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Source: Southeastern Naturalist, 11(3):517-528. 2012.
Published By: Eagle Hill Institute
DOI: http://dx.doi.org/10.1656/058.011.0314
URL: http://www.bioone.org/doi/full/10.1656/058.011.0314

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Denning Ecology of Florida Black Bears in North-Central Florida

Elina P. Garrison[1,*], J. Walter McCown[1], Mark A. Barrett[2], and Madan K. Oli[3]

Abstract - We studied the denning chronology, den type, and den-site characteristics of *Ursus americanus floridanus* (Florida Black Bear) in Ocala National Forest (ONF) and the adjacent residential area of Lynne, FL. We monitored 35 radio-collared females for 62 den years from 1999 through 2003. Den entry dates did not differ between parturient females (females that gave birth to cubs during the winter) and nonparturient (solitary females or females with yearlings) ($P = 0.139$). Females with cubs exited dens later ($P < 0.001$), and denned longer (mean =113 ± 3.3 days) than females without cubs (mean = 54 ± 6.0 days; $P < 0.001$). Among females with cubs, primiparous females entered dens on average 28 days later than multiparous females ($P = 0.003$); however, exit date and duration of denning did not differ between the two groups. Female bears denned in ground nests most frequently ($n = 45$), followed by excavated dens ($n = 7$); one female used a tree den. Compositional analysis revealed that denning habitat selection occurred in ONF, with sand pine as the preferred denning habitat, followed by swamp and pine flatwoods habitats. Denning habitat selection was not evident in Lynne, although the majority of females denned in swamp habitats. Parturient females often denned in ecotones with dense vegetation, due perhaps to the fact that such ecotones offer better protection to the female and her cubs from potential predators and weather elements. Habitat management activities should be limited during peak denning of parturient females, from late December to mid-April, particularly in Sand Pine - xeric oak and pine flatwood - swamp ecotones.

Introduction

Denning, or winter dormancy, in bears is thought to have evolved in response to seasonally occurring periods of adverse weather conditions and lack of food resources (Hayes and Pelton 1994). Denning is obligatory for parturient females, as birth and early maternal care of altricial young occur during winter dormancy (Alt 1983, Hellgren 1998). Denning is not, however, obligatory for all bears. In North American *Ursus maritimus* Phipps (Polar Bear) and some *U. arctos* L. (Brown Bear) populations, males may remain active during all or part of the winter if sufficient food is available (Ramsay and Stirling 1988, Van Daele et al. 1990). In the southern range of *U. americanus* Pallas (American Black Bear), adult and subadult males and some nonparturient females may remain active during all or part of the winter (Dobey et al. 2005, Graber 1990, Hellgren and Vaughan 1989, Mitchell et al. 2005, Weaver and Pelton 1994, Wooding and Hardisky 1992).

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While denning, particularly in northern latitudes, bears cease ingressive and eliminative functions and are in a lethargic state or deep sleep (Nelson et al. 1983). Disturbance during this period, particularly disturbance of females with cubs, can diminish fitness by increasing energy expenditure and may cause cub abandonment (Alt 1984, Elowe and Dodge 1989, Linnell et al. 2000, Oli et al. 1997). The period with potential for disturbance to denning bears varies by region because den entry and exit dates as well as duration of denning may vary regionally (Johnson and Pelton 1980, Smith et al. 1994). Types of dens used by Black Bears also vary considerably among populations, because different habitats provide different denning options (Hayes and Pelton 1994, Johnson and Pelton 1981). Thus, population-specific knowledge of denning habitat requirements and chronology is necessary for formulating appropriate management strategies for Black Bears (Hightower et al. 2002).

