SURVIVAL AND CONFLICT BEHAVIOR OF AMERICAN BLACK BEARS AFTER RELEASE FROM APPALACHIAN BEAR RESCUE

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DEDICATION

To my loving wife

Amber Blair

and my amazing sons

Colton and Landon Blair

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I found out the hard way that graduate degrees are not easily obtained. This is especially true while caring for over 70 orphaned and/or injured American black bears (*Ursus americanus*) in addition to my wife and our own two little Blair cubs at the same time. That said, this project would not have been possible without the contributions of many individuals interested in advancing our knowledge of American black bear rehabilitation. Appalachian Bear Rescue (ABR) is a small non-profit organization in a tiny town with a huge interest in caring for orphaned American black bears; I am extremely thankful for them and all of their supporters who contributed most of the funding for this project. This included paying for graduate school credit hours, purchasing global positioning system (GPS) wildlife tracking collars, associated tracking equipment, and backcountry hiking gear, to gas money for driving back and forth between the north and south ends of the Cherokee National Forest (CNF) or throughout the Great Smoky Mountains National Park (GSMNP). I would also like to thank the Tennessee Wildlife Resources Agency (TWRA) for their very generous support to help pay for GPS collars.

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ABSTRACT

Wildlife agencies are forced to deal with difficult situations when orphaned or injured American black bear (*Ursus americanus*) cubs (<12 months old) or yearlings (>12 and <24 months old) are captured. However, bears have strong public support and interest and simply euthanizing orphaned animals would be opposed by much of the public. One option is bear rehabilitation. Unfortunately, the survival and movements of bears released from rehabilitation facilities are rarely documented. My goal was to assess survival and post-release conflict of orphaned bear cubs and yearlings following rehabilitation and release from a rehabilitation facility, Appalachian Bear Rescue (ABR), in Townsend, Tennessee, USA. My specific objectives were to (1) estimate first-year survival, (2) identify key variables affecting survival, (3) determine cause-specific mortality, and (4) assess conflict behavior of bears released from ABR. I hypothesized that rehabilitated bears would survive at similar rates, die from similar causes, and engage in similar conflict behavior to wild conspecifics. I equipped 42 black bear cubs and yearlings from ABR with Global Positioning System (GPS) wildlife tracking collars during 2015 and 2016 and released them in either Great Smoky Mountains National Park (GSMNP) or Cherokee National Forest (CNF). I estimated survival using known-fate methods in Program MARK. Wildlife agencies provided reports of released bears in conflict situations. I estimated survival by treating lost telemetry signals as collar failure on a living bear (optimistic estimate) or as collar destruction related to mortality (pessimistic estimate). Pessimistic and optimistic estimates of overall annual survival of bears was 0.88 (SE = 0.07) and 0.93 (SE = 0.06), respectively. Survival for bears released as cubs (0.64, SE = 0.14, n = 13) was lower than for bears released as yearlings (1.00, SE = 0.00, n = 29), and the major cause of mortality was vehicular-collisions.

Three of 42 bears (7.1%) released from ABR engaged in conflict up to 1 year post-release. Survival, cause-specific mortality, and engagement in post-release conflict of my study bears was similar to or higher than published reports for wild conspecifics. Bear rehabilitation should be considered a viable option for orphaned or injured cubs or yearlings.

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INTRODUCTION

Management Options for Orphaned American Black Bears

Wildlife managers are frequently faced with the dilemma of how to best deal with orphaned and injured wildlife. Whether a manager's choice is to provide medical treatment, no intervention, or humane euthanasia, the decision is rarely ever straightforward. Decisions are complicated by public opinion, which may outweigh ecological variables in shaping some wildlife management policies (Swan et al. 2017), especially when managing charismatic species such as bears (*Ursus* spp., Peine 2001). For most North Americans, bears are appealing because of their intelligence, large size, physical appearance, ability to stand erect, and cultural significance (Kellert 1994). As a result, bear management decisions are often controversial (Teel et al. 2002, Ryan et al. 2009).

Dealing with orphaned American black bear (*Ursus americanus*) cubs (< 12 months old) and yearlings (> 12 and < 24 months old) has become a recurring issue for wildlife managers (Stiver et al. 1997). Reasons for orphaning are both natural and anthropogenic. Unfavorable environmental conditions such as drought, fire, or flooding can lead to bear mothers abandoning their cubs (Clark et al. 2002, Waller et al. 2012). In addition, habitat loss, poaching, vehicular collisions, and other forms of human-bear conflict increase the numbers of orphaned bears (Garrison et al. 2007, Beecham et al. 2016).

Human perspectives on wildlife have shifted over the years, and many residents currently living in urban settings demand action for injured and orphaned wildlife (Lindsey and Adams 2006). Some individuals believe orphaned bears should be reintroduced into the wild and expect managers to assist (Beecham et al. 2016). As bear and human population densities around the urban-wildland interface increase, so may the numbers of orphaned bears. Prior to making any decisions regarding orphaned American black bears, wildlife managers need more information about options including (1) non-intervention; (2) humane euthanasia; (3) reuniting bears with their biological mother; (4) fostering bears to wild, adoptive females; (5) transporting bears to a permanent, captive facility; and (6) transporting bears to a rehabilitation facility for eventual release back into the wild (Beecham 2015).

No intervention for orphaned bears could be appropriate if orphans are above a certain age. Alt and Beecham (1984) reported successful releases of pen-reared American black bear cubs at 5 months of age. Erickson (1959) reported that orphaned American black bear cubs survived the winter in Michigan as young as 5.5 months old (Erickson 1959). Some of these cubs were injured (e.g., lacerated paw pads and amputated paws from trap injuries, and a fractured mandible in one case; Erickson 1959). Payne (1975) reported 2 male American black bear cubs orphaned in Newfoundland during September 1969 had survived and were later recaptured in June 1971 (Payne 1975). Johnson and Leroux (1973) reported a 7-month-old grizzly (brown) bear (*Ursus arctos*) cub that survived on its own in the wild for 12 months after orphaning (Johnson and LeRoux 1973). Palomero and Banco (1997) observed 3 orphaned brown bear cubs surviving on their own in the Cantabrian Mountains of Spain from summer 1991 to May 1992 (Palomero and Banco 1997). Regardless of these reports, leaving orphaned bears on their own could possibly lead to prolonged, unnecessary suffering of animals as well as public condemnation of wildlife agencies.

Euthanasia may be the appropriate choice for orphaned bears that are suffering, have substantial injuries or illnesses that will prevent them from living a normal life in the wild, or when the prognoses demand great time commitments with human intervention for complete recovery. Critically-injured bears may require immediate euthanasia in the field by wildlife managers to prevent unwarranted suffering. Some bears may be admitted to wildlife veterinary hospitals in emergency situations, but these bears may still be euthanized if their ability to thrive in the wild is compromised. Lengthy recovery times with human caretakers could also hinder the wild nature of bears (Beecham et al. 2016). Bears in close, frequent contact with humans can become habituated (McCullough 1982). Euthanizing neonate bear cubs that could not survive on their own to prevent suffering is also an option for managers. The public may disapprove of euthanasia or non-intervention and oppose these actions, especially if other options are available.

If feasible, placing bears back with their biological mothers is a publicly acceptable option. Seibert et al. (1999) were able to locate the natal den of a young American black bear cub in Pisgah National Forest, North Carolina, and successfully place it back with its mother. In Great Smoky Mountains National Park (GSMNP), a bear mother and 3 cubs were accidentally separated for about a week. The mother was later trapped, and the 3 cubs were placed with her in a partitioned transfer cage. The animals immediately starting vocalizing and once the divider was raised, the cubs went to the adult female and began nursing. The bear family group was released together (W. H. Stiver, GSMNP, personal communication). However, placing young bears back with their mothers is usually not feasible because wildlife officials may not know the location of the mother. Also, the death of a bear mother would rule out this management option.

Although rare, bears have adopted orphans unrelated to them in the wild (Alt 1984). This behavior was observed in American black bears (Benson and Chamberlain 2006), brown bears (Erickson and Miller 1963), and polar bears (*Ursus maritimus*; Atkinson et al. 1996, Derocher and Wiig 1999). Successful human-mediated fostering of young bears has also occurred. For example, Clarke et al. (1980) placed 2 two-week-old orphaned black bear cubs into the excavated den of a radio-collared bear mother in the Catskill Mountain region of southeastern New York. The mother was thought to have only 1 biological cub based on auditory recordings taken outside the den. Subsequent observations in the spring and summer revealed the mother with 3 cubs (Clarke et al. 1980). Alt and Beecham (1984) used 3 different methods to attempt fostering orphaned black bears to post-parturient females. They found adoption was successful when orphans were placed into the natal dens of bear mothers (75.9% success, n = 29), when orphans were placed at the bases of trees of treed bear mothers with biological young after den emergence (9.1% success, n = 11), and when orphans were introduced to immobilized females and her offspring after trapping in culvert traps following den emergence (20.0% success, n = 5). Alt and Beecham (1984) found that timing of potential adoption was critical. Fostering cubs after the denning period using either the treed or culvert trap methods resulted in only 2 successes in 16 attempts (12.5% adoption rate). Females were observed killing 2 of the orphans during the treed reintroduction process, and another cub was thought to have died in a similar manner (Alt and Beecham 1984).

Maternal body condition due to habitat quality may also affect the outcome of fostering attempts. Carney and Vaughan (1987) introduced 7 black bear cubs to 8 different foster mothers in Shenandoah National Park. They reported high adoption rates (>85%), but low survival rates (20%) for the introduced cubs. They recommended that researchers should be wary of introducing cubs to mothers living in marginal- or poor-quality habitats. Rogers (1985) examined the effects of cub adoptions on bear foster families of varying litter sizes in Minnesota. He reported a total litter loss and death of the orphan when fostering a cub to a mother with a litter of 3. However, survival of both the biological and orphaned cub occurred when fostering to a mother with only 1 cub (Rogers 1985). Added benefits to fostering black bear cubs to wild females with neonates include improved socialization skills, better nutrition from a mother's milk, and reduced potential for human habituation (Servheen et al. 1987). However, the availability of potential adoptive females may necessitate having adult females with neonates already radio collared. Managers are reluctant to radio tag adult females for the sole purpose of future fostering due to the risks and high costs of collaring bears. Additionally, managers must consider the timing of planned adoptions and the nutritional status, current litter size, den type (e.g. high in a tree cavity), and den location of potential surrogate mothers prior to attempting to foster foreign cubs.

As another possibility, managers could place orphaned cubs into permanent captivity such as zoos or sanctuaries. However, bears are long-lived and require large enclosures, which can make it difficult to find permanent, captive wildlife facilities willing to accept bears into their programs (Beecham 2006). At the same time, many people do not want to see wild, orphaned bear cubs placed into permanent captivity (Beecham 2006) and wildlife managers would prefer wild bears be released back into the wild (Stiver et al. 1997).

Placing orphaned bears into rehabilitation programs for care with eventual release back into the wild is another option. According to the International Wildlife Rehabilitation Council (IWRC), "Rehabilitation is the process by which orphaned, injured, or ill wildlife regain the health and skills required to function normally and live self-sufficiently when released back into their natural habitat" (Kanaan and Pajor 2010:7). Rehabilitation and release of wildlife has become a popular practice throughout the world, with millions of animals being cared for each year (Pyke and Szabo 2007). Rehabilitation facilities are typically permitted to care for animals under strict guidelines set forth by the jurisdictional authority responsible for managing wildlife (Beecham 2016). Animal patients are admitted under differing circumstances, including orphaning, illness, and injury. Upon recovery, these individuals are released back into their natural habitat and sometimes followed post-release. Captive care and release of American black bears to the wild has been in practice for decades (Beecham et al. 2016).

Proper rehabilitation and release can also benefit the recovery of declining bear populations and aid in maintaining genetic diversity (Beecham et al. 2016). Also, rehabilitation centers often provide all the funding necessary for caring for orphaned bears (Beecham 2006). Despite these benefits, bear rehabilitation is rarely used by wildlife officials (Beecham et al. 2016). There is concern about the survival of rehabilitated bears in the wild and possible effects of newly-released bears on local bear populations by disease transmission and undesirable conflict behavior among conspecifics (Waples and Staggol 1997, Huber 2010, Beecham et al. 2016). Beecham et al. (2015) reported direct conflict with humans and rehabilitated individuals was also a concern of managers.

Fates of Orphaned American Black Bears

Between 1973 and 1983, Alt and Beecham (1984) released 39 pen-reared American black bears to the wild in Idaho. All bears were released at ≥5 months of age and marked with ear tags (Alt and Beecham 1984). Twenty-three bears were released as cubs, 14 as yearlings, and 2 as 6-year-olds. Alt and Beecham (1984) classified reintroductions as successful if orphans were recaptured alive after 30 days in the wild in non-conflict situations. There were 5 successes, 4 failures, and

14 unknown outcomes for bears released as cubs and 9 successes and 5 unknown outcomes for bears released as yearlings (Alt and Beecham 1984).

