 2013). Given that personality is influential upon overall animal fitness (Smith and Blumstein 2008) and many fundamental components of life, such as reproduction (Cote and Clobert 2007), foraging (Johnson and Sih 2005), dispersal (Cote et al. 2010), metabolism (Careau et al. 2008), and growth rate (Adriaenssens and Johnsson 2010), wildlife conservation and rehabilitation could benefit greatly from a more thorough understanding of animal
personality (McDougall et al. 2006). Moreover, elucidating the ecological and evolutionary consequences of personality facilitates an understanding of the mechanisms inherent to the phenomenon (Wolf and Weissing 2012).

Studies of human and non-human subjects maintain definitions of personality that are largely identical, but are assessed differently; the former often include metrics associated with emotion (Nettle and Penke 2010), while the latter include expressions that can be readily identified and quantified by human observers (Gosling 2008). Assessments of animal personality have relied on several principal testing strategies. Open-field trials, used to assay a variety of behavioral traits, consist of observations of behaviors by individuals in environments to which they are naïve (Valle 1970; Walsh and Cummins 1976; Burns 2008). One such behavior, “wall-hugging,” is an anxiety-related response along the bold-shy axis in which less bold subjects avoid the interior of unfamiliar or stressful environments – a behavior observed in many taxa, including fish (Sharma et al. 2009), rodents (Treit and Fundytus 1988), and humans (Kallai et al. 2007). Exploration is measured as the inclination of animals to investigate novel environments, and has been demonstrated to be correlated with risk-taking and negatively related to neophobia (Meehan and Mench 2002; Mettke-Hoffmann et al. 2002; van Oers et al. 2004; Dingemanse et al. 2010; Cole and Quinn 2014). Assays in which animals are presented with an object to which they are naïve, and which may be interpreted as a threat, are referred to as novel-object tests, and are commonly used as measures of fear, with bold subjects less fearful of the object (Burns 2008). Similarly, startle objects are used to measure behavior along the bold-shy axis, whereby flight from, or latency to return to, an object following a stimulus, such as light or sound, often corresponds with
levels of boldness (van Oers et al. 2004; Ward et al. 2007). Extended periods of detailed observation on individual subjects is often referred to as focal-animal sampling (Altmann 1974), which is a form of non-manipulative, observational research that has been widely used for a variety of species in captive and field settings, and allows for the incorporation of a vast array of behavioral data (Coleman and Wilson 1998; Stoinski et al. 2003; Rieucau et al. 2012; Seyfarth et al. 2012), including activity levels (Renner 1990; review in Réale et al. 2007).

Here, we present the first investigation into personality of American black bears (Ursus americanus). Through the use of open-field, novel object, startle object, and focal-animal sampling, we examine the existence of repeatable, across-context, individual differences in behavior along the bold-shy and activity axes of black bear cubs. We predicted that the bears would exhibit intra-individual consistency and inter-individual variation in behaviors across assays for each axis. Similar to previous studies (Huntingford 1976; Lantová et al. 2011; Herde and Eccard 2013), we anticipated correlation between the bold-shy and activity axes. We also investigated the potential for relationships between captive personality and wild behavior – a phenomenon which has been previously demonstrated, albeit in but a few instances (Coleman and Wilson 1998; Herborn et al. 2010; Cole and Quinn 2014). We compared bold-shy and activity data from captive tests to behavioral metrics collected during the bears’ first year in the wild following rehabilitation (Chapter 2), including hourly movement rate, post-release dispersal distance, release-site fidelity, and seasonal home range size. We predicted that bold-shy and activity measurements would be correlated with wild activity metrics. This study aimed to facilitate a better understanding of black bear behavior, include black
bears in the ongoing pursuit of personality research, identify *in situ* and *ex situ* relationships for animal behavior, and broaden the tools with which we approach wildlife ecology and conservation.

**METHODS**

*Subjects* – Between 1 July and 29 August 2014, orphaned black bear cubs were captured by Utah Division of Wildlife Resources (UDWR) personnel and transported to the United States Department of Agriculture (USDA) National Wildlife Research Center’s (NWRC) Predator Research Facility in Millville, Utah, U.S.A. for rehabilitation. The housing structure contained two enclosures, each 16.5 m long, 7 m wide, and 2.5 tall (288.8 m³), separated by a 7.5 m long, 2 m wide, and 2.5 m tall transitional pen, called a shift (Fig. 3.1). The walls and ceilings of the pens and shift were chain-link fencing. Solid-metal, guillotine-style doors, operated from an adjacent room, allowed for entrance and egress of bears between the pens and shift. Both pens were functionally identical and contained wood climbing structures, logs, a large pool of water, two den boxes, natural vegetation, and a constantly flowing source of fresh water. After an initial period that included frequent care and the provisioning of liquid formula, cubs were fed once daily, with quantities continually increasing in accordance with their body mass. In an effort to reduce familiarity with humans, the cubs had one primary caretaker and all bear-human interactions were minimal. All captive care was provided in accordance with NRWC animal care protocol, derived from widely accepted procedures (Beecham and Ramanathan 2007), administered under the authority of NWRC-SOP #ACUT-006.00,
with research permitted under NWRC QA-2354 and Institutional Animal Care and Use Committee (IACUC) of Utah State University permit #2434.

