REPRODUCTIVE BIOLOGY AND DENNING ECOLOGY OF THE AMERICAN BLACK BEAR (*URSUS AMERICANUS*) IN CENTRAL GEORGIA

by

CASEY A. GRAY

(Under the Direction of Michael J. Chamberlain)

ABSTRACT

Understanding the biological and ecological requirements of small populations of wildlife is imperative for maintaining or promoting population growth. During 2012-2014, I studied the reproductive biology, cub survival, and den selection of black bears (*Ursus americanus*) in an isolated population in central Georgia. I visited dens of 13 females and documented production of 24 cubs of the year (COY). I tracked and obtained visual observations of COY for 11 family units (19 COY) to estimate survival for a 6-month period. Mean survival rate for the first 6 months of life was 0.765 ± 0.102 (SE). I assessed the effects of microhabitat and landscape characteristics on den selection. My findings indicate the importance of early successional habitats associated with upland forests due to their higher topography and availability of dense understory vegetation.

INDEX WORDS: black bear, cub survival, denning, den selection, Georgia, reproduction, reproductive biology, survival, *Ursus americanus*

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DEDICATION

I dedicate this thesis to my parents: to my mother, Mary, who taught me to appreciate the value of a solid education, and to my father, Jon, for teaching me to appreciate the outdoors and to work for what I want in life. From a young age, you both showed me the beauty in nature and encouraged my curiosity in animals. None of this would have been possible without your love and support.

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To all those I’ve met along the way, “Watch your top knot.”

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Within the United States, large carnivores have been extirpated from much of their historical ranges because of factors such as overhunting and land use changes. This is particularly true in the eastern U.S. where large carnivores are generally absent from much of the landscape. The American black bear (*Ursus americanus*) once ranged throughout the southeastern United States, but increased exploitation of natural resources and human pressures have reduced black bears to fragmented populations (Maehr and Brady 1984). To sustain or promote growth of black bear populations in the Southeast, an understanding of their biological and ecological requirements is imperative.

Many life history traits of the American black bear are consistent throughout North America, but reproductive habits and habitat availability can differ drastically among populations (Beston 2011). Changes in landscape and climate can impact events such as timing of reproductive events and quality of habitat selected. Factors that influence black bears in one region may be less important in other regions. This variation requires that management strategies of black bears be population-specific and adaptive, thus increasing the need for sufficient research to make informed decisions.

A small (< 200 individuals) population of black bears exists in central Georgia. In addition to being geographically isolated from other Georgia black bear populations, human development has decreased suitable habitat. Due to its small population size and isolation, the

Central Georgia Population (CGP) has the potential for reduced genetic diversity and a higher probability of extirpation (Frankham et al. 2004). This places increased importance on the quality of denning habitat available. Birth, initial care, and early development of cubs occurs in dens, therefore dens are critical for cub survival and thus an essential component for reproductive success.

While studies have estimated the population size of the CGP (Sanderlin 2009, Sylvest 2014), very little is known about the reproductive and ecological characteristics of these bears. Reproductive success and population growth parameters such as cub survival, litter size, and health of breeding females are unknown. In addition, the quality of dens selected and availability of preferred denning habitat has not been evaluated.

My objective was to assess reproductive ecology of the CGP. I collected information to quantify reproduction by monitoring dens to document rates of parturition, and then monitored females with cubs to assess cub survival. I also evaluated dens in the CGP study area at a microhabitat and landscape level to determine which habitat variables were important to females when selecting dens. In addition, I assessed the impacts of prescribed fire during denning season. The combination of reproductive biology and denning ecology data will provide information needed to evaluate the viability and sustainability of the CGP for researchers and managers. Additionally, this research will offer insights regarding some of the issues facing fragmented American black bear populations in the southeastern U.S.

LITERATURE REVIEW

The American black bear (*Ursus americanus*) historically occurred in forested areas throughout North America but human land use changes and overharvest have contributed to declining populations since the 1700's (Maehr and Brady 1984, Pelton and Vanmanen 1994, Pelton 2003). Despite documentation of recent expansion in some populations, black bears in the United States are estimated to occupy less than 50% of their historic range (Scheick and McCowen 2014). Along with decreasing population numbers, black bear range has become increasingly fragmented, particularly in the southeastern United States. Black bears once ranged throughout the Southeastern Coastal Plain, but populations have been reduced to approximately 10% of their historical range and an estimated 30 disjunct populations (Maehr and Brady 1984, Pelton 1990). This fragmentation is a result of land conversion for agriculture, urban development, and forestry practices common in this region (Pelton 1990). In the Southeast, black bear habitat and distribution has experienced greater loss than any other region and continues to be an area of concern in bear management (Maehr and Brady 1984, Scheick and McCowen 2014).

There are 3 black bear populations in Georgia: a northern population in the Appalachian Mountains, a southern population associated with the Okefenokee Swamp, and an isolated population in central Georgia associated with the Ocmulgee River drainage system (Figure 1.1). Recent studies have estimated population size of the CGP at 213 individuals in 2009 and as few as 139 individuals in 2013 (Sanderlin 2009, Sylvest 2014). This small population is confined to areas surrounded by human development within the Ocmulgee River flood plain. Core use areas fall within forested areas of Oaky Woods and Ocmulgee Wildlife Management Areas (WMAs) which provide approximately 32,400 ha of managed land bordering the east and west banks of the Ocmulgee River (Carlock et al. 1999). The CGP continues to be influenced by decreases in habitat availability because of human encroachment and fragmentation from urban sprawl. Due to a lack of suitable habitat corridors for dispersal and connectivity to other bear populations, it is assumed that the CGP is reproductively isolated, similar to other populations in the southeastern United States (Troxler 2013).

Reproduction is essential to population persistence because reproduction rates and recruitment of young into the breeding population drive bear abundance (Oli and Dobson 2003, Wildt et al. 2003). Because these components are critical to population success, they become increasingly more important when managing small populations. Small populations in isolated fragments of habitat have increased extinction probabilities because they are more exposed to environmental catastrophes and random genetic and demographic events (Shaffer and Samson 1985, Miller 1990). To ensure persistence of a small population, managers must identify factors that encourage production and survival of young. Black bear reproductive rates are determined by age of reproductive maturity, litter production intervals, and litter size (Bunnel and Tait 1981, Pelton 2003). Additionally, reproductive success is measured by cub survival and recruitment into the population.

Black bear reproduction is unique when compared to other large mammals because females reach sexual maturity between the ages of 3-5 years (Elowe and Dodge 1989) and breed only every other year. Black bears breed in the summer with females typically giving birth to 2 to 4 cubs during January or February. Cubs are altricial at birth, fully relying on the female for care and protection. Maternal care continues for the first 16-17 months of life, as they stay with their mother and den with her through their second winter (Clevenger and Pelton 1990, Pelton 2003). Typically, separation of yearlings and their mother occurs during the second summer together, when the female is ready to breed again (Jonkel and Cowen 1971). Due to the delayed sexual maturation in female bears, the relatively low number of cubs produced, and the intermittent production of young, population stability is widely affected by changes in these reproductive factors.

Reproductive success is directly related to the condition of potentially breeding females (Jonkel and Cowen 1971, Elowe and Dodge 1989). In years of mast failures and low availability of food, females may lack the proper nutrition to sustain pregnancy, thus young may be aborted (Elowe and Dodge 1989). Likewise, litter size may be reduced. Previous research has shown that in years of mast failure, litter sizes are generally smaller and fewer females have young (Rogers 1987). In the southeastern U.S., average litter sizes have ranged from 1.85 to 2.37 cubs per litter (Dobey et al. 2005, Clark and Eastridge 2006, Garrison et al. 2007, Crook 2008).

Cub survival rates across black bear populations can be highly variable and are affected by environmental conditions and quality of maternal care (LeCount 1987, Rogers 1987, Eiler et al. 1989, Beston 2011). Typically, cub survival rates are approximately 55% during the first year and 65% after they disperse from their mother and prior to recruitment into the breeding population (Pelton 2003, Garrison et al. 2007). Overall, cub survival is estimated to be 65% for eastern populations of black bears (Beston 2011). Causes of mortality for cubs may include cannibalism, predation, disease, anthropogenic sources, abandonment, and malnutrition (LeCount 1987, Elowe and Dodge 1989, Garrison et al. 2007). Winter dens can provide protection from many of these dangers and, therefore, increase cub survival during the crucial first months (Hamilton and Marchinton 1980, Hellgren 1998). LeCount (1987) concluded that cub production is density independent and a function of the number of potentially reproducing females in a population and habitat quality.

Winter dens are necessary habitat requirements for black bears and are essential to cub survival because parturition and initial care occur in winter dens (Powell et al. 1997). Lack of adequate den sites may result in increased cub mortality and subsequently lower recruitment. Central Georgia bear habitat is dominated by pine (*Pinus* spp.) and mixed hardwood-pine forests. Although many black bear populations use elevated tree cavities as dens (Crook and Chamberlain 2010), a general lack of tree dens in the CGP results in most bears denning on the ground. Ground dens usually are located in dense vegetation such as greenbriar (*Smilax* spp.), but they can be more susceptible to disturbance caused by human activities such as land management and recreational use (Carlock et al. 1999). Although black bears can withstand low levels of disturbance in or around the den, increasing and consistent disturbance can cause early emergence or abandonment (Linnell et al. 2000).

Little information is available about the ecological requirements or preferences of the CGP (Carlock et al. 1999). Both microhabitat and macrohabitat features have been shown to affect bear den selection (Martorello and Pelton 2003, Crook and Chamberlain 2010). Microhabitat characteristics such as understory cover and den association with trees can protect bears from predation, disturbance, and reduce energetic loss caused by harsh winter weather (Hayes and Pelton 1994). On a larger spatial scale, land cover and topographic features can predict plant communities and landscape features that are preferred by bears. Evaluating habitat at multiple scales allows for a more comprehensive understanding of den selection, which is beneficial in identifying factors affecting female reproductive success as well as population viability (Benson and Chamberlain 2007, Crook and Chamberlain 2010).

