CHARACTERISTICS OF BLACK BEAR DENS IN THE SOUTHERN APPALACHIAN REGION

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Abstract: Dens of radio-instrumented black bears (*Ursus americanus*) were examined in the southern Appalachian Mountains from 1973 to 1982. Most dens were in tree cavities high above ground. Entrance height differed among tree species with high entrances in yellow poplars (*Liriodendron tulipifera*) and low entrances in chestnut oak (*Quercus prinus*), red maple (*Acer rubrum*), and yellow birch (*Betula alleghaniensis*). Den tree species differed with elevation, macrotopography, and microtopography. Both tree dens and ground dens were characterized by high microtopographic position. Chestnut oaks and northern red oaks (*Q. rubra*) comprised 10 of 15 tree dens in the exterior of the study area. Extensive use of these 2 species indicates the importance of incorporating site provisions into timber management plans in the Southern Appalachian Region.

Int. Conf. Bear Res. and Manage. 6:119–127

Black bears exhibit considerable versatility in den selection in various parts of their range. In regions with harsh winters most dens are excavations beneath standing trees, stumps, and fallen logs, or excavations directly into the hillside (Erickson 1964, Beecham 1980, Tietje and Ruff 1980). Jonkel and Cowan (1971) found most bears in Montana denned at the base of hollow trees and Beecham (1980) found some black bears in Idaho denned at the base of live trees. Dens in rock crevices are important to black bears in the southwestern United States (LeCount 1980, Graber 1981, Novick et al. 1981), and Lindzey and Meslow (1976) reported bears used stumps of fallen trees in Washington.

In the southeastern United States, black bears extensively use tree cavities high above ground. Use of tree dens has been reported in the mountainous regions of the southeast (Pelton et al. 1980, Johnson et al. 1981, Lentz and Marchinton 1983), and the river bottoms of Arkansas (Smith 1985) and Louisiana (Taylor 1971). Hamilton and Marchinton (1980) recorded a single instance of a black bear using a tree den in the North Carolina coastal plain, although they usually denned on the ground in a thick "Carolina bay" vegetation type. Other occasional instances of bears denning in trees have been reported in Michigan (Switzenberg 1955), Washington (Lindzey and Meslow 1976), and Pennsylvania (G. Alt, pers. commun.).

The denning period of black bears in the Southern Appalachian Region may extend from late November to early May (Johnson and Pelton 1980, Eiler 1981, Wathen 1983) and the birth of cubs occurs during this time. Because of the time and energy spent denning, during which bears do not eat, drink, urinate, or defecate (Folk et al. 1972), adequate dens may be important to survival and reproductive success. Tree dens may be superior to ground dens in the Southern Appalachian Region because they are relatively dry and secluded (Eiler 1981, Johnson and Pelton 1981). Johnson et al. (1978) reported that tree dens afforded bears a 15.0% energy savings compared to ground dens.

Little is known about the dynamics of cavity formation or the longevity of tree dens. However, preliminary tree age data collected by increment boring indicate that den trees are very old (275–300 years; Johnson and Pelton 1980). Current U.S. Dep. Agric., For. Serv. (USFS) timber rotations of 80–100 years for hardwoods have raised concerns that den tree resources may be reduced and adversely impact southern Appalachian black bear populations.

Our objectives are to report on den tree species and types of ground dens used by black bears in the Southern Appalachian Region and to describe characteristics of dens and their relevance to den selection. The physical and site characteristics of chestnut oak and northern red oak dens are presented and discussed relative to timber management practices in this region because they are used extensively as tree dens.

We gratefully acknowledge all those who assisted in field data collection. R. Wathen assisted tremendously in manuscript preparation. Financial support was provided by McIntire-Stennis Proj. No. 27, Agric. Exp. Sta. and Dep. of For., Wildl., and Fish, Univ. of Tenn., Knoxville, and the Tenn. Wildl. Resour. Agency.

STUDY AREA

The study area included the Great Smoky Mountains National Park (GSMNP) and adjacent Cherokee National Forest (CNF). The study concentrated in the northwestern quadrant of the GSMNP and the

Tellico Ranger District of the CNF, consisting of 994 km^2 and located between 35° 20′ 35° 47′ N latitude and 83° 05′ and 84° 20′ W longitude (Fig. 1).

The Great Smoky and Unicoi mountains occur in the Unaka Range of the Blue Ridge Province of the southern division of the Appalachian Highlands (Fenneman 1938). The area is mountainous with steep slopes. Much of the CNF is accessible by logging roads whereas most of the GSMNP is accessible only by foot trail.