Ursus a. floridanus Merriam (Florida Black Bear), a threatened subspecies of the American Black Bear, historically inhabited all of Florida (Brady and Maehr 1985, Maehr et al. 2001). However, unregulated hunting in the 1800s to 1970s and loss and fragmentation of habitat substantially reduced the range of Florida Black Bears (Brady and Maehr 1985). Currently, the Florida Black Bear exists in 7 relatively isolated populations that exhibit limited connectivity (Dixon et al. 2007, Eason 2000). Conservation of the remaining populations of the Florida Black Bear requires a thorough understanding of the local ecological requirements, including for denning; however, limited data are available for this subspecies (Seibert 1995, Wooding and Hardisky 1992). We therefore investigated denning ecology of female Florida Black Bears in Ocala National Forest (ONF) and the adjacent residential area of Lynne, in north central Florida (Fig. 1). Specifically, we investigated denning chronology, determined den types used, and tested for the selection of macroscale denning habitat by Florida Black Bears in north-central Florida.

Field-Site Description

Ocala National Forest covers more than 1740 km^2 and supports the core habitat for the largest Black Bear population in Florida (Simek et al. 2005). ONF is bounded to the west and north by the Ocklawaha River and to the east by the St. Johns River. Our study area covered the central portion of ONF and an adjacent residential community of Lynne, and encompassed approximately 760 km^2 (520 km^2 in ONF and 240 km^2 in Lynne; Fig. 1).

The vegetation in ONF was dominated by a central ridge with a Sand Pine–scrub oak community, dominated by *Pinus clausa* Chapman ex Engelm. (Sand Pine), *Quercus myrtifolia* Willd. (Myrtle Oak), *Q. geminata* Small (Sand Live Oak), and *Q. chapmanii* Sarg. (Chapman Oak). Other major vegetation types in ONF included swamps and marshes along the Ocklawaha and St. Johns rivers, pine flatwoods between the rivers and central ridge, mixed hardwood swamps, and numerous lakes, ponds, and prairies (Aydelott et al. 1975). Pine flatwoods were dominated by *P. elliottii* Engelm. (Slash Pine), with scattered bays such as

Magnolia virginiana L. (Sweetbay Magnolia) and *Gordonia lasianthus* (L.) Ellis (Loblolly Bay). In addition to the scrub oaks, common shrub species included

