12-1978

Den Ecology of Black Bears (*Ursus americanus*) in the Great Smoky Mountains National Park

Kenneth Gregory Johnson
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Kenneth Gregory Johnson entitled "Den Ecology of Black Bears (*Ursus americanus*) in the Great Smoky Mountains National Park." 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.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

James T. Tanner, Boyd L. Dearden

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

To the Graduate Council:

I am submitting herewith a thesis written by Kenneth Gregory Johnson entitled "Den Ecology of Black Bears (Ursus americanus) in the Great Smoky Mountains National Park." I 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.

Michael R. Pelton, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

DEN ECOLOGY OF BLACK BEARS (*URSUS AMERICANUS*) IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Kenneth Gregory Johnson

December 1978

ACKNOWLEDGMENTS

Appreciation is extended to Dr. Michael R. Pelton, Associate Professor of Forestry, Wildlife and Fisheries, The University of Tennessee, Knoxville, who served as my major professor and coordinator of the black bear project. Thanks are also expressed to Drs. Boyd L. Dearden, Associate Professor of Forestry, Wildlife and Fisheries and James T. Tanner, Professor of Zoology who served on my committee. Dr. Clif C. Amundsen gave helpful suggestions on gathering vegetation data and Dr. H. Alan Lasater generously provided valuable statistical advice.

I am grateful to Paul R. Brown for aging tree dens, William G. Minser III for assistance in climbing tree dens, and to Kirk S. Rau and John H. Eiler for many hours of vegetation sampling. Assistance, insights and companionship were provided by fellow students, particularly Tom L. Burst, Dan C. Eagar, Tom C. Eagle and David L. Garshelis. Special thanks are extended to the many people who helped but were too numerous to list without possible omissions.

And finally, I am most grateful to my wife, Debbie, who assisted in all aspects of the project--field work, data analysis, editing and typing of rough drafts--and who served as a constant source of moral support.

Financial support for this project was obtained through McIntire-Stennis Project Number 12, Department of Forestry, Wildlife and Fisheries, The University of Tennessee, Knoxville.

ABSTRACT

Radiotelemetry was used to locate winter dens, determine the denning period, and gather observations on the denning behavior of black bears (<u>Ursus americanus</u>) in a 42,800 ha portion of the Great Smoky Mountains National Park (GSMNP). After spring emergence, dens and the site parameters were measured and the vegetation sampled. Random transects and factor and discriminant function analysis were used to determine the availability of dens and denning habitat.

The denning period averaged 94 days with most bears entering dens between the last week in December and the first week in January and emerging from dens between the last week in March and the first week in April. Adult females entered dens first, adult males next, and sub-adults of both sexes denned last. Emergence was in the reverse sequence. Females with newborn cubs exited dens later ($P < .002$) and denned longer ($P < .0107$) than other females.

Weather, principally increased precipitation, and lower maximum and higher minimum daily temperatures, provided the proximate stimulus to den but food availability also apparently influenced entrance of bears into dens since bears denned earlier ($P < .0004$) in years (1972-74) with a fair to poor mast yield than in years (1976-78) with excellent mast yields. A circannual (endogenous) rhythm as the ultimate mechanism encompasses the observed variations in environmental factors affecting the denning period of bears over their broad geographic range and diverse ecological conditions.

Significant increases in inactivity occurred in the pre- and postdenning periods with the transition into and out of dormancy occurring gradually over a period of about one month. This may be a physiological transition period. The frequency of head movements increased ($P < .005$) prior to den emergence indicating movements within dens and readjustment to normal behavior.

Preferred den sites were cavities high above ground ($\overline{x} = 11.15$ m) in large ($\overline{x}$ dbh = 94.8 cm) yellow birches (Betula alleghaniensis), eastern hemlocks (Tsuga canadensis), red maples (Acer rubrum) and northern red oaks (Quercus rubra). The majority of ground dens (78%) were cavities under root systems of wind-tilted trees or in association with stumps. Dens generally occurred on steep slopes ($\overline{x} = 33°$) at high elevations ($\overline{x} = 1104$ m). This was probably related to the inaccessibility of these areas to pre-Park logging activities and the importance of wind damage to den formation.

Adult females and sub-adults of both sexes more often ($P < .078$) selected tree cavities above ground than did adult males. Tree dens offered seclusion from ground disturbances and superior energy conservation over ground dens and likely serve as important maternity denning areas and centers of dispersal. Population data from the watershed with the majority of active tree dens showed a higher concentration ($P < .0102$) of adult females and higher density than the study area wide population of wild bears. Tree dens may afford the extra protection necessary to maintain viable black bear populations in islands of dwindling and often marginal habitat.

Application of the Poisson distribution to 30 random transects

(60 ha) yielded an estimate of 2140 ± 92 (two standard deviations) tree dens in the study area which has an estimated population of 129 bears (range 93 to 174, CI = 95%). However, the clumped distribution of tree dens resulting from the pre-Park logging history results in tree cavities being less available to bears in certain watersheds and especially at low elevations. Consequently, ground dens are more frequently selected ($P < .005$) and indications are that bear densities are generally lower in these areas. No use or reuse of potential and active tree dens further indicated an abundant supply of tree cavities available to bears in the virgin portions of the GSMNP. Ground dens were 4.7 times more abundant than tree dens.

Discrete differences of site and vegetation parameters at tree and ground dens enabled classification through discriminant function analysis of areas with the highest den potential. Preservation of tree den habitat, as well as the specific den sites, could then be incorporated into forest management outside the Park. A productive approach for the future would be to coordinate black bear sanctuary and wilderness establishment with areas identified as having high tree den potential.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Winter dormancy is one of the more interesting and important aspects of the biology of bears. The survival value of this unique behavioral adaptation is particularly evident in black bears since they are the least predacious of the carnivores and most closely tied to the seasonal plant cycles. By becoming dormant bears circumvent severe weather conditions and food shortages.

Winter sleep of bears has received considerable coverage in the literature by early naturalists. Morse (1937) and Aldous (1937) observed hibernating black bears in northern Minnesota to be in a "deep slumber" or "partial stupor" from which arousal was possible. But more importantly, they documented birth of cubs in winter dens and postulated that the den affords protection for survival of the cubs. Other early accounts by Schoonmaker (1938), Clodfelter (1943), Smith (1946) and Matson (1946, 1954) are in general agreement regarding behavioral response, den types, and reproductive aspects of denning bears. Matson (1946) was the first to speculate on possible environmental stimuli triggering dormancy. He postulated that bears denned earlier in years of abundant food supply since adequate fat stores were easily accumulated. However, the early reports were usually coincidental observations of a general nature.

Erickson (1964) studied winter dormancy by analyzing statistics on black bear kills in Michigan. He reported differential timing of den entrance among the sex and age classes, den types utilized, and

the more careful preparation of den sites by females.

The advent of radiotelemetry provided an excellent means for objective studies of winter dormancy in bears. Jonkel and Cowan (1971), Craighead et al. (1971) and Taylor (1971) employed telemetric methods to delineate den selection, temporal aspects, and behavioral and physiological responses of hibernating black bears. Prehibernation and denning activities of grizzly bears (Ursus arctos) have also been successfully studied with radiotelemetry (Craighead and Craighead 1972a, 1972b).

Lindzey and Meslow (1976a) showed significant differences in the timing of den entrance; adult females entered dens first, yearlings entered next, and three-year-old males entered last. They noted a distinct period of pre- and postdenning inactivity and postulated the cumulative effect of weather and physical condition as the stimulus to enter the den. Den characteristics were also described (Lindzey and Meslow 1976b).

Rogers (1977) demonstrated the value of capturing bears in winter dens for monitoring reproduction, survival and social relationships. LeCount (1977), Hamilton and Marchington (1977) and Mykytka (personal communication) have added telemetry data from southern regions which show that winter dormancy is universal throughout the range of black bears in North America.

Observations of denning behavior for bears in the wild may aid in bridging gaps between laboratory and field studies and contribute to an understanding of the physiology of hibernation. An understanding of various aspects of the physiology of hibernation has shown promise

for such human health problems as kidney disease, control of obesity, and as an aid in the comprehension of the complex processes of aging (Lundberg et al. 1976).

The timing of winter dormancy is an important consideration for regulating back-country use in the Great Smoky Mountains National Park (GSMNP) and setting hunting seasons outside the Park. Information concerning environmental factors which influence the denning period is valuable in understanding how bears synchronize their physiological behavior with the environment. This is an area which is poorly understood, especially in regions with relatively mild climates.

Early implications were that den requirements were of little significance to the survival of black bears due to the flexibility of den selection reported in the literature. However, the majority of the reports were from northern regions where snow cover played an important role in insulation and concealment of denning bears. Southern regions are generally free from snow cover and experience high amounts of precipitation, principally rain. Protective den sites seem particularly important since bears often spend over one-fourth of the year in one location and parturition is limited to winter dens. As suitable habitat declines, more attention on such subtleties as preferred den sites may be necessary to insure viable black bear populations.

The objectives of the present study were 1) to gather observational data on denning behavior, 2) to determine the denning period and environmental factors influencing it, 3) to determine den site selection and describe the physical characteristics, vegetation and site parameters of dens, and 4) to determine availability of dens and denning habitat.

CHAPTER II

THE STUDY AREA

I. LOCATION

The Great Smoky Mountains National Park is bisected by the Tennessee-North Carolina border between 35°29' and 35°47' N latitude, 83°05' and 83°55' W longitude. The Park comprises 207,382 ha in Blount, Sevier, and Cocke Counties, Tennessee, and Swain and Haywood Counties, North Carolina. There are two major highways passing through the Park: U.S. 441, the transmountain road from Gatlinburg, Tennessee to Cherokee, North Carolina and Tennessee State Route 73, which parallels the northern Park boundary from Townsend, Tennessee to Gatlinburg. However, most of the Park is accessible only by the 1048 km of hiking trails (National Park Service 1969).

This investigation was limited to that portion of the Park bounded by U.S. Highway 441 on the East, the Tennessee-North Carolina border on the South, State Route 73, Laurel Creek Road, the northern half of the Cades Cove Loop Road and Abrams Creek on the North and the Park boundary on the West (Figure 1). This section comprises a total area of approximately 42,800 ha. There are four main drainages within this area: the East, Middle and West Prongs of the Little River (E, M, WPLR) and Abrams Creek.

