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Research Article

Survival and Conflict Behavior of American Black Bears after Rehabilitation

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ABSTRACT Wildlife agencies face difficult situations when orphaned or injured American black bear (*Ursus americanus*) cubs (<12 months old) or yearlings (≥12 and <24 months old) are captured. One option is bear rehabilitation, the care and feeding of cubs or yearlings in a semi-natural environment, followed by release. Unfortunately, the survival and movements of bears released from rehabilitation facilities are often poorly documented and the ultimate reasons for success or failure poorly understood. Our goal was to assess survival and post-release conflict of orphaned bear cubs and yearlings following release from a rehabilitation facility, Appalachian Bear Rescue (ABR), in Townsend, Tennessee, USA, from 2015–2016. We predicted that rehabilitated bears would survive at similar rates, die from similar causes, and engage in similar conflict behavior to wild conspecifics. We equipped 42 black bear cubs and yearlings from ABR with global positioning system-collars and released them in Great Smoky Mountains National Park or Cherokee National Forest, Tennessee and North Carolina, USA. Estimated annual survival using known-fate methods for all released bears was 0.93 ± 0.06 [SE]). Survival for 13 bears released as cubs was 0.64 ± 0.14, whereas none of the bears released as yearlings died within 1 year after release ($n = 29$). Survival of rehabilitated bears was similar to or higher than published rates for wild conspecifics. Three of 42 bears (7.1%) released from ABR engaged in conflict behavior up to 1 year following release, and those had spent time involved in conflict behavior with their mothers (e.g., approaching humans) prior to being orphaned. Despite not having the typical post-natal experience with their mothers, the bears in our study appeared to behave and survive similarly to their wild conspecifics. Rehabilitation is effective for managing orphaned or injured bears. Best survival occurred for bears released as yearlings; however, managers can maximize cub survival through fall releases when plentiful wild foods are available.

KEY WORDS black bear, conflict behavior, cub, orphan, rehabilitation, survival, *Ursus americanus*, yearling.

Orphaned American black bears (*Ursus americanus*) are a concern for wildlife managers (Stiver et al. 1997) because the public often demands action for injured and orphaned wildlife (Lindsey and Adams 2006) and expects 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. Some causes of orphaning include abandonment, vehicular collisions, conflict bear management, poaching, falling from trees, drought, fire, and flooding, which may be exacerbated by habitat alteration (Clark et al. 2002, Waller et al. 2012, Beecham et al. 2016). Options for dealing with orphaned American black bears include non-intervention; humane euthanasia; reuniting bears with their biological mothers; fostering bears to wild, adoptive females; transporting bears to a permanent captive facility; and transporting bears to a rehabilitation facility for eventual release (Beecham et al. 2015). Captive care and release of American black bears into the wild has been practiced for decades and Beecham et al. (2016) describe components of successful captive rearing and release of ursids. There is variation in how rehabilitation programs are carried out, ranging from short to long durations in captivity, high versus low levels of contact with humans (including human guardians accompanying free-ranging cubs in the wild), and hard (i.e., no period of acclimation before release) versus soft releases (i.e., a period of acclimation to the release site).

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The major benefit of rehabilitation programs is that bears can be released to the wild if biological or surrogate mothers cannot be located at time of discovery (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). For example, rehabilitation and release has been an important component of the giant panda (*Ailuropoda melanoleuca*) conservation program in China (Wei et al. 2015). Preventing the loss of even 1 individual bear in some small and isolated American black bear subpopulations could make a difference in their long-term population persistence. For example, cubs of Louisiana black bears (*U. a. luteolus*) have been rescued from floodwaters, rehabilitated, and then used to help establish new populations in suitable areas within their historical range (J. Clark, U.S. Geological Survey, unpublished data). Moreover, rehabilitation of orphaned cubs could be valuable for genetic rescue of imperiled bear populations (Murphy et al. 2018).

Despite these benefits, wildlife officials rarely use bear rehabilitation (Beecham et al. 2016). There may be a lack of trusted, authorized facilities or state laws or agency policies may prevent rehabilitation. Also, there may be concern about the possible effects of released bears on local bear populations through disease transmission. Other concerns include survival of rehabilitated bears in the wild and potential conflict activity (Waples and Stagoll 1997, Huber 2010, Beecham et al. 2016). Furthermore, managers must consider the availability of anthropogenic foods attracting bears to human dwellings (Merkle et al. 2013) and the potential for long-distance travel of released bears, which may influence the potential for recolonizing an area and adding to the local gene pool (Liley and Walker 2015).

Unfortunately, much of the post-release information currently available for rehabilitated American black bears is limited. High rates of radio-collar failure have been persistent issues in bear rehabilitation studies (Clark et al. 2002, Binks 2008, Smith et al. 2016). The most comprehensive study on the feasibility of releasing orphaned bears was a meta-analysis of data from 550 captive-reared bears in 12 separate areas by Beecham et al. (2015). They found survival rates in American black bears were variable with hunting and bear-vehicle collisions being the primary causes of mortality.

