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Availability and distribution of potential black bear den trees in Cherokee National Forest

Gregory Lewis Pearce

To the Graduate Council:

I am submitting herewith a thesis written by Gregory Lewis Pearce entitled "Availability and distribution of potential black bear den trees in Cherokee National Forest." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

M.R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Bord L. Dearden, John C. Rennie, John W. Philpot

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Date January 1989

AVAILABILITY AND DISTRIBUTION OF POTENTIAL BLACK BEAR DEN TREES IN CHEROKEE NATIONAL FOREST

A Thesis
Presented for the
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Degree
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Gregory Lewis Pearce

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ABSTRACT

This thesis examines the availability and distribution of potential black bear den trees in Cherokee National Forest (CNF). Potential den trees are defined as any tree greater than 66 cm diameter at breast height (DBH).

Forty potential den trees were located on 44 transects. These transects were selected randomly from United States Forest Service stand inventories. Sampling of these transects resulted in a total of 61 ha sampled in the Hiwassee, Ocoee, and Tellico Ranger Districts of the CNF.

Each stand was categorized by age class and cover type. The age classes were 0-10, 10-30, 30-60, and 60+ years. Cover types were Pine, Pine-Hardwood, Hardwood-Pine, and Hardwood. Cover type was shown to be helpful in predicting the availability of potential den trees. Significantly more ($p=0.0003$) potential den trees were located in hardwood stands than in the other cover types. Age class did not prove to be a useful predictor of potential den tree availability in this study.

There does not appear to be an absolute shortage of potential den trees in CNF. However, due to past

logging practices, many of these trees are clumped in distribution. That is, many times several such trees are found in close proximity. Ground den opportunities in CNF appear to be abundant.

In terms of sheer numbers, wilderness areas and designated old-growth hardwood areas should provide ample denning opportunities for black bears. However, it would be wise to limit access to potential maternity areas forest wide. This would help ensure the successful reproduction of black bears in the southern Appalachians.

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CHAPTER I

INTRODUCTION

The importance of large tree cavities to black bears (*Ursus americanus*) has been well documented for the southern Appalachians (Pelton et al. 1977, 1980, Lentz et al. 1981, Wathen et al. 1983). Within this region, black bears show a preference for tree cavities as winter dens. In fact, the Tri-State Black Bear Study (1983) reported that 67% of all black bear dens in the mountains of Tennessee, Georgia, and North Carolina were found in trees. Studies conducted by the University of Tennessee have continually shown a high percentage of bears denning in trees.

Tree dens protect black bears from the harsh winter environment by minimizing the adverse cooling effects of cold air drainage, cold winds, and moisture (Pelton et al. 1977). Johnson et al. (1978) found that bears can experience an energy savings of approximately 15% by using tree dens rather than ground dens. Furthermore, since parturition and lactation occur during the denning period, tree dens might be important to the reproductive success of black bears in the southern Appalachians. The reduction of energy required for body maintenance allows female black bears to direct more of their energy resources to the reproductive effort. Several studies indicate the availability of suitable tree dens could be a limiting factor in the perpetuation of viable black bear populations in the marginal habitat of the southern Appalachians (Pelton et al. 1980, Tri-State Black Bear Study 1983).

Den trees also serve as protection from harassment. Bears denning on the ground often are disturbed and rousted from their dens by human activity (Pelton et al. 1980). Reproductive females are less likely to be disturbed in tree dens. This extra protection increases the chances for a successful reproductive effort.

Dens of black bears can be divided into two main categories: (1) tree dens and (2) ground dens. Overblown trees or rock outcrops often form the basis for ground dens. Although suitable ground dens are much more plentiful, tree dens are preferred (Johnson 1978, Johnson and Pelton 1978).

The main criterion for a suitable tree den is size. The average size (diameter at breast height or DBH) of trees that were used as dens in two studies approached 100 cm (Pelton et al. 1980 and Wathen et al. 1983). The smallest tree utilized was found to have a diameter (DBH) of 56.7 cm and the largest 159.2 cm. Trees must be old in order to reach these large sizes. Johnson (1978), for example, found the average age of 10 trees used as dens to be 311 years.

In addition to size, species is an important criterion. Hardwoods are more likely than pines to be damaged in a manner that might produce a den cavity. This is due in part to the larger limbs on hardwood species. The decay processes of hardwoods also result in more suitable cavities. Hence, hardwoods are used almost exclusively as den trees (Johnson and Pelton 1979, Wathen et al. 1983).

Den cavities are formed when a large tree is damaged in some manner. Lightning, insect damage, and disease are some of the more common damaging forces (Johnson and Pelton 1978). This damage is usually found in the form of a limb that has been broken; a cavity then forms as the damaged area deteriorates. Black bears will actively excavate such cavities in order to produce areas of sufficient size for denning (Wathen et al. 1983).

The dynamics of such cavity formation are not well understood (Wathen et al. 1983).

The entrances of dens averaged approximately 12 m (range = 5.1-27.5 m) above the ground (Pelton et al. 1980, Wathen et al. 1980). The size of the entrance to tree dens was approximately 105 cm high by 37.2 cm wide (range = 42x27 -160x45). Some variation in the height of the dens was found among the different tree species. However, there was no evidence of preference for any particular hardwood species (Wathen et al. 1983).

There is little information concerning the availability of potential den trees in the southern Appalachians with the exception of Johnson's (1978) work in Great Smoky Mountains National Park (GSMNP). Although Johnson addressed the topic directly, there are major differences in current land use patterns between the GSMNP and the CNF. Historically, however, land use patterns are very similar. The forest resources of GSMNP are completely protected and unharvested (timber and wildlife). The CNF, on the other hand is managed as a multiple use area. Its timber resources are harvested regularly. Moreover, the presence of consumptive uses (particularly hunting) produces more impact on black bears. This additional pressure compounds the importance of potential den trees as escape cover.

Furthermore, consideration must be given to all other resources when developing a management plan. The overall status of black bears, therefore, becomes more complicated in the CNF.

The objectives of this study were to: (1) delineate the current availability and distribution of potential black bear den trees in the Cherokee National Forest, and (2) develop criteria for the USFS for delineating potential tree den or old growth areas on the national forest.

CHAPTER II

STUDY AREA

The Cherokee National Forest (CNF) contains 252,253 ha located in 10 east Tennessee counties (Carter, Cocke, Greene, Johnson, McMinn, Monroe, Polk, Sullivan, Unicoi, and Washington). In addition, Ashe County of North Carolina contains 132 ha of CNF land. Along the Tennessee-North Carolina border, the CNF spans from Georgia to Virginia. Great Smoky Mountains National Park divides the CNF into two sections, north and south.

This study was conducted in the Tellico, Hiwassee, and Ocoee ranger districts of the Cherokee National Forest. McMinn, Monroe, and Polk counties contain the 121,693 ha of the study area. The Tellico ranger district is the largest with 50,242 ha. The others are the Hiwassee district (36,849 ha) and the Ocoee district (34,603 ha). The study area is bordered to the north and east by Great Smoky Mountains National Park and to the south and east by the

Tennessee-North Carolina line. The Tennessee-Georgia line lies to the south (Figure 1).

PHYSIOGRAPHY

The CNF is part of the Unicoi Mountains of the Unaka range in the Blue Ridge Province (Fenneman, 1938). Steep, rugged mountains containing numerous fast flowing streams characterize the area. Tributaries of the Tennessee River drain most of the Forest. Elevations in the southern half of the CNF range from approximately 300 to 1,800 meters (above mean sea level). The average elevation is 900 meters.

GEOLOGY

Igneous, metamorphic and highly deformed sedimentary rocks form the foundation of the CNF. Rocks were formed from the Pre-Cambrian to the Mississippian eras. Periods of the metamorphism and tectonism have changed rock composition in the CNF. Although tremors are occasionally felt in the area, the numerous faults are thought to be inactive. Formations of Anakeesta and Wilhite produce acid in some areas of the CNF (USFS 1986).

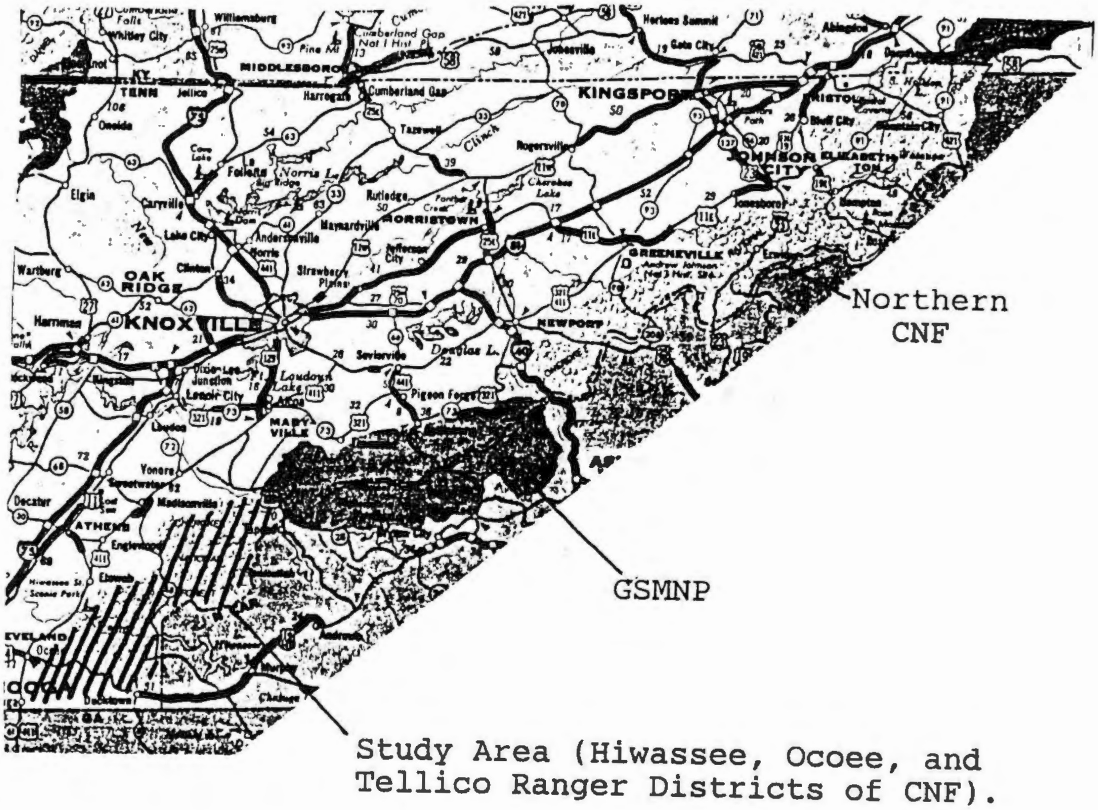

Figure 1. Study Area. The hatched area shows the portion of the CNF in which this study was conducted.

