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Multi-Scale Den-Site Selection by American Black Bears in Mississippi

Brittany Winchester Waller

Multi-scale den-site selection by American black bears in Mississippi

By

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Dens are a critical component of black bear (*Ursus americanus*) habitat, yet scale-dependent den-site selection has received limited attention. Natural and anthropogenic factors (e.g., vegetation, roads) may also influence bear den-site selection. I quantified black bear denning chronology and den use and evaluated multi-scale den-site selection in Mississippi, USA during 2005–2011. Females entered dens earlier than males and emerged later; multiple den use by both sexes in a single winter was common. I recorded equal numbers of tree and ground dens, with ground dens at higher elevations surrounded by dense vegetation. Chronology and other denning characteristics of bears in Mississippi were similar to other black bear populations in the southeastern United States. Bears exhibited scale-dependent den-site selection selecting sites with greater percentage horizontal cover and farther from roads. Greater percentage horizontal cover may provide security and increase energetic efficiency. Denning farther from roads likely decreases risk of human disturbance.

DEDICATION

I dedicate this research to my awe-inspiring husband, Michael Waller, and to my loving family Mitch, Kelly, and Maggie Winchester. I would not be where I am today without your love, patience, and support. I cannot thank you enough.

ACKNOWLEDGEMENTS

This project would not have been possible without the support and assistance of so many people. I am forever grateful to Dr. Jerrold Belant, my advisor, for giving me the opportunity to fulfill my dream of studying black bears. I am also thankful for his continued patience, encouragement, and help throughout my time at Mississippi State University (MSU). I am also thankful for the input and help I received from my other committee members, Dr. Bruce Leopold and Dr. David Evans. Additionally, I owe tremendous thanks to Brad Young, Stephanie Simek, and members of the Carnivore Ecology Laboratory at MSU including Chris Ayers, Nate Libal, Morgan Ihlefeld, Evelyn Interis, Cole Brazil, Christian Singleton, Meghan Jordan Klingler, Michael Bryant, Christopher Cooley, Jamie Holt, and Evan O'Donnell for assistance with fieldwork.

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CHAPTER I

INTRODUCTION

Dens are an important habitat component for American black bears (*Ursus americanus*). Bears use dens during winter dormancy because of seasonal food shortages and for protection from disturbance (Lindzey and Meslow 1976, Johnson and Pelton 1980a, Hayes and Pelton 1994, Oli et al. 1997). Additionally, dens provide a secure site for parturition and early maternal care (Alt and Gruttadauria 1984, Oli et al. 1997), which protects against litter loss (Alt 1984, Alt and Gruttadauria 1984). While denning, bears enter a state of dormancy with reduced metabolism to conserve energy (Linnell et al. 2000) and disturbance can be energetically costly (Hayes and Pelton 1994, Linnell et al. 2000). Therefore, selection and acquisition of secure dens are important, particularly for species like bears that use dens for up to 6 months annually (Rogers 1987, Linnell et al. 2000).

Habitat selection by animals is a hierarchical process in which specific habitat characteristics are selected at different spatial scales (Johnson 1980). Factors such as surrounding vegetation and topography influence den-site selection by black bears at smaller spatial scales (Hellgren and Vaughan 1989, Oli et al. 1997, White et al. 2001). Vegetation density is important for ground dens, apparently to increase security and decrease likelihood of disturbance (Hellgren and Vaughan 1989). Dense vegetation surrounding ground nests can also reduce energetic costs from exposure to inclement weather (Hellgren and Vaughan 1989). Elevation can influence black bear den-site selection in flood-prone forests, with ground dens located on higher sites where flooding is less likely (White et al. 2001).

Natural and anthropogenic sources of disturbance, such as flooding, conspecifics, and human activity, influence den-site selection by black bears (White et al. 2001, Reynolds-Hogland et al. 2007). Riparian areas (Reynolds-Hogland et al. 2007) and habitat edges (Donovan et al. 1997) serve as travel corridors for large carnivores, including large male bears which could be sources of disturbance to denning conspecifics. Streams and rivers also can be a source of flooding. Finally, human activity (e.g., recreationists, motorists, timber harvest) can negatively influence black bear den-site selection (Reynolds-Hogland et al. 2007).

Although some types of disturbances can be lethal to black bears, most are non-lethal. Human and non-human disturbances to black bears have been well documented during the non-denning season; however, comparatively little work on black bear disturbances during the denning season has been reported (Gaines 2002, Reynolds-Hogland et al. 2007, Crook 2008). Understanding types and magnitude of disturbances affecting species can be used to improve conservation, and is especially relevant to conservation of endangered species (Frid and Dill 2002).

Once common throughout Mississippi, black bears were nearly extirpated by the mid 1900s (Shropshire 1996). As a consequence of repatriation projects in Arkansas and Louisiana, Mississippi now has a small recolonizing population estimated at 50 individuals (Young 2006). Black bears in Mississippi are a state-listed endangered species and include the federally-threatened Louisiana black bear (*U. a. luteolus*; USFWS 1992). My study was the first to quantify denning ecology of and scale-dependent den-site selection by black bears in Mississippi which is necessary to verify adequacy of current conservation and management practices.

CHAPTER II

DENNING CHRONOLOGY AND DEN CHARACTERISTICS OF AMERICAN BLACK BEARS IN MISSISSIPPI

Introduction

Dens are an important habitat component for American black bears (*Ursus americanus*). Bears use dens during winter dormancy because of seasonal food shortages and for protection from disturbance (Lindzey and Meslow 1976, Johnson and Pelton 1980a, Hayes and Pelton 1994, Oli et al. 1997). Additionally, dens provide a secure site for parturition and early maternal care (Alt and Gruttadauria 1984, Oli et al. 1997), which protects against litter loss (Alt 1984, Alt and Gruttadauria 1984).

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My study is the first to quantify denning ecology of black bears in Mississippi. Due to variation among den types used across the Southeast (Hamilton and Marchinton 1980, Smith 1985, Hellgren and Vaughan 1989, Hightower et al. 2002), and the importance of conserving such a limited population, baseline denning ecology information is necessary to verify adequacy of current conservation and management practices.

Study Area

I conducted fieldwork primarily in the Delta region of western Mississippi where most black bear sightings occur (Simek et al. 2012). The Delta is about 20,000 km^2 and has low topographic relief with elevations from 3–136 m above mean sea level (MARIS 2002). The humid subtropical climate produces long, hot summers and short, mild winters (Bowman 1999). Common trees in the Delta include oak (*Quercus* spp.), hickory and pecan (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), elm (*Ulmus* spp.), and cottonwood (*Populus deltoides*). The Delta consists of various land covers including agriculture, forests, and urban areas (Bowman 1999). Although bear hunting is illegal, hunting other wildlife species, with and without dogs, and timber harvest are common winter activities in the Delta.

Methods

Data collection

Trap site locations were selected based on areas of known black bear occurrence from observations made by MDWFP personnel, the general public, and myself. Black bears were captured using modified Aldrich foot snares (Johnson and Pelton 1980b) and culvert traps and equipped with global positioning system (GPS) or very high frequency (VHF) radiocollars from 2004–2010. I immobilized captured individuals with tiletamine and zolazepam at a dosage of 4–5 mg/kg of estimated body weight (Telazol; A.H. Robins Company, Richmond, Virginia, USA), administered with a dart syringe fired from a CO_2-powered pistol or syringe pole. I equipped captured bears with GPS (Telonics, Inc., Mesa, Arizona, USA; Advanced Telemetry Systems Inc. [ATS], Isanti, Minnesota; Northstar, King George, Virginia, USA) or VHF (Telonics, Inc. and ATS) radiocollars, passive integrated transponder (PIT) tags (BioMark, Boise, Idaho, USA), and ear tags. I used leather breakaway links with all GPS and VHF radiocollars (Garshelis and McLaughlin 1998). I recorded sex and released all bears at their capture site upon recovery. All capturing and handling of bears followed American Society of Mammalogists guidelines (Gannon et al. 2007) and was approved by the Mississippi Department of Wildlife, Fisheries and Parks and the Mississippi State University Institutional Animal Care and Use Committee (protocol 11-107).

I located dens using aerial and ground-based telemetry during winters 2009/2010–2010/2011. I attempted den visits of all radiocollared bears. I immobilized bears at dens with the same techniques used during trapping. Radiocollars of adults were replaced and cubs-of-the-year (cubs) received PIT tags only.

