# AMERICAN BLACK BEAR ECOLOGY IN SOUTHEASTERN OKLAHOMA: POPULATION STATUS AND CAPTURE METHODOLOGY

By

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Bachelor of Science in Natural Resource Management

University of Arizona

Tucson, Arizona

2011

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2016

AMERICAN BLACK BEAR ECOLOGY IN

SOUTHEASTERN OKLAHOMA: POPULATION

STATUS AND CAPTURE METHODOLOGY

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# ACKNOWLEDGEMENTS

Thank you to all of the people who have made this research project possible. It has been a wonderful experience working with all of the graduate students, faculty, and staff here at Oklahoma State University and I feel blessed to have had the opportunity to spend a couple of years in the bear woods of Oklahoma. Thank you especially to my thesis advisor, Dr. W. Sue Fairbanks, for the opportunity to be a part of such an amazing project and for all of the encouragement and advice throughout the research process. I am also grateful to my committee members, Dr. Chip Leslie and Dr. Barney Luttbeg, for their invaluable contributions to the development and analysis of this study. Thank you to Sara Lyda for introducing me to the bear woods and for all of her help with training and project logistics. I would also like to thank all of the Oklahoma Department of Wildlife Conservation officials, especially Jeff Ford and Joe Hemphill, and my summer technicians and volunteers for all of their help in the field. Thank you also to the Hurliman family for allowing us to work on their property and for all of the Lone Rock Ranch hospitality. Thank you to my family for their love, patience, and support throughout my life.

Financial support for this project was provided by the Oklahoma Department of Wildlife Conservation through the Wildlife Restoration Grant F14AF00251 (W-174-R-1) Oklahoma State University. Additional funding was also provided by the Sigma Xi Grants in Aid of Research Program.



Acknowledgements reflect the views of the author and are not endorsed by committee members or Oklahoma State University.

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Date of Degree: MAY, 2016

Title of Study: AMERICAN BLACK BEAR ECOLOGY IN SOUTHEASTERN OKLAHOMA: POPULATION STATUS AND CAPTURE METHODOLOGY

Major Field: NATURAL RESOURCE ECOLOGY AND MANAGEMENT

Abstract: Black bears (*Ursus americanus*) were extirpated from Oklahoma in the early 1900s but have since recolonized eastern portions of the state after successful reintroductions in Arkansas. After initial demographic studies were completed, the Oklahoma Department of Wildlife Conservation approved a hunting season for the southeastern population in 2009. To investigate the population-level impacts of the hunting season, we undertook a capture-based study of the population. We complemented the demographic analyses with a camera trap study of the capture efficiency of our trapping method. From May to August 2014 and 2015, we placed bucket snares along trap lines in southeastern Oklahoma. During 1,975 trap-nights, we handled 123 individual bears (58M, 65F) 171 times. The sex ratio of captured bears did not differ significantly from 1:1. We visited 26 collared individuals (4M, 22F) in their winter dens to collect reproductive data and handled 40 cubs (22M, 18F). We calculated fecundity to be 0.56 female cubs/adult female/year. Average litter size was 2.5 ± 0.4 cubs with an over-winter survival rate of 83%. Average annual survival rate of adult bears was 0.90 ± 0.07 during the study period. Average annual harvest rate was 8.7 ± 1.67% and accounted for 87% of adult mortality. The population estimate for the core area was 175.0 ± 79.2 bears (95% CI) using only live captures. When we included camera trap captures in the calculations, abundance was estimated at 175.8 ± 49.4 bears. Using a Lefkovitch population model, the estimate of the asymptotic growth rate ($\lambda$) was 1.04.

During 1,285 camera trap-nights in 2015, we recorded 712 bear visitation events and 106 successful captures. Of the 403 visitation events in which the trap was active, 26.3% resulted in a successful capture ($n$ = 106). By-catch was limited to 1 species, northern raccoons (*Procyon lotor)*. The results of our capture models indicate that it is important to keep capture heterogeneity in mind when characterizing population demographics and calculating abundance using this capture method because sex, previous capture, and weight characteristics appeared to affect the capture process.

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# CHAPTER I

## INTRODUCTION

The conservation of large mammalian carnivores presents a number of daunting challenges to wildlife management agencies worldwide. Large carnivores are difficult to conserve due to their large area requirements, low reproductive rates, and social conflicts related to their predatory behaviors (Linnell et al. 2001). Increases in human densities during the past two centuries have contributed to the continued fragmentation of natural landscapes around the globe, reducing the amount of uninterrupted habitat available to species such as cougars (*Puma concolor*) and wolves (*Canis lupus*) that range over large areas (Wilcox and Murphy 1985; Sweanor et al. 2000). These pressures have led to the extirpation of many carnivore species from much of their native range in numerous countries (Cardillo et al. 2005). Intrinsic biological constraints, such as delayed age at first reproduction and long interbirth intervals, make large carnivores particularly sensitive to anthropogenic pressures (Cardillo et al. 2005).

In North America, effects of human activities on the population dynamics of wildlife species became evident as European settlers expanded into the interior of the continent, exposing many carnivore species to intense exploitation by way of harvest and eradication regimes that continued in some areas into the late 20$^{th}$ century

(Linnell et al. 2001). Nevertheless, large carnivore populations have recovered in many jurisdictions after favorable legislation was introduced, emphasizing the importance of effective wildlife management programs (Linnell et al. 2001). The American black bear (*Ursus americanus*) is one such species. Unlike many large carnivores elsewhere in the world, black bears have recolonized much of their historical range throughout North America in recent decades, through natural dispersal and through targeted reintroductions. While favorable management regimes led to the recovery of several North American species such as black bears, it is not a certainty that these gains will last. Unfavorable changes in management goals or strategies could contribute again to their decline.

Population studies have shown that bear population growth is most sensitive to adult survival, a population metric readily affected by harvest pressure, as harvest is the primary cause of adult mortality in hunted populations (Koehler and Pierce 2005; Lee and Vaughan 2005). Overharvest was one of the main causes of the historical contraction of black bear distribution and led to the extirpation of many other carnivore species including wolves (*Canis lupus*), pumas (*Puma concolor*), and brown bears (*Ursus arctos*) from many of the states in the continental United States (Laliberte and Ripple 2004). Large mammalian carnivores such as black bears typically have very low adult mortality in unhunted populations, so introduction of a hunting season and decreased adult survival that accompanies it is a significant alteration to the natural population dynamics of the species. Measuring direct impacts of the harvest on the population is a crucial first step in preventing overharvest, but the indirect effects of hunting on wildlife populations, although more difficult to quantify, are no less important to consider.

While bears are considered solitary animals, the removal of adult bears has the potential to disrupt the social hierarchy at a local scale, which could lead to increased levels of sexually selected infanticide (SSI), as potentially infanticidal males immigrate into the area. While the evidence of this phenomenon in ursid species is still controversial, support for its effect is growing (Wielgus and Bunnell 2000; Milner et al. 2007; Gosselin et al. 2014). In Sweden, killing 1 adult male brown bear had a population level effect equivalent to killing 0.5 to 1 adult females (Swenson et al. 1997). Researchers also noted behavioral adaptations by adult females in the hunted population as they altered their habitat use patterns to avoid food-rich areas used by potentially infanticidal immigrant males (Wielgus and Bunnell 2000). Additional indirect effects of hunting can include changes to the age and sex structure of the population (Milner et al. 2007). These shifts can occur as a result of uneven harvest pressures that lead to some age and sex classes being more vulnerable to harvest. Black bear harvest samples tend to be younger and contain a larger proportion of males than the population as a whole (Bunnell and Tait 1985; Diefenbach et al. 2004). Furthermore, the age and sex composition of harvested bears and overall hunting success has been shown to vary with harvest method, hunt design, and environmental variables (Kane and Litvaitis 1992; Diefenbach et al. 2004; Inman et al. 2007; Malcolm et al. 2010). Other behavioral adaptations also have been noted. Brown bears can alter their movement patterns during the hunting season, increasing nocturnal movements (Ordiz et al. 2012). Hunting might also affect dispersal patterns and the success of dispersal events as dispersing individuals are particularly vulnerable to harvest (Elowe and Dodge 1989; Moore et al. 2014).

Despite the potential for direct and indirect impacts of harvest pressure on black bears, little is known about what changes have occurred since the initiation of the hunting season in Oklahoma. If we want to ensure the persistence of black bears in Oklahoma, this is a critical gap in knowledge because wildlife managers need accurate estimates of population parameters such as survival, fecundity, and abundance to understand what levels of harvest the population can sustain and how it will respond to proposed management actions in the future. To help to fill in this gap, we undertook a capture-based study of the contemporary population dynamics of black bears in southeastern Oklahoma.

To understand the population dynamics of black bears in southeastern Oklahoma we needed a reliable method of assessing population characteristics such as abundance, fecundity, survival, and density. Several noninvasive methods of population assessment have been used in the past to study large mammalian carnivore species including camera trap surveys, scat collection, and spatially structured hair snare studies. While these methods continue to be improved, they are limited in the data they can provide. Such noninvasive methods do not allow researchers to directly measure the age structure of the population and limit researchers' ability to collect movement and habitat use data. For these reasons, live capture remains an essential part of wildlife population research (Mills et al. 2000; Gompper et al. 2006; Solberg et al. 2006; Sawaya et al. 2011; Bischof and Swenson 2012). We chose to use live capture as a central component of our project because it would allow us to gather demographic data, morphometric measurements, habitat and movement data through the deployment of satellite collars on captured individuals, and a mark-recapture based population estimate for the study area. This information is extremely useful in determining demographic effects of the hunting season on the black bear population in southeastern Oklahoma.

Because of the limited number of trapping seasons, the Petersen equation with the Chapman modification is the most appropriate method to use to estimate abundance (Williams et al. 2002). Abundance ($N$) was estimated using the following equation:

$$\widetilde{N} = \frac{(n_1 + 1)(n_2 + 1)}{m_2 + 1} - 1$$

where $n_1$was the number of individuals captured in 2014, $n_2$ was the total number of bears captured in 2015, and $m_2$ was the number of bears marked in 2014 that were recaptured in 2015. Only the first capture of an individual bear in each year was included in the data set and cubs were excluded to meet the negligible births assumption of the mark-recapture model. Bears known to have died between the first and second sampling period were also removed from calculations of abundance. Assumptions in this analysis are that the population is closed to additions (births and immigration) and losses (death and emigration), marks are neither lost nor overlooked, and all animals are equally likely to be captured in each sample (Williams et al. 2002).

We used a 4-x-4 Lefkovitch projection matrix to calculate the stable age distribution and approximate the population growth rate. The 4 age categories used in this calculation were cubs, yearlings, 2 – 3 year olds, and adults (>3 years old). We used the calculated vital rates from this study area for fecundity, and cub and adult survival. We also used survival rates from applicable demographic studies in the region for yearling, 2- and 3-year-old survival (Beston 2011).

To obtain an appropriately sized capture sample and maximize recapture rates, we needed a reliable capture method. Commonly used methods for capturing carnivores include cage traps, jawed and snare-based foot-hold traps, neck and body snares, and nets (Boitani and Powell 2012). The majority of black bear population studies involving live capture have used Aldrich foot-hold snares and barrel and culvert traps to capture individuals, but new designs including the bucket snare are gaining popularity (Powell and Proulx 2003).

