

## Denning chronology and den characteristics of American black bears in Mississippi

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**Abstract:** Winter denning is a critical component of American black bear (*Ursus americanus*) ecology. Mississippi has a small recolonizing population (about 50 individuals), including the federally-threatened Louisiana black bear (*U. a. luteolus*), and knowledge of den use is needed to effectively conserve the species. We quantified black bear denning chronology ( $n = 15$ ) and den use ( $n = 18$ ) in Mississippi during 2005–2011. Denning was highly variable and females entered dens earlier than males and emerged later; multiple den use by both sexes in a single winter was common. We recorded equal numbers of tree and ground dens, with ground dens at higher elevations surrounded by dense vegetation. With the exception of all bears denning each winter, black bears in Mississippi exhibited denning chronology and characteristics similar to other black bear populations in the southeastern United States.

**Key words:** American black bear, den chronology, den use, Mississippi, *Ursus americanus*

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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).

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*).

Our 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

We conducted fieldwork on public and private lands in the Delta region of western Mississippi where most black bear sightings occur (Young 2006). The Delta is about 20,000 km<sup>2</sup> and has low topographic relief with elevations from 3–136 m above mean sea level (Mississippi Automated Resource Information System [MARIS] 2002). The humid subtropical climate produces long, hot summers and short, mild winters (Bowman 1999). Common trees include oak (*Quercus* spp.), hickory (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), elm (*Ulmus* spp.), pecan (*Carya* spp.), and cottonwood (*Populus* spp.). 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

Black bears were captured using modified Aldrich foot snares (Johnson and Pelton 1980b) and culvert traps from 2004–10. We immobilized captured

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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<sub>2</sub>-powered pistol or syringe pole. We equipped captured bears with global positioning system (GPS; Telonics, Inc., Mesa, Arizona, USA; Advanced Telemetry Systems Inc. [ATS], Isanti, Minnesota; Northstar, King George, Virginia, USA) or very high frequency (VHF; Telonics, Inc. and ATS) radiocollars, passive integrated transponder (PIT) tags (BioMark, Boise, Idaho, USA), and ear tags. We used leather breakaway links with all GPS and VHF radiocollars (Garshelis and McLaughlin 1998). We recorded sex and released all bears at their capture site upon recovery.

We located dens using aerial and ground-based telemetry during winters 2005–11. We attempted den visits of all radiocollared bears. We 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, we collected relocation data from GPS collars recovered during recaptures and den visits. Relocation schedules for GPS collars were 3.5-, 5-, and 11-hr intervals. We considered a bear to be denning if it remained within an area with a radius  $\leq 135$  m for at least 6 consecutive days. We used these characteristics based on telemetry error of bears known to be denning and the minimum known length of time a bear denned in our study based on our observations and GPS collar relocation data. We defined date of den entrance as the first day a bear remained within the defined denning area centered on the den location. We collected universal transverse Mercator (UTM) coordinates of each den during den visits to establish its center point. We defined den emergence as the first day the bear was located and remained outside the denning area ( $>135$  m from den). We estimated denning duration as number of days between den entrance and emergence from each den. Because some bears used multiple dens during a winter, we 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, we included dens used before and after disturbance for calculation of mean number of dens used per winter.

We classified dens as tree or ground. We 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. We recorded aspect, overall den dimensions ( $l \times w \times d$ ), presence of a bed, and composition of bedding material. We also measured dimensions ( $l \times w$ ) and location on tree of den entrances. Additionally for tree dens, we recorded tree species, diameter at breast height (dbh), tree height, and height of cavity entrance. We 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.