Elevations range from 230 to 2,024 m and climate varies with elevation. Average annual precipitation ranges from 140 to 220 cm at lower and higher elevations, respectively. Average annual temperature ranges from 14 C at elevations below 450 m to 8 C at elevations above 1,900 m (Stephens 1969).

Rock formations are classified in the Ocoee Series of the late Precambrian (King et al. 1968). Soils are predominantly of the Ramsey association, and characterized by low fertility, low water holding capacity, and susceptibility to erosion (Anonymous 1945, 1953). Most of the area is unsuitable for agriculture.

The vegetation of GSMNP is diverse and classified as topographic climax or secondary (Whittaker 1956). Six major forest types are recognized within the GSMNP: cove hardwood, hemlock, northern hardwood, closed oak, open oak-pine, and spruce-fir (Shanks 1954). Intensive logging was prevalent in the GSMNP from the 1900s until park establishment in 1934 (Lambert 1961). Approximately 39% of GSMNP is virgin, and many cull trees remain (Johnson and Pelton 1981).

As part of the CNF, Tellico Ranger District is managed for multiple use and sustained yield of timber, outdoor recreation, watershed, and wildlife resources. Timber is managed on an even-aged rotation. A 67 km^2 bear sanctuary, where no bear hunting is allowed, has been established in a portion of the Tellico Ranger District. Annual bear hunts are held in December in other portions of the CNF. Bears in the GSMNP are unexploited except for illegal hunting.

Four main sections are recognized in the study area: 1) Sugarland/Elkmont area (Sugarland Mountain), 2) Bote Mountain/Defeat Ridge/Tremont area (Bote Mountain), 3) Parsons Branch Road/Bunker Hill area (PNR), and 4) Tellico Ranger District of the Cherokee National Forest (CNF) (Fig. 1). The PBR and CNF sections were similar in habitat and elevation and designated as the "exterior" of the study area. Sugarland Mountain and Bote Mountain were designated as the "interior" of the study area.

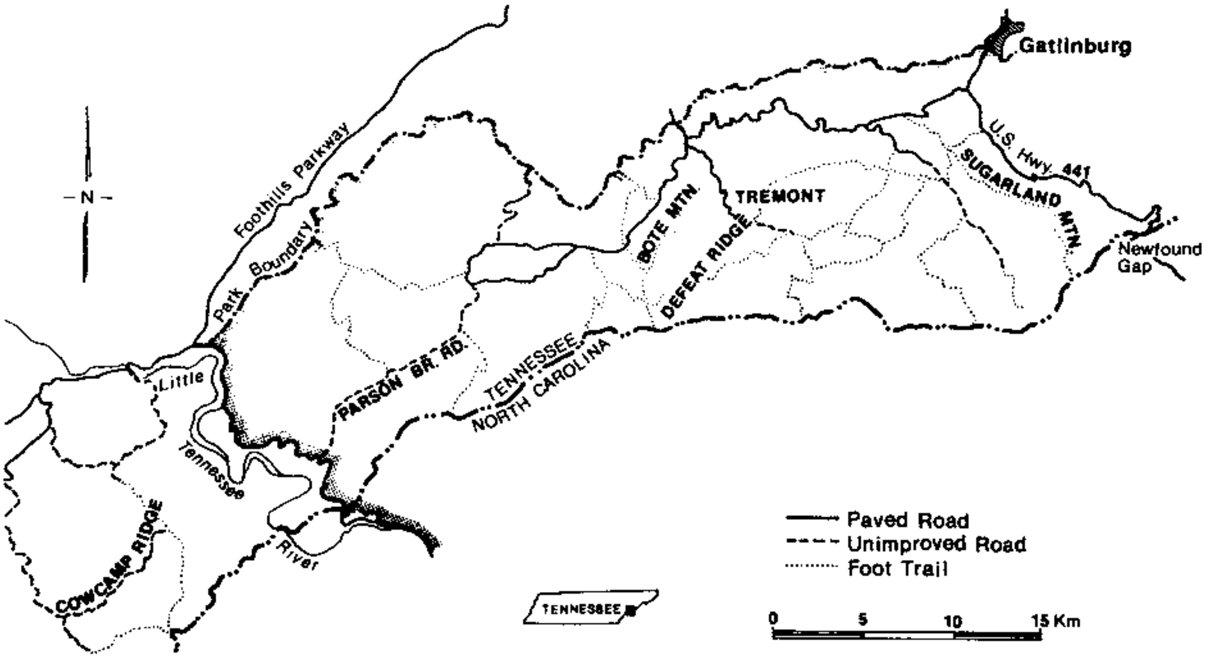

Fig. 1. The Southern Appalachian Region black bear den site study area.