SOILS

Sandstone, phyllite, and shale parent materials provide the source of most of the soil in the CNF. Limestone, granite, quartzite, gneiss, schist, and slate also contribute to the soil in some areas. Most of the soil is dry . The textures are highly variable ranging from loam to clay. The fertility of the soils is also variable. Moderate fertility is observed for browse, mast, and forage production. In terms of timber, the soils are classified as having moderate to low fertility for pine production, and low hardwood productivity. Most of the CNF has moderate soil productivity (USFS 1986).

CLIMATE

Thornwaite (1948) classified the climate of the area as mesothermal perhumid (warm-temperate rain forest). Temperature and precipitation vary significantly among different elevations, exposures, and topographic types (Shanks 1954, Tanner 1963, Stephens 1969).

At elevations below 450 m, the average annual temperature is 14^{o}C. The average annual temperature drops to 8^{o}C at elevations greater than

1,900 m. Lowest temperatures occur in February, and highest temperatures occur in July.

The average annual precipitation ranges from 140 cm at lower elevations to 220 cm at higher elevations (Stephens 1969). Two peaks in precipitation are observed in the area. The first peak occurs in late winter, the second in July. At lower elevations, snowfall occurs and average of 6.75 days annually. At higher elevations the average is 25.9 days.

The effects of acid rain on the CNF are not well understood. The problem does, however, exist. The normal pH of rain is approximately 5.6. On the CNF rainfall is generally more acidic (pH=4.5, USFS 1986).

WATER QUALITY

As previously mentioned, the CNF is drained primarily by tributaries of the Tennessee River system. These outlets, many of them small rapid streams, yield approximately 881,622 ha-m of water each year. The quality of water in CNF is generally good. Bordering these streams are approximately 9,470 ha of riparian zones (USFS 1986).

FLORA

The GSMNP-CNF complex contains a great deal of vegetative diversity. Over 1,300 flowering plant species, 130 native trees, 230 lichens, 2,000 fungi, and 350 mosses are present in the area (Stupka 1960).

Pine and mixed hardwoods comprise the largest portion of the forest canopy. The majority (55%) of stands are between 50 and 70 years of age (Table 1). Presently, there are approximately 25,500,000 m^3 of timber on the CNF (USFS 1986).

Specifically, the CNF has five major plant communities:

1) Cove Hardwood--Yellow poplar (*Liriodendron tulipifera*), white oak (*Quercus alba*), and northern red oak (*Q. rubra*) compose the majority of this communities canopy. Strawberry bush (*Euonymus americanus*) spicebush (*Lindera benzoin*), serviceberry (*Amelancier laevis*), wild hydrangea (*Hydrangea arborescens*), and fire cherry (*Prunus pennsylvanica*) are common components of the understory. Coves, ravines, and moist flats of northern aspects and lower slopes are typical sites for this community. The elevation for cove hardwood communities ranges between 170 and 1,330 meters.

Table 1. The approximate area (hectares) covered by stands in age classes (10 year intervals) from 0-10 to 80+ in CNF, Tennessee (USFS 1986).

Age Class	Hectares
0-10	17,786
11-20	11,360
21-30	5,324
31-40	4,563
41-50	23,909
51-60	69,008
61-70	69,255
71-80	31,514
80+	16,731

2) Oak-Hickory--The canopy of this community consists largely of southern red oak (*Q. falcata*), white oak, hickories (*Carya* spp.), black oak (*Q. velutina*), scarlet oak (*Q. coccinea*), post oak (*Q. stellata*), and chestnut oak (*Q. prinus*). Virginia pine (*Pinus virginiana*), shortleaf pine (*P. echinata*), and pitch pine (*P. rigida*) can also be found in the Oak-Hickory community. Understory species include sourwood (*Oxydendrum arboreum*), buckthorne (*Rhamus* spp.), redbud (*Cercis canadensis*), and mountain laurel (*Kalmia latifolia*). Oak-Hickory communities can be found in coves, high valleys, and flat ridge tops.

3) Pine--White pine (*P. strobus*), Table Mountain pine (*P. pungens*), shortleaf pine, Virginia pine, and pitch pine compose the majority of this community. Mountain laurel, huckleberry (*Gaylussacia* spp.), blueberry (*Vaccinium* spp.), blackberry (*Rubus* spp.), holly (*Ilex* spp.), and flame azalea (*Rhododendron colendulaceum*) are all common understory species. This community typically occurs on old fields, infertile ridges, and dry flats. Pine communities usually occur below 1,000 m of elevation.

4) Mesic Hemlock--This community consists primarily of hemlock (*Tsuga canadensis*), white

pine, yellow poplar, yellow birch (Betula alleghanensis), sugar maple (Acer saccharum), basswood (Tilia americana), blackgum (Nyssa sylvatica), cucumber magnolia (Magnolia acuminata), and northern red oak. Common understory species include rosebay rhododendron (R. maximum), dog hobble (Leucothoe spp.), and mountain laurel. Moist coves, ravines, and northern aspects above 500 m typify the site of this community.

5) Northern Hardwoods--Sugar maple, red maple, basswood, black cherry, northern red oak, American beech (Fagus sylvatica), Yellow birch, sweet birch (B. lenta), and hemlock dominate the northern hardwood community. Mountain maple (A. spicatum), striped maple (A. pensylvanicum), and serviceberry are common understory components. Moist areas of high fertility and elevations above 1,200 m are typical sites for this community. Due to site requirements and past management practices this community is uncommon in the CNF.

The USFS stand inventory divides the CNF into four major cover types: (1) Pine, (2) Pine-Hardwood, (3) Hardwood-Pine, and (4) Hardwood (USFS 1976). The pine type consists of at least 70% pine species. White pine, hemlock, Virginia pine, and shortleaf pine are among the more common species found in the pine cover type. A Pine-Hardwood area consists of 51-69% pine. White pine-hardwood mixtures commonly constitute this cover type. Virginia pine and shortleaf pine also are found mixed with various hardwoods. Hardwood-Pine areas must be 51-69% hardwood. Various oak species often combine with white and yellow pine to make hardwood-pine cover types. Hardwood areas must be at least 70% hardwoods. Yellow poplar, red oaks, and white oaks are common components of this cover type.

FAUNA

The study area exhibits 59 species of mammals (Linzey and Linzey, 1971). Black bears (*Ursus americanus*), white-tailed deer (*Odocoileus virginianus*), and European wild hogs (*Sus scrofa*) are the most important large mammals found in the CNF. Additionally, there are more than 200 bird species, 80 amphibian and reptile species, and 80 fish species found in the area.

SOCIOECONOMICS

The three counties in the study area are predominantly rural. The 1980 census showed 84,181 people populating the area. The average per capita income for the three counties was $4,966. The economic situation of the area plays a vital role in deciding which management strategies will be followed on the CNF. The USFS must (ethically and by law) base management decisions partially on the welfare of the people inhabiting the areas in and around the CNF.

MANAGEMENT

The CNF is considered to be a multiple use area (Multiple Use-Sustained Yield of 1960). That is, it is managed for the sustained yield of a variety of resources. These resources include recreation, visual resources, wilderness, timber, water, soils, air, wildlife and fisheries, minerals, lands, and cultural resources. Furthermore, fire protection, insect and disease control, and law enforcement must be considered in management plans (USFS 1986).

The entire CNF is designated as a cooperative wildlife management area. It is managed by the USFS with the cooperation of the Tennessee Wildlife Resources Agency. Wildlife resources are managed as management indicator species (MIS). Moreover, the habitat needed to support these MIS is considered in the formulation of management plans (Table 2).

Portions (16,472 ha) of the southern CNF have been designated as wilderness under the Eastern Wilderness Act of 1975 and the Tennessee Wilderness Act of 1984 (1986). These areas include the Citico Creek (6,431 ha), Bald River Gorge (1,573 ha), and Joyce Kilmer-Slickrock (1,571 ha) Wilderness Areas. The Gee Creek Wilderness Area (1,009 ha) is located in the Hiwassee Ranger District. Portions of the Cohutta (686 ha), Big Frog (2,046 ha), Big Frog Extension (1,214 ha), and Little Frog Mountain (1,942 ha) Wilderness Areas are located in the Ocoee Ranger District.

Furthermore, approximately 12,400 ha of the Tellico Ranger District are designated as a black bear sanctuary. Much of this area is provided by the Citico Creek and Joyce Kilmer Slickrock Wilderness Areas. Also, the Ocoee Bear Reserve provides 21,782 ha of sanctuary. These areas are excluded from annual bear hunts which are held in

Table 2. Areas under USFS control are managed in part according to their Management Indicator Species (MIS). The current supply of selected MIS and their density is given below (USFS 1986).

SPECIES	ESTIMATED FOREST POPULATION	ANIMALS/HA
White-tailed Deer	10,950	1/23
Turkey	2,100	1/120
Black Bear	274	1/918

early December in some parts of the CNF (TWRA 1987).

The USFS (1986) estimates the black bear population of the CNF at 274 animals (one per 918 ha). For the 23,482 ha of forest land where the black bear is featured, a maximum density of one bear per 259 ha has been established. A realistic population goal for the CNF is approximately 400 animals (1/631 ha). The USFS estimates that 12,620 ha (5% of CNF land) of old growth hardwood areas are needed to provide necessary habitat to sustain such a population of 340 bears (USFS 1986).

CHAPTER III

METHODS AND MATERIALS

Forest stands for this study were selected randomly from the USFS's stand inventory using a random numbers table. The USFS (1986) defines a stand as "an aggregation of trees or other growth occupying a specific area and sufficiently uniform in composition (species), age arrangement, and condition as to be distinguishable from the Forest or other growth on adjoining areas."

Four different cover types (Pine, Pine-Hardwood, Hardwood-Pine, and Hardwood) were utilized. Within these classifications four age classes were identified (0-10 years, 10-30 years, 30-60 years, and 60+ years). Use of the four cover types (Table 3) and four age classifications resulted in 16 possible combinations to be sampled (Table 4).

Field work for this study was conducted during the summer and fall of 1985. USFS personnel assisted in the location of stands on USFS stand maps. A transect was established through the

Table 3. Basic Forest Cover Types on CNF, Tennessee. Cover types are listed with tree species most likely to be principle components of the stand cover type.

Forest Cover Type*	Probable Components
Pine	White Pine, Hemlock, Shortleaf Pine, Pitch Pine, Table Mountain Pine
Pine-Hardwood	Hemlock-Hardwood, White Pine-Cove Hardwood, White Pine-Upland Hardwood, Virginia Pine-Oak
Hardwood-Pine	Cove Hardwood-White Pine-Hemlock, Upland Hardwood-White Pine, Oak-Eastern Red Cedar, Oak-Yellow Pine
Hardwood	Yellow Poplar, Oak spp., Maple spp., Hickory spp.

*Stands in which 70 percent or more of the crowns in the dominant or co-dominant position are a particular type (eg. Pine or Hardwood), are classified as that type.

Table 4. Sampling categories on CNF, Tennessee. Sixteen categories result when combining cover type and age class.