Stiver et al. (1997) studied the fates of 23 American black bears raised in captivity and released to the wild in the southern Appalachian Mountains of North Carolina and Tennessee between 1982 and 1995. Mean release age of bears was 2.5 (SE = 0.5) years (Stiver et al. 1997). All bears were marked with ear tags and/or identification tattoos, and 7 bears were telemetered with VHF radio-tracking collars (Stiver et al. 1997). Stiver et al. (1997) determined the fates of 4 of 7 and 3 of 16 bears that were telemetered and not telemetered, respectively. Five bears were involved in post-release conflict behavior and 6 bears died (Stiver et al. 1997). Distances between release sites and final locations ranged from 0.1 to 25.2 km and were determined for the 7 telemetered and 4 of the non-telemetered bears based on 1 bear being relocated, 1 involved in a car collision, and 2 being killed by hunters (Stiver et al. 1997.

During 2002 and 2003, Binks (2008) used VHF telemetry to track 73 American black bears rehabilitated and released from 1 of 3 different facilities or wild-trapped as controls by wildlife officials in Ontario, Canada. Binks (2008) reported a tracking collar failure rate of 53% (n = 39). Survival rates of rehabilitated bears ranged between 0.70 and 0.93 depending on the rehabilitation facility from which they were released, and the survival rate for the control group was 0.68 (Binks 2008). Bears dispersed, on average, between 23.3 and 55.7 km and did not exhibit homing behavior based on directionality of movements (Binks 2008). Cause of death for the 10 bears that died during the first year after release were hunter kill (n = 6), removal because of conflict (n = 3; Binks 2008), and vehicle collision (n = 1).

Beecham et al. (2015) performed a meta-analysis of 550 bears released from captive-rearing facilities throughout the world between 1991 and 2012, including 424 American black bears from 7 different rehabilitation facilities. American black bear release ages ranged from 11 to 23 months and overall, annual survival across programs was 0.73 (*n* = 209; Beecham et al. 2015). Modeling suggested survival was most affected by age at orphaning, release weight, and the interaction between these 2 variables (Beecham et al. 2015). The main cause of mortality was hunter harvest (53.3%), followed by conflict removals (28.3%), vehicular collisions (13.3%), predator kills (3.3%), and natural mortality (1.7%). Distances between release sites and harvest locations of American black bears ranged from 1 to 251 km (Beecham et al. 2015). Only 6.1% (*n* = 26) of American black bears were involved in post-release conflict behavior.

Myers (2015) used GPS tracking collars to follow the post-release movements, space use, denning ecology, and resource selection of 6 American black bear cubs rehabilitated and released to the wild in Utah during 2014. Five of the cubs retained their collars for about 18 months, and distances between release sites and first dens ranged from 0.4 to 24.9 km. Mean den entrance and emergence dates for the 2014–2015 winter were 16 December and 11 April, respectively, and the mean den entrance and emergence dates for the 2015–2016 winter were 1 December and 10 April, respectively. The mean annual rate of movement was 103.3 m/hr for these bears. Movement rates and space use increased from 95.0 m/hr and 42.4 km^2, respectively, during pre-hyperphagia to 116.3 m/hr and 51.1 km^2, respectively, during hyperphagia. Aspen (*Populus tremuloides*) was the most strongly selected vegetation type (Myers 2015).

Smith et al. (2016) used VHF telemetry to follow 11 yearling American black bears released from a rehabilitation facility in New Hampshire during 2011 and 2012. These bears were monitored for 6 months post-release. One bear prematurely dropped its collar, and 10 bears survived the first 30 days after release. Six of 7 bears released during 2011 survived $\geq$6 months, and none of the 3 bears released during 2012 survived. Most mortality was human-related (hunter harvest, $n = 2$; poaching, $n = 1$; or human-bear conflict, $n = 1$). Three bears that engaged in post-release conflict were released in 2012. The mean distance from release sites to the mortality locations was 15.9 km (Smith et al. 2016).

Care, Release, and Monitoring of Orphaned American Black Bears at Appalachian Bear Rescue, Townsend, Tennessee, USA

Appalachian Bear Rescue, located in Townsend, Tennessee, USA (formerly Appalachian Bear Center) has been caring for injured and orphaned bear cubs and yearlings since 1996. Appalachian Bear Rescue was originally established to care for injured and orphaned bears discovered by TWRA and GSMNP. However, ABR has also cared for bears from Arkansas, Kentucky, Virginia, North Carolina, South Carolina, Georgia, and Louisiana (ABR 2016). Appalachian Bear Rescue is privately funded, consists of 7 employees, and is governed by a board of directors.

From 1996 to November 2015, ABR has cared for 203 bears. Of those, 167 (82.3%) bears were released into the wild after rehabilitation; most released bears ($n = 136$, 81.4%) originated in Tennessee. The remaining non-released bears were either placed in zoos or sanctuaries ($n = 11$, 5.4%), fostered to wild females ($n = 8$, 3.9%), escaped ($n = 2$, 1.0%), or died prior to release ($n = 15$, 7.4%). Unfortunately, the majority ($n = 156$, 93.4%) of bears from ABR were not followed after release into the wild and thus their fates were mostly unknown.

Clark et al. (2002) studied the fates of 11 American black bears released to the wild from ABR during 1998. At that time, ABR received 1 yearling from GSMNP and 10 cubs from the Tennessee Wildlife Resources Agency (TWRA). After rehabilitation, researchers fitted the 11 bears with VHF radio-tracking collars to estimate short-term survival post-release (Clark et al. 2002). Clark et al. (2002) reported the probability of survival to 120 and 180 days after release was 0.90 and 0.77, respectively, assuming 2 bears of unknown fate died. Straight-line distances between release sites and collar recovery locations ranged from 0.6 to 34.9 km, and no bears were observed in conflict behavior following release (Clark et al. 2002). Not including bears from this study, there have been a number of anecdotal reports from wildlife officials regarding released bears being legally harvested (n = 2), poached (n = 1), killed in car collisions (n = 1), or involved in post-release conflict (n = 4).

Better estimates of post-release survival and activity of rehabilitated bears are crucial for wildlife managers. Managers must know if rehabilitated bears survive and avoid post-release conflict similar to wild conspecifics to justify reintroductions and the costs and resources allocated to bear rehabilitation. Most prior research on bear rehabilitation was limited to short time periods, comprised of few telemetered bears, used less precise VHF telemetry, or employed no post-release tracking at all. Some studies were based on the assumption that if eartagged bears were not subsequently recovered, that the animal survived and the rehabilitation was successful. Clearly, this will positively bias estimates of survival. Information of post-release travel is important to managers deciding on release sites for rehabilitated bears especially as the current expansion of human settlement along the urban-wildland interface increases the potential for human-bear conflict (Evans et al. 2014, Beecham et al. 2015). VHF telemetry is not as precise as Global-Positioning-System-derived relocation data, which can provide managers with more reliable estimates of post-release movements. Furthermore, survival estimated using GPS telemetry is more precise than using VHF telemetry as researchers are notified almost immediately of mortality events. Collectively, data generated using current GPS technology can provide wildlife managers with more complete and accurate information when considering rehabilitation as an option for orphaned and/or injured American black bears. Finally, sample sizes should be adequate to capture the natural variability and reduce the sampling bias that can result when only a few animals are tracked for a limited period of time.

Objectives and Hypotheses

The purpose of this study was to estimate first-year survival, cause-specific mortality, and conflict behavior of American black bears released from ABR during 2015 and 2016 using GPS technology and compare results with what is known about both parameters for wild conspecifics and other rehabilitated bears. My specific objectives were to (1) estimate first-year survival; (2) identify key variables affecting survival; (3) determine cause-specific mortality; and (4) assess conflict behavior of bears released from ABR. I hypothesized that bears rehabilitated at ABR would survive at similar rates, die from similar causes, and engage in similar conflict behavior to wild conspecifics.

CHAPTER 1

SURVIVAL AND CONFLICT BEHAVIOR OF AMERICAN BLACK BEARS AFTER RELEASE FROM APPALACHIAN BEAR RESCUE

Introduction

Orphaned American black bears (*Ursus americanus*) are a concern for wildlife managers (Stiver et al. 1997). Reasons for orphaning are both natural and anthropogenic. Unfavorable environmental conditions (e.g., drought, fire, or flooding) can lead to bear mothers abandoning their cubs (Clark et al. 2002, Waller et al. 2012). In addition, habitat loss, poaching, and human-bear conflict increases the numbers of orphaned bears (Beecham et al. 2016).

Many residents currently living in urban settings demand action for injured and orphaned wildlife (Lindsey and Adams 2006). Some individuals believe orphan bears should receive an opportunity for reintroduction into the wild and expect wildlife managers to assist (Beecham et al. 2016). As bear and human population densities around the urban-wildland interface increase, so may the numbers of orphaned bears. Options for aiding orphaned American black bears include non-intervention, humane euthanasia, reuniting bears with their biological mother, fostering bears to wild, adoptive females, transporting bears to a permanent, captive facility and transporting bears to a rehabilitation facility for eventual release back into the wild (Beecham 2015).

The major benefit of placing orphans in rehabilitation programs is that they can offer managers the option of releasing bears back into the wild if biological or surrogate mothers cannot be located (Beecham 2006). Proper rehabilitation and release can also benefit the recovery of declining bear populations and aid in maintaining genetic diversity (Beecham et al. 2016), and rehabilitation centers often provide funding necessary to care for orphaned bears (Beecham 2006). Despite these benefits, wildlife officials rarely use this option (Beecham et al. 2016). There is concern about the survival of rehabilitated bears in the wild as well as possible effects of released bears on local bear populations through disease transmission and encouraging undesirable conflict behavior among conspecifics (Waples and Staggol 1997, Huber 2010, Beecham et al. 2016). Managers may also have reservations regarding direct conflict with humans and rehabilitated individuals (Beecham et al. 2016).

Captive care and release of American black bears to the wild has been in practice for decades (Beecham et al. 2016). However, the post-release information currently available for rehabilitated American black bears is limited and largely derived from studies incorporating small sample sizes, 1 age class of young bears (cubs or yearlings), short study periods, or no or limited post-release tracking. Studies relying on capture-recapture data for survival information require large data sets to compare between sexes and age classes (Sorenson and Powell 1996), and early studies used opportunistic reports of released bears or tracking with Very High Frequency (VHF) telemetry.

Relying on future ear tag identification of bears can positively bias survival rates of bears if ear tags are lost prior to recapture or if bears are never recaptured. Alt and Beecham (1984) relied on ear tag identification to follow captive-reared and released American black bears. However, the fate of many of these bears was unknown as most bears were never recovered. Releases were considered successful if bears were recaptured alive without conflict after 30 days. A short study period could also have failed to accurately estimate survival and post-release conflict.

Using VHF telemetry, bears of unknown fate may be censored (e.g. removed from the study at that time) due to detection limitations, which could positively bias survival results if censoring was due to actual mortality rather than radio failure (Sorenson and Powell 1996).

Stiver et al. (1997) telemetered a small cohort of captive-reared American black bears. All bears received ear tags and/or identification tattoos, and 7 bears were fitted with VHF tracking collars (Stiver et al. 1997). Stiver et al. (1997) was able to determine the fates of 4 out of 7 bears using telemetry and only 3 of the 16 bears that were marked with tags. Clark et al. (2002) collared 11 cubs and yearling American black bears and monitored survival to 180 days. Seven of the 11 bears dropped their collars before 180 days. One collar was never retrieved, and radio contact with 1 bear was lost (Clark et al. 2002). Binks (2008) analyzed 73 American black bears rehabilitated and released in Ontario, Canada but 53% of the collars failed or became detached from the bear during the first year after release. Beecham et al. (2015) also analyzed a large sample size of 550 rehabilitated yearling bears, including American black bears. However, he reported that 30% of all bears were not located post-release and, consequently, their fates were recorded as unknown (Beecham et al. 2015). Including these bears as successes would positively bias survival estimates, but excluding them would negatively bias estimates because harvested bears were more likely to be included in the analysis than bears dying from other causes.

Global positioning system (GPS) collars provide precise data with better estimates of post-release survival and movements than VHF technology. Knowledge of post-release activity of released bears is crucial for managers deciding on release sites, especially in the urban-wildland interface where expansion of human and bear populations increase the potential for human-bear conflict (Evans et al. 2014, Beecham et al. 2015). Myers (2015) and Smith et al. (2016) used GPS wildlife tracking collars to follow American black bears post release, but both collared small sample sizes consisting of 1 age class of young bears and thus were not able to analyze survival based on differing release ages. Also, Smith et al. (2016) only tracked bears for

6 months. Longer study periods (e.g. 1 year or more) may increase the ability to capture the effects of variation in natural food abundance in the wild on survival and post-release conflict. Therefore, advanced technology combined with large sample sizes and longer study durations for monitoring rehabilitated bears is needed to thoroughly evaluate rehabilitation as a management tool.