The primary advantage of barrel and culvert traps is improved human safety. These traps are frequently used in areas where humans are likely to be present, such as residential areas or popular recreation areas, and are a commonly used method of trapping nuisance animals (Schemnitz et al. 2012). Another advantage of culvert traps is that captured bears can be transported or released without immobilization. In some cases, however, barrel and culvert traps present increased risk to the animals from overheating and may have to be closed when temperatures are high. Other disadvantages include large storage space requirements when the traps are not in use and the high cost of purchasing or constructing the traps. Culvert traps are also difficult to use in remote areas because of the need for roads and vehicles to transport the heavy traps. Aldrich foot snares are another common method of capturing black bears and are inexpensive and relatively compact, addressing the issues of cost and mobility of barrel and culvert traps. Snares are generally set on the ground, however, and can easily be triggered by other wild or domestic species (Logan et al. 1999). Hind foot and toe captures are also a risk and can lead to serious injury and mortality in some cases (Logan et al. 1999; Reagan et al. 2002).

The Arkansas Game and Fish Commission (AGFC) has been successfully using bucket snares for several years in a neighboring population of black bears after switching to the method in the early 2000s (M. Means, Arkansas Game and Fish Commission, personal communication). Several projects and management agencies in Canada have also used bucket snares, but despite their use by several wildlife management agencies, little is known about the capture efficiency, injury rates, and capture biases of the trapping method. Capture-recapture models used to estimate population parameters and demographics assume that captured animals represent an unbiased sample of the population, but violations of the equal catchability assumption can result in biased estimates (Pierce 1997). It is important to understand capture heterogeneity to choose appropriate models and accurately interpret demographic characteristics. Without this information, researchers and management agencies cannot make an informed decision about which capture method will best achieve their objectives. Ethical motivations and increasing public scrutiny make improving capture methods and understanding advantages and disadvantages of each extremely important.

The following chapters detail my research on demographic effects of the hunting season on the black bear population in southeastern Oklahoma, where hunting occurs, and my investigation into the utility of the bucket snare for black bear capture. These studies will assist Oklahoma managers in shaping future management actions, and will help to ensure the persistence of a viable black bear population in Oklahoma. This information will also help to fill knowledge gaps surrounding the population dynamics of large mammalian carnivore species after the recent initiation of a hunting season and improve our understanding of the use of bucket snares as a capture method for black bears.

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# CHAPTER II

## POPULATION STATUS OF THE AMERICAN BLACK BEAR IN SOUTHEASTERN OKLAHOMA

Increases in human population, overharvest, and degradation of habitat have led to the extirpation of many carnivore species from much of their native distributions worldwide (Cardillo et al. 2005). By the early 1900s, American black bears (*Ursus americanus*) had been extirpated from more than one-half of their distribution in North America. In the last 50 years, however, the species has made substantial gains, recolonizing much of the eastern United States, in part due to successful reintroduction programs throughout the region (Smith and Clark 1994). As a result of the natural expansion of a reintroduced population in Arkansas, black bears returned to eastern Oklahoma in the last decades of the 20$^{th}$ century (Bales et al. 2005). Oklahoma eventually opened a black bear hunting season in 4 counties in 2009 and, in the seven seasons since, more than 280 bears have been harvested (Oklahoma Department of Wildlife Conservation (ODWC), *unpublished data*). While several demographic and ecological studies were completed in the early 2000s, no quantitative research has been undertaken examining the population dynamics of black bears in southeastern Oklahoma since the introduction of the hunting season.

The direct impact of a hunting season, the removal of adult bears through harvest by hunters, is the easiest to quantify and, consequently, has received a lot of attention from researchers and management agencies (Kojola et al. 2006; Clark et al. 2010; Unger et al. 2013). Overharvest is one of the main causes of the historic contraction of black bear range and led to the extirpation of many other carnivore species including wolves (*Canis lupus*), pumas (*Puma concolor*), and brown bears (*Ursus arctos*) from many of the states in the continental United States (Laliberte and Ripple 2004). While understanding the direct impact of the harvest on the population is a crucial first step in preventing overharvest, the indirect effects of hunting on wildlife populations, although more difficult to quantify, are no less important to consider than direct effects.

While bears are considered solitary animals, the removal of adult bears has the potential to disrupt the social hierarchy at a local scale, which can lead to increased levels of sexually selected infanticide (SSI) as potentially infanticidal males immigrate into the area. While the evidence of this phenomenon in bear species is still controversial, support for its effect is growing (Wielgus and Bunnell 2000; Milner et al. 2007; Gosselin et al. 2014). In a study of brown bears in Sweden, killing 1 adult male had a population level effect equivalent to killing 0.5 to 1 adult females (Swenson et al. 1997). Reproductive rates were higher in an unhunted population of brown bears compared with a neighboring population subject to hunting pressure (Wielgus and Bunnell 2000). Researchers also noted behavioral adaptations by adult females in the hunted population as they altered their habitat use patterns to avoid food-rich areas used by potentially infanticidal immigrant males (Wielgus and Bunnell 2000). Additional indirect effects of hunting can include changes to the age and sex structure of the population (Milner et al. 2007). These shifts can occur as a result of uneven harvest pressures that lead to some age and sex classes being more vulnerable to harvest. Black bear harvest samples tend to be younger and contain a larger proportion of males than the population as a whole (Bunnell and Tait 1985; Diefenbach et al. 2004). Furthermore, the age and sex composition of harvested bears and overall hunt success vary with harvest method, hunt design, and environmental variables (Kane and Litvaitis 1992; Diefenbach et al. 2004; Inman et al. 2007; Malcolm et al. 2010). Other behavioral adaptations also have been noted. Brown bears alter their movement patterns during the hunting season, increasing nocturnal movements (Ordiz et al. 2012). Hunting may also affect dispersal patterns and the success of dispersal events as dispersing individuals may be particularly vulnerable to harvest (Elowe and Dodge 1989; Moore et al. 2014).

Despite the potential for direct and indirect impacts of harvest pressure on black bears, little is known about what changes have occurred since the initiation of the hunting season in Oklahoma. This population presents a unique opportunity to compare demographics of a black bear population before and after the implementation of a hunting season. Because we will be able to directly compare the characteristics of the captured sample from the core area trap lines, this study will provide insight on the population dynamics of other managed populations.  To help to fill in this gap in knowledge, we undertook a capture-based study of the contemporary population dynamics of black bears in southeastern Oklahoma.

## Study area

We conducted our study in the four counties in Oklahoma that have an open black bear hunting season: Latimer, Leflore, McCurtain, and Pushmataha. Dominated by the Ouachita Mountain and Arkansas River ecoregions, the 14,662-km$^2$ area is characterized by long, east – west ridges that reach elevations of up to 800 m (Tyrl et al. 2008). The Ouachita region of southeastern Oklahoma has a humid, subtropical climate, and mean annual precipitation across the counties averaged 107 – 137 cm (Tyrl et al. 2008). Average temperatures ranged from a July high of 35° C to a January low of –2.2° C. Oak-pine forest is the most common vegetation community, with shortleaf pine (*Pinus echinata*) and oaks (*Quercus* spp.) dominating south-facing slopes, white oak (*Q. alba*) on the ridgetops, and mockernut hickory (*Carya tomentosa*) dominating upper and middle north-facing slopes (Johnson 1986). On average, the counties experience 203 – 231 frost-free days each year (Tyrl et al. 2008). Major land uses in the region include recreation, logging, cattle grazing, and commercial pine plantations (Tyrl et al. 2008). More than 70% of the study area is privately owned.

## Methods

### Capture and handling

We used bucket snares constructed with a M-15 spring arm, a 19-L bucket, and a modified Aldrich foot snare (The Snare Shop, 330 S Main P.O. Box 70, Lidderdale, IA 51452) to capture bears. Assembly and installation are described in Chapter 3. In summer 2014, we placed bucket snares along previously established trap lines in the core study area as delineated by Bales (2003) to facilitate comparison to pre-harvest population estimates. The trap lines were located entirely within the eastern part of Oklahoma's Ouachita National Forest (Bales 2003). These established trap lines were run for a second season in 2015, and 4 additional trap lines were placed in western and northern parts of the Ouachita National Forest, and on private lands in McCurtain and Pushmataha counties (Figure 2.1). Trap lines consisted of 9 – 12 traps placed a minimum of 1 km apart along forest roads. We selected sites that ensured captured bears were not visible from the road and ran each line for about 3 weeks each year between 12 May and 12 August 2014 and 2015. Traps were checked within 24 hours of being set between 0800 and 1000 h. We immobilized captured bears using Telazol (A.H. Robbins Co., Richmond, VA 23220), a mixture of tiletamine hydrochloride and zolazepam hydrochloride, and Xylazine at a dosage rate of 4.8-7.0mg/kg (Kreeger and Arnemo 2012). Drugs were administered to the hind leg or the shoulder using an X-2 Gauged $CO_2$ dart pistol (Pneu-Dart, 5223 Route 87 Highway, Williamsport, PA 17701) or pole syringe (Zoolu Arms of Omaha, 10315 Wright St, Omaha, NE 68124). We marked bears using numbered, round, plastic ear tags in each ear and a lip tattoo with unique numbers for each individual. We also took body measurements and recorded the reproductive status of each bear. An upper first premolar was extracted for age estimation by cementum annuli analysis (Costello et al. 2004). For pain relief, bears were given an injection of 2-4 mg/kg Carprofen in a hind limb. Throughout sedation, vital signs were monitored and, at the conclusion of handling procedures, bears were placed in a shady, flat area away from hazards with a cloth over their eyes and allowed to recover. Personnel returned within 4 – 6 hours to verify the bear had recovered and left the area. All animal handling procedures were approved by Oklahoma State University Institutional Animal Care and Use Committee (IACUC) Protocol # AG-13-6.

To determine reproductive rates and to check collar fit, the same sedation procedures described above were used to sedate bears in their winter dens. Yearling bears present in the den were also sedated. Adult bears were not removed from their dens or weighed. We removed cubs from the den and kept them warm with blankets as we measured their total length, body mass, and chest girth and implanted passive integrated transponder (PIT) tags subcutaneously. We placed two motion-activated cameras outside the den entrance to record den exit dates and over-winter cub survival. Personnel checked back 1 – 3 days after the initial visit to insure that the sedated bears had fully recovered and that the den was not abandoned.

**Population characteristics**

Using a Chi-squared test we compared observed sex ratios of young of the year and captured bears to 1:1 and to the sex ratios observed by Bales (2003). We used the Petersen equation with the Chapman modification (Seber 2002; Williams et al. 2002) to estimate abundance for the core area based on the two years of capture data from the four established trap lines. Because of the limited number of trapping seasons, the Petersen equation with the Chapman modification is the most appropriate method to use to estimate abundance (Williams, Nichols, & Conroy 2002). Abundance ($N$) was estimated using the following equation:

$$\widetilde{N} = \frac{(n_1 + 1)(n_2 + 1)}{m_2 + 1} - 1$$

where $n_1$was the number of individuals captured in 2014, $n_2$ was the number of individuals captured in 2015, and $m_2$ was the number of bears marked in 2014 that were recaptured in 2015. Only the first capture of an individual bear each year was included in the data set, and cubs were excluded to meet the negligible births assumption of the mark-recapture model. Bears known to have died between the first and second sampling period were also removed from calculations of abundance. Assumptions in this analysis are that the population is closed to additions (births and immigration) and losses (death and emigration), marks are neither lost nor overlooked, and all animals are equally likely to be captured in each sample (Williams et al. 2002).

All extracted premolars were sent to Matson's Laboratory LLC (P.O. Box 308, Milltown, MT 59851) for cementum annuli analysis. These ages were used to determine the age structure and reproductive history of captured bears (Carrel 1994; Costello et al. 2004). We used the Kolmogorov-Smirnov test in R to compare age structures of males and females (R Core Team 2014). The Kolmogorov-Smirnov test was also used to compare age distributions between bears captured on the core and expanded trap lines, bears captured during the pre-harvest period (2001 – 2005), and harvested individuals. We used the Wilcoxon rank sum test to test for differences in median ages between males and females, and harvested and captured bears.