METHODS AND MATERIALS

Black bears were captured with Aldrich spring-activated foot snares or barrel traps, immobilized with M-99 (etorphine hydrochloride) or phencyclidine hydrochloride. Radiotransmitters (Wildlife Materials, Inc., Carbondale, Ill. and Telonics, Inc., Mesa, Ariz.) were attached to selected individuals (N = 66) for further monitoring. A 1st premolar was extracted to determine age by the cementum annuli technique (Willey 1974).

Dens of radio-instrumented bears were located and physical and site characteristics were measured during the winter or after den emergence. Topography was measured in 2 ways: microtopographic (micro) position was measured as the percentage of elevational distance of the den from the nearest ridgetop to the bottom of the nearest concavity; macrotopographic (macro) position was measured as the percentage distance of the den from the large ridge most affecting the local topography to the nearest downslope stream (ridgetop = 0%, mid-slope = 50%, cove bottom = 100%) (Golden 1974:51). Other site parameters recorded included elevation, slope steepness and aspect, forest type, and understory density. Den physical characteristics measured included entrance size, entrance aspect, diameter at breast height (DBH) of tree dens, and height of entrance above ground (tree dens). Cavity dimensions of some tree dens were not obtained because the den was occupied or the den presented physical constraints. Cavity dimensions of black bear dens in the GSMNP were previously reported by Johnson and Pelton (1981).

Statistical analysis of parametric data was performed using t-test and analysis of variance (ANOVA). Variables analyzed with ANOVA were compared with the least-squares means (SAS 1982). Analysis of categorical data was performed with the G-test (Sokal and Rohlf 1969:561). The 0.05 probability level was accepted as significant, but all probabilities are presented to clarify data interpretation (Tacha et al. 1982).

RESULTS AND DISCUSSION

Ninety-five dens of 14 male and 52 female black bears were examined from 1973 to 1982. A majority (55.8%) of the dens were located in tree cavities high above the ground ($\bar{x}$ = 11.9 m). Den tree species included chestnut oak (N = 13), northern red oak (N = 10), eastern hemlock (*Tsuga canadensis*) (N = 6), yellow poplar (N = 5), yellow birch (N = 5), black gum (*Nyssa sylvatica*) (N = 4), red maple (N = 4), black cherry (*Prunus serotina*) (N = 1), scarlet oak (*Q. coccinea*) (N = 1), yellow buckeye (*Aesculus octandra*) (N = 1), and an American chestnut snag (*Castanea dentata*) (N = 1). Ground dens included cavities under roots of wind-tilted trees (N = 12), rock crevices (N = 10), tree stumps (N = 9), overblown logs (N = 4), ground nests (N = 4), and at the base of live trees (N = 3).

Physical Characteristics of Dens

The DBH of tree dens averaged 100.7 cm (Table 1). The DBH of tree stump dens ($\bar{x}$ = 112.4 cm) and den cavities at the base of live trees ($\bar{x}$ = 102.7 cm; Table 2) indicated that large trees were important in the formation of ground dens as well as tree dens (Johnson and Pelton 1981).

Entrances of ground dens ($\bar{x}$ = 0.316 m^2; Table 2) and tree dens ($\bar{x}$ = 0.392 m^2; Table 1) were similar. However, several (N = 8) ground dens (primarily ground nests and overblown logs) were without discrete measurable entrances and were not included in the analysis of entrance data. Therefore, the calculated mean entrance size of ground dens (0.316 m^2) is underestimated. Cavities at the base of live trees, root system cavities, and rock crevices generally had small entrances into protected cavities. Cavities under overblown logs and those associated with tree stumps typically were less protective, and ground nests offered little or no protection from climatic elements.

Eighteen of 35 tree dens had entrances at the top of the main truck and 17 had lateral openings. No species exhibited a disproportionate number of side or top entrances. Entrances at the top ot the main truck ($\bar{x}$ = 0.623 m^2) were larger (P < 0.01) than side entrances ($\bar{x}$ = 0.293 m^2). Lentz and Marchinton (1983) calculated that 11% of the heat retention of a tree den could be accounted for by the position of the entrance. Side entrances provided greater heat retention than top entrances (Thorkelson and Maxwell 1974, Lentz and Marchinton 1983), possibly a result of the size of the entrances, but also related to the view factor (Thorkelson and Maxwell 1974, Johnson et al. 1978).

Lentz and Marchinton (1983) indicated that depth of cavity below the entrance provided most (59%) of the heat retention capabilities of tree dens. Although this parameter was measured for only a portion of our tree dens (N = 17, $\bar{x}$ = 2.2 m; Johnson and Pelton 1981), the relative depths for the remaining sample were visually estimated. Eight tree dens had cavities extending to the base of the tree; most (N = 7) of these were chestnut oaks. The average depth was 8.7 m, about 4 times the 2.2 m average depth reported by Johnson and Pelton (1981). Based on cavity depth, chestnut oak dens probably offer some heat retention advantages over other den trees. However, some of these advantages may be negated by generally larger entrances (Table 1) and ground moisture associated with ground level dens (Johnson and Pelton 1981).