Appalachian Bear Rescue (ABR), 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 across the southeastern United States (ABR 2016). Of those, 167 (82.3%) bears were released to the wild after rehabilitation; most released bears ($n = 136$, 81.4%) were from Tennessee. Although Clark et al. (2002) radio-tracked 11 of these bears after release, the majority ($n = 156$, 93.4%) of bears released into the wild from ABR were not followed. 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 ($n = 4$). Thus, the information on survival, post-release movements, and conflict activity of ABR bears is limited.

The purpose of our study was to assess first-year survival and conflict behavior of American black bears released from ABR during 2015 and 2016. Our specific objectives were to use global positioning system (GPS) data in conjunction with known-fate models to estimate first-year survival, identify key variables affecting survival, determine cause-specific mortality, and assess conflict behavior of bears released from ABR.

STUDY AREA

Our study was conducted in Cherokee National Forest (CNF) and Great Smoky Mountains National Park (GSMNP), Tennessee and North Carolina, USA from 2015 to 2016 (Fig. S1, available online in Supporting Information). Both GSMNP (2,072 km^2) and CNF (2,630 km^2) 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). Steep slopes are common on both areas and elevations range from 266 m to 2,025 m (Southworth et al. 2012). Average annual rainfall varied from 102 cm to 220 cm in lower and higher elevations, respectively (Shanks 1954, Matmon et al. 2003, U.S. Department of Agriculture 2004). Forest communities consisted of northern hardwood forest, montane red spruce (*Picea rubens*)-Frasier fir (*Abies fraseri*) forest, mixed mesophytic-hardwood forest, conifer-northern hardwood forest, dry to mesic oak (*Quercus* spp.) forest, dry to mesic oak-pine (*Pinus* spp.) forest, xeric oak forest, xeric pine forest, and eastern riverfront and river floodplain hardwood forest (U.S. Department of Agriculture 2004, Jenkins 2007). King and Stupka (1950) estimated more than 50 species of mammals, 200 birds, and 80 reptiles and amphibians in GSMNP. Most of the CNF was open to hunting within legal seasons managed by the Tennessee Wildlife Resources Agency (TWRA). Bear hunting in the CNF occurred as a series of open and closed periods from late September to late December but was not allowed on any of 6 bear reserve areas (U.S. Department of Agriculture 2016). Hunting was prohibited in all areas of GSMNP, but hiking and potential human disturbance was a common recreational activity during all times of the year (National Park Service 2016).

Primary foods for bears in the region consisted of soft mast (e.g., blackberry [*Rubus* spp.], blueberry [*Vaccinium* spp.], huckleberry [*Gaylussacia* spp.], black cherry [*Prunus serotina*]) in the summer and fall and hard mast (e.g., acorns [*Quercus* spp.], beechnuts [*Fagus* spp.], and hickory nuts [*Carya* spp.]) in the fall and early winter. Bears in the region typically denned from December to April, depending on age or sex (Johnson and Pelton 1980). The black bear population in the southern Appalachians has increased during the past 30 years and continues to grow in most locales. The bear population density in GSMNP was high

(0.78 bears/km^2) but was lower in surrounding national forests (0.12 bears/km^2; Clark 2019).

METHODS

Bear Housing, Capture, Evaluation, and Collaring

Curators employed by ABR cared for the bears, and someone was present at the site 24 hours/day as mandated by TWRA. We temporarily housed neonate cubs and injured bears in secured, clean cages within climate-controlled buildings until the bears were ready for release into larger acclimation pens or wild (i.e., natural) enclosures. We bottle-fed neonates as necessary. There were 4 wild enclosures at ABR with each being about 0.20 ha in size. We housed up to 10 bears in each wild enclosure at a time. Each wild enclosure consisted of chain link fencing about 3 m in height surrounded by a similar fence 4.5 m outside the perimeter. We electrified the interior fencing with 3–5 strands of wire at the bottom 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 [*Liriodendron tulipifera*], hemlocks [*Tsuga canadensis*], oaks, and hickories). We equipped enclosures with large plastic water tubs for drinking and large-diameter (2.5 m) plastic pools for wading. We tossed all food over the fencing from behind the blind to prevent bears from seeing curators and to encourage natural foraging behavior. We limited feedings to once daily or every other day to limit human presence (auditory and olfactory stimuli) at the bear areas. Foods consisted of a commercially available pelleted bear diet (Mazuri Bear Diet, Purina Mills, Gray Summit, MO, USA) in addition to supplementation with seasonally available natural foods, including blackberries, blueberries, muscadines (*Vitis rotundifolia*), and acorns. On occasion, we gave bears carrion such as fresh-killed white-tailed deer (*Odocoileus virginianus*).