**Harvest data**

We obtained data on harvested bears between 2009 and 2015 from the ODWC. Every bear hunter in Oklahoma was required to physically check in their harvested bear with an ODWC official, who recorded the animal's weight and sex and collected a variety of morphometric measurements and a first premolar for cementum annuli analysis.

**Reproduction and survival**

Fecundity, the number of female young per female per year, was calculated using average litter size, proportion of female young per litter, and interbirth interval for the area. Average interbirth interval was estimated from known reproductive histories of collared female bears and cementum annuli analyses of the extracted premolars of reproductive females (Coy and Garshelis 1992; Carrel 1994; Echols 2000).

We estimated survival rates using the Kaplan-Meier Limit Estimator (K-MLE) (Pollock et al. 1989; Williams et al. 2002). This method allows newly marked individuals to be added to the sample size at any time. K-MLE is based on the assumptions that censored individuals have the same survival prospects as those that continue to be followed, that the survival probabilities are the same for individuals that enter the study early and late, and that death occurs at the time specified (Pollock et al. 1989).We estimated harvest rate by dividing the number of tagged bears killed by the total number of tagged bears (≥1 year old) available at the beginning of the hunting season each year.

**Home range and population density**

We calculated annual home ranges for individuals with at least 50 recorded locations using the kernel density estimation (KDE) method within Geospatial Modeling Environment (Beyer 2012). We selected the KDE method of home range estimation over other home range estimation techniques, such as minimum convex polygons, because the kernel technique is not as strongly affected by outlying locations and more readily captures core area activity patterns in areas of high density of use (Seaman & Powell, 1996). Additionally, KDE can exclude internal areas that were not used by the animal (Hemson et al. 2005). This makes the method an excellent choice for estimating black bear home ranges because bears often exhibit clumped activity patterns rather than evenly distributed use across the landscape (Horner et al. 1990). Bandwidth was calculated using the Least Squares Cross Validation (LSCV) method (Seaman & Powell, 1996). Cell size was set to 30 m. We defined outliers as home range values that were less or greater than 1.5 times the interquartile range (Dovoedo and Chakraborti 2015). Because sex can affect home range size, average home range size of male and female bears was calculated separately (Dahle and Swenson 2003). We used the Mann-Whitney *U*-test to compare home-range size between males and females.

We calculated the effective study area size by creating a minimum convex polygon (MCP) in ArcMap 10.3 using all of the GPS collar locations of individuals captured on the 4 lines trapped in 2014 (ESRI 2011). We also created male- and female-specific study area MCPs using only locations of individuals of each respective sex.

**Population growth**

We used a 4-x-4 Lefkovitch projection matrix to calculate the stable age distribution, parameter sensitivities and elasticities, and to approximate asymptotic population growth rate ($\lambda$) in the core area using the primer package in R 3.1.2 (Stevens 2009). The 4 age categories used in this calculation were cubs, yearlings, 2 – 3 year olds and adults (>3 years old). We used the calculated vital rates from this study area for fecundity and cub and adult survival. We used survival rates from applicable demographic studies in the region for yearling, 2- and 3-year-old survival (Beston 2011).

## Results

During 1,975 trap-nights, we handled 123 individual bears (58M, 65F) 171 times. In total, 49 individuals were fitted with satellite collars. We had 5 collars misfire and detach prematurely and 5 GPS failures. Trap success, the number of trap nights that resulted in successful captures, averaged 9.3% for the core area lines and 8.1% for the expanded lines for an overall average trap success of 8.9%.

### Population characteristics

Sex ratio of captured bears ≥1 year of age in both the expanded and core areas did not differ significantly from 1:1 (Core area: 0.78:1 M:F, G = 1.22, P = 0.27, df =1; Expansion area: 1.23:1 M:F, G = 0.42, P = 0.52, df = 1). This held true when sex ratios were calculated by individual trap line except for the Lone Rock line, which had a male-biased sex ratio (Table 2.1).

Age distributions of bears captured in 2014 and 2015 did not differ significantly and were combined in further analyses (D = 0.14, P = 0.59). Both the age distributions and median ages of males and females ($n_f$ = 54, $median_f$ = 5.5 years; $n_m$ = 50, $median_m$ = 3) were significantly different (KS: D = 0.3, P = 0.012; Wilcoxon: W = 1066, P = 0.002). There were more females in the adult age class (≥4 years) than males (0.52 M: 1F; $\chi^2$ = 4.92, P = 0.03). The age distributions of bears harvested during the 2014 and 2015 hunting seasons did not differ and were combined in further analyses (D = 0.22, P =

0.20). Captured individuals ($n$ = 125, $\bar{x}$ = 5.24 ± 0.37) were, on average older than harvested individuals ($n$ = 98, $\bar{x}$ = 3.69 ± 0.57; W = 4067, P < 0.001). Subadults made up 37.5% of captured bears. Recently captured bears were an average of 1.57 years older than bears captured by Bales (2003) in the same study area (W = 2345, P = 0.025). We made 6 recaptures of bears originally marked in the early 2000s (1M, 5F). Four of the 5 females were accompanied by young at the time of their recapture.

**Harvest data**

Between 2009 and 2015, hunters harvested 285 bears in the four counties of Oklahoma with an open season. Every year males made up a larger proportion of the harvest than females; however, this difference was only significant for 2 of the 7 years (Table 2.2). Hunters harvested 5 marked bears in 2014 and 8 in 2015 for an average annual harvest rate of 8.7 ± 1.67 %.

**Reproduction and survival**

Between 2014 and 2016, we visited the den sites of 26 collared individuals (4M, 22F) and handled 40 cubs (22M, 18F). We calculated fecundity to be 0.56. Average litter size was 2.5 ± 0.39 with an over-winter survival rate of 83% ($n$ = 6). Cementum annuli analysis identified 7 females captured in 2014 and 2015 with the necessary markers to determine reproductive history based on 9 interbirth intervals. These markers indicated that all 7 females gave birth to their first litter of cubs at 4 years of age and continued to produce cubs every 2 years. We submitted 201 teeth from both captured and harvested bears for analysis. One female that lost her entire litter in the den in 2015 reproduced again the following spring. Two collared, reproductive aged females visited in their winter dens missed a total of 3 reproductive cycles.

We observed 5 mortalities of collared bears, 3 of which were harvested during the hunting season. In total, 104 bears were harvested in 2014 and 2015 (65M, 39F). The average annual survival rate of adult collared bears was 0.90 ± 0.07 during the study period. Harvest accounted for 87% of adult mortality. Non-harvest mortalities included 1 collared adult female that died of unknown causes and an adult male that was hit by a train.

**Home range and population density**

Forty-five of the 49 collared bears met the criteria for inclusion in home range calculations (33 females, 12 males). Female home ranges ranged from 7.3 $km^2$ to 194.7 $km^2$ while those of males ranged from 18.4 $km^2$ to 1081.7 $km^2$. Outliers were present in the sample of calculated home ranges and were removed from the calculation of average home range size. For males this resulted in the exclusion of two subadult bears with a home range of 18.4 $km^2$ and 1081.7 $km^2$, respectively. One subadult female and 1 adult female with a home range size of 179.2 $km^2$ and 194.7 $km^2$ were also excluded from the calculation of average home range size. The average female and male home range sizes were 39.9 ± 4.4 $km^2$ and 243.6 ± 40.2 $km^2$, respectively. Male bears had significantly larger home range sizes than female bears ($W = 364.5$, $P < 0.001$). Average home range size for both sexes combined was 89.6 ± 17.1 $km^2$.

Using the cumulative locations of all individuals captured on the core area trap lines, the MCP-delineated study area was 1578.5 $km^2$. The male- and female-specific study area sizes were 1214.5 $km^2$ and 766.5 $km^2$ respectively. The overall, male, and female densities were 11.4 bears/100 $km^2$, 5.5 males/100 $km^2$, and 12.8 females/100$km^2$.

## Population growth

Excluding the 7 individuals that died between sampling periods, the overall population estimate for the core area was 175.0 ± 79.2 bears, 61.4 ± 34.8 for males, and 97.0 ± 54.4 for females (95% CI). This estimate was calculated using only live captures on the 4 core area trap lines. When we included camera trap captures in the calculations, abundance was estimated at 175.8 ± 49.4 bears.

To calculate an estimate of the population growth rate we used the following population parameters: cub survival (0.60), yearling survival (0.74), subadult survival (0.77), adult survival (0.90), and adult fecundity (0.56). The resulting estimate of the asymptotic population growth rate ($\lambda$) was 1.04. The estimated stable age distribution was 25% cubs, 14% yearlings, 16% subadults, and 45% adults. Lambda was most sensitive to female adult survival ($s$ = 0.68), followed by subadult survival ($s$ = 0.24), adult fecundity ($s$ = 0.17), cub survival ($s$ = 0.15), subadult within-class survival ($s$ = 0.14), and yearling survival ($s$ = 0.13). Adult survival had the highest elasticity value ($e$ = 0.59) followed by subadult survival ($e$ = 0.089), adult fecundity ($e$ = 0.089), cub survival ($e$ = 0.089), yearling survival ($e$ = 0.089), and subadult within-class survival ($e$ = 0.089).

# Discussion

There appears to have been no significant change in the sex ratio since initial research was completed in 2005. We observed balanced sex ratios for bears ≥1 year of age across most of the study area, similar to those seen by Bales (2003) and Brown (2005). We expected to see an increase in the proportion of females in the core area because female-biased sex ratios have been observed in other well-established black bear populations in the region (Clark and Smith 1994). The initiation of the hunting season may have slowed the transition to a female-biased population as females make up a substantial proportion of the harvest in Oklahoma. Our westernmost trap line was a notable exception from the balanced sex ratios seen in the other trapping areas because it had an extremely male-biased capture sample. The male-biased sex ratio observed on this trap line may be an indication that this trap line is located on the expanding edge of the black bear population in Oklahoma as male-biased sex ratios have been seen on the periphery in other ursid populations (Swenson et al. 1998). This male-biased sex ratio may be a result of the male-biased dispersal patterns seen in bears (Costello et al. 2008; Immell et al. 2014; Moore et al. 2014). Female black bears typically do not disperse as far as males, often establishing their own home range partially within or adjacent to their mothers' home range (Costello and Cecily 2010). This could contribute to a slower rate of expansion for females which may lead to lower densities of females at the leading edge of population expansion. An alternative explanation for the male-biased sex ratio observed on the Lone Rock trap line could be the concentrated availability of human food resources (e.g. deer feeders) on the property. In Oklahoma, it is legal to have bait available year-round on private property. While the majority of bait is intended for deer, bears readily access deer feeders as a food source (Dobey et al. 2005; The Wildlife Society 2006). Between 1 January and 31 December 2015, hunters placed more than 36 tons of protein supplement, mule feed, and corn into wildlife feeders distributed across the 4,500-ha property, and have regularly put out up to 90 tons of feed annually since 2005 (E. Hurliman, private landowner, personal communication). The absence of female bears in the captured sample in this area may be a result of the exclusion of females from the area by large, dominant males as they have been shown to exclude females and other subordinate individuals from high quality food resources in other populations (Mattson 1990; Wielgus et al. 2013).