The entrances to tree dens averaged 11.9 m (range 5.1–27.5) above ground, with significant differences ($P < 0.0001$) among species (Table 1). High entrances occurred in yellow poplar ($\bar{x}$ = 21.3 m) and yellow buckeye ($\bar{x}$ = 19.8 m), and low entrances occurred in chestnut oak ($\bar{x}$ = 9.4 m), red maple ($\bar{x}$ = 9.2 m), and yellow birch ($\bar{x}$ = 8.7 m). Entrances above the ground offer black bears seclusion and tree dens may be especially important to females (Eiler 1981, Johnson and Pelton 1981). Bears in dens with higher entrances were less likely than others to be disturbed by researchers. In this study, females denned higher ($\bar{x}$ = 12.4 m) in trees than males ($\bar{x}$ = 9.5 m, $P < 0.04$). Several investigators have indicated that female black bears are more selective of den sites (Erickson 1964, Johnson and Pelton 1981, Lentz et al. 1981), and the higher entrances to their dens may reflect selection for more seclusion.

More den entrances had western than eastern aspects (G = 5.024, $P < 0.03$). Ground dens (G = 2.206, $0.10 < P < 0.50$) did not reflect this relationship as well as tree dens (G = 2.750, $0.05 < P < 0.10$). The predominance of westerly openings to tree cavities may reflect the effect of the prevailing westerly winds on cavity formation. Most (92%) tree den cavities apparently resulted from wind breakage of large limbs and ensuing natural decay.

Table 1. Mean physical and site characteristics of black bear tree dens in the Southern Appalachian Region.

Tree den species	N	DBH (cm)	Entrance height above ground (m)	Entrance size (m^2) (H[cm] by W[cm])	Elevation (m)	Slope (degrees)	Microtopographic position (%)	Macrotopographic position (%)
Chestnut oak	13	91.5	9.4	0.566 (159.8 by 33.5)	771.4	30.2	23.9	23.9
Northern red oak	10	99.4	13.3	0.372 (91.0 by 38.6)	982.1	30.9	29.2	44.0
Eastern hemlock	6	121.1	11.1	0.407 (89.0 by 41.0)	1,241.4	28.5	42.5	50.0
Yellow poplar	5	116.6	21.3	0.451 (105.0 by 43.5	843.7	22.0	66.0	75.0
Yellow birch	5	99.3	8.7	0.247 (75.4 by 36.2)	1,289.9	35.0	55.0	53.6
Blackgum	4	95.2	14.7	0.146 (41.8 by 35.0)	962.4	27.3	31.3	54.5
Red maple	4	97.1	9.2	0.497 (118.0 by 44.8)	1,232.9	34.0	6.0	13.3
Black cherry	1	123.5	—	—	975.4	30.0	80.0	50.0
Scarlet oak	1	81.8	11.5	0.240 (80.0 by 30.0)	1,219.2	20.0	5.0	0.0
Yellow buckeye	1	94.9	19.8	0.130 (48.0 by 27.0)	1,438.7	32.0	7.0	88.0
Chestnut snag	1	101.9	11.4	0.095 (28.0 by 34.0)	1,194.8	31.0	17.0	4.0
Mean for all dens		100.7	12.1	0.402 (105.6 by 37.2)	1,006.7	29.9	33.9	41.5
F		1.60	4.35	0.88	4.94	1.05	2.05	2.71
$P <$		0.1406	0.0006	0.5528	0.0001	0.4210	0.0551	0.0132

In certain regions of black bear range, particulary those with severe winters, den entrance aspect may be important in den selection. Beecham (1980) found that most dens in Idaho faced west, northwest, or north, and believed that these exposures allowed deeper snow accumulation and better insulation. Tietje and Ruff (1980) found that most dens in Alberta faced north and west, but believed that den entrance aspect was not a primary factor in site selection. Other investigators have proposed that entrance aspect was minimally important in den selection (Lindzey and Meslow 1976, Johnson and Pelton 1981). Johnson and Pelton (1981) indicated that protection from wind and precipitation was adequate when the tree cavity was well below the entrance. Our study indicates that entrance aspect was of little importance in den selection, but it likely reflects den availability.