To estimate denning chronology, I collected relocation data from GPS collars recovered during recaptures and den visits. Relocation schedules for GPS collars were 3.5-, 5-, or 11-hr intervals. I also used relocation data from GPS collars recovered by MDWFP personnel before my study. I considered a bear to be denning if it remained within an area with a radius ≤135 m for at least 6 consecutive days. I used these characteristics based on telemetry error of bears known to be denning and the minimum known length of time a bear denned in my study based on my observations and GPS collar relocation data. I defined date of den entrance as the first day a bear remained within the defined denning area centered on the den location. I collected universal transverse Mercator (UTM) coordinates of each den during den visits to establish its center point. I defined den emergence as the first day the bear was located and remained outside the denning area (>135 m from den). I estimated denning duration as number of days between den entrance and emergence from each den. Because some bears used multiple dens during a winter, I identified the interval from date of entrance at the first den to date of emergence at the last den during a winter as the denning period. Thus, denning duration and denning period were identical for bears that used only one den in a winter. In the event that bears entered a different den following den abandonment due to natural disturbances, I included dens used before and after disturbance for calculation of mean number of dens used per winter.

I classified dens as tree or ground. I assumed ground dens were less secure due to increased chance of disturbance including den inundation and encounters with other bears or humans. Therefore, dens in basal tree cavities where bears were located on the ground were considered ground dens. I recorded aspect, overall den dimensions ($l \times w \times d$), presence of a bed, and composition of bedding material. I also measured dimensions ($l \times w$) and location in tree of den entrances. Additionally for tree dens, I recorded tree species, diameter at breast height (dbh), tree height, and height of cavity entrance. I estimated tree and cavity entrance heights using a hypsometer (Vertex IV, Haglöf Sweden, Långsele, Sweden). Tree height was measured from base of tree to top of crown, and height of cavity was measured from base of tree to bottom of cavity opening.

I recorded elevation, vertical cover, horizontal cover, basal area, frequency of potential den trees (dbh ≥ 91 cm), and habitat type for each den site. I estimated elevation (m) using digital elevation models (DEM; MARIS 2002). I measured percentage vertical cover using a spherical densitometer (Lemmon 1956, Hayes and Pelton 1994). Standing with my back adjacent to the den, I took one reading in each cardinal direction, another directly over ground dens, and averaged readings to estimate mean percentage vertical cover for each den. I measured percentage horizontal cover using a modified Nudds density board (Nudds 1977). I placed the density board adjacent to the den and read from locations 15 m away in each cardinal direction. The 15 m distance was the predetermined den-site boundary (Squires et al. 2008). I estimated basal area (m^2/ha) using a 10-factor prism. I classified habitat type as bottomland hardwood forest (predominantly hardwood species in areas subject to seasonal flooding), swamp (forested wetlands flooded generally throughout the year with predominant trees including bald cypress [*Taxodium distichum*], water tupelo [*Nyssa aquatica*], and other flood-tolerant species), agriculture (vacant or fallow crop fields), ridge (predominantly hardwood species in areas with steeper slopes and relatively higher elevations), Wetlands Reserve Program (WRP; US Department of Agriculture [USDA] 2011), and clear- or select-cut forest. For instances when dens were not located aerially or on the ground ($n = 5$), I used relocation data from GPS collars as previously described (i.e., $\geq$6 days in duration with all locations $\leq$135 m of the arithmetic center of the location cluster) to estimate den sites. The arithmetic center of these clusters was assumed to be the den site, and only den site characteristics were measured.

Data analysis

I used den-year as the experimental unit for analyses after I pooled data across years; I thus assumed no inter-annual differences in denning chronology and den-site selection patterns. I used Wilcoxon-Mann-Whitney and *t*-tests to compare male and female denning chronology and duration. I compared den characteristics including mean elevation, percentage vertical cover, and percentage horizontal cover by den type and sex using Wilcoxon-Mann-Whitney tests. Multiple dens used by the same bear were considered to represent independent events for statistical tests of den characteristics; this can cause under-estimates of variance. Statistical significance was accepted with $\alpha \leq 0.05$.

Results

I estimated den entrance ($n = 24$) and emergence dates ($n = 23$) for 15 bears (7 female, 8 male; Table 2.1). Overall mean success rate of GPS collars was 67% (SD = 18%). Median dates of den entrance for males (17 Jan) was 45 days later than females (3 Dec). Median date of den emergence for males (12 Mar) was 6 days earlier than females (18 Mar). I recorded 19 estimates of denning duration and denning period. The difference in mean duration of denning between males (51 days) and females (75) approached significance ($t_{17} = 1.96$, $P = 0.067$). Mean denning period for females (83 days) was 26 days longer than males (57 days; $Z = -2.16$, $P = 0.030$).

Mean number of dens used by females (1.7) and males (2.0) each winter was similar ($Z = 0.84$, $P = 0.404$). Four females and 7 males used >1 den during a winter. Additionally, I observed 3 cases of den abandonment: a tornado damaged a tree with a basal cavity ground den, a tree den cavity became inundated, and a researcher disturbed a ground nest.

Table 2.1 Denning chronology of black bears in Mississippi, USA, 2006–2011

Age–sex class	*n*	Den-years	Median entrance (range)	Median emergence (range)	Denning duration, days (SD, range)	Denning period, days (SD, range)	Total no. dens (SD, range)
Adult male	8	11	17 Jan (26 Dec–28 Feb)	12 Mar (4 Mar–28 Mar)	51 (24, 7–84)	57 (27, 7–85)	2.0 (1.0, 1–4)
Female	7[a]	17	3 Dec (16 Nov–21 Jan)	18 Mar (26 Jan–13 Apr)	75 (29, 12–100)	83 (27, 12–107)	1.7 (1.1, 1–4)
Subadult	2	2	2 Jan (14 Dec–21 Jan)	31 Mar (18 Mar–13 Apr)	88 (8, 82–94)	88 (8, 82–94)	1.0 (0.0, 0)
Solitary	3	4	9 Dec (8 Dec–16 Dec)	18 Mar (8 Mar–20 Mar)	94 (3, 92–96)	97 (6, 92–101)	3.0 (1.4, 2–4)
Parturient[c]	5	6	27 Nov (16 Nov–3 Jan)	22 Mar (18 Mar–6 Apr)	78[b]	78[b]	1[b]
With cubs[d]	1	1	14 Jan	26 Jan	12	12	1
Unknown litter	2	4	13 Dec (29 Nov–25 Dec)	14 Mar (10 Mar–21 Mar)	74 (28, 35–100)	92 (14, 79–107)	1.8 (1.0, 1–3)

[a]Data were recorded for 7 individual females who were classified into different age and reproductive classes during 2006–2011.
[b]Only one parturient female had data for denning duration, denning period, and total number of dens.
[c]Female that gave birth to cubs following den entrance.
[d]Female that entered den with cubs-of-the-year.

I characterized 40 dens across 38 den years (Table 2.2). Fifty-three percent of female and 38% of male dens were in trees. Two females used tree and ground dens, one of which used both within a single denning period. Den dimensions were similar overall for tree and ground dens (Table 2.3). Although den entrance measurements varied by den type, den entrance areas (*l* x *w*) overlapped considerably.

Table 2.2 Types of dens used by black bears in Mississippi, USA, 2005–2011

			Den type	
Age–sex class	*n*	Den years	Tree	Ground
Adult male	5	8	3	5
Female	13	30	17	15
Subadult	3	4	4	0
Solitary	6	9	6	5
Parturient	10	12	4	8
With cubs	2	2	2	0
Unknown litter	3	3	1	2

[a]Data were recorded for 13 individual females who were classified into different age and reproductive classes during 2005–2011.