II. PHYSIOGRAPHY AND GEOLOGY

The Smokies are part of the Unaka Mountains of the Blue Ridge Province in the southern division of the Appalachian Highlands

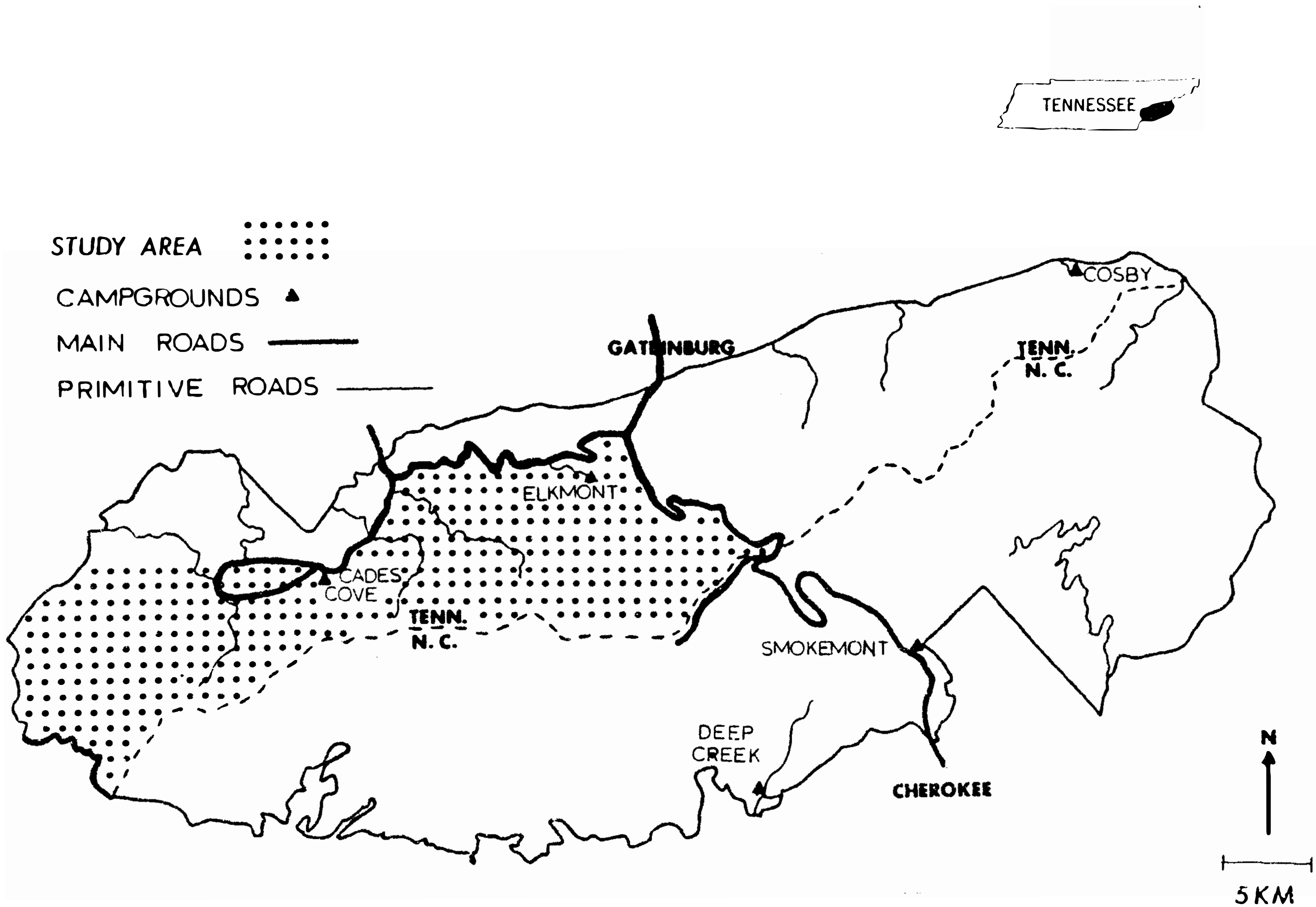

Figure 1. Location of the study area within the northwest portion of the Great Smoky Mountains National Park, Tennessee.

(Fenneman 1938). They lie to the northwest and parallel to the main divide of the southern Blue Ridge Mountains. The Big Pigeon and Little Tennessee Rivers terminate the Great Smokies on the East and West and separate them from other ranges of the Appalachian Highlands.

The main ridge of the Smokies is oriented generally northeast to southwest and connects a series of high peaks with large ridges radiating to each side. The topography is extremely steep and complex with less than 10% of the surface area having less than 10 degrees slope (Message from the President 1902). The elevation ranges from 2024 m at Clingman's Dome to 270 m at the confluence of Abrams Creek and the Little Tennessee River. Both extremes occur within the study area and approximately half of the study area is over 1000 m.

Most of the Smokies are underlain by rock of the Ocoee series which dates to the late Precambian and is made up predominately of quartz, feldspar and slate, with schist and limestone (King et al. 1968). The predominant soil classification is the Ramsey soil type, which displays moderate natural fertility, low water storage capacity and medium to high acidity (United States Forest Service 1970).

III. CLIMATE

The climate of the Great Smokies exhibits much variation due primarily to a large range in elevation. The area is characterized by high precipitation and cool temperatures with a temperature gradient of 4.07° C per 1000 m rise in elevation (Shanks 1954a). Precipitation at the higher elevations is about 40% greater than at lower elevations, with the high elevation areas receiving as much as 231 cm per year

which is more than any other area in the eastern United States (Shanks 1954a). The annual mean number of days with snowfall increased from 6.75 at 445 m elevation to 25.9 at 1920 m elevation (Stephens 1969).

Weather patterns result in precipitation maxima in late winter-early spring and in July-August. The winter primary maximum results from depressions moving from northwestern North America into Texas, picking up moisture from the Gulf of Mexico, then moving northeastward and depositing the accumulated moisture (Dickson 1960, Trewartha 1966). The midsummer secondary precipitation maximum results from showers and thundershowers generated by the interaction of midtropospheric troughs and ridges located over Florida with a midcontinent pressure ridge (Dickson 1960). A precipitation minimum generally occurs in October (Stephens 1969). Temperature and precipitation data for the study period are presented in Tables 1 and 2, respectively.

IV. FLORA

As the result of a high diversity of habitats and their great geological age, the Smokies support a very rich flora which includes more than 1300 species of flowering plants, approximately 350 mosses and liverworts, 230 lichens and more than 2000 fungi (Stupka 1960). Thirty species of trees and shrubs are endemic to the Unaka range in eastern Tennessee and western North Carolina (Cain 1930a).

The Smokies support a wide variety of forest vegetation due primarily to elevational change and complex topography. Large

Table 1. Monthly average temperatures in the Great Smoky Mountains National Park.[a]

Month	Average Temperature in °C (°F)			
	1923-1967	1976	1977	1978
January	4.0 (39.3)	-0.7 (30.7)	-4.9 (23.2)	-2.9 (26.7)
February	5.5 (41.9)	6.8 (44.3)	2.4 (36.4)	-1.4 (29.4)
March	8.8 (47.8)	10.5 (50.9)	9.8 (49.6)	6.7 (44.0)
April	13.8 (56.8)	13.2 (55.7)	14.6 (58.3)	13.9 (57.0)
May	18.2 (64.8)	14.9 (58.8)	17.6 (63.7)	15.9 (60.7)
June	22.2 (72.0)	20.6 (69.1)	20.9 (69.7)	
July	23.1 (73.6)	21.7 (71.1)	23.3 (73.9)	
August	23.2 (73.7)	21.3 (70.4)	22.3 (72.2)	
September	20.2 (68.9)	17.4 (63.4)	19.7 (67.5)	
October	14.4 (57.9)	10.7 (51.2)	11.1 (51.9)	
November	8.2 (46.7)	4.3 (39.7)	9.3 (48.8)	
December	4.6 (40.2)	1.1 (33.9)	2.5 (36.5)	

[a]From National Park Service records at Gatlinburg, Tennessee (elevation 445 m).

Table 2. Monthly average precipitation in the Great Smoky Mountains National Park.[a]

Month	Average Precipitation in Centimeters (Inches)			
	1923-1972	1976	1977	1978
January	11.60 (4.57)	11.05 (4.35)	6.53 (2.57)	16.21 (6.38)
February	12.49 (4.92)	7.09 (2.79)	5.31 (2.09)	1.83 (0.72)
March	14.07 (5.54)	11.86 (4.67)	15.24 (6.00)	12.17 (4.79)
April	11.93 (4.70)	1.02 (0.40)	15.65 (6.16)	11.91 (4.69)
May	10.79 (4.25)	21.77 (8.57)	10.16 (4.00)	15.55 (6.12)
June	13.25 (5.22)	24.00 (9.45)	26.75 (10.53)	
July	16.17 (6.37)	10.92 (4.30)	14.83 (5.84)	
August	13.51 (5.32)	6.66 (2.62)	19.66 (7.74)	
September	7.89 (3.11)	9.47 (3.73)	22.35 (8.80)	
October	7.69 (3.03)	13.95 (5.49)	9.53 (3.75)	
November	10.18 (4.01)	6.99 (2.75)	10.08 (3.97)	
December	10.84 (4.27)	12.78 (5.03)	11.35 (4.47)	
Annual	140.48 (55.31)	137.54 (54.15)	167.44 (65.92)	

[a]From National Park Service records at Gatlinburg, Tennessee (elevation 445 m).

areas of both virgin and secondary vegetation add to the diversity of existing vegetation types. Approximately 39% of the study area is virgin, 12% is light cut with only the more valuable trees taken and 49% is heavy cut (Lambert 1958).

The Smokies are famous for the record size of many of the trees. Examples are a yellow poplar (Liriodendron tulipifera) with a circumference of 732 cm, an eastern hemlock (Tsuga canadensis) of 602 cm and a yellow buckeye (Aesculus octandra) of 465 cm (King and Stupka 1950). A silverbell (Halesia carolina) of 410 cm circumference located in conjunction with vegetation analysis during the present study exceeds the previous record which occurs in Pennsylvania. A report for verification has been submitted to the American Forestry Association.

Major vegetation studies of the Smokies have been conducted by Cain (1935), Shanks (1954b), Whitaker (1956) and Golden (1974). Much emphasis has been placed on categorizing the complex plant associations into forest types and understanding the gradients responsible for such patterns. The simplest and probably the most widely utilized classification of forest types is that of Shanks' (1954b) (Table 3). Golden (1974) delineated 17 forest types based on taxa importance value with the aid of the agglomerative minimum dispersion clustering procedure (Table 4). When applicable the classification of Golden (1974) will be utilized; however, his lack of low elevation plots necessitated reliance on Shanks' (1954) classifications in these areas.

The high elevations, especially those above 1500 m, in the southeast corner of the study area are dominated by the spruce-fir

Table 3. Forest types and their important tree species in the Great Smoky Mountains.

Forest Type	Important Species
Cove hardwood	Yellow poplar Eastern hemlock Yellow buckeye Silverbell Beech (*Fagus grandiflora*) Yellow birch (*Betula alleghaniensis*) Black cherry (*Prunus serotina*)
Hemlock	Eastern hemlock Yellow birch Silverbell Fraser magnolia (*Magnolia fraseri*)
Northern hardwood	Beech Sugar maple (*Acer saccharum*) Yellow buckeye Yellow birch
Closed oak	Chestnut oak (*Quercus prinus*) White oak (*Quercus alba*) Black oak (*Quercus velutina*) Northern red oak (*Quercus rubra*) Pignut hickory (*Carya glabra*) Mockernut hickory (*Carya tomentosa*) Sourwood (*Oxydendrum arboreum*)
Open oak and pine	Pitch pine (*Pinus rigida*) Scarlet oak (*Quercus coccinea*) Virginia pine (*Pinus virginiana*) Sassafras (*Sassafras albidum*)
Spruce-fir	Red spruce (*Picea rubens*) Fraser fir (*Albies fraseri*)

Source: R. E. Shanks, 1954, Reference list of native plants in the Great Smoky Mountains, Botany Department, The University of Tennessee, Knoxville. (Mimeographed.)

Table 4. Forest associations and their important tree species in the Great Smoky Mountains National Park.