Behavior tests – All bears were given a minimum of seven days to acclimate to various aspects of their captive environment – structures, conspecifics, feeding schedule, human caretaker – before behavioral assays began. No enrichment items were proffered to the bears during the acclimation or testing periods. Prior to the start of trials, the bears had been allowed access to one pen and the shift, but remained naïve to the second pen, which was used as the arena for several assays that would measure their responses related to the bold-shy behavioral axis. Subsequent bold-shy and activity tests, not reliant on novelty of environment, and after bears were familiar with both pens, were then administered with the trial pen selected opportunistically based on ease of bear isolation. Trials were ordered in a manner that preserved the novelty of individual testing paradigms; for instance, novel object trial date preceded that of the startle object, as potential trepidation surrounding introduced objects would be expected to wane with each occurrence. Dates of trials were selected opportunistically according to weather conditions, times of trial were randomized from all possible times during daylight hours, and subject order was randomized for each trial. As some studies have reported that olfactory or chemical cues from previous subjects or human caretakers may influence behavior (Whittier and McReynolds 1965; McCall et al. 1969), the arena and all of its contents were sprayed with high-pressure water and left to dry and ventilate ≥ 1 hour between all tests. All trials were conducted in mild weather, and administered and recorded by the same human observer.
Open-field trials were preceded by subjects being individually isolated in the
shift, and all non-participating individuals confined to one pen. Following an acclimation
period of ≥ 15 minutes, the door on the opposite side of the shift was opened to allow
egress into the novel pen. Prior to this point, bears did not have access to the arena,
although we could not limit all arena visibility. The start of the open-field trial was
delineated by the point at which the subject had entered the novel environment, defined
by all four feet of the subject being on the ground of the arena. The time and duration of
several coded behaviors were used to assess three measures of boldness: two variants of
“wall-hugging” behavior – latency to the interior and thigmotaxis – and exploration.
Latency to the interior was measured according to the number of seconds between the
start of the trial and the time at which the individual entered the middle of the arena (> 2
m from the perimeter), with boldness negatively related to the number of seconds.
Thigmotaxis was measured as the proportion of time an individual spent on the perimeter
(< 2 m from the fence), with the proportion inversely related to boldness. Exploration was
measured as the time during which subjects actively moved about and inspected the novel
environment, with boldness positively related to active behaviors. Open-field trials
terminated after each subject had been in the arena for 300 seconds (5 min), in order to
mitigate for the animals becoming familiar with the environment. Open-field trials were
recorded via four video cameras (SDR-H85, Panasonic Corporation, Osaka, Japan)
placed on the exterior of the pen, and later analyzed using VLC software (VideoLAN,
Paris, France).

Novel-object tests were preceded by subjects being individually isolated in the
shift, and all non-participating individuals confined to the pen previously used for open-
field trials. To not confound subject responses to the novel object with responses associated with a stress-inducing arena, novel-object testing was administered in the familiar pen. The novel object was represented by an orange traffic cone (1 m tall) placed on the floor of the arena (Fig. 3.1). A black bag was used for concealment of the object during placement, and a wood climbing structure, to which the subjects were familiar, was situated between the shift and the object in order to restrict visual-information transfer until the subject was in the arena. To reduce biases from observer effects, observations occurred from behind visual barriers on the exterior of the arena. Following an acclimation period of $\geq 15$ minutes, the shift door was opened to allow access of the subjects to the arena. The novel-object trial phase began when the subjects had fully entered the arena, and terminated when the subject was $\leq 1$ m distance from the object, with the differential in time termed as latency to approach, and scores inversely related to boldness.

Startle-object trials were conducted two days after novel-object trials. The startle object consisted of two items: a ~22 cm diameter, blue plastic ball, used to attract the interest of the test subjects, and an acoustics playback device (FOXPRO Crossfire, FOXPRO Inc., Lewiston, PA, USA). Both objects were situated $< 1$ m outside of the arena fence (for the preservation of the speaker system), with the speaker directly behind the ball, and, similar to the novel object test, both obfuscated by a visual barrier until the subject had entered the arena (Fig. 3.1). When the subject reached the fence in front of the object, the human observer, recording behavior from behind visual barriers on the exterior of the arena, remotely activated the acoustic device. The device was programmed to emit a sound at ~90 decibels (at 1 m) – a volume loud enough to elicit a response from
the test subjects, but not attract the attention of conspecifics, who were ≥ 15 m away in
the adjacent pen, with noise-attenuating structures between. An animal (raccoon; *Procyon
lotor*) growling/fighting noise was selected as the stimulus because of its potential to
produce a fear-induced response and for its novelty. Unlike common testing stimuli, such
as beeps, sirens, or lights, this noise would likely not have been encountered during lives
of the bears, either in the wild or during capture and transport. The recorded metric was
the time between the flight response of the subjects after the sound was emitted, and the
subject returning to the object, with the number of seconds inversely proportional to
boldness.