Table 2.3 Den characteristics used by black bears in Mississippi, USA 2005–2011

Parameter	*N*	Tree (SD, range)	*n*	Ground (SD, range)
Den				
Length (cm)	12	90.6 (29.0, 59.0–155.4)	7	109.2 (30.3, 79.2–164.6)
Width (cm)	12	88.9 (18.9, 71.6–116.3)	7	99.6 (24.6, 77.1–146.6)
Depth (m)	15	3.6 (4.4, 0.0–13.2)	6	0.4 (0.3, 0.0–0.8)
Entrance				
Height (cm)	19	190.1 (107.2, 49.7–423.6)	5	95.4 (46.4, 46.9–167.6)
Width (cm)	17	47.3 (17.1, 21.0–85.3)	5	158.4 (101.2, 32.8–237.7)

Ten den trees were bald cypress, 8 were oak, one was sweetgum, and one was willow (*Salix* sp.). Three den trees were snags (oak, sweetgum, and willow). Mean height of den trees (excluding snags) was 30.9 m (SD = 8.2, range = 10.5–41.8). Mean dbh was

166.9 cm (SD = 69.8, range = 56.6–291.8) for bald cypress and 116.3 cm (SD = 11.4, range = 103.9–135.8) for all other species combined. Ten trees were in bottomland hardwood forests (all dens were occupied by females), 4 (2 F, 2 M) were in swamps, and 6 (5 F, 1 M) were in regenerating clear- or select-cut areas. All tree cavity entrances were located along the main trunk. Mean cavity entrance height was 11.5 m (SD = 5.2, range = 2.7–17.7). Aspect of cavity entrances included 4 north, 6 east, 5 south, and 5 west. Tree den (n = 7) bedding material typically included woody material from within cavities.

I recorded use of 8 ground nests, 4 basal tree cavities, 4 brush piles or logging slash, and 4 downed trees or logs. Four ground dens were located in bottomland hardwood forests (occupied by 2 female and 2 male bears), 1(M) in a swamp, 4 (3 F, 1 M) in regenerating clear or select cut areas, 1(F) in an abandoned agriculture field, 7 (7 F) on ridges, and 1 (F) in a WRP field. We also documented excavated depressions within the dens of 4 parturient females. Aspects of 6 den entrances included 1 north, 2 east, 1 south, and 2 west. Ground den (n = 6) bedding material included adjacent herbaceous vegetation.

Between-year den reuse was observed in 2 of 11 individuals. One male and one female used the same respective bald cypress trees 2 consecutive years. Also, a female used an overcup oak (*Q. lyrata*) tree in 2010, and her adult female offspring with 2 yearlings used the same tree in 2011.

I measured den site characteristics for 41 den sites (17 ground, 19 tree, and 5 GPS-determined). Mean elevation for sexes combined and females only was greater for ground dens (41 m, SD = 18 and 45 m, SD = 19, respectively; $Z = 2.84$, $P = 0.005$) than tree dens (27 m, SD = 4 and 27 m, SD = 4, respectively; $Z = 3.02$, $P = 0.003$).

Mean percentage vertical cover was greater at female dens (84%, SD = 13, n = 28) than male dens (60%, SD = 31, n = 10; Z = -2.19, P = 0.029) but overall similar (Z = 0.52, P = 0.601) between tree (80%, SD = 15, n = 17) and ground (82%, SD = 19, n = 16) dens. Mean percentage 15-m horizontal cover for sexes combined was greater at ground dens (77%, SD = 14) than tree dens (45%, SD = 26; Z = 3.62, P < 0.001). Similarly, mean percentage 15-m horizontal cover for females was greater at ground dens (78%, SD = 14) than tree dens (43%, SD = 27; Z = 3.25, P = 0.001).

Mean basal area was 15.3 m^2/ha (SD = 11.4, n = 39) for den sites including 19.1 m^2/ha for tree (SD = 13.6 n = 18) and 14.5 m^2/ha for ground (SD = 7.4, n = 16) dens. Overall mean number of potential den trees was 0.3 (SD = 0.6, range = 0–3, n = 41) and did not differ by sex (Z = 0.55, P = 0.582) or den type (Z = -1.27, P = 0.205).

Discussion

I provide the first description of black bear denning chronology and den use in Mississippi. This is important for evaluating the adequacy of bear management and conservation in the state. I recognize my small sample sizes may limit statistical power; however, I consider it representative of black bears in Mississippi because it constituted a large proportion of the estimated black bear population and because bears exhibited denning behavior similar to other black bear populations in the Southeast. For example, females entered dens before and emerged later than males (Hamilton and Marchinton 1980, Weaver and Pelton 1994, Oli et al. 1997), and parturient females entered dens before other age-sex classes (Smith 1985, Hellgren and Vaughan 1989, Weaver and Pelton 1994, Oli et al. 1997). I observed similar entrance (early Dec–mid-Jan) and emergence (mid-Mar–late Apr) dates and denning durations (51–134 days) as previous studies (Hamilton and Marchinton 1980, Wathen 1983, Smith 1985, Hellgren and Vaughan 1989, Oli et al. 1997). Multiple den use was also common for male and female black bears in Mississippi, demonstrating winter activity (Hamilton and Marchinton 1980, Hellgren and Vaughan 1989, Weaver and Pelton 1994, Oli et al. 1997), which I attributed to greater food availability and disturbance from flooding, severe weather, and human disturbance (Hamilton and Marchinton 1980, Graber 1990, Oli et al. 1997, Hightower et al. 2002). However, unlike bears in other Southeastern studies (e.g., Smith 1985, Hellgren and Vaughan 1989, Weaver and Pelton 1994, Oli et al. 1997), all bears I studied exhibited denning behavior each winter.

I documented one confirmed case of tree den abandonment (by an adult female with 2 cubs) due to flooding. Smith (1985) documented tree den abandonment on 3 occasions due to flooding in White River National Wildlife Refuge, Arkansas, including one occasion by an adult female. Two cubs in this latter den drowned, but it is not known if they drowned before or after the adult female abandoned the den. To escape flooding, bears in flood-prone areas tend to select tree dens with elevated cavities or ground dens located at elevations high enough to prevent inundation (White 1996, Benson 2005, Crook 2008).

Tree and ground dens are used commonly by black bears throughout the Southeast (Hellgren and Vaughan 1989, Weaver and Pelton 1994, Hightower et al. 2002). I recorded similar proportions of tree and ground den use by both sexes, including parturient females. Although I did not measure den tree availability, den trees appear to be an important habitat component of black bears in bottomland hardwood forests prone to flooding such as Mississippi (Smith 1985, Oli et al. 1997). Additionally, ground dens were surrounded by dense vegetation and occurred at elevations above flood-prone areas, characteristics likely to provide seclusion and protection from disturbance (Hellgren and Vaughan 1989, White et al. 2001, Hightower et al. 2002).

Observed den reuse was similar to other studies (5–21%; Wathen 1983, Alt and Gruttadauria 1984, Crook 2008). Den reuse may be related to den availability (Johnson and Pelton 1981, Alt and Gruttadauria 1984); thus, areas with greater rates of den reuse may suggest a lack of suitable dens. Den reuse in the Southeast typically involves tree dens (Smith 1985, White 1996, Crook 2008), and high tree den reuse may indicate selection, especially in areas prone to flooding with few suitable den trees (Schwartz et al. 1987).

CHAPTER III

SCALE-DEPENDENT DEN-SITE SELECTION BY AMERICAN BLACK BEARS

Introduction

Habitat selection by animals is a hierarchical process in which specific habitat characteristics are selected at different spatial scales (Johnson 1980). Factors which limit fitness likely influence habitat selection with most-limiting factors influencing selection at larger spatial scales such as home range and less-limiting factors influencing selection at finer spatial scales (Rettie and Messier 2000, McLoughlin et al. 2002). Scale-dependent den-site selection has been reported for several carnivore species including striped skunks (*Mephitis mephitis*; Hwang et al. 2007), Canada lynx (*Lynx canadensis*; Squires et al. 2008), and grizzly bears (*Ursus arctos*; Libal 2011). These studies emphasized importance of cover for security at den sites at finer spatial scales. Additionally, Crook and Chamberlain (2010) assessed den-site selection by black bears (*U. americanus*) in Louisiana and found greater proportions of swamp and lowland forests near den sites than within annual home ranges.

Bears den during winter because of seasonal food shortages (Hayes and Pelton 1994) and for parturition (Oli et al. 1997). Natural factors such as surrounding vegetation, topography, and sources of disturbance influence den-site selection by black bears (Hellgren and Vaughan 1989, Oli et al. 1997, White et al. 2001). Vegetation density is important for ground dens, apparently to increase security and decrease likelihood of disturbance (Hellgren and Vaughan 1989). Dense vegetation surrounding ground nests also can reduce energetic costs from exposure to inclement weather (Hellgren and Vaughan 1989). Elevation can influence black bear den-site selection in flood-prone forests, with ground dens located on higher sites where flooding is less likely (White et al. 2001). Riparian areas (Reynolds-Hogland et al. 2007) and habitat edges (Donovan et al. 1997) serve as travel corridors for large carnivores, including large male bears which could be sources of disturbance to denning conspecifics. Finally, human activity associated with roads can negatively influence black bear den-site selection (Reynolds-Hogland et al. 2007), potentially a consequence of risk from poaching or hunting (Brody and Stone 1987).