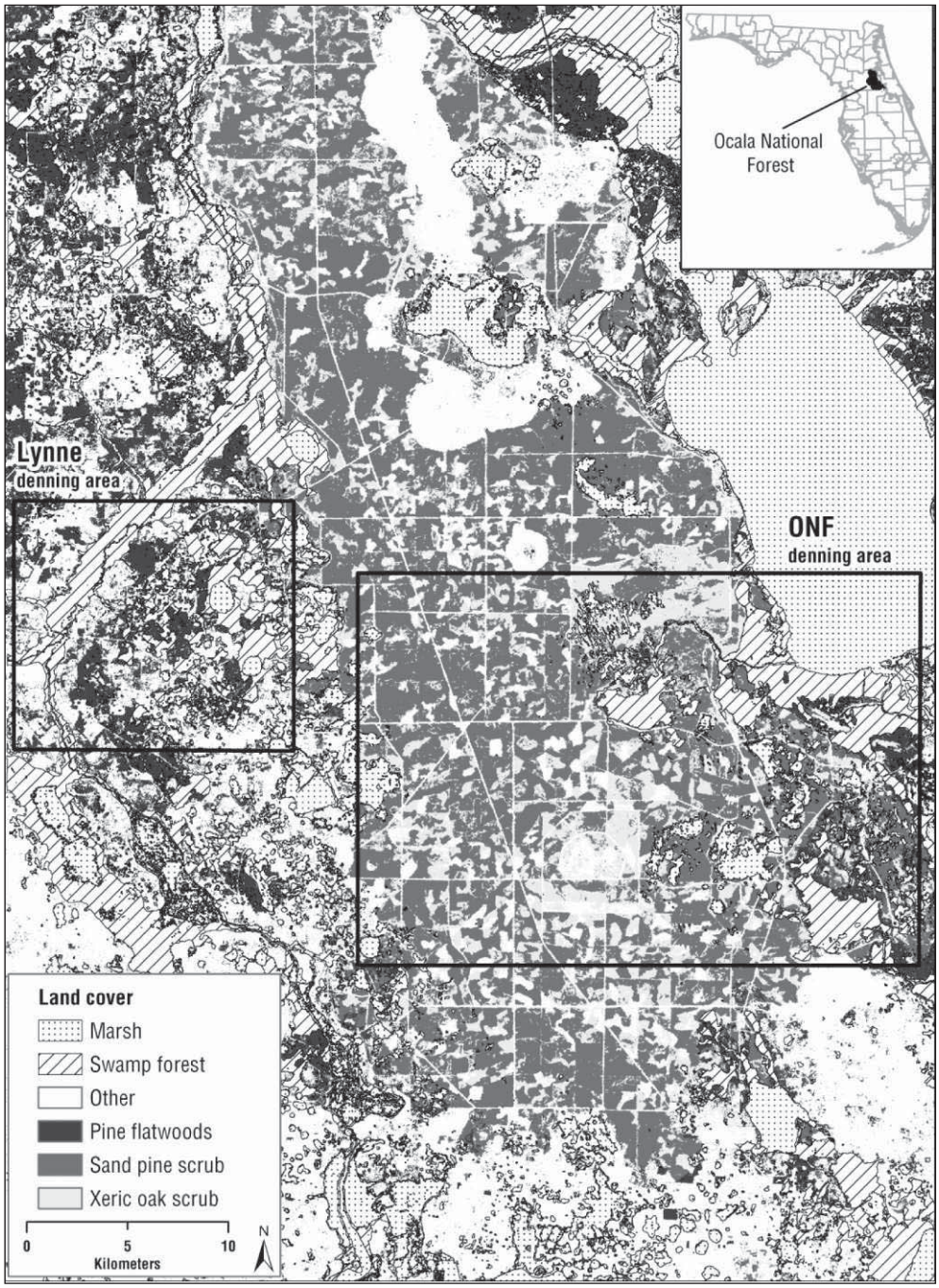

Figure 1. Map of Ocala National Forest (ONF) displaying the ONF and Lynne study areas (thick-line polygons) within which Black Bear dens were located. Land-cover classes are grayscale or patterned. Inset map depicts geographic location of the study area in north-central Florida.

Sabal etonia Swingle ex Nash (Scrub Palmetto) and *Ceratiola ericoides* Michx. (Florida Rosemary). In wetter areas, *Serenoa repens* (Bartman) Small (Saw Palmetto) and *Lyonia ferruginea* (Walter) Nutt (Fetterbush) were common.

ONF is managed with an ecological approach to achieve multiple-use management that results in a healthy ecosystem while meeting the needs of people, including outdoor recreation (United States Department of Agriculture 1999). Sand Pine is harvested to regenerate scrub to early successional conditions, with stand age ranging from recently harvested clear-cuts to stands ≥20 years. ONF receives more visitors than any other national forest in Florida (US Forest Service 2010). With the exception of 4 designated wilderness areas, ONF contains off-road-vehicle and logging roads, forest trails, and an extensive grid of roads maintained by the US Forest Service. Natural habitats in Lynne mainly consisted of swamp forest, pine flatwoods, marsh, and Sand Pine. However, compared to ONF, Lynne habitat was highly fragmented by roads and residential and commercial developments (Hostetler et al. 2009).

Methods

We captured bears during July 1999–May 2003 with Aldrich spring-activated foot snares (Johnson and Pelton 1980) modified for safety (Scheick et al. 2009). We immobilized captured bears with a 1:1 mixture of tiletamine hydrochloride and zolazepam hydrochloride (Telazol®) administered at 3.0–4.5 mg/kg (adapted from Taylor et al. 1989) of estimated body weight via CO_2-charged dart delivery system (Model 1V.31NPL, Telinject, Victoria, Australia). We fitted all adult female bears with a VHF motion-sensitive radiocollar (Telonics, Mesa, AZ). Collars had a leather breakaway connector that allowed them to fall off after approximately 2–3 years (Seibert and Wooding 1994). We lip-tattooed and ear-tagged bears for identification, extracted a 1st premolar to determine age (Willey 1974), collected standard morphometric data, and determined reproductive status (Garrison et al. 2007, McCown et al. 2009). Bears were handled in a humane manner, and all procedures complied with guidelines of the American Society of Mammalogists (Animal Care and Use Committee 1998) and had been approved by the University of Florida's Institutional Animal Care and Use Committee (protocol # A707).