Category	Cover Type	Age Class (Years)
1	Pine	0-10
2	Pine	10-30
3	Pine	30-60
4	Pine	60+
5	Pine-Hardwood	0-10
6	Pine-Hardwood	10-30
7	Pine-Hardwood	30-60
8	Pine-Hardwood	60+
9	Hardwood-Pine	0-10
10	Hardwood-Pine	10-30
11	Hardwood-Pine	30-60
12	Hardwood-Pine	60+
13	Hardwood	0-10
14	Hardwood	10-30
15	Hardwood	30-60
16	Hardwood	60+

center of each stand. The transects were established up and down elevational contours to capture potential variability in elevation.

Transects usually bisected the stands due to relatively small stand sizes. When stand size was too great for this method (> 1 km across), transects ended at the top or bottom of a slope. Each transect was approximately 25 meters wide. By multiplying transect length by transect width and totaling these figures, the total area sampled was found to be approximately 61 ha.

Certain data were collected and recorded in the field. The number of potential den trees (trees > 66 cm DBH) was recorded first. Other data concerning potential den trees included:

(1) DBH,

(2) tree species,

(3) microtopographic slope,

(4) aspect, and

(5) amount and kind of damage to the tree.

Data concerning the existence of potential ground dens also were recorded in the field. The data included such information as 1) the number of potential ground dens, 2) the associated cover (eg. uprooted tree, rock outcrop, thicket, etc.), and 3) the position on the slope.

Information regarding the distribution of potential den trees in relation to other parameters was taken from USGS quad maps. This information included:

(1) proximity to roads,

(2) proximity to streams, and

(3) elevation.

It should be noted that due to the age of some of the maps, information regarding the positions of roads was not always exact.

Statistical Analysis Systems (SAS 1985) computer programs were used to evaluate the relationships among the previously mentioned parameters and the distribution of potential den trees. Bonferroni and Tukey-Kramer tests (Neter, Wasserman, and Kutner 1985) were employed in testing the relationships between the preceding variables and the number of potential den trees per stand.

An analysis of variance (ANOVA) approach was used since the independent variables were largely categorical (or were easily transformed into categories). All of the models used had the number of potential den trees as the dependent variable.

Due to non-significance (alpha = 0.05), certain variables (slope, aspect, elevation, and proximity to roads and streams) were deleted from the model. That is, no evidence was found to support the hypothesis that the mean number of potential den trees per stand differed in the levels of these variables. The most parsimonious model proved to include only cover type as an independent variable. However, due to the importance of age to a stand's maturity, the variable was included. Hypotheses as to why age class was not a useful predictor for the number of potential den trees in a stand are presented in the following section. The final model used was:

NUMBER = COVER AGE COVER*AGE;

where NUMBER = number of potential den trees,

COVER = cover type (Pine, Pine-Hardwood, Hardwood-Pine, or Hardwood),

AGE = age class (0-10 years, 10-30 years, 30-60 years, or 60+ years), and

COVER*AGE = interaction between cover type and age class.

Interaction would be present, for example, if age class had a greater effect on hardwood stands than on pine stands. The interaction term was included although it was not found to be significant. That is, no evidence of an interaction was found.

The two variables each have four levels. The result was a four by four factorial design with 16 cells. Bonferroni tests were used to test for differences in the mean number of potential den trees per stand among the levels of the two variables (Figure 2). Two primary hypothesis tests were performed:

(1) The mean number of potential den trees for hardwood stands is greater than the number for other stand types (Pine, Pine-Hardwood, or Hardwood-Pine) and,

(2) The mean number of potential den trees for stands in the 60+ year class is greater than the number for other age classes (0-10 years, 10-30 years, or 30-60 years).

Both of these hypotheses were tested on a per contrast Bonferroni level of significance of 0.025 (Family alpha=0.05/2 hypotheses tests).

Additionally, the Tukey-Kramer test was used to test all possible pairwise comparisons. That is, Hardwood stands were compared to Pine stands, then to Pine-Hardwood stands, and then Hardwood-Pine stands. Next, Pine was compared to Pine-Hardwood, and then to Hardwood-Pine stands. Pine-Hardwood stands were then compared to Hardwood-Pine stands. This process was continued

4 X 4 ANOVA DESIGN

	P	P-H	H-P	H
0-10	1(3)	5(3)	9(3)	13(3)
10-30	2(2)	6(1)	10(3)	14(2)
30-60	3(1)	7(3)	11(3)	15(4)
60+	4(2)	8(3)	12(5)	16(3)

Hypotheses Tests

(1) H_o: $X_{13}+X_{14}+X_{15}+X_{16}/4 - X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9+X_{10}+X_{11}+X_{12}/12 = 0$

H_a: $X_{13}+X_{14}+X_{15}+X_{16}/4 - X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9+X_{10}+X_{11}+X_{12}/12 = 0$

(2) H_o: $X_4+X_8+X_{12}+X_{16}/4 - X_1+X_2+X_3+X_5+X_6+X_7+X_9+X_{10}+X_{11}+X_{13}+X_{14}+X_{15}/12 = 0$

H_a: $X_4+X_8+X_{12}+X_{16}/4 - X_1+X_2+X_3+X_5+X_6+X_7+X_9+X_{10}+X_{11}+X_{13}+X_{14}+X_{15}/12 = 0$

Figure 2. Experimental design and hypothesis tests. A breakdown of the 16 cell 4 x 4 ANOVA design and the two primary tests of hypothesis (with the number of transects sampled).

with the various age classes until all six possible pairwise comparisons were made.

CHAPTER IV

RESULTS AND DISCUSSION

AVAILABILITY OF POTENTIAL DEN TREES

Forty-four transects resulted in 61 ha being sampled. Twenty-two ha were sampled in the Tellico Ranger District, 17 ha in the Hiwassee District, and 20 ha in the Ocoee District. Seventeen transects were located in the Tellico District, 14 in the Hiwassee District, and 13 in the Ocoee.

A potential den tree is any tree greater than 66 cm DBH. For a tree to be used for denning it must have a cavity of sufficient size to accommodate a black bear and its cubs in the case of a maternal female. Forty potential den trees were located along transects in all cover types and age classes. Projecting for the entire southern CNF, this leads to an estimate of one potential den tree for every 1.5 ha or 80,000 trees greater than 66 cm DBH (95% confidence interval: 74,760, 85,240).

However, not all (approximately 20 or 50%) of the 40 potential den trees located were damaged in a manner that would make them suitable for denning. These trees were included in the estimates since a damaging force could produce the necessary cavity at any time. Yet, the inclusion of these trees probably led to an inflated estimate of the number of potential den trees in the southern CNF. If only damaged trees are included, a figure of approximately one potential den tree for every 3.0 hectares or 40,600 potential den trees (95% confidence interval: 35,360, 45,840) of the southern CNF is derived. This figure suggests no absolute shortage of potential den trees for black bears.

However, not all of these trees could be used in a given winter. The potential den trees often were found in clusters, within a few meters of one another. Locations of denning bears by UT researchers rarely show bears denning this close to each other. This would suggest the figure of potential den trees available in a given year would be lower than 40,600.

The actual number of trees located that could be utilized in a given winter would probably be closer to 7. That is, there were 7 stands which had trees of sufficient size that were damaged in a manner that provided adequate cavities for denning. Using this figure an estimate of one potential den tree for every nine hectares or 13,500 (95% confidence interval: 8,260, 18,740) is derived.

The preceding figures also indicate that there is not an absolute shortage of potential black bear den trees in the southern CNF . However, these figures might also be inflated despite the previously mentioned adjustments. For example, some potential den trees (2, 5%) were located in areas not containing black bears. These culls might not be available for denning because the surrounding environment would not accommodate bear populations. Others might not be available as den trees due to their proximity to roads or other human activities. In this study, six (15%) of the potential den trees were located within 20 meters of a road. The activity caused by the road might prevent a bear from selecting such a tree as a den site. Moreover, if such a tree were selected, the bear would certainly be more vulnerable to illegal hunting pressure.

Furthermore, a potential den tree must not only exist in a suitable environment and be damaged in an appropriate manner; but it must be found by a bear in search of a den. No information exists pertaining to the chance of a bear in search of a den finding a particular tree. One might guess, however, that the probability would be relatively low. However, resident bears are probably familiar with most of the denning opportunities within their home range.

The above and other limiting factors could significantly reduce the number of "usable" potential den trees. Moreover, if there are too few potential den trees, it might facilitate illegal hunting by leading poachers to the bears. Thus, careful management decisions are required in order to insure their continued availability.

AVAILABILITY OF POTENTIAL DEN TREES BY COVER TYPE

Cover type proved to be the only variable useful for predicting the number of potential den trees in a particular stand ($F = 5.80$, $p = 0.0033$). The Hardwood cover type exhibited significantly ($F = 16.94$, $p = 0.0003$) greater numbers of potential den trees than the other three cover types (Figure 3). Age class and the interaction between age class and cover type proved to be non-significant ($F = 1.68$, $p = 0.1933$ and $F = 2.06$, $p = 0.0697$ respectively). The terms, however, were included in the full (saturated) model. Other parameters such a microtopographic slope, aspect, elevation,