I evaluated habitat and topographic characteristics to determine if black bears exhibited scale-dependent den-site selection. At larger spatial scales, I hypothesized bears would den farther from streams and rivers, habitat edges, and roads to avoid potential disturbance from flooding, conspecifics, and humans. I also hypothesized bears would select for topographic features such as higher elevations. In the Delta region of Mississippi where topographic relief is low, slight changes in elevation may result in dramatically different hydrologic conditions (Crook 2008). Similarly, I hypothesized black bears would select habitat features, such as greater horizontal vegetative cover, that provide protection from potential disturbances at smaller spatial scales.

Study Area

Mississippi has a small, recolonizing black bear population estimated at 50 individuals (Young 2006), including the federally-listed Louisiana black bear (*U. a. luteolus*; USFWS 1992). I conducted fieldwork primarily in the Delta region of western Mississippi where most black bear sightings occur (Simek et al. 2012). The Delta is about

20,000 km^2 and has low topographic relief with elevations from 3–136 m above mean sea level (MARIS 2002). The humid subtropical climate produces long, hot summers and short, mild winters (Bowman 1999). Common trees in the Delta include oak (*Quercus* spp.), hickory and pecan (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), elm (*Ulmus* spp.), and cottonwood (*Populus deltoides*). The Delta consists of various land covers including agriculture, forests, and urban areas (Bowman 1999). Although bear hunting is illegal, hunting other wildlife species, with and without dogs, and timber harvest are common winter activities in the Delta.

Methods

Data collection

Trap site locations were selected based on areas of known black bear occurrence from observations made by MDWFP personnel, the general public, and myself. Black bears were captured and equipped with Global Positioning System (GPS) radio-collars from 2004–2010 using modified Aldrich foot snares (Johnson and Pelton 1980) and culvert traps. I immobilized captured individuals with tiletamine and zolazepam at a dosage of 4–5 mg/kg of estimated body weight (Telazol; A. H. Robins Company, Richmond, Virginia, USA), administered with a dart syringe fired from a CO_2-powered pistol or syringe pole. I equipped captured bears with GPS (Telonics, Inc., Mesa, Arizona, USA; Advanced Telemetry Systems Inc. [ATS], Insanti, Minnesota, USA; Northstar, King George, Virginia, USA) or VHF (Telonics, Inc. and ATS) radio-collars, passive integrated transponder (PIT) tag (BioMark, Boise, Idaho, USA), and ear tags. I used leather breakaway links with all GPS and VHF radio-collars (Garshelis and McLaughlin 1998). I recorded sex and released all bears at their capture site upon recovery. All capturing and handling of bears followed American Society of Mammalogists guidelines (Gannon et al. 2007) and was approved by the Mississippi Department of Wildlife, Fisheries and Parks and the Mississippi State University Institutional Animal Care and Use Committee (protocol 11-107).

I located dens using aerial and ground-based telemetry and attempted den visits of all radio-collared bears during winters 2009/2010–2010/2011. I immobilized bears at dens with the same techniques used during trapping. I collected 3.5- or 5-hour relocation data from GPS collars recovered during recaptures and den visits. I also used relocation data from GPS collars recovered by MDWFP personnel before my study. I used 95% fixed kernel density estimators using least squares cross validation for the bandwidth (Seaman et al. 1998) to estimate annual home ranges of bears with at least 7.5 months of data. For instances when dens were not located aerially or on the ground (n = 5), we used relocation data from GPS collars to identify den sites (Waller et al. 2012). I considered a bear in a den if it remained within an area with a radius ≤135 m for at least 6 consecutive days. I used these characteristics based on telemetry error of bears known to be in dens and minimum known length of time a bear occupied a den in our study (Waller et al. 2012). The arithmetic center of these location clusters was assumed to be the den site.

I evaluated den-site selection using dens and one randomly selected point from each annual home range at 3 spatial scales: 1) den site (15-m radius), 2) den area (100-m radius), and 3) den landscape (1,000-m radius), similar to scales used to assess lynx den-site selection (Figure 3.1; Squires et al. 2008). At den sites, we recorded elevation (m), percentage vertical cover, percentage horizontal cover, and number of potential den trees (dbh ≥91 cm) for each den site. I determined elevation using 30-m DEMs (MARIS 2002). I measured percentage vertical cover using a spherical densitometer (Lemmon 1956, Hayes and Pelton 1994). Standing with my back adjacent to the den, I took one reading in each cardinal direction, another directly over ground dens, and then averaged readings to estimate mean percentage vertical cover for each den. I measured percentage horizontal cover using a modified Nudds density board (Nudds 1977). I placed the density board adjacent to the den and measured percentage horizontal obstruction from locations 15 m away in each cardinal direction.

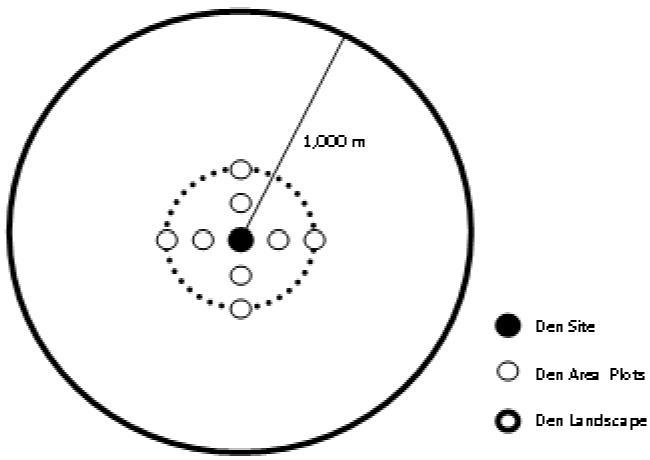

Figure 3.1 Evaluation of black bear den-site selection at 3 spatial scales (den site [15-m radius], den area [100-m radius], and den landscape [1,000-m radius]), Mississippi, USA, 2006–2011.

I described den areas by sampling 8 15-m-radius plots established 50 m and 100 m from dens or random points in each cardinal direction, using the same variables as for den site plots. To evaluate den landscape selection, I estimated mean elevation of den and random landscapes by averaging elevation values extracted from 30-m DEMs for each area. I classified forest areas of den and random landscapes as open, lowland conifer, lowland deciduous, or lowland mixed using forest patch types and boundaries obtained from Landsat-derived Mississippi Institute of Forest Inventory (MIFI) data. Additionally, I used MIFI data to classify forest patches as regenerating (0–10 years old), young (11–40 years old), or mature (>40 years old).

I estimated distance (m) from dens and random points to nearest stream or river, habitat edge, and road using the National Hydrography Dataset (NHD; USGS 2011), MIFI data, and Topologically Integrated Geographic Encoding and Referencing (TIGER) system data (U.S. Census Bureau 2010), respectively. I also estimated area (ha) of forest patch encompassing each den and random point. I quantified number of forest patch types per landscape and percentage of lowland regenerating hardwood forest, lowland mature hardwood forest, and lowland mature mixed forest within each landscape. I considered these 3 habitat types most suitable for denning because regenerating forests frequently have dense understory vegetation (Hellgren and Vaughan 1989) and mature forests include large trees more likely to be den trees (Johnson and Pelton 1981).

Data analysis

I used den-year as the experimental unit for all analyses. For univariate analyses, I used Wilcoxon-Mann-Whitney and *t*-tests to compare mean habitat and topographic characteristics of den and random spatial scales. Statistical significance was accepted with $\alpha \leq 0.05$; means are reported with ± 1 standard deviation. For multivariate modeling, I first assessed multicollinearity among model parameters at each spatial scale using Pearson's correlation. Next, to assess whether use of multiple years of den and home range data from the same bears influenced model performance by potential reduction of parameter variances, I conducted fixed effects and mixed model logistic regressions and used the likelihood ratio test of spatial covariance, with individual bears as the random effect (i.e., covariate). I found no differences ($P > 0.05$) between paired models with and without random effects. Consequently, to eliminate nuisance parameters, for final analyses I used multivariate logistic regression with fixed effects only. Specifically, I used logistic regression to evaluate differences between habitat parameters of den sites and den areas in addition to parameters of den and random sites and den and random areas. I tested all model combinations at each spatial scale, excluding those parameters with very correlated ($|r| > 0.7$) variables. Because of sample size and number of parameters modeled, I used stepwise logistic regression to assess differences between den and random landscapes.