We evaluated health status and weight gain of bears, food availability in the prospective release areas, and timing of the hunting season before considering release from the facility. We allowed injured bears to heal following treatment plans outlined by veterinarians at the University of Tennessee's College of Veterinary Medicine (UTCVM). We were not able to weigh bears prior to release from the enclosures but monitored bears via visual observations of body size during housing. We deemed cubs or yearlings had gained sufficient weight for release based on estimated masses (>18 kg) and the appearance of adequate adipose tissue. We coordinated release dates between ABR and the jurisdictional authority responsible for the bear. We immobilized bears with a combination of 6.6 mg/kg(estimated) ketamine hydrochloride (200 mg/ml; ZooPharm, Fort Collins, CO, USA) and 3.3 mg/kg (estimated) xylazine hydrochloride (300 mg/ml; ZooPharm) or 0.5 ml/23 kg BAM (27.3 mg/ml butorphanol tartrate, 9.1 mg/ml azaperone tartrate, 10.9 mg/ml medetomidine hydrochloride; ZooPharm) and monitored temperature, pulse, respiration, and saturated oxygen concentration as described by Williamson et al. (2018). We weighed, measured, and tagged (ear tags, lip identification tattoo, and passive integrated transponder) bears, and outfitted them with GPS-radio collars (Vectronic Aerospace GmbH, GPS PLUS Iridium, Berlin, Germany). After workups, wildlife officials transported and released bears in GSMNP or CNF to areas as close to their capture sites as possible. We used hard-release methods without human accompaniment for all releases (Clark et al. 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

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

We relied on state and federal wildlife agencies to report conflict behavior of collared bears. We defined conflict behavior as any action by bears that resulted in destruction of property or threatened public safety during or after the period of monitoring. We did not consider sightings of collared bears as conflict incidents. We did not solicit reports of conflict behavior of released bears from the public to prevent bias of reporting (Smith et al. 2016).

Spatial Data Analysis

We minimized GPS location error by screening data for positional dilution of precision (PDOP) values and fix type (2-dimensional [2D] or 3-dimensional [3D]; Lewis et al. 2007). We calculated retention values for our data using 4 screening methods, selecting 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 began 1 day after the dates we released the bears. End dates were 2 days prior to the dates collars entered mortality mode or were retrieved by us.

We generated movement metrics using a geographic information system and the Tracking Analyst tool within the software package ArcMap version 10.5 (Esri, Redlands, CA, USA). Movement metrics included distances traveled (i.e., the total distance between successive radio fixes during the period of monitoring [km]), annual displacement distances from release sites (i.e., the Euclidean distances from a bear's release site to its last-known location about 1 yr later), and maximum displacement distances from release sites (i.e., the Euclidean distances from a bear's release site to its farthest location from its release site within the first yr of release). We estimated annual displacement only for bears radio-monitored for >328.5 days.

Survival Analysis

We modeled survival in Program MARK (White and Burnham 1999) using Kaplan-Meier known-fate methods (Pollock et al. 1989). We used Program R (R Core Team 2018) to create encounter history input files for Program MARK. We standardized the start times so that the encounter 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 wore their collars or 2 days prior to collars entering mortality mode. We coded encounter histories as weekly intervals and we assumed all bears were born on 17 January based on black bear parturition data collected in Virginia, USA (Bridges et al. 2011). We estimated release ages of bears by calculating the days between dates that bears were released and 17 January of the birth year. We considered bears released at <12 months of age to be cubs and bears released at ≥12 and <24 months of age to be yearlings.

We used sex as a grouping variable and constructed all survival models using individual covariates consisting of release age (all ages are in days), release area (GSMNP or CNF), age at admission to ABR, release mass (kg), number of days at ABR, total distances traveled, and maximum displacement distances from release sites. We estimated age at admission by calculating the differences between dates that bears entered the rehabilitation facility and 17 January of the birth year. We calculated the number of care days as the differences between dates of bear admission and release. We evaluated support for models using Akaike's Information Criterion (Akaike 1974) corrected for small sample sizes (AIC_c; Burnham and Anderson 2002). We defined the best or most parsimonious model as that with the lowest AIC_c value. We considered models to be competing when differences in AIC_c values (ΔAIC_c) were ≤2.0 (Burnham and Anderson 2002). We considered effects to be supported if 95% confidence intervals around β-values excluded zero. We considered survival estimates of bears released from ABR and survival estimates of wild conspecifics and rehabilitated bears from published reports (identified through search engines and agency reports) to differ if 95% confidence intervals did not overlap.