Focal-animal sampling occurred on days in which no other tests were
administered, after all bears had been fully acclimated to both pens, and with no
restrictions to pen access or conspecific interaction – measures to ensure that no
unintended, confounding stimuli, threats, or novelty were present (Réale et al. 2007).
Eight focal-animal sampling events occurred, each 15 min (900 s) in duration, with an
interval average of 6 days (SE = 1.3) between trials. The human observer recorded
behaviors from behind visual barriers on the exterior of the arena. Active behaviors
included locomotion, climbing, and playing alone or with conspecifics, while inactivity
included sitting, laying, or otherwise remaining stationary. Time and duration of
behaviors were recorded in seconds and converted to proportions to reflect activity
scores.

*Statistical Analysis* – All analyses were conducted and summarized using
Program R 3.2.3 (R Development Core Team 2016). Analysis began by transforming
bold-shy data for intuitive directionality, with high scores corresponding to high degrees
of boldness, and rescaling data to standardize scores around a mean of 0 and a standard deviation of 1. Activity scores were already represented as proportions, so no rescaling or transformations were necessary. We first tested for individual consistency, or repeatability, in behavior. As described by Lessells and Boag (1987), repeatability can be characterized by the proportion of variance in responses for one individual, relative to the variance among individuals. We calculated intraclass correlation (ICC; R package ‘irr’; Gamer et al. 2012) coefficients, derived from the variance components produced by one-way analysis of variance (ANOVA), to assess consistency of responses for each individual among the suite of tests for each of the two behavior axes. As bold-shy tests were designed to provide multiple measures for responses along the same axis, we looked for correlation between scores for each individual by performing principal component analysis (PCA). PCA reduced and enhanced directionality of variables, and illustrated relationships between variables. The number of components retained was determined according to the Kaiser-Guttman criterion (Kaiser 1991), variance contributed, and scree plot visualization. Using the loadings matrix from the retained components, composite scores were generated for each individual, representing single values for the subjects along the bold-shy continuum. Unlike bold-shy scores, activity-level scores consisted of repeated focal-animal samplings with identical measurements and units across each sampling occasion; as such, composite scores of captive activity-level for each individual were achieved by averaging the eight scores. Using Spearman’s rank correlation, we tested for rank-order consistency between bold-shy composite scores and activity-level composite scores. We also tested each bold-shy and activity-level composite score for correlations to metrics of wild behavior collected from the bears after release, including
RESULTS

_Intra-individual consistency_ – Six orphaned black bear cubs (2 females, 4 males), approximately 8 months of age (Table 3.1), were tested. The bears displayed intra-individual consistency and between-individual variation with regard to responses within each of the suite of tests for both the bold-shy and activity axes (Table 3.2). Intraclass correlation coefficients for analysis of the five bold-shy measurements indicate that some bears were consistently bolder than others in captivity, across time and context ($F_{5,20} = 3.61, P = 0.017$). Similarly, intraclass correlation coefficients indicate that activity tests revealed some bears to be consistently more active than others in captive settings ($F_{5,35} = 3.61, P = 0.052$).

_Behavioral Axes_ – Principal components analysis allowed us to retain two components, each with eigenvalues greater than 1 which, when combined, accounted for 87% of the total variance (Table 3.3). The first principal component explained 53% of the variance and was characterized by the three metrics measured in the open-field tests. PCA loadings for latency to the interior (0.550), thigmotaxis (0.529), and exploration (0.555) all contributed equally to the first principal component. Conversely, the two metrics that were associated with novel objects – latency to approach and startle object response – were the primary contributing variables for the second principle component (-0.664 and 0.616, respectively), which accounted for 34% of the variance.
Captive versus wild behavior – We were not able to identify a correlation between the bold-shy composite score for the first principal component, that which was associated with tests within the novel captive environment, and captive activity-level composite score (Spearman’s $r_s = -0.1$, $P = 0.95$). However, results allude to a possible link between the second principal component, that which was associated with novel object and startle object, and bear captive activity level (Spearman’s $r_s = -0.9$, $P = 0.083$). We did not identify strong relationships between personality, as elucidated from captive bold-shy and activity-level tests, and the wild activity metrics of movement rate, post-release dispersal, release-site fidelity, or seasonal home range size (Table 3.4).

DISCUSSION

To our knowledge, this study represents the first application of tests administered for the purpose of revealing individual personality for black bears or any other species in family Ursidae. Our results lend support to the presence of personality in black bears. Responses to a suite of behavioral assays, commonly-utilized in the field of personality research – open field, novel object, startle object, and focal-animal sampling – reveal that some bears are consistently bolder or more active than others across contexts in captive settings. Results allude to a possible relationship between bold-shy object testing – novel and startle – and captive activity-level. We were not able, however, to identify relationships between captive and wild behavior.