I evaluated performance and predictive power of models at den site and den area scales using area under the receiver operating characteristic curves (AUC) (Cumming 2000, Hosmer and Lemeshow 2000). I assumed models with greater strength and predictive power (i.e., greater AUC values) better represented the spatial scale at which black bears selected den sites. I calculated 95% confidence intervals for parameters of the most parsimonious model at each spatial scale.

Results

I estimated annual home ranges of 11 bears (6 M, 5 F) for 20 den years (7 M, 13 F). I documented 20 dens, all located in bottomland hardwood forests. Mean habitat characteristics at den and random spatial scales were similar except 15-m percentage horizontal cover was greater at den areas (58 ± 22) than random areas (40 ± 20) and distance to nearest road was greater for den (762.7 ± 574.3 m) than random landscapes (540.6 ± 423.7 m; Table 3.1). Mean percentage vertical cover ($S = -13$, $P = 0.616$), percentage horizontal cover ($t_{18} = 0.13$, $P = 0.899$), number of potential den trees ($S =$

12.5, $P = 0.402$), and elevation ($S = 4.5$, $P = 0.752$) were similar between den sites and adjacent den areas.

Table 3.1 Model parameters and univariate test results for den-site, den-area, and den-landscape selection by black bears in Mississippi, USA, 2006-2011

			Used		Available			
Spatial Scale	n	Parameter[a]		SD		SD	Test Statistic	P Value
Den site (15 m)	19	VC	71.7	24.5	67.1	42.4	$S = -4$	0.891
		HC	57	27	41	27	$t_{18} = 1.66$	0.114
		PDT	0.5	0.8	0.1	0.3	$S = 12.5$	0.402
		ELEV	28.0	4.8	28.0	4.1	$S = -13.5$	0.580
Den area (100 m)	20	VC	77.1	13.3	71.2	34.9	$S = -9$	0.756
		HC	58	22	40	20	$t_{19} = 3.06$	0.007
		PDT	0.3	0.4	0.2	0.2	$S = 23.5$	0.107
		ELEV	27.9	4.7	27.9	4.0	$S = -8$	0.768
Den landscape (1000 m)	20	ELEV	27.8	4.6	28.1	4.4	$S = -39$	0.154
		DIST TO STREAM	575.5	475.7	525.1	607.3	$S = 18$	0.522
		DIST TO EDGE	259.4	303.5	204.5	196.8	$S = 29$	0.294
		DIST TO ROAD	762.7	574.3	540.6	423.7	$S = 59$	0.027
		PATCH AREA	215.0	104.6	226.4	86.8	$S = -6$	0.841
		PATCH TYPES	2.7	0.9	3.2	0.6	$S = -24.5$	0.099
		REGEN HARDWOOD	8.90	11.20	6.26	6.15	$S = 22$	0.396
		MATURE HARDWOOD	54.58	32.34	53.30	32.23	$S = -3$	0.927
		MATURE MIXED	0.00	0.00	0.03	0.13	$S = -1.5$	0.500

[a] Parameters included percentage vertical cover (VC), percentage horizontal cover at 15 m (HC), frequency of potential den trees (PDT), elevation (m; ELEV), distance (m) to nearest stream from center point (DIST TO STREAM), distance (m) to nearest habitat edge from center point (DIST TO EDGE), distance (m) to nearest road from center point (DIST TO ROAD), area (ha) of patch surrounding center point (PATCH AREA), number of patch types per landscape (PATCH TYPES), percentage of lowland regenerating hardwood forest within landscape (REGEN HARDWOOD), percentage of lowland mature hardwood forest within landscape (MATURE HARDWOOD), and percentage of lowland mature mixed forest within landscape (MATURE MIXED)

I found no very correlated ($|r| > 0.7$) variables for den site to den area or den landscape to random landscape comparisons. However, for den to random sites and den to random areas comparisons, percentage vertical cover and percentage horizontal cover (r = 0.97 and 0.89, respectively) and percentage horizontal cover and elevation (r = 0.94 and 0.98, respectively) were very correlated.

The leading models for den to random site and den to random area scales included percentage horizontal cover and frequency of potential den trees, each of which exhibited moderate model fit (Table 3.2). Also, 95% confidence intervals for model parameter estimates for these 2 models included zero except percentage horizontal cover for the den area scale. The leading model for the den landscape scale included number of patch types per landscape but had no predictive power.

Table 3.2 Most supported model results for den-site, den-area, and den-landscape selection by black bears in Mississippi, USA, 2006-2011

				95% Confidence Limit		
Spatial Scale	*n*	Parameter[a]	B	Upper	Lower	AUC[b]
Den site (15 m)	19	HC	1.79	4.38	-0.79	68.7
		PDT	1.05	2.60	-0.49	
Den area (100 m)	20	HC	3.50	6.91	0.09	72.5
		PDT	1.47	4.03	-1.08	
Den landscape (1000 m)	20	PATCH TYPES	-0.95	0.01	-1.91	51.1

[a] Model parameters included percentage horizontal cover at 15 m (HC), number of potential den trees (PDT), and number of patch types per landscape (PATCH TYPES).
[b] Area under the receiver operating characteristic curve (AUC).

Discussion

Black bears in Mississippi demonstrated scale-dependent den-site selection by selecting greater percentage horizontal cover at 100-m resolution. Denser horizontal cover likely provides greater security by concealing dens (Johnson and Pelton 1981, Hellgren and Vaughan 1989, Hayes and Pelton 1994). Additionally, ground dens surrounded by dense vegetation are more energetically efficient (Hellgren and Vaughan 1989). Protection from disturbance and surrounding elements while denning is necessary for bears because disturbance during the denning period can be energetically costly, especially for parturient females, and result in litter loss (Linnell et al. 2000).

Other carnivore species have similarly demonstrated selection for dense vegetation at den sites (Hwang et al. 2007, Squires et al. 2008, Libal 2011). However, lynx and skunks (i.e., smaller species) selected this attribute at finer spatial scales (e.g., 11.2 m and 50 m resolutions, respectively) than grizzly bears (e.g., 100 m), likely a consequence of body size in which larger animals perceive their environments at larger spatial scales (Mech and Zollner 2002). Therefore, I would expect black bears to select for similar habitat attributes at a spatial scale greater than smaller carnivore species, as demonstrated in this study.

Elevation can be an important factor in den-site selection by black bears (White et al. 2001, Mitchell et al. 2005, Reynolds-Hogland et al. 2007) but did not influence den-site selection in my study. This may be because bears in Mississippi use tree and ground dens (Waller et al. 2012). Tree dens allow bears to use flood-prone areas by providing dry den sites above the flood line (White et al. 2001). Also, the Mississippi River and other smaller rivers (e.g., Yazoo River) have levees which prevent flooding when rivers rise. Thus, ground denning can occur at elevations outside the levees which would otherwise flood. Similarly, distance to nearest stream or river did not influence den-site selection though streams can be a source of flooding (White et al. 2001).

Distances to nearest stream or river and habitat edge were not important model parameters despite travel corridors may increase risk of disturbance by conspecifics and humans (Rogers 1983, Tietje et al. 1986, LeCount 1987). The small bear population in Mississippi likely decreases risk from conspecifics (Garneau et al. 2006). Although distance to nearest road was greater for den than random points within den landscapes, it was not an important model predictor. However, other studies suggested distance from roads influences den-site selection by black bears (Mitchell et al. 2005, Reynolds-Hogland et al. 2007). Selection of den sites with dense vegetation could ameliorate potential adverse effects from human activity along roads (e.g., Sahlén et al. 2011).

Number of potential den trees did not influence black bear den-site selection; however, Oli et al. (1997) suggested den trees are necessary for black bears denning in flood-prone bottomland hardwoods such as in Mississippi. This could be a consequence of a suitable number of den trees being available. Alternatively, potential den trees may not provide a suitable index to number of actual trees suitable for den use by black bears. Additionally, Waller et al. (2012) found bears in Mississippi used an equal proportion of tree and ground dens. Therefore, den trees may be less important for bears in Mississippi than in other areas of the southeastern United States (e.g., Oli et al.1997) because alternative den sites are available (e.g., ground dens located at higher elevations and surrounded by dense vegetation).