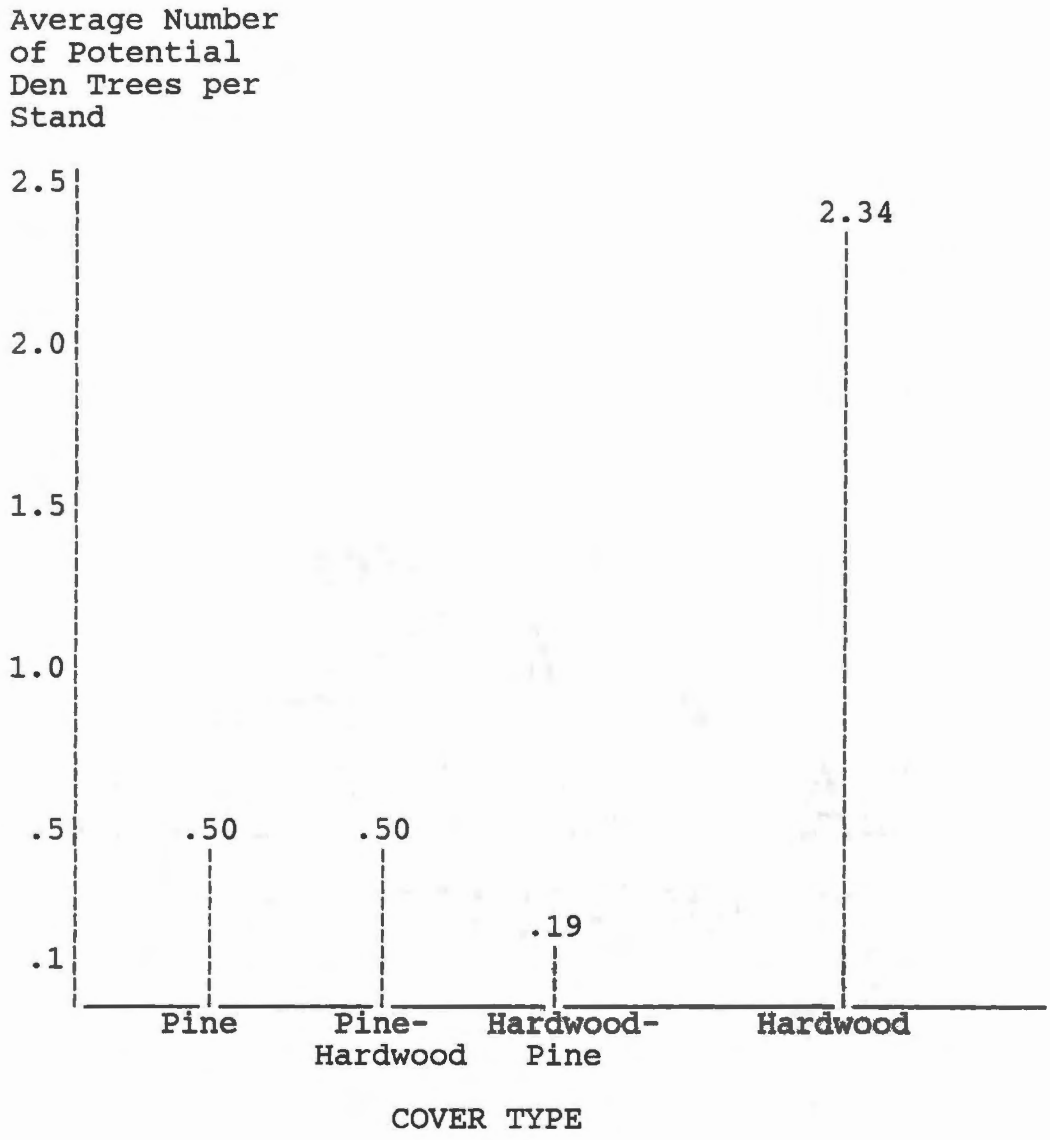

Figure 3. Average number of potential den trees (>66 cm DBH) found per stand on CNF, Tennessee according to cover type.

and distance from roads and streams were deleted as they were not useful in predicting the number of potential den trees in a stand.

<u>Pine Cover Type</u>

A total of 12 stands were sampled in the pine cover type. The Tellico, Hiwassee, Ocoee Ranger Districts each contained four stands. Twelve transects totaled 15.5 ha of sampled area (Table 5). Six potential den trees were found in transects within the Pine cover type. However, only two of the 12 transects contained trees large enough to be used as den trees by black bears. On the average, 0.05 potential den trees were found in each transect of Pine cover type. That is, one would expect to find a potential den tree for every two stands sampled. However, this figure may be too high due to the clumped distribution.

<u>Pine-Hardwood Cover Type</u>

Eight Pine-Hardwood stands were sampled totaling 8.7 hectares sampled. Four potential den trees were located in this cover type (Table 6). Two stands contained the four potential den tree. Like Pine, two Pine-Hardwood stands would be expected to harbor one potential den tree.

Table 5. Potential den trees (PDT) in Pine stands on CNF, Tennessee. This table shows the number and area of transects sampled in each of the three Ranger Districts in the study area, the number of potential den trees located, and the number of transects with potential den trees.

Ranger Station	Number of Transects	Area (ha) Sampled	Number of PDT	Transects with PDT
Hiwassee	4	5.3	5	1
Ocoee	4	5.6	1	1
Tellico	4	4.6	0	0
	12	15.5	6	2

Table 6. Potential den trees (PDT) in Pine-Hardwood stands on CNF, Tennessee. This table shows the number and area of transects sampled in each of the three Ranger Districts in the study area, the number of potential den trees located, and the number of transects with potential den trees.

Ranger Station	Number of Transects	Area (ha) Sampled	Number of PDT	Transects with PDT
Hiwassee	3	2.9	4	2
Ocoee	3	3.1	0	0
Tellico	2	2.7	0	0
	8	8.7	4	2

Hardwood-Pine Cover Type

Eleven Hardwood-Pine stands were sampled totaling 15.6 hectares (Table 7). Only one stand was found to contain potential black bear den trees; three trees were found in this stand. The average number of Hardwood-Pine stands needed to locate a potential den tree is approximately four.

Hardwood Cover Type

Thirteen of the stands sampled were classified as Hardwood. The transects in these stands comprised 20.8 ha. A total of 27 potential den trees was found in ten hardwood stands (Table 8). The average number of potential den trees per Hardwood stand was approximately two. The average number of potential den trees per stand is significantly ($F = 16.94$, $p = 0.0003$) higher for the Hardwood cover type than for the Pine, Pine-Hardwood, or Hardwood-Pine cover types (Bonferroni, alpha = 0.025).

DISTRIBUTION OF POTENTIAL DEN TREES

A total of 40 potential den trees were located on the 44 random transects. However, potential den trees were found on only 15 (37.5%) of the transects. Johnson (1978) found a similar

Table 7. Potential den trees (PDT) in Hardwood-Pine stands on CNF, Tennessee. This table shows the number and area of transects sampled in each of the three Ranger Districts in the study area, the number of potential den trees located, and the number of transects with potential den trees.

Ranger Station	Number of Transects	Area (ha) Sampled	Number of PDT	Transects with PDT
Hiwassee	3	3.9	0	1
Ocoee	3	5.3	3	0
Tellico	5	6.4	0	0
	11	15.6	3	1

Table 8. Potential den trees (PDT) in Hardwood stands on CNF, Tennessee. This table shows the number and area of transects sampled in each of the three Ranger Districts in the study area, the number of potential den trees located, and the number of transects with potential den trees.

Ranger Station	Number of Transects	Area (ha) Sampled	Number of PDT	Transects with PDT
Hiwassee	4	5.2	8	4
Ocoee	3	7.0	3	2
Tellico	6	8.6	16	4
	13	20.8	27	10

clustered distribution in GSMNP. The following section details the distribution of the potential den trees for the variables of age, elevation, species, aspect, and microtopographic slope.

Age Class

Forest stand age class was not found to be a useful predictor of the number of potential den trees in a stand (F = 1.68, p = 0.1933). Since the size of a tree is related to its age to some extent, one might expect age class to help predict whether a particular stand might contain potential den trees. This expectation is augmented by Johnson's (1978) finding that the average age of 10 den trees was 311 years. The evidence points to a relationship between tree size and age. However, no evidence of a relationship between stand age and tree size was found in the present study.

A problem with using age class of a stand as a predictor of the presence of potential den trees arises from the nature of these den trees. Many of the trees are culls left over from previous logging operations. Culls are trees that were uncut because they had little or no market value. They often are much older than the majority of trees in the stand where they occur. Other trees are now left in stands that are clearcut because 100% of the stand is not harvested. Shelterwood cuts also leave trees unharvested. Trees located in riparian zones also are left behind during logging operations. Due to these reasons, the age class of a stand as a whole may not have much bearing on whether or not a potential den tree might be located in the stand.

The variable, age class, may have been too restrictive to be useful. That is, the four age classes (0-10 years, 10-30 years, 30-60 years, and 60+ years) are not different in their potential to produce a tree of sufficient size to be a den tree. For example, if it takes 60 years (the lower limit of the highest age class) or longer for a tree to reach a diameter of at least 66 cm, the lower three age classes all have the same likelihood of producing a potential den tree; none of the tree age classes gives a tree enough time to reach adequate size. In fact, the 60+ year age class might include numerous stands of insufficient maturity to produce potential den trees. Moreover, stands within the same age class might have different potentials to produce den trees due to site index.

Finally, data concerning stand age might be unreliable if the stand's birthdate predates 1936.

This is when CNF was created as a managed forest. Estimates can be made, but they likely would be confounding to the analysis. That is, age might prove useful in predicting the number of potential den trees (large trees), but age was measured as a function of the presence or absence of large trees.

In the 0-10 year age class, potential den trees found were in clusters; ten potential den trees were found in this age class in three clusters. Only one potential den tree was found in the 10-30 year age class. The 30-60 year age class yielded 12 trees of sufficient size in six stands. Seventeen potential den trees were located in stands of 60+ years (Table 9). These data suggest that the 60+ year age class might have more potential den trees per stand than the other age classes. Yet, the difference was not significant. Moreover, the difference between the 60+ and 0-10 year age classes is surprisingly small (Figure 4).

Elevation

Elevation (range = 328 m-1,116 m) was not found to be a reliable predictor for determining the probability of locating a potential den tree on a particular stand. Due to random selection most of the stands sampled were in the intermediate elevation range. Johnson (1978), however,

Table 9. The distribution of potential black bear den trees (PDT) according to age class in southern CNF, Tennessee.

Age Class (years)	Number of Transects	Number of PDT	Number of Transects with PDT
0-10	8	10	3
10-30	10	1	1
30-60	14	12	6
60+	12	17	5

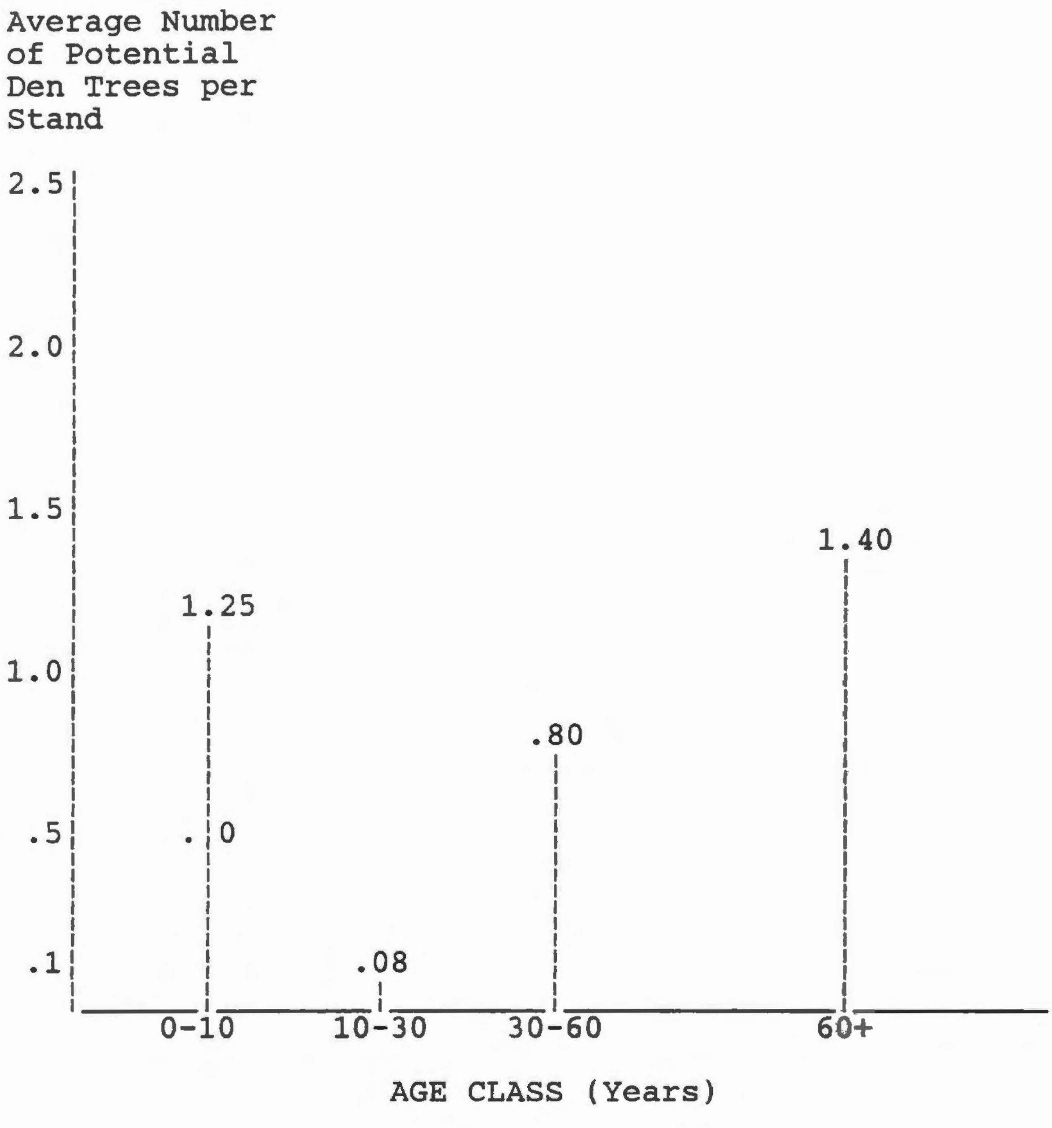

Figure 4. Average number of potential den trees (>66 cm DBH) found per stand on CNF, Tennessee according to age class.