The age structure of our population of black bears was similar to other populations in the region (Bales 2003; Brown 2008). Both captured and harvested females were older than their male counterparts. This tendency toward higher numbers of females in older age classes has been seen in other populations and can be attributed to higher survival rates of females (Kane and Litvaitis 1992; Schwartz and Franzmann 1992).While cementum annuli analysis is not as reliable at older ages, there were higher proportions of females in the adult age class (≥4 years) than males, which lends additional support to this relationship (Harshyne et al. 1998; Costello et al. 2004). The age structure of the harvested sample is also typical of similarly designed black bear hunting seasons elsewhere (Kane and Litvaitis 1992; Malcolm et al. 2010; Obbard et al. 2014). The tendency toward a younger harvest sample is likely a result of behavioral differences associated with inexperience, dispersal activities, and lower nutritional status of subadult bears (Schwartz and Franzmann 1992; Schwartz et al. 2013). Between 2009 and 2015, subadults made up 64.18% of harvested bears, but only 37.5% of bears captured in 2014 and 2015. While these percentages do not include cubs, which are occasionally harvested, the difference between the proportion of yearlings in the harvested and captured sample suggests that they are being harvested at higher rates than adult bears. Furthermore, more than 90% of bears are harvested over bait in Oklahoma (J. Ford, Oklahoma Department of Wildlife Conservation, personal communication). Bears of all age classes are harvested in greater number during poor food years, suggesting that bears are more likely to engage in risky behaviors to meet caloric requirements when their nutritional status is compromised (Schroeder 1986; Ryan et al. 2004; Obbard et al. 2014). As subadult bears generally have lower body condition scores, their poor nutritional status may contribute to more risky behaviors regardless of natural food availability (Schroeder 1986; Mueller et al. 2004). Dispersal may also contribute to increased harvest rates of young bears because they move through new surroundings and may be less familiar with natural food resources in the area.

Overall, the population did appear to be maturing. Bears captured in 2014 and 2015 were slightly older than bears captured 12 – 14 years earlier (Bales et al. 2005; Brown 2005). The oldest male and female bears captured in the earlier studies were 10 and 11 years old, respectively. Based on recaptures of bears originally marked in the early 2000s, our study population had several male and female bears older than the age of 18.

Fecundity was lower than previous estimates for the area, but was within the published range for black bears in the eastern United States (Bales et al. 2005; Beston 2011). Lower fecundity rates are typical of more well-established, stable populations, but it is also important to remember limitations of this estimate as it is based on a relatively small sample size collected during two seasons of den visits (Ferrer and Donazar 1996; Burton et al. 2010). Survival rates were also lower than estimates from the early 2000s for all age classes (Bales 2003). The decrease in survival for adult bears is expected with the introduction of a hunting season as large-bodied, long-lived carnivore species such as black bears typically have high adult survival in unhunted populations (Doan Crider and Hellgren 1996; Bales et al. 2005). Nonetheless, we also saw higher rates of non-harvest mortality. Lower cub survival was due in part to non-harvest related human activities. One female was pushed to abandon her litter while still in the den after being repeatedly disturbed by a group of poachers and their dogs. Several bears have been killed by vehicle collisions and outside of the hunting season because of nuisance activities (J. Ford, Oklahoma Department of Wildlife Conservation, unpublished data).

The estimate of average female home range size (39.9 ± 4.4 $km^2$) based on the cumulative dataset is larger than previous estimates from the area (21 ± 4.4 $km^2$ ; Bales 2003). This difference could be the result of differences in data collection or estimation techniques. The 2003 study obtained bear locations using VHF telemetry and had fewer individuals and fewer locations. It is also important to note the variable nature of home range size for both males (18.37 to 1081.67 $km^2$) and females (7.32 $km^2$ to 194.68 $km^2$). While the outliers were removed before calculating average home range sizes, this variability highlights the strength of individual differences. Home range size also varies between seasons and years with fluctuations in resource availability (Moyer et al. 2007; Schradin et al. 2010). The relative size of home range estimates for male and female bears, however, is consistent with trends seen in other populations of black bears as male bears tend to have substantially larger home ranges than female bears (Dahle and Swenson 2003; Immell et al. 2014). This difference is most dramatic during the breeding season when breeding males will increase their activity levels to locate and breed with oestrus females (Lewis and Rachlow 2011; Lewis et al. 2014).

Two large adult males captured in July on the Lone Rock trap line had traveled more than 97 km west from where they were first captured near the Arkansas border in early June 2015. We collared one of these individuals who later denned in the area. We were able to observe his return journey eastward after spring emergence. It appears that some males are undertaking a seasonal movement east during breeding season to areas with higher female density and returning west during the dry, hot months, possibly because of the reliable, abundant anthropogenic food resources in the area. Seasonal migration occurs in other populations of black bears in Minnesota (Noyce and Garshelis 2011).

The estimated population growth rate is lower than previously noted, but this decrease would be an expected result of the transition from an expanding population as described in the early 2000s to the established population we appear to have today. In a grizzly bear population in the Greater Yellow Stone Ecosystem, slowing population growth was associated with increased bear density as the population became better established in the region (Manen et al. 2016). Proximate explanations can be found in the lower population parameter estimates used to calculate λ. Adult female survival plays a central role in ursid population dynamics as adult females have the highest reproductive value and λ is most sensitive to fluctuations in their survival rates (Mitchell et al. 2009; Lewis et al. 2014). Despite the importance of accurate estimates of population change, confidence intervals surrounding λ are often broader than desirable for typical bear datasets, weakening the conclusions of demographic studies (Harris et al. 2011). The application of an estimator developed to predict the effects of sparse data on demographic analyses indicated that the variation of black bear population parameter estimates led to relatively high levels of uncertainty surrounding estimates of λ unless sample sizes were increased or more than 10 years of data were evaluated (Harris et al. 2011). Within this model, increasing the monitoring intensity of juvenile survival and recruitment was the most efficient means of increasing precision, indicating that the variation in juvenile survival has a greater influence on $\lambda$ than variation in adult survival (Harris et al. 2011). We argue that, while the variation in juvenile survival and recruitment is important to know, managers can more readily affect adult survival through changes in harvest design and public education campaigns focused on preventing human-bear conflict. Therefore, adult (female) survival may still be the important demographic parameter to monitor and manipulate for the most effective management of hunted black bear populations.

We calculated a higher population estimate for the core area than Bales (2003). Our estimate using only live-captures, however, was more variable due to a relatively low recapture rate. Results of our capture methodology study would tend to reduce the population estimate further as the assumption of equal catchability does not appear to be realistic (see Chapter 3).

## Management implications

Although this study has already improved our understanding of the current population status of black bears in southeastern Oklahoma, it is just a first step. Long-term research is essential to more accurately determine population parameters and to monitor trends.

We also need to continue to look into how bear densities vary across the landscape. We have already seen early indications that densities can vary drastically from trap line to trap line as habitat availability and quality also vary. The demographic and abundance estimates presented here are for what we consider some of the best bear habitat in the state. Basing management decisions on the assumption that the trends seen in one area are reflected across the entire 4-county harvest unit could contribute to overharvest in some areas, negatively impacting the population's continued expansion in eastern Oklahoma. While the observed decrease in the population growth rate is not on its own an immediate cause for concern, environmental variability is expected to increase in the coming decades which could contribute to more variable survival and recruitment rates. Managers should not discount the indirect effects of the hunting season on the age and sex structure of the black bear population in southeastern Oklahoma. A better understanding of hunter effort and population dynamics on the periphery will be crucial if managers are to anticipate and properly respond to the impacts of changes to harvest design and variable environmental conditions.

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**Table 2.1** Sex ratio of American black bears (*Ursus americanus*) captured on 8 trap lines in southeastern Oklahoma, 2014 – 2015, compared to an expected 1:1 ratio.

| Trap Line | Males | Females | G | df | P |
|---|---|---|---|---|---|
| Lynn Mountain | 17 | 12 | 0.86 | 1 | 0.35 |
| Spring | 6 | 13 | 2.64 | 1 | 0.10 |
| Three Sticks | 2 | 6 | 2.09 | 1 | 0.15 |
| Walnut | 11 | 15 | 0.62 | 1 | 0.43 |
| Deadman* | 3 | 6 | 1.02 | 1 | 0.31 |
| Lone Rock* | 8 | 0 | 11.09 | 1 | <0.001 |
| Timber* | 2 | 5 | 1.33 | 1 | 0.25 |
| Zoe* | 8 | 6 | 0.29 | 1 | 0.59 |

*Trap lines denoted with an asterisk have only 1 year of data.

**Table 2.2** Number of male and female American black bears (*Ursus americanus*) harvested by year between 2009 and 2015 in Oklahoma, USA.

| | Male | Female | Total | M:F | $\chi^2$ | df | P |
|---|---|---|---|---|---|---|---|
| 2009 | 10 | 9 | 19 | 1.11:1 | 0.053 | 1 | 0.82 |
| 2010 | 26 | 6 | 32 | 4.33:1 | 12.5 | 1 | <0.001* |
| 2011 | 18 | 13 | 31 | 1.38:1 | 0.81 | 1 | 0.37 |
| 2012 | 37 | 34 | 71 | 1.09:1 | 0.13 | 1 | 0.72 |
| 2013 | 19 | 9 | 28 | 2.11:1 | 3.57 | 1 | 0.059 |
| 2014 | 36 | 16 | 52 | 2.25:1 | 7.69 | 1 | 0.0055* |
| 2015 | 29 | 23 | 52 | 1.26:1 | 0.69 | 1 | 0.40 |
| total | 175 | 110 | 285 | 1.68:1 | 14.82 | 1 | <0.001* |

*Significant results are denoted with an asterisk.

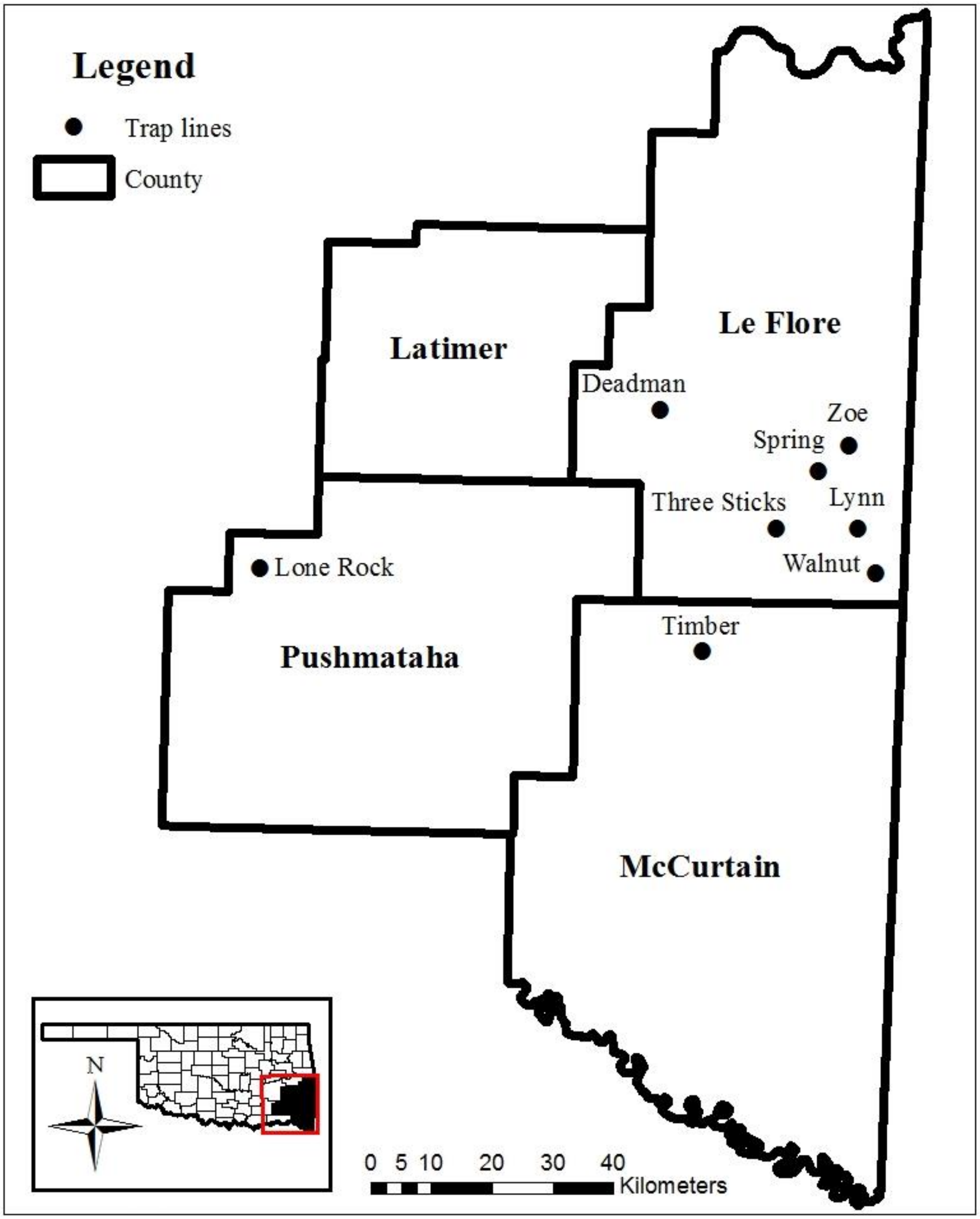


**Figure 2.1** American black bear (*Ursus americanus*) study area in southeastern Oklahoma, USA, 2014-2016. Four trap lines (Lynn, Walnut, Spring, and Three Sticks) were run for two trapping seasons between May 2014 and August 2015. The remaining 4 trap lines (Deadman, Zoe, Lone Rock, and Timber) were run for only one trapping season between May and August 2015.