Denning bears in the CGP are affected by forest management activities such as timber harvest and prescribed fire (Carlock et al. 1999). These practices can directly affect bears because they often continue through the winter months when bears are susceptible to disturbance in the den (Carlock et al. 1999, Linnell et al. 2000). Successional changes in understory composition and availability of forage occur for years after logging, providing varying levels of habitat quality (Johnson 1987). Clearly, changes to forested habitats in the CGP may produce shorter and longer-term impacts to den selection. Likewise, prescribed fire is a common management technique used in the CGP with most burns occurring from January through March (B. T. Bond, GA DNR, personal communication). Researchers have described abandonment of denning bears in response to fire (Weaver 2000), but whether fire affects bears in the CGP similarly is unclear.

Between 2011 and 2014, a bear hunt was established by the Georgia Department of Natural Resources (GADNR) in central Georgia. Increasing pressure from local hunters due to the perception of a growing bear population prompted the one-day season. In 2011 and 2012, the hunt occurred during the second weekend in November. The hunt was delayed to the second weekend in December in 2013 and 2014 in an effort to decrease mortality of parturient females. Although the number of hunters was not restricted, each hunter was limited to taking one bear weighing more than 75 pounds. The hunt was restricted to private lands within Bibb, Houston, and Twiggs counties. Hunting can have relevant impacts on small bear populations, primarily because they are disproportionately affected by the loss of females due to their role in reproduction and population growth (Miller 1990). Bears have one of the slowest reproductive rates of any land mammal in North America (Jonkel and Cowan 1971). Populations are particularly affected by the harvest of females due to their breeding asynchrony and strong investments in their cubs (Powell et al. 1997). Because population productivity is a function of the number of females (Beecham 1980), overharvest of females could cause the CGP population to decrease. Information on reproductive ecology gained from this study will be beneficial in management recommendations for a sustainable bear population in the face of the current hunting season affecting the CGP.

This study is part of a comprehensive research initiative designed to estimate population size of the CGP as well as determine the effects of a highway-widening project occurring in the core of the area occupied by the CGP. My research will compliment this larger project by gaining information critical in understanding the population dynamics of the CGP. I will study denning ecology, estimate cub survival, and provide information on reproductive parameters for purposes of providing data needed to assess population viability and sustainability.

OBJECTIVES

The purpose of this project was to (1) quantify cub production, cub survival, and litter size, and (2) assess patterns of den selection at multiple spatial scales by collecting data on microhabitat characteristics present at den sites, and evaluating the effect of broader-scale habitat features on den selection.

THESIS FORMAT

This thesis is presented in manuscript format. Chapter 1 is an introduction and literature review of previous research on similar biological and ecological aspects of black bear reproduction. Chapter 2 focuses on the reproductive biology and cub survival of black bears (*Ursus americanus*) in central Georgia. Chapter 3 presents analyses on den selection at a microhabitat and landscape level. Chapters 2 and 3 will be submitted to a peer-reviewed journal for publication. Chapter 4 discusses conclusions drawn from this study and management implications.

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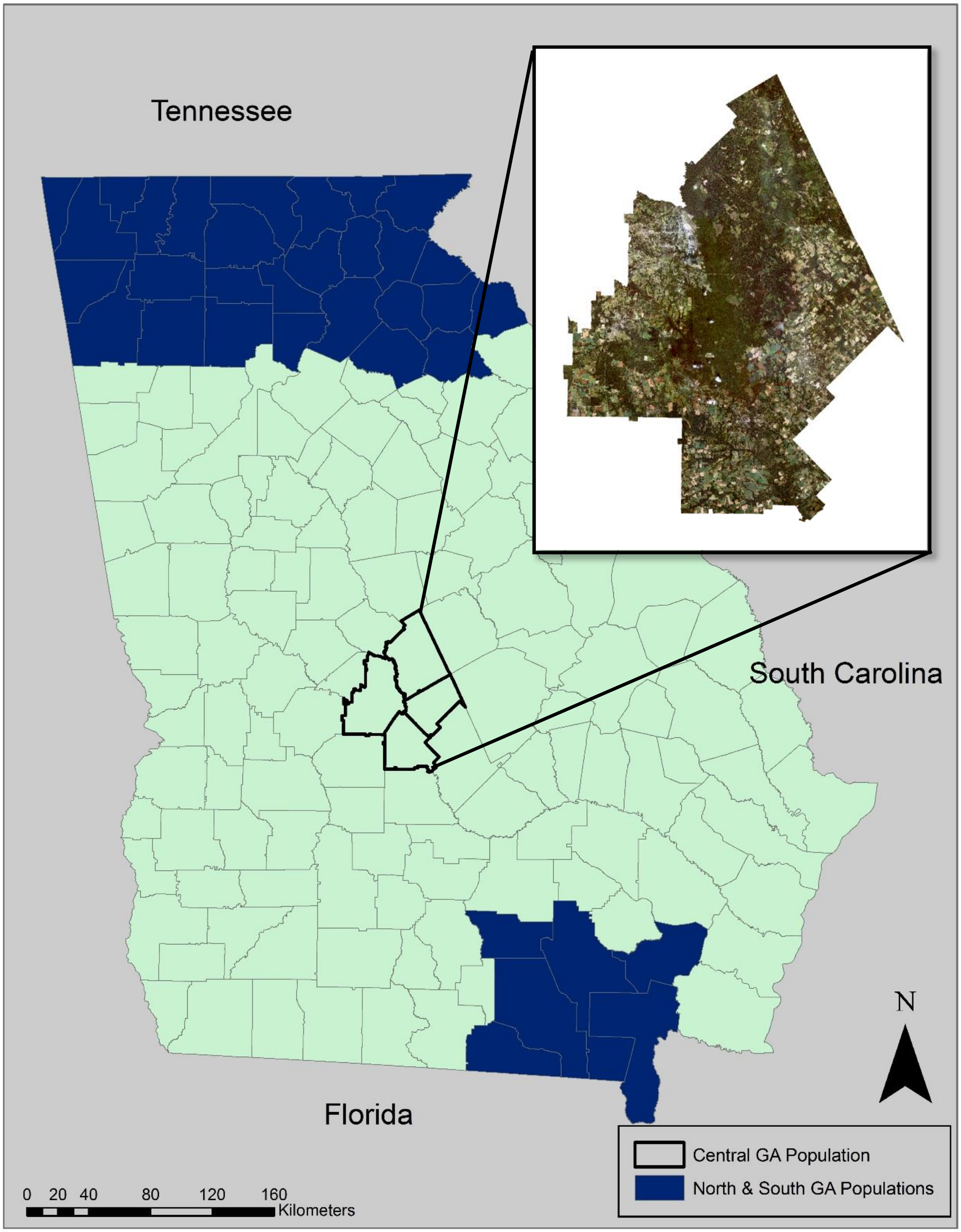

Figure 1.1. Location of the study area for the central Georgia black bear population.

CHAPTER 2

REPRODUCTIVE BIOLOGY AND CUB SURVIVAL OF AMERICAN BLACK BEARS (*URSUS AMERICANUS*) IN CENTRAL GEORGIA

Gray, C. A., M. J. Hooker, and M. J. Chamberlain. To be submitted to *Ursus.*

ABSTRACT

During 2012-2014, we studied the reproductive biology and cub survival of American black bears (*Ursus americanus*) in central Georgia. We visited dens of 13 females and documented production of 24 cubs of the year (COY). Mean litter size was 1.85 ± 0.25 (SE). We measured 11 COY in 7 dens and found a sex ratio of 7M: 4F. We tracked and obtained visual observations of COY for 11 family units (19 COY) to estimate survival for a 6-month period. Mean survival rate for the first 6 months of life was 0.765 ± 0.102 (SE). Litter size was smaller than other black bear populations in the southeastern United States, but our estimated cub survival rate was higher than most reported populations in the region. Reproductive parameters and survival rates provided from this research will be useful in estimating population viability and developing management strategies for the central Georgia bear population.

INDEX WORDS: black bear, cub survival, Georgia, reproduction, reproductive biology, survival, *Ursus americanus*

INTRODUCTION

Three black bear populations occur in Georgia: a northern population in the Southern Appalachians, a southern population associated with the Okefenokee Swamp, and a small (< 200 individuals), isolated population in central Georgia associated with the Ocmulgee River drainage system. The Central Georgia Population (CGP) has experienced habitat loss due to human encroachment and fragmentation from urban sprawl. Due to lack of suitable habitat corridors for dispersal and connectivity to other bear populations, it is assumed that the CGP is reproductively isolated, similar to other populations in the southeastern United States (Troxler 2013).

Reproduction is essential to population persistence because reproduction rates and recruitment of young into the breeding population drive bear abundance (Oli and Dobson 2003, Wildt et al. 2003). Because these components are critical to population success, they become increasingly important when managing small populations. Small populations in isolated fragments of habitat have increased extinction probabilities because they are more exposed to environmental catastrophes and random genetic and demographic events (Shaffer and Samson 1985, Miller 1990). To ensure persistence of a small population, managers must identify factors that encourage production and survival of young. Black bear reproductive and recruitment rates are often evaluated by parameters such as proportion of females, litter size, and survival of young (Bunnel and Tait 1981, Fuller and Sievert 2001, Pelton 2003).