Forest Association	Important Species (Importance Values)[a]	
Buckeye	Yellow buckeye	(87)
	Yellow birch	(30)
	White basswood (*Tilia heterophylla*)	(23)
	Silverbell	(12)
	Sugar maple	(12)
Hemlock-buckeye	Eastern hemlock	(70)
	Yellow buckeye	(42)
	Sugar maple	(32)
	Silverbell	(12)
Basswood	White basswood	(60)
	Sugar maple	(29)
	Eastern hemlock	(27)
	Yellow buckeye	(15)
	Beech	(13)
	Northern red oak	(11)
Yellow poplar	Yellow poplar	(98)
	Silverbell	(16)
	Red maple (*Acer rubrum*)	(15)
	White basswood	(14)
	Sweet birch (*Betula lenta*)	(12)
	Eastern hemlock	(12)
Sugar maple	Sugar maple	(72)
	Silverbell	(28)
	Yellow buckeye	(26)
	Beech	(25)
	White basswood	(21)
Silverbell-hemlock	Silverbell	(65)
	Eastern hemlock	(54)
	Beech	(28)
Hemlock	Eastern hemlock	(102)
	Silverbell	(24)
	Red maple	(14)
	Yellow birch	(12)
	Beech	(12)
Yellow birch-hemlock	Yellow birch	(108)
	Eastern hemlock	(53)
Red maple-sweet birch	Red maple	(50)
	Sweet birch	(42)
	Yellow poplar	(16)
	Sourwood	(13)

Table 4 (Continued)

Forest Association	Important Species (Importance Values)[a]	
Beech	Beech	(116)
	Silverbell	(26)
	Yellow birch	(16)
	Yellow buckeye	(14)
Red maple-northern red oak	Red maple	(78)
	Northern red oak	(36)
	Silverbell	(13)
Spruce-yellow birch	Red spruce	(99)
	Yellow birch	(65)
	Fraser fir	(12)
Chestnut oak	Chestnut oak	(94)
	Red maple	(23)
	Scarlet oak	(22)
	Northern red oak	(15)
	Sourwood	(12)
Northern red oak	Northern red oak	(120)
	Red maple	(24)
	Silverbell	(16)
Oak-pine	Pitch pine	(67)
	Scarlet oak	(43)
	Table mountain pine (*Pinus pungens*)	(42)
	Chestnut oak	(31)
	Black gum (*Nyssa sylvatica*)	(11)
Table mountain pine	Table mountain pine	(78)
	Pitch pine	(13)
Table mountain-pitch pines	Table mountain pine	(99)
	Pitch pine	(88)

[a]Importance values range from 0 to 200 and only species having values greater than 10 are listed.

Source: M. S. Golden, 1974, Forest vegetation and site relationships in the central portion of the Great Smoky Mountains National Park, unpublished Ph.D. dissertation, The University of Tennessee, Knoxville, 275 pp.

forest type. This type comprises approximately 10% of the study area. The northern hardwood forest type, which occupies 25% of the study area, occurs in coves and mesic sites above 1400 m. Hemlock forests are found along streams and on sheltered slopes up to 1100 m and make up only about 25% of the study area. Sub-mesic to xeric sites of middle to low elevations support the closed oak forest type which comprises 5% of the study area. Open oak-pine forests occur on the more xeric, exposed sites where the soil is shallow and often rocky. This type usually occurs in association with heath and makes up approximately 15% of the study area. Mesic forests of low to middle elevation coves and lower slopes have been collectively termed the cove hardwood complex. These are forests of great diversity and various mixtures of taxa predominate up to 1400 m. This type comprises approximately 20% of the study area.

Three non-forest vegetation types occupy a small percentage of the study area. Heath balds, which occur on steep rocky ridges and slopes above 1300 m, are usually composed of some mixture of mountain laurel (Kalmia latifolia) and/or rhododendron (Rhododendron spp.) (Cain 1930b). These generally treeless "slicks" are almost impenetrable. Grassy balds are found on several exposed, broad ridges along the Tennessee-North Carolina border in the southwestern half of the Park. These are usually open meadows dominated by mountain oat grass (Danthonia compressa) and/or sedges (Carex spp.) (Mark 1958). In addition, 738 ha of pasture land are maintained as an historic site in Cades Cove. The complex topography and elevational changes account for a high degree of interspersion among all vegetation types.

V. MAMMALS

In contrast to the vegetational diversity, the Smokies do not support an unusually rich variety of mammals. Linzey and Linzey (1971) report 59 species of mammals are found in the Park and an additional six species are listed as extirpated. The only large mammals other than the black bear are the white-tailed deer (Odocoileus virginianus) and the European wild hog (Sus scrofa).

VI. HISTORY OF LAND USE

The Overhill tribes of the Cherokee Indians were the first human inhabitants of the Great Smoky Mountains (King 1964). They practiced primitive agriculture on alluvial bottoms of the larger streams of the foothills and penetrated the higher mountains only on occasional hunting expeditions. The annual burning of understory which probably kept the forest in an open condition was the Indian's major influence on the Southern Appalachians (National Park Service 1969).

White settlers arrived in Wear Cove in 1795 and White Oak Flats (later Gatlinburg) shortly thereafter (King 1964). As their numbers grew, the impact from clearing land for farming and cabin logs and wood increased. However, it was not until the rugged mountains were approached by commercial loggers that major disturbances occurred.

Two distinct periods of logging occurred in the Park (Lambert 1958). The first (1880 to 1900) depended heavily on stream and oxen transportation and resulted in only selective cutting of black cherry, black walnut (Juglans nigra), ash (Fraxinus spp.) and yellow poplar.

Most of the lower streams were stripped of their choice poplar and the upper reaches of the more accessible cherry, ash and poplar. Fires were rare and no large areas above the streams were completely denuded of timber.

The second period began with a flurry of land purchases and railroad construction by large lumber companies around 1900 (Lambert 1958). The Little River Lumber Company owned three of the four watersheds in the study area and produced the largest single cut in the Park, approximately 560,000,000 board feet. The WPLR watershed was cut between 1904-07 with a railroad being built only to the lower reaches and logs skidded entirely by teams of oxen or horses. Fires were rare and only the more accessible areas were cut resulting in this watershed containing a greater proportion (20%) of virgin forest.

As logging operations proceeded to the EPLR in 1907, mechanized logging technology and extension of railroads provided for the clearing of very large areas previously considered inaccessible. Fires were common and this watershed was extensively cut even to the highest peaks harboring the spruce-fir forest type.

From 1926 to 1939 the MPLR received the most extensive cutting of any section in the study area (Lambert 1958). The impending establishment of the Park prompted systematic clearing of large areas and their abandonment in rapid succession; only about 2% escaped cutting.

The Abrams Creek watershed is characterized by low elevation, rolling, broad ridges predominated by oak-pine forest types. The owner

of the land prior to establishment of the Park (Morton Butler Timber Co., Chicago) deemed it economically unfeasible to lumber this "low-value" timber with the available technology of the day (Lambert 1958). Thus it was uncut except for the larger flats and coves which were cleared for farmland. Fires were very common farm practice and a high incidence of basal fire damage to large trees is still evident.

CHAPTER III

METHODS

I. CAPTURE AND HANDLING

The inaccessibility of much of the study area necessitated capturing bears with Aldrich spring-activated snares. The snare is easily transported and an efficient capture technique. Prebaiting, snare sets and baits are described by Marcum (1974) and Eagar (1977). Trap lines were located to sample bears in all four watersheds of the study area.

Bears were immobilized with an intramuscular injection of M99 (Etorphine hydrochloride, American Cyanamid Co.) or Sernylan (Phenycyclidine hydrochloride, Parke, Davis and Co.). The dosage of M99 and Sernylan was 1 mg/45.5 kg and 100 mg/45.5 kg of estimated body weight, respectively. M50-50 (Diprenorphine) was used as an antagonist for M99 at a dosage of 2 mg/45.5 kg of estimated body weight.

The immobilizing drugs were administered with a projectile syringe fired from a CO_2-charged pistol (Palmer Chemical and Supply Co., Inc.). M50-50 was usually injected into the femoral vein producing complete recovery within two minutes. Intramuscular injection of M50-50 resulted in recovery in 15-20 minutes.

II. AGING

Either the first or fourth premolar was extracted for age determination by a modification of the cementum-annuli technique described by Willey (1974). Simplifications and modifications of the technique, particularly those concerning stains, are discussed by Eagle (1978).

III. RADIOTELEMETRY

Bears were fitted with radiotransmitters (Wildlife Materials, Inc., Carbondale, Illinois) and monitored in conjunction with a concurrent study (Garshelis 1978). Most (84%) of the transmitters were equipped with a motion-sensitive mercury switch in the circuit to vary the pulse rate. These activity monitors were used to delineate pre- and postdenning activity patterns, movements in dens and denning behavior.

Triangulation from known points on the ground was used to determine subsequent locations. Occasional aerial tracking was also employed. Bears were located every two-three days to obtain den entrance and exit dates. More frequent locations were precluded by the inaccessibility of the study area and the distribution of radio-equipped bears all across the study area. Activity readings also aided in determination of den entrance and exit.

Once the bear denned the radio-signal was quietly "walked-in" with a three-element folding Yagi antenna. Approach was only as close as necessary to locate the den. The presence of cubs as

evidenced by suckling and growling sounds was recorded when observed. An ultrasonic detector was used to test possible emissions from a mother (E7) and three 73-76 day-old cubs in a den on 12 April 1978.

A Rustrak strip-chart recorder (Wildlife Materials, Inc., Carbondale, Illinois) was used to monitor movements in the den and possible excursions from the den. The recorder was too sensitive (non-discriminating) in recording audible changes in signal tone and strength from an inactive bear and external interferences in the 150.850-151.150 range. Thus the present recorder system is impractical for activity monitoring of bears, however, the recorder proved beneficial in determining possible movement from and return to the den.

IV. VEGETATION ANALYSIS

After spring emergence, dens and the physical site parameters were measured and the vegetation sampled. The variables measured and the methodology involved are presented in Table 5. The complex topography of the study area necessitated measurement of the position on slope by two methods in order to present an adequate picture of topographic relationships. Den trees were climbed with 2.75 m aluminum section ladders or spikes and a climbing belt.

The Bitterlich variable radius method (Grosenbaugh 1952) and the point-centered quarter method (Cottam and Curtis 1956) were used for phytosociological comparison of tree communities at den sites. Treeless thickets (a common situation for ground dens) were classified by the species association and density. Understory density was

Table 5. Variables and methodology used to describe the characteristics of dens of black bears in the Great Smoky Mountains National Park.

Variable	Methods
Den type	Classified as tree or ground den
Species	Taxonomic classification of tree to species
Dbh	Direct measurement in centimeters
Tree age	Obtained by extrapolation from growth rings in a 30.48 cm core sample
Distance of den entrance above ground	Direct measurement in centimeters after climbing tree dens
Cavity size (H x W x L)	Direct measurement in centimeters
Entrance dimensions (H x W)	Direct measurement in centimeters
Bedding material	Contents identified
Amount of bedding material	Estimated to nearest liter
Vegetation type	Classified by species composition: 1 = Wild grape (*Vitis* spp.) and greenbrier (*Smilax* spp.) 2 = Cove hardwood-hemlock associations 3 = Northern hardwoods 4 = Red maple associations 5 = Closed oak 6 = Table mountain pine
Understory	Classified by species composition as: 1 = None 2 = Light 3 = Moderate 4 = Dense
Slope	Measured with a clinometer in degrees
Slope aspect	Measured with a compass in degrees
Den entrance aspect	Measured with a compass in degrees
Microtopographic position on slope	Measured as the elevational distance of the den from the nearest upslope convexity expressed as a percent of the total elevational distance from the convexity to the bottom of the nearest downslope concavity (ridge top = 0%, mid-slope = 50%, cove bottom = 100%) (Golden 1974)
Macrotopographic position on slope	Measured as the percent distance of the den from the large ridge most affecting the local topography to the nearest downslope stream represented as a blue line on the topographic map (ridge top = 0%, mid-slope = 50%, cove bottom = 100%) (Golden 1974)

Table 5 (Continued)

Variable	Methods
Elevation	Measured with an altimeter and plotted on a topographic map
Total basal area	Bitterlich and quarter methods, m^2/ha
Basal area per tree	Quarter method, m^2/tree
Density	Quarter method, trees/ha
Percent composition	Bitterlich method
Percent species frequency	Bitterlich method
Relative density	Quarter method, percent
Relative dominance	Quarter method, percent
Relative frequency	Quarter method, percent
Importance value	Quarter method (sum of relative density, dominance and frequency)
Mean distance	Quarter method, m
Mean area	Quarter method, m^2

categorized as absent, light, moderate or dense.