Appalachian Bear Rescue, located in Townsend, Tennessee, USA, has been caring for injured and orphaned bear cubs and yearlings since 1996. As of November 2015, ABR had cared for 203 bears from Tennessee, North Carolina, Arkansas, Kentucky, Virginia, North Carolina, South Carolina, Georgia, and Louisiana (ABR 2016). Of those, 167 (82.3%) bears were released to the wild after rehabilitation; most released bears (n = 136, 81.4%) have been from Tennessee. The remaining 36 bears were either placed in zoos or sanctuaries (5.4%), fostered to wild females (3.9%), escaped (1.0%), or died prior to release (7.4%). Clark et al. (2002) followed 11 of these bears post-release. Unfortunately, the majority (n = 156, 93.4%) of bears released into the wild from ABR were not followed, thus, their fates were mostly unknown. Of this majority, ABR received occasional reports from wildlife officials regarding released bears being legally harvested (n = 2), poached (n = 1), killed in car collisions (n = 1), or involved in post-release conflict (n = 4). This information provided limited anecdotal information about ABR bear survival, post-release movements, and conflict activity, but prevented ABR from contributing needed, sound post-release data of rehabilitated bears to the scientific community.

Knowledge of post-release survival and conflict behavior of rehabilitated bears is crucial for wildlife managers. Managers must know if released rehabilitated bears survive similar to wild conspecifics. With urban sprawl increasing and former bear habitat decreasing, managers also need information on the potential for rehabilitated bears to engage in post-release conflict. Managers often have restricted access to remote release sites far from human settlement (Beeman and Pelton 1976). Planning releases for American black bears must consider the potential for long-distance travel of bears (Liley and Walker 2015) and the availability of anthropogenic foods (Merkle et al. 2013). The greatest driver for human-bear conflicts is the spatial arrangement of humans (anthropogenic foods) and black bear habitat (Spencer et al. 2007). For rehabilitation of bears to be accepted and effective, managers need information comparing survival and conflict behavior with bears in the wild.

The purpose of this study was to estimate first-year survival and conflict behavior of American black bears released from ABR during 2015 and 2016 and compare results with parameters for wild conspecifics and other rehabilitated bears. My specific objectives were to (1) estimate first-year survival; (2) identify key variables affecting survival; (3) determine cause-specific mortality; and (4) assess conflict behavior of bears released from ABR. I hypothesized that bears rehabilitated at ABR would survive at similar rates, die from similar causes, and engage in conflict behavior similar to wild conspecifics.

Methods

Study Area

I conducted my study in Cherokee National Forest (CNF), Tennessee and GSMNP, Tennessee and North Carolina, USA (Figure 1, APPENDIX). Both GSMNP and CNF lie within the Unaka Mountain Range of the Blue Ridge province, which is in the southern division of the Appalachian Mountain Range (Fenneman 1938, King et al. 1968). The Unaka Mountains face the Appalachian Valley and parts of the Valley and Ridge provinces on the northwest and create a barrier between the valley and the rest of the Blue Ridge Province in North Carolina (King et al. 1968).

Great Smoky Mountains National Park was a 2,072-km^2 area of federally protected mountainous, temperate forest in eastern Tennessee and western North Carolina (Yarkovich et al. 2011). Steep slopes are common in GSMNP, and elevations range from 266 m in the foothills around the Little Tennessee River to 2,025 m in the highlands on Clingman's Dome (Southworth 2012). Average annual rainfall varied from 140 to 220 cm between lower and higher elevations, respectively (Shanks 1954, Matmon et al. 2003). Jenkins (2007) grouped vegetation communities found in GSMNP into 11 major types, which consisted of montane alluvial forests, early successional forests, cove forests, hemlock (*Tsuga canadensis*) forests, montane oak (*Quercus* spp.)-hickory (*Carya* spp.) forests, xeric ridge forests, high-elevation hardwood forests, Red spruce (*Picea rubens*)- Frasier fir (*Abies fraseri*) forests, heath balds, grassy balds, and pasture and old fields. Montane oak-hickory forests were the most common forest type, covering 31% of GSMNP between 340 and 1370 m, and dominated by northern red oak (*Quercus rubra*) (Jenkins 2007). The U.S. Department of the Interior managed GSMNP and hunting was prohibited in all areas.

The CNF consisted of 2630-km^2 of public land in 10 counties in eastern Tennessee and 1 county in western North Carolina (United States Department of Agriculture 2004). The CNF was separated by GSMNP into northern and southern regions. Average annual rainfall in the CNF ranged between 101.6 and 190.5 cm (United States Department of Agriculture 2004). Nine major forest communities were described for the CNF and consisted of northern hardwood forests, montane red spruce-fir forests, mixed mesophytic-hardwood forests, conifer-northern hardwood forests, dry to mesic oak forests, dry to mesic oak-pine (*Pinus* spp.) forests, xeric oak forests, xeric pine forests, and eastern riverfront and river floodplain hardwood forests (United States Department of Agriculture 2004). The U.S. Department of Agriculture Forest Service and the Tennessee Wildlife Resources Agency (TWRA) jointly managed the CNF. The majority of the land was open to hunting within legal seasons managed by TWRA except on recreational or administrative sites. Bear hunting and using dogs to hunt wild boar (*Sus scrofa*) were not allowed on any of the 6 bear reserve areas (United States Department of Agriculture 2016).

Bear Capture, Evaluation, and Collaring after Housing at ABR

Curators employed by ABR cared for the bears, and someone was present at the site 24 hrs/day as mandated by TWRA. I temporarily housed neonate cubs and injured bears in secured, clean cages within climate-controlled buildings until they were ready for release into larger acclimation pens or into wild enclosures. There were 4 wild enclosures at ABR with each being about 0.20 ha in size (Figure 2). Each wild enclosure consisted of chain link fencing about 3 m in height (enclosure fencing) surrounded by a similar fence 4.5 m outside the perimeter (perimeter fencing). I electrified the interior fencing with 3–5 strands of wire at the bottom portion of the fencing and 2 strands at the top. The outside fence was covered by heavy, dark material as a visual barrier. All wild enclosures resembled natural forested settings and included natural ground cover and various tree species for bears to climb (including tulip poplars, hemlocks, oaks, and hickories). I equipped enclosures with large plastic water tubs for drinking as well as large-diameter (2.5-m), plastic pools for wading. I threw and scattered all food over the fencing from behind the blind to prevent bears from seeing curators and to encourage natural foraging behavior. I limited feedings to one time per day or every other day to limit human presence (auditory and olfactory) at the bear areas. Foods consisted of a commercially available pelleted bear diet (Mazuri Bear Diet, Purina Mills LLC., Gray Summit, Missouri, USA) in addition to supplementation of a selection of seasonally available natural foods, including blackberries (*Rubus* spp.), blueberries (*Vaccinium* spp.), muscadines (*Vitis rotundifolia*), and acorns (*Quercus* spp.). On occasion, I gave bears carrion such as fresh-killed white-tailed deer (*Odocoileus virginianus*) carcasses.

I evaluated health status and sufficient weight gain of bears, food availability in the wild, and hunting season before considering release from the facility. I allowed injured bears to heal following treatment plans outlined by the University of Tennessee's College of Veterinary Medicine (UTCVM). I was not able to weigh bears prior to capture from the enclosures but monitored bears for sufficient weight gain via visual observations of body size during housing. I deemed bears had gained sufficient weight for release based on estimated masses (>18 kg) and the appearance of adequate adipose tissue. I coordinated release dates between ABR and the jurisdictional authority responsible for the bear. I immobilized bears and monitored temperature, pulse, respiration, and saturated oxygen concentration (Williamson et al. 2018). I weighed, measured, tagged (ear tags, lip ID tattoo, and Passive Integrated Transponder (PIT) tag), and outfitted bears with GPS radio-collars (Vectronic Aerospace GmbH, GPS PLUS Iridium, Berlin, Germany). After workups, wildlife officials transported bears and released bears in GSMNP or CNF to areas as close to their origination sites as possible. I used hard-release methods without an acclimation period for all releases (Clark 2009) and released bears in forested settings away from human habitation and disturbance when possible. The University of Tennessee's

Institutional Animal Care and Use Committee (UT-IACUC No.: 2451) approved all animal procedures.

Post-Release Monitoring

I programmed collars to take 1 location every 3 hours. I pre-programmed all collars with mortality event alert capabilities, which sent an email and/or text message when collars went into mortality mode (motionless for 8 to 24 hours). I pre-programmed collars with hibernation delay sensors and a scheduled drop-off mechanism to release the collars after about 1 year (scheduled drop). I downloaded bear locations using GPS Plus X software (Vectronic Aerospace) and monitored locations via Google Earth (Google Inc., Google Earth, Mountain View, California, USA). I used a drop-off receiver and 2-element antenna (Vectronic Aerospace) to remotely communicate with the collar for drop-off prior to one year if I suspected that the bear was in danger of outgrowing the collar. I investigated all mortality events in the field by traveling to the last-known coordinates for the collar and using the VHF beacon transmitter to locate the collar. I assessed mortalities versus premature drops by searching a ≥10-m diameter area for a bear carcass or other remains. I relied on aerial telemetry by a TWRA licensed pilot if a bear's last-known location was not available.

Survival Analysis

I modeled survival in Program MARK (White and Burnham 1999) using Kaplan-Meier known-fate methods (Pollock et al. 1989). I used R (R Core Team 2018) to create capture history input files for Program MARK. I standardized the start times so that the capture history for each bear began on week 1; i.e., all bears had the same start dates (Clark et al. 2002). In this way, the first-year post-release survival rates would be comparable across animals, regardless of when they were released. End times were the last day bears were known to wear their collars or 2 days prior to collars entering mortality mode; the 2-day period was to account for a potential 24-hr delay in when the mortality occurred and when the collar entered mortality mode. I coded capture histories as weekly intervals and performed separate analyses grouping by sex (male or female) and release age (released as cubs or yearlings). When grouped by sex, I entered release age as an individual continuous covariate based on the estimated age (days) of bears at release. For age determination, I assumed all bears were born on 17 January based on black bear parturition data collected in Virginia by Bridges et al. (2011). I estimated release ages of bears by calculating the differences (days) between dates that bears were released and 17 January of the birth year. When grouped by release age, I entered release age as a categorical variable. I considered bears released at <12 months old to be cubs and bears released at ≥12 and <24 months old to be yearlings.

When grouped by sex, I constructed all survival models using individual covariates consisting of release age (days), release area (GSMNP or CNF), age at intake (days), release mass (kg), number of days at ABR (care days), total distances traveled (km), and maximum dispersal distances from release sites (km). I estimated age at intake by calculating the differences (days) between dates that bears entered the rehabilitation facility and 17 January of the birth year. I calculated the number of care days as the differences (days) between dates of bear intake and release. When grouped by release age, I constructed all survival models using individual covariates consisting of sex (male or female), release area (GSMNP or CNF), age at intake (days), release mass (kg), number of days at ABR (care days), total distances traveled (km), and maximum dispersal distances from release sites (km). I did not model combinations of distance metrics and age variables due to possible correlative effects within the data (e.g., older bears may have had greater travel rates than younger bears). I evaluated support for models using Akaike's Information Criterion (Akaike 1974) corrected for small sample sizes (AICc, Burnham and Anderson 2002) generated within Program MARK. I defined the best or most parsimonious model as that with the lowest AICc value. I considered competing models where differences in AICc values (ΔAICc) were ≤2.0 (Burnham and Anderson 1998). I considered effects to be supported if 95% confidence intervals around β-values excluded zero. I compared survival estimates of bears released from ABR to survival estimates of wild conspecifics and rehabilitated bears from published reports.

I determined cause-specific mortality of bears when possible; I transported carcasses and remains to the University of Tennessee's College of Veterinary Medicine (UTCVM) for necropsy. I censored bears from the analysis when their collars malfunctioned and ceased transmitting location data or when bears dropped their collars prior to the end of the study period (52 weeks). I did not include bears in the survival analysis beyond the dates they were censored if they were rediscovered later (alive or dead) to prevent potential bias in results (Beecham et al. 2015). If a bear was censored and its collar was not retrieved (fate unknown), I estimated survival 2 ways. I estimated survival assuming the bear died (pessimistic estimate) and estimated survival assuming the bear lived (optimistic estimate), thus bracketing the estimates based on assumptions related to unknown fates. I estimated survival by release age class (cubs or yearlings) by using the survival analysis that grouped by release age (categorical release age). I estimated overall annual survival (pessimistic and optimistic estimates) by model averaging survival estimates using the survival analysis that grouped by sex (release age as continuous covariate).