We present an important finding within the fields of animal behavior, ecology, and evolution – that black bears exhibit consistent individual behavioral differences. While this study represents many firsts with regard to bear personality, it is a concept
which has been previously considered, although we are unable to compare our results to this earlier study. Fagen and Fagen (1996) conducted observations of brown bears at a wild feeding site and considered nearly 70, subjective behavioral classifications to identify individuality among observed bears: the “more stringent” metrics included bears exhibiting “conceited,” “devious,” “flamboyant,” “insecure,” and “sparkly” behaviors. We do not wish to criticize the merits of their methodology, as the authors themselves acknowledge several shortcomings of the study. Rather, given this is the sole investigation into bear personality research, we seek to highlight how this taxon has been largely overlooked. Although sample size was small, we believe our study provides strong support for evidence of personality in bears, with an approach common among many similar studies that explore consistency of animal behavior (Bell et al. 2009).

Identifying the mechanisms that shape, and are shaped by, behavioral traits is fundamental to understanding individual life history and population dynamics (Stamps and Groothuis 2010). Behavioral traits and personality have historically been referred to as coping styles (Koolhaas et al. 1999); for instance, reactions along the bold-shy axis may, in large part, reflect an organism’s ability to cope with environmental stressors. Yet, just as behavior may be expressed as an adaptive response to environmental stimuli, so too may environment influence behavior. Indeed, an individual’s exposure to predators (Bell and Sih 2007) and the availability of resources (Brydges et al. 2008; Chapman et al. 2010) have been shown to influence personality and, ultimately, fitness. These effects are particularly influential upon animals during development and early life, and can have lasting impacts on future fitness (Lindstrom 1999). Maternal effects are early-life influences that are able to alter a variety of individual traits, with mammals most
profoundly affected, given their extended gestation, lactation, and other facets of maternal care (Reinhold 2002).

These concerns are relevant for rehabilitated animals, which have been denied the many benefits that come from extended maternal care, adding to the already critical need to assess the behavioral expressions and the potential for future fitness (Guy et al. 2013). Previous research has identified correlations between personality and the fitness and behavior of animals after release (Cavigelli and McClintock 2003; Bremner-Harrison et al. 2004; Smith and Blumstein 2008). Administering bold-shy tests, like those in our study, allows researchers to quantify the level of fear elicited by unfamiliar and potentially threatening objects and situations (Réale et al. 2007). For rehabilitated carnivores, such as the black bears in this study, behavioral testing may be able to provide predictive insights into their individual levels of fear toward novelty, reflecting upon their responses to anthropogenic activity in the wild, and ultimately, their propensity to engage in human-conflict situations.

The results of this study suggest a relationship between the novel and startle object testing and captive activity levels, although we contend that this should be investigated further. Several studies reported relationships between the boldness and activity axes (Boyer et al. 2010; Lantová et al. 2011; Dammhahn 2012; Herde and Eccard 2013) while others have demonstrated links between those traits and dispersal (Fraser et al. 2001; Dingemanse et al. 2003) or space use (Boon et al. 2007: Minderman et al. 2010). Contrary to our predictions, we were unable to identify several expected correlations between captive behavior scores along bold-shy and activity axes and wild behaviors, and posit several reasons why this might be so. First, empirical research has
observed common behavioral trait clusterings, such as links between boldness and aggressiveness, or between activity and exploration, however these associations are not always predictable and are recognized as a key area of needed research (Sih and Bell 2008). For example, while Cote et al. (2010) found that mosquitofish dispersal was linked to personality, it was unpredictably associated with sociability, instead of the more commonly related boldness, exploration, or activity traits. Second, studies investigating links between wild-behaviors and personality have focused strongly on a subset of taxa, such as birds (Dingemanse et al. 2003; Herborn et al. 2010; Cole and Quinn 2014) and fish (Coleman and Wilson 1998; Bell 2005; Burns 2008). Studies of mammalian temperament have been undertaken, although often require subjects being recaptured (Dammhahn 2012) or restrained by humans during testing (Réale et al. 2009). Because black bears are wide-ranging, cryptic, and not easily manipulated, logistical constraints did not permit direct observations or recapture for subsequent testing; thus, we were limited by our need to use GPS-derived data as metrics for wild behavior. Further, the metrics selected may not have been the most efficacious for behavioral comparisons. Third, when measuring wild-behavior as was performed in our study, there are many complex issues of scale which might not always be considered. For instance, Minderman et al. (2010) detected a correlation between exploration and home range size, but in a somewhat indirect relationship: important to the correlation were specific parts of the novel environment explored and, while measuring the wild behavior, habitat-specific areas of the home range. And, still yet, we acknowledge the small sample size for this study, which, if augmented, may have yielded results and offered insight that we were not able to elucidate. For these several reasons, we were unable to find statistically
significant captive-wild behavioral relationships, however, oftentimes a strong biological significance may be operating, masked by the inability of our analytical powers to detect them (Sih and Bell 2008), which necessitates further research.