reported the availability of large, over-mature trees to be lower at low elevations. Four trees in three stands were located where the elevation was less than 450 meters. Twelve potential den trees were found on four stands with elevations from 451-600 m. Thirteen trees were located in six stands with elevations between 601 and 750 m. Finally, eleven trees were located in stands with elevations greater than 750 m (Table 10).

Species

Six different species comprised the 40 trees greater than 66 cm DBH (Table 11). Northern red oak was the most common with 16 trees. Eight yellow poplars were large enough. Chestnut oaks comprised seven of the potential den trees. Six white oaks were of sufficient size. Two scarlet oaks and one hickory were also large enough to be potential den trees. In contrast, Johnson (1978) found eastern hemlock, yellow birch, chestnut oak, and yellow poplar to be the most numerous large tree species in GSMNP.

Aspect and Slope

Aspect is defined as the direction in which the slope of an area faces. In this case, it is the direction in which the lowest point of the tree trunk meets the ground. The aspect of each

Table 10. The distribution of potential black bear den trees (PDT) according to elevation in southern CNF, Tennessee.

Elevation (meters)	Number of Transects	Number of PDT	Number of Transects with PDT
<450	15	4	3
451-600	17	12	4
601-750	9	13	6
750+	3	11	2

Table 11. The number of potential den trees found in southern CNF, Tennessee according to species.

Species	Number of Potential Den Trees
Northern Red Oak	16
Yellow Poplar	8
Chestnut Oak	7
White Oak	6
Scarlet Oak	2
Hickory	1
	40

potential den tree was recorded in the field. Readings were taken and direction assigned as follows: (1) Northeast (1-89°), (2) Southeast (91-179°), (3) Southwest (181-269°), and (4) Northwest (271-359°). Due north is defined as 0° or 360°, due east is 90°, due south is 180°, and due west is 270°.

Seventeen of the potential den trees had northwest aspects; eight trees faced the northeast; six potential den trees faced the southeast; and seven faced the southwest. As expected more of the large trees were found on the more productive northern slopes (Table 12). However, this difference failed to prove statistically significant.

The microtopographic slope also was recorded for each tree. That is, the slope of the ground in which the tree was rooted. A zero degree slope indicates completely flat ground, and a 90° slope indicates a straight vertical face. Obviously, all observations fell in between these two extremes. Ten potential den trees were found on slopes less than 20°. Slopes between 20° and 39° also contained ten of the potential den trees. Six potential den trees were found on slopes between 40° and 59°, and four were found on slopes greater

Table 12. Distribution patterns for potential black bear den trees in southern CNF, Tennessee according to aspect.

Aspect	Number of Potential Den Trees
NE	8
NW	17
SE	6
SW	8
	39*

One aspect reading deleted.

than 60° (Table 13). No significant differences for potential den tree production were found among the differing slopes.

The position of a potential den tree on the slope also is important. This is because trees higher on the slope are apparently more susceptible to damaging forces such as wind and lightning that can lead to cavity formation. Fourteen of the 20 large trees that were damaged (70%) were found on the upper third of the slope.

Table 13. Distribution patterns for potential black bear den trees in southern CNF, Tennesse according to microtopographic slope.

Slope	Number of Potential Den Trees
0-19°	18
20-39°	10
40-59°	8
60+°	4
	40

CHAPTER V

MANAGEMENT CONSIDERATIONS

VALUE OF DEN TREE SUPPLY

Johnson et al. (1978) delineated the value of den trees to black bears for saving energy. The fact that black bears give birth to their young during the harsh winter months increases the value of these trees. By minimizing the effects of cold and moisture, cubs have an increased chance of survival. Furthermore, the exclusion provided by den trees affords the denning bear protection from harassment. Human activity such as hunting or off road vehicle use could potentially disturb a denning bear. The activity of other animals could also unsettle a denning bear. Such disturbances might prove detrimental to the reproductive effort. For instance, a mother rousted from the den might not return to the cubs. The abandonment would result in the death of the cubs. Thus, old-growth hardwood areas could be important maternity areas that increase the chances for successful reproductive efforts.

Due to the importance of den trees to black bears in the southern Appalachians, it is critical that management strategies assure the continued presence of old-growth hardwood areas. Johnson (1978) found no absolute shortage of den trees in the GSMNP. The same apparently holds true for the CNF. Although there does not appear to be an absolute shortage of potential black bear den trees, there is some concern about their extended future. This doubt stems from several factors.

PAST LOGGING PRACTICES

Poor logging practices of the past undermined the integrity of the forest. Lumbermen in the late nineteenth and early twentieth centuries heavily exploited the timber resources of the southern Appalachians. Lambert (1961) identified two phases in the early logging history of the area.

Harvesting began by 1880. At this point the cutting was selective. The timber harvesters desired only particular species such as black walnut, cherry, ash, yellow poplar, and oaks. The majority of cutting took place in areas that exhibited fairly easy accessibility. However, this selective harvest took a dramatic toll. By 1887 black walnut and cherry "existed in Tennessee only far back in the mountains (Lambert 1961)." In the first phase, which lasted until approximately 1900, cutting eliminated prime yellow poplar stands from areas surrounding the lower creeks.

The second phase lasted until approximately 1925. This phase was initiated with a frenzy of land acquisition. Loggers also began to use railroads to increase their timber production. Existing railroad lines were connected to lumber mills. Then, as logging operations progressed, the railroads were extended further into the mountains. Logging operations at this time proceeded at a furious pace. Lambert (1961) stated that it was not uncommon for a company to log 70,000 to 80,000 board feet per day. In fact, by the mid 1930's, the Little River Lumber Company removed over 1.5 billion board feet of timber from the mountains of Tennessee.

The use of steam powered logging machines had an even greater effect than railroads on logging operations. The use of ground skidders and overhead cableway skidders allowed the lumbermen to access rugged areas of the southern Appalachians which they had previously been unable to log. In most watersheds selective cutting ended with the adaptation of machine logging. The common method of harvest consisted of cutting any tree greater than 30.48 cm (one foot) DBH. This practice left a shortage of large hardwoods. Moreover, there was no effort to insure the reproduction of hardwoods in areas that were denuded (Lambert 1961).

Lambert (1961) cited fires caused by logging operations as a major source of timber destruction. Careless use of machinery and railroads caused many fires. These fires destroyed a great deal of forest area. In addition, the fires often disrupted the reproductive process in recently logged areas. Young hardwoods in the understory were particularly vulnerable.

The reason that the intensive logging operations ceased in the southern Appalachians shows the extent of the destruction of forest resources. The loggers quit harvesting timber mainly because "virtually all of the timber had been expended (Lambert 1961)." Therefore, it is evident that early logging practices greatly reduced the number and type of trees that could be used by bears for winter dens.

CHESTNUT BLIGHT

In addition to poor logging practices and wildfire, the chestnut blight of the 1930's destroyed many old-growth areas in the southern Appalachians. Initially introduced in 1904, the fungus (*Endothia parasitica*) caused wholesale destruction throughout the range of the chestnut (Harlow et al. 1978). The species composition of these forests was dramatically altered as a result. The result of these factors has been a young forest with older, larger trees left only in small pockets or as culls. In fact, the majority of the CNF is comprised of stands 55-70 years of age.

GYPSY MOTH

There are also several ever-present threats to the CNF (including old-growth forests). One such concern is the gypsy moth (*Lymanntria dispar*). This species was accidentally introduced from Europe in 1869. The moth thrives in coniferous, deciduous, or mixed forests. The caterpillars of the gypsy moth have denuded many millions of hectares of forest land in the northeast United States and southern Canada. Their range, however, appears to be expanding. The arrival of this destructive moth in the southern Appalachians seems inevitable. Although the impact that the gypsy moth will have is unknown, it should be closely monitored. This is especially true for old-growth hardwood areas.

ARSON

Wildfires damage and destroy many hectares of forests each year. Lightning causes some of the fires in the CNF. Burning is not necessarily undesirable. It can clear undesirable understory species and facilitates new growth vital to the well being of species dependent on early successional vegetation. However, arson continues to be a problem in the forests of the southern Appalachians. Many hectares are wantonly destroyed by arsonists annually. An average of 233 intentionally set fires destroy over 500 ha of CNF land each year (USFS 1986).

MORTALITY OF POTENTIAL DEN TREES

Natural mortality of mature trees could also present a problem. Little is known about the dynamics and ramifications of the mortality of old-growth trees. Simply prohibiting the logging of existing old-growth hardwood stands may not be enough. McGee (1984) found that large mature hardwoods in a mixed mesophytic forest had high mortality rates.

Wathen et al. (1983) found that oaks were used heavily as den trees by black bears. McGee found these preferred species also experienced high mortality rates in his eight year study. McGee, in fact, found mortality in the larger trees (dominants and co-dominants) to be higher than for smaller understory trees. During the study 15% of trees 46 cm DBH or larger died. Twenty three percent of trees greater than 76 cm DBH died. These findings refute the assumption that mortality in old-growth trees is occasional and dispersed over time (Runkle 1981, 1982). The exact cause of mortality in individual trees is difficult to ascertain. The high mortality rates could have been caused by an isolated and unusual agent. However, the fact that mature stands are susceptible to massive mortality rates is alarming.

McGee also found that oaks were scarce in the understory while occupying a prominent position in the canopy. This fact compounds the effects of mortality among large mature oaks. McGee feels that the species structure might be shifting from oaks to sugar maples and yellow poplars. The possibilities of such changes in stand composition are obviously unknown. Moreover, the ramifications of such changes are also unknown.