# CHAPTER III

## UTILITY OF THE BUCKET SNARE TO CAPTURE AMERICAN BLACK BEARS

While noninvasive methods of population estimation continue to be improved, live capture remains an essential part of wildlife population research (Mills et al. 2000; Gompper et al. 2006; Solberg et al. 2006; Sawaya et al. 2011; Bischof and Swenson 2012). Live capture allows researchers to gather demographic data, morphometric measurements, and habitat and movement data through the deployment of satellite or telemetry collars on captured animals. Commonly used methods for capturing carnivores include cage traps, jawed and snare-based foot-hold traps, neck and body snares, and nets (Boitani and Powell 2012). The majority of American black bear (*Ursus americanus*) population studies involving live capture have used Aldrich foot-hold snares and barrel and culvert traps to capture individuals, but new designs including the bucket snare are increasingly being used by wildlife management agencies and researchers throughout the United States and Canada (Powell and Proulx 2003). Barrel traps are generally constructed using two 190-L steel barrels connected end to end. One end is closed off and a trap door is installed at the opposite end. Culvert traps are similar to barrel traps, but they have a larger diameter and are often mounted on wheels so that they can be hauled behind vehicles. The primary advantage of barrel and culvert traps is improved human safety. These traps are frequently used in areas where humans are likely to be present, such as residential areas or popular recreation areas, and are a commonly used method of trapping nuisance animals (Schemnitz et al. 2012). A particular advantage of culvert traps is that captured bears can be transported or released without immobilization. In some cases, however, barrel and culvert traps present increased risk to the animals from overheating and may have to be closed when temperatures are high. Other disadvantages include large storage space requirements when the traps are not in use, and the high cost of purchasing or constructing the traps. Culvert traps are also difficult to use in remote areas because of the need for roads and vehicles to transport the heavy traps.

Aldrich foot snares are another common method of capturing black bears and consist of a spring arm, foot loop, and anchor cable. These components can be arranged into a variety of trap sets including cubby, trail, and pipe sets (Boitani and Powell 2012). Aldrich snares are inexpensive and relatively compact, addressing issues of cost and mobility of barrel and culvert traps. Snares are generally set on the ground and can easily be triggered by other wild or domestic species (Logan et al. 1999). Hind foot and toe captures are also a risk and can lead to serious injury and in some cases mortality (Logan et al. 1999; Reagan et al. 2002). Modifications to the original design exist that can reduce by-catch and risk of some injuries (Reagan et al. 2002). Nevertheless, evidence exists that indicates that leg hold snares are more likely to cause higher levels of stress-related injuries than barrel and culvert traps (Cattet et al. 2008). Foot-hold snares are not suited for use in areas of high human activity due to risk to the public and increased stress to the bear. Similar to barrel and culvert traps, Aldrich snares are not designed to facilitate the capture of entire family units, but they do have the advantage of allowing the young to remain with their mother to nurse before researchers arrive.

Similar to Aldrich foothold snares, bucket snares are constructed using a 19-L plastic bucket, foot loop, spring arm, and cable set. The Arkansas Game and Fish Commission (AGFC) has been using bucket snares for several years after switching to the method in the early 2000s (M. Means, Arkansas Game and Fish Commission, personal communication). Several projects and management agencies in Canada have also used bucket snares, but despite their use by several wildlife management agencies little is known about the capture efficiency, injury rates, and capture biases of the trapping method. Capture-recapture models used to estimate population parameters and demographics assume that captured animals represent an unbiased sample of the population, but violations of the equal catchability assumption can result in biased estimates (Pierce 1997). It is important to understand capture heterogeneity to choose appropriate models and accurately interpret demographic characteristics. Without this information, researchers and management agencies cannot make an informed decision about which capture method will best achieve their objectives. Ethical motivations and increasing public scrutiny make improving capture methods and understanding advantages and disadvantages of each extremely important. We designed this project to address gaps in knowledge about the use of bucket snares and to improve our understanding and use of this capture method for black bears.

## Study area

We conducted our study in four counties in southeast Oklahoma: Latimer, Leflore, McCurtain and Pushmataha. Dominated by the Ouachita Mountain and Arkansas River ecoregions, the 14,662-km$^2$ area is characterized by long, east – west ridges that reach elevations of up to 800 m (Tyrl et al. 2008). The Ouachita region of southeastern Oklahoma has a humid, subtropical climate and mean annual precipitation across the counties averaged 107 – 137 cm (Tyrl et al. 2008). Average temperatures ranged from an average July high of 95° F to an average January low of 28° F. Oak-pine forest is the most common vegetation community, with shortleaf pine (*Pinus echinata*) and oaks (*Quercus* spp.) dominating south-facing slopes, white oak (*Q. alba*) on the ridgetops and mockernut hickory (*Carya tomentosa*) dominating upper and middle north-facing slopes (Johnson 1986). On average, the counties experience 203 – 231 frost-free days each year (Tyrl et al. 2008). Major land uses in the region include recreation, logging, cattle grazing, and commercial pine plantations (Tyrl et al. 2008). More than 70% of the study area is privately owned.

## Methods

### Trap construction

We constructed traps using a black 19-L plastic bucket with lid, 4.25 m of 0.48-cm galvanized steel cable, 4 cable clamps, 2 aluminum double barreled ferrules, 0.64-cm × 3.18-cm steel washers, 2.5-cm and 3.81-cm wood screws, a bear lock, and an M15 bear snare spring arm (The Snare Shop, 330 S. Main, P.O. BOX 70, Lidderdale, IA 51452). We modified the bucket lids using a hand-held disk saw so that each lid had a 12-cm ×

22-cm trapezoidal opening at the bottom and a 7-cm × 10-cm notch at the top. We also cut a 0.5-cm × 15-cm notch into the side of the bucket, parallel to the bucket lip to allow the foot loop to sit flush with the bucket surface. Foot loops were made using a 114-cm length of steel aircraft cable, a bear lock, and two ferrules. We took the natural curvature of the cable into account when assembling the foot loops and filed down sharp edges on the crimped aluminum ferrule, which we then wrapped with electrical tape to reduce risk of abrasion on the capture paw. We also strung 4 0.5-cm pieces of rubber fuel line onto the cable, securing them with glue to the upper length of the loop immediately next to the ferrule to reduce the risk of pressure necrosis (Lemieux and Czetwertynski 2006). Tree cable sets were constructed using a 4.25-m length of cable, a car hood spring, a sturdy swivel, and 2 cable clamps. Each bucket snare was mounted on a tree ≥ 30 cm in diameter. We removed any branches less than 4.5 m from the ground and any trees, large rocks, or downed logs within 3.5 m of the trap tree. We notched each trap tree using a handsaw, installing the tree set with the cable placed in this notch to ensure that a captured bear would not be able to pull the cable up the tree as it climbed. We attached each bucket to the tree using 3 wood screws and 3 steel washers.

While the majority of trapping was conducted on the Ouachita National Forest, several trap lines were established on private lands with permission. On timber company properties, our standard attachment methods were not acceptable due to concerns surrounding screw fragments remaining in the trees and causing damage to equipment or personnel during the felling or milling process. We addressed these concerns by developing an alternative attachment method. Buckets were attached to trees using a 46-cm length of 5-cm × 10-cm treated pine board with 2-cm notches 5 cm from the top and bottom, 2 1.5-m sections of aircraft cable, and 4 cable clamps. Buckets were attached directly to these boards using 2 2.5-cm and 1 3.8-cm wood screws and 3 washers, eliminating any direct damage to the tree from the trap. We secured boards to the trees using the 2 sections of aircraft cable, each set in one of the 2 notches, and tightened and secured the cable with the cable clamps.

Traps were baited using a combination of pastries, frosting, and sardines. The trigger arm itself was baited with a sardine can and a piece of canvas coated with frosting. Perimeter baits were hung surrounding the trap, 3 to 6 m away from the trap tree.

**Camera installation**

We placed one Stealth Cam G42 game camera (Stealth Cam LLC, P.O. Box 535189, Grand Prairie, TX 75053) at each active trap site between 12 May and 12 August 2015. Cameras remained active for the entire trapping period on each trap line. Cameras were placed at about 90 degrees from the direction of the trap opening between 3.5 to 5 m from the snare tree and 1.5 – 2.5 m above the ground and angled downward. Cameras were protected with steel cases (Camlockbox, 2000 Verlin Road, Green Bay, WI 54311) and secured to the tree using adjustable python cable locks (Master Lock Company LLC, 137 W. Forest Hill Avenue, Oak Creek, WI 53154) after several cameras were destroyed by bears early in the season. The units were programed to photograph 24 h/day with a three photo burst when triggered, and a one minute delay between bursts.

## Capture and handling

We used the modified M-15 bear foot snares as described above to capture bears. Trap lines consisted of 9 – 12 traps placed a minimum of 1 km apart along forest roads in Leflore, McCurtain, and Pushmataha counties. We selected sites that ensured captured bears were not visible from the road and ran each line for about 3 weeks between 12 May and 12 August 2015. Traps were checked within 24 hours of being set, between 0800 and 1000 h. We immobilized captured bears using Telazol (A.H. Robbins Co., Richmond, VA 23220), a mixture of tiletamine hydrochloride and zolazepam hydrochloride, and Xylazine at a dosage rate of 4.8-7.0 mg/kg (Kreeger and Arnemo 2012). Drugs were administered to the hind leg or the shoulder using an X-2 Gauged $CO_2$ dart pistol (Pneu-Dart, 5223 Route 87 Highway, Williamsport, PA 17701) or pole syringe (Zoolu Arms of Omaha, 10315 Wright St., Omaha, NE 68124). Bears were marked with numbered, round, plastic ear tags in each ear and a lip tattoo with unique numbers for each individual. We also took body measurements and recorded reproductive status of each bear. An upper first premolar was extracted for age estimation by cementum annuli analysis (Costello et al. 2004). For pain relief, we administered an injection of 2-4 mg/kg Carprofen to a hind limb. Throughout sedation, we monitored vital signs and, at the conclusion of handling procedures, placed the bears in a shady flat area away from hazards with a cloth over their eyes. Personnel returned within 4 to 6 h to verify the bear had recovered and left the area. See Oklahoma State University Institutional Animal Care and Use Committee (IACUC) Protocol # AG-13-6 for further detail.