To determine the availability of dens, denning habitat and large trees (dbh > 84 cm) for bears, random transects (1 km by 20 m, plot size = 2 ha) were searched and the information recorded on a data form (Appendix A). In addition the forest type, understory, and wind and lightning damage were recorded at 100 m intervals. At randomly selected points along these transects the physical site parameters were measured and the vegetation sampled by methods identical to those applied at den sites.

In the West Prong of the Little River (WPLR) watershed where most of the active dens were located, direct counts of large hemlocks (one of the most utilized den trees in this area) were made with binoculars and a 60 power spotting scope during winter from heath balds overlooking the watershed. The trees were plotted on 7.5 minute topographic maps and ground checks made for dbh, frequency of damage and number of potential dens.

Also in this watershed, systematic searches of the home ranges of two radio-instrumented females were conducted by running transects (0.5 km by 20 m, plot size = 1 ha) perpendicular to all major branches of the WPLR, alternating sides of the streams at major contour intervals of 20 m. In conjunction with food availability, mark tree, and movement ecology studies an additional 46.4 ha were searched for availability of dens. Also five selected areas were mapped to obtain accurate data for comparison of occurrence of large trees (> 84 cm dbh), frequency of damage, frequency of potential dens and density estimates.

A high attrition rate (3, 43%) of the first den trees located in the GSMNP (Pelton et al. 1977) suggested the possible importance of den dynamics in availability of tree dens to bears. To better understand the dynamics of dens all large trees located in the study area with damage or a potential cavity were catalogued using a standard data form (Appendix B). The type, age and severity of damage were recorded to delineate possible factors affecting the formation, longevity and destruction of den cavities. All active dens were monitored throughout the study to determine their longevity.

Tree dens were aged from growth rings in core samples of the available live wood, taken with a 5 mm increment bore, 30.48 cm in length. The rings were counted per unit length of the sample containing rings and extrapolated to the known diameter of the tree. The large size, irregular growth forms, high incidence of rotten heartwood and inaccessibility of suitable limbs precluded use of other techniques. Due to rapid growth early in the life of a tree, the age estimates from this method are believed to be inflated by as much as 25% (F. W. Woods, personal communication).

The mast yield was monitored by use of the methods employed in the annual statewide survey by the Tennessee Wildlife Resources Agency (TWRA). The information was recorded on standardized data forms for inclusion in the analysis of the mast crop in the east Tennessee mountain counties.

V. STATISTICAL ANALYSIS

Various comparisons of sex and age differences in den entrance and exit, den characteristics, between year differences and differences

in denning behavior were made using Student's t-distribution. The 10% level was the cut-off for the F-test of variance equality of the two samples being compared. Other statistical comparisons of data that only classify observations such as den and habitat selection and activity readings were made using Chi-squared contingency tables.

Multiple regression analysis was used to delineate relationships of weather factors to den entrance and exit. Total precipitation, the number of days with precipitation, minimum and maximum daily temperature and the range for both, average daily wind and the maximum daily wind for the three days prior to den entrance were "screened" through an all possible regressions and stepwise procedure.

The occurrence of a den in a random plot is indeed a "rare event" and thus fits the Poisson frequency distribution (Sokal and Rohlf 1969). The Poisson distribution allows an estimate of the absolute abundance of dens, particularly tree dens, in the study area and placement of confidence intervals on the estimate.

The den characteristics and physical site and vegetation parameters of dens (Table 5, page 21) were subjected to factor analysis. Factor analysis has been described as a data reduction and exploratory technique which elucidates a factor's importance in a population (of dens in this case) by allocating the observed variance in the sample (Harman 1960). Five and seven factors encompassed the measured variables of ground and tree dens, respectively. The six most highly correlated variables ($r < .7890$), other than the actual den characteristics, were extracted for use in classifying 115 random vegetation plots into potential tree and ground den habitat (Table 6).

Table 6. Variables extracted through factor analysis for use in classifying 115 random vegetation plots into potential tree and ground den habitat.

Den Type	Variables	r Value
Tree dens	Elevation	0.9500
	Mean distance	0.9436
	Understory	0.9171
	Basal area per tree	0.9059
	Vegetation type	0.8687
	Slope	0.8324
Ground dens	Mean distance	0.9573
	Vegetation type	0.9219
	Basal area per tree	0.8690
	Macro-position on slope	0.8010
	Elevation	0.7933
	Slope	0.7890

Discriminant function analysis is the classification of an observation, or in this instance a random vegetation plot, into one of two categories (tree or ground den habitat) (Morrison 1967). From the six variables extracted by factor analysis, a weighting vector was derived with known tree and ground dens serving as the previously established categories. When applied to a new observation, this weighting vector will assign the observation to one or another of the categories with the smallest probability of error. The vector of weights (w) which provides the optimum assignment is given by $w = V^{-1}d$ where d is the vector of differences between the six pairs of means of the two categories and V is the weighted average of the dispersion matrices of the two categories.

Statistical programs provided by Nie et al. (1975) and Barr et al. (1976) were implemented on an IBM 360 computer at The University of Tennessee, Knoxville.

CHAPTER IV

RESULTS AND DISCUSSION

I. THE DENNING PERIOD

Radio-instrumented bears entered dens between 15 December and 22 January 1976-77 and 23 December and 15 February 1977-78 (Table 7). All radio-instrumented bears entered dens. No significant differences were found between the den entrance dates for the two winters. The majority of the bears (14, 82%) denned between the last week in December and the first week in January. Only three bears (one sub-adult female, one sub-adult male and one adult male) extended activity after 6 January. A low incidence of field signs after 6 January further indicated that most bears in the study area had also denned.

Emergence dates varied from 17 March to 16 April 1977 and from 11 March to 4 May 1978 (Table 7). There was no significant difference between the dates of den exit for the two years. Eight bears (57%) exited dens between the last week in March and the first week in April. Of the four bears that remained in dens after 7 April, three had cubs of the year. Only two bears exited dens earlier than 23 March.

The length of the denning period ranged from 56 to 119 days ($\overline{x}$ = 94 days) with no between-year differences being detected. Indications are that once bears enter dens they do not intermittently leave and return to the den. In no case was this noted while periodically radiotracking bears for den entrance and exit dates, nor

Table 7. Den entrance and emergence dates and physical characteristics of dens of black bears in the Great Smoky Mountains National Park, 1972-78.

Bear No.	Sex	Age	Date Entered	Date Vacated	Den Type	Dbh (cm)	Tree Age (Years)	Dist. (cm) Above Ground	Cavity Size (cm) H X W X L	Entrance Dimensions (cm) H X W	Bedding Material	Amt. of Bedding Material (Liters)[a]
89[b]	F	8	12/15/76-12/23/76	3/18/77[c]	Inside hollow sawed off stump	75.1	-	0	132X 81X 75	53X 30[d]	Wild grape vines and twigs and deciduous leaves	13.2
65	M	7	12/27/76-12/28/76	1/ 2/77[c]	Under wind tilted eastern hemlock stump	95.5	-	0	66X 67X100	50X 83[d]	Deciduous leaves	17.6
A 28	F	7	12/27/76-12/31/76	4/ 5/77-4/ 7/77	Cavity in eastern hemlock	158.2	652	600	78X 80X 98	63X 23	Humus and wood splinters	3.3
A 26	M	10	12/27/76-12/28/76	1/ 6/77[c]	Inside rotted red maple stump	178.3	-	0	71X126X140	58X 81	Rhododendron and mountain laurel leaves and twigs	5.5
A 8	F	11	-	1/21/77[c]	Cavity in chestnut (*Castanea dentata*) snag	101.9	-	1140	95X 57X 67	28X 34	Humus and wood splinters	7.7
A 9	F	3	1/27/77-1/22/77	3/17/77-3/19/77	Cavity in yellow birch	80.5	-	1280	219X 46X 47	114X 23	Humus and wood splinters	4.4
A 30	M	2	-	4/15/77-4/16/77	Cavity in northern red oak	56.7	235	823	68X 41X 51	55X 34	Red maple twigs and bark, twigs from den tree	1.1
A 29	F	2	After 12/30/76	3/31/77-4/ 3/77	Cavity in yellow buckeye	94.9	448	1982	93X 40X 60	48X 27	Humus	8.8
F 5[e]	F	7	Before 1/ 8/77	4/ 1/77-4/ 6/77	Rock crevice	-	-	0	49X 76X251	46X122	Rhododendron and mountain laurel leaves and twigs	11.0
A 44[b]	F	11	12/23/77-12/27/77	4/ 3/78-4/ 5/78	Cavity in black gum	113.6	413	1219	305X 46X 53	42X 35	Wood splinters and black gum twigs	4.1

Table 7 (Continued)

Bear No.	Sex	Age	Date Entered	Date Vacated	Den Type	Dbh (cm)	Tree Age (Years)	Dist. (cm) Above Ground	Cavity Size (cm) H X W X L	Entrance Dimensions (cm) H X W	Bedding Material	Amt. of Bedding Material (Liters)[a]
A 9	F	4	12/27/77-12/29/77	3/27/78-3/29/78	Cavity in yellow birch	79.6	458	623	305X 48X 56	62X 34	Humus and wood splinters	1.8
A 47	M	3	1/ 2/78-1/ 5/78	3/23/78-3/27/78	Cavity in red maple	111.4	245	785	221X 63X 54	233X 46	Humus and twigs from den tree	3.6
H 1[e]	F	8	12/29/77-1/ 2/78	4/21/78-4/23/78	Cavity in yellow birch	93.9	700	545	153X 77X 69	49X 48	Humus and eastern hemlock boughs from ground level	2.7
B 12	M	6	After 12/27/77	-	Cavity in red maple	100.6	210	740	417X 58X 58	171X 34[d]	Humus and wood chips	2.7
B 18	F	2	12/26/77-12/28/77	1/15/78-1/19/78	Rock crevice	-	-	0	49X 74X 61	64X 37[d]	Wild grape vines and twigs and deciduous leaves	6.4
B 18	F	2	1/15/78-1/19/78	3/22/78[c]	Under fallen log	71.6	-	0	37X 57X 79	27X 39[d]	Wood chips and wild grape vines	1.8
B 10	F	7	12/26/77-12/28/77	4/ 4/78-4/ 6/78	Under stump	130.5	-	0	108X 82X 71	62X 53	Wood chips and wild grape vines	2.3
F 7[e]	F	15	1/ 3/78-1/ 6/78	5/ 2/78-5/ 4/78	Under root cap of wind-fallen tree	58.0	-	0	47X 81X 91	25X 69[d]	Humus	.9
A 50	M	6	1/ 2/78-1/ 5/78	3/29/78-4/ 3/78	Inside stump	126.1	-	0	83X 81X 67	72X 56	Wood chips and rhododendron twigs and leaves	3.6
A 52	M	8	1/12/78-1/15/78	-	Under root cap of wind-fallen tree	68.0	-	0	59X112X 93	46X 79	Rhododendron and doghobble (Leucothoe editorum) leaves and twigs	192.0
A 45[e]	F	9	1/ 2/78-1/ 5/78	4/23/78-4/27/78	Under root cap of wind-fallen tree	95.5	-	0	55X 92X 91	39X 71	Wild grape vines and twigs	2.7
A 53	M	4	After 12/30/78	-	Under root cap of wind-fallen tree	23.9	-	0	67X162X185	86X 92	Rhododendron leaves and twigs and fine roots	3.6

Table 7 (Continued)