However, the structure shifts McGee reports could adversely affect den tree production. Sugar maples rarely attain the size necessary to be used as den trees. Yellow poplars have been used as dens. However, their leaner form and smaller limb size make them less susceptible to the types of damage required to produce den trees.

Stephenson (1986), however, found great changes in species composition in a Virginia forest after 50 years. The chestnut blight of the 1930's wiped out the previously dominant chestnuts. In 1983 northern red oak had become the dominant species (Table 14). Surprisingly, however, white oak was also absent, although it had previously been present in the canopy. Sweet birch now appears where it was absent 50 years ago. Although the chestnut blight is an extreme example, it is evident that the potential for species shifting does exist.

On the other hand, not all studies show the potential for major shifts in species structure. Runkle and Yeter (1987) studied gap regeneration in

Table 14. The change in species composition of a Virginia forest after 50 years (Stephenson 1986).

Species	Percent of canopy 1932	1982-83
Castanea dentata	84.6	0
Quercus rubra	11.1	69.0
Q. alba	2.6	0
A. rubrum	0.8	7.7
Betula lenta	0	5.1

the southern Appalachians. These gaps (areas in the canopy left open due to mortality of dominant trees) were of two types: (1) large scale mortality leaving large openings and, (2) isolated small scale disturbances. Their findings were that the "species composition of individual gaps remained consistent over time." That is, dominant species remained dominant despite the demise of individual trees. Therefore, mortality in old-growth forests might not be a problem.

To assure the future presence of tree species commonly used as den trees, managers must do more than simply prohibit the logging of mature forests. Changing species composition in these old-growth areas must be carefully monitored. Furthermore, the presence of young oaks should be actively encouraged.

CURRENT MANAGEMENT PRESCRIPTIONS

The USFS defines goals as "concise statements of the state or condition that a Land Resource Management Plan are designed to achieve." The management plan for CNF calls for timber resources to be managed such that "high quality sawtimber will be grown and harvested on a sustained yield basis under the principles of multiple use (USFS 1986)." Several methods can be employed in order to meet this goal.

Conversion is the practice of replacing the cover type of a stand with a cover type. This is accomplished by restocking a recently harvested area with trees of a different species. Usually this means replacing hardwoods with pines because pine species are generally more economically efficient. That is, pine species grow faster and have more uniform quality than hardwoods.

Consideration must be given to the fact that some wildlife species benefit from the conversion to pine. However, pine does not produce the mast critical to such species as wild turkey and black bear. Furthermore, pine will not provide the potential dens needed by raccoons and black bears. It is, therefore, imperative that the value of hardwood stands not be overlooked.

The 1986 CNF Land and Resource Management Plan recognizes this fact. Conversion will not be used as a primary means of meeting the timber goals of CNF. Limited conversion is planned. For example, in the upland hardwood working group there will be "some artificial regeneration to white pine or yellow pine on poorer sites." Limited artificial regeneration to black cherry will occur in the cove hardwood working group. No conversion is to take place on Fir or Spruce Fir stands. Moreover, no Maple-Beech-Birch communities are to be converted to pine.

These safeguards are intended to ben

Upland hardwood and cove hardwood areas will primarily be generated naturally after harvest. Limited conversion of poor sites to white pine or yellow pine is planned.

Utilizing more of the potential timber in harvested areas would lead to increased timber production. The available supply could be increased by adding topwood to sales contracts. Another possibility would be lowering the minimum DBH of stems harvested (USFS 1986). Either of these methods might adversely affect black bears. The future supply of mast and/or dens could be diminished by lowering the age structure of the forest.

A final method for meeting the goals of timber management is through site preparation and stand improvement. These methods have merit in that the potential adverse effects on wildlife are minimized.

Site preparation is defined as the "deliberate manipulation of (1) physical factors of the atmospheric microenvironment, (2) forest floor and competing vegetation, (3) soil and, (4) biotic factors (Daniel et al. 1979)." The main goal of site preparation is to manipulate these factors so that rapid growth of the desired vegetation is optimal. Stand improvement should also facilitate the rapid growth of desired species. This advantage could be used to insure the production of potential den trees on sites with good hardwood potential. The production of oaks in cove hardwood areas is particularly important. Yellow poplar tends to dominate such areas if the generation of oaks is not actively encouraged. The presence of oaks is critical since they provide denning opportunities as well as mast. Poplars have limited potential to provide dens and are not mast producers. Some of the primary methods employed in stand improvement include thinning and prescribed burning (Daniel et al. 1979).

Harvest Methods

The USFS (1986) will manage CNF timber resources in order to "provide a non-declining yield of forest products consistent with land suitability" while protecting other resources.

Furthermore, timber resources are to be produced in an "energy and cost effective manner while maintaining diversity of plant communities." For this reason, the Final Land and Resource Plan (USFS 1986) sets aside 110,384 ha (44%) of the forest that will not be managed for timber. Forest land will be deemed unsuitable for timber management "if such production would result in adverse impacts to soils productivity, watershed, threatened or endangered species, if the stand cannot be adequately restocked in five years, if the lands have been administratively withdrawn (USFS 1986).

The USFS will attempt to attain these goals primarily through even-aged silvicultural management. That is, forest stands will be managed such that the majority of trees in each stand are approximately the same age. When the stand has reached the prescribed rotation age (age of harvest), the age of trees forming the main canopy will differ no more than 20 percent of the rotation age (USFS 1986). For example, if a stand's rotation age were 100 years, the majority of trees forming the main canopy would be 90-110 years of age.

The even-aged management system is initiated when a stand is harvested. The primary method of harvest in the CNF will be clearcutting (USFS 1986). The clearcut method is defined as a harvesting technique in which every tree in a stand is cut. That is, merchantable and unmerchantable trees alike are cut. The clearcut method results in the establishment of an even-aged stand through the cutting of an existing mature stand (Daniel et al. 1979).

Shelterwood cuts will be made in areas where the desired reproduction needs protection from overstory. Resource goals other than timber management will dictate the need for this practice. The classic shelterwood method consists of three stages. First, a preparatory cut is made. This cut is designed to correct a stand condition that is unfavorable to desired development. For example, a cut might be made to improve seed production of trees in the canopy. The next step is the regeneration cut. This cut opens the canopy enough to produce optimal conditions for the regeneration of the desired tree species. The first two steps can be combined into a single cut. Finally, a removal cut is made. The harvest of the merchantable trees is made after the desired species have become established (Daniel et al. 1979).

Rotation Age

The rotation age of a stand is the "number of years required to establish and grow timber crops to a specified condition or maturity for regeneration cuts (USFS 1986). Under the USFS management plan for the CNF, "rotations will be the length of time...required for the production of high quality sawtimber and veneer logs."

Rotation ages for hardwood stands are of vital importance in insuring sufficient mast production and denning opportunities. For cove hardwoods, rotations of 45-120 years are suggested. Rotations of 45-140 years are suggested for upland hardwoods (USFS 1986).

These rotation ages might be too short to provide the environmental conditions required by wildlife species that depend on old growth forests. Data concerning the average age of den trees (311 years) suggests that these rotations do not provide ample time for the development of den trees for black bears (Johnson 1978, Johnson and Pelton 1981). In areas featuring black bears, care must be taken to provide a forest age structure compatible with the bears' needs. The following section will provide additional commentary on the USFS's plans addressing these needs. Particularly the management plans in regard to old-growth areas.

Mast production is also of vital importance. USFS guidelines (1986) require mast production of at least 93 kg/ha. The above rotations should provide ample mast as long as care is taken to make sure rotation ages do not cluster toward the younger years.

DISTRIBUTION OF TIMBER RESOURCES

The CNF contains approximately 25,500,000 m^3 of timber. Of this, about 225,000 m^3 is allowed for sale each year. The CNF Final Land and Resource Management Plan (1986) calls for the amount of timber allowable for sale to double by the year 2030. However, 110,384 ha (44%) of CNF will not be managed for timber production.

The future age distribution of potential den trees is a concern. The existence of old growth areas is essential for wildlife dependent on late successional areas. Mast and den trees are of primary importance.

Presently 55 percent of the CNF is comprised of stands 50-70 years old. The CNF Final Land and

Resource Management Plan (1986) calls for a shift in this age distribution (Table 15). After the first ten year period, the majority of timber volume will be in the 60+ age class. This distribution would seem to provide good opportunities for mast production. In order to insure den tree availability, 250+ year old hardwood stands are to be maintained. However, after 150 years there will be a reduction in the timber maintained in the 60+ age class. The majority of timber will be found in the 10-30 and 30-60 year age classes. This information raises doubt concerning the future availability of den trees for black bears. The USFS has, however, made provisions to insure the availability of potential den trees.

Four percent of each compartment is to be maintained in 91+ year old cove and upland hardwoods. This is contingent on site capabilities. With the exception of Virginia pine areas, 20% of each working group is to be maintained in the 60+ year old class. Specifically, upland hardwoods will comprise nine percent of the 60+ age class. Five percent of the 60+ age class will be comprised of cove hardwoods. No more than six percent of any management area

Table 15. Changes in the age structure of CNF, Tennessee under the Land and Resource Management Plan (USFS 1986).

Age Class	Present	After 10 years	After 150 years
0-10	10,415	15,639	68,374
10-30	14,421	22,980	53,154
30-60	68,973	4,655	48,252
60+	63,425	113,691	28,158

featuring late successional species will be in the 0-10 year age class at any given time. Finally, the average stand age of the CNF (excluding old-growth) "will average no less than 50 years (USFS 1986)."

While these measures will be helpful in maintaining essential requirements for late successional dependent wildlife, they may not be enough. For example, simply having 90+ year old trees does not necessarily insure the availability of potential den trees. Site quality must also be taken into account. An effort must be made to maintain old growth areas on some better quality sites. This issue is addressed in that for areas managed for late successional species "at least sixty four percent of each compartment should be maintained in older age stands to provide optimum den habitat (USFS 1986)." Moreover, a minimum of five percent of the cove and upland hardwood groups on high quality sites will be allowed to reach at least 250 years of age. This specification is included for the purpose of providing denning opportunities.

Riparian areas in all forest types will provide old growth. All land and vegetation within 30 m of perennial water sources will be protected. This will insure old growth distribution throughout the CNF.

The species structure of the CNF should not be altered drastically under the 1986 Land and Resource Management Plan. Natural regeneration will be the primary method of stand reproduction for the upland hardwood and cove hardwood working groups. These hardwood areas are of primary importance to black bears.

These safeguards are intended to benefit targeted wildlife species (MIS) as well as provide an economically efficient timber resource. The silvicultural methods employed by the Land and Resource Management Plan are intended to create desirable levels of species diversity.

WILDLIFE GOALS

The 1986 Land and Resource Management Plan manages for wildlife in terms of management indicator species (MIS). MIS "relate forest age class distribution to the effects of habitat supply." That is, MIS are used to measure the effects of various management strategies on targeted wildlife species and their corresponding habitat requirements. Black bears, for example, are dependent on late successional areas (Table 16). The USFS management strategies for areas featuring black bear mandate the presence of old-growth hardwood areas.