Reproductive success is directly related to the condition of potentially breeding females (Jonkel and Cowen 1971, Elowe and Dodge 1989). In years of mast failures and low availability of food, females may lack the proper nutrition for pregnancy or maternal care, thus young may be aborted or litter sizes may be smaller (Rogers 1987, Elowe and Dodge 1989). Cub production is a particularly important aspect of recruitment for black bears since females are biennial breeders and young experience approximately 45% mortality in the first year (Beston 2011). Causes of mortality for cubs may include cannibalism, predation, disease, anthropogenic sources, abandonment, and malnutrition (LeCount 1987, Elowe and Dodge 1989, Garrison et al. 2007). Cub survival rates across black bear populations can be highly variable and are affected by environmental conditions and quality of maternal care (LeCount 1987, Rogers 1987, Eiler et al. 1989, Beston 2011). This variation requires that management strategies for black bears be population-specific and adaptive, thus increasing the need for sufficient research to make informed decisions.

During our research, an experimental hunt was been established by the Georgia Department of Natural Resources (GADNR) in central Georgia. Hunting can have relevant impacts on small bear populations, primarily because they are disproportionately affected by the loss of females due to their role in reproduction and population growth (Miller 1990). Understanding the reproductive parameters of a population becomes more important as hunter pressure increases (Beecham 1980). Although certain aspects of black bear life history traits have been studied in the CGP (Cook 2007, Sanderlin 2009, Sylvest 2014), little is known about the reproductive parameters of this population. Information on reproductive ecology gained from this study will be beneficial in making management recommendations to ensure sustainable management of the CGP.

We predicted that reproductive traits such as litter size and cub survival would be similar to other populations in the region, despite the small population size. The objective of this study was to examine reproductive biology of black bears in the CGP by quantifying litter size and providing an estimate of cub survival.

STUDY AREA

We conducted research on Oaky Woods Wildlife Management Area (WMA), Ocmulgee WMA, and privately owned lands in Houston, Pulaski, Twiggs, and Bleckley counties during 2012-2014. This area was located in the Upper Coastal Plain geophysical region of central Georgia, was associated with the Ocmulgee River drainage system, and was almost completely surrounded by human development. These areas encompassed approximately 32,400 ha dominated by pine (*Pinus* spp.) plantations, upland and bottomland hardwood forests, and cypress-gum swamps. About 90% of the WMA property was forested. Private lands included in the study area were dominated by pine plantations, but also included agricultural fields and areas of human development. Plum Creek Timber Company was the largest landowner in the area and their properties consisted of variable-aged planted pine stands. Timber harvest and management techniques were conducted on private timber lands.

Prominent habitat types in the WMAs included pine plantations, mixed pine-hardwood, bottomland hardwoods, cypress-gum swamps, clearcuts, and black belt prairies. Common overstory plant species included loblolly pine (*P. taeda*), slash pine (*P. elliottii*), shortleaf pine (*P. echinata*), various oaks (*Quercus* spp.), American elm (*Ulmus alata*), sweetgum (*Liquidambar styraciflua*), maples (*Acer* spp.), hickories (*Carya* spp.), magnolias (*Magnolia* spp.), and dogwoods (*Cornus* spp.). Understory flora included American beautyberry (*Callicarpa americana*), wax myrtle (*Morella cerifera*), blueberries (*Vaccinium* spp.), blackberries (*Rubus* spp.), wild grapes (*Vitis* spp.), Japanese honeysuckle (*Lonicera japonica*), persimmon (*Diospyros virginiana*), wild plum (*Prunus americana*), and hawthorne (*Crataegus* spp.). Local fauna included white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), feral hog (*Sus scrofa*), bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis* *latrans*), and raccoon (*Procyon lotor*). Agricultural fields that provided additional food sources to black bears were planted in corn, peanuts, wheat, and soybeans.

Prescribed burning is a common management tool used on both of the WMAs. Typically, fields and prairies are burned every other year, and mature pine stands are burned on a 3-5 year rotation. Nearly 95% of the burns occur from January to March (B. Bond, GA DNR, personal communication). Additional management included food plots targeted for game species such as wild turkey and white-tailed deer. Recreational opportunities allowed on the WMAs included hunting, fishing, and camping. Bear hunting was prohibited on the WMAs. While private landowners would use fire on a small scale, Plum Creek and other timber companies did not use prescribed burns as a management technique.

An experimental hunt was established by the Georgia Department of Natural Resources (GADNR) in central Georgia. A one-day season occurred during 2011-2014. In 2011 and 2012, the hunt occurred during the second weekend in November. The hunt was delayed to the second weekend in December in 2013 and 2014. The hunt is restricted to private lands within Bibb, Houston, and Twiggs counties.

METHODS AND MATERIALS

Capture and Radio Telemetry

From May-October of 2012 and 2013, we captured female black bears on Oaky Woods WMA, Ocmulgee WMA, and surrounding private lands using modified Aldrich foot snares (Johnson and Pelton 1981). Captured bears were immobilized chemically with Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) or xylazine (100mg/ml, Vedco, Inc., St. Joseph, Missouri, USA) combined with Telazol® (XZT). Drugs were administered using a pressurized dart by blow pipe. Each bear was given a 3-digit number that was displayed on ear tags and a lip tattoo. Each female was fitted with either a Lotek Wildcell® GPS collar (Lotek Wireless Inc., Newmarket, Ontario, Canada) or a Telonics® MOD- 500 VHF collar (Telonics, Inc., Mesa, Arizona, USA) equipped with leather break-away spacers (Garshelis and McLaughlin 1998). Bears were weighed, measured, and given a qualitative value for body condition (poor, fair, good, excellent). The right upper pre-molar was extracted for aging using cementum annuli (Willey 1974). In addition, age (sub-adult, adult) was estimated on-site using tooth wear and reproductive status. We defined sub-adults as bears that had not yet reproduced. Reproductive status was determined by recording observations of young, teat color and size, lactation, and vulval swelling as an indicator of estrus (Jonkel and Cowan 1971).

We monitored bears by ground-based telemetry using a receiver (Advanced Telemetry Systems® R2000) and antenna (Telonics® RA-23K 4-element H, Telonics® RA-5A whip). GPS-collared bears were monitored using Lotek Total Host GPS® software, whereas standard telemetry techniques were used to monitor bears fitted with VHF collars. From December- May, radio-collared female bears were triangulated 2-3 times per week to locate dens and monitor movements during denning season.

Once bears were presumed to be denned, we conducted an initial den visit. Black bears have been observed to have young from January to early February (Pelton 2003), therefore visits began after February 5th. We used telemetry to approach within approximately 15m of the den. Because black bears may abandon dens in response to humans, we minimized disturbance as much as possible. Litter size was obtained by a visual or auditory confirmation of cubs of the year (COY). At the den site, we used a handheld Garmin® GPS to record universal transverse Mercator (UTM) coordinates. Additionally, we recorded the den type, behavior of the female, and reproductive status of the female as having COY, yearlings (young from the previous year), or solitary. If young were not observed on the initial visit, then we made a second visit later in the den season to verify reproductive status. If females were active throughout the den season, they were assumed to be solitary or have yearlings. Once reproductive status was determined, we conducted a follow-up visit to females that needed new collars due to pending battery failure. We attempted to sedate the females and replace existing radio-collars. We then determined the number of COY as well as their sex and weight. COY also received a sub-cutaneous passive infrared transponder (PIT; Avid Identification Systems, Inc., Norco, California, USA) tag. To avoid flushing the female from the den, we weighed, measured, and sexed cubs at dens only when the female was chemically immobilized. Any COY that were found dead were brought to the Southeastern Cooperative Wildlife Disease Study (SCWDS) lab in Athens, GA for necropsy.

We performed all analysis using program R version 3.1.2 (R Core Team 2013). Summary statistics were calculated for female weight and age at capture (determined by tooth aging analysis), and we partitioned data by age-class. The proportion of bears in each body condition classification was calculated and partitioned by age class. In addition, we evaluated reproductive status of females by the number and proportion of females lactating or that had a swollen vulva. The mean weight of cubs was calculated and partitioned by sex. We also calculated mean litter size and sex ratio of COY.

Cub Survival

After litter size was determined from den walk-ins and visits, we used triangulation to determine when bears emerged from the den. We determined initial litter size from observations during den visits. After the last parturient bear exited the den (mid-May), we monitored parturient females via homing to obtain visual confirmation of cubs. Female bears tree their cubs to protect them from predators (Herrero 1982), therefore we were able to home close enough to females to count surviving cubs. Each female with offspring was visually observed once per month during May, June, and July. The extended periods between observations were set to decrease the risk of abandonment of cubs and to reduce the weariness of the bear to the researcher. If the number of cubs decreased from the initial or previous visit, or the observer was uncertain of the number of young, then the female was tracked again within the week.

We used the known-fate model in program MARK (version 8.0) to derive cub survival estimates (White and Burnham 1999). The known-fate model accounts for staggered entry. Survival estimates were calculated using one month observations for a 6-month time period (February-July). To determine the timing of cub mortality, we used the mid-point between the last visual confirmation and the first observation of the female without the cub. We fit 2 different models: one with survival as a constant across months and one using months as fixed effects to test if survival differed among months. We then used an information theoretic approach and second order Akaike's information criterion (AICc) to select the best approximating model (Burnham and Anderson 1998).

RESULTS

Reproductive Parameters

From May 2012-August 2014, we captured 41 female black bears and fit them with radio-collars. Mean weight at capture was 53.5 kg (n=41; SE=2.4, range: 20.4-95.3). Sub-adult and adult female weights were 42.6 kg (n= 14; SE= 3.2 range: 20.4-68.0) and 59.1 kg (n= 27; SE= 2.7, range: 36.3-95.3), respectively. Two adult females were substantially underweight in comparison to the rest of the adult study population. One 5-year-old female weighed 36.3 kg and was observed with 2 yearlings. Another 4-year-old female weighed 37.4 kg at her capture date in July 2012 and gave birth to 2 cubs that following winter. Most (61%) captured females were classified as having fair body condition. There were 8 occurrences (30%) of adult females in estrus as indicated by a swollen vulva. We observed lactation in 13 adult females (48%). We observed COY with 4 captured females and yearlings with 4 other captured females. During January-March of 2013 and 2014, 13 females gave birth to 24 COY (Table 2.1). In 2013, 16 females were monitored and 10 gave birth to 19 COY. In 2014, 18 females were monitored and 3 gave birth to 5 COY. Litter size was estimated to be 1.85 cubs per litter (*n*= 13; SE= 0.3, range: 1-4).