Evaluating den-site selection as a hierarchical process provides improved understanding of the spatial scale at which black bears selected den sites. Rettie and Messier (2000) and McLoughlin et al. (2002) suggested greater fitness-limiting factors influence habitat selection at larger spatial scales such as home range and lesser fitness-limiting factors influence selection at finer spatial scales. Den sites for black bears do not appear to be limited in Mississippi. Selection for dense horizontal cover at finer spatial scales suggests security at den sites for this population is a lower-order fitness-limiting factor.

CHAPTER IV

NON-LETHAL DISTURBANCE INFLUENCES BLACK BEAR DEN-SITE SELECTION

Introduction

Increasingly, human activities influence wildlife populations in numerous ways including habitat selection, demography, behavior, and physiology (Apps et al. 2004, Beale 2007). These effects are magnified in urban and exurban environments; however, they also occur in rural and remote environments (Mattson 1990, Yorio et al. 2001, Reynolds-Hogland et al. 2007). Anthropogenic disturbances (e.g., recreational activities, timber harvest, and roads) may cause habitat degradation or loss as well as increased stress levels and energetic losses to animals (Mattson 1990, Linnell et al. 2000, White et al. 2001, Beale 2007). Consequently, individuals of species such as grizzly bears (*Ursus arctos*) may select home ranges in areas that are uninhabited by, or inaccessible to, humans to avoid interaction (Gaines 2002, Apps et al. 2004).

Non-anthropogenic factors including conspecifics, competitors, habitat edges, and topographic features also may cause or increase likelihood of disturbances in animals (Mattson 1990, Donovan 1997, White et al. 2001, Garneau et al. 2006). For example, risk to bears from conspecifics and competitors can cause variation in home range size or habitat use as segregation of age-sex classes and species occurs (Garneau et al. 2006, Libal et al. 2011). Mammalian carnivores commonly use streams, rivers, and habitat edges as travel corridors which can negatively affect prey species (Donovan 1997, Reynolds-Hogland et al. 2007). Additionally, streams and rivers can be a source of flooding, especially in areas with low relief, which can alter habitat selection by animals (White et al. 2001).

Although some types of disturbances can be lethal to black bears (*U. americanus*), most are non-lethal. The risk-disturbance hypothesis posits that non-lethal disturbance stimuli are equivalent to predation risk and therefore elicit similar responses from individuals (Frid and Dill 2002, Kornilev 2008). These responses are from animals attempting to balance resource acquisition and risk of predation (Frid and Dill 2002). Resources can represent any resource attribute used by a species including food, space or habitat use, and mate choice. For example, black bears avoid risk through habitat selection, which can vary seasonally by gender and age class to reduce encounters with conspecifics and competitors (Garneau et al. 2006, Belant et al. 2010). Black bears may avoid roads to reduce risk, particularly roads with greater traffic volume or unpredictable human use (Brody and Pelton 1989, Reynolds-Hogland et al 2007).

Although human and non-human disturbances to black bears have been well documented during the non-denning season, comparatively little work on black bear disturbances during the denning season has been reported (Gaines 2002, Reynolds-Hogland et al. 2007, Crook 2008). White et al. (2001) and Waller et al. (2012) documented black bear use of den structures and sites (i.e., elevated tree cavities and ground dens surrounded by dense vegetation and located at higher elevations) to avoid flood inundation and increase security. To understand how potential risks can influence animal space use, I examined black bear den-site selection at 2 spatial scales in relation to indices of human and non-human disturbance. Black bears use dens during winter dormancy when food resources are typically scarce and parturition and early maternal care occur (Johnson and Pelton 1980a, Alt 1983, Hayes and Pelton 1994, Oli et al. 1997). While denning, bears enter a state of dormancy with reduced metabolism to conserve energy (Linnell et al. 2000) and disturbance can be energetically costly (Hayes and Pelton 1994, Linnell et al. 2000). Therefore, selection and acquisition of secure dens are important, particularly for species like bears that use dens for up to 6 months annually (Rogers 1987, Linnell et al. 2000).

Understanding types and magnitude of disturbances affecting species can be used to improve conservation, and is especially relevant to conservation of endangered species (Frid and Dill 2002). Mississippi, USA, has a small colonizing black bear population (estimated at 50 individuals) that is state-listed as endangered and includes the federally-threatened Louisiana black bear (*U. a.* luteolus; USFWS 1992, Young 2006). Consequently, I assessed if den-site selection by this endangered species supported the risk-disturbance hypothesis. I hypothesized black bears would select den sites located at higher elevations and farther from streams or rivers to prevent den inundation during floods. I also hypothesized bears would den farther from streams or rivers and habitat edges to avoid potential disturbance from conspecifics. Finally, I hypothesized bears would den farther from roads to avoid disturbance from humans.

Study Area

Mississippi has a small, recolonizing black bear population estimated at 50 individuals (Young 2006), including the federally-listed Louisiana black bear (USFWS 1992). I conducted fieldwork primarily in the Delta region of western Mississippi where most black bear sightings occur (Simek et al. 2012). The Delta is about 20,000 km^2 and has low topographic relief with elevations from 3–136 m above mean sea level (MARIS

2002). The humid subtropical climate produces long, hot summers and short, mild winters (Bowman 1999). Common trees in the Delta include oak (*Quercus* spp.), hickory and pecan (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), elm (*Ulmus* spp.), and cottonwood (*Populus deltoides*). The Delta consists of various land covers including agriculture, forests, and urban areas (Bowman 1999). Although bear hunting is illegal, hunting other wildlife species, with and without dogs, and timber harvest are common winter activities in the Delta.

Methods

Data collection

Trap site locations were selected based on areas of known black bear occurrence from observations made by MDWFP personnel, the general public, and myself. I captured black bears from 2005–2010 using modified Aldrich foot snares (Johnson and Pelton 1980b) and culvert traps (e.g., Beeman and Pelton 1976). I immobilized captured individuals with tiletamine and zolazepam (Telazol; A. H. Robins Company, Richmond, Virginia, USA; White et al. 1996) at a dosage of 4–5 mg/kg of estimated body weight, administered with a dart syringe fired from a CO_2-powered pistol or syringe pole. I also equipped captured bears with global positioning system (GPS) radio-collars (Telonics, Inc., Mesa, Arizona, USA; Advanced Telemetry Systems Inc. [ATS], Insanti, Minnesota; Northstar, King George, Virginia, USA), passive integrated transponder (PIT) tags (BioMark, Boise, Idaho, USA), and ear tags. I used leather breakaway links with all radio-collars which deteriorate within 1–3 years (Garshelis and McLaughlin 1998) and released bears at their capture site upon recovery. All capturing and handling of bears followed American Society of Mammalogists guidelines (Gannon et al. 2007) and was approved by the Mississippi Department of Wildlife, Fisheries and Parks and the Mississippi State University Institutional Animal Care and Use Committee (protocol 11-107).

I located dens using aerial and ground-based telemetry and attempted den visits of all radio-collared bears during winters 2009-2011. I collected 3.5-, 5-, or 11-hour relocation data from GPS collars recovered during den visits and recaptures. I also used relocation data from GPS collars recovered by MDWFP personnel before my study. I used 95% fixed kernel density estimators with least squares cross validation for bandwidth selection to estimate annual and autumn home ranges (Seaman et al. 1998) using relocation data for each bear and year with adequate data. Thus, multiple annual or autumn home ranges were calculated for bears with >1 year relocation data, provided an associated den for that bear was located each respective year. I defined annual home range as the area used for $\geq$7.5 consecutive months within a 12-month period and autumn home range as the area used from 15 September to 14 December, similar to Benson and Chamberlain (2007).

I used a geographic information system (GIS; ESRI, Redlands, California, USA) to create map layers describing habitat characteristics and distribution of human activity within home ranges of black bears. I used UTM coordinates of den sites collected during den visits, 30-m digital elevation models (DEM; MARIS 2002), the National Hydrography Dataset (NHD; USGS 2011), Mississippi Institute for Forest Inventory (MIFI) data (29-m resolution; Mississippi Institute for Forest Inventory 2006), and Topologically Integrated Geographic Encoding and Referencing (TIGER) system data (U.S. Census Bureau 2010).