Spatial Data Analysis

I minimized GPS location error by screening data for positional dilution of precision (PDOP) values and fix type (2D or 3D) (Lewis et al. 2007). I calculated data retention values for my data using the following four different screening methods and used the method that minimized the most location error but retained the most data: removing 2D locations with a PDOP >5, removing all 2D locations, removing 2D locations with a PDOP >5 and removing 3D locations with a PDOP >10, and removing all 2D locations and removing 3D locations with a PDOP >7 . Start dates for spatial analyses were the dates immediately after the dates I released the bears. End dates were 2 days prior to the dates collars first entered mortality mode or were retrieved prior to entering mortality mode to account for a 24-hr mortality delay and investigator disturbance when remotely releasing collars.

Movement metrics and associated maps were generated using a geographic information system and the *Tracking Analyst* tool within the software package ArcMap version 10.5 (Environmental Systems Research Institute, Inc., Redlands, California, USA). Movement metrics included total distances traveled (km), annual dispersal distances from release sites (km), and maximum dispersal distances from release sites (km). I estimated annual and maximum dispersal distances as the Euclidean distances from a bear's release site to its last-known location or its farthest location from its release site, respectively. I estimated total movement and annual dispersal only for bears that I monitored with telemetry for $\geq$90% of a full year (>328.5 days). I used total distances traveled and maximum dispersal distances from release sites as covariates in my survival analysis.

Conflict Behavior

I relied on state and federal wildlife agencies to report conflict behavior of collared bears. I did not consider reports of general sightings of collared bears as conflict incidents, and reports of conflict behavior of released bears were not solicited from the public to prevent bias of reporting (Smith et al. 2016). I assumed that all bears engaging in conflict behavior were identified (Beecham et al. 2015). I calculated the percentage of released bears engaging in conflict behavior during the first year after release as the number of bears reported in conflict situations divided by the total number of released bears in the study.

Results

I rehabilitated, collared, and released 42 American black bears (23 males and 19 females) from ABR between 2015 and 2017 (Table 1, APPENDIX). I released 13 bears as cubs, and 29 as yearlings. Most (73.8%) bears were released to GSMNP (CNF = 11, GSMNP = 31). Release ages of bears ranged from 292 to 548 days ($\bar{x}$ = 414, SE = 11.9). Age at intake ranged from 98 to 238 days ($\bar{x}$ = 179, SE = 9.1) for bears released as cubs and 273 to 493 days ($\bar{x}$ = 347, SE = 9.9) for bears released as yearlings. Release weights ranged from 23.4 to 56.2 kg ($\bar{x}$ = 37.4, SE = 3.0) for cubs and 18.1 to 45.4 kg ($\bar{x}$ = 29.8, SE = 1.3) for yearlings. Care days ranged from 90 to 198 days ($\bar{x}$ = 128, SE = 7.2) for bears released as cubs and 55 to 190 days ($\bar{x}$ = 115, SE = 7.7) for bears released as yearlings. Twenty-one bears retained their collars for more than a year, and 24 retained their collars for $\geq$90% of a full year. Collar retention ranged from 6 to 447 days ($\bar{x}$ = 305, SE = 22.3). I recovered 41 of 42 (97.6%) GPS collars. I recorded 93,640 post-release locations prior to screening the data for fix type and DOP. My method of screening the location data by removing all 2D fixes and removing all 3D fixes with a PDOP >7 resulted in 93.8% data retention (Table 2). Finally, 57,243 locations remained after removing locations outside the release and 1-year duration. Total distance traveled ranged from 5.5 to 504.2 km ($\bar{x}$ = 223.2, SE = 44.8, n = 13) for bears released as cubs and 3.9 to 722.7 km ($\bar{x}$ = 339.7, SE = 33.2, n = 27) for bears released as yearlings (Figure 3). Annual dispersal distance from release sites ranged from 4.4 to 23.3 km ($\bar{x}$ = 12.5, SE = 2.4, n = 4) for bears released as cubs and 1.2 to 21.1 km ($\bar{x}$ = 10.9, SE = 1.2, n = 20) for bears released as yearlings (Figure 4). Maximum dispersal distance from release sites ranged from 1.4 to 30.8 km ($\bar{x}$ = 8.7, SE = 2.2, n = 13) for bears released as cubs and 1.5 to 55.0 km ($\bar{x}$ = 14.7, SE = 2.2, n = 27) for bears released as yearlings (Figure 5).

I recorded 4 known bear mortalities 1-year post-release, all of which were released as cubs. Bear 946's collar was never recovered. Therefore, the estimate of overall bear survival was bracketed with this bear assumed dead (pessimistic estimate) and assumed alive (optimistic estimate) at the date it was censored. Pessimistic and optimistic overall annual post-release survival estimates of bears were 0.88 (SE = 0.065) and 0.93 (SE = 0.059), respectively. The highest-ranked pessimistic model accounting for 50% of the AICc weight (w_i) consisted of total distance traveled as a covariate (β = 0.0074, 95% CI = 0.0015–0.0133, Table 3). The model consisting of release age (w_i = 0.19, β = 0.0123, 95% CI = -0.0004–0.0251) was a competing pessimistic model (ΔAIC_c = 1.87). The highest-ranked optimistic model accounting for 37% of the weight consisted of release age as a covariate (β = 0.0200, 95% CI = -0.0006–0.0406, Table 4). The model consisting of total distance traveled (w_i = 0.34, β = 0.0086, 95% CI = 0.0017–0.0154) was a competing optimistic model (ΔAIC_c = 0.20). Cubs had lower survival (0.64, 95%

CI = 0.35–0.86) than yearlings (1.00, 95% CI = 1.00–1.00). Vehicular collisions were responsible for 2 deaths (both females), one was removed because of conflict (male), and the cause of death for one bear was undetermined (female). Seven bears came from known, habitual, conflict mothers (Table 5) although only 3 (7.1%) of the released bears engaged in conflict behavior within 1 year post-release. The 3 released bears with conflict behavior all had mothers with conflict histories. The other 4 rehabilitated offspring of known, conflict mothers did not engage in conflict behavior one-year post-release.

Discussion

Survival

Modeling survival using release age as a categorical variable produced standard errors of zero for bears released as yearlings. This can be attributed to no deaths observed in the class of bears released as yearlings. However, the model using release age as a continuous covariate was also supported, and the 95% CI of the β-value only narrowly overlapped zero. I therefore conclude that there was support for a release age effect on survival.

Pessimistic (0.88) and optimistic (0.93) overall annual survival rates of bears released from ABR were among the highest (0.45–0.94) reported for wild yearling and subadult American black bears in the southern Appalachians (McLean and Pelton 1994, Ryan 1997, Lee and Vaughan 2005). My estimates of overall annual survival were within the range of short-term (to 180 days) ABR bear survival rates (0.77–1.00) found by Clark et al. (2002), but estimated at twice the duration. My pessimistic and optimistic estimates of ABR bear survival was similar to or higher than the highest survival rate for rehabilitated bears (0.50–0.90) reported by Beecham et al. (2015) for 7 different black bear rehabilitation facilities throughout North America.

However, I used more advanced telemetry methods (GPS) and a larger sample size than most (5 of 7; 71.4%) of the black bear rehabilitation facilities they analyzed (Beecham et al. 2015). Also, many of the bears in my study were released as cubs, which would typically have lower survival rates than yearlings.

Comparable studies of survival for wild bears in protected areas included those by Sorenson and Powell (1998) who used percent survival estimation to calculate survival between age classes. One-year-old survival was estimated at 0.77 (SE = 0.12), and 2-year-old survival was estimated at 0.80 (SE = 0.08) for American black bears radio-telemetered in Pisgah Bear Sanctuary in North Carolina, USA (Sorenson and Powell 1998). McLean and Pelton (1994) estimated survivorship by age class for female bears in protected areas of GSMNP (1972–1989) and CNF (1978–1989). Survival between the 1.5 and 2.5-year-old classes was 0.88 in GSMNP and 0.84 in CNF (McLean and Pelton 1994). Wild bear survival in protected areas of the southern Appalachians appears to be similar to my estimate of survival for bears released as cubs (0.64) and slightly lower than my estimate for bears released as yearlings (1.00). My survival rate reported for bears released as yearlings is also higher than the combined yearling survival rate (0.81, 95% CI = 0.67–0.96) reported for bears released from 3 different black bear rehabilitation facilities in Ontario, Canada (Binks 2008).

Most black bear rehabilitation facilities care for bears until they are yearlings, which in the wild occurs around the time of natural family breakup (Beecham et al. 2016). In the southern Appalachians, the onset of separation between bear mothers and their young typically occurs between late May to early July with a peak in June when yearlings are 15–17 months old (Clevenger and Pelton 1990, Lee and Vaughan 2004). Appalachian Bear Rescue is one of a few bear rehabilitation facilities that releases bears as both cubs and yearlings which allowed me to study the effect of release age on rehabilitated bear survival. The highest-ranked optimistic survival model in my study consisted of release age, and the 95% CI included zero, but only marginally (Table 4). Likewise, release age was also a competing model in my pessimistic survival analysis, again with only marginal overlap of zero (Table 3).

Beecham et al. (2015) did not find differences between survival rates of rehabilitated bears released as cubs (n = 54) and yearlings (n = 155) in their study. Their top models explaining survival of released bears in Idaho, Montana, and Washington included age at orphaning, release weight, and the interaction between the two variables. They found that survival increased with release weight for bears orphaned <8 months old and decreased with release weight for bears orphaned >8 months old (Beecham et al. 2015). They suggested that heavier weights of younger bears may have compensated for inexperience in the wild and older, heavier bears may have been selected for harvest (Beecham et al. 2015). Neither release weight nor intake age models were supported in my study. However, the age at actual orphaning could not be determined with precision. My models did not support release weight as an important predictor of survival possibly due to heavy release weights for all bears and bears being released to protected areas, where harvest was not permitted.

Cause-Specific Mortality

Causes of mortality may be a concern for managers if rehabilitated individuals are more susceptible to certain forms of mortality than their wild conspecifics. Food shortages (Rogers 1977), disease (Elowe and Dodge 1989), interspecific predation (Boyer 1949, Rogers and Mech 1981), intraspecific predation (Rogers 1977, Lecount 1982, Alt and Gruttadauria 1984), and flooding of natal dens (Alt 1984) are examples of natural causes of young bear mortality. Human-induced forms of mortality for young bears include harvest (Elowe and Dodge 1989, Beringer et al. 1998), den disturbance (Elowe and Dodge 1989), and vehicular collisions (Garrison et al. 2007, van Manen et al. 2012). Released black bears homing toward origination ranges may be more susceptible to mortality events (Fies et al. 1987, Stiver 1991, Eastridge and Clark 2001, Wear et al. 2005).

Translocated American black bears can travel large distances back toward their capture sites (Beeman and Pelton 1976, Fies et al. 1987) and dispersing young male bears may be particularly vulnerable (Schwartz and Franzmann 1992). Therefore, I attempted to release ABR bears as close to their origination sites as possible in an effort to reduce post-release travel and encourage settling. However, release sites were limited, and I could not be certain that bears were returned to their natal ranges. Annual dispersal distances from release sites for ABR bears ranged between 1.2 and 23.3 km ($\bar{x}$ = 11.2 km, SE = 1.4). Binks (2008) did not attempt to release bears near their natal ranges and suggested that this practice may not prevent long dispersals. He found wider-ranging annual dispersal distances from release sites than was observed in my study ranging from 1.1 to 171.7 km with means ranging between 23.3 and 55.7 km for 3 bear rehabilitation facilities in Ontario, Canada.

The top model in my pessimistic survival analysis and a competing model in my optimistic survival analysis consisted of total distance traveled. Specifically, the data showed a positive relationship (slope) between total distance traveled by bears and survival. This is contradictory to earlier reports that more transient bears are more susceptible to mortality. However, there were only 4 mortalities and 1 unknown fate in this study, which may have attributed to this result. All 4 known mortalities occurred within the age class of bears released as cubs, which were all released during the fall (November and December). The onset of the denning period may have lessened the likelihood for these bears to travel prior to their deaths. In the southern Appalachian region, the denning period typically ranges between late November and early May of the following year (Wathen et al. 1986). This would have given the 4 bears that died less than 4 months to travel post-denning, whereas half of the bears in this study were given a full year to travel and survived the 1-year study period.