We were able to immobilize 6 individual females at 7 dens (one female was parturient 2 consecutive years after litter loss) and handled 11 COY (Table 2.2). Observations of cubs were made from March 12-21 in 2013 and 2014. The sex ratio of COY was 7:4 (M:F). Mean weight of cubs was 1.37 kg (*n*=11, SE=0.17, range= 0.68-2.38). Mean male and female weight was 1.59 kg (*n*= 7, SE= 0.2, range= 0.68-2.38) and 0.99 kg (*n*=4, SE= 0.1, range: 0.68-1.13), respectively. Most (64%) COY had opened eyes. Two cubs were observed with deformities on hind feet that appeared to be congenital, whereas one had multiple shorter (roughly half normal length) toes and missing nails. The smallest COY in a litter of 3 was missing a digit on a back foot. Additionally, a female COY was observed with lesions in the skin of the ventral thorax, abdomen, limbs, paws, and muzzle. A necropsy performed by the SCWDS lab diagnosed bacterial pyoderma, an infection of the skin and/or hair follicles.

Cub Survival

During the spring and summer of 2013 and 2014, we tracked 11 females that were traveling with 19 cubs for cub survival estimates (Table 2.3). We recorded 4 mortalities from

February - May. One mortality was confirmed before den emergence after the adult female relocated her den twice due to flooding. Another COY died shortly (3 days) after emerging from the den. It is unknown if the 2 remaining mortalities occurred in the natal den or post-emergence due to the gap between when they were observed in the den (late February-early March) until the family unit was observed post-emergence (mid-May). In the known-fates model, the null model (months as fixed effects) carried 95% of AICc weight, therefore we only reported results from this model. The 6-month survival estimate was 0.77 ± 0.10 (estimate ± SE).

In initial attempts to track females with yearlings and during incidental observations, we noted occurrences of delayed separation of cubs from females. Yearlings were observed in 2 different family groups up to 20 and 23 months. Additionally, we observed 2-year-old offspring in their 28^{th} month together with their mother until the female dropped her collar.

DISCUSSION

In the CGP, we observed a mean litter size of 1.85, which is similar to the previously reported litter size of 1.8 (Sanderlin 2009). However, mean litter size in the CGP was smaller compared to reported litter sizes of black bears in other populations in the southeastern U. S. (Table 2.4) and the reported 2.56 mean litter size for black bears in eastern North America (McDonald and Fuller 2001). Litter size is inherently difficult to estimate accurately. Since timing of birth is variable, mortality may occur in the den before the researcher visits the den to record number of offspring. This may have influenced our estimates of litter size, however previous studies that have estimated litter size have used similar methodology. In addition to small litter sizes, in 2014 we observed a low proportion of parturient females within our study (3 of 18 tracked animals). Even though black bears are asynchronous breeders, only giving birth every 2-3 years, this reproductive rate was very low. The combination of small litter sizes and fluctuating reproductive success could reduce growth rates of this population.

Cub survival estimates are commonly derived by comparing cubs present in natal dens to the number of yearlings that den with the female the following year. In our study area, females with yearlings remained mostly active throughout the winter and proved to be difficult to visually observe with homing. Therefore, we were unable to observe yearlings in the den the second winter and instead, focused efforts on estimating cub survival for COY during their first summer. LeCount (1987) found that most cub mortality occurred within 60 days after den emergence. Additionally, Elowe and Dodge (1989) and Garrison (2007) observed that mortality was highest in the 1.5-5 months following den emergence. Hence, our 6-month survival estimate would account for the time period in which the highest mortality has been reported to occur.

We observed that 100% of mortalities occurred with 45 days of den emergence, and estimated cub survival for 6 months was 77%. Our 6-month survival estimate is higher than the estimated survival for black bears in the eastern U. S. (65%, 1 year estimate; Beston 2011) and black bears on the southeastern Coastal Plain (75%, 6 month estimate; Freedman et al. 2003). Compared to reported 9-month and 12-month survival rates in the Southeast, the 6-month CGP survival rate is higher than other populations in the region (Table 2.5). The higher survival rate estimated for the CGP may be due to the shorter observation times and, in part, to the small litter sizes observed. Smaller litter sizes would decrease inter-litter competition for food, and increase maternal care and protection of young, thus increasing survival.

Although black bear family dissolution typically happens after 16-17 months together (Clevanger and Pelton 1990, Seibert 1993), it can occur as late as 2.5 years (Jonkel and Cowan 1971). Yearlings typically separate from their mother during the breeding season when the female comes into estrus (Rogers 1977). Although we were unable to track females with yearlings until final dissolution, 3 family groups were observed together after their second summer together. Reasons for variable timing in family separation are often unclear, although it has been suggested to be related to condition and reproductive history of the mother. Clevenger and Pelton (1990) observed that primiparous females separated from their young later than multiparous females. Other studies have documented separation due to the presence of males during breeding season or sudden intolerance of young from the mother (Rogers 1977).

Life history and reproductive data are essential for predicting population viability and growth. Although just an initial assessment, the data gained from this project can be used to develop models for further population analysis. Human influences have continued to fragment the CGP both geographically and reproductively. Due to this isolation, persistence of this population will depend on growth independent of immigration (Freedman at al. 2003). In addition to isolation, the current hunting season adds challenges to managing the CGP black bear population.

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Table 2.1. Numbers of parturient females and litter sizes observed in the central Georgia black bear population, 2013-2014.

Year	Female ID	# of COY During Den Visit	COY Handled in Den	# of COY Survived Through July	Included in COY Survival Analysis	Comments
2013	112	2	Yes	2	Yes	
2013	113	2	Yes	2	Yes	
2013	117	1	Yes	0	Yes	
2013	120	1	Yes	0	--	COY was removed from den for necropsy. Removed from analysis due to unnatural cause of death.
2013	121	2	--	1	Yes	
2013	124	2	--	2	Yes	
2013	127	4	--	0	--	Den abandoned by mother due to research efforts. Data removed from analysis due to unnatural cause of death.
2013	131	2	--	2	Yes	
2013	132	1	--	1	Yes	
2013	135	2	--	2	Yes	
2014	117	1	Yes	1	Yes	
2014	127	1	Yes	1	Yes	
2014	150	3	Yes	1	Yes	
Total	**13**	**24**	**7**	**15**	**19**	

Table 2.2. Characteristics of cubs of the year (COY) weighed and evaluated in the central Georgia black bear population, 2013-2014.

Cub ID	Female	Date Handled	PIT #	Sex	Weight (kg)	Eyes	Known Fate	Est. Date of Mortality	Observational Notes
C112A-13	112	3/12/2013	077-895-305	F	1.13	Open	--	--	
C112B-13	112	3/12/2013	078-002-559	M	1.81	Open	--	--	
C113A-13	113	3/15/2013	077-877-526	F	1.02	Closed	--	--	
C113B-13	113	3/15/2013	078-010-613	F	1.13	Closed	--	--	Deformed toes on hind foot
C117A-13	117	3/12/2013	077-881-882	M	0.68	Open	Mortality	3/13/2013	Early den emergence; COY presumed dead
C117A-14	117	3/21/2014	013-088-611	M	2.04	Open	--	--	
C120A-13	120	3/13/2013	--	F	0.68	Closed	Removed from den	--	Bacterial pyoderma; SCWDS necropsy
C127A-14	127	3/15/2014	013-260-621	M	2.38	Closed	--	--	
C150A-14	150	3/21/2014	013-104-517	M	1.59	Open	Mortality	5/12/2014	Found hung in a tree
C150B-14	150	3/21/2014	013-124-279	M	0.91	Open	--	--	Missing toes on hind foot
C150C-14	150	3/21/2014	013-257-311	M	1.70	Open	--	--	

Table 2.3. Cubs of the year (COY) visually observed by homing and estimated date of death from May-July in the central Georgia black bear population, 2013-2014.

COY Tracking ID	Mother	1st Observation	Estimated Date of Death	Comments
112.1	112	2/8/2013		
112.2	112	2/8/2013		
113.1	113	3/14/2013		
113.2	113	3/14/2013		
117.1	117	2/8/2013	3/13/2013	Mortality occurred before den emergence
121.1	121	3/7/2013		
121.2	121	3/7/2013	4/17/2013	
124.1	124	3/20/2013		
124.2	124	3/20/2013		
131.1	131	3/16/2013		
131.2	131	3/16/2013		
132.1	132	3/14/2013		
135.1	135	2/15/2013		
135.2	135	2/15/2013		
117.1	117	2/27/2014		
127.1	127	3/4/2014		
150.1	150	2/27/2014		
150.2	150	2/27/2014	4/6/2014	
150.3	150	2/27/2014	5/12/2014	COY was found hung in tree, dead

Table 2.4. Mean litter sizes reported for black bear populations in the southeastern United States.

Location	n	$\bar{x}$	Source
Alleghany Mtns, WV	183	2.49	Bridges et al. 2011
White River NWR, AR	108	1.872	Clark and Eastridge 2006
North and Central Louisiana	24	2.17	Crook 2008
Okefenoke, FL	34	2.11	Dobey et al. 2005
Osceola, FL	22	2.08	Dobey et al. 2005
Ocala NF, FL	39	2.08	Garrison et al. 2007
Central Georgia	13	1.85	Current Study 2012-2014

Table 2.5. Cub survival reported for black bear populations in the southeastern United States.