The consistency in behavior observed in our study alludes to personality, an important but traditionally overlooked component of wildlife ecology and evolution. Although the concept of individual variation has been around for a considerable time (Darwin 1861), many ecological pursuits which seek to identify patterns and make population-level inference have treated these differences as noise (Wolf and Weissing 2012). Identifying personality in black bears could allow for a better understanding of their ecological needs and functioning, just as other research has shown links between personality and morphology (Brodie 1989; Ahlgren et al. 2015), metabolism (Careau et al. 2008), growth rate (Adriaenssens and Johnsson 2010), reproduction (Cote and Clobert 2007), foraging (Johnson and Sih 2005), dispersal (Cote et al. 2010), and parasitism (Barber and Dingemanse 2010).

One important consideration for the behavior or personality of wildlife, which is of particular import for rehabilitated bears that must demonstrate their ability to rejoin a wild population, is that behavioral consistency does not indicate that individuals will possess these traits for their entire lives. Internal and environmental characteristics will continually shape their behavioral phenotype (Stamps and Groothuis 2010), during life stages long after captive testing. However, even short term expressions are important and could mean the difference between life and death in a species with potentially lethal conspecific-interaction (Sih and Bell 2008), or in a world of increasing anthropogenic dangers (Wilcove et al. 1998). Ultimately, understanding the mechanisms behind animal
behavior and broadening our scope to include new members in personality research, such as black bears, will illuminate relationships to fundamental components of life-history and provide integral information for effective management and conservation of the species.

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Table 3.1. Details surrounding the capture and orphaning of the six cubs rehabilitated in 2016. The sex of each bear is denoted by the prefix to their alphanumerical identification.

<table>
<thead>
<tr>
<th>Bear</th>
<th>Capture date</th>
<th>Orphaning and capture details</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1401</td>
<td>07/01/16</td>
<td>Inadvertently captured as state biologists attempted to trap her mother</td>
</tr>
<tr>
<td>F1402</td>
<td>07/15/16</td>
<td>Orphaned after her mother was killed for predating on a domestic goat</td>
</tr>
<tr>
<td>M1403</td>
<td>07/26/16</td>
<td>Sibling of M1404; mother was killed in a vehicle collision</td>
</tr>
<tr>
<td>M1404</td>
<td>07/26/16</td>
<td>Sibling of M1403; mother was killed in a vehicle collision</td>
</tr>
<tr>
<td>M1405</td>
<td>08/20/16</td>
<td>Found in a dog kennel at a private residence</td>
</tr>
<tr>
<td>M1406</td>
<td>08/29/16</td>
<td>Captured after utilizing anthropogenic resources within city limits</td>
</tr>
</tbody>
</table>
Table 3.2. Scores from assays measuring responses of six black bear cubs for personality along the bold-shy and activity behavior axes, with individual rankings (R; 1 is the boldest or most active, 6 is the least).

<table>
<thead>
<tr>
<th>Bear</th>
<th>Latency to interior</th>
<th>R</th>
<th>Thigmotaxis</th>
<th>R</th>
<th>Exploration</th>
<th>R</th>
<th>Latency to approach</th>
<th>R</th>
<th>Latency to return</th>
<th>R</th>
<th>Composite bold-shy</th>
<th>R</th>
<th>Activity Score</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1401</td>
<td>-0.090</td>
<td>5</td>
<td>-0.351</td>
<td>4</td>
<td>0.817</td>
<td>2</td>
<td>0.432</td>
<td>3</td>
<td>-1.389</td>
<td>6</td>
<td>-0.055</td>
<td>4</td>
<td>0.823</td>
<td>1</td>
</tr>
<tr>
<td>1402</td>
<td>-1.907</td>
<td>6</td>
<td>-1.263</td>
<td>6</td>
<td>-1.624</td>
<td>6</td>
<td>-0.707</td>
<td>5</td>
<td>-0.025</td>
<td>4</td>
<td>-2.769</td>
<td>6</td>
<td>0.637</td>
<td>3</td>
</tr>
<tr>
<td>1403</td>
<td>0.174</td>
<td>4</td>
<td>0.660</td>
<td>3</td>
<td>-0.032</td>
<td>5</td>
<td>-1.546</td>
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<td>0.290</td>
<td>6</td>
</tr>
<tr>
<td>1404</td>
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<td>3</td>
<td>1.158</td>
<td>1</td>
<td>0.297</td>
<td>4</td>
<td>-0.131</td>
<td>4</td>
<td>0.276</td>
<td>3</td>
<td>0.989</td>
<td>2</td>
<td>0.584</td>
<td>4</td>
</tr>
<tr>
<td>1405</td>
<td>0.562</td>
<td>2</td>
<td>-0.964</td>
<td>5</td>
<td>0.584</td>
<td>3</td>
<td>0.953</td>
<td>2</td>
<td>-0.927</td>
<td>5</td>
<td>-0.573</td>
<td>5</td>
<td>0.377</td>
<td>5</td>
</tr>
<tr>
<td>1406</td>
<td>0.957</td>
<td>1</td>
<td>0.760</td>
<td>2</td>
<td>1.125</td>
<td>1</td>
<td>0.999</td>
<td>1</td>
<td>1.037</td>
<td>1</td>
<td>2.028</td>
<td>1</td>
<td>0.694</td>
<td>2</td>
</tr>
</tbody>
</table>

a Open-field trial; b Novel object trial; c Startle object trial; d From bold-shy assays and first PC; e Mean of activity-level scores from eight focal-animal sampling trials
Table 3.3. Results from principal component analysis of responses to captive tests of bold-shy behavior for six black bear cubs. The first two components were retained, explaining 87% of the overall variance. Loadings in bold typeface represent those that contributed heavily to the formation of respective components.