Wildlife officials in our area had limited access to remote, backcountry areas for releasing bears and therefore, most bears in my study were released a mean distance of 3.7 km (SE = 0.4) from a road. Although I had relatively few mortalities in my study, 2 of 4 (50%) known deaths were from collisions with vehicles within one year after release, and both were females (bears 809, 941; Table 2). Vehicular collisions can be a major source of mortality for black bears in the wild (Ryan et al. 2007). Between 2007 and 2017, vehicular collisions accounted for over 50% of known American black bear deaths within GSMNP (R. H. Williamson, GSMNP, personal communication). Beecham (2015) found that 8 of 60 (13.3%) rehabilitated black bears were killed from car collisions. Smith et al. (2016) did not document any vehicular collisions of rehabilitated yearling black bears released in New Hampshire, but only monitored bears after release in the spring to denning that winter. Myers (2015) did not report vehicular-caused or any other black bear mortalities in his study of 6 rehabilitated cubs in Utah that were tracked for up to 18 months in the wild.

Tri et al. (2017) studied the survival of American black bears captured within the wildland-urban interface of Pennsylvania, New Jersey, and West Virginia and reported 1- to 2-

year-old females appeared particularly vulnerable to vehicular mortality (33% of subadult female deaths vs. 8% of subadult male deaths). Binks (2008) found that vehicular collisions accounted for 10% of rehabilitated black bear deaths 1 year following release in Canada. He concluded that rehabilitated females may be more susceptible than wild-reared females to this form of mortality due to greater post-release travel. Subadult females in the wild tend to remain within or close by their natal ranges, and males typically disperse (Schwartz and Franzmann 1992, Lee and Vaughan 2003). Lee and Vaughan (2003) defined dispersal distances of wild subadult American black bears in Virginia as >15 km for males and >8km for females. They reported no dispersals of yearling females (n = 14), whereas 37% of yearling males (n = 11) dispersed. I found that half (50%) of bears dispersing >15 km (n = 8) from their release sites were female. Although my movement metrics focused on dispersal distances from release sites rather than dispersal in an ecological sense, I make this comparison to demonstrate natural movements among sexes of wild, yearling bears to bears rehabilitated and released in my study. I agree with Binks (2008) that rehabilitated subadult females may be more vulnerable to vehicular-related mortalities than wild subadult females due to higher post-release travel. This may be a result of releasing rehabilitated females (and males) to unfamiliar areas because I did not know the precise locations of natal ranges. It could also be because rehabilitated bears were orphaned at such a young age they had no recollection of their natal ranges.

Harvest is the main cause of wild, subadult American black bear deaths (Lee and Vaughan 2005, Tri et al. 2017) and the main cause of mortality for rehabilitated American black bears (Binks 2008, Beecham et al. 2015, Smith et al. 2016) in areas where hunting is permitted. Bears in my study were released into protected areas where hunting was not permitted.

However, wild black bears can travel large distances (Liley and Walker 2015) and are certainly capable of moving outside protected areas and be exposed to harvest mortality (Sorenson and Powell 1996, Berringer et al. 1998). Obbard et al. (2017) reported that American black bears were 7 times more likely to die outside of Algonquin Provincial Park than within its interior. Bear hunting is allowed on CNF lands adjacent to bear reserve areas and there is heavy hunting pressure along the periphery of GSMNP (Beeman and Pelton 1976). Rehabilitated bears in my study and Clark et al. (2002) moved outside protected areas and were exposed to harvest risk. I did not document any harvest-related mortalities of ABR bears 1-year post-release, but 3 of my study bears were taken by hunters following the 1-year post-release monitoring period. Clark et al. (2002) reported one of their rehabilitated bears was legally harvested in the North Carolina bear hunting season after their study had concluded.

Conflict Behavior

Pelton and Burghardt (1976) estimated that 5% of the wild black bear population in GSMNP engages in conflict behavior. Recent findings suggest the conflict rate of bears in GSMNP may be higher (J. Giacomini, unpublished data). I found that 7.1% of rehabilitated bears in my study engaged in conflict behavior post-release, which appears similar to, or possibly less than conflict rates in the wild. Similarly, Beecham et al. (2015) reported that 6.1% of 424 rehabilitated black bears engaged in conflict behavior in their study.

Previous studies have found an inverse relationship between periods of low natural food availability and human-bear conflict in wild bears and in rehabilitated bears (Obbard et al. 2014, Smith et al. 2016). Smith et al. (2016) reported that rehabilitated bears in their study only engaged in conflict behavior during a period when natural food availability was low. Two of the

3 conflict bears (810, 943) in my study were released during a regional hard mast failure and engaged in conflict behavior the following May. The third ABR bear (931) was relocated after it was found opportunistically feeding on spilled grain and approaching humans during late September of 2016. This bear's sibling (930) was rehabilitated under identical conditions without reported conflict. Ditmer et al. (2015) reported that wild bears, especially males, preferred calorically-dense foods such as sunflower seeds over natural foods when available and 1 of my conflict bears (bear 943) was feeding from a bird feeder when reported. All 3 bears that engaged in conflict behavior in my study were yearling males. In GSMNP, 1 to 3-year-old males are most often responsible for conflict behavior (W. H. Stiver, GSMNP, personal communication).

Wildlife officials euthanized 1 (2.4%; bear 810) of my study bears as a result of human conflict activity. Binks (2008) reported that 3 out of 60 rehabilitated American black bears were shot by landowners due to conflict behavior 1-year post release. Smith et al. (2016) reported 3 male rehabilitated American black bear yearlings engaged in conflict within 1-year post-release during a time of poor natural food availability, and 2 of these conflict bears were killed by landowners (Smith et al. 2016).

There is concern among wildlife managers that rehabilitated offspring of mother bears with conflict history are more likely to engage in post-release conflict than offspring of non-conflict mothers (Beecham et al. 2015). Current knowledge of black bear maternal foraging strategies on human foods and how it influences the learning of cub foraging strategies is conflicting (Breck et al. 2008, Hopkins 2013). Breck et al. (2008) attributed cub foraging behavior to asocial learning mechanisms. More recent findings suggest that the primary method by which black bear cubs learn to forage on human foods is through social learning mechanisms by observing bear mothers (Hopkins 2013). Beecham (2015) et al. did not find a link between rehabilitated offspring of known-conflict mothers and post-release conflict engagement of rehabilitated bears in their study. Seven bears in my study came from known, habitual, conflict mothers and 3 released bears continued the behavior in the first year after release (Table 4). Two of the 4 non-conflict rehabilitated bears had siblings involved in conflict behavior. Almost half (43%) of conflict offspring engaged, and almost half (57%) did not engage. Therefore, it appears that conflict behavior of the mother does not seem to influence human-bear conflict engagement in all offspring. However, this does suggest that cubs from conflict-prone mothers have a greater chance of later being involved in conflict behavior themselves.

Management Implications

Bears rehabilitated and released from ABR survived at similar rates, died of similar causes, and engaged in similar post-release conflict to wild conspecifics. Minimal human-bear interaction for care of injured or orphaned bears, careful selection of release sites close to original capture locations, and accelerated health restoration led to successful release of bears back to the wild. My results substantiate the findings of Clark et al. (2002) and Beecham et al. (2015) that rehabilitation is a defensible and effective alternative for managers dealing with orphaned and injured bears. Although rehabilitated bears released as cubs had lower survival than bears released as yearlings, the survival rate for bears released as cubs was similar to the survival rates of wild conspecifics. Therefore, releasing rehabilitated bears as cubs can be successful. I would recommend releasing rehabilitated cubs during late fall prior to denning if natural foods are available. If natural foods are scarce, I would recommend releasing these bears at heavy weights

(>18 kg) that fall or the following spring as yearlings. Offspring of conflict mothers should be considered for rehabilitation based on results by Beecham et al. (2015) and conflicting results of this study, but these bears should be released to remote areas far from human settlement to lessen the chance of conflict occurrence.

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CONCLUSION

Wildlife managers face difficult decisions when dealing with orphaned American black bears. Sometimes euthanasia is the clear, ethical choice if bears are suffering or unable to be released due to injury or illness. Reuniting orphans with their mothers or fostering them to surrogate, wild females would be an optimal solution from a wildlife manager's or public constituent's perspective, but that usually is not an option. In contrast, euthanizing healthy orphans, non-intervention, or placing orphans into permanent captive facilities may not be publicly acceptable. Captive care and subsequent release of American black bears into the wild has been successfully used as an option (Beecham et al. 2015). Rehabilitation and release of bear orphans has benefits, but there are concerns about the survival and possible engagement in post-release conflict of rehabilitated bears.

Post-release information for rehabilitated American black bears is limited, especially for cubs. The post-release information currently available was largely derived from studies incorporating either small sample sizes, 1 age class of young bears (cubs or yearlings), short study periods, no post-release tracking, estimates generated using less precise and dated tracking methods (VHF telemetry), or a combination of these. I followed the fates of 42 American black bears rehabilitated at Appalachian Bear Rescue in Townsend, TN, USA and released in Great Smoky Mountains National Park (GSMNP) or Cherokee National Forest (CNF). My objectives were to assess 1-year survival and post-release conflict.

As hypothesized, bears rehabilitated and released from ABR survived at similar rates, died from similar causes, and engaged in post-release conflict similar to wild conspecifics. My results were also consistent with those of Clark et al. (2002), Binks (2008), and Beecham et al. (2015) that showed rehabilitated bears survive at rates similar to wild conspecifics and have limited conflict behaviors. Vehicular collisions accounted for the majority of bear deaths in my study although post-release movements were not as pronounced as in other studies of rehabilitated bears (Binks 2008, Beecham et al. 2015). Bears in my study appeared to have relatively high release site fidelity, but most release sites were near roads, which may have attributed to the vehicular collisions I observed. Most bears did not engage in conflict behavior 1 year post-release, and development of conflict behavior was not verifiably linked to known conflict behavior of their mother

Beecham (2015) defined primary success of a rehabilitation program as one that released bears back into the wild that survived at normal rates to wild conspecifics and avoided human-bear conflict post-release. By this definition, I have demonstrated that rehabilitation of American black bears can be a valuable tool for wildlife managers. Public acceptance of management action is important in shaping wildlife policies for publicly-owned natural resources (Zinn et al. 2008). Successful bear rehabilitation with documented practices promote support for this option for wildlife managers and the public.

LIST OF REFERENCES

Akaike, H. 1974. A new look at statistical model identification. IEEE Transactions on Automatic Control AC-19:716–723.

Alt, G. L. 1984. Cub adoption in the black bear. Journal of Mammalogy 65:511–512.

Alt, G. L., and J. J. Beecham. 1984. Reintroduction of orphaned black bear cubs into the wild. Wildlife Society Bulletin 12:169–174.

Alt, G. L., and J. M. Gruttadauria. 1984. Reuse of black bear dens in northeastern Pennsylvania. Journal of Wildlife Management 48:236–239.

Appalachian Bear Rescue [ABR]. 2016. ABR homepage.<http://www.appalachianbear rescue.org>. Accessed 20 June 2016.

Atkinson, S. N., M. R. L. Cattet, S.C. Polischuk, and M.A. Ramsay. 1996. A case of offspring adoption in free-ranging polar bears (*Ursus maritimus*). Arctic 49:94–96.

Beecham, J. J. 2006. Orphan bear cubs: rehabilitation and release guidelines. World Society of the Protection of Animals, London, United Kingdom.

Beecham, J. J., M. D. G. Hernando, A. A. Karamanlidis, R. A. Beausoleil, K. Burguess, D. Jeong, M. Binks, L. Bereczky, N. V. K. Ashraf, K. Skripova, L. Rhodin, J. Auger, and B. Lee. 2015. Management implications for releasing orphaned, captive-reared bears back to the wild. Journal of Wildlife Management 79:1327–1336.

Beecham, J. J., I. K. Loeffler, and R. A. Beausoleil. 2016. Strategies for captive rearing and reintroduction of orphaned bears. Journal of Wildlife Rehabilitation 36:7–16.

Beeman, L. E., and M. R. Pelton. 1976. Homing of black bears in the Great Smoky Mountains National Park. Bears: Their Biology and Management. A Selection of Papers from the Third International Conference on Bear Research and Management 3:87–95.

Benson, J. F., and M. J. Chamberlain 2006. Cub adoption by a translocated Louisiana black bear. Ursus 17:178–181.

Beringer, J., S. G. Seibert, S. Reagan, A. J. Brody, M. R. Pelton, and L. D. Vangilder. 1998. The influence of a small sanctuary on survival rates of black bears in North Carolina. Journal of Wildlife Management 62:727–734.

Binks, M. 2008. Survival and behavior of orphaned and rehabilitated black bears in central Ontario. Thesis, Cambrian College, Sudbury, Ontario, Canada.

Boyer, R. H. 1949. Mountain coyotes kill yearling black bear in Sequoia National Park. Journal of Mammalogy 30:75.

Breck, S., C. Williams, J. Beckmann, S. Matthews, C. Lackey, and J. Beecham. 2008. Using genetic relatedness to investigate the development of conflict behavior in black bears. Journal of Mammalogy 89:428–434.