Location	n	Survival (%)	Time Period (Months)	Source
Central Georgia	19	77	6	Current Study
Shenandoah NP, VA	40	73	12	Kasbohm 1996
Dry Creek, AR	13	65	12	Clark and Smith 1994
Great Smoky Mountains NP, TN	29	62	12	Eiler et al. 1989
Ocala NF, FL	41	46	9	Garrison et al. 2007
White River NWR, AR	21	41	12	Clark and Eastridge 2006
White Rock, AR	15	40	12	Clark and Smith 1994

CHAPTER 3

DENNING ECOLOGY OF BLACK BEARS (*URSUS AMERICANUS*) IN CENTRAL GEORGIA

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ABSTRACT

We evaluated den selection of American black bears (*Ursus americanus*) at multiple spatial scales in an isolated population in central Georgia from 2012-2014. We assessed den types, microhabitat characteristics at den sites (*n*=27), and modeled the important habitat variables involved in den selection. We also examined effects of landscape characteristics on den selection (*n*=23). All dens in the study area were located on the ground, but most (78%) bears chose nests associated with a standing or downed tree. The greatest proportion of dens (41%) was in early successional stands. Selection of dens at the microhabitat level was associated with increasing density of understory cover. Den selection at the landscape level was positively related to total area of upland forests. My findings indicate the importance of early successional habitats associated with upland forests due to their higher topography and availability of dense understory vegetation.

INDEX WORDS: black bear, denning, den selection, Georgia, *Ursus americanus*

INTRODUCTION

There are 3 black bear populations in Georgia: a northern population in the Appalachian Mountains, a southern population associated with the Okefenokee Swamp, and an isolated population in central Georgia associated with the Ocmulgee River drainage system. The Central Georgia Population (CGP) has experienced habitat loss due to human encroachment and fragmentation from urban sprawl. In addition, timber harvest and habitat management practices have resulted in frequent changes that alter the landscape (Carlock et al. 1999). Due to lack of suitable habitat corridors for dispersal and connectivity to other bear populations, it is assumed that the CGP is reproductively isolated, similar to other populations in the southeastern United States (Troxler 2013). To ensure viable bear populations, managers must identify and understand reproductive habits and ecological requirements, such available denning habitat that impacts reproductive success (Johnson and Pelton 1981).

Winter dens are necessary habitat for black bears and are essential to cub survival because parturition and initial parental care occur in winter dens (Johnson and Pelton 1981, Powell et al. 1997). Central Georgia bear habitat lacks the availability of den sites commonly used in other populations such as rock crevices, cavities, and tree dens (Powell et al. 1997, Pelton 2003). This results in most bears denning on the ground, which could make bears more susceptible to disturbance. Therefore, the quality of denning habitat becomes increasingly important in managing the CGP.

Disruption during denning can cause abandonment or relocation of dens and result in increased cub mortality and subsequently lower recruitment (Bromley 1985, Goodrich and Berger 1994, Linnell et al. 2000). The length of time that parturient females remain in dens determines the period when disruption can potentially occur. Denning duration varies among populations depending on climate, latitude, and availability of food (Hamilton and Marchinton 1980, Reynolds and Beecham 1980, Pelton 2003). Mean denning duration ranges from 2.5 months in Mississippi (Waller et al. 2012) to 7 months in Alaska (Smith et al. 1994). Therefore, research on denning chronology must be population specific to make effective management decisions to decrease disturbance.

Little information is available detailing denning preferences of bears in the CGP (Carlock et al. 1999). Because the American black bear inhabits a wide variety of habitats throughout North America, den selection differs from region to region (Pelton 2003). In other populations, microhabitat and landscape features have been shown to influence den selection (Martorello and Pelton 2003, Reynolds-Hogland et al. 2007, Crook and Chamberlain 2010). Microhabitat characteristics such as understory cover and den association with trees can protect bears from predation and disturbance, and reduce energetic loss caused by harsh winter weather (Hayes and Pelton 1994). At larger spatial scales, land cover and topographic features can predict plant communities and landscape features that are preferred by bears (Skeen et al. 1993, Reynolds-Hogland et al. 2007). Evaluating habitat at multiple scales allows for a more comprehensive understanding of den selection, which is beneficial in identifying factors affecting female reproductive success and population viability (Benson and Chamberlain 2007, Crook and Chamberlain 2010).

Prescribed fire is a common management technique used in the CGP study area during winter months (January-March). The effect of burns on den selection and disturbance is unknown in the CGP and many populations in the southeastern U. S (Weaver 2000). Studies in North Carolina and Florida have reported abandonment of dens in response to fire (Lombardo 1993, Stratman 1998), whereas Seibert (1993) reported that bears in ground dens were not disturbed by fire. Weaver (2000) suggested that prescribed fire may improve bear habitat by providing soft mast and other foods preferred by black bears. Information on the impacts of fire on black bears and their habitat in the CGP can provide insight to adapt land management practices and promote suitable habitat, while minimizing den disturbance.

Our objectives were to assess patterns of den selection at multiple spatial scales by measuring microhabitat characteristics at den sites and evaluating the effect of broader-scale habitat features on den selection. Secondarily, we described basic denning chronology and observed the effects of prescribed fire on denning ecology.

STUDY AREA

We conducted research on Oaky Woods Wildlife Management Area (WMA), Ocmulgee WMA, and privately owned lands in Houston, Pulaski, Twiggs, and Bleckley counties during 2012-2014. This area was located in the Upper Coastal Plain geophysical region of central Georgia, was associated with the Ocmulgee River drainage system, and was almost completely surrounded by human development. These areas encompassed approximately 32,400 ha dominated by pine (*Pinus* spp.) plantations, upland and bottomland hardwood forests, and cypress-gum swamps. About 90% of the WMA property was forested. Private lands included in the study area were dominated by pine plantations, but also included agricultural fields and areas of human development. Plum Creek Timber Company was the largest landowner in the area and their properties consisted of variable-aged planted pine stands. Timber harvest and management techniques were conducted on private timber lands.

Prominent habitat types in the WMAs included pine plantations, mixed pine-hardwood, bottomland hardwoods, cypress-gum swamps, clearcuts, and black belt prairies. Common overstory plant species included loblolly pine (*P. taeda*), slash pine (*P. elliottii*), shortleaf pine (*P. echinata*), various oaks (*Quercus* spp.), American elm (*Ulmus alata*), sweetgum (*Liquidambar styraciflua*), maples (*Acer* spp.), hickories (*Carya* spp.), magnolias (*Magnolia* spp.), and dogwoods (*Cornus* spp.). Understory flora included American beautyberry (*Callicarpa americana*), wax myrtle (*Morella cerifera*), blueberries (*Vaccinium* spp.), blackberries (*Rubus* spp.), wild grapes (*Vitis* spp.), Japanese honeysuckle (*Lonicera japonica*), persimmon (*Diospyros virginiana*), wild plum (*Prunus americana*), and hawthorne (*Crataegus* spp.). Local fauna included white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), feral hog (*Sus scrofa*), bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), and raccoon (*Procyon lotor*). Agricultural fields that provided additional food sources to black bears were planted in corn, peanuts, wheat, and soybeans.

Prescribed burning is a common management tool used on both of the WMAs. Typically, fields and prairies are burned every other year, and mature pine stands are burned on a 3-5 year rotation. Nearly 95% of the burns occur from January to March (B. Bond, GA DNR, personal communication). Additional management included food plots targeted for game species such as wild turkey and white-tailed deer. Recreational opportunities allowed on the WMAs included hunting, fishing, and camping. Bear hunting was prohibited on the WMAs. While private landowners would use fire on a small scale, Plum Creek and other timber companies did not use prescribed burns as a management technique.

An experimental hunt was established by the Georgia Department of Natural Resources (GADNR) in central Georgia. A one-day season occurred during 2011-2014. In 2011 and 2012, the hunt occurred during the second weekend in November. The hunt was delayed to the second weekend in December in 2013 and 2014. The hunt is restricted to private lands within Bibb, Houston, and Twiggs counties.

METHODS AND MATERIALS

Capture and Radio Telemetry

From May-October of 2012 and 2013, we captured female black bears on Oaky Woods WMA, Ocmulgee WMA, and surrounding private lands using modified Aldrich foot snares (Johnson and Pelton 1981). Captured bears were immobilized chemically with Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) or xylazine (100mg/ml, Vedco, Inc., St. Joseph, Missouri, USA) combined with Telazol® (XZT). Drugs were administered using a pressurized dart by blow pipe. Each bear was given a 3 digit number which was displayed on ear tags and a lip tattoo. Each female was fitted with either a Lotek Wildcell® GPS collar (Lotek Wireless Inc., Newmarket, Ontario, Canada) or a Telonics® MOD- 500 VHF collar (Telonics, Inc., Mesa, Arizona, USA) equipped with leather break-away spacers (Garshelis and McLaughlin 1998).

We monitored bears by ground-based telemetry using a receiver (Advanced Telemetry Systems® R2000) and antenna (Telonics® RA-23K 4-element H, Telonics® RA-5A whip). GPS-collared bears were monitored using Lotek Total Host GPS® software, whereas standard telemetry techniques were used to monitor bears fitted with VHF collars. From December- May, we triangulated radio-collared female bears 2-3 times a week to locate dens and monitor movements during denning season. At least 3 bearings were recorded within 20 minutes to reduce error from bear movement. Data were recorded using Location of a Signal (LOAS; version 4.0.3.8) software (Ecological Software Solutions, LLC 2010).

Denning and Disturbance

Bears were considered denned when estimated locations were within 300m of each other for more than 3 observations (>7 days). Den entrance dates were considered the mid-point between the last triangulation when the bear was active and the first day the bear was triangulated at the den site. We considered den emergence dates as the midway point between the last day bears were observed in the den and the first day they were >300m away from the den site. We defined the denning period as the number of days between den entrance and emergence. If a denned bear moved and occupied a different den, we counted denning duration as the length between den entrance at the first den site to the emergence of the last den site. If any movement occurred after a bear was presumed to be denned, we recorded the date and investigated and documented reasons for the observed movement.