<table>
<thead>
<tr>
<th>Behavioral test</th>
<th>PC1</th>
<th>PC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency to interior</td>
<td>0.550</td>
<td>-0.201</td>
</tr>
<tr>
<td>Thigmotaxis</td>
<td>0.529</td>
<td>0.335</td>
</tr>
<tr>
<td>Exploration</td>
<td>0.555</td>
<td>-0.165</td>
</tr>
<tr>
<td>Latency to approach</td>
<td>0.204</td>
<td>-0.664</td>
</tr>
<tr>
<td>Startle response</td>
<td>0.260</td>
<td>0.616</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.627</td>
<td>1.302</td>
</tr>
<tr>
<td>Proportion of variance (%)</td>
<td>52.9</td>
<td>33.9</td>
</tr>
<tr>
<td>Cumulative proportion</td>
<td>52.9</td>
<td>86.8</td>
</tr>
</tbody>
</table>
Table 3.4. Correlation coefficients (Spearman’s) for captive activity-level composite scores, captive bold-shy composite scores from the two retained components, and wild activity metrics for six rehabilitated black bears.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Bold-shy component 1</th>
<th>Bold-shy component 2</th>
<th>Activity-level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r_s$</td>
<td>$p$</td>
<td>$r_s$</td>
</tr>
<tr>
<td>Activity-level</td>
<td>-0.1</td>
<td>0.950</td>
<td>-0.9</td>
</tr>
<tr>
<td>Movement rate</td>
<td>-0.6</td>
<td>0.350</td>
<td>-0.1</td>
</tr>
<tr>
<td>Post-release dispersal</td>
<td>-0.3</td>
<td>0.683</td>
<td>0.7</td>
</tr>
<tr>
<td>Release-site fidelity</td>
<td>0.3</td>
<td>0.683</td>
<td>0.2</td>
</tr>
<tr>
<td>Pre-hyperphagia area</td>
<td>0</td>
<td>1</td>
<td>-0.3</td>
</tr>
<tr>
<td>Hyperphagia area</td>
<td><strong>-0.9</strong></td>
<td><strong>0.083</strong></td>
<td>0.6</td>
</tr>
</tbody>
</table>
Fig. 3.1. One of two black bear cub rehabilitation enclosures at the USDA-NWRC Predator Research Facility in Millville, Utah, U.S.A., with approximate locations of object placement for two of the behavioral tests.
This research evaluated the post-release movements, space use, and resource selection of rehabilitated black bears (*Ursus americanus*) during their first year following captive-rearing, and sought to identify individual consistencies in behavior – personality – during the rehabilitation process, while looking for links between personality and wild behavior. This study provides the first application of several approaches to wildlife ecology and behavior. To our knowledge, rehabilitated black bear cubs or yearlings had never been monitored with GPS collars, nor studied with regard to habitat selection in a manner with high spatiotemporal resolution. A meta-analysis of orphan black bear rehabilitation practices by Beecham et al. (2015) indicated that monitoring happens rarely and opportunistically, a puzzling fact given the resources required for wildlife rehabilitation, and the concerns that surround captive-raised carnivores (Herrero et al. 2005, Jule et al. 2008). We also demonstrate the first application of behavioral testing for the purposes of revealing personality in black bears, and the first captive test of Ursids of any species, to our knowledge. We believe that this thesis will provide information to professionals and researchers across several disciplines. Black bears are an important conservation species and one which, despite the litany of research and public interest surrounding them, is still surrounded by many unanswered questions.

Chapter 2 of this thesis provided detailed movement, and space and resource use for the rehabilitated bears in Utah, in 2015, and should be of value to black bear management, conservation, and behavior. We discovered that with one exception, black bears denned shortly after release (within 5.8 days; SE = 1.6) and in the general
proximity of their release site (within 0.40 to 6.81 km; $\bar{x} = 2.86$, SE = 1.15). The bear which proved anomalous with regard to post-release activity should not be considered an outlier, in the traditional sense of the word, given the importance placed on release-site selection by managers for translocated animals – his behavior was atypical, but noteworthy. M1405 traveled a 51.45 km straight-line distance from the release site over the first 9 days at a rate of 336.8 m hour$^{-1}$ (SE = 68.8), and denned 20 days after release and 24.85 km from the release site.