We located radiocollared bears 1–7 days a week from the ground via standard triangulation methods (White et al. 2001) and from a Cessna 172 aircraft equipped with wing-mounted antennas. We classified bears as denning when successive telemetry locations during the denning season were <400 m apart. Denning status and den location (if the bear was indeed denning) were subsequently verified by approaching the den using handheld telemetry equipment during January and February 1999–2003. To minimize disturbance to the denning bears, we quietly clipped a trail with small pruning shears through the vegetation as we approached the den site.

We estimated den entry date as the midpoint between the last date of recorded movement and the first date at the den (Oli et al. 1997). Den

emergence date was defined as the midpoint between the last location of a bear in the den and the first location of that bear away from the den (O'Pezio et al. 1983). Duration of denning was defined as the period between the entry and exit dates; this definition was used even when a bear moved a den (e.g., due to disturbance), as long as location did not change after the move. We classified females into 2 categories based on their reproductive status: (1) parturient (females that gave birth to cubs during the winter) and (2) non-parturient (solitary females and those with yearlings). Parturient females were further classified as either primiparous (first-time mothers) or multiparous (females that had given birth previously) based on physical characteristics of the female at capture (lactating, characteristics of teats indicating previous nursing) or presence of cubs or yearlings (at capture or through remote camera photos). We used the Kruskal-Wallis test to compare den entry and exit dates, and duration of denning with respect to year, reproductive status, and reproductive experience (primiparous or multiparous).

Den sites were examined after bears emerged. We obtained Universal Transverse Mercator (UTM) coordinates of den sites with a Garmin eTrex (Garmin International, Olathe, KS) global positioning system (GPS). We classified dens as ground nests, excavations, or tree dens, measured den dimensions, and noted non-quantitative, descriptive characteristics of the den surroundings.

Several studies have shown that female Black Bears do not select den sites at random (Hayes and Pelton 1994, Johnson and Pelton 1980, Klenzendorf et al. 2002, Oli et al. 1997), and it is important to consider both use and availability to understand selection of den sites (Reynolds-Hogland et al. 2007); therefore, we tested for denning habitat selection using compositional analysis (Aebischer et al. 1993). We used a geographic information system (GIS; ArcMap 9.2, ESRI, Redlands, CA) to aid in estimating use and availability. Land-cover types were represented by a 30-m resolution, digital land-cover layer created at a statewide scale for Florida (Kautz et al. 2007; see Gilbert and Stys 2004 for a detailed description of land-cover types). Twenty-four land-cover types occurred within each study area, but were reclassified into 6 habitat types for our analysis (Fig. 1) because most were analogous types or scarce in the study areas. The 6 habitat types were Sand Pine, xeric oak scrub, pine flatwoods, marsh, swamp forest, and other (Table 1). To assign dens to habitat type, we used the GIS to intersect the habitat-type layer with den-site locations. Furthermore, each forest cover type was verified with field observations during den visits. We estimated use as the proportion of dens in each habitat type. We generated 95% minimum convex polygon (MCP) home ranges from telemetry location data (mean locations/bear: ONF = 41, Lynne = 38) for each female bear for every den year. The percentage area of each habitat type within an MCP was considered the availability of that habitat type. However, for individual bears with multiple den years, we summarized percentage habitat availability over their multiple MCP areas. We therefore considered each bear, rather than each year, as an experimental unit. Annual home-range size (MCP areas) ranged from 4.89 to 98.77 km^2 for ONF and from 3.45 to 39.6 km^2 for Lynne.

A compositional analysis was conducted for ONF females (n = 18) and for Lynne females (n = 11). First, we used a MANOVA to test the null hypothesis that habitat selection did not occur. If the null hypothesis was rejected, we compiled a ranking matrix where selection (or lack thereof) for each habitat type was compared with that for all other habitat types. Significance of pair-wise comparisons of habitat selection was based on randomization tests with 10,000 runs, as described by Aebischer et al. (1993). If a habitat was available but not used, we replaced the missing value with a small positive number (0.01) to avoid computational problems (Aebischer et al. 1993).