## Photo analysis

We visually analyzed photographs, grouping captures by visitation type and outcome. Individuals were categorized by sex, weight, and mark status (whether the bear was marked or unmarked). A single observer estimated weights of all photographed bears. To assess accuracy of weight estimates, we compared the estimated weight of all captured bears to their measured weight. Behaviors were classified into 4 categories: in trap area, approached trap, handled trap, and trap already sprung (Table 3.1). Outcomes were classified into 6 categories: did not approach trap, did not handle trap, did not spring trap, sprung trap, failed capture, and successful capture (Table 3.2). We assigned an experience level to each visitation event of identifiable individuals according to the number of recorded instances in which the individual had handled the trap previous to the interaction in question. To determine whether behaviors and outcomes varied by sex, we compiled a count of visitation events and the exhibited behaviors and outcomes for each identified individual. Based on these counts, we then calculated the proportion of visitation events at which each individual exhibited each behavior and outcome and compared these proportions using a t-test. We then used chi-squared tests to compare all individuals' behaviors and outcomes by mark status and sex.

## Model development and selection procedures

We modeled the capture process as a series of binary responses (i.e. 1 = yes, 0 = no) using 5 stages: whether the bear approached within 2 m of the trap, whether the bear handled the trap, whether the spring arm deployed, whether the snare loop closed on the bear's wrist, and whether the snare resulted in a successful capture. We developed between 11 and 14 models using different combinations of our predictor variables for each stage of the capture process. Variables were selected based on biologically plausible *a priori* hypotheses developed based on the literature and researcher observations of black bear behavior. Males and females of various species have been shown to interact with human food resources differently, with males tending to be bolder (Gehrt and Fritzell 1996). Evidence suggests that males are more vulnerable to capture due to greater movement, especially during different periods of the year (e.g. breeding season, preceding den entrance and emergence). We felt that size could also play an important role in the likelihood of successful capture as a bear's size mediates how it interacts with the snare. Size biases have been observed with other trapping methods and species (Finstad and Berg 2004; Willson et al. 2008; Bisi et al. 2011). The mark status variable was included to determine if the capture experience was affecting how bears interacted with the snare in the future. We developed the experience variable to determine whether bears altered their behavior after each successive interaction with the snare, regardless of whether they were successfully captured.

We used the lme4 package in R to build generalized linear mixed effect models (GLMMs) with binomial link functions of the 5 stages of the capture process (R Core Team 2014; Bates et al. 2015). Generalized linear mixed effects models allowed us to differentiate between the within-group variation due to random effects and between-group variation due to fixed effects. Fixed effects were mark status, sex, weight, and experience. We included Bear ID as a random effect in all models to control for individual behavioral tendencies and pseudoreplication. We included models containing the 2-way interaction terms between marked status, sex, and experience. We evaluated models for each stage of the capture process that combined mark status, sex, weight, and experience and a null model with only a random intercept. We also developed generalized linear models (GLMs) of the first and last steps of the capture process using the stats package in R (R Core Team 2014). These models included events in which the individual was not uniquely identified, but other characteristics were known. These models did not incorporate bear ID or experience, but included weight, sex, and capture status. We developed these models because the sample of uniquely identified bears was potentially biased towards individuals that approached the trap and were successfully captured.

We assessed model support using Akaike's Information Criterion ($AIC_c$) corrected for small sample sizes and the difference between the best model and the *i*th model ($\Delta AIC_c$) to rank and compare models (Akaike 1973; Burnham and Anderson 2002). We considered models supported only when they performed better than the null model and had a $\Delta AIC_c$ value $\leq 7$. We then compared model importance using Akaike weights ($\omega_i$; Burnham and Anderson 2002). If a model had a $\Delta AIC_c$ value greater than that of one of its simpler nested models it was removed from further consideration (Richards 2008). We considered individual models to be competing models when their AICc was within 2 units of the best model.

We predicted that (1) unmarked bears would be more likely to approach, handle, spring, be snared, and be captured than marked bears, (2) the likelihood of successful capture would increase with weight, (3) with increasing experience the probability of successful capture would decrease, and (4) males would be more likely to approach and handle a trap than females.

## Results

During 1,285 camera trap-nights, we recorded 712 black bear visitation events and 106 successful captures. We included 403 of these events in our analysis of capture success. We removed the 309 events from the analysis for which the trap was already sprung (*n* = 292) or the mark status of the bear, the behavior, or outcome was unknown (*n* = 17). We were unable to determine mark status, behavior, or outcome when the bear disturbed the camera before approaching the trap, photo quality was low, or the photo burst missed the behavior of interest. Within the set of included visitation events, 86 individuals (46 males, 40 females) were conclusively identified in 208 cases (Table 3.1). Estimated weights and measured weights were highly correlated (corr = 0.97). The average weight estimate error of captured bears was 11% of body weight (*n* = 33).

In 75.2% of recorded black bear visitation events, the individual handled the trap (*n* = 303). The bear failed to approach the trap in only 2.2% of events (*n* = 9) and approached but did not handle the trap in 23.1% of events (*n* = 91). Of the 303 visitation events in which the individual handled the trap, 35.0% resulted in a successful capture (*n* = 106), 43.5% in the trap being sprung without deploying the snare (*n* = 132), and 10.0% in a failed capture (*n* = 30). In 11.5% of visitation events, the bear handled, but did not spring the trap (*n* = 35).

### Capture heterogeneity

Grouping visitation events by sex and mark status, proportions of behaviors exhibited differed between marked and unmarked individuals. Marked individuals were 3.2% less likely to approach the trap, 29.6% more likely to approach but not handle the trap, and 32.8% less likely to handle the trap than unmarked individuals ($\chi^2$ = 57.84, df = 2, P < 0.001). Males and females did not differ significantly in their exhibited behaviors ($\chi^2$ = 2.72, df = 2, P = 0.26).

The proportions of outcomes differed by sex and mark status. Males were 54.6% more likely to handle the trap without springing it and 15% more likely to be successfully captured, while females were 33.4% more likely to have a failed capture, and 13% more likely to spring the trap without being snared ($\chi^2$ = 11.57, df = 3, P = 0.009). Marked bears were 9% more likely to handle the trap without springing it and 48.4% more likely to spring the trap without being snared, while unmarked bears were 14.2% more likely to have a failed capture, and 26.4% more likely to be successfully captured ($\chi^2$ = 22.52, df = 3, P < 0.001).

Uniquely identified males and females did not differ significantly in the number of recorded visitation events (t = 0.18, df = 84, P = 0.86), the number of times they approached the trap (t = –2.45, df = 49, P = 0.15), number of times they were recorded in the trap area but did not approach the trap (t = -1.46, df = 39, P = 0.18), or the outcomes of handling the trap (t = 4.42, df = 3, P = 0.22). Males were significantly heavier than females ($\bar{x}_{\text{male}}$ = 75 ± 5.80 kg, $\bar{x}_{\text{female}}$ = 55 ± 2.28 kg, t = 3.56, df = 58, P = 0.001), and males were more likely to handle the trap (t = 2.6, df = 48, P = 0.012). Behaviors differed significantly between marked and unmarked individuals with marked individuals being 21.5% more likely to approach the trap without handling it, and 24.1% less likely to handle the trap than unmarked individuals ($\chi^2 = 21.26$, df = 2, P < 0.001). Outcomes also differed significantly between marked and unmarked individuals with marked individuals being 5.9% less likely to handle the trap without springing it, 40.3% less likely to be successfully captured, 3.5% more likely to have a failed capture, and 18.6% more likely to spring the trap without being snared ($\chi^2 = 25.02$, df = 3, P < 0.001).

**Capture models**

The top generalized linear model of approaching the trap included mark status and accounted for 38% of the $AIC_c$ weight (Table 3.4). The second best model (sex + mark status) had a $\Delta AIC_c$ value of 0.3 and accounted for 33% of the $AIC_c$ weight. The best mixed effects model for predicting the probability that a trap was handled accounted for 35% of the $AIC_c$ weight and had 2 explanatory variables (mark status and sex; Table 3.5). The best model indicated that being male and being unmarked both increased the probability that the bear would handle the trap. The best mixed effects models for springing the trap and for deploying the snare each included 1 explanatory variable (mark status) and accounted for 43% and 36% of the $AIC_c$ weight, respectively. Both models indicated that unmarked bears were more likely to spring the trap and to deploy the snares than marked individuals. The best mixed effects model for successful capture contained 3 explanatory variables (mark status, sex, and weight) and accounted for 65% of the $AIC_c$ weight. This model indicated that being heavier, male, and unmarked all increased the likelihood of a successful capture. All remaining models either contained a nested model with a lower $\Delta AIC_c$ or had a $\Delta AIC_c$ value $\geq 2$. The top generalized linear model of successful capture included 1 variable (weight) accounted for 63% of the $AIC_c$

weight. The second best model of successful captures included sex, mark status, and weight and had 35% of the $AIC_c$ weight.

**Injuries, mortalities, and by-catch**

Of the 107 black bears handled during the 2015 trapping season, we observed one broken arm. We also observed 5 captures in which the bear was snared by the head. We successfully marked and released 1 individual and 2 individuals were able to escape before the arrival of researchers. Two individuals had died when researchers arrived. We noted mild cable rubs on the snared paw of 24.1% captures. Mild pressure necrosis was noted on some of the bears recaptured within the season, but the injuries had all healed by the time collared bears were visited in their winter dens with only mild scarring on a few individuals. By-catch was limited to northern raccoon (*Procyon lotor*).

## Discussion

The bucket snare appears to be an effective method of capturing black bears. While there is not a comparable study available on the capture efficiency of Aldrich foot snares, barrel or culvert traps, we had more than twice as many live captures as previous studies carried out in the study area that used a combination of Aldrich foot snares, barrel, and culvert traps ($n$ = 77, Bales 2005; $n$ = 43, Brown 2008). It is possible, however, that the dramatic increase in captures may be the result of changes in population abundance or density.

Marked and unmarked bears differed in their behaviors, and those differences in exhibited behaviors led to differences in outcomes. This may be indicative of trap avoidance or a learned ability to manipulate the trap without being captured. This effect of mark status is a violation of the equal catchability assumption of the Lincoln-Petersen population estimate technique (Williams et al. 2002).

Males were 20 kg heavier than females on average. This is consistent with trends seen in the literature (Schroeder 1986; Lariviere 2001). This relationship between sex and weight may help to partially explain the difference in capture success rates for male and female bears because weight was included as a variable in two of the top models of successful captures.

Males appear to interact with the trap more readily and are successfully captured more often than females. This could be a direct effect of behavioral differences between males and females because males have shown higher rates of use of anthropogenic resources and may be less risk averse than females.The age structure of the sample could also be contributing to this difference through a correlation between age and sex. Uniquely identified females captured on camera tended to be slightly older than males ($\bar{x}_f = 6.32 \pm 0.74$ years, $\bar{x}_m = 4.6 \pm 0.41$ years). Age has been linked to differences in foraging behaviors in bears in other areas and could be affecting the behavioral tendencies of bears in Oklahoma as well (Mueller et al. 2004).

Results of the capture models indicated that sex, mark status, and weight characteristics affected the composition of the sample captured using bucket snares. As predicted, mark status affected capture process at every stage and was included as a parameter in each of the 5 stages' top models. In each model, being unmarked had a positive effect on an individual's likelihood of approaching, handling, springing the trap, deploying the snare, and being successfully captured. Sex appeared to be playing a role as well, however the relationship is not as clear or consistent. Sex was selected as a parameter in the handling the trap and successful capture models. In both models, being male had a positive effect on an individual's likelihood of handling the trap or being captured. Its inclusion may be an effect of the correlation between males and heavier weights. Nevertheless, the direction of the effect of being male in our models is in line with previous studies that found males to be less risk averse than females (Mattson 1990; Wielgus et al. 2013).