Bear No.	Sex	Age	Date Entered	Date Vacated	Den Type	Dbh (cm)	Tree Age (Years)	Dist. (cm) Above Ground	Cavity Size (cm) H X W X L	Entrance Dimensions (cm) H X W	Bedding Material	Amt. of Bedding Material (Liters)[a]
A 42	M	5	2/12/78-2/15/78	2/25/78[c]	Under stump	68.8	-	0	49X 66X 43	36X 54	Rhododendron and wild grape twigs and leaves	13.6
A 28	F	8	12/29/77-1/ 2/78	3/11/78-3/15/78	Under root system of standing yellow birch	88.2	-	0	51X 74X 78	33X 31	Humus and rhododendron and doghobble leaves and twigs	4.5
B 50[b]	F	-	-	-	Cavity in yellow birch	137.2	-	1020	145X 48X 64	57X 51	-	-
63[f]	F	9	-	-	Base of a dead snag	-	-	0	-	-	-	-
B 29	F	4	12/10/74-12/21/74	1/21/75	Cavity in northern red oak	94.9	-	1220	180X 45X 51	35X149	Humus and wood scrapings	-
B 29	F	4	1/21/75-1/28/75	-[c]	Bed on root system of wind-tilted red maple	77.7	-	0	-	-	Rhododendron leaves and twigs	-
A 45	F	6	-	After 3/20/75	Cavity in northern red oak	122.3	330	2090	923X 61X 74	26X 38	-	-
R 31	M	3	Before 1/20/75	1/20/75[c]	Under root system of red maple sprout	-	-	0	65X 69X 79	58X 43[d]	Deciduous leaves, twigs and humus	-
Y 30	F	5	12/12/72-12/18/72	1/ 4/73[c]	Cavity in red maple	92.4	455	1070	69X 48X 38	30X 53	Humus and wood scrapings	-
Y 30	F	5	1/ 4/73-1/ 5/73	After 3/1/73	Cavity in eastern hemlock	93.9	-	610	122X 61X 61	61X 61	Humus and wood scrapings	-
Y 52[f]	F	5	12/ 5/73-12/15/73	-	Cavity in eastern hemlock	103.5	-	1520	152X 46X 46	28X 33	-	-
P 53[f]	F	5	12/ 1/73-12/15/73	After 3/1/73	Cavity in eastern hemlock	108.3	-	1740	183X 86X 76	33X 38	Humus and wood scrapings	-
Y 60[f]	M	3	12/15/73-12/20/73	1/10/74-1/15/74	Under dead tree stump	-	-	0	53X 61X 71	30X 38	Deciduous leaves	-
R 56[f]	M	4	12/ 5/73-12/15/73	After 2/20/74	Cavity in red maple	84.1	-	1070 (est)	-	38X 46 (est)	-	-

Table 7 (Continued)

Bear No.	Sex	Age	Date Entered	Date Vacated	Den Type	Dbh (cm)	Tree Age (Years)	Dist. (cm) Above Ground	Cavity Size (cm) H X W X L	Entrance Dimensions (cm) H X W	Bedding Material	Amt. of Bedding Material (Liters)[a]
Average for tree dens						94.8	415	1115	219X 53X 60	68X 45		4.0
Average for ground dens						89.0			65X 85X 98	47X 61		19.9
Average for both						92.4			146X 69X 69	58X 53		13.3

[a]Estimated to nearest liter.

[b]Accompanied by one-year-old cubs.

[c]Abandoned due to human approach.

[d]More than one opening to den cavity.

[e]Produced cubs in winter den.

[f]Not used in statistical analysis due to a lack of measured parameters.

was any "sign" such as bedding sites or tracks located in the vicinity of active dens. Bears apparently enter abruptly and move away from dens upon exit and do not return. This is also evidenced by the absence of fecal plugs from most areas surrounding dens (p. 47).

Bear B10 was continuously monitored with the Rustrak activity recorder for 60.8 days between 3 February and 6 April 1978. She did not leave and return to the den. Taylor (1971) reported that bears in Louisiana left and returned to tree dens. However, his observations were biased by leaving an artificial food source (bacon) at the base of the tree. Beeman (1975) found fresh claw marks on a den tree between 2 and 8 February 1974, but they may have been made by a wandering male or sub-adult in search of a den, rather than the bear occupying the cavity. Lindzey and Meslow (1976a) also reported a strong fidelity to dens after entrance and that high temperatures did not elicit movement from dens.

Considerable variation exists in the denning period for black bears across their range in North America with a trend for longer denning periods in the more northerly latitudes (Table 8). Dates of den entrance for the GSMNP are considerably later than dates reported in other studies. This is probably related to a milder climate which allows the food supply to influence the denning period.

Dates of den emergence are much more consistent among regions. Spring being a time of consistent scarcity of nutritious foods across most of the black bear's range (Jonkel and Cowan 1971, Beeman 1971 and Rogers 1977) and differences in den selection and snow cover (p. 38) may aid in equalizing dates of den exit.

Table 8. Den entrance and emergence dates and the denning period of black bears in North America.

Entrance	Emergence	Approx. Length	State	Source
Late Oct.	Mid-May	6.5 mo.	Montana	Jonkel and Cowan (1971)
Early Dec.	Early April	4	Maine	Spencer (1955)
Early-Mid Nov.	Mid-Late March	4	Washington	Lindzey and Meslow (1976a)
Mid Dec.	Early April	3.5	North Carolina	Hamilton and Marchinton (1977)
Late Oct.	April-May	6	Alaska	Erickson (1965)
Oct.	Early-Mid April	5.5	Minnesota	Rogers (1977)
Late Dec.-Early Jan.	Late Mar.-Early April	3	Tennessee	This Study

Sex and Age Differences

Adult females were the first bears to enter dens; the mean date of den entrance was 31 December. Adult males entered dens an average of four days later (4 January) and sub-adults of both sexes denned an average of nine days (13 January) after adult males. The differences were not significant among the groups; the difference between the adult females and sub-adults exhibited the most significant relationship ($P < 0.1131$). Adults denned earlier than sub-adults ($P < .0851$) but no significant differences were found between males and females.

The average dates of den exit for five sub-adults, one adult male and eight adult females were 31 March, 3 April and 12 April, respectively. The differences were not significant for the present sample size. Emergence dates for males, particularly adult males, are lacking due to their easy arousal and frequent abandonment of dens on approach by a researcher; such information could be obtained by monitoring the bear without approaching for an exact den location.

The average length of the denning period was 77, 88 and 101 days for three sub-adults, one adult male and seven adult females, respectively. Again, the sex and age differences in the lengths of the denning period were not significant among the groups. No significant differences were found between adults and sub-adults or between males and females.

Females with newborn cubs vacated dens later ($\bar{x}$ = 26 days later) ($P < 0.002$) and denned longer ($P < .0107$) than other females. The longer denning period was due entirely to den exit dates rather

than den entrance dates since females known to produce cubs entered dens seven days later than other females; a difference which was significant ($P < .0163$).

One female (F5) with yearling cubs extended activity until 5 February 1978 at which time the radiotransmitter ceased functioning. Her activity centered on a low elevation (790 m), southwesterly slope which supported a predominantly oak forest type free from snow cover. This observation supports the findings that females with yearlings extend winter activity under favorable environmental conditions (Alt 1977). However two other females (A44, 89) with yearlings under conditions of snowcover did not extend winter activity.

Erickson (1964), Jonkel and Cowan (1971) and Lindzey and Meslow (1976a) reported differential timing of winter dormancy among sex and age groups. According to them, adult females generally den first and are followed by sub-adults and adult males. Bears usually vacate dens in the reverse sequence, but Jonkel and Cowan (1971) found that adults of both sexes emerged before sub-adults. Reproductive condition of females, variations in fat deposition and different tolerances to weather factors are believed to account for these sex and age differences. Late emergence of females is often attributed to lack of mobility by young cubs (Craighead and Craighead 1972b, Lindzey and Meslow 1976a). Also late emergence by females with cubs in the GSMNP may assist in protecting cubs from the torrential rains and cold temperatures of early spring.

Data from the GSMNP generally agree with these patterns except that sub-adults are the last bears to den and the first to emerge.

Hamilton and Marchinton (1977) observed more winter activity by sub-adults in North Carolina. The last bears to den in Washington were also three-year-old "adult" males (Lindzey and Meslow 1976a). Whether this extended activity by sub-adults is related to physical condition or behavioral differences is difficult to determine. Two sub-adults (A9, A42) which had extended winter activity were in excellent physical condition when recaptured the following summer, indicating that a basic behavioral difference may indeed be involved.

Environmental Relationships and the Denning Period

Weather factors showing the strongest linear relationship to bears entering dens were total precipitation, number of days precipitation occurred, and minimum and maximum temperature for the three days prior to den entrance ($P < .0037$). Student's t-statistic showed all four independent variables to be significant ($P < .0200$) in the above relationship. The cumulative effects of increased precipitation, lower maximum and higher minimum temperatures which correlated strongly ($R = .8375$) with den entrance, corresponds to passage of a low pressure weather front (C. Watson, U.S. Weather Service, Knoxville, personal communication). The average barometric pressure for the three days prior to den entrance was significantly lower than the average one week prior to den entrance ($P < .0070$).

Food availability apparently influences entrance of bears into dens since bears denned significantly earlier in years (1972-74) with a fair to poor mast yield (Beeman 1975) than in the present study with excellent mast yields ($P < .0004$). Two winter observations were made of bears feeding on chestnut oak acorns in 5 cm of snow.

"Exceptionally mild weather" accompanied den entrance in Beeman's (1975) study while the weather in the winters of 1976-78 was unusually severe.

Weather factors exhibited a much weaker relationship to bears exiting than to bears entering dens. The average daily and maximum daily wind for the three days prior to exiting dens produced the strongest linear relationship ($P < .0485$). Increasing winds as a stimulus for bears to arouse and exit dens is particularly interesting since over one-half of the observations were of bears denning in tree cavities high above ground.

Emergence of bears denning at ground level may be caused by a different environmental stimulus. Bears F5, A28 and A45 emerged during three-day periods when rainfall of 9.70, 2.95 and 6.60 cm occurred, respectively. In each case the relatively unprotected ground dens experienced saturation. Also the two bears that changed dens during winter did so during periods of heavy rainfall. This is similar to observations in Minnesota where bears emerge when the den becomes a catch-basin for rapidly melting snow (Aldous 1937, Morse 1937 and Rogers 1974).

Heavy snowfall (Jonkel and Cowan 1971, Northcott and Elsey 1971 and Craighead and Craighead 1972a,b), the cumulative effects of low temperature and above average precipitation (Lindzey and Meslow 1976a), and physical condition of the bear (Matson 1946, Spencer 1955) have been suggested as factors which initiate entrance into dens by bears. The most likely approach to understanding the temporal aspects of den ecology would be to follow an ultimate and proximate

rationale as proposed by Lindzey and Meslow (1976a) for black bears. They suggested such a pattern with weather serving as the proximate stimulus and physical condition as the ultimate stimulus. Weather also appears to be the proximate stimulus to den in the GSMNP.

However, there is physiological and behavioral evidence for an ultimate stimulus to den which occurs earlier than the proximate stimulus. This ultimate readiness is reflected in increased movements, activities and accelerated fat deposition in the fall, return to the denning areas and a gradual decline in movements and activities prior to entering dens (Beeman 1975, Rogers 1977, p. 44). It would seem evolutionarily unadaptive to cue a complex physiological behavior (Lundberg et al. 1976, Folk et al. 1977) so critical to survival on short-term, erratic factors such as weather or year-to-year variations in food supply, particularly in the present study area where oak mast is such an inconsistent producer and is the staple food in fall (Beeman 1971).

The ultimate mechanism in such hibernators as chipmunks (Eutamias) and ground squirrels (Spermophilus) is a circannual (endogenous) rhythm which through natural selection has programmed the animal's physiology and behavior in a seasonal context to annual plant cycles (Heller and Paulson 1970, Pengelley and Asmundson 1972). Bears approach the "hibernator" designation (Folk et al. 1976, Folk et al. 1977) and are the least predaceous of the carnivores (Ewer 1973) and consequently the most closely tied to seasonal plant cycles; therefore it may be that the dormancy period is ultimately controlled by such a circannual rhythm. Thus a check and balance system insures

proper timing of dormancy with a broad time frame and physiological readiness set by the ultimate factor and proximate factors such as weather and food supply then interact to provide the final stimulus to den.