Results

During 1999–2003, we monitored 35 females for 62 den years. We determined denning chronology for 38 parturient den years, and 18 nonparturient den years. Six nonparturient females remained active through the winter. Den entry dates did not differ between parturient and nonparturient females (χ^2 = 2.19, d.f. = 1, P = 0.139). Parturient females exited dens later (χ^2 = 34.7, d.f. = 1, P < 0.001), and denned longer (mean ± SE = 113 ± 3.3 days) than nonparturient females (54 ± 5.7 days; χ^2 = 30.28, d.f. = 1, P < 0.0001; Table 2). Den entry and exit dates of parturient females differed among years (χ^2 = 12.3, d.f. = 3, P = 0.006; χ^2= 14.4,

Table 1. Habitat availability and use for Florida Black Bears denning in Ocala National Forest (ONF) and Lynne, FL. Percentage availability (A%) is the mean (± SE) percentage cover of each habitat type that occurred within the home range (95% minimum convex polygon) of female bears with dens in ONF (n = 18) and Lynne (n = 11). Percentage use (U%) is the percentage of dens (n = 25 for ONF and n = 11 for Lynne) that occurred in each habitat type. Land-cover type is based on a statewide, 30-m-resolution digital land-cover layer (Kautz et al. 2007); some cover types were combined because they were analogous types or scarce.

	ONF		Lynne		
Habitat type	A% ± (SE)	U%	A% ± (SE)	U%	Land-cover type
Sand Pine	52.2 (3.8)	56	8.9 (4.1)	0	Sand Pine
Xeric oak scrub	23.3 (1.3)	8	n/a[A]	n/a	Xeric oak scrub
Pine flatwoods	1.1(0.3)[B]	8	28.6 (4.2)	18	Pinelands
Swamp forest	4.8 (1.3)	24	29.5 (2.8)	64	Shrub swamp, hardwood swamp, bay swamp, cypress swamp, mixed wetland forest.
Marsh	8.6 (4.2)	4	9.8 (2.7)	9	Freshwater marsh and wet prairie, open water
Other	10.1 (1.1)	0	22.8 (2.1)	9	Sandhill, dry prairie, mixed pine–hardwood forest, hardwood hammock and forest, shrub/brushland, grassland, bare soil/clearcut, high- and low-impact urban, improved and unimproved pasture, other agriculture

[A]Xeric oak scrub was added to the "other" class for Lynne due to the small percentage composition (2.5%) and availability to only a few female bears.

[B]Although pine flatwoods had a small percentage composition in ONF, it was available to all female bears in ONF.

d.f. = 3, $P = 0.002$), but duration of denning did not ($\chi^2 = 4.8$, d.f. = 3, $P = 0.187$). Among parturient females, primiparous females entered dens on average 28 days later than multiparous females ($\chi^2 = 8.71$, d.f. = 1, $P = 0.003$). However, exit date and total denning period did not differ between these 2 groups ($\chi^2 = 3.27$, d.f. = 1, $P = 0.07$; $\chi^2 = 1.53$, d.f. = 1, $P = 0.22$). Den exit and entry dates, or duration of denning of nonparturient females did not differ among years (Table 2).

We located 53 dens, of which 42 (79%) were used by parturient females and 11 by nonparturient females. Solitary females and females with yearlings typically left the den when approached, making location of these dens difficult. Thirty-four (81%) of the parturient females denned in ground nests, 7 (17%) denned in excavations, and 1 (2%) female used a tree den. All nonparturient females denned in ground nests. Ground nests were typically oval, and dimensions averaged 71 × 56 × 23 cm (length × width × depth). Bedding material consisted of dry leaves, pine needles, or other dry litter available in the habitat. Dimensions of the excavated dens averaged 96 × 74 × 100 cm (height × width × depth), and all but 2 excavated dens were in sandy soil. Entrances to excavated dens were half moon–shaped and typically contained very little bedding material, such as dry leaves, on top of the sand. The only bear that used a tree den was a 10-year-old female with a litter of 3 cubs. The den tree was a *Nyssa sylvatica* Marsh (Black Gum). In ONF, dens were located in all habitat types except "other" (Table 1). Compositional analysis revealed that den-site selection was