Site and Vegetative Characteristics of Dens

The average slope of all den sites was 31.3° with ground dens ($\bar{x}$ = 33.3°; Table 2) occurring on steeper slopes ($P < 0.04$) than tree dens ($\bar{x}$ = 29.9°; Table 1). The slope aspects on which dens occurred were evenly distributed among northeast ($N = 29$), northwest ($N = 28$), and southwest ($N = 21$) exposures, with fewer ($N = 10$) on southeast slopes. This relationship was consistent for both tree and ground dens and likely reflects study area topography, with the major ridge (Tenn.-N. Carol. border) running northeast to southwest (Fig. 1).

The average elevation of all dens was 962.7 m. No significant differences were noted between ground and tree dens with respect to micro- ($P < 0.60$) or macro- ($P < 0.13$) positions on slopes. However, the micro-position of ground and tree dens was higher than the macro-position. Most dens (84.1%) occurred on the upper half (0–50%) of the micro-position (G = 43.2, $P < 0.0005$). This significant relationship existed for ground (G = 14.9, $P < 0.0005$) and tree dens (G = 27.0, $P < 0.0005$). Most tree dens (62.7%) were also on the upper half of the macro-position, although the relationship was not significant (G = 3.4, $0.05 < P < 0.10$). Ground dens were evenly distributed between the upper ($N = 19$) and lower halves ($N = 18$).

Tree den species differed with elevation ($P < 0.0001$) and macro-position ($P < 0.01$; Table 1); micro-position differences were nearly significant ($P < 0.06$). Chestnut oak ($\bar{x}$ = 771.4 m) and yellow poplar ($\bar{x}$ = 843.7 m) dens occurred at low elevations; red maple ($\bar{x}$ = 1,232.9 m), eastern hemlock ($\bar{x}$ = 1,214.4 m), and yellow birch ($\bar{x}$ = 1,289.9 m) dens were at high elevations. Yellow poplar ($\bar{x}$ = 75.0%) and yellow buckeye ($\bar{x}$ = 88.0%) den macro-position was low, whereas red maple ($\bar{x}$ = 13.3%) and chestnut oak ($\bar{x}$ = 23.9%) den macro-position was high. The micro-position patterns of den tree species was similar to macro-position; yellow poplar dens ($\bar{x}$ = 66.0%) occurred low, and red maple ($\bar{x}$ = 6.0%) and chestnut oak ($\bar{x}$ = 23.8%) dens occurred high.

The relationship of site characteristics to den selection by black bears is complex and likely related to availability. For instance, ground dens were distributed over a wide range of elevational and topographical situations, although there was some variation among ground den types with respect to slope and elevation (Table 2). The predominance of ground dens on the upper half of the micro-position may reflect a tendency of bears to select ground dens on drier and better-drained soils on upper slopes. Also, the importance of large trees and wind damage (Johnson and Pelton 1981) to cavities associated with the root systems of wind-tilted trees probably increases their availability higher on slopes.

Den tree species were more closely related to elevation, and micro- and macro-position than were ground dens. Differences are largely related to specific growth requirements of the den tree species associated with elevation and soil characteristics (micro- and macro-position). Furthermore, the high micro-position of most den trees apparently reflected the susceptibility and increased availability of these trees to ice and wind damage and subsequent cavity formation.

The density of understory vegetation was greater (G = 14.3, $P < 0.0005$) around ground dens than tree dens. Most ground dens (87.2%) had dense or moderate understories, whereas most tree dens (66.0%) were associated with moderate and light understories. Five tree dens had no understory, but no ground dens lacked understory. Predominant understory species associated with ground dens with dense understories included rhododendron (*Rhododendron maximum*) (47.6%), wild grape (*Vitis* sp.) and greenbriar (*Smilax* sp.) (38.1%), and mountain laurel (*Kalmia latifolia*) (14.3%). Lentz and Marchinton (1983) also found that rhododendron and mountain laurel offered concealment and wind protection to dens in northeastern Georgia.

The relationship of understory density to ground dens may be a function of past disturbances such as

Table 2. Mean physical and site characteristics of black bear ground dens in the Southern Appalachian Region.

Den type	N	DBH (cm)	Entrance size (m^2) (H[cm] by W[cm])	Elevation (m)	Slope (degrees)	Microtopographic position (%)	Macrotopgraphic position (%)
Cavity associated with root system	12	—	0.277 (45.8 by 57.7)	934.5	35.2	31.5	56.5
Rock crevice	10	—	0.362 (45.5 by 82.9)	1,035.6	34.4	26.1	51.6
Tree stump	9	112.4	0.382 (53.9 by 70.8)	927.9	36.0	37.6	41.1
Overblown logs	4	—	0.105[a] (27.0 by 39.0)	594.4	32.0	26.7	67.3
Ground nest	4	—	—	809.2	28.3	21.3	62.5
Cavity at base of live tree	3	102.7	0.180 (43.7 by 42.7)	792.5	25.3	31.7	35.0
Mean for all dens		109.9	0.316 (47.1 by 66.7)	903.8	33.3	30.2	51.5
F		0.10	1.51	2.03	2.34	0.18	0.83
$P <$		0.7632	0.2254	0.1003	0.0661	0.9679	0.5379