Such a rhythm allows the bear flexibility in an environment that changes from year to year. This enables it to integrate a large number of environmental cues with the environmental (proximate) stimuli acting to either shorten or lengthen some portion of the rhythm, i.e., to phase it without affecting its circannual period (Pengelley and Asmundson 1972). Phasing would depend on the species' ecology and environmental harshness, with denning in temperate zones being more susceptible to phasing than denning in arctic zones. This model encompasses the observed variations in environmental factors affecting the denning period of bears over their broad geographic range and diverse ecological conditions.

II. DENNING BEHAVIOR

Denning behavior was characterized by a reduction in sensitivity, with females being much more lethargic than males. Males more readily abandoned dens upon approach than did females ($P < .005$), however, this difference is also related to the more common selection of tree dens by females (p. 67). Upon approach most bears (69%) were aroused enough to raise their heads; however, four bears denned in tree cavities did not detect the researcher's presence. The motion-sensitive activity monitor showed that bears in tree cavities were less likely to be disturbed ($P < .050$) than ground denning bears.

Arousal was accompanied by shivering, slow movement of the head from side to side and extremely slow body movements. Bears did not focus their eyes very effectively. Only one incidence of agonistic behavior was observed, but it was an unusual circumstance since it was not believed that the bear (A28) was in the extremely small cavity. Thus a closer than normal approach was made evoking a "woof" and rush to the entrance by the bear. This disturbance did not cause abandonment. The den was located on 20 February 1978 and the bear was not thought to have cubs. On 9 July 1978 she was observed with a large male, further indicating that reproductive condition was not involved in this agonistic behavior.

Bears apparently sleep in a curled position with the forehead pressed to the floor of the den and the extremities underneath the body (p. 54). Bear B18 was observed from both sides of the den, and it could not be determined which was her posterior and anterior ends. She was curled in a very tight ball which appeared almost symmetrical. Folk et al. (1972) reported that bears sleep in a similar position and move very little during the entire winter. Changes in the signal pulse between periodic checks and a small incidence of head movements throughout the winter (p. 44) indicate bears do move and change positions in dens. This movement increases as the time of emergence nears (p. 45).

The unique physiological adaptations of bears to winter dormancy have resulted in varying classifications of this behavior. For black bears body temperature is reduced only 7-8° C, metabolism is reduced 50-60%, heart rate drops from 40-50 bpm to 8-10 bpm and a weight loss

of 20-27% (strictly in the adipose tissue) occurs with the bear not eating, drinking, defecating or urinating during the entire denning period (Hock 1957, Nelson et al. 1973, Folk et al. 1977). A typical mammalian hibernator reduces its body temperature, heart rate and metabolism until body temperature is within 1° C of the ambient temperature. A regular awakening every few days to eat, drink, defecate and urinate is also typical, but when in hibernation the animal can be handled and even removed from the den without awakening (Hock 1960, Folk et al. 1972). On the contrary bears can be easily aroused and will react to a disturbance (Jonkel and Cowan 1971, Folk et al. 1972, this study).

Deviations from the norm established for "true" hibernators has resulted in such phrases as "dormancy" (Matson 1946), "ecological hibernators" (Morrison 1960) and "carnivorean lethargy" (Hock 1960) to describe the denning behavior of bears. Further physiological evidence, particularly concerning the electrocardiogram of bears (Folk et al. 1977) and their metabolic and excretory mechanisms (Lundberg et al. 1976), indicates that the "hibernator" designation applies to bears. The winter weight loss for bears (20-27%) versus smaller mammalian hibernators (25-30%, Hock 1960, Kayser 1961) indicates the adaptations of bears are equivalent to or even superior to those of other hibernators since a relatively high body temperature enables the bear to remain somewhat alert and care for the young in the winter den. This ability to react to disturbances is important to an animal as large as a bear since complete concealment in a den is not usually possible.

Pre- and Postdenning Activity Patterns

The onset of denning behavior and lethargy was noted prior to actual den entrance. Upon return to the spring and summer home ranges from the fall ranges, often over substantial distances, movements and activities gradually decreased and were centered around the denning areas (Figure 2). Activities declined significantly ($P < .005$) between the first two weeks in December and the last two weeks in December. Activities again declined ($P < .005$) between the last two weeks in December and the first two weeks in January. No other significant differences were found until activities began to increase ($P < .005$) between the last two weeks in March to the first two weeks in April. Inactivity was still predominant in the postdenning period until activity again gradually increased ($P < .025$) between the first two weeks in April and the last two weeks in April. There was no significant difference in the pre- and postdenning activity patterns between the two years of the study.

A similar increase in inactivity in the pre- and postdenning periods was observed by Jonkel and Cowan (1971), Rogers (1974) and Lindzey and Meslow (1976a). Rogers (1974) postulated the postdenning inactivity was related to tender footedness due to shedding of foot pads during denning. The extent of this phenomenon is unknown, but it probably plays a minor role in influencing postdenning activities. One of three bears tranquilized in winter dens during the present study showed evidence of shedding of foot pads. Lindzey and Meslow (1976a) correlated pre- and postdenning inactivity with daily weather, principally maximum daily temperature and precipitation. The gradual

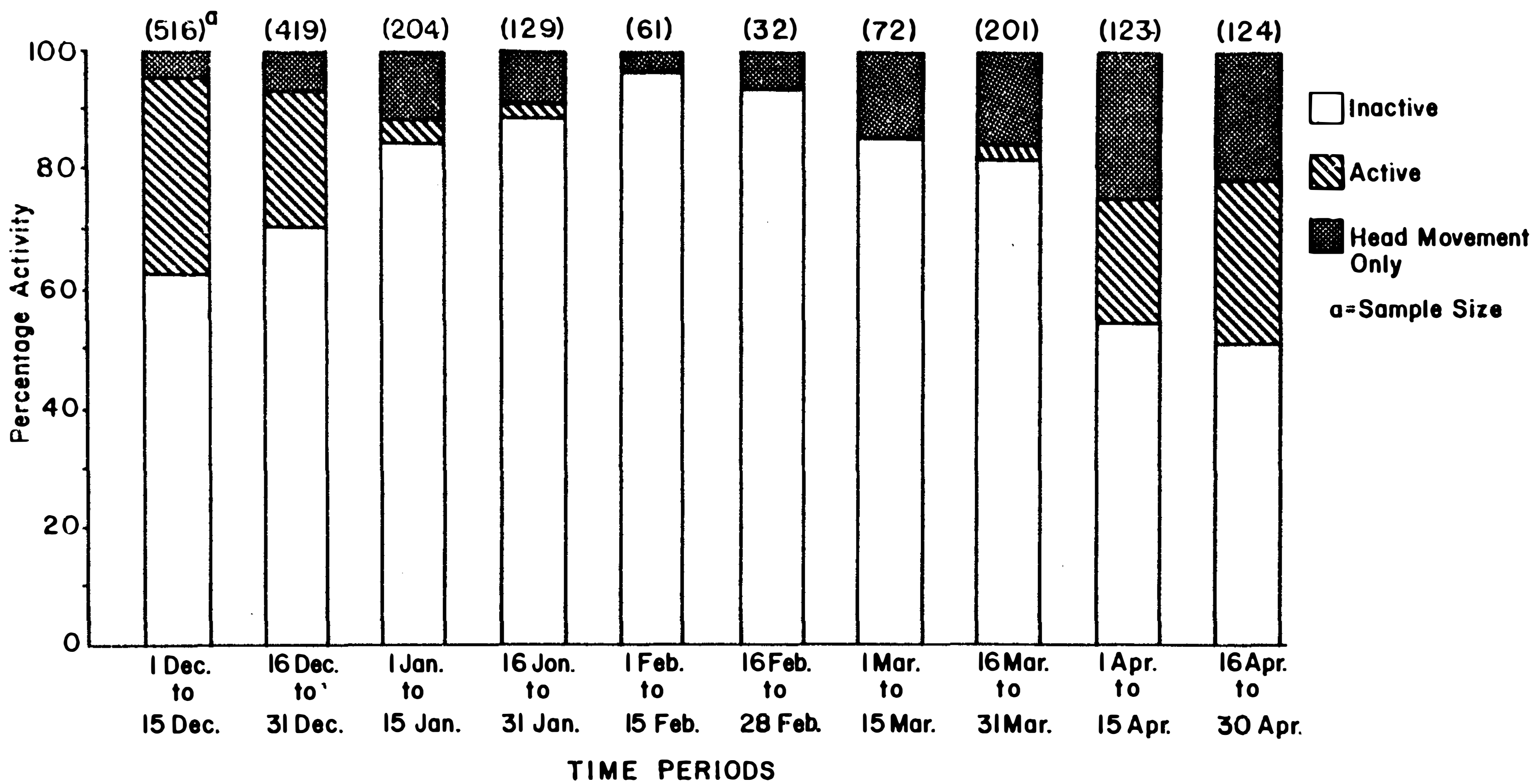

Figure 2. Pre- and postdenning and winter activity patterns of black bears in the Great Smoky Mountains National Park, 1976-78.

decrease and increase in activity and the nature of the metabolic alterations of hibernation (Folk et al. 1972, Nelson et al. 1973, Folk et al. 1976) suggest that this pre- and postdenning behavior may be a physiological transition period.

The frequency of head movements increased significantly ($P < .005$) prior to den emergence indicating movements within dens and readjustment to normal behavior. Jonkel and Cowan (1971) noted two denned bears that rushed the observer late in the spring and concluded that a marked behavioral change occurs before bears leave their dens.

Location of Tree Cavities by Bears

The location and utilization of tree cavities high above ground by an animal as large as a black bear seems unusual. But adult females in the GSMNP average only 52 kg in summer and by the time of den entrance probably weigh less than 68 kg (Beeman 1975). Sub-adults utilizing tree dens are usually smaller than adult females. Also observations from enclosures as well as in the wild indicate that black bears spend considerable time resting and feeding in trees (Taylor 1971, Beeman 1971). The morphological adaptations and use of the forested habitat for defense by the black bear are well known (Herrero 1972). Such arboreal activities would enhance the ability to locate tree cavities.

But evidence from the present study indicates more than coincidental location of tree dens during normal arboreal activities. A total of 45 (34%) large trees (> 84 cm dbh) had been climbed by

bears, the majority (59%) being non-food item species. A comparison with smaller trees (< 84 cm dbh) measured and inspected in application of the quarter method revealed that significantly fewer smaller trees had been climbed ($P < .005$). The high frequency of climb marks on large trees (plus the fact that 24% of the active tree dens had entrances which were not visible from ground level) suggest bears locate tree cavities by a trial and error approach and possibly learn to associate large trees of certain species with the likelihood of cavities. Such learning and retention capabilities have been demonstrated to be available to black bears (Bacon 1973). Bromeli (1973) reported that Asiatic black bears (*Selenarctos thibetanus*) climb and inspect many trees before a suitable cavity is selected.

Den Site Preparation

All dens examined contained bedding material with ground dens containing a greater volume than tree dens (p. 55). An adult female (HI) was the only bear observed to carry bedding material (seven hemlock boughs) from the ground into a tree den. She later gave birth, but three other females (A45, E7 and F5) known to produce cubs showed no unusual behavior in den preparation. Three bears (two sub-adult males and one adult female with yearling cubs) lined tree cavities with twigs and branches broken from the den tree or trees adjacent to the den. The clawing of the inside walls of tree dens may enlarge the cavity but more importantly it provides bedding material. No attempt was made to block den entrances as is common for smaller hibernators.