We determined cause-specific mortality of bears when possible; we transported carcasses and remains to UTCVM for necropsy. We censored bears from the analysis after the last known location when their collars malfunctioned and ceased transmitting or when bears dropped their collars prior to the end of the study period (52 weeks). We 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.

RESULTS

We rehabilitated, collared, and released 42 American black bears (23 males and 19 females, 13 cubs and 29 yearlings) from ABR between 2015 and 2016 (Table S1, available online in Supporting Information). Most (73.8%) bears were released in GSMNP (CNF = 11, GSMNP = 31). Release ages ranged from 292 days (10 months) to 548 days (18 months; $\bar{x}$ = 414 ± 11.9 [SD] days). Age at admission ranged from 98 days (3 months) to 238 days (8 months; $\bar{x}$ = 179 ± 9.1 days) for bears released as cubs and 273 days (9 months) to 493 days (16 months; $\bar{x}$ = 347 ± 9.9 days) for bears released as yearlings. Body masses at time of release ranged from 23.4–56.2 kg ($\bar{x}$ = 37.4 ± 3.0 kg) for cubs and 18.1–45.4 kg ($\bar{x}$ = 29.8 ± 1.3 kg) for yearlings. Care days ranged from 90 days (3 months) to 198 days (7 months; $\bar{x}$ = 128 ± 7.2 days) for bears released as cubs and 55 days (2 months) to 190 days (6 months; $\bar{x}$ = 115 ± 7.7 days) for bears released as yearlings.

Twenty-one bears retained their collars for >1 year, and 24 retained their collars for ≥90% of a full year. Collar retention ranged from 8–449 days ($\bar{x}$ = 299 ± 22.6 days). We recovered 41 of 42 GPS collars. We recorded 93,640 post-release locations prior to screening the data for fix type and PDOP. Our 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 S2, available online in Supporting Information). Finally, 57,243 locations remained after removing locations not taken within the first year post-release for each bear. Estimates of total distance traveled ranged from 5.5–504.2 km ($\bar{x}$ = 223.2 ± 44.8 km, n = 13) for bears released as cubs and 3.9–722.7 km ($\bar{x}$ = 339.7 ± 33.2 km, n = 27) for bears released as yearlings (Fig. 1). Annual displacement distance from release sites ranged from 4.4–23.3 km ($\bar{x}$ = 12.5 ± 2.4 km, n = 4) for bears released as cubs and 1.2–21.1 km ($\bar{x}$ = 10.9 ± 1.2 km, n = 20) for bears released as yearlings (Fig. 2). Maximum displacement distance from release sites ranged from 1.4–30.8 km ($\bar{x}$ = 8.7 ± 2.2 km, n = 13) for bears released as cubs and 1.5–55.0 km ($\bar{x}$ = 14.7 ± 2.2 km, n = 27) for bears released as yearlings (Fig. S2, available online in Supporting Information).

Overall 1-year post-release survival was 0.93 (95% CI = 0.81–1.00). Our estimate of annual survival for bears released as cubs was 0.64 (0.64 ± 0.14, 95% CI = 0.35–0.86), and we did not record mortalities for yearlings within 1 year post release. The highest-ranked model accounted for 37% of the AIC_c weight (w_i) and consisted of release age as a covariate (β = 0.020, 95% CI = −0.001–0.041; Table 1). The lower confidence interval for release age rounded to