The majority of the southern CNF is categorized as Management Area 15. A management area is defined as "an area with similar management objectives and a common management prescription (USFS 1986)." Forest wide there are 108,063 ha of land classified as Management Area 15. This management classification emphasizes late successional species such as black bear.

Where black bear are considered significant, old-growth timber resources will be a priority. Old-growth areas will be provided through areas that will be left unharvested. Wilderness areas and land unsuitable for timber management will provide the majority of late successional areas. Additional land will be set aside as needed.

Optimally, the age class distribution of the CNF will be based on the habitat needs of MIS. Furthermore, those species demanded by consumptive users will be emphasized where possible. The black bear is such a species.

In general, the goal in regard to wildlife management (for CNF) is to manage for timber and

TABLE 16. Examples of various management indicator species and their required environment on CNF, Tennessee.

Early Successional Species	Late Successional Species
Whitetail deer	Black bear
American kestrel	Gray squirrel
Bluebird	Eastern wild turkey
Yellow breasted chat	Pileated woodpecker
Chestnut-sided warbler	Cerulean warbler

other resources in a manner that will maintain or improve the "habitat necessary to maintain viable populations of all native vertebrates, and to meet, within resource capabilities, demand for certain target species (USFS 1986)." The plan lists many goals for resource management. The following discussion explores several of the goals that have a direct bearing on the future status of potential black bear den trees on the CNF.

GOALS FOR DIVERSITY OF RESOURCES

(1) "Provide for diversity of plant and animal communities." The USFS (1986) desires a diverse forest featuring many different plant and animal communities. The chief method for providing this diversity will be through even-aged management. Forest stands will be harvested primarily through clearcutting. These regeneration cuts will be between four and 16 ha in size. By interspersing these clearcuts through time and space, the USFS hopes to create a diverse forest community.

The even-aged management philosophy should not adversely effect black bears or the production of potential den trees if certain precautions are taken. Care must be taken to insure that adequate old-growth hardwood stands are allowed to reach the age and size necessary to provide dens. This is particularly important because past silvicultural practices (prior to 1936) and the chestnut blight left such stands in short supply. The importance of hardwood stands is seen in the fact that they were found to produce significantly (alpha=0.05) more potential black bear den trees than pine, pine-hardwood, or hardwood-pine stands.

Furthermore, the presence of old-growth areas provides trees the time necessary to attain adequate size (>66 cm DBH) for den formation. The presence of 250+ year old stands also is necessary for den production in light of Johnson's (1978) finding that the average age of 10 den trees was 311 years.

An even-aged management system can be used very effectively to produce the desired diversity of forest communities. Carefully planned regeneration cuts that leave old-growth hardwood areas unharvested will help insure the availability of potential black bear den trees. The rotation age of hardwood stands to be harvested, however, should be lengthy enough to insure abundant mast production.

WILDERNESS AREAS

(2) "Provide wilderness areas in keeping with the National Wilderness Preservation System." The CNF currently has 28,978 ha (11.5%) of land officially designated as wilderness in 13 areas. A Wilderness area is defined as an area (1) featuring substantially natural ecological conditions and (2) offering the visitor outstanding opportunities for solitude in his pursuit of a primitive and unconfined type of recreation (Hendee et al. 1978)." The Wilderness Act (1964) further stipulates that such areas have "at least 5,000 acres (2,024 ha) of land..." The Eastern Wilderness Act (1975), however, allows for the designation of smaller tracts as wilderness.

Currently, the Gee Creek, Cohutta, Joyce Kilmer-Slickrock, Citico Creek, Big Frog, Bald River Gorge, Little Frog Mountain, and Big Frog Extension Wildernesses comprise the study area's 16,472 ha of wilderness areas. Approximately 13.5 % of the current study area is designated as wilderness.

These lands are to be managed under the guidelines established in the Wilderness Act of 1964 and the Eastern Wilderness Act of 1975. These acts (and their amendments) suggest that wilderness areas be managed so as "to protect the attributes that caused the areas to be designated in the first place (USFS 1986)."

The maintenance of wilderness areas will be a major factor in providing the old-growth forest needed by black bears. Wilderness areas provide land in which timber harvesting activities will be excluded. Old-growth forests for late successional MIS will be one result. For example, in such areas, at least four percent of hardwood stands must be in the 90+ year age class. Wilderness areas will probably provide a great deal of the old-growth forests mandated in the management plan. Clearly, wilderness areas will help provide much of the land needed to produce potential den trees for black bears. These areas are not viewed as the exclusive means of providing old-growth areas. Yet, if existing and additional wilderness areas are distributed throughout the forest, the clumped distribution of potential den trees in CNF might be partially alleviated.

CONSUMPTIVE USES

(3) "Provide for consumptive uses of resources so long as the uses are compatible with the

management of other resource values." Timber harvesting, hunting, and fishing are the primary consumptive uses of the CNF and its resources. This section will focus on the hunting of black bears. Timber harvesting and its effects on black bears (and potential den trees) have previously been discussed.

For black bears, hunter demand far exceeds supply. The estimated black bear population in CNF is 274 animals. Yet, the number of hunter trips for black bear was 1,651 (Table 17). Moreover, this figure does not include the constant threat of poaching. The demand caused by hunting (legal and illegal) certainly produces a great deal of pressure on the black bear population in CNF. The availability of den trees could ease this pressure.

Den trees offer the black bears much greater protection than ground dens. This is particularly important to reproductive females. The chances of human disturbance are greatly reduced when bears den in trees. However, if too few potential den trees are available, illegal hunters knowledgeable about black bears' preference of den trees could use these trees as the focal point of their illegal hunting.

Table 17. Demand for black bear as measured by hunter trips to CNF, Tennessee, 1977-1978 (USFS 1986).

	Trips
Bear & Boar	2,498
Bear Only	1,651

SAWTIMBER QUALITY

(4) "Improve quality and quantity of sawtimber being produced." An even-aged silvicultural system will be used to improve the quantity and quality of sawtimber produced in CNF.

Lowering rotation ages is also an alternative that could help achieve the goal of improved quantity of sawtimber. Where late successional MIS are managed for, rotation ages for hardwood stands should be maintained within a time frame that will allow for optimum mast and den production.

Another option for increasing the quantity of sawtimber would be to convert hardwood stands to faster growing pine stands. The management plan calls for only limited conversions from hardwood to pine. Such conversions will be limited to sites not capable of producing high quality hardwood stands. In areas that have good site quality, hardwood stands will be maintained.

RIPARIAN ZONES

(5) "Protect...land and vegetation for approximately 100 feet (30 meters) from the edge of all perennial streams, lakes and other bodies of water." Due to the abundance of streams in the

CNF, there will be a significant amount of protected land. These riparian zones will be important sources of old-growth in the southern Appalachians. By not allowing timber harvesting in riparian zones, a source of potential dens could be provided in areas that would normally not feature such trees. However, because bears prefer to den on the upper third of slopes (Johnson and Pelton 1981), the supply of potential den trees from this source is likely limited. The proximity of many streams to roads could further limit den treetial. Yet, the presence of old growth in riparian zones could lessen the clumped distribution of potential den trees seen in CNF. Potential den trees would be available in diverse environments. That is, compartments could provide denning habitat without specifically being old-growth areas.

ECONOMICS

(6) "Improve the quality of life in the Appalachian area by using National Forest programs to promote the social, economic and cultural growth of the area." Economics must obviously play a role in the decision making processes involving the

resources of the CNF. All management programs must be economically efficient. However, the economic gains must be weighed against possible adverse effects to other forest resources. These other resources (e.g. wildlife, fisheries, recreation, soil and water) can produce direct and indirect monetary benefits. For example, many dollars are spent in local communities each year by recreational users of the CNF.

The presence of black bears and other wildlife draws many visitors to CNF each year. These visitors stimulate the local economy. Therefore, black bears can be viewed as a valuable economic resource.

ROADS

(7) The goals of the Land and Resource Management Plan (1986) concerning roads are to "provide public traffic access to National Forest lands where compatible with management of other resources." Roads provide potentially negative impacts on bears and should be held to a minimum. That is, accessibility of old-growth areas might render potential den trees undesirable to the black bear. Studies indicate that black bears avoid

roads (Quigley 1982, Villarubia 1982). If roads penetrate mature forests, humans will inevitably follow. The result could be the disturbance of denning bears. As previously mentioned, harassment of a denning mother might lead to abandonment of cubs. Thus, not only must potential den trees be provided, but access must be limited.

Obviously, roads are necessary to conduct timber harvesting. In the CNF there are approximately 2,478 km of roads. Forest Service roads account for 1,907 km of these roads. The Land and Resource Management Plan (1986) calls for an additional 1,460 km of new roads forest wide over the next 50 years. The placement of these new roads is critical. An open road density of 1 km/161 ha will be maintained on the CNF except in areas with significant black bear populations. Where black bears are considered significant, the open road density will be no greater than 1 km/322 ha. Wilderness areas are protected against the intrusion of roads. Other promising old-growth areas should also be exempt from road construction and access.

Governing the access of roads could prove very useful in limiting the possible adverse effects on wildlife. For instance, 78% of the new roads constructed will be designated as traffic service level D. This means that public access will be restricted by gates or other restraining devices. In sum, 45% of all roads will have restricted access for at least part of the year (USFS 1986).

Restricting access into old-growth in the winter could be a very useful management technique. Black bears in GSMNP showed no aversion to limited access roads (Carr and Pelton 1984). By eliminating (or at least discouraging) undesirable traffic, the potential for disturbing denning bears could be minimized. Also, hunting pressure (legal or illegal) would be reduced by limiting access to these areas.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The southern Appalachians provide marginal habitat for black bears. In order to perpetuate the existing population in the region, all resources that might make the environment more favorable should be encouraged. Large, over-mature trees are such a resource. These den trees can increase the likelihood that bears will survive the harsh winter environment. Bears that den in trees spend less energy on body maintenance than those denning on the ground. Tree dens also provide seclusion for bears. Harassment from people or other animals is less likely to occur. These factors combine to increase the chances of successful reproduction. This is true because parturition and lactation occur while bears are denning. Old-growth hardwood areas (and the potential den trees they provide) , therefore, might provide important maternity areas for black bears in the southern Appalachians.

The CNF provides many denning opportunities for black bears. Ground den opportunities appear to be extremely abundant. Moreover, there appears to be no absolute shortage of potential den trees in CNF. This study examined several variables in an attempt to identify the type of area on which potential den trees might be located. Variables such as age class, elevation, slope, and aspect proved to be non-significant (alpha = 0.05). The results concerning age class may have been misleading due to flaws in the structure of the variable. Cover type proved to be a good predictor of the availability of potential den trees. Such trees are more likely to be found in hardwood stands than other stand types (pine, pine-hardwood, or hardwood-pine).