Bear A52 (adult male) collected an estimated 192 liters of rhododendron and doghobble (*Leucothoe editorium*) branches and leaves

and wove them into an intricate "nest" by breaking several large rhododendron branches into the rather open ground den to serve as the framework. A 19.8 m^2 area in front of the den was cleared of vegetation. The elaborate structure provided a level bed on the steep slope (32°) and aided in insulation and protection against ground moisture.

<u>Fecal Plugs</u>

Four fecal plugs located near dens of radio-instrumented bears are described in Table 9. Searches at other dens yielded no additional fecal plugs indicating that most bears retain the plug and may not feed for some time after emergence. Plug formation and other excretory alterations (Lundberg et al. 1976) raise doubts if it is physiologically possible for bears to intermittently forage in winter during favorable weather conditions as postulated by Lindzey and Meslow (1976a).

The plugs were densely compressed with bear hair mixed throughout and serving as the framework of the plug (Figure 3). The contents may have been the result of grooming in the den and ingestion of debris adhering to damp fur since bears often entered dens during periods of rainfall (p. 37). Also some debris may have been ingested during collection of bedding material. A dark green mucous coated the outside of all plugs.

Three other scats of a very loose consistency were located in the vicinity of dens. They consisted entirely of a greenish-yellow jelly-like substance which was probably an internal secretion passed

Table 9. Description of fecal plugs located in the Great Smoky Mountains National Park, 1976-78.

Plug Number	Bear Number	Plug Wgt. (g)	Length (cm)	Diameter (cm)	Volume (ml, Water Displacement)	Contents
1	A30	182.0	22.8	3.9	192	Bear hair, wood chips, twigs
2	E7	156.5	20.5	4.1	145	Bear hair, clay chips and fine roots, small rocks, and leaf fragments
3	A44 and yearling cubs	153.0	19.5	3.7	155	Bear hair, wood chips, twigs and buds
4	A44 and yearling cubs	76.0	9.4	3.6	80	Bear hair, twigs and wood chips

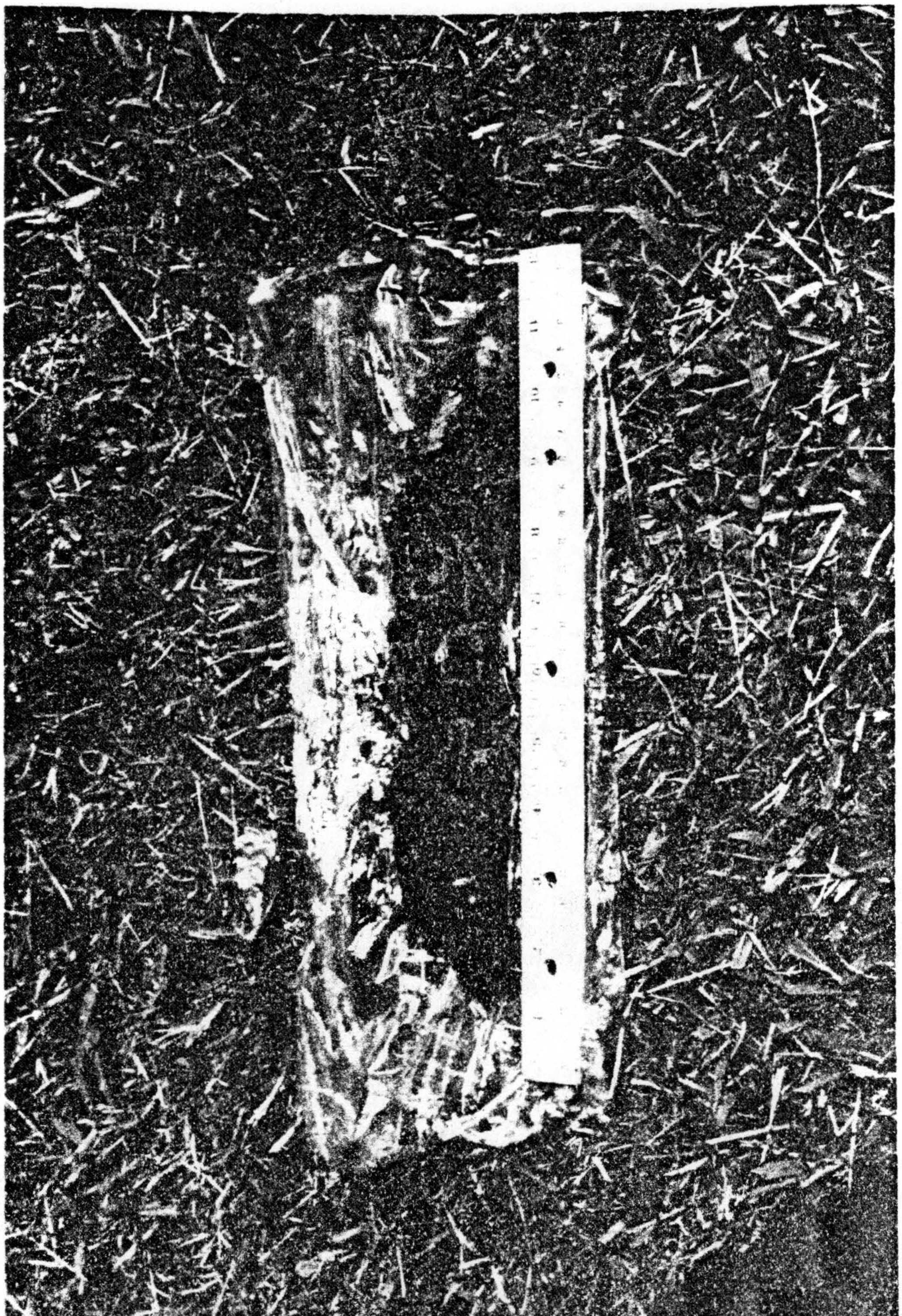

Figure 3. Fecal plug located at the den of bear A30.

just prior to plug formation. Craighead (1972) reported passage of a "very dark watery stool" by grizzly bears and postulated it "to be a scouring of the digestive tract in preparation for hibernation."

III. DEN SITE SELECTION

Twenty-six active dens were located for 23 different bears during the winters of 1976-77 and 1977-78. Twenty-four dens were located with radiotelemetry and two ground dens were located by personnel of the National Park Service during hog control operations or by research personnel of The University of Tennessee, Knoxville. Bears radiotracked to their dens included six adult males, nine adult females, three sub-adult males and three sub-adult females. A total of 36 dens have been located for 29 radio-instrumented bears in the GSMNP since 1972. Pelton et al. (1977) described general characteristics of the first 10 dens.

Characteristics of Dens

Characteristics of dens for 1972-78 are given in Table 7, page 29. Fifty percent (18) of all dens located for radio-instrumented bears were in tree cavities above ground level (Figures 4 and 5) formed by wind or lightning damage and natural decay. Of the remainder, 22% (8) were cavities in association with root systems of wind-tilted trees, 17% (6) were stump dens, 6% (2) were rock dens, 3% (1) was at the base of a dead snag and 3% (1) was in a fallen log.

Yellow birch (4, 22%), eastern hemlock (4, 22%), red maple (4, 22%) and northern red oak (3, 17%) were the most common tree dens.

Figure 4. Characteristic tree den in the Great Smoky Mountains National Park used by bears during the winters of 1972-78. This particular cavity served as a maternity den for bear H1 during the winter of 1977-78.

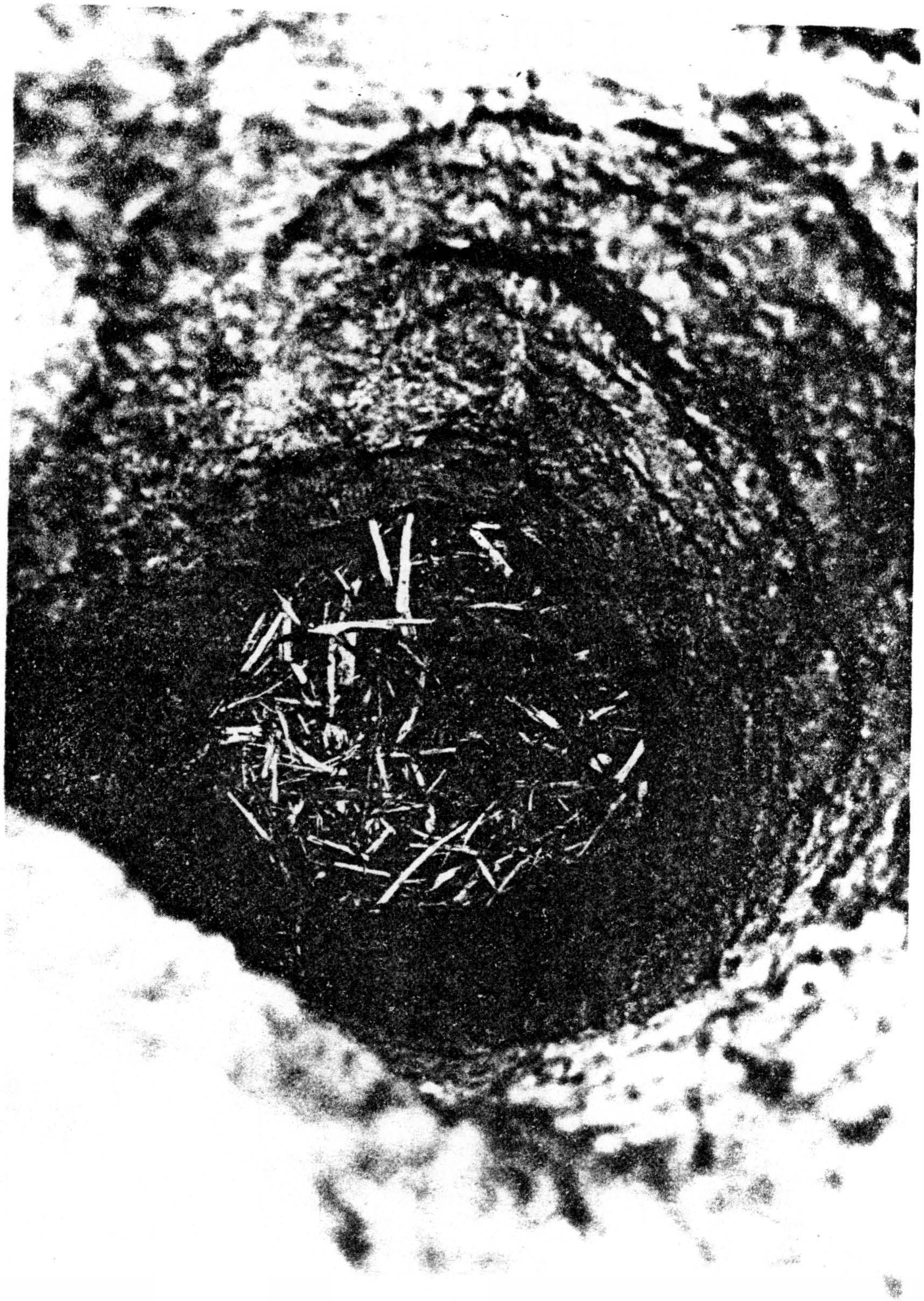

Figure 5. Inside view of a tree cavity (Bear A44) showing the depth of the bed below the entrance (305 cm) and the bedding material (wood scrapings and shredded twigs gathered from the den tree).

A den cavity was also located in a yellow buckeye, black gum and chestnut snag. The majority (63%) of ground dens (excluding rock dens) were in association with chestnut logs and/or stumps. The preponderant use of the remains of old chestnut trees is probably the result of their disproportionate availability due to the chestnut blight during the 1930's.

Further analysis of the characteristics of tree and ground dens reveals other distinctive differences. The average dbh of trees associated with ground dens was 89.0 cm while the average dbh of tree dens was 94.8 cm; a lack of significance reflects the importance of large trees in providing ground dens as well as tree dens.