As predicted, weight was also selected as a parameter in the successful capture model. The relationship between heavier bears and successful capture may exist because the snare loop more securely tightens on larger adults' wrists. This capture bias towards larger bears could be reduced by alterations to the foot loop to increase capture efficiency.

Experience was not selected in any top model. The exclusion of experience from the capture models may indicate that our estimation of experience does not effectively capture the effect of the learning process. Another explanation could be that the effect of being successfully captured may be more important than the number of interactions each individual has had with the trap.

Injury and mortality rates using the bucket snare were similar to other capture methods and met established ethical standards for live capture methods (Logan et al. 1999; Powell and Proulx 2003; Cattet et al. 2008). Capturing bears by the head is a particular risk of the bucket snare and was the primary source of capture-related mortalities during the study. This risk could be lessened by design modifications to prevent bears from being snared by the head. Additional padding on foot loops may also be useful in reducing pressure necrosis (Lemieux and Czetwertynski 2006).

Captured bears would often cause damage to the trap tree as they chewed and clawed at the bark in an attempt to escape. Damage was generally more severe on smaller diameter trees. This may be a concern when placing traps on private land. Landowner and project cooperators should be made aware of the potential for tree damage.

## Management implications

Our results show that bucket snares are an effective and humane capture method for black bears. Trap modifications to reduce the risk of bears being snared by the head will be an important next step in increasing the utility of the capture method. An advantage of the bucket snare is that it is less likely to be triggered by wild ungulates, feral hogs, livestock, and dogs than Aldrich foot hold sets. Improvements need to be made to reduce the likelihood of being triggered by raccoons, however. The bucket snares are also fairly inexpensive, compact, and can be assembled quickly. The results of our capture models indicate that it is important to keep capture heterogeneity in mind when characterizing population demographics and calculating abundance using this method.

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**Table 3.1** Behaviors exhibited by American black bears (*Ursus americanus*) during trap site visitation events in southeastern Oklahoma, USA, 2015.

| Behavior | Definition |
|---|---|
| In trap area (ITA) | Bear was recorded in trap area, but did not approach to within 2 m of the trap |
| Approached trap (AT) | Bear approached to within 2 m of the trap, but did not make contact with the snare |
| Handled trap (HT) | Made contact with the snare |
| Trap already sprung (TAS) | The spring arm had already released when the bear arrived at the trap site |

**Table 3.2** Outcomes of trap site visitation events by American black bears (*Ursus americanus*) in southeastern Oklahoma, USA, 2015.

| Outcome | Definition |
|---|---|
| Did not approach trap (DNAT) | Bear was recorded in the trap area but did not approach to within 2 m of the trap |
| Did not handle trap (DNHT) | Did not come in contact with the trap |
| Did not spring trap (DNST) | Handled the trap, but did not cause the spring arm to release |
| Sprung trap (ST) | Handled the trap and caused the spring arm to release without being captured |
| Failed capture (FC) | Bear escaped from a deployed snare |
| Successful capture (SC) | Snare successfully deployed and the bear remained in place until processed by researchers |

**Table 3.3** Number of trials, failures, and successes at the 5 modeled stages of the capture process at black bear trap site visitation events in southeastern Oklahoma, USA, 2015.

| | Trials | Failures | Successes |
|---|---|---|---|
| Approach the trap | 208 | 3 | 205 |
| Handle the trap | 205 | 32 | 173 |
| Spring the trap | 173 | 16 | 157 |
| Deploy the snare | 157 | 40 | 117 |
| Successful capture | 117 | 11 | 106 |

**Table 3.4** Model selection results for generalized linear models of approaching the trap and being successfully captured during black bear trap visitation events in southeast Oklahoma, USA. We only presented models with a ΔAICc less than that of the null model and ≤7.

| Model | $AIC_c$[a] | $\Delta AIC_c$[b] | $\omega_i$[c] | K[d] |
|---|---|---|---|---|
| *Approach the trap* | | | | |
| ID Status | 49.2 | 0.0 | 0.3800 | 2 |
| ID Status + Sex | 49.4 | 0.3 | 0.3310 | 3 |
| ID Status + Sex + ID Status*Sex | 51.5 | 2.3 | 0.1180 | 4 |
| *Successful Capture* | | | | |
| Weight | 106.0 | 0.0 | 0.6290 | 2 |
| ID Status + Sex + Weight | 107.2 | 1.2 | 0.3449 | 4 |

[a]Akaike's Information Criterion corrected for small sample sizes.

[b]The difference between the model listed and the best $AIC_c$ model.

[c]Akaike weight.

[d]No. parameters in model.

**Table 3.5** Model selection results for generalized linear mixed models of approaching the trap, handling the trap, springing the trap, deploying the snare, and being successfully captured during uniquely identified American black bears (*Ursus americanus*) trap visitation events in southeastern Oklahoma, USA. We only presented models with a $\Delta AIC_c$ less than that of the null model and ≤7.

| Model | $AIC_c$[a] | $\Delta AIC_c$[b] | $\omega_i$[c] | K[d] |
|---|---|---|---|---|
| *Handle the trap* | | | | |
| Mark Status + Sex | 109.7 | 0.0 | 0.3540 | 4 |
| Mark Status | 112.0 | 2.3 | 0.1140 | 3 |
| Experience + Mark Status + Experience × Mark Status | 113.0 | 3.3 | 0.0690 | 5 |
| Experience + Mark Status | 114.0 | 4.3 | 0.0420 | 4 |
| *Spring the trap* | | | | |
| Mark Status | 56.1 | 0.0 | 0.4342 | 3 |
| Mark Status + Sex | 58.1 | 2.0 | 0.1598 | 4 |
| Experience + Mark Status | 59.3 | 3.2 | 0.0859 | 4 |
| *Deploy the snare* | | | | |
| Mark Status | 125.0 | 0.0 | 0.3596 | 3 |
| Mark Status + Sex | 126.6 | 1.6 | 0.1595 | 4 |
| Experience + Mark Status | 127.0 | 2.0 | 0.1339 | 4 |
| *Successful Capture* | | | | |
| Mark Status + Sex + Weight | 51.3 | 0.0 | 0.6490 | 5 |
| Mark Status + Sex + Weight + Experience | 52.8 | 1.5 | 0.3077 | 6 |

[a]Akaike's Information Criterion corrected for small sample sizes.

[b]The difference between the model listed and the best $AIC_c$ model.

[c]Akaike weight.

[d]No. parameters in model.

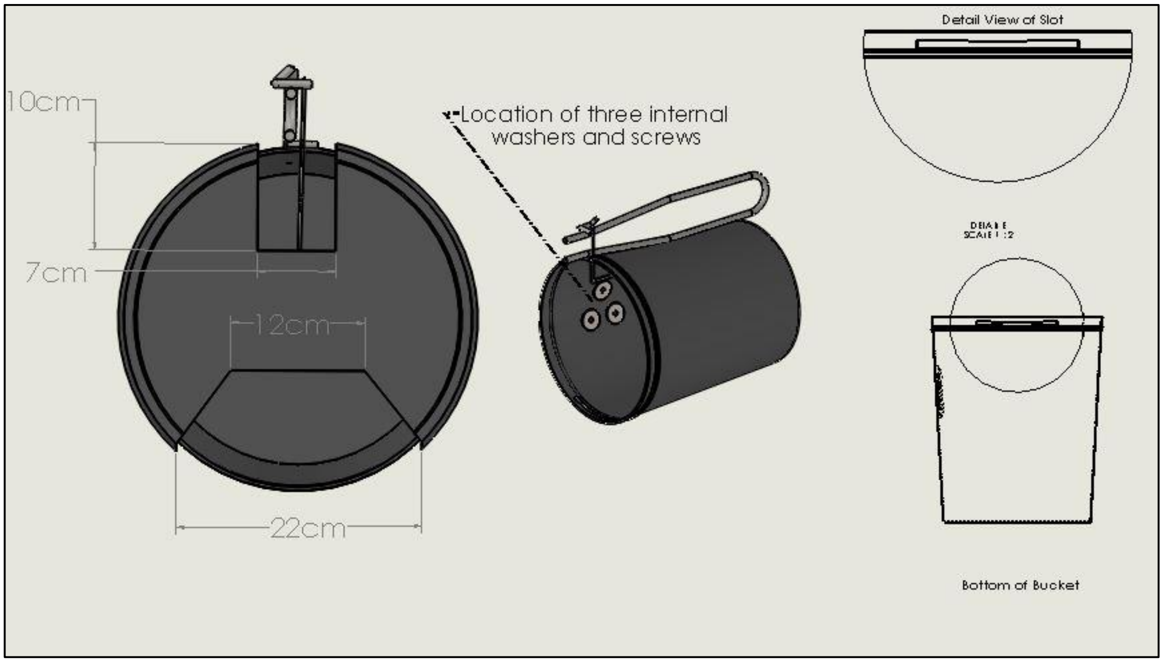


**Figure 3.1** Bucket snare diagram. The bucket snare is constructed using a 19-L plastic bucket with a modified lid. The spring arm is attached to the top of the bucket and the bucket is attached to the snare tree using 3 washers and screws.

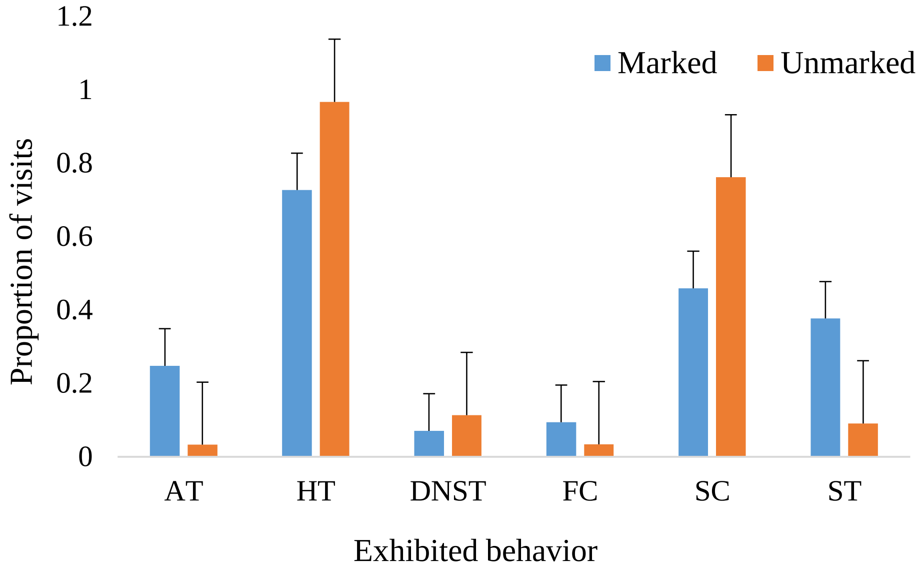


**Figure 3.2** Behaviors exhibited by uniquely identified marked and unmarked American black bears (*Ursus americanus*) (*n* = 205) at bucket snare trap sites in southeastern Oklahoma. AT, approached to within 2 m of the trap: HT, handled the trap; DNST, handled, but did not spring trap; FC, failed capture; SC, successful capture; ST, handled and sprung trap, but was not snared.