We recorded elevation, vertical cover, horizontal cover, basal area, frequency of potential den trees (dbh  $\geq 91$  cm), and habitat type for each den site. We estimated elevation (m) using digital elevation models (DEM; MARIS 2002). We measured percentage vertical cover using a spherical densiometer (Lemmon 1956, Hayes and Pelton 1994). Standing with our backs adjacent to the den, we took one reading in each cardinal direction, another directly over ground dens, and averaged readings to estimate mean percentage vertical cover for each den. We measured percentage horizontal cover using a modified Nudds density board (Nudds 1977). We 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). We estimated basal area (m<sup>2</sup>/ha) using a 10-factor prism. We 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 ( $n = 5$ ), we used relocation data from GPS collars as previously described (i.e.,  $\geq 6$  days in duration with all locations

**Table 1. Denning chronology of black bears in Mississippi, 2006–11, including mean, standard deviation, denning durations, denning periods, and total number of dens.**

| Age–sex class  | <i>n</i>       | 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 <sup>a</sup> | 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                        |
| 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     | 5              | 6         | 27 Nov (16 Nov–3 Jan)   | 22 Mar (18 Mar–6 Apr)    | 78 <sup>b</sup>                    | 78 <sup>b</sup>                  | 1 <sup>b</sup>             |
| With cubs      | 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)             |

<sup>a</sup>Data were recorded for 7 individual females who were classified into different age and reproductive classes during 2006–11.

<sup>b</sup>Only 1 parturient female had data for denning duration, denning period, and total number of dens.

≤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.

We used den-year as the experimental unit for analyses after we pooled data across years; we thus assumed no inter-annual differences in denning chronology and den-site selection patterns. We used Wilcoxon-Mann-Whitney and *t*-tests to compare male and female denning chronology and duration. We 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

We estimated den entrance ( $n = 24$ ) and emergence dates ( $n = 23$ ) for 15 bears (7 F, 8 M; Table 1). Overall mean success rate of GPS collars was 67%

**Table 2. Types of dens used by American black bears in Mississippi, 2005–11.**

| Age–sex class  | <i>n</i>        | Den years | Den type |        |
|----------------|-----------------|-----------|----------|--------|
|                |                 |           | Tree     | Ground |
| Adult male     | 5               | 8         | 3        | 5      |
| Female         | 13 <sup>a</sup> | 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      |

<sup>a</sup>Data were recorded for 13 individual females who were classified into different age and reproductive classes during 2005–11.

(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). We recorded 19 estimates of denning duration and denning period. The difference in mean duration of denning between males (51 days) and females (75 days) approached significance ( $t = 1.96$ , 17 df,  $P = 0.067$ ). 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, we 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.

We characterized 40 dens across 38 den years (Table 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 3). Although den entrance measurements varied by den type, den entrance areas ( $l \times w$ ) overlapped considerably.

Ten den trees were bald cypress, 8 were oak, 1 was sweetgum, and 1 was willow (*Salix* sp.). Three den trees were snags (1 oak, 1 sweetgum, and 1 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

**Table 3. Mean, standard deviation, and range of measurements of dens used by American black bears in Mississippi, 2005–11.**

| Parameter   | <i>n</i> | Tree (SD, range)          | <i>n</i> | 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) |

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.

We 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.

We 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 percent 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 percent 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<sup>2</sup>/ha (SD = 11.4,  $n = 39$ ) for den sites including 19.1 m<sup>2</sup>/ha for tree (SD = 13.6  $n = 18$ ) and 14.5 m<sup>2</sup>/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

We provide the first description of black bear denning chronology and den use in Mississippi. This is important in evaluating the adequacy of bear management and conservation in the state. We recognize our small sample sizes may limit statistical power; however, we 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). We 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 we attributed to greater food availability and disturbance from flooding, severe weather, and humans (Hamilton and March-

inton 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 we studied exhibited denning behavior each winter.

We documented one confirmed case of tree den abandonment (by an adult female with 2 cubs) due to flooding. Smith (1985) also documented tree den abandonment on 3 occasions due to flooding for 3 bears in White River National Wildlife Refuge, Arkansas, including 1 occasion by an adult female that abandoned 2 2-month old cubs. The 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 commonly used by black bears throughout the Southeast (Hellgren and Vaughan 1989, Weaver and Pelton 1994, Hightower et al. 2002). We recorded similar proportions of tree and ground dens use by both sexes, including parturient females. Although we 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%; Alt and Gruttadauria 1984, Wathen 1983, 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).

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