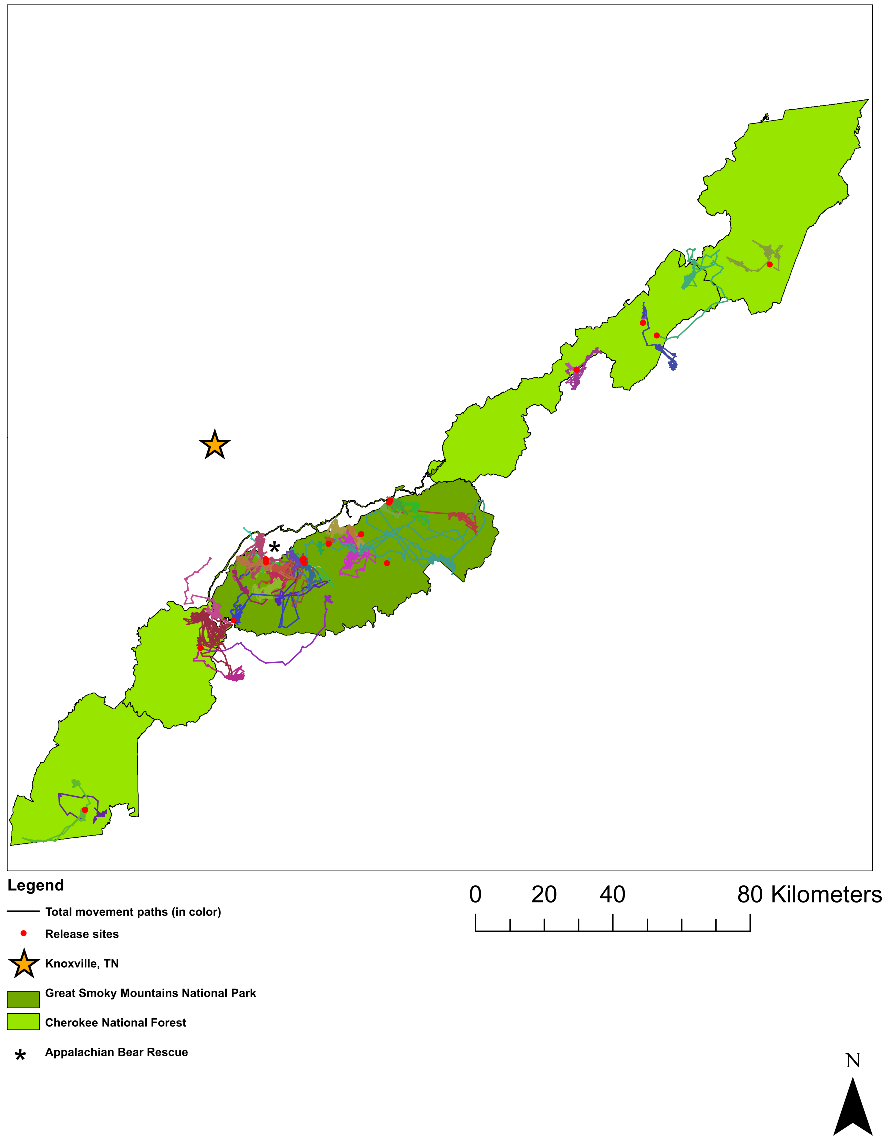

Figure 1. Total movement paths for American black bears ($n = 40$) rehabilitated at Appalachian Bear Rescue in Townsend, Tennessee, USA, and released in Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, 2015–2017.

0.00 and we considered this covariate as supported in the model. The model consisting of total distance traveled ($w_i = 0.34$, $\beta = 0.009$, 95% CI = 0.002–0.015) was also supported ($\Delta AIC_c = 0.20$).

We recorded 4 bear mortalities during the 1-year post-release period, all of which were released as cubs. Vehicular collisions were the cause of 2 deaths (both females). A male bear was euthanized because of conflict after property damage of a screen door to a residence. The cause of death for 1 bear (female) was undetermined. Partial remains of this female were found at the base of a tree but too degraded for necropsy. Three (all male) of the released bears engaged in conflict behavior within 1 year after release (Table 2). All 3 of these bears had mothers with histories of habitual conflict. Four other rehabilitated offspring of conflict mothers did not engage in known conflict behavior. Admission ages of bears that engaged in conflict within the first year post-release, and thus total number of days spent with mothers prior to orphaning, ranged from 188–323 days (Table 2).

DISCUSSION

Survival

Our estimate of annual survival (bears released in 2015–2016) for bears released as cubs (0.64, 95% CI = 0.35–0.86) was similar to that of wild black bear cubs (0.65, 95% CI = 0.60–0.70) in eastern North America as estimated by Beston (2011) for a demographic meta-analysis. Our estimates and those of Beston (2011) are not directly comparable, however, because wild cub survival typically is calculated from birth to 1 year later, whereas our estimates began at time of release, which for cubs was about 8 months of age and did not include the vulnerable neonate period. In addition, all cubs were released just prior to winter denning, a period when bears typically are less vulnerable to mortality than active bears. Captive