Bridges, A. S., M. R. Vaughan, and J. A. Fox. 2011. American black bear estrus and parturition in the Alleghany Mountains of Virginia. Ursus 22:1–8.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information-theoretic approach. 2nd ed. Springer-Verlag, New York, USA.

Carney, D. W., and M. R. Vaughan. 1987. Survival of introduced black bear cubs in Shenandoah National Park, Virginia. Bears: Their Biology and Management. A Selection of Papers from the Seventh International Conference on Bear Research and Management 7:83–85.

Clark, J. E., M. R. Pelton, B. J. Wear, and D. R. Ratajczak. 2002. Survival of orphaned black bears released in the Smoky Mountains. Ursus 13:269–273.

Clarke, S. H., J. O'Pezio, and C. Hackford. 1980. Fostering black bear cubs in the wild. Bears: Their Biology and Management. A Selection of Papers from the Fourth International Conference on Bear Research and Management 4:163–166.

Clevenger, A. P., M. R. Pelton. 1990. Pre and post breakup movements and space use of black bear family groups in Cherokee National Forest, Tennessee. Bears: Their Biology and Management. A Selection of Papers from the Eighth International Conference on Bear Research and Management 8:289–295.

Derocher, A. E., and Wiig Ø. 1999. Observation of adoption in polar bears (*Ursus maritimus*). Arctic 52:413–415.

Ditmer, M. A., T. E. Burk, D. L. Garshelis. 2015. Do innate food preferences and learning affect crop raiding by American black bears? Ursus 26:40–52.

Eagle, T. C., and M. R. Pelton. 1983. Seasonal nutrition of black bears in the Great Smoky Mountains National Park. Bears: Their Biology and Management. A Selection of Papers from the Fifth International Conference on Bear Research and Management 5:94–101.

Eastridge, R., and J. D. Clark. 2001. Evaluation of 2 soft-release techniques to reintroduce black bears. Wildlife Society Bulletin 29:1163–1174.

Elowe, K. D., and W. E. Dodge. 1989. Factors affecting black bear reproductive success and cub survival. Journal of Wildlife Management 53:962–968.

Erickson, A. W. 1959. The age of self-sufficiency in the black bear. Journal of Wildlife Management 23:401–405.

Erickson, A. W., and L. H. Miller. 1963. Cub adoption in the brown bear. 1963. Journal of Mammology 44:584–585.

Evans, M. J., J. E. Hawley, P. W. Rego, and T. A. G. Rittenhouse. 2014. Exurban land use facilitates human-black bear conflicts. Journal of Wildlife Management 78:1477–1485.

Fenneman, N. M. 1938. Physiography of the eastern United States. McGraw-Hill, New York, New York, USA.

Fies, M. L., D. D. Martin, G. T. Blank. 1987. Movements and rates of return of translocated black bears in Virginia. Bears: Their Biology and Management. A Selection of Papers from the Seventh International Conference on Bear Research and Management 7:369–372.

Garrison, E. P., J. W. McCown, and M. K. Oli. 2007. Reproductive ecology and cub survival of Florida black bears. Journal of Wildlife Management 71:720–727.

Hopkins, J. 2013. Use of genetics to investigate socially learned foraging behavior in free-ranging black bears. Journal of Mammalogy 94:1214–1222.

Huber, D. 2010. Rehabilitation and reintroduction of captive-reared bears: feasibility and methodology for European brown bears *Ursus arctos*. International Zoo Yearbook 44:47–54.

Jenkins, M. A. 2007. Vegetation communities of Great Smoky Mountains National Park. Southeastern Naturalist 1:35–56.

Johnson, L. J., and P. LeRoux. 1973. Age of self-sufficiency in brown/grizzly bear in Alaska. Journal of Wildlife Management 37:122–123.

Kanaan, V. T., and E. A. Pajor. 2010. Increasing pre-weaning social complexity affects orphan raccoon behavioral development before and after weaning. Journal of Wildlife Rehabilitation 30:7–5.

Kellert, S. R. 1994. Public attitudes toward bears and their conservation. Bears: Their Biology and Management. A Selection of Papers from the Ninth International Conference on Bear Research and Management 9:43–50.

King, P. B., R. B. Newman, and J. B. Hadley. 1968. Geology of the Great Smoky Mountains National Park, U. S. Geological Survey, Washington, D.C., USA.

Lee, D. J., and M. R. Vaughan. 2003. Dispersal movements by subadult American black bears in Virginia. Ursus 14:162–170.

Lee, D. J., and M. R. Vaughan. 2004. Black bear family breakup in Western Virginia. Northeastern Naturalist 11:111–122.

Lee, D. J., and M. R. Vaughan. 2005. Yearling and subadult black bear survival in a hunted Virginia population. Journal of Wildlife Management 69:1641–1651.

LeCount, A. L. 1987. Causes of black bear cub mortality. Bears: Their Biology and Management. A Selection of Papers from the Seventh International Conference on Bear Research and Management 7:75–82.

Lewis, J.S., J.L Rachlow, E.O. Garton, and L.A. Vierling. 2007. Effects of habitat on GPS collar performance: using data screening to reduce location error. Journal of Applied Ecology 44:663–671.

Liley, S. G., and R. N. Walker. 2015. Extreme movement by an American black bear in New Mexico and Colorado. Ursus 26:1–-6.

Lindsey, K. J., and C. E. Adams. 2006. Public demand for information and assistance at the human-wildland interface. Human Dimensions of Wildlife 11:267–283.

Matmon, A., P. R. Bierman, J. Larsen, S. Southworth, M. Pavich, R. Finkel, and M. Caffee. 2003. Erosion of an ancient mountain range, the Great Smoky Mountains, North Carolina and Tennessee. American Journal of Science 303:817–855.

McCullough, D. R. 1982. Behavior, bears, and humans. Wildlife Society Bulletin 10:27–33.

McLean, P. K., and M. R. Pelton. 1994. Estimates of population density and growth of black bears in the Smoky Mountains. Bears: Their Biology and Management. A Selection of Papers from the Ninth International Conference on Bear Research and Management 9:253–261.

Merkle, J. A., H. S. Robinson, P. R. Krausman, and P. Alaback. 2013. Food availability and foraging near human developments by black bears. Journal of Mammalogy 94:378–385.

Mills, L. S. 2013. Conservation of wildlife populations: demography, genetics, and management. Second edition. Wiley-Blackwell, Chichester, West Sussex, UK.

Myers, P. J. 2015. Spatial ecology and captive behavior of rehabilitated black bears in Utah. Thesis, Utah State University, Logan, USA.

National Park Service [NPS]. 2016. Great Smoky Mountains National Park. Nature. < https://www.nps.gov/grsm/index.htm>. Accessed 8 Aug 2016.

Obbard, M. E., E. J. Howe, L. L. Wall, B. Allison, R. Black, P. Davis, L. Dix-Gibson, M. Gatt, and M. N. Hall. 2014. Relationships among food availability, harvest, and human-bear conflict at landscape scales in Ontario, Canada. Ursus 25:98–110.

Obbard, M. E., E. J. Newton, D. Potter, A. Orton, B. R. Patterson, and B. D. Steinberg. 2017. Big enough for bears? American black bears at heightened risk of mortality during seasonal forays outside Algonquin Provincial Park, Ontario. Ursus 28:182–194.

Palamero, G., and J. C. Blanco. 1997. Ecology and behavior of 3 wild orphaned brown bear cubs in Spain. Bears: Their Biology and Management. A Selection of Papers from the Ninth International Conference on Bear Research and Management 9:85-–90.

Payne, N. F. 1975. Unusual movements of Newfoundland black bears. Journal of Wildlife Management 39:812–813.

Peine, J. D. 2001. Nuisance bears in communities: strategies to reduce conflict. Human Dimensions of Wildlife 6:223–237.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

Pyke, G. H., and J. K. Szabo. 2007. Conservation and the 4 Rs, which are rescue, rehabilitation, release, and research. Conservation Biology 32:50–59.

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/. Accessed 06 June 2018.

Rogers, L. L. 1977. Social relationships, movements, and population dynamics of black bears in northeastern Minnesota. Dissertation, University of Minnesota, Minneapolis, USA.

Rogers, L. L., and L. D. Mech. 1981. Interactions of wolves and black bears in northeastern Minnesota. Journal of Mammalogy 62:434–436.

Rogers, L. L. 1985. Aiding the wild survival of orphaned bear cubs. Proceedings of the Annual Symposium of the National Wildlife Rehabilitator’s Association. National Wildlife Rehabilitation Association 4:104–111.

Ryan, C. W. 1997. Reproduction, survival, and denning ecology of black bears in southwestern Virginia. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, USA.

Ryan, C. W., J. C. Pack, W. K. Igo, and A. Billings. 2007. Influence of mast production on black bear non-hunting mortalities in West Virginia. Ursus 18:46–53.

Ryan, C. W., J. W. Edwards, and M. D. Duda. 2009. West Virginia residents' attitudes and opinions toward American black bear hunting. Ursus 20:131–142.

Schwartz, C. C., and A. W. Franzmann. 1992. Dispersal and survival of subadult black bears from Kenai Peninsula, Alaska. Journal of Wildlife Management 56:426–431.

Seibert, S. G., Stiver W. H., Delozier K. D., and Pelton M. R. 1999. Reuniting black bear cubs to their natural mother. Eastern Workshop on Black Bear Research and Management 14:58–59.

Servheen, C., W. Kasworm, and A. Christensen. 1987. Approaches to augmenting grizzly bear populations in the Cabinet Mountains of Montana. Bears: Their Biology and Management. A Selection of Papers from the Seventh International Conference on Bear Research and Management 7:363–367.

Shanks, R. E. 1954. Climates of the Great Smoky Mountains. Ecology 35:354–361.

Smith, W. E., P. J. Pekins, A. A. Timmins, and B. Kilham. 2016. Short-term fate of rehabilitated orphan black bears released in New Hampshire. Human-Wildlife Interactions 10:258–267.

Sorenson, V. A. and R. A. Powell. 1996. Estimating survival rates of black bears. Canadian Journal of Zoology 76: 1335–1343.

Southworth, S., A. Schultz, J. N. Aleinikoff, and A. J. Merschat. 2012. Geological map of the Great Smoky Mountains National Park region, Tennessee and North Carolina, U.S. Geological Survey Headquarters, Reston, Virginia, USA.

Spencer, R. D., R. A. Beausoleil, and D. A. Martorello. 2007. How agencies respond to human-black bear conflicts: a survey of wildlife agencies in North America. Ursus 18:217–229.

Stiver, W. H. 1991. Population dynamics and movements of problem black bears in Great Smoky Mountains National Park. Thesis, University of Tennessee, Knoxville, USA.

Stiver, W.H., M. R. Pelton, and C. D. Scott. 1997. Use of pen-reared black bears for augmentation of reintroductions. Bears: Their Biology and Management. A Selection of Papers from the Ninth International Conference on Bear Research and Management 9:145–150.

Swan, G. J. F., S. M. Redpath, S. Bearhop, and R. A. McDonald. 2017. Ecology of problem individuals and the efficacy of selective wildlife management. Trends in Ecology and Evolution 32:518–530.

Teel, T. L., R. S. Krannich, and R. H. Schmidt. 2002. Utah stakeholders’ attitudes toward selected cougar and black bear management practices. Wildlife Society Bulletin 30:2–15.

Tri, A. N., J. W. Edwards, C. W. Ryan, C. P. Carpenter. 2017. Harvest rates and cause-specific mortality of American black bears in the wildland-urban interface of the Mid-Atlantic region, USA. Ursus 28:195–207.

United States Department of Agriculture. 2016. Forest Service. Cherokee National Forest Vicinity Map. <http://www.fs.usda.gov/main/Cherokee>. Accessed 8 Aug 2016.

United States Department of Agriculture. 2004. Revised land and resource management plan: Cherokee National Forest. U. S. Forest Service, Cleveland, TN, USA.

van Manen, F. T., M. F. McCollister, J. M. Nicholson, L. M. Thompson, J. L. Kindall, and M. D. Jones. 2012. Short-term impacts of a 4-lane highway on American black bears in eastern North Carolina. Wildlife Monographs 181:1–35.

Waller, B. W., J. L. Belant, B. W. Young, B. D. Leopold, and S. L. Simek. 2012. Denning chronology and den characteristics of American black bears in Mississippi. Ursus 23:6–11.

Waples, K. A., and C. S. Stagoll. 1997. Ethical issues in the release of animals from captivity. Bioscience 47:115–121.

Wathen, W. G., K. G. Johnson, and M. R. Pelton. 1986. Characterisitcs of black bear dens in the southern Appalachian region. Bears: Their Biology and Management. A Selection of Papers from the Sixth International Conference on Bear Research and Management 6:119-127.