I created a habitat characteristics layer using DEMs and the NHD. I estimated elevation of den sites and mean elevation of each bears' corresponding annual and autumn home ranges using DEMs (ELEVATION). I used elevation of each 30-m cell within each bears' corresponding annual or autumn home range to calculate respective mean elevations of home ranges. I also estimated distance from each den to nearest stream or river (STREAM) and habitat edge (EDGE) using the NHD and MIFI data, respectively. Similarly, I also estimated mean distances to nearest stream or river and nearest habitat edge for each corresponding annual and autumn home ranges. I created a human activity layer using TIGER data from which I estimated distance to nearest road (ROAD) from each den and mean distance to nearest road for each corresponding annual and autumn home range. I used the Euclidean distance tool in ArcMap (ESRI, Redlands, California, USA) to calculate mean distances to nearest stream or river, habitat edge, and road for each den. For each corresponding annual and autumn home range, I averaged distances from the centroid of all 100-m cell within each home range to the nearest respective feature of interest (i.e., stream or river, habitat edge, road).

Data analysis

To evaluate if elevation, habitat features, (i.e., distance to stream or river, distance to habitat edge), and roads differed between den sites and corresponding annual or autumn home ranges, I compared den-site data with respective mean values obtained from annual and autumn home ranges using univariate Wilcoxon signed rank sum tests. I used Wilcoxon signed rank sum tests to control for individual variation in discrete home ranges and because data were continuous.

For multivariate models, I first assessed multicollinearity among model parameters at annual and autumn home range scales using Pearson's correlation. No variables were very correlated ($|r| > 0.7$). Next, to assess whether use of multiple years of den and home range data from the same bears influenced model performance by potential reduction of parameter variances, I conducted fixed effects and mixed model logistic regressions and used the likelihood ratio test of spatial covariance, with individual bears as the random effect (i.e., covariate). I found no differences ($P > 0.05$) between paired models with and without random effects. Consequently, to eliminate nuisance parameters, for final analyses I used multivariate logistic regression with fixed effects only to evaluate differences between parameters of den sites and annual and autumn home ranges. I used Akaike's Information Criterion adjusted for small sample size (AIC_c) to estimate the best-supported models using model ranks and weights (Akaike 1973, Burnham and Anderson 2002). I used model-averaged weighting to calculate parameter estimates and determined relative importance of model parameters (Burnham and Anderson 2002). I also calculated unconditional standard errors (SE) and 95% confidence intervals (CIs) for model parameters and considered the parameters influential if their CIs did not include zero. Statistical significance was considered for all analyses at $\alpha = 0.05$.

Results

I captured and radio-collared 29 bears (15M, 14F) from 2005–2010. I estimated elevation and distance to nearest road, stream or river, and habitat edge for den sites of 13 bears and compared to mean values of respective annual ($n = 25$) and autumn ($n = 23$) home ranges (Table 4.1). I calculated more annual than autumn home ranges because my minimum data requirement for annual home range calculation was 7.5 months which did not always include or may not have included our predetermined autumn dates (i.e., 15 Sept–14 Dec). Bears denned farther from roads compared to respective mean distances within annual and autumn home ranges. However, bears denned closer to habitat edges relative to distances available within annual home ranges. Distance to nearest stream or river and elevation of den sites was similar to mean values within annual and autumn home ranges. Also, distance to nearest habitat edge of den sites was similar to mean distance to nearest habitat edge within autumn home ranges.

Table 4.1 Wilcoxon signed rank sum tests for mean (± standard deviation [SD]) den and annual (n = 25) and autumn home range (n = 23) parameters for black bears, Mississippi, USA, 2005–2011.

Home Range	Parameter[a]	Den		Non Den		Signed Rank (S)	P Value
Annual	ROAD	771	521	467	161	121	0.002
	EDGE	219	279	307	84	-74.5	0.042
	STREAM	623	550	462	160	15	0.726
	ELEVATION	30.7	8.1	29.6	6.6	10	0.815
Autumn	ROAD	816	517	443	173	99	0.003
	EDGE	243	289	300	86	-40	0.232
	STREAM	573	505	458	183	10	0.782
	ELEVATION	31.1	8.3	30.8	7.5	-3	0.934

[a]Model terms include distance (m) to nearest road (ROAD), distance (m) to nearest stream or river (STREAM), elevation based on 30 m DEMs (m; ELEVATION), and distance (m) to nearest habitat edge (EDGE).

The best-supported models for annual and autumn home ranges included distance to nearest road and distance to nearest habitat edge (AIC_c = 62.20 and 56.81, respectively w_i = 0.53 and 0.42, respectively; Table 4.2). The second best model for autumn home ranges included distance to nearest road only (AIC_c = 1.17; w_i = 0.23). No other models contained AIC_c scores ≤2 of the best-supported models for annual and autumn home ranges. Model parameter estimates for distance to nearest road at annual and autumn home range scales and distance to nearest habitat edge at the annual home range scale did not include zero (Table 4.3). Relative importance values suggested distance to nearest road was ≥1.13 times more important than other parameters at annual and autumn home range levels. Distance to nearest habitat edge and distance to nearest stream or river followed consecutively. Elevation was least important of all parameters for both home range levels. The best-supported model at the annual home range scale was: Den site = -0.8630

Table 4.2	Model results for sources of disturbance influencing den-site selection by black bears by annual and autumn home ranges, Mississippi, USA, 2005–2011

Home Range	Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Annual	ROAD + EDGE	3	62.20	0.00	0.53
	ROAD + STREAM + EDGE	4	64.56	2.35	0.16
	ROAD + ELEVATION + EDGE	4	65.05	2.85	0.13
	ROAD	2	66.15	3.95	0.07
	ROAD + STREAM + ELEVATION + EDGE	5	67.70	5.50	0.03
	ROAD + STREAM	3	68.26	6.06	0.03
	ROAD + ELEVATION	3	68.60	6.40	0.02
	ROAD + STREAM + ELEVATION	4	71.09	8.89	<0.01
	STREAM + EDGE	3	71.27	9.07	<0.01
	EDGE	2	71. 50	9.29	<0.01
	NULL	1	71.49	9.29	<0.01
	STREAM	2	71.78	9.58	<0.01
	STREAM + ELEVATION + EDGE	4	74.01	11.81	<0.01
	ELEVATION	2	73.54	11.33	<0.01
	ELEVATION + EDGE	3	73.92	11.71	<0.01
	STREAM + ELEVATION	3	74.37	12.17	<0.01
Autumn	ROAD + EDGE	3	56.81	0.00	0.42
	ROAD	2	57.98	1.17	0.23
	ROAD + STREAM + EDGE	4	59.71	2.91	0.10
	ROAD + ELEVATION + EDGE	4	59.75	2.95	0.09
	ROAD + STREAM	3	60.26	3.45	0.07
	ROAD + ELEVATION	3	60.63	3.83	0.06
	ROAD + STREAM + ELEVATION + EDGE	5	63.02	6.22	0.02
	ROAD + STREAM + ELEVATION	4	63.15	6.34	0.02
	NULL	1	65.96	9.16	0.04
	STREAM	2	67.24	10.44	0.02
	EDGE	2	67.50	10.69	0.02
	STREAM + EDGE	3	68.20	11.39	0.01
	ELEVATION	2	68.35	11.54	0.01
	STREAM + ELEVATION	3	69.70	12. 90	0.01
	ELEVATION + EDGE	3	70.15	13.34	0.01
	STREAM + ELEVATION + EDGE	4	70.63	13.82	<0.01

[a]Model terms include distance (m) to nearest road (ROAD), distance (m) to nearest stream or river (STREAM), elevation based on 30 m DEMs (ELEVATION), and distance (m) to nearest habitat edge (EDGE).
[b]K = number of parameters in model.
[c]Akaike's Information Criterion adjusted for small sample size.
[d]ΔAIC_c = difference between the AIC_c value of the top model and successive models. All models are included.
[e]w_i = Akaike model weight.

Table 4.3 Model averaged parameter estimates for sources of den-site disturbance for black bears, Mississippi, USA, 2005–2011

				95% Confidence Limit		
Home Range	Model Term[a]	Parameter Estimate	Standard Error	Upper	Lower	Relative Importance
Annual	ROAD	0.0034	0.0015	0.0063	0.0005	0.974
	EDGE	-0.0039	0.0019	-0.0003	-0.0076	0.862
	STREAM	0.0002	0.0003	0.0007	-0.0003	0.240
	ELEVATION	0.0008	0.0095	0.0193	-0.0176	0.194
Autumn	ROAD	0.0035	0.0014	0.0063	0.0007	0.988
	EDGE	-0.0022	0.0015	0.0007	-0.0051	0.616
	STREAM	-0.0001	0.0003	0.0004	-0.0006	0.207
	ELEVATION	-0.0005	0.0092	0.0174	-0.0184	0.191

[a]Model terms include distance (m) to nearest road (ROAD), distance (m) to nearest stream or river (STREAM), elevation based on 30 m DEMs (m; ELEVATION), and distance (m) to nearest habitat edge (EDGE).