[a] Entrance size based on 1 measurement; other entrances were immeasurable.

logging (tree stump cavities) or wind damage (overblown logs, root systems of wind-tilted trees) opening the canopy and creating seral vegetation stages. The dense understory typical around ground dens likely conceals black bears (Johnson and Pelton 1981), but apparently was not as important to bears in rock crevices or cavities at the base of live trees. In these dens, small openings and enclosed cavities probably provide adequate concealment and protection.

Ground dens occurred in a variety of vegetation types including open oak-pine (27.5%), wild grape and greenbiar (22.5%), other early successional stages (12.5%), cove hardwood (12.5%), closed oak (10.3%), northern hardwood (7.7%), eastern hemlock (5.1%), table mountain pine (*Pinus pungens*) (2.6%), and a clear-cut area (2.6%). Tree dens occurred in northern hardwood (26.4%), open oak (22.6%), cove hardwood (18.9%), closed oak (17.0%), eastern hemlock (11.3%), and early successional (3.8%) forest types. We did not find general patterns associating certain types of ground dens with specific vegetation types. However, most (78%) tree stump cavities occurred in early successional (N = 2) or wild grape (N = 5) vegetation types. The disturbance from earlier logging activities in these areas probably resulted in the influx of these early seral stages. Den tree species were largely restricted to specific forest types, with yellow poplar and yellow birch occurring exclusively in cove hardwood and northern hardwood forest types, respectively.

The relationship of black bear dens to site and vegetative characteristics is complex, especially in areas of less severe winters. Lindzey and Meslow (1976) found no evidence of slope aspect influencing den selection in Washington, but noted that adults selected dens in secure timbered areas, whereas yearlings tended to den in open, less secure areas. Black bears in southern California selected dens associated with the Canyon Oak Series vegetation type which offered thermal advantages (cooling) compared to dens in less protected areas (Novick et al. 1981). In Arizona, black bear dens were surrounded by dense vegetation and occurred on north- or west-facing slopes between 1,300 m and 1,500 m (LeCount 1980). Black bears of North Carolina's coastal plain denned in Carolina bays surrounded by dense vegetation (Hamilton and Marchinton 1980).

In the Southern Appalachian Region, black bears appear to prefer tree dens over ground dens. Eiler (1981) and Johnson and Pelton (1981) found a disproportionate use of tree dens, especially by female bears, even in areas that had been subjected to clear-cut logging operations (Tremont) or to even-age timber management (CNF). Apparently, site and vegetative characteristics had little influence on the actual selection of a tree den, but was more related to that tree's specific site requirements. Although tree dens offer better protection than ground dens, results of this study indicated that selection of certain den tree species was a function of availability rather than superior protection afforded by specific tree den species.

Area Differences

A wider variety of den types was used in the interior (N = 15) of the study area than in the exterior (N = 6, G = 3.126, $0.05 < P < 0.10$), probably because of elevational differences between the 2 areas. Dens in the interior occurred from 518 m to 1,036 m ($\bar{x}$ = 770 m). The greatest number of den types (N = 15) occurred between 915 m and 1,219 m because of the increased availability of different den tree species at higher elevations. All types of ground dens were used at elevations below 762 m. Increased diversity of interior den types was also a result of increased habitat complexity.

The relative lack of den type diversity in the exterior of the study area magnifies the importance of chestnut oak and northern red oak as den tree species. Chestnut oak and northern red oak comprised 4 of 8 tree dens in the PBR area and 6 of 7 tree dens in the CNF. The availability and use of yellow poplar (N = 3) and black cherry (N = 1) in the PBR are probably related to the lack of logging activities. The yellow poplar used as a den in the CNF area was in a virgin timber stand in North Carolina. Therefore, chestnut oak and northern red oak dens appear to be extremely important in low elevation areas undergoing timber management in the Southern Appalachian Region.