Once bears were presumed to be denned, we conducted an initial den visit. Black bears give birth from January to early February (Pelton 2003), therefore visits began after February 5th and extended into March for bears that entered dens later. We generally used ground-based telemetry to locate radiocollared females and their dens. In addition, 3 GPS-collared males denned during our study and were included in our analysis. Because black bears may abandon dens in response to human activities, we minimized disturbance as much as possible (Linnell et al. 2000). We recorded universal transverse mercator (UTM) coordinates of den sites using a hand-held global positioning system (GPS) unit.

Microhabitat

To determine the type of den structure that was most commonly selected in the CGP, we partitioned dens by structure type (Table 3.1). We recorded 9 microhabitat characteristics within 15 m of each den site after den emergence in April- May (Table 3.2). To decrease observer bias, one researcher estimated percent cover at all sites sampled. Stand type was determined based on the dominant species in the overstory. We classified stands as early successional, pine, bottomland hardwood, hardwood, and mixed pined/hardwood. To assess the importance of cover above the den, we estimated overhead cover at the center of the den, and at den height, using a forest densiometer (Lemmon 1956) facing north. Any obstructions between the den and the sky, including downed trees, were included and were considered overhead cover. We also identified dominant species of plants in the overstory, mid-story, and understory within the 15 m buffer. To evaluate if density of different sized trees impacted den selection, trees with a diameter at breast height (DBH) between 10-20 cm and trees with a DBH above 20 cm were counted within a 15 m buffer from the den. Black bears using ground dens often prefer dense understories (Hayes and Pelton 1994, Garrison et al. 2007, Waller at al. 2013). Therefore, we estimated vegetative density around the den site. We estimated vertical cover using a modified 6ft Nudds board (Nudds 1977). We recorded measurements in the center of the den and in each cardinal direction 15m away from the den. From kneeling height, we assigned a value of 1-5 for each 1ft section (1=0-20% coverage of section, 2=20-40%, etc.). We measured vertical obstruction using a modified Robel pole that measured up to 110cm (Robel et al. 1970). The pole was placed in the center of the den and measurements were taken in each cardinal direction 15m from the den.

If the bear fled the den due to disturbance or relocated dens during the den season, we collected microhabitat characteristics ≥3 days after their exit. If multiple dens were used, data for the first and second dens were collected. We calculated summary statistics for microhabitat characteristics to determine which vegetative characteristics were prominent at dens. Using Geographic Information Systems (ArcGIS 10.1), we generated random points for each den site. We created a single random point for each used den within a radius of 500 m from the actual den site, but at least 30 m away to prevent random points from overlapping with den sites. We quantified vegetation structure at random points using the same protocol used for den sites.

We compared den sites and random points using the statistical program R version 3.1.2 (R Core Team 2013). We used 5 parameters that were collected at both den sites and random sites (Table 3.3). We assessed collinearity between model parameters using Pearson's correlation coefficients and correlated variables were removed from models ($r > 0.7$).

We developed 6 *a priori* models that predicted ground dens as a function of microhabitat features (Table 3.4). We developed these models based on previous research and prior observations of used dens in the CGP. Because black bears choose sites with dense cover (Martorello and Pelton 2003, Waller et al. 2013), we constructed models using various combinations of ground and overhead cover. Because understory density and cover at the den may impact den selection in other populations (Hayes and Pelton 1994), we developed vertical cover and vertical obstruction models. We observed dens with dense cover above the den, therefore we developed an overhead cover model. To assess the impacts of understory density and overhead cover together, we used combinations of vertical cover, vertical obstruction, and overhead cover to model the locations of dens. We predicted that bears would prefer forested stands with higher density of trees, so we developed a model combining the density of trees with a DBH of 10-20cm and the density of trees with a DBH of more than 20cm.

We used logistic regression to develop predictive models for den sites and random points. We used an information theoretic approach (AIC; Burnham and Anderson 1998) to select the most parsimonious model to predict den selection based on microhabitat variables. We calculated AIC scores and adjusted them for a small sample size (AIC_c). We considered both ΔAIC_c values from the top model and the AIC_c weight (w_i) to evaluate a candidate set of models that best described our data. Using each parameter included in the 90% confidence set, we calculated a scaled odds ratio to predict the occurrence of den sites in relation to the presence or absence of each parameter.

Landscape

Presumably, females select dens within their home ranges based on encounters with suitable den sites or previous experience within these areas. Therefore, we calculated area of space use prior to denning. We calculated 4 month home ranges (period prior to denning) for female black bears using locations from GPS collared bears in 2012 and 2013. Because of factors such as collar loss and failure, we only used females that had 4 consecutive months of data during the period of May to January. Using program R (R Core Team 2013), we calculated 50% and 95% Kernel Utilization Distributions (KUD; Worton 1989) to represent core areas and home ranges, respectively. We created 2 circular buffers around each den site (buffers rounded to the nearest 100 m) that would encompass the area of the mean core and home range areas. The core area buffer had a 700 m radius and the home range buffer had a 1600 m radius.

To evaluate the effects of landscape-level characteristics on den selection, we developed a land cover layer in ArcGIS 10.1 (ESRI 2011) using the 2013 Cropland Data Layer (CDL). We reclassified land cover types into 7 categories (Table 3.5). Spatial coordinates of den sites were overlaid on the land cover layer with corresponding buffered areas (700 m and 1600 m). We used Geospatial Modelling Environment (GME; Beyer 2012) to calculate the percent composition of each land cover type within the buffered areas. We replaced zero values with 0.000001. To determine which sized buffer to use for landscape-level analysis, we used compositional analysis (Aebischer et al. 1993) to compare differences in habitat composition at the core area scale to the home range scale. Differences of log ratios of proportions of each habitat type found at both scales were tested with a multivariate analysis of variance (MANOVA). We found that the composition of habitats within the core area was similar to the composition within the home range. Therefore, we used the smaller, 700 m buffer for analysis because we assumed this area to be the area of greatest use by individual bears. Using *a priori* knowledge of den selection in the area and from previous studies, we developed layers in ArcGIS to calculate landscape metrics thought to influence den selection. Specifically, we developed an elevation layer using a digital elevation model (USGS), and a distance to water layer using Euclidean distance to water features in ArcGIS. We also combined pine forest, hardwood forest, and mixed forest layers into one upland forest layer to represent higher elevation forests. Additional class and landscape level metrics were calculated within each buffer using Fragstats version 4 (Table 3.6, McGarigal et al. 2012). We quantified total area of bottomland forests and upland forests to evaluate the impacts of different elevation forests on den selection. To determine if patch size of forested areas influenced den selection, we determined mean patch size of upland forests within the buffered areas.

To compare buffered den sites to random sites on a landscape scale, we used ArcGIS to generate a geographic extent within the CGP study area which random points could occur. We buffered all den sites with a 1600 m buffer (home range buffer) to encompass areas each bear may have encountered prior to denning. We then combined all of the buffered den sites into a single extent using a convex hull (Getz and Wilmers 2004). Using GME, we set criteria that the random points must exist within the created extent and the 700 m buffers of the random points and den sites would not overlap. We then ran similar landscapes metrics within buffered random sites as den sites.

Using the landscape metrics calculated, we developed 5 *a priori* models to predict den locations as a function of landscape characteristics (Table 3.7). Models were based on prior knowledge of dens selected in the CGP and the results of our compositional analysis. Dens in the CGP were found in upland areas, presumably to decrease the risk of den loss to flooding. Because flooding frequently occurs in the river floodplain, we developed models based on the assumption that bears would choose higher elevation den sites farther from water and bottomland hardwoods. Therefore, 3 models used combinations of elevation, total area of bottomland forests, and distance to water. Compositional analysis suggested that areas surrounding dens were comprised of more pine forests, mixed forests, and hardwood forest habitats than other habitat types, therefore we developed a model based on total area of upland forest and mean patch size of upland forest. Because we predicted that bears would choose dens farther away from water and in forested areas, we developed a model with a combination of distance to water and total area of upland forest.

After calculating all landscape metrics for den sites and random sites, we used the statistical program R (R Core Team 2013) to analyze which landscape characteristics were selected relative to random sites. Collinearity between model parameters was assessed using Pearson's correlation coefficients and correlated variables were removed from models ($r > 0.7$). We used logistic regression to develop predictive models for buffered den sites and random points. We used an information theoretic approach (AIC; Burnham and Anderson 1998) to select the most parsimonious model to predict den selection. We calculated AIC scores and adjusted them for a small sample size (AICc). We considered both ΔAICc values from the top model and the AICc weight (w_i) to evaluate a candidate set of models that best describe our data. We then calculated a 90% confidence set of models.

Prescribed Fire

We monitored female response to burns that occurred during the denning season in 2012-2014. We monitored radiocollared females using triangulation and Lotek Total Host GPS® software. Bear locations were assessed before, during, and after burns to determine potential influences of fire on female behavior. Using data acquired from GA DNR, we developed spatial layers that included stands burned at least once from 2006-2014 within the WMAs. This provided an 8-year prescribed fire history. We overlaid spatial coordinates of dens located in the WMAs in 2012-2014 on these layers and determined how frequently areas chosen by denning females had been burned during the prior 8 years.

RESULTS

Denning and Disturbance

We recorded den entrance, emergence, and duration of denning for 13 parturient females in 2012-2014. Mean den entrance and exit was January 7th (n=8, SE=5.8) and April 24th (n=10, SE=4.3), respectively. Duration of denning averaged 115 days (n=6, SE=5.6).

In 2013, 3 female bears were disturbed before parturition occurred. All 3 relocated dens and gave birth at the new den location. All denning disturbances occurred late in the denning season (January 10-29) and were directly related to human activity. Disturbance of one female was caused by heavy machinery within 25 m of the den. Another female relocated when an adjacent stand was burned and heavy smoke entered the area where she had denned. No other causes of potential disturbance were observed, therefore we assumed residual smoke to be the reason for the movement. The third female was flushed from the den by personnel cruising timber. In 2014, one female was disturbed while denning; this incident involved a tree planting crew that flushed the female, which subsequently moved to another den site.