Discussion

My results indicate black bear den-site selection supports the risk-disturbance hypothesis (Frid and Dill 2002). Bears modified habitat selection by selecting den sites farther from roads compared to mean distances to nearest road within annual and autumn home ranges. Human activity associated with roads appears to negatively influence black bear behavior including den-site selection (Brody and Pelton 1989, Reynolds-Hogland et al. 2007). Brody and Pelton (1989) suggested bears avoided areas with greater road densities and roads with greater traffic volume in western North Carolina. More specifically, Reynolds-Hogland et al. (2007) suggested bears avoided roads based on the predictability of human use; therefore, bears avoided roads with unpredictable human use more than roads with predictable human use. This avoidance of human activity may reduce likelihood of mortality by poachers, hunters, or vehicle collisions (Brody and Stone 1987, Brody and Pelton 1989, Reynolds-Hogland et al. 2007). However, in

Mississippi, bear hunting is illegal and incidents of poaching and vehicle mortalities are limited (Simek et al. 2012). Therefore, bears are likely avoiding areas near roads due to non-lethal disturbances (e.g., vehicle traffic, recreationists, timber harvest).

I found no difference between distance to nearest habitat edge and mean distance to nearest habitat edge within autumn home ranges or between distance of dens to nearest stream or river and mean distance to nearest stream or river within autumn and annual home ranges. However, bears denned closer to habitat edges compared to mean distance to nearest habitat edge within annual home ranges. This may be from reduced predation risk (Garneau et al. 2006); bears in Mississippi no longer coexist with other large carnivores which have been extirpated (e.g., wolves [*Canis rufus* and *C. lupus*], cougars [*Felis concolor*]) and could have posed potential risks. Thus, black bears may not avoid these areas as these potential threats no longer exist. Similarly, the black bear population size in Mississippi is not likely large enough to exhibit density-dependent risk from conspecifics as suggested by Polis (1981) in which intraspecific predation increases as density of bears increases. Bears in the Southeast also exhibit periods of winter activity (Weaver and Pelton 1994, Waller et al. 2012), and denning closer to travel corridors (i.e., habitat edges) may increase efficiency of winter excursions to and from dens.

I found no differences in elevation of den sites and mean elevations of annual and autumn home ranges. Bears in Mississippi use tree and ground dens and typically use tree dens in areas prone to inundation which reduces risk of flooding, similar to bears in Arkansas (White et al. 2001, Waller et al. 2012). Additionally, water control levees installed along the Mississippi River and other smaller rivers (e.g., Yazoo River) prevent flooding in many low-lying areas. This allows bears to use otherwise flood-prone areas without risk of inundation. Higher-resolution and more accurate floodplain elevation data (i.e., Light Detection and Ranging [LiDAR] data) were not available for my study but would be useful for future studies.

It is necessary to identify anthropogenic and natural factors which influence habitat selection by wildlife to appropriately prescribe management regimes. Den-site selection by black bears is particularly important because parturition occurs during the denning period, and disturbance during this time can cause substantial energetic and litter losses (Alt 1984, Linnell et al. 2000). Therefore, conservation of black bear denning habitat (e.g., den trees in flood-prone areas, ground dens surrounded by dense vegetation and located at elevations above flood level) is critical (Hellgren and Vaughan 1989, Linnell et al. 2000, Waller et al. 2012), especially for threatened and endangered populations as occur in Mississippi. Consideration of important denning habitat should occur during land-use planning (e.g., installation of roads, commercial and housing developments) to reduce impact of humans on black bears.

CHAPTER V

CONCLUSIONS

I provided the first description of black bear (*Ursus americanus*) denning ecology in Mississippi which is important in evaluating adequacy of bear management and conservation in the state. Black bears in Mississippi exhibited denning behavior (i.e., denning chronology and den use) similar to other black bear populations in the Southeast such as similar entrance (early Dec–mid-Jan) and emergence (mid-Mar–late Apr) dates and denning durations (51–134 days; Hamilton and Marchinton 1980, Wathen 1983, Smith 1985, Hellgren and Vaughan 1989, Oli et al. 1997). Multiple den use also was common for male and female black bears in Mississippi, demonstrating winter activity (Hamilton and Marchinton 1980, Hellgren and Vaughan 1989, Weaver and Pelton 1994, Oli et al. 1997), which I attributed to greater food availability and disturbance from flooding, severe weather, and human disturbance (Hamilton and Marchinton 1980, Graber 1990, Oli et al. 1997, Hightower et al. 2002). However, unlike bears in other Southeastern studies (e.g., Smith 1985, Hellgren and Vaughan 1989, Weaver and Pelton 1994, Oli et al. 1997), all bears I studied exhibited denning behavior each winter.

Tree and ground dens are used commonly by black bears throughout the Southeast (Hellgren and Vaughan 1989, Weaver and Pelton 1994, Hightower et al. 2002). I recorded similar proportions of tree and ground den use by both sexes, including parturient females. Although I did not measure den tree availability, den trees appear to be an important habitat component of black bears in bottomland hardwood forests prone to flooding such as in Mississippi (Smith 1985, Oli et al. 1997).

Black bears in Mississippi demonstrated scale-dependent den-site selection by selecting greater percentage horizontal cover at 100-m resolution. Denser horizontal cover likely provides greater security by concealing dens (Johnson and Pelton 1981, Hellgren and Vaughan 1989, Hayes and Pelton 1994). Additionally, ground dens surrounded by dense vegetation are more energetically efficient (Hellgren and Vaughan 1989). Protection from disturbance and surrounding elements while denning is necessary for bears because disturbance during the denning period can be energetically costly, especially for parturient females, and result in litter loss (Linnell et al. 2000).

Similarly, my results indicate black bear den-site selection supports the risk-disturbance hypothesis (Frid and Dill 2002). Bears modified habitat selection by selecting den sites farther from roads compared to mean distances to nearest road of annual and autumn home ranges. Human activity associated with roads appears to negatively influence black bear behavior including den-site selection (Brody and Pelton 1989, Reynolds-Hogland et al. 2007). This avoidance of human activity may reduce likelihood of mortality by poachers, hunters, or vehicle collisions (Brody and Stone 1987, Brody and Pelton 1989, Reynolds-Hogland et al. 2007). However, in Mississippi, bear hunting is illegal and incidents of poaching and vehicle mortalities are limited (Simek et al. 2012). Therefore, bears are likely avoiding areas near roads due to non-lethal disturbances (e.g., vehicle traffic, recreationists, timber harvest).

Distance to nearest habitat edge was not significant at any scale. However, bears denned closer to habitat edges compared to mean distance to nearest habitat edge within annual home ranges. This may be from reduced predation risk (Garneau et al. 2006);

bears in Mississippi no longer coexist with other large carnivores which have been extirpated (e.g., wolves [*Canis rufus* and *C. lupus*], cougars [*Felis concolor*]) and could have posed potential risks. Thus, black bears may not avoid these areas as these potential threats no longer exist. Similarly, the black bear population size in Mississippi is not likely large enough to exhibit density-dependent risk from conspecifics as suggested by Polis (1981) in which intraspecific predation increases as density of bears increases. Bears in the Southeast also exhibit periods of winter activity (Weaver and Pelton 1994, Waller et al. 2012), and denning closer to travel corridors may increase efficiency of winter excursions to and from dens.

In addition to identifying the spatial scale at which wildlife select for certain attributes, it is also necessary to identify factors which influence habitat selection by wildlife to appropriately prescribe management regimes. Den-site selection by black bears is particularly important because parturition occurs during the denning period, and disturbance during this time can cause substantial energetic and litter losses (Alt 1984, Linnell et al. 2000). Therefore, conservation of black bear denning habitat (e.g., den trees in flood-prone areas, ground dens surrounded by dense vegetation and located at elevations above flood level) is critical (Hellgren and Vaughan 1989, Linnell et al. 2000, Waller et al. 2012), especially for threatened and endangered populations as occur in Mississippi. Consideration of important denning habitat should occur during land-use planning (e.g., installation of roads) to reduce human impact on black bears.

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