Characteristics of Chestnut Oak and Northern Red Oak Tree Dens

The DBH of chestnut oak dens ($\bar{x}$ = 91.5 cm) and northern red oak dens ($\bar{x}$ = 99.4 cm) was similar ($P < 0.33$) as were entrance sizes ($\bar{x}$ = 0.566 m^2 and 0.351 m^2, respectively; $P < 0.25$). However, entrances to northern red oak dens ($\bar{x}$ = 13.3 m) were significantly higher ($P < 0.03$) than chestnut oak dens ($\bar{x}$ = 9.5 m). Nine of 13 entrances to chestnut oak dens had southeast or southwest aspects, whereas most entrances to northern red oak dens had northwest or southeast aspects. Northern red oak dens ($\bar{x}$ = 982.1 m) occurred at higher elevations ($P < 0.02$) than chestnut oak dens ($\bar{x}$ = 771.4 m). Both species were used at elevations between 610 and 1,219 m, but chestnut oak dens were apparently the only species used below 610 m. Both chestnut oak and northern red oak dens ($\bar{x}$ = 23.9% and 29.2%, respectively) had high micro-positions, but northern red oak dens ($\bar{x}$ = 44.0%) had lower macro-position than chestnut oak dens ($\bar{x}$ = 23.9%). The micro- and macro-position patterns demonstrated by these 2 species probably reflect the importance of wind damage to cavity formation resulting on high micro-position sites (Johnson and Pelton 1981), and general soil and topography requirements of the respective species. Chestnut oaks are typically found in dry, sandy, and rocky soils characteristic of ridges of the Southern Appalachian Region (Fowells 1965:574, Harlow and Harrar 1969:308-309), whereas northern red oaks grow on sandy loam soils from middle to lower slopes (Fowells 1965:589, Harlow and Harrar 1969:315). Both chestnut oak (9 of 13) and northern red oak (7 of 9) tree dens were predominantly on northern aspects.

Most (9 of 10) northern red oak dens were found in closed oak (N = 6) or northern hardwood (N = 3) forest types, whereas most (10 of 13) chestnut oak dens occurred in open oak-pine. Predominant understory species associated with chestnut oak dens included mountain laurel, rhododendron, hardwood tree saplings, hemlock, blueberries (*Vaccinium* spp.), and huckleberries (*Gaylusaccia* spp.) characteristic of drier sites. Eight of 13 chestnut oak dens were associated with moderate understories. Northern red oak dens occurred in understories classified as none (N = 13), light (N = 3), or moderate (N = 4), consisting primarily of hardwood saplings, rhododendron, and wild grape—species characteristic of more mesic sites.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Black bears prefer tree cavities above ground as winter dens in the Southern Appalachian Region. Chestnut oaks and northern red oaks are the primary species used as den trees outside the GSMNP. The availability of tree dens on national forests is largely unknown, but projected increases in timber production, use of cable logging, and conversion of "poor" quality sites to white pine (*Pinus strobus*) will reduce available den trees on national forests in the Southern Appalachian Region. Therefore, timber management should be coordinated with den tree requirements and based on short-term and long-term management strategies.

Short-term management should assess the availability of den trees on USFS lands, and ensure preservation of individual den trees through careful coordination with logging activities. Long-term considerations should include initiating research to determine site and vegetative characteristics useful in quantitatively classifying and mapping areas with high potential for den tree production. Areas with high potential should be placed in old-growth management compartments or wilderness areas.

LITERATURE CITED

ANONYMOUS. 1945. Soil survey, Sevier County. U.S. Dep. Agric., Univ. Tenn. Agric. Exp. Sta., and Tenn. Valley Authority, Knoxville. 119pp.

ANONYMOUS. 1953. Soil survey, Blount County. U.S. Dep. Agric., Univ. Tenn. Agric. Exp. Sta., and Tenn. Valley Authority, Knoxville. 119pp.

BEECHAM, J. J. 1980. Population characteristics, denning, and growth patterns of black bear in Idaho. Ph.D. Thesis, Univ. Mont., Missoula. 101pp.

CRAIGHEAD, F. C. JR., AND J. J. CRAIGHEAD. 1972. Grizzly bear prehibernation and denning activities as determined by radio tracking. Wildl. Monogr. 32. 35pp.

EILER, J. H. 1981. Reproductive biology of black bears in the Smoky Mountains of Tennessee. M.S. Thesis, Univ. Tenn., Knoxville. 117pp.

ERICKSON, A. W. 1964. An analysis of black bear kill statistics in Michigan. Pages 68–102 *in* The black bear in Michigan. Mich. State Univ., Agric. Exp. Sta. Res. Bull 4. 102pp.

FENNEMAN, N. M. 1938. Physiography of the eastern United States. McGraw-Hill, New York. 714pp.

FOLK, F. E., JR., M. A. FOLK, AND J. J. MINOR. 1972. Physiological condition of three species of bears in winter dens. Int. Conf. Bear Res. and Manage. 2:107–24.

FOWELLS, A. A. 1965. Silvics of forest trees of the United States. U.S. Dep. Agric., For. Serv., Handbook No. 271. 762pp.