Wear, B. J., R. Eastridge, and J. D. Clark. 2005. Factors affecting settling, survival, and viability of black bears reintroduced to Felsenthal National Wildlife Refuge, Arkansas. Wildlife Society Bulletin 33:1363–1374.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplemental):S120–S139.

Zinn, H. C., M. J. Manfredo, J. J. Vaske, and K. Wittman. 2008. Using normative beliefs to determine the acceptability of wildlife management actions. Society and Natural Resources 11:649–662.

APPENDIX

Table 1. Post-release fates and release characteristics of rehabilitated American black bears released to Great Smoky Mountains National Park (GSMNP) and Cherokee National Forest (CNF) in Tennessee and North Carolina, USA, 2015–2017.

Bear ID	Sex	Release Age	Release Area	Release Weight (kg)	Release Date	Weeks Collared	Fate
1	F	Yearling	GSMNP	24.5	2016-07-18	52	Alive
807	F	Cub	CNF	35.4	2015-11-09	52	Alive
809	F	Cub	CNF	34.5	2015-12-04	33	Dead
810	M	Cub	CNF	41.5	2015-11-30	23	Dead
811	F	Cub	CNF	44.0	2015-11-09	32	Alive
813	M	Yearling	CNF	45.4	2016-04-11	52	Alive
815	F	Yearling	CNF	25.9	2016-04-11	9	Alive
816	M	Cub	CNF	44.0	2015-11-09	52	Alive
817	M	Cub	CNF	34.9	2015-11-09	52	Alive
820	F	Yearling	CNF	28.4	2016-04-11	52	Alive
822	M	Cub	CNF	27.7	2016-11-04	2	Alive
823	F	Cub	CNF	24.3	2016-11-04	52	Alive
926	F	Cub	GSMNP	27.7	2015-11-25	28	Dead
928	F	Cub	GSMNP	36.7	2015-11-25	41	Alive
930	M	Cub	GSMNP	55.8	2015-11-30	23	Alive

Table 1 Continued.

Bear ID	Sex	Release Age	Release Area	Release Weight (kg)	Release Date	Weeks Collared	Fate
931	M	Cub	GSMNP	56.2	2015-11-30	43	Alive
932	M	Yearling	GSMNP	38.1	2016-03-09	52	Alive
933	M	Yearling	GSMNP	27.7	2016-04-11	23	Alive
934	M	Yearling	GSMNP	28.1	2016-04-14	52	Alive
936	M	Yearling	GSMNP	33.1	2016-04-28	52	Alive
937	M	Yearling	GSMNP	34.5	2016-04-11	52	Alive
938	F	Yearling	GSMNP	31.5	2016-04-11	52	Alive
939	F	Yearling	GSMNP	30.8	2016-04-11	8	Alive
940	M	Yearling	GSMNP	32.2	2016-04-12	52	Alive
941	F	Cub	GSMNP	23.4	2015-12-11	40	Dead
942	F	Yearling	GSMNP	27.2	2016-04-11	52	Alive
943	M	Yearling	GSMNP	41.3	2016-02-26	14	Alive
944	M	Yearling	GSMNP	30.8	2016-06-23	2	Alive
946	M	Yearling	GSMNP	38.6	2016-04-12	34	Unknown
947	F	Yearling	GSMNP	24.5	2016-04-13	3	Alive
949	M	Yearling	GSMNP	42.9	2016-04-11	52	Alive
950	F	Yearling	GSMNP	22.9	2016-04-14	52	Alive
952	F	Yearling	GSMNP	23.1	2016-04-29	5	Alive

Table 1 Continued.

Bear ID	Sex	Release Age	Release Area	Release Weight (kg)	Release Date	Weeks Collared	Fate
953	M	Yearling	GSMNP	29.5	2016-04-11	52	Alive
954	F	Yearling	GSMNP	18.1	2016-04-13	52	Alive
955	M	Yearling	GSMNP	31.3	2016-04-11	52	Alive
956	M	Yearling	GSMNP	20.0	2016-06-03	51	Alive
957	M	Yearling	GSMNP	24.9	2016-06-10	52	Alive
958	F	Yearling	GSMNP	20.4	2016-04-13	52	Alive
959	M	Yearling	GSMNP	32.0	2016-04-28	41	Alive
961	F	Yearling	GSMNP	33.6	2016-04-29	52	Alive
962	M	Yearling	GSMNP	22.7	2016-06-10	50	Alive

Table 2. Percent (%) of total spatial location data remaining after using 4 different methods to screen Global Positioning System-acquired relocation data for rehabilitated American black bears, Tennessee and North Carolina, USA, 2015—2017.

Screening method[a]	Total Fixes	Data Retention (%)
None	71,675	100.0
Remove 2D with PDOP >5	71,668	99.99
Remove 2D	71,659	99.98
Remove 2D with PDOP >5 and 3D with PDOP >10	71,032	99.10
Remove 2D and 3D with PDOP >7	67,199	93.76

[a.] Screening method definitions: None is only "no fixes" removed (locations that could not be determined); 2D is two-dimensional fixes (3 satellites used to acquire locations); 3D is three-dimensional fixes (≥4 satellites used to acquire locations); PDOP is positional dilution of precision

Table 3. Pessimistic survival models associated with rehabilitated American black bears released to Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, between 2015—2017.

Model[a]	k[b]	AICc[c]	ΔAICc[d]	w_i[e]	LL[f]
Total distance	2	65.78	0.00	0.50	1.00
Release age	2	67.66	1.87	0.19	0.39
Intake Age	2	69.22	3.43	0.09	0.18
Null	1	69.97	4.19	0.06	0.12
Maximum dispersal	2	70.19	4.41	0.05	0.11
Release area	2	71.43	5.64	0.03	0.06
Sex	2	71.43	5.65	0.03	0.06
Release weight	2	71.90	6.12	0.02	0.05
Care days	2	71.96	6.18	0.02	0.05

a. Model definitions: release age is difference (days) in date of bear release and assumed day of birth of 17 January (Bridges et al. 2011) for a bear in a given year ; total distance is total distance (km) traveled between sequential locations while telemetered; intake age is difference (days) in date of bear intake and assumed day of birth of 17 January (Bridges et al. 2011) for a bear in a given year; maximum dispersal is maximum Euclidean distance (km) a bear traveled from its release site while telemetered; null is model when all variables are pooled (held constant) and the only parameter modeled is survival; sex is gender (male or female); release area is GSMNP or CNF; care days is difference (days) between bear intake and release dates; release weight is weight (kg) of bear at release day.
b. Number of parameters in model.
c. Akaike's Information Criterion values corrected for small sample sizes (AICc).
d. Distance from AICc.
e. AICc model weights.
f. Model likelihood.

Table 4. Optimistic survival models associated with rehabilitated American black bears released in Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, between 2015—2017.

Model[a]	k[b]	AICc[c]	ΔAICc[d]	w_i[e]	LL[f]
Release age	2	53.41	0.00	0.37	1.00
Total Distance	2	53.61	0.20	0.34	0.90
Intake Age	2	55.47	2.06	0.13	0.36
Maximum Dispersal	2	57.88	4.47	0.04	0.11
Null	1	58.17	4.75	0.03	0.09
Sex	2	58.54	5.13	0.03	0.08
Release Area	2	59.01	5.60	0.02	0.06
Care Days	2	60.15	6.74	0.01	0.03
Release Weight	2	60.17	6.75	0.01	0.03

a. Model definitions: release age is difference (days) in date of bear release and assumed day of birth of 17 January (Bridges et al. 2011) for a bear in a given year ; total distance is total distance (km) traveled between sequential locations while telemetered; intake age is difference (days) in date of bear intake and assumed day of birth of 17 January (Bridges et al. 2011) for a bear in a given year; maximum dispersal is maximum Euclidean distance (km) a bear traveled from its release site while telemetered; null is model when all variables are pooled (held constant) and the only parameter modeled is survival; sex is gender (male or female); release area is GSMNP or CNF; care days is difference (days) between bear intake and release dates; release weight is weight (kg) of bear at release day.

b. Number of parameters in model.

c. Akaike's Information Criterion values corrected for small sample sizes (AICc).

d. Distance from AICc.

e. AICc model weights.

f. Model likelihood.

Table 5. Conflict engagement and management action for American black bears born to known, conflict mothers prior to rehabilitation and release, Tennessee and North Carolina, USA, 2015—2017.

Bear ID	Sex	Release Age	Release Date	Conflict Engagement	Conflict Date	Action
809 [a]	F	Cub	2015-12-04	No	–	None
810 [a]	M	Cub	2015-11-30	Yes	2016-05-04	Euthanized
926 [b]	F	Cub	2015-11-25	No	–	None
928 [b]	F	Cub	2015-11-25	No	–	None
930 [c]	M	Cub	2015-11-30	No	–	None
931 [c]	M	Cub	2015-11-30	Yes	2016-09-20	Relocated
943	M	Cub	2016-02-26	Yes	2016-05-28	Relocated
943	M	Cub	2016-02-26	Yes	2016-06-12	Relocated

[a, b, c.] Denotes sibling pairs.

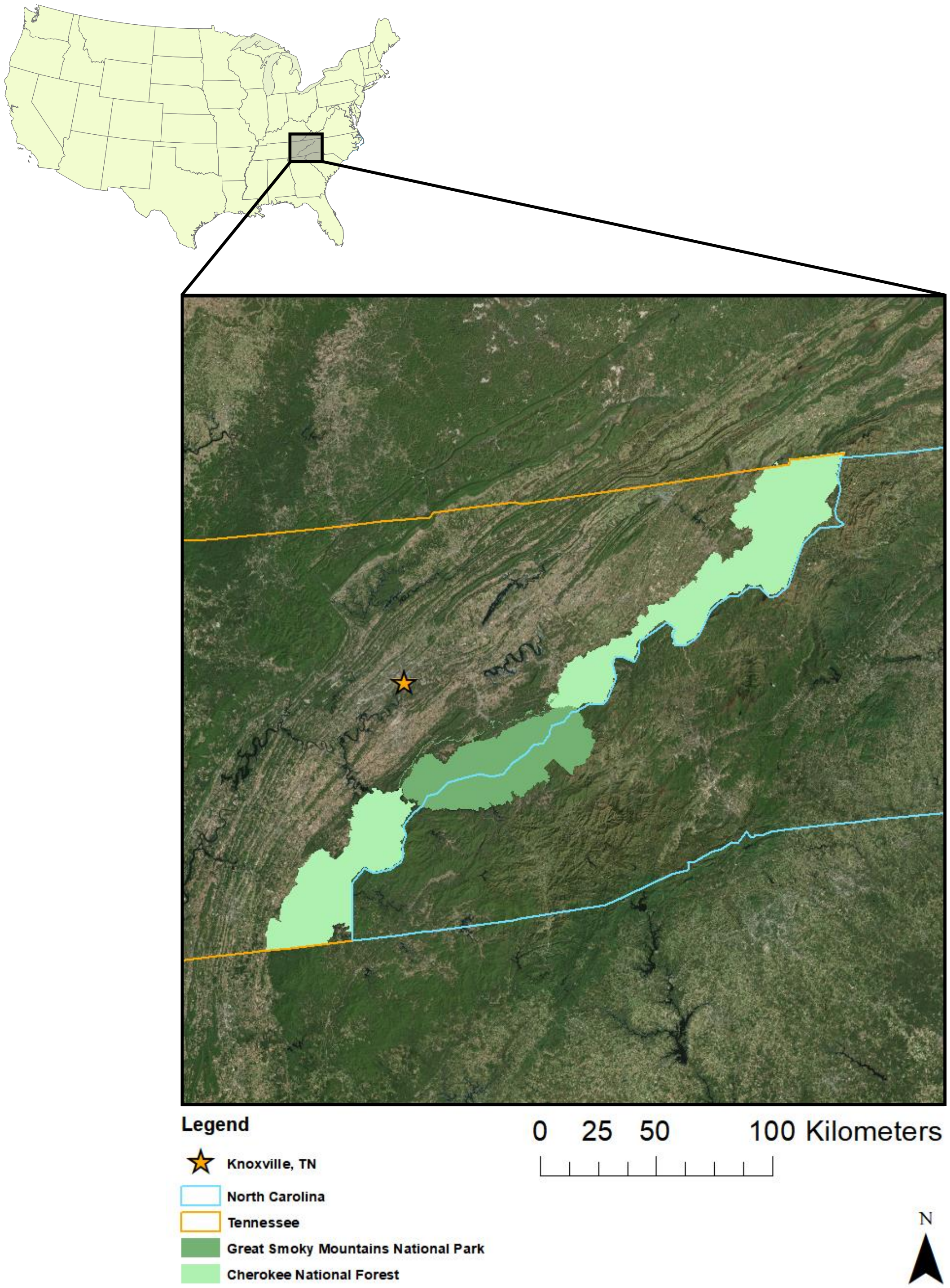

Figure 1. Great Smoky Mountains National Park and Cherokee National Forest in Tennessee and North Carolina, USA, 2018.