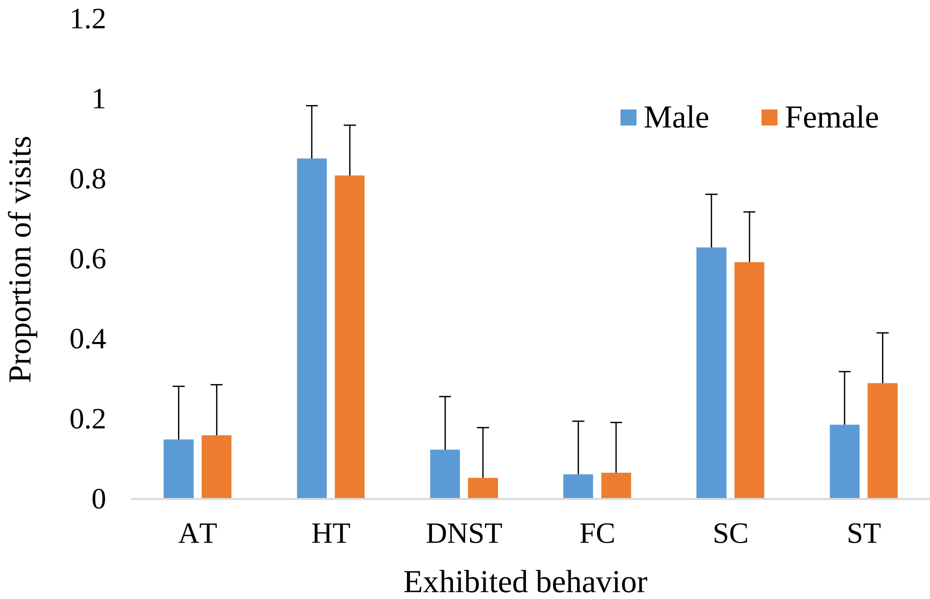


**Figure 3.3** Behaviors exhibited by uniquely identified male and female American black bears (*Ursus americanus*) ($n$ = 205) at bucket snare trap sites in southeastern Oklahoma. AT, approached to within 2 m of the trap: HT, handled the trap; DNST, handled, but did not spring trap; FC, failed capture; SC, successful capture; ST, handled and sprung trap, but was not snared.

# CHAPTER IV

## CONCLUSION

Black bears in southeastern Oklahoma appear to have increased in abundance since the pre-harvest period, despite the removal of more than 280 bears by hunters. We calculated a higher population estimate for the core area than Bales (2003). Our estimate, however, was more variable due to a relatively low recapture rate. Results of our capture bias study would tend to reduce the population estimate further because the assumption of equal catchability does not appear to be realistic.

While growth has slowed since the initiation of the hunting season, this decrease would also be an expected result of the transition from an expanding population as described in the early 2000s to the established population we appear to have today. Proximate explanations can be found in the lower population parameter estimates used to calculate $\lambda$. Adult female survival plays a central role in ursid population dynamics because adult females have the highest reproductive value and $\lambda$ is most sensitive to fluctuations in their survival rates (Mitchell et al. 2009; Lewis et al. 2014). It follows that if female survival is lowered, population growth may slow. Despite the importance of accurate estimates of population change, confidence intervals surrounding $\lambda$ are often broader than desirable for typical bear data sets, weakening the conclusions of demographic studies. The application of an estimator developed to predict the effects of sparse data on demographic analyses showed that the variation of parameter estimates led to relatively high levels of uncertainty surrounding estimates of λ unless sample sizes were increased or more than 10 years of data were evaluated (Harris et al. 2011). Based on demographic data from 4 case studies, increasing the monitoring intensity of juvenile survival and recruitment was the most efficient means of increasing precision, indicating that the variation in juvenile survival has a greater influence on λ than variation in adult survival likely because the latter tends to have low variance. While the variation in juvenile survival and recruitment is important to know, managers can more readily affect adult survival through changes in harvest design and public education campaigns focused on preventing human-bear conflict.

Fecundity was lower than previous estimates for the area, but was within the published range for black bears in the Eastern United States (Bales et al. 2005; Beston 2011). Lower fecundity rates are typical of more well-established, stable populations, but it is also important to remember the limitations of this estimate because it is based on a relatively small sample size collected during two seasons of den visits (Ferrer and Donazar 1996; Burton et al. 2010). Survival rates were lower for all age classes. The decrease in survival for adult bears is expected with the introduction of a hunting season because large-bodied, long-lived carnivore species such as black bears typically have high adult survival in unhunted populations (Doan Crider and Hellgren 1996; Bales et al. 2005). Nonetheless, we have also seen higher rates of non-harvest mortality.

There appears to have been no significant change in the sex ratio since initial research was completed in 2005. We observed balanced sex ratios for bears ≥1 year of age across most of the study area, similar to those seen by Bales (2003) and Brown (2005). We expected to see an increase in the proportion of females in the core area because female-biased sex ratios have been observed in other well-established black bear populations in the region (Clark and Smith 1994). The initiation of the hunting season may have slowed the transition to a female-biased population because females make up a significant proportion of the harvest in Oklahoma (Chapter 2). Our westernmost trap line was a marked exception from the balanced sex ratios seen in the other trapping areas because it had an extremely male-biased captured sample (Chapter 2). The male-biased sex ratio observed on this trap line may be an indication that this trap line is located on the expanding edge of the black bear population in Oklahoma because male-biased sex ratios have been seen on the periphery in other ursid populations (Swenson et al. 1998). This male-biased sex ratio may be a result of the male-biased dispersal patterns seen in bears (Costello et al. 2008; Immell et al. 2014; Moore et al. 2014). An alternative explanation for the male biased sex ratio observed on the Lone Rock trap line could be the concentrated availability of human food resources (e.g. deer feeders) on the property. The absence of female bears in the captured sample may be a result of the exclusion of females from the area by large, dominant males because they have been shown to exclude females and other subordinate individuals from high quality food resources in other populations (Mattson 1990; Wielgus et al. 2013).

The age structure characteristics of our population of black bears were similar to other populations in the region (Bales 2003; Brown 2008). Both captured and harvested females were older than their male counterparts. This tendency towards higher numbers of females in older age classes has been seen in other populations and can be attributed to higher survival rates of females (Kane and Litvaitis 1992; Schwartz and Franzmann 1992). The age structure of the harvested sample is also typical of similarly designed black bears hunts elsewhere (Kane and Litvaitis 1992; Malcolm et al. 2010; Obbard et al. 2014). The tendency towards a younger harvest sample is likely a result of behavioral differences associated with inexperience, dispersal activities, and the lower nutritional status of subadult bears (Schwartz and Franzmann 1992; Schwartz et al. 2013). Overall, the population does appear to be maturing. Bears captured between 2014 and 2015 are slightly older than bears captured in the early 2000s, suggesting that the population has a more mature age structure than previously noted. This may be a result of inaccuracies of cementum annuli analysis, however, because the proportion of adults to subadult bears was the same for both studies and cementum annuli analysis of premolars of known-age individuals underestimated age.

The average estimate of female home range size (39.89 ± 4.37 $km^2$) based on the cumulative dataset is larger than previous estimates from the area (21 ± 4.35 $km^2$ ; Bales 2003). It is important to note the variable nature of home range size for both males (18.37 to 1081.67 $km^2$) and females (7.32 $km^2$ to 194.68 $km^2$). Home range size also varies between seasons and years with fluctuations in resource availability (Moyer et al. 2007; Schradin et al. 2010). The relative size of home range estimates for male and female bears, however, is consistent with trends seen in other populations of black bears because male bears tend to have substantially larger home ranges than female bears (Dahle and Swenson 2003; Immell et al. 2014). This difference is most dramatic during the breeding season when breeding males will increase their activity levels to locate and breed with oestrus females (Lewis and Rachlow 2011; Lewis et al. 2014).

Two large adult males captured in July on the Lone Rock trap line had traveled more than 97 km west from where they were first captured near the Arkansas border in early June. We collared one of these individuals who later denned in the area. We were able to observe his return journey eastwards after spring emergence. It appears that some males are undertaking a seasonal movement east during breeding season to areas with higher female density and returning west during the dry, hot months, possibly because of the reliable, abundant anthropogenic food resources in the area. Seasonal migration has been seen in other populations of black bears in Minnesota (Noyce and Garshelis 2011).

The bucket snare appears to be an effective method of capturing black bears. While there is not a comparable study available on the capture efficiency of Aldrich foot snares, barrel or culvert traps, we had more than twice as many live captures as previous studies carried out in the study area that used a combination of Aldrich foot snares, barrel and culvert traps ($n$ = 77, Bales 2005; $n$ = 43, Brown 2008). It is possible, however, that the dramatic increase in captures may be result of changes in population abundance or density.

Results of the capture models indicate that sex, mark status, and weight characteristics are affecting the composition of the sample being captured using bucket snares. As predicted, mark status is affecting the capture process at every stage, and is included as a parameter in each of the 5 stages' top model. In each model, being unmarked had a positive effect on an individual's likelihood of approaching, handling, springing the trap, deploying the snare, and being successfully captured. Sex appears to be playing a role.

Marked and unmarked bears differed in their behaviors and those differences in exhibited behaviors led to differences in outcomes. This may be indicative of trap avoidance or a learned ability to manipulate the trap. This effect of mark status is a violation of the equal catchability assumption of the Lincoln-Petersen population estimate technique (Williams et al. 2002). Males appear to interact with the trap more readily and are successfully captured more often than females.

As predicted, weight was also selected as a parameter in the successful capture model. The relationship between heavier bears and successful capture may exist because the snare loop more securely tightens on larger adults' wrists.

Injury and mortality rates using the bucket snare were similar to other capture methods (Logan et al. 1999; Cattet et al. 2008). Bears being snared by the head is a particular risk of the bucket snare and was the primary cause of capture-related mortalities during the study. This risk could be lessened by design modifications to prevent bears from being snared by the head. Game and Fish officials in Alberta, Canada use an alternative lid design and have had lower rates of bears being snared by the head (T. Ponich, Alberta Game and Fish Department, personal communication). Going forward, we plan to incorporate elements of this snare design into our capture methods. Additional padding on foot loops may also be useful in further reducing the occurrence of pressure necrosis (Lemieux and Czetwertynski 2006).

## Management implications

Although this study has contributed a better understanding of the current population status of black bears in southeastern Oklahoma, it is just a first step. Long-term research is essential to more accurately determine population parameters (Harris et al. 2011). We also need to continue to look into how bear densities vary across the landscape. We have already seen early indications that densities can vary drastically from trap line to trap line, likely due to spatial variation in habitat availability and quality. The demographic and abundance estimates presented here are for what we consider some of the best bear habitat in the state. Basing management decisions on the assumption that the trends seen in one area are reflected across the entire 4 county harvest unit could contribute to overharvest in some areas, negatively impacting the population’s continued expansion in eastern Oklahoma.  While the observed decrease in the population growth rate is not on its own an immediate cause for concern, environmental variability is expected to increase in the coming decades, which could contribute to more variable survival and recruitment rates. As such, it is best to maintain conservative harvest limits. Additionally, managers should not discount the indirect effects of the hunting season on black bear population dynamics in southeastern Oklahoma. A better understanding of hunter effort and population dynamics on the periphery will be crucial if managers are to anticipate and properly respond to the impacts of changes to harvest design and variable environmental conditions.

Our results show that bucket snares are an effective and humane capture method for black bears. Trap modifications to reduce the risk of bears being snared by the head will be an important next step in increasing the utility of the capture method. An advantage of the bucket snare is that it is less likely to be triggered by wild ungulates, feral hogs, livestock, and dogs than Aldrich foot hold sets. Improvements need to be made to reduce the likelihood of being triggered by raccoons, however. The bucket snares are also fairly inexpensive, compact, and can be assembled quickly.

The results of our capture models indicate that it will be important in population monitoring efforts to keep capture heterogeneity in mind when characterizing population demographics and calculating abundance using this method.

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