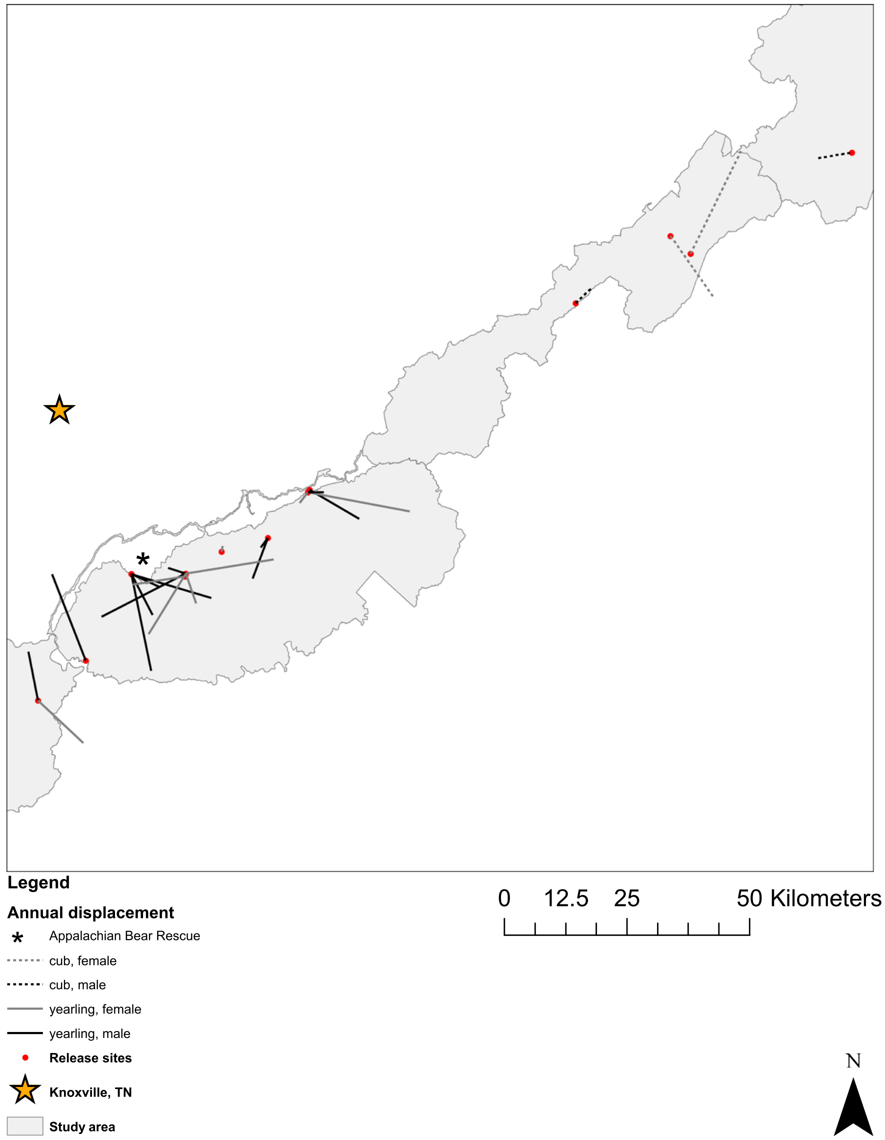

Figure 2. Annual displacement paths from release sites for American black bears ($n = 24$) rehabilitated at Appalachian Bear Rescue in Townsend, Tennessee, USA, and released in Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, 2015–2017.

cubs were also protected from potential infanticide by other bears (LeCount 1982, Lindzey et al. 1983, Czetwertynski et al. 2007). All our monitored yearlings survived, resulting in a survival rate of 1.00, which was higher than yearling wild bears in eastern North America as estimated by Beston (2011; $\bar{x} = 0.74$, 95% CI = 0.65–0.81). Survival of both age classes combined (0.93, 95% CI = 0.81–1.00) was at least comparable to survival of wild bears and higher than survival rates of rehabilitated black bears from 7 different rehabilitation facilities throughout North America, which included cubs and yearlings (Beecham et al. 2015; $\bar{x} = 0.734$, range = 0.502–0.897). Finally, our mean survival estimate for yearlings was higher than the combined mean yearling annual survival rate (0.81) reported for bears released from 3 different black bear rehabilitation facilities in Ontario, Canada (Binks 2008).

The highest-ranked model in our study included an effect of release age on survival. The 95% confidence interval included zero but only marginally (Table 1). Beecham et al. (2015) did not report differences between survival rates of rehabilitated bears released as cubs ($n = 54$) and yearlings ($n = 155$) in their study. Instead, they reported that survival increased with release mass for bears orphaned at <8 months of age and decreased with release mass for bears orphaned at >8 months (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 by hunters (Beecham et al. 2015). Neither release mass nor admission age models were supported in our study. This finding may be because the mean body mass in our study was greater for cubs than yearlings. Cubs that were acquired early in the summer appeared to respond better to ABR foods than did yearlings that were acquired later, resulting in greater body masses. In addition, 2 of the cubs released in our study were about 4.5 kg heavier than the heaviest yearling we released. We could not determine the age at actual orphaning with precision. Therefore, we were not able to study an interaction effect between release mass and actual age at

Table 1. Survival models (unknown fates censored) associated with rehabilitated American black bears released in Great Smoky Mountains National Park or Cherokee National Forest in Tennessee and North Carolina, USA, 2015–2017.