Figure 2. Four enclosures used to house injured and orphaned American black bears at Appalachian Bear Rescue in Townsend, TN, USA. All four enclosures are marked with light green arrows.

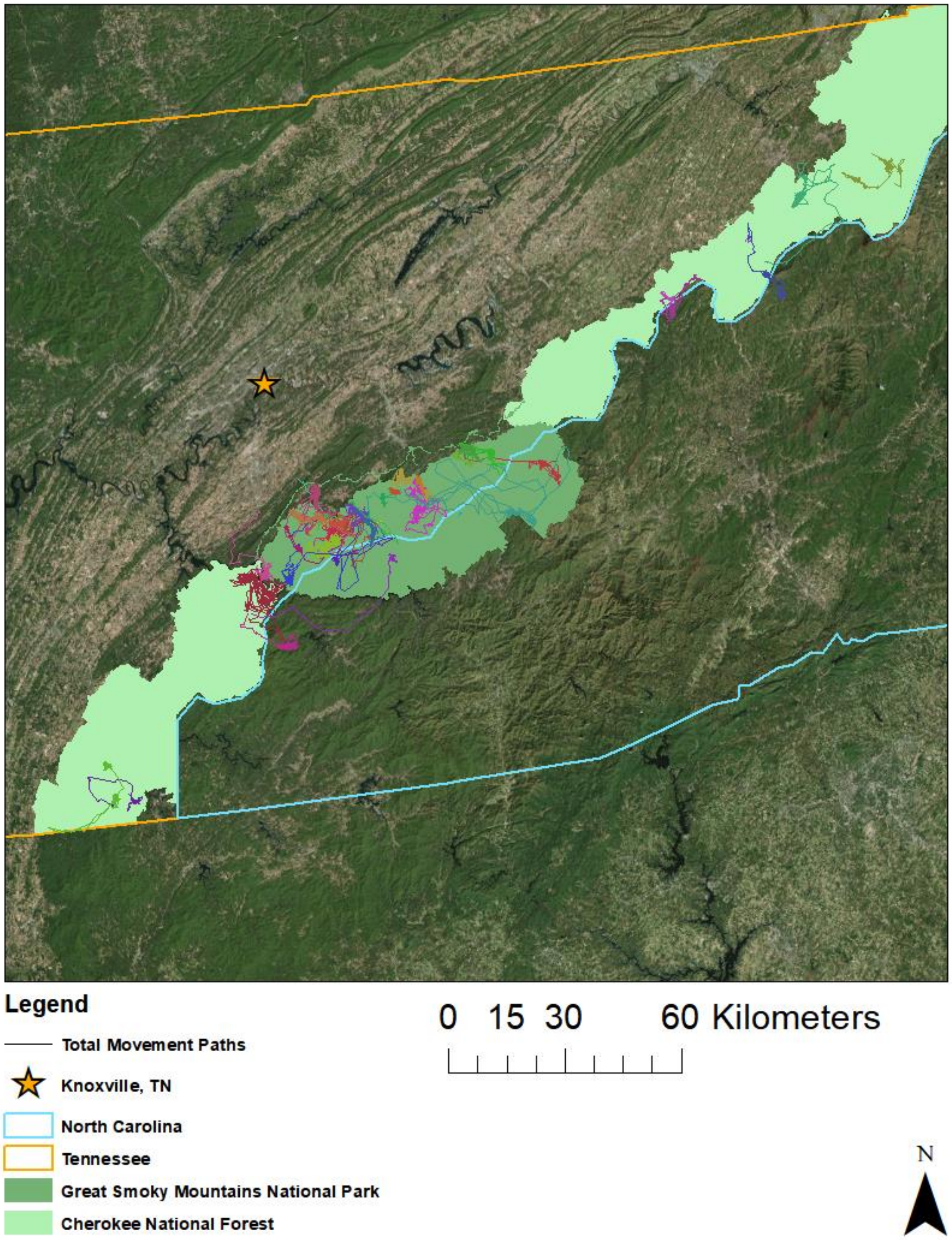

Figure 3. Total movement paths for American black bears (n = 40) rehabilitated at Appalachian Bear Rescue in Townsend, TN, USA and released in Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, 2015—2017.

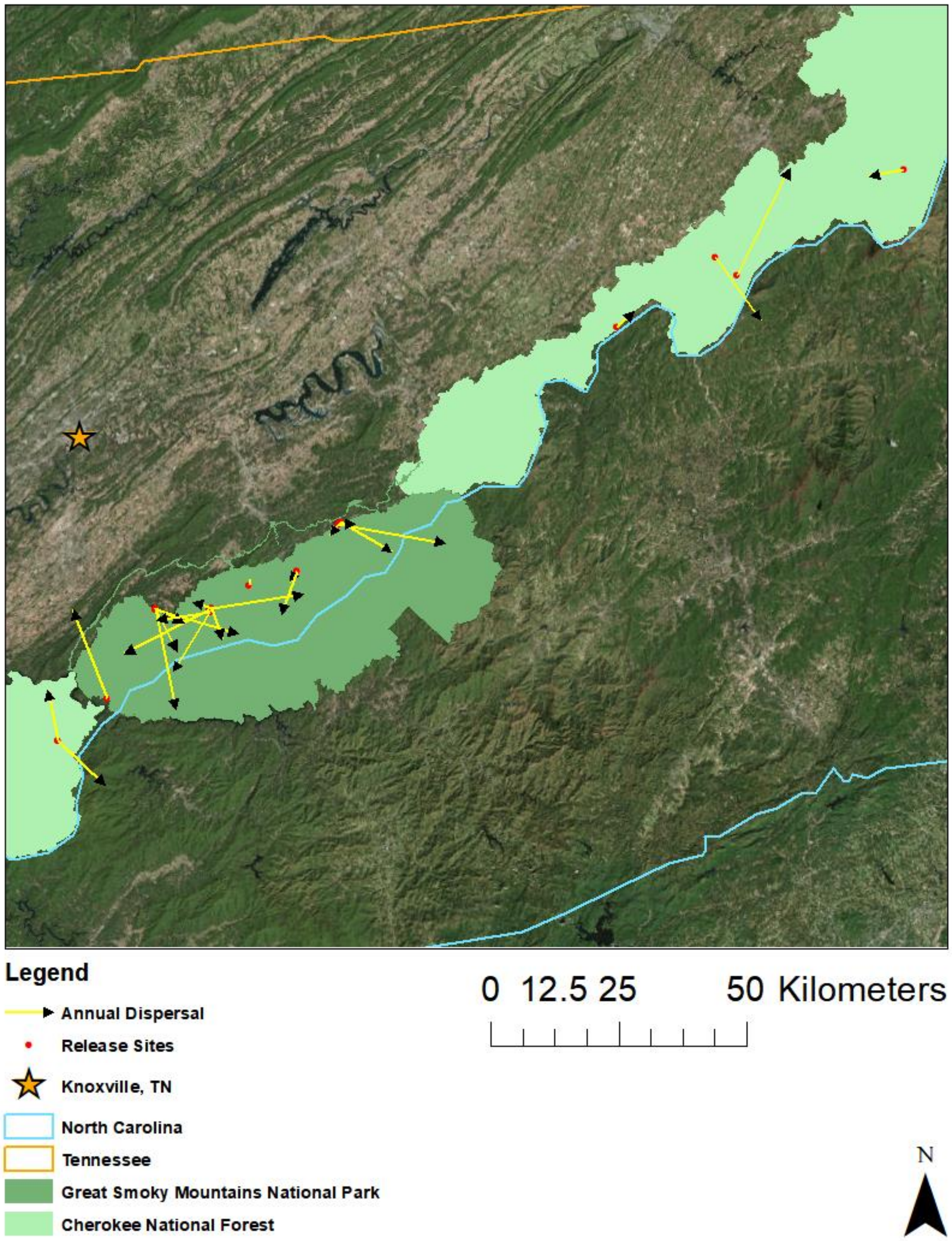

Figure 4. Annual dispersal paths from release sites for American black bears (n = 24) rehabilitated at Appalachian Bear Rescue in Townsend, TN, USA and released in Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, 2015—2017.

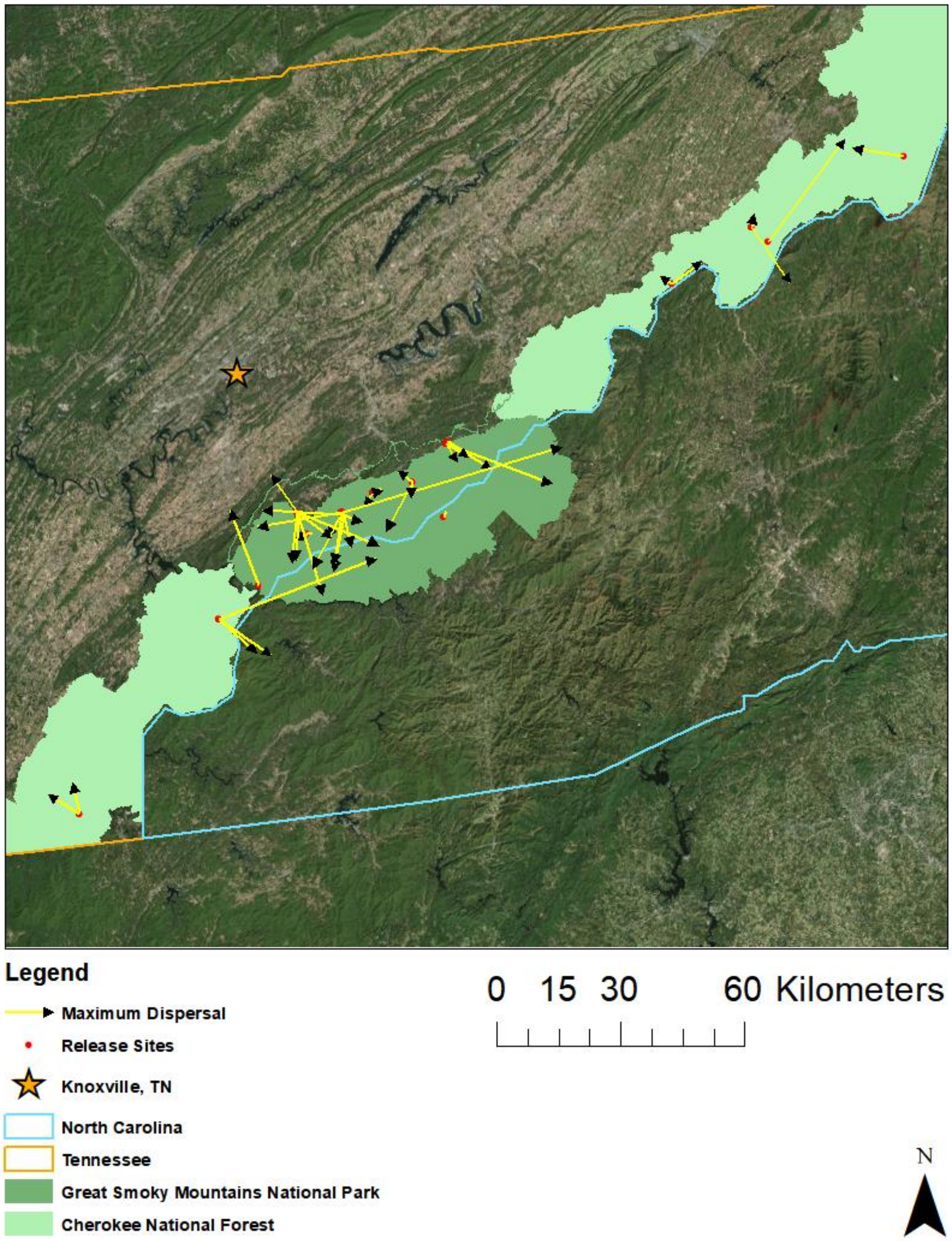

Figure 5. Maximum dispersal paths from release sites for American black bears (n = 40) rehabilitated at Appalachian Bear Rescue in Townsend, TN, USA and released in Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, 2015—2017.

VITA

Coy Blair was born and grew up in Blount County, TN, where he lived with his parents, Lori and Gary Blair, his brother, Cole Blair, and sister, Brandi Stewart. From a young age his interests were in the sciences from wildlife to medicine. He received his Bachelor of Arts in Biology from Maryville College in 2009, where he was on a pre-med path. After graduating, he worked full time with a local housing agency and later at an analytical laboratory while deciding on furthering his education. Coy decided to pursue a career in wildlife and secured a job as lead curator at Appalachian Bear Rescue in Townsend, TN, where he has been employed since July 2012. Coy began graduate school in 2014 at the University of Tennessee, Knoxville, where he began the current project that culminated in this thesis.