Table 2. Denning chronology of female Florida Black Bears in north-central Florida. Den entry dates, emergence dates, and duration of denning are given for each year and for all years pooled, by reproductive status (parturient, nonparturient) and, for pooled years, reproductive experience (primiparous, multiparous).

	Den entry			Den exit			Duration of denning		
Group	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*
1999–2000									
Parturient	19 Jan	4.5	8	28 Apr	3.5	7	103	4.1	7
Nonparturient	-[A]			-			-		
2000–2001									
Parturient	18 Dec	6.3	10	12 Apr	1.8	8	114	6.9	8
Nonparturient	1 Jan	5.9	12	1 Mar	3.7	12	61	6.4	12
2001–2002									
Parturient	19 Dec	5.4	11	14 Apr	3.3	12	116	6.2	11
Nonparturient	29 Jan	9.8	3	12 Mar	5.0	3	43	9.9	3
2002–2003									
Parturient	2 Jan	7.8	8	1 May	4.7	8	121	4.4	8
Nonparturient	6 Jan	6.2	3	16 Feb	14.0	3	41	20.4	3
Pooled years									
Parturient	28 Dec	3.5	37	19 Apr	2.2	35	113	3.3	34
Nonparturient	6 Jan	4.9	18	1 Mar	3.7	18	54	5.7	18
Primiparous	20 Jan	8.7	7	30 Apr	6.8	6	106	8.6	6
Multiparous	23 Dec	3.3	30	17 Apr	2.1	28	116	3.1	27

[A]No data.

not random (Wilk's $\Lambda = 0.11$, $P = 0.0001$), and Sand Pine ranked as the most preferred denning habitat, followed by swamp forests and pine flatwoods. Sand Pine was preferred over scrub, marsh, and other, while pine flatwoods and swamp habitats were preferred over scrub and other. In Lynne, dens were located in all habitat classes except Sand Pine. The randomization test did not provide evidence for denning-habitat selection in Lynne ($\Lambda = 0.19$, $P = 0.114$).

Discussion

Understanding aspects of denning ecology is important for effective management of Black Bear populations because birth and early maternal care occur in dens (Hellgren and Vaughan 1989, Linnell et al. 2000). In our study area, parturient females generally entered dens earlier and denned longer than nonparturient females, a finding consistent with those of other studies (Kashbohm et al. 1996, Mitchell et al. 2005, Oli et al. 1997, Schooley et al. 1994, Wathen 1983). The average duration of denning of parturient females (113 days) and the prevalent use of ground dens recorded in this study are similar to those reported for other southeastern populations of Black Bears (Dobey et al. 2005, Hamilton and Marchinton 1980, Hellgren and Vaughan 1989, Martorello and Pelton 2003, Weaver and Pelton 1994, White et al. 2001, Wooding and Hardisky 1992). Use of tree dens has also been reported in southeastern populations of Black Bear (Crook and Chamberlain 2010, Dobey et al. 2005, Hellgren and Vaughan 1989, Weaver and Pelton 1994, White et al. 2001). In our study, only one female used a tree den.

Although tree dens or excavated dens likely provide more protection from weather and disturbance than do ground nests, bears have apparently adapted to using ground nests by using thick vegetation as a substitute for the concealment and protection that a tree den or excavated den might provide (Martorello and Pelton 2003). We speculate that in addition to providing concealment, dense vegetation surrounding a den site allows females to more easily hear an approaching predator and therefore serves as a means of warning. It often took us several hours to reach the den sites within hearing or viewing distance of a female with cubs; although we took precautions (e.g., only 1 or 2 people would approach the den, and to reduce noise we clipped vegetation with small pruning shears rather than break it), we found it difficult to move through the thick vegetation quietly enough to avoid alerting the denning female. In most cases, the females were fully awake by the time we were within viewing distance. In contrast, den sites of females without cubs were more accessible, and it appeared that ease of escape, greater visibility, and awareness of the surroundings were important factors influencing selection of den sites.