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]	LL[f]	β	95% CI
Release age	2	53.41	0.00	0.37	1.00	0.02	−0.001–0.041
Total distance	2	53.61	0.20	0.34	0.90	0.009	0.002–0.015
Admission age	2	55.47	2.06	0.13	0.36	0.012	−0.00001–0.024
Maximum displacement	2	57.88	4.47	0.04	0.11	0.119	−0.065–0.303
Null	1	58.17	4.75	0.03	0.09	1.472	1.424–1.521
Sex	2	58.54	5.13	0.03	0.08	1.359	−0.906–3.624
Release area	2	59.01	5.60	0.02	0.06	−1.106	−3.069–0.857
Care days	2	60.15	6.74	0.01	0.03	−0.002	−0.027–0.023
Release weight	2	60.17	6.75	0.01	0.03	0.004	−0.110–0.118

[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; admission age is difference (days) in date of bear admission and assumed day of birth of 17 January (Bridges et al. 2011) for a bear in a given year; maximum displacement 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 male or female; release area is Great Smoky Mountains National Park or Cherokee National Forest; care days is difference (days) between bear admission 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.
[d] Difference in AIC_c with the top model.
[e] AIC_c model weights.
[f] Model likelihood.

orphaning. All 4 known mortalities in our study were of bears released as cubs. Though the number of mortalities in our study was low, release age appears to be a more important predictor of survival than release mass.

Movements and Mortality Causes

Translocated American black bears can travel great distances back toward their capture sites (Beeman and Pelton 1976, Eastridge and Clark 2001, Wear et al. 2005). We attempted to release ABR bears near their capture sites in an effort to reduce post-release travel and encourage settling. Release sites were limited, however, and we could not be certain that bears were returned to their natal ranges. Binks (2008) did not attempt to release bears near their natal ranges and suggested that this practice may not prevent long displacements. He reported wider-ranging annual displacement distances from release sites than was observed in our study ($\bar{x} = 11.2$ km) with means ranging from 23.3–55.7 km for 3 bear rehabilitation facilities in Ontario, Canada. The shorter displacement distances in our study support the idea that release near capture sites reduces post-release displacement.

A competing top model in our analysis included a covariate consisting of total distance traveled. Specifically, the data showed a positive relationship (slope) between total distance traveled by bears and survival. This is contradictory to research that suggests that transient bears are more susceptible to mortality (Fies et al. 1987, Stiver 1991, Eastridge and Clark 2001). All 4 known mortalities in our study were of bears released as cubs, which were all released during fall (Nov and Dec, just prior to and during the denning period; Wathen et al. 1986). Myers and Young (2018) reported that 5 of 6 rehabilitated black bear cubs in Utah, USA, denned within an average distance of 2.9 km from their release sites when released during the denning period. The onset of the denning period may have lessened the travel distances for cubs in our study, thereby producing this counterintuitive result.

Wildlife officials in our area had limited access to remote, backcountry areas for releasing bears; therefore, most bears in our study were released relatively close to an improved road ($\bar{x} = 3.7$ km, SE $= 0.4$). Although we had relatively few mortalities in our study, 2 of 4 known deaths were from collisions with vehicles, and both were females.

Table 2. 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 identification	Sex	Release age	Release date	Days with mother[a]	Conflict engagement	Conflict date	Action
809[b]	F	Cub	4 Dec 2015	188	No		None
810[b]	M	Cub	30 Nov 2015	188	Yes	4 May 2016	Euthanized
926[c]	F	Cub	25 Nov 2015	180	No		None
928[c]	F	Cub	25 Nov 2015	180	No		None
930[d]	M	Cub	30 Nov 2015	201	No		None
931[d]	M	Cub	30 Nov 2015	201	Yes	20 Sep 2016	Relocated
943	M	Cub	26 Feb 2016	323	Yes	28 May 2016	Relocated
943	M	Cub	26 Feb 2016	323	Yes	12 Jun 2016	Relocated

[a] Estimated number of days bears were with known-conflict mothers prior to date of admission based on an assumed birth date of 17 January taken from bear parturition data collected in Virginia (Bridges et al. 2011).
[b,c,d] Denotes sibling pairs.

Half of bears that moved >15 km ($n = 8$) from their release sites were female. Subadult females in the wild tend to remain within or near their natal ranges, whereas 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 >8 km for females. They reported no dispersals of yearling females ($n = 14$), whereas 37% of yearling males ($n = 11$) dispersed. Although our movement metrics focused on displacement distances from release sites rather than dispersal in an ecological sense, we make this comparison to demonstrate differences in movements among sexes of wild, yearling bears to bears rehabilitated and released in our study. Myers and Young (2018) reported that female black bear cubs in their study exhibited high release site fidelity, although sample size for this analysis was low ($n = 6$; 2 females and 4 males). We agree with Binks (2008) that rehabilitated subadult females may be more vulnerable to vehicular-related mortalities than wild subadult females because of higher post-release travel.

Harvest is an important cause of wild, American black bear deaths and this was the main cause of mortality for rehabilitated bears in areas where hunting was permitted (Lee and Vaughan 2005, Beecham et al. 2015). Although bears in our study were released into protected areas, some moved outside protected areas and were exposed to harvest risk. We did not document any harvest-related mortalities of rehabilitated bears within 1 year of release, but 3 of our study bears were taken by hunters following the 1-year post-release monitoring period. The low exposure of most of our study bears to hunting undoubtedly contributed to the high survival rates.