GOLDEN, M. S. 1974. Forest vegetation and site relationships in the central portion of the Great Smoky Mountains National Park. Ph.D. Thesis, Univ. Tenn., Knoxville. 275pp.

GRABER, D. M. 1981. Ecology and management of black bears in Yosemite National Park. Ph.D. Thesis, Univ. Calif., Davis. 206pp.

HAMILTON, R. J., AND R. J. MARCHINTON. 1980. Denning and related activities of black bears in the coastal plain of North Carolina. Int. Conf. Bear Res. and Manage. 4:122–26.

HARLOW, W. M., AND E. S. HARRAR. 1969. Textbook of dendrology. McGraw-Hill, New York. 512pp.

JOHNSON, K. G., D. O. JOHNSON, AND M. R. PELTON. 1978. Simulation of winter heat loss for a black bear in a closed tree den. Proc. East. Black Bear Workshop 4:155–166.

———, AND M. R. PELTON. Environmental relationships and the denning period of black bears in Tennessee. J. Mammal. 61:653–660.

———, AND ———. 1981. Selection and availability of dens for black bears in Tennessee. J. Wildl. Manage. 45:111–119.

JONKEL, C. J., AND I. MCT. COWAN. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27. 57pp.

KING, P. B., R. B. NEUMAN, AND J. B. HADLEY. 1968. Geology of the Great Smoky Mountains National Park, Tennessee and North Carolina. Geol. Surv. Prof. Pap. 587. 23pp.

LAMBERT, R. S. 1961. Logging the Great Smokies, 1880–1930. Tenn. Hist. Quart. 20:350–363.

LECOUNT, A. L. 1980. Some aspects of black bear ecology in the Arizona chaparral. Int. Conf. Bear Res. and Manage. 4:175–179.

LENTZ, W. M., R. L. MARCHINTON, AND D. M. CARLOCK. 1981. Black bear habitat in north Georgia: some implications of wilderness designation. Proc. S.E. Assoc. Fish and Wildl. Agencies 34:550–556.

———, AND ———. 1983. Thermodynamic analysis of northeastern Georgia black bear dens. J. Wildl. Manage. 47:545–550.

LINDZEY, F. G., AND E. C. MESLOW. 1976. Characteristics of black bear dens on Long Island, Washington. Northwest Sci. 50:236–242.

NOVICK, J. H., J. M. SIPEREK, AND G. R. STEWART. 1981. Denning characteristics of black bears, *Ursus americanus,* in the San Bernardino Mountains of southern California. Calif. Fish and Game 67:52–61.

PELTON, M. R., L. E. BEEMAN, AND D. C. EAGAR. 1980. Den selection by black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 4:149–151.

SAS. 1982. SAS user's guide: statistics. SAS Institute, Inc., Cary, North Carolina. 584pp.

SHANKS, R. A. 1954. Reference list of native plants of the Great Smoky Mountains. Botany Dep., Univ. Tenn., Knoxville. 14pp. (Mimeo.)

SMITH, T. R. 1985. Ecology of black bears in a bottomland hardwood forest in Arkansas. Ph.D. Thesis, Univ. Tenn., Knoxville. 209pp.

SOKAL, R. R., AND F. J. ROHLF. 1969. Biometry. W. H. Freeman and Co., San Francisco, Calif. 776pp.

STEPHENS, L. A. 1969. A comparison of climatic elements at four elevations in the Great Smoky Mountains. M.S. Thesis, Univ. Tenn., Knoxville. 119pp.

SWITZENBERG, D. F. 1955. Black bear denning in tree. J. Mammal. 36:459.

TACHA, T. C., W. D. WARDE, AND K. P. BURNHAM. 1982. Use and interpretation of statistics in wildlife journals. Wildl. Soc. Bull. 10:355–362.

TAYLOR, D. F. 1971. A radio-telemetry study of the black bear (*Euarctos americanus*) with notes on its history and present status in Louisiana. M.S. Thesis, Louisiana State Univ., Baton Rouge. 87pp.

THORKELSON, J., AND R. K. MAXWELL. 1974. Design and testing of a heat transfer model of a raccoon (*Procyon lotor*) in a closed tree den. Ecology 55:29–39.

TIETJE, W. D., AND R. L. RUFF. 1980. Denning behavior of black bears in boreal forest of Alberta. J. Wildl. Manage. 44:858–870.

WATHEN, W. G. 1983. Reproduction and denning of black bears in the Great Smoky Mountains. M.S. Thesis, Univ. Tenn., Knoxville. 135pp.

WHITTAKER, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monogr. 26:1–80.

WILLEY, C. H. 1974. Aging black bears from first premolar tooth sections. J. Wildl. Manage. 38:97–100.