Sand Pine was the most preferred denning habitat in ONF, and it was also the most abundant habitat type. Swamp forests also were selected for; on average, swamp forests covered only 5% of the female's home ranges, yet 25% of the dens occurred in swamp forests, making it an important denning habitat. The lack of statistical evidence for denning habitat selection in Lynne may be a consequence of small sample size. Nonetheless, most (64%) of the dens in Lynne occurred in

swamp forests. Typical understory vegetation in swamp forests (e.g., Fetterbush, *Ilex glabra* (L.) Gray [Gallberry], *Smilax* spp. [greenbriar]) provides a dense cover, making it difficult for intruders to approach the den without being noticed. Many dens were located near habitat edges (or within ecotones). Fifteen of 20 dens used by parturient females in mesic-hydrid habitats occurred in ecotones; 5 of the 20 dens in mesic-hydric habitat were located next to lakes or ponds. In ONF, the dens occurred in sandpine - xeric oak ecotones in the center of the forest and near lakes and ponds in the eastern edge of the forest. In Lynne, dens occurred mainly in the pine flatwoods - swamp forest ecotone. No nonparturient females denned in ecotones. Whether proximity of dens to habitat edge is a result of coarse-scale habitat classification, edge effects, or proximity to water, it may be important to consider ecotones in bear management strategies in addition to focusing on specific habitat types.

We found no evidence of feeding by parturient females during denning, whereas most den sites of nonparturient females had evidence of feeding (e.g., pulled shoots of Saw or Scrub Palmetto) surrounding the nests. Although activity during denning is rare in Black Bears inhabiting northern habitats, evidence of feeding and movement has been reported in other southern Black Bear populations (Hightower et al. 2002, Pelton et al. 1980).

The Ocala bear population is characterized by low cub survival (Garrison et al. 2007), and human disturbance of denning bears may further reduce cub survival. Thus, forest management practices and recreational activities during the denning season should be planned to minimize disturbance to denning bears. Specifically, prescribed burning and timber harvesting should be limited between mid-December and mid-April in habitats suitable for denning, including sand pine, pine flatwoods, and swamp forest. If prescribed burning or logging is unavoidable, it should be carried out early in the denning season so that pregnant females may leave disturbed areas before they have given birth.

The majority of the dens in our study sites were ground nests, and availability of suitable den sites does not appear to be a limiting factor in the ONF and Lynne. Although open nests do not provide the thermoregulatory benefits offered by enclosed dens, dense vegetation can provide structural security and reduce heat loss from wind (Hayes and Pelton 1994, Hellgren and Vaughan 1989, Ryan and Vaughan 2004). In the mild winters of northern Florida, however, protection from weather is probably not as critical as the protection from disturbance afforded by dense vegetation. Based on results of compositional analysis, and anecdotal observation (e.g., the difficulty of reaching den sites of parturient females due to the thick vegetation), it appears that den-site selection is non-random. Further research is needed to evaluate the microhabitat characteristics of den sites of females with young of the year.

Acknowledgments

Our research was funded by the Florida Fish and Wildlife Conservation Commission (FWC), Florida Department of Transportation, Wildlife Foundation of Florida, African Safari Club International, Jennings Scholarship, and Department of Wildlife Ecology

and Conservation, University of Florida. Special thanks to M. Cunningham, J. Dixon, M. Moyer, D. Masters, K. Oven, K. Hanson, C. Long, and E. Merchant for assistance with all aspects of the fieldwork. We thank FWC pilots J. Wisniesky, J. Johnston, and P. Crippen for telemetry flights. We also thank T. Eason, M. Sunquist, G. Tanner, D. Onorato, B. Scheick, and two anonymous reviewers for helpful comments on the manuscript.

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