During the full year of monitoring, two bears conducted long distance, late-summer dispersals, while three exhibited strong release-site fidelity. The two dispersing bears resettled 43.81 and 46.27 km from their pre-hyperphagia ranges and traveled at a time when bear forays are common. Noyce and Garshelis (2011) report that about half of all bears in Minnesota engage in late-summer movements that average 10 km for females and 26 km for males. While the mechanisms are unknown, other studies report similar results: average dispersals of 34 km for 60 released, rehabilitated black bears in Canada (Binks 2008), 13 km for yearling bears in West Virginia (Lee and Vaughn 2003), and 40 km for male yearling black bears in New Mexico (Costello 2010). The three non-dispersing bears had distances between their release sites and their final recorded locations (2015-16 den sites) ranging from 3.79 to 8.35 km ($\bar{x} = 5.68$, SE = 1.37). When studying movement rates, we discovered dramatic escalation and curtailment of activity, respectively, for the month after den emergence and the month before den entrance, and an asymptote in September demonstrating the bears’ greatest levels of activity. On average, bears moved at a mean rate of 103.3 m hour$^{-1}$ (SE = 1.9), but had markedly higher rates of movement during the late-season, hyperphagia period. Pre-hyperphagia
home ranges varied in size from 18.11 to 52.97 km$^2$ ($\bar{x} = 42.41$, SE = 6.32), and hyperphagia home ranges varied from 14.68 to 120.24 km$^2$ ($\bar{x} = 51.08$, SE = 18.28).

Investigating third-order habitat selection revealed that distance to roads did not appear to be an influential space-use factor – an important consideration for rehabilitated animals, or animals familiar with anthropogenic resources. Coefficients indicated that bear selection was strongest for northerly aspects (reference class), aspen ($\beta = -1.565$), oak ($\beta = -0.322$), and mixed conifer ($\beta = -0.515$). 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 ($\beta = -1.565$ and 1.651, respectively), and oak habitats elicited modest selection in general, but were strongly avoided during hyperphagia ($\beta = -0.322$ and 0.893, respectively). Grasses and forbs were strongly selected earlier in the year, and strongly avoided during the hyperphagia period ($\beta = 0.171$). These results were not surprising, given that spring and early summer aspen habitats often contain sources of water and serve as parturition sites for mule deer (*Odocoileus hemionus*) and other ungulates (Pajar and Bowden 2004, Latham et al. 2011), the offspring of which are reliable, protein-rich resources for bears (Zager and Beecham 2006). Young and Ruff (1982) showed bears in Alberta selecting aspen sites for their seasonally available resources, while in Utah, aspen habitats in summer accounted for 21.7% of bear locations (Pederson et al. 2008). In early spring, grasses and forbs, while lower-quality, 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.
One interesting finding included the denning chronology of the bears and its allusion toward photoperiod importance. It is presumed that photoperiod and circadian rhythm are predominant drivers for many species life-history processes (Dibner 2010), including the denning chronology of black bears (Johnson and Pelton 1980, Schooley et al. 1994). Despite the differences between sites with regard to latitude, microclimates, and landscape-level biophysical components, the den emergences for the five 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 five bears, some hundreds of kilometers apart, spanned just three days (100-102). While these results allude to the importance of photoperiod on bear behavior, this relationship should be explored further.

Chapter 3 of this thesis investigated the consistency in individual behavior that is fundamental to the presence of personality in humans and non-human animals. We also sought correlations between captive and wild behaviors, as informed by several activity metrics measured in Chapter 2. In our study, the bears displayed intra-individual consistency and between-individual variation with regard to responses within each of the suite of tests for both the bold-shy and activity axes. Intraclass correlation coefficients for analysis of the five bold-shy measurements indicate that some bears were consistently bolder than others in captivity, across time and context ($F_{5,20} = 3.61$, $P = 0.017$). Similarly, intraclass correlation coefficients indicate that activity tests revealed some bears to be consistently more active than others in captive settings ($F_{5,35} = 3.61$, $P = 0.052$). These results lend support to the presence of personality in black bears, as elucidated by a suite of behavioral assays common to the field of personality research – open field, novel object, startle object, and focal-animal sampling. We discovered that
some bears are consistently bolder or more active than others across contexts in captive settings. We present an important finding within the fields of animal behavior: the first application of behavior tests administered for the purpose of revealing individual personality for black bears or any other species in family Ursidae. Identifying the mechanisms that shape, and are shaped by, behavioral traits is fundamental to understanding individual life history and population dynamics (Stamps and Groothuis 2010).

The first principal component – that which explained the greatest amount of variance – produced from the PCA of behavioral assays, did not appear to be correlated to captive activity-level (Spearman’s $r_s = -0.1$, $P = 0.95$). The second principal component, however, suggests a relationship between activity-level and novel and startle object testing (Spearman’s $r_s = -0.9$, $P = 0.083$) – and link which necessitates further research. We were not able to identify correlations between bold-shy composite scores, from either of the components, or captive activity-level composite scores, and the wild activity metrics of movement rate, post-release dispersal, release-site fidelity, or seasonal home range size. For several potential reasons outlined in Chapter 3, a host of factors may be at play which explain this lack of correlation, principally among them being a small sample size, or that we did not investigate wild metrics that may most closely relate to personality. Oftentimes a strong biological significance may be operating, masked by the inability of our analytical powers to detect them (Sih and Bell 2008). Further research will be required to reveal these connections, and we hope our study will have laid the ground work for doing so.
This data provides insight into the activity of released rehabilitated black bear cubs, and highlight the variability of individual behavior. We provide strong support for a short term rehabilitation strategy for orphan bear cubs, which has been demonstrated to reduce the probability of human-bear conflict (Beecham et al. 2015) and greatly reducing on rehabilitation time and effort (Beecham and Ramanathan 2007). We were able to demonstrate that the cubs quickly adapted to life in the wild, denning shortly after release and showing no inclinations to utilize anthropogenic resources. Results from this study also highlight how prior knowledge regarding species-specific ecology should be used to tailor monitoring efforts, and how exploring wild activity data at different scales may yield valuable insights as compared to coarser approaches.