The distribution of potential den trees in CNF was clumped. That is, potential den trees often were found in close proximity. Past logging and silvicultural practices caused this pattern. In the late nineteenth and early twentieth centuries the southern Appalachians were logged extensively. Nearly all accessible areas were stripped of their timber resources. Little or no effort was made to regenerate logged areas. In many areas, the only trees left were those deemed unmerchantable. These culls represent a large portion (approximately 75% in this study) of potential den trees now available. Pockets of trees also were left where they could not be reached for harvest. Wildfires caused by careless loggers also destroyed many acres of forest. Finally, the Chestnut blight of the 1930's killed the remaining chestnuts in the southern Appalachians. The preceding factors combined to produce a young forest with few old-growth areas that are distributed in patches.

The USFS presented its goals for CNF in the Final Land and Resource Management Plan (1986). The emphasis of the plan is for non-commodity resources such as wildlife, fisheries, recreation, and resources. The USFS plans to manage for timber only in areas were it does not conflict with other management goals. Timber resources in CNF will be managed under the principles of even-aged silviculture. The primary means of harvest will be clearcutting. The goal of creating a more diverse forest will be accomplished through dispersing these clearcuts through time and space. Natural regeneration will predominate. The age structure of the forest will increase in the near future. However, a long term shift in the age structure is planned. This could be detrimental to wildlife species such as black bears that depend on late successional forests.

Management indicator species (MIS) provide the basis of wildlife management plans. Each compartment has an assigned MIS. The timber resources are then managed to accommodate that MIS. For example, where white-tailed deer are the MIS, timber management plans will provide the early successional forests needed. Where black bears are featured, late successional forests will be provided. Optimally, the age and species structure of the forest will be determined in large part by each area's MIS.

Several other aspects of the USFS management plan for CNF will affect black bears. These mainly involve the manner in which forest lands will be administered. Access is the common element. The accessibility of forest areas for harvest or other human activities can influence the black bear population in CNF.

For instance, USFS policies concerning roads could play an important role in the future of black bears in the southern Appalachians. Limiting access on many roads will provide black bears extra protection against human intrusion which could have negative impacts on the reproductive effort. The

Land and Resource Management Plan calls for new road construction into inaccessible areas where feasible. Care must be taken to protect the status of roadless areas. Human harassment can only adversely affect the black bear population. Poaching is a prime example of such a negative impact. The USFS addresses this problem by suggesting limited access on most of the new roads constructed. Limited access might be particularly important at times immediately prior to den entrance and immediately after den emergence.

Wilderness areas will provide roadless and old-growth areas in CNF. Approximately 11 percent of the CNF is designated as wilderness (under the Wilderness Act of 1964, the Eastern Wilderness Act of 1975, and the Tennessee Wilderness Bill of 1986). These areas will provide excellent opportunities to develop old-growth hardwood stands. Timber harvesting is prohibited in wilderness areas. Therefore, wilderness areas will provide old-growth areas which will provide many potential black bear den trees.

Black bear sanctuaries also are important denning sources. Because no legal hunting pressure is allowed in bear sanctuaries, they provide important maternity areas.

Additional den trees could be provided through the protection of riparian zones from timber harvest if suitable tree species are present. USFS proposals call for the protection of land and vegetation for 30 m from streams, rivers, lakes, and other perennial water sources. The presence of potential den trees in riparian zones could provide denning opportunities in diverse and interspersed habitats. This could be very important in the event of large scale forest destruction such as the Chestnut blight of the 1930's.

There are encouraging indications that the future supply of potential den trees in CNF, through active management, will continue to be adequate for population needs. The importance of old-growth areas for wildlife species dependent on late successional forests is recognized by the USFS. Currently, there appears to be no absolute shortage of potential den trees. Their availability in the near future can be insured by prohibiting logging of current old-growth stands capable of producing potential den trees, established wilderness areas, riparian zones, and other areas determined unsuitable for timber management.

There are concerns, however, regarding the extended future of potential den trees in the CNF.

The gypsy moth is of primary concern. The caterpillars of this moth have denuded a great deal of forest land in the northeast United States and southeast Canada. The range of the gypsy moth continues to expand southward. In time, the gypsy moth will be present in the southern Appalachians. The ramifications of its presence are unknown. However, there is a possibility of widespread catastrophic damage to forest land.

Arson continues to be a problem in CNF. A great deal of forest is lost each year due to arson. Although this problem probably does not endanger the supply of potential den trees forest-wide, it can have serious local impacts. Such a fire in a black bear sanctuary or wilderness area could destroy important black bear habitat.

Furthermore, uncertain mortality patterns in old-growth forests remain a question. Some data indicate that mortality can be widespread in such areas (McGee 1984, Stephenson 1986). The result would be a shift in age structure. Moreover, a shift in species structure might occur. This could result in the replacement of preferred den tree species with trees not capable of producing potential dens. However, this possibility is unproven. Other studies find no such patterns. In fact, Runkle and Yeter (1987) concluded that after mortality, areas generally returned to their former species composition. Nonetheless, mortality patterns and subsequent species composition should be monitored in old-growth areas. This would be particularly important in the case of widespread mortality as occurred during the chestnut blight.

MANAGEMENT RECOMMENDATIONS

Basic management recommendations are as follows:

1) Identify hardwood areas with high site index. The production of hardwoods should be actively encouraged. Site preparation and stand improvement can help insure the propagation of the desired hardwood species (primarily oaks).

2) During field activities (on all stand types) identify potential den trees or clusters of potential den trees and stipulate these for total protection. To insure quality denning sites interspersed in various environments throughout the forest, specific site management or individual tree management may be necessary.

3) Rotation ages for hardwood stands with high den tree potential should be 250+ years to provide adequate time for den tree production.

4) Continue to work within the framework of the wilderness concept to limit access to areas with high den tree potential. The exclusion of timber harvesting in wilderness areas allows for the development of old-growth areas. Furthermore, the absence of roads eases the pressure of human harassment of black bears.

5) Coordinate areas of high den tree potential with additional black bear sanctuaries.

6) Wilderness areas and/or bear sanctuaries should be distributed forest wide. This will help lessen the potential of illegal hunters singling out large trees as sources of bear by easing the clumped distribution of potential den trees now seen in CNF. Widely dispersed old-growth areas also will lessen the impact of potential harmful agents such as the Gypsy moth and arson.

7) The presence of potential den trees might prove secondary if black bears are deterred by human activity. Therefore, access to important black bear habitat should be limited. Specifically, roads providing access to potential maternity areas should be closed. The designation of wilderness

areas will limit access to other old-growth forests.

These protective measures should help insure the future availability of potential den trees in CNF. Such den trees may provide the additional protection needed for the continuance of a viable black bear population in the southern Appalachians.

LITERATURE CITED

Carr, P. C. and M. R. Pelton. 1984. Proximity of adult female black bears to limited access roads. In Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies.

Daniel, T. W., J. A. Helms, and F. S. Baker. 1979. Principles of Silviculture. McGraw-Hill, New York. 500pp.

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

Harlow, W. M., E. S. Harrar, and F. M. White. 1978. Textbook of Dendrology. McGraw-Hill, New York. 510pp.

Hendee, J. C., G. H. Stankey, and R. C. Lucas. 1978. Wilderness Management. Forest Service. Washington, D.C. 381pp.

Husch, B., C. I. Miller, and T. C. Beers. 1982. Forest Mensuration. John Wiley and Sons. New York. 402pp.

Johnson, K. G., 1978. Den ecology of black bears in the Great Smoky Mountains National Park. M. S. Thesis, University of Tennessee, Knoxville. 107pp.

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. Pages 155-166 in Proceedings of the Fourth Eastern Black Bear Workshop.

Johnson, K. G. and M. R. Pelton. 1979. Denning behavior of black bears in the Great Smoky Mountains National Park. Pages 239-249 in Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies.

__________ and ____________. 1980. Environmental relationships and the denning period of black bears in Tennessee. Journal of Mammalogy 61:653-60.

__________ and ____________. 1981. Selection and Availability of dens for black bear in Tennessee. J. Wildl. Manage. 45:111-19.

Lambert, R. S. 1961. Logging the Great Smokies, 1880-1930. Tennessee Hist. Quart. 20:350-63.

Lentz, W. M., R. L. Marchinton, and D. M. Carlock. 1981. Black bear habitat in north Georgia: some implications of wilderness designation. Proc. Ann. Conf. S.E. Assoc. Fish and Wildl. Agencies. 34:550-556.

Linzey, A. V. and D. N. Linzey. 1971. Mammals of the Great Smoky Mountains National Park. The University of Tennessee Press, Knoxville. 114pp.

McGee, C. E. 1984. Heavy mortality and succession in a virgin mixed mesophytic forest. USDA, USFS.

Milne, L. and M. Milne. 1984. The Audubon Society Field Guide to North American Insects and Spiders. Alfred A. Knopf, New York. 989pp.

Neter, J., W. Wasserman, and M. H. Kutner. Applied Linear Statistical Models. Richard D. Irwin, Inc. Homewood, Illinois. 1127pp.

Pelton, M. R., L. E. Beeman, and D. C. Eagar. 1980. Den selection by black bears in the Great Smoky Mountains National Park. In Proceedings from the Fourth International Conference on Bear Research and Management.

Quigley, H. B. 1982. Activity patterns, movement ecology, and habitat utilization of black bears in the Great Smoky Mountains National Park, Tennessee. M.S. Theses, Univ. of Tennessee, Knoxville. 140 pp.

Runkle, J. R. 1981. Gap regeneration in some old-growth forests of the eastern United States. Ecology. 62:1041-1051.

______________. 1982. Patterns of disturbance in some old-growth mesic forests of eastern North America. Ecology. 63:1533-1546.

Runkle, J. R. and T. C. Yeter. 1987. Treefalls revisited: gap dynamics in the southern Appalachians. Ecology. 68:417-24.

SAS. 1985. SAS user's guide: statistics, version 5 edition. Statistical Analysis System Institute, Inc. Cary, NC. 956pp.

Shanks, R. E. 1954a. Climates of the Great Smoky Mountains. Ecology. 35:354-361.

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

Stephenson, S. L. 1986. Changes in a former Chestnut-dominated forest after half century of succession. American Midland Naturalist. 116:173-9.

Stupka, A. 1960. Great Smoky Mountains National Park. Natural History Handbook No. 5. U.S. Government Printing Office, Washington. 75pp.

Tanner, J. T. 1963. Mountain temperatures in the southeastern and southwestern United States during late spring and early summer. J. Applied Meteor. 2:473-483.

Thornwaite, C. W. 1948. An approach toward a rational classification; of climate. Geog. Rev. 38:55-94.

USFS. 1986. Final land and resource management plan. Cherokee National Forest. USDA, USFS.

Wathen, W. G., K. G. Johnson, and M. R. Pelton. 1983. Characteristics of black bear dens in the southern Appalachians. In Proceedings of the Sixth International Conference on Bear Research and Management.

Villarrubia, C. R. 1982. Movement Ecology and habitat utilization of black bears in Cherokee National Forest, Tennessee. M.S. Thesis, Univ. of Tennessee, Knoxville. 159pp.

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