Microhabitat

We recorded microhabitat characteristics at 27 ground dens. Most (78%) of the bears selected a den that had some association with a tree (Table 3.8). The greatest proportion of bears (48%) chose a den associated with a standing tree, whereas 30% chose sites associated with a downed tree. In early successional habitats, bears often selected residual trees that were left standing or downed trees that remained after cutting. The greatest percentage (41%) of dens were located in stands classified as early successional habitats, typically in 3-5-year-old clearcuts dominated with blackberry (*Rubus* spp.) and other thick vegetation. All other dens were located in a forested stand type (mixed, pine, hardwood, bottomland hardwood; Table 3.9). Mean overhead cover at den sites was 85% (SE=3.8, range= 15.76-100%). Within the 15 m radius around den sites in forested stand types, there were an average of 15.6 trees (n=16, SE=2.0) with a DBH between 10-20 cm There was an average of 9.0 trees (n=16, SE=1.4) with a DBH above 20 cm in the 15 m radius around den sites in forested stand types. Vertical cover was relatively high with a mean of 93.63% (SE=2.0). Mean vertical obstruction was 95.1 cm (SE= 0.5).

We used 27 den sites and corresponding random points to predict den selection relative to microhabitat characteristics. The most parsimonious model (ΔAIC=0, w_i=0.72; Table 3.10) included 2 parameters: an intercept term (β=-6.56, SE=2.63, P=0.013) and vertical cover as quantified by a Nudds board (β=0.11, SE=0.05, P=0.016). The 90% confidence set of models included 2 models: vertical cover and the combination of vertical cover and overhead cover. After calculating the scaled odds ratio for parameters included in the top models, we found that for every 10% increase in vertical cover, dens were 2.31 times more likely to occur. Dens were 1.02 times less likely to occur for every 10% increase of overhead cover.

Landscape

Mean core area size was 1.49 ± 0.3 km^2 (mean ± SE; range 0.30-4.99). Mean home range was 7.74 ± 1.6 km^2 (range 2.54-30.58). Compositional analysis comparing den sites at the mean core area buffer (700m) and the mean home range buffer (1600m) indicated non-random selection of dens (Λ= 2.883, df= 6, P<0.001). Pine and mixed forest stands were selected most, whereas agricultural and low vegetation habitats were selected least.

We used 23 den sites and an equal number of random points to predict den selection relative to landscape metrics and landscape features. We removed 4 dens from the landscape analysis because they were second selection dens of females that were in close proximity to the first selected den already included in the data. The amount of overlap from the large buffer areas on the landscape scale would have cause replication that would have compromised accurate analysis. The most parsimonious model (ΔAIC=0, w_i=0.68; Table 3.11) included 3 parameters: an intercept term (β=-1.97, SE=0.96, P=0.041), total area of upland forest (β=0.03, SE=0.01, P=0.012), and mean patch size of upland forest (β=-0.019, SE=0.01, P=0.034). This model suggested that dens were more likely to occur in areas with increased area of upland forests and smaller patch sizes of upland forests within the core area (700 m) sized buffer. The 90% confidence set of models included 4 models: upland, null, the combination of upland and water, and the combination of water and bottomland.

Prescribed Fire

No collared bears were located in areas burned during denning season, and therefore were not directly impacted by fire. One unmarked bear was visually observed running out of a burn area. Five females chose dens on a WMA during the 2012-2013 denning seasons. No locations chosen for den sites had been burned since 2006.

DISCUSSION

The mean den entrance date of the CGP is later than other black bear populations in the southern and eastern U.S. (Table 3.12). The mean emergence date and the mean duration were comparable to previous studies. Black bears may forgo denning or continue activity through the winter in the southeastern U.S. (Hamilton and Marchinton 1980, Hellgren and Vaughan 1989, Weaver and Pelton 1994, Hightower et al. 2002), because black bears in the South are not faced with the energetic costs of harsh winters and lack of food. Parturient females are the exception as denning is required to provide maternal care to their young. Delayed entry dates in the CGP may be attributed to the availability of food in the months prior to denning. Because food sources exist throughout most of the year in the southeastern U.S., females may benefit from foraging and storing fat in preparation for the energetic costs of gestation and maternal care closer to their parturition dates.

Denning disturbance caused by human practices impacted bears in the CGP. During den visits, we observed that bears in the CGP were inclined to flee the den when approached by humans. Linnell et al. (2000) suggested that bears in warmer climates may more readily abandon dens because the energetic costs are lower. In 2013, 30% of parturient females relocated dens due to impacts of human activity. It is likely that this relatively high amount of disturbance is associated with the selection of dens on or near the ground, and considerable human activity in areas used by denning bears in support of forest management activities, such as cruising, marking, and logging timberland.

Although commonly used for habitat management on study area WMAs, prescribed fire did not have direct consequences to denning bears in the CGP. Studies in North Carolina and Florida have reported abandonment of dens in response to fire (Lombardo 1993, Stratman 1998). Conversely, Seibert (1993) reported that bears in ground dens were not disturbed by fire. None of the denned bears in our study area were in areas that were burned, so we cannot draw conclusions on direct impacts of fire on denned bears in the CGP. However, bears did select sites that had not been previously burned in the past 6 years, likely due to the lack of dense understory associated with burned areas.

Similar to previous research, bears in the CGP selected dens that were associated with some type of immediate structure and dense understories (Hayes and Pelton 1994, Weaver and Pelton 1994, Martorello and Pelton 2003, Crook and Chamberlain 2010, Waller et al. 2013). Greater vertical cover in coordination with a den site positioned against a standing or downed tree is likely a method to increase protection from predators, disturbance, or environmental factors (Hayes and Pelton 1994, Lombardo 1993, Waller et al. 2013). Thicker understory can also alert bears to approaching intruders (Lombardo 1993, Martorello and Pelton 2003). Selection of early successional stands and high percentages of vertical cover suggest that bears preferred areas with greater concealment. Vertical cover was the best predictor of den occurrence. Many bears denned in thick patches of blackberry (*Rubus* spp.) that completely concealed them 15m away from the den. The scaled odds ratio showed an inverse relationship between den presence and overhead cover. This relationship also corresponds with denser cover, since more openings in the canopy allows for greater understory growth.

Comparable to other landscape level research, bears in the CGP chose ground den sites in wooded areas (Weaver and Pelton 1994, Crook and Chamberlain 2010). Our top model suggested that den sites were positively associated with higher total areas of upland forests within buffer areas, but were also more likely to occur in buffers with smaller mean patch size of upland forests. Patch size was a relevant parameter in our analysis, but this may be due, in part, to the way patch sizes were calculated within the 700 m buffer. The buffer may have artificially created smaller patches of upland forest around dens when it intersected the land cover layer. In other words, what was determined to be smaller stands in our analysis may have been parts of larger stands. Using total area of upland forests and mean patch size in analysis, we found upland forests were the preferred overall habitat type, while smaller upland forest patch sizes were preferred instead of large patches of a singular habitat type. Abundant patches of upland forests would create a more diverse mosaic of habitat types in which black bears could benefit. For example, an upland forest would provide needed denning habitat while an adjoining early successional patch would provide food. Although elevation was not ranked as a prominent predictor in our models, upland forests occur at higher elevations and above the flood plain of the Ocmulgee River. This may impact den selection in the CGP since den sites chosen in areas that have lower risks of flooding can increase litter survival and avoid energetic costs associated with relocating dens (Linnell et al. 2000, White et al. 2001). Areas associated with large areas of bottomland forests were typically avoided.

The combination of microhabitat selection based on dense understories along with landscape-level selection based on upland forest availability suggests that female black bears in the CGP need higher elevation, forested tracts with patches of early successional habitats for denning. This reduces the risks for flooding, provides refuge on a large scale, and ensures adequate, immediate cover needed for concealment of dens.

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Table 3.1. Types of dens used by GPS and VHF- collared black bears in central Georgia during 2012-2014.

Types of ground dens	
Nest	Ground den not associated with supplementary structure
Nest associated with a standing tree	Nest $\leq$ 1m away from tree
Nest associated with a downed tree	Nest either under or abut to a downed tree
Slash pile	Den within a pile of woody debris piled up from timber harvest

Table 3.2. Microhabitat characteristics recorded at dens used by GPS and VHF- collared black bears in central Georgia population during 2012-2014.

Microhabitat characteristics recorded within a 15m radius of all dens	
Stand type	Dominant species in the overstory, classified as: early successional, pine, bottomland hardwood, hardwood, and mixed (pine and hardwood)
Overhead cover	Percentage of overhead cover, measured using a densiometer in the center of the den facing north.
Dominant species	Identification of prevalent plant species in the overstory, mid-story, and understory
Tree density 10-20cm	The number of trees within the 15 m radius with a DBH between 10-20cm
Tree density >20cm	The number of trees within the 15 m radius with a DBH greater than 20cm
Vertical cover	Percentage of vegetation obstruction, measured using a modified Nudds board, and calculated as the mean of readings 15m away from den in cardinal directions
Vertical obstruction	Height of first visible mark on Robel pole, measured to the nearest 5cm and calculated as the mean of readings 15m away from den in cardinal directions.
Microhabitat characteristics recorded at dens associated with a standing tree	
Tree species	Species of the tree ≤1m of den
DBH	Diameter at breast height of tree associated with the den

Table 3.3. Microhabitat metrics used to develop microhabitat- level models of den selection for black bears in central Georgia, 2012-2014.

Parameter	Description
CAN	Overhead cover
TDO	Tree density 10-20cm DBH
TDT	Tree density >20cm DBH
VTC	Vertical cover
VTO	Vertical obstruction

Table 3.4. *A priori* candidate models developed to assess den selection on a microhabitat level by black bears in central Georgia, 2012-2014.