Conflict Behavior

We found that 7.1% of rehabilitated bears in our study engaged in conflict behavior post-release, which appears similar to conflict rates in the wild (Pelton and Burghardt 1976, Teunissen van Manen et al. 2014). Similarly, Beecham et al. (2015) reported that 6.1% of 424 rehabilitated black bears engaged in conflict behavior, and Binks (2008) reported that 3 of 60 (5%) rehabilitated American black bears were shot by landowners because of conflict behavior. Smith et al. (2016), however, reported that 3 of 11 rehabilitated American black bear yearlings engaged in conflict within 1 year after release. We acknowledge that not all conflict incidents may have been reported and several bears lost their collars within 10 weeks of release. Therefore, we view our estimate of conflict behavior as a minimum.

There is concern among wildlife managers that rehabilitated offspring of mother bears with conflict history are more likely to engage in post-release conflict (Beecham et al. 2015), and all the conflict bears in our study had mothers with habitual conflict histories. 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 their mothers (Mazur and Seher 2008, Hopkins 2013, Morehouse et al. 2016). Although Beecham et al. (2015) did not report a link between rehabilitated offspring of known-conflict mothers and post-release conflict engagement of rehabilitated bears in their study, our data suggest that cubs from conflict-prone mothers had a greater chance of later being involved in conflict, though our sample sizes were low. That does not necessarily mean that all cubs with conflict mothers will become conflict bears themselves. Four of the 7 cubs with conflict mothers were not known to have engaged in conflict activity and 2 of those had siblings that later exhibited conflict behavior. All 3 bears that engaged in conflict behavior in our study were yearling males. In GSMNP, 1- to 3-year-old males have most often been responsible for conflict behavior (W. H. Stiver, GSMNP, personal communication).

Previous researchers have reported an inverse relationship between natural food availability and human-bear conflict in wild and 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 known-conflict bears in our study were released during a regional hard mast failure in 2015 (C. Olfenbuttel, North Carolina Wildlife Resources Commission, unpublished data) and engaged in conflict behavior the following May. The third bear was relocated after it was found opportunistically feeding on spilled grain and approaching humans during late September 2016. As previously reported, however, these bears had been exposed to conflict behavior by their mothers, and the overall rate of known conflict behavior was low. It therefore appears that this behavior may be more strongly linked to the behavior of their mothers than food availability.

Rehabilitation strategies and protocols for bears differ markedly depending on species, locale, presence of predators, and tradition. One common method has been for humans to train unrestrained cubs by walking with them in release areas to learn where food resources are and familiarize themselves with their local environments before final release. These training bouts occur regularly, and the cubs are returned to confinement at the end of the training period. The method has been employed on American black bears, brown bears (*Ursus arctos*), sun bears (*Helarctos malayanus*), and Asiatic black bears (*Ursus thibetanus*; Kilham and Gray 2002, Pazhetnov and Pazhetnov 2005, Fredriksson 2005, and Ashraf et al. 2008). We found high survival rates and low instances of conflict behavior in American black bears without such training. Smith et al. (2016) reported conflict rates from a rehabilitation center that uses this method that were higher than the conflict rates we reported or those reported by Binks (2008) and Beecham et al. (2015). Our approach was to keep human contact to an absolute minimum to reduce habituation. Given the expense, effort, and potential for human habituation of human-assisted training regimens, we suggest managers of other bear species consider a low human-contact, hard-release approach.

Wildlife rehabilitation programs that monitor the animals after reintroduction offer great benefit to our knowledge of wildlife rehabilitation as a management practice. Future studies may wish to follow similarly-aged reintroduced bears for a longer duration (i.e., >2 yr) to better understand the fates of these bears after dispersal events and to monitor their reproductive capacity.

MANAGEMENT IMPLICATIONS

Bears rehabilitated and released in our study survived at similar rates, died of similar causes, and engaged in similar post-release conflict to literature reports of wild conspecifics. Although we compared our data to other results from American black bear studies, our findings may be applicable to other bear species as well. Minimal human-bear interaction for care of injured or orphaned bears, release sites that were not subjected to hunting and close to original capture locations, and accelerated health restoration probably led to the high survival rates, low conflict activity, and low rates of displacement of the bears in our study. Our results support the concept that rehabilitation is a defensible and effective alternative for managers dealing with orphaned and injured bears. Our data suggest that success will be greatest if rehabilitated bears are released as yearlings in spring. If cubs must be released, we suggest they be released in the fall when natural foods are widely available. Offspring of conflict mothers should be released to remote areas far from human settlement to lessen the chance of conflict occurrence. Our data suggest that human-assisted training, as is typical for some other bear species prior to release, may not be necessary.

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