We submit that the data presented here will fill gaps in the literature for rehabilitated or translocated bears, for spatiotemporal dynamics of black bear ecology in Utah, and for black bears in the field of personality research. We encourage the development of short-term captive rehabilitation programs of orphan black bear cubs, given the success shown in this study, with complete survival and no incidents of human-conflict. We also support a continuance into the study of personality in black bears, a pursuit which may illuminate relationships to fundamental components of life-history and provide integral information for effective management and conservation of the species.

LITERATURE CITED


Latham, A. D. M., M. C. Latham, and M. S. Boyce. 2011. Habitat selection and spatial relationships of black bears (Ursus americanus) with woodland caribou (Rangifer


APPENDICES
Table A.1. Table illustrating the difference in body mass from the dates on which the six rehabilitated orphan bear cubs entered the rehabilitation facility in 2014 and the dates on which the bears were released.

<table>
<thead>
<tr>
<th>Bear</th>
<th>Date of Arrival</th>
<th>Body Mass (kg)</th>
<th>Date of Release</th>
<th>Body Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1401</td>
<td>2 July</td>
<td>4.0</td>
<td>3 December</td>
<td>43.5</td>
</tr>
<tr>
<td>F1402</td>
<td>16 July</td>
<td>5.6</td>
<td>3 December</td>
<td>47.1</td>
</tr>
<tr>
<td>M1403</td>
<td>26 July</td>
<td>13.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 December</td>
<td>66.4</td>
</tr>
<tr>
<td>M1404</td>
<td>26 July</td>
<td>13.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4 December</td>
<td>64.3</td>
</tr>
<tr>
<td>M1405</td>
<td>21 August</td>
<td>15.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 December</td>
<td>62.2</td>
</tr>
<tr>
<td>M1406</td>
<td>28 August</td>
<td>15.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3 December</td>
<td>57.1</td>
</tr>
</tbody>
</table>

<sup>a</sup> Estimated mass
Figure A.1. Mean daily movement rates for all bears during the 2015 monitoring year, as represented by Julian date. The lower two graphs include the points associated with the late summer dispersal events of M1403 and M1406. The dashed line indicates 1 September – the date of seasonal delineation for this study.
Figure A.2. Graphs representing the seasonal effects of the estimated relative probability of selection of barren and riparian vegetation classes, which did not possess ecological significance in this study as either a main effect, or as an interaction of season, shown here.
Figure A.3. Graph representing the estimated relative probability of selection for habitats near roadways. Distance to roads was not a covariate in the top model.
Table B.1. Loadings matrix showing results from all five principal components produced from Principal Components Analysis of the captive behavioral tests.

<table>
<thead>
<tr>
<th>Behavioral test</th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
<th>PC4</th>
<th>PC5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency to interior</td>
<td>0.550</td>
<td>-0.201</td>
<td>-0.189</td>
<td>0.768</td>
<td>0.177</td>
</tr>
<tr>
<td>Thigmotaxis</td>
<td>0.529</td>
<td>0.335</td>
<td>0.248</td>
<td>-0.060</td>
<td>-0.737</td>
</tr>
<tr>
<td>Exploration</td>
<td>0.555</td>
<td>-0.165</td>
<td>0.449</td>
<td>-0.448</td>
<td>0.512</td>
</tr>
<tr>
<td>Latency to approach</td>
<td>0.204</td>
<td>-0.664</td>
<td>-0.530</td>
<td>-0.380</td>
<td>-0.303</td>
</tr>
<tr>
<td>Startle response</td>
<td>0.260</td>
<td>0.616</td>
<td>-0.648</td>
<td>-0.246</td>
<td>0.269</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.627</td>
<td>1.302</td>
<td>0.616</td>
<td>0.444</td>
<td>0.287</td>
</tr>
<tr>
<td>Proportion of variance (%)</td>
<td>52.9</td>
<td>33.9</td>
<td>7.6</td>
<td>3.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Cumulative proportion</td>
<td>52.9</td>
<td>86.8</td>
<td>94.4</td>
<td>98.4</td>
<td>100</td>
</tr>
</tbody>
</table>
Figure B.1. Biplot illustrating the correlation between three bold-shy metrics (latency to the interior, thigmotaxis, and exploration) and the seemingly inverse relationship between startle object response and latency to approach the novel object. Subjects appear in light grey, relative to their responses to the various tests.