Model	Metric Included
Vertical cover	VTC[1]
Overhead cover	CAN[2]
Tree density	TDO[3], TDT[4]
Vertical obstruction and overhead cover	VTO[5], CAN
Vertical cover and overhead cover	VTC, CAN
Vertical obstruction	VTO

[1]VTC= Vertical cover
[2]CAN= Overhead cover
[3]TDO= Tree density 10-20cm DBH
[4]TDT= Tree density >20cm DBH
[5]VTO= Vertical obstruction

Table 3.5. Description of cover layers used from Cropland Data Layer (CDL) to develop habitat types used in compositional analysis and model selection for den selection of black bears in central Georgia, 2012-2014.

Compositional Analysis	
Habitat Type	**Layers from CDLL**
Pine forest	Evergreen forest
Hardwood forest	Deciduous forest
Bottomland hardwood forest	Woody wetlands, herbaceous wetlands
Mixed forest	Mixed pine and hardwood forests
Agriculture	All crop layers
Low vegetation	Shrub land
Other	Open water, barren, aquaculture, emergent vegetation, wetlands, human development, and fallow/idle crop land

Model Selection	
Habitat Type	**Layers from Compositional Analysis**
Upland forest	Pine forest, hardwood forest, and mixed forest
Bottomland forest	Bottomland hardwood forest
Agriculture	Agriculture
Low vegetation	Low vegetation
Other	Other

Table 3.6. Landscape metrics used to develop landscape-level models of den selection for black bears in central Georgia, 2012-2014.

Parameter	Description	Level
ABL	Total area of bottomland forest	Class
AUP	Total area of upland forest	Class
PUP	Mean patch size of upland forest	Class
DWA	Distance to water	Landscape
ELV	Elevation	Landscape

Table 3.7. *A priori* candidate models used to evaluate den selection at a landscape level for black bears in central Georgia, 2012-2014.

Model	Landscape Metric Included
Upland	AUP[1], PUP[2]
Upland and water	AUP, DWA[3]
Elevation	ELV[4]
Water and bottomland	DWA, ABL[5]
Elevation and water	ELV, DWA

[1]AUP= Total area of upland forest
[2]PUP= Mean patch size of upland forest
[3]ELV= Elevation
[4]DWA= Distance to water
[5]ABL= Total area of bottomland forest

Table 3.8. Den types chosen by black bears in central Georgia, 2012-2014.

	n	Percent (%)
Nest	4	15
Nest associated with a standing tree	13	48
Nest associated with a downed tree	8	30
Slash pile	2	7
Total	**27**	

Table 3.9. Summary of microhabitat characteristics measured within 15 m of black bear dens in central Georgia, 2012-2014.

	n	Mean ± SE	Min	Max	Percent Total
Stand type	27				
Early successional	11	-	-	-	41
Pine	8	-	-	-	29
Bottomland hardwood	1	-	-	-	4
Hardwood	1	-	-	-	4
Mixed	6	-	-	-	22
Overhead cover (%)	27	85.6±3.8	15.8	100.0	-
Number of trees 10-20cm	27	10.3±2.0	0	32.0	-
Number of trees >20cm	27	5.9±1.4	0	31.0	-
Vertical cover (%)	27	93.4±2.0	63.3	100.0	-
Vertical obstruction (cm)	27	95.10±0.5	6.5	110.0	-
Microhabitat characteristics of dens associated with a standing tree					
Tree species	13				
Pine	5	-	-	-	38.5
Oak	4	-	-	-	30.8
Other	4	-	-	-	30.8
DBH (cm)	13	20.8±6.0	3.8	63.6	-

Table 3.10. The number of parameters (K), AIC_c values, ΔAIC values, and weights (w_i) for *a priori* models of microhabitat den selection by black bears in central Georgia, 2012-2014.

Model	K	AIC_c	ΔAIC	w_i
Vertical cover	2	61.18	0.00	0.72
Vertical cover and overhead cover	3	63.41	2.23	0.24
Global	6	67.45	6.27	0.03
Vertical obstruction	2	70.34	9.16	0.007
Vertical obstruction and overhead cover	3	71.54	10.36	0.004
Tree density 10-20cm and tree density >20cm	3	73.49	12.31	0.002
Null	1	76.94	15.76	2.72E-4
Overhead cover	2	78.41	17.23	1.30E-4

Table 3.11. The number of parameters (K), AIC_c values, ΔAIC values, and weights (w_i) for *a priori* models of landscape level den selection by black bears in central Georgia, 2012-2014.

Model	K	AIC_c	ΔAIC	w_i
Upland	3	61.92	0.00	0.68
Null	1	65.86	3.95	0.10
Upland and water	3	66.24	4.33	0.08
Water and bottomland	3	66.97	5.05	0.05
Elevation	2	67.11	5.20	0.05
Global	3	69.08	7.17	0.02
Elevation and water	3	69.29	7.37	0.02

Table 3.12. Comparison of den entry, emergence, denning duration, and range of days within dens for previous black bear studies in the eastern and southern U.S.

Citation	Location	Entry Date $\bar{x}$	Emergence Date $\bar{x}$	Denning Duration $\bar{x}$	Range
Waller et al. 2013	Delta Region, Mississippi	27-Nov*	14-Mar*	78	-
Weaver and Pelton 1994	Tensas River Basin, Louisiana	4-Dec	24-Apr	142	116-186
Hellgren and Vaughn 1989	Virginia and North Carolina	15-Dec	14-Apr	119	106-131
Doan-Crider and Hellgren 1996	Coahuila, Mexico	25-Dec	22-Apr	118	-
Garrison et al. 2012	Ocala National Forest, Florida	28-Dec	19-Apr	113	-
Mitchell et al. 2005	Big Bend National Park, Texas	30-Dec	27-Apr	119	-
Oli et al. 1997	White River NWR, Arkansas	1-Jan	25-Apr	117.8	105-139
Current Study	Central Georgia	7-Jan	24-Apr	115	93-130

*Median of entry and emergence dates.

CHAPTER 4

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The American black bear (*Ursus americanus*) once ranged throughout the United States, but human impacts have reduced black bears to fragmented populations in the Southeast. The central Georgia black bear population (CGP) has become geographically and reproductively isolated from other more contiguous populations, thus increasing the need for an understanding of the CGP's biological and reproductive requirements. Population-specific research on black bears provides information essential to making informed management decisions. Therefore, I monitored female black bears in the CGP and assessed rates of parturition, cub survival, and determined important variables for den selection.

From May 2012- August 2014, 41 females were captured, fit with radio-collars, and monitored. I observed a mean litter size that was smaller than reported litter sizes in the southeastern U.S. and eastern North America. Additionally, the proportion of parturient females in 2014 was low even with fluctuations expected from asynchronous breeders. The combination of small litter sizes and fluctuating reproductive success may have impacts on population growth. Conversely, I observed cub survival that was greater than estimates in other black bear populations in the eastern U.S. and the southeastern Coastal Plain. I speculate that greater observed cub survival may be due to the smaller litter sizes observed. A smaller litter size would increase opportunities for maternal care to cubs, while decreasing inter-litter competition, thus increasing survival. Whereas small litter sizes may not promote rapid population growth, high survival rates may increase the chance of offspring being recruited into the population. The mean den entrance and emergence dates for parturient females in the CGP were January 7th and April 24th, respectively. Currently, the one-day bear hunt in central Georgia occurs during the second weekend in December. If management goals aim to protect females that will give birth during the same year, I recommend that the one-day hunt occur after January 7th. This will protect most pregnant females from the threat of harvest as most will have entered the den or show decreased movement by this time. Additionally, if management goals aim to increase cub survival, I recommend reducing intensive land management practices such as timber harvest, planting, and work involving heavy machinery during the estimated denning duration observed in this study. I observed disturbance and relocation of denning females because of human activities in the winter months of 2012-2014.

I evaluated den selection of bears in the CGP at multiple spatial scales. All dens observed were located on the ground due to the lack of alternative structures for dens such as rock crevices, natural cavities, and large, hollow trees. At the microhabitat level, bears in the CGP selected dens associated with either a standing or fallen tree and dense understories. I found that the greatest percentage of dens were located in early successional stands. Vertical cover was the best predictor of den occurrence, which supports the notion that black bears prefer dense cover to conceal the den and protect cubs from predators. At a broader landscape scale, bears chose den sites in areas with greater percentages of wooded areas. In particular, bears chose areas with higher elevation or upland forests. Higher elevations may prevent dens from potentially flooding when water levels rise within the Ocmulgee River flood plain. Whereas areas with greater total areas of forests were selected, smaller patch sizes of upland forests were positively related to den selection. Abundant patches of forested lands in combination with patches of other habitat types would create a mosaic in which black bears could benefit. Early successional stands would provide cover in the immediate area of the dens, whereas forested areas would provide necessary habitat on a larger scale. Hardwood stands provide food in the fall, whereas early successional stands produce food in the spring and summer. Microhabitat selection based on dense understories paired with landscape-level selection based on upland forest availability suggests that female black bears need an arrangement of habitats that includes early successional patches mixed within tracts of forests.

Although I did not observe any direct consequences of prescribed burns to denning females, I did conclude that bears did not select den sites that had been burned in the previous 6 years on either WMAs. Currently, the burn rotation on land managed by GA DNR in central Georgia is every 2-3 years. I recommend a rotating burn regime of 3-5 years if management goals are to increase preferred black bear denning habitat. This would allow for increased understory growth, providing thicker cover observed in dens previously selected in the CGP.

Winter dens are a necessary requirement for the successful rearing of young and cub survival. Therefore, the quality of available denning habitat can influence recruitment of breeding individuals and subsequent population growth. Providing sufficient denning habitat becomes even more critical due to the small litter sizes and the reproductive isolation observed in the CGP. Management and conservation of preferred denning habitat will continue to be an essential component to sustain the black bear population in central Georgia.