Entrance dimensions ($P < .0421$) and cavity width and length ($P < .0078$) were significantly smaller for tree dens than ground dens. The average depth of tree den cavities below the entrance (219 cm) was larger than the average height of cavities in ground dens (69 cm). The distance from the cavity to entrance (view factor, Figure 6) results in greater energy conservation in tree dens since heat exchange with the open air and wind is reduced (Thorkelson and Maxwell 1974, Johnson and Johnson 1978). Also the smaller entrances to tree dens provide better protection from wind and precipitation. Seclusion above ground decreased the chance of disturbances (p. 40) and isolated bears from ground moisture. All ground dens examined in the GSMNP exhibited some degree of ground moisture.

A simulation model of winter heat loss for a black bear in a tree den showed a 15.05% energy savings over ground dens (Johnson and Johnson 1978). Less exposure to wind, moisture, outside air temperature

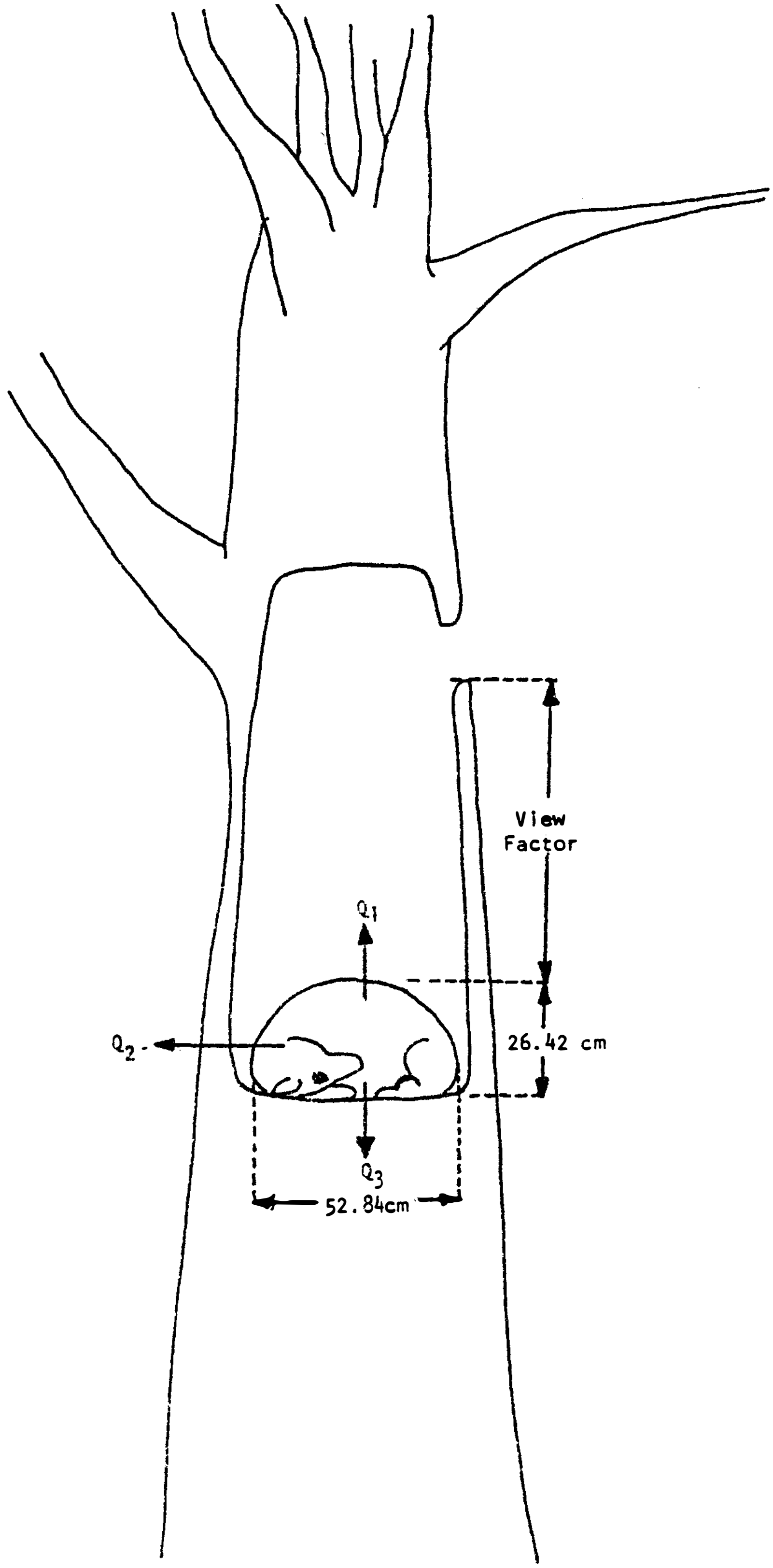

Figure 6. Cross-section of a black bear in a tree den showing the view factor and hibernation posture.

and better insulation of tree dens accounted for the energy conservation. Also seclusion in tree cavities above ground reduces the chance of arousal and subsequent increases in energy consumption as reflected by shivering (Jonkel and Cowan 1971, p. 41).

All dens examined contained bedding material. Humus from decaying heartwood and wood scrapings from the inside walls were the most common material in tree dens while dried deciduous leaves and rhododendron, mountain laurel, and wild grape leaves and twigs were the most common material in ground dens. Ground dens contained a greater volume ($P < .0648$) of bedding material than did tree dens (excludes bear A52, p. 46). This is probably reflected in availability of material and the less protected nature of ground dens.

The average age of 10 den trees was 311 years when adjusted downward by 25% (F. W. Woods, personal communication) to account for rapid growth early in the life of the tree. The advanced age of den trees indicates that extended rotations may not be practical for insuring available tree dens, particularly since so little is known about the dynamics of cavity formation and longevity.

Site Characteristics of Dens

Site characteristics of dens for 1972-78 are given in Table 10. Ground dens occurred on steeper slopes ($P < .0382$) and at lower elevations ($P < .0009$) than tree dens. The steep slopes of ground dens ($\bar{x}$ = 36°) are probably a function of the fact that 56% of these dens were associated with wind-tilted trees. The high elevations ($\bar{x}$ = 1244 m) and steep slopes of tree dens ($\bar{x}$ = 31°) are related to the inaccessibility of these areas to pre-Park logging activities.

Table 10. Site and vegetation characteristics of dens of black bears in the Great Smoky Mountains National Park, 1972-78.

Bear No.	Den Type	Vegetation Type	Understory	Slope Degree	Slope Aspect Degree	Den Entrance Aspect Degree	Position on Slope Micro Percent	Position on Slope Macro Percent	Elevation (m)	History of Land Use
89	Inside hollow sawed-off stump	Wild grape and greenbrier thicket	Dense wild grape and greenbrier	46	36	200	67	32	780	Heavily logged 1930's (MPLR watershed)
65	Under wind-tilted eastern hemlock stump	Eastern hemlock	Dense rhododendron	31	38	261	25	67	1170	Virgin (WPLR watershed)
A 28	Cavity in eastern hemlock	Eastern hemlock	Moderate rhododendron	29	36	109	50	50	1182	Virgin (WPLR watershed)
A 26	Inside rotted red maple stump	Red maple-sweet birch	Dense mountain laurel	22	37	up	0	0	1122	Light-cut, 1905 (WPLR watershed)
A 8	Cavity in chestnut snag	Sweet birch-fire cherry (<u>Prunus pensylvanica</u>)	Light rhododendron and greenbrier	31	260	274	17	4	1195	Light-cut, 1905 (WPLR watershed)
A 9	Cavity in yellow birch	Yellow buckeye	Moderate rhododendron	51	278	254	0	89	1292	Virgin (WPLR watershed)
A 30	Cavity in northern red oak	Northern red oak	None	20	176	222	10	79	1451	Light-cut (Eagle Creek watershed, N.C.)
A 29	Cavity in yellow buckeye	Northern red oak	None	32	200	188	7	88	1439	Light-cut (Bone Valley watershed N.C.)
F 5	Rock crevice	Table mountain pine	Moderate mountain laurel	38	211	209	30	20	1244	Heavily logged 1920's (EPLR watershed)
A 44	Cavity in black gum	Red maple-sourwood	Dense rhododendron	21	344	113	0	43	1082	Light-cut, 1905 (WPLR watershed)
A 9	Cavity in yellow birch	Yellow birch	Dense rhododendron	29	340	358	100	38	1353	Virgin (WPLR watershed)

Table 10 (Continued)

Bear No.	Den Type	Vegetation Type	Understory	Slope Degree	Slope Aspect Degree	Den Entrance Aspect Degree	Position on Slope: Micro Percent	Position on Slope: Macro Percent	Elevation (m)	History of Land Use
A 47	Cavity in red maple	Hemlock-yellow birch	Moderate rhododendron	28	12	198	0	0	1250	Virgin (Anthony Creek watershed)
H 1	Cavity in yellow birch	Yellow birch-yellow buckeye-sugar maple	None	24	345	210	100	36	1280	Virgin (WPLR watershed)
B 12	Cavity in red maple	Red maple-sweet birch-fire cherry	Moderate rhododendron	35	336	4	10	20	1006	Heavily logged 1930's (MPLR watershed)
B 18	Rock crevice	Wild grape and greenbrier thicket	Dense wild grape and greenbrier	33	288	277	0	28	678	Heavily logged 1930's (MPLR watershed)
B 18	Under fallen log	Wild grape and greenbrier thicket	Dense wild grape and greenbrier	34	99	118	5	57	716	Heavily logged 1930's (MPLR watershed)
B 10	Under stump	Wild grape and greenbrier thicket	Dense wild grape and greenbrier	38	34	343	90	18	549	Heavily logged 1930's (MPLR watershed)
E 7	Under root cap of wind-fallen tree	Closed oak	Light wild grape and greenbrier	31	242	204	15	41	878	Virgin (Abrams Creek watershed)
A 50	Inside stump	Red maple-sweet birch	Dense rhododendron	37	239	210	31	54	1036	Light-cut, 1905 (WPLR watershed)
A 52	Under root cap of wind-fallen tree	Red maple	Moderate rhododendron	32	289	316	5	57	1018	Light-cut, 1905 (WPLR watershed)
A 45	Under root cap of wind-fallen tree	Wild grape and greenbrier thicket	Dense wild grape and greenbrier	44	301	329	10	60	914	Light-cut, 1905 (WPLR watershed)
A 53	Under root cap of wind-fallen tree	Red maple-sweet birch	Dense rhododendron	47	28	88	0	79	1021	Heavily logged 1930's (MPLR) watershed)

Table 10 (Continued)

Bear No.	Den Type	Vegetation Type	Understory	Slope Degree	Slope Aspect Degree	Den Entrance Aspect Degree	Position on Slope: Micro Percent	Position on Slope: Macro Percent	Elevation (m)	History of Land Use
A 42	Under stump	Wild grape and greenbrier thicket	Dense wild grape and greenbrier	42	303	299	90	24	817	Heavy-cut, 1905 (WPLR watershed)
A 28	Under root system of standing yellow birch	Yellow birch	Moderate rhododendron	35	19	111	100	58	1318	Virgin (WPLR watershed)
B 50	Cavity in yellow birch	Yellow birch	Moderate rhododendron	34	329	32	25	85	1305	Light-cut (Eagle Creek watershed, N.C.)
63a	Base of a dead snag	-	-	-	-	-	-	-	768	Heavily logged 1905 (WPLR watershed)
B 29	Cavity in northern red oak	Beech-northern red oak	None	24	220	226	27	27	1475	Light-cut (Eagle Creek watershed, N.C.)
B 29a	Bed on root system of wind-tilted red maple	Northern hardwood	Dense rhododendron	-	N	-	-	-	1403	Virgin (WPLR watershed)
A 45	Cavity in northern red oak	Ecotone between cove hardwood and closed oak	None	38	306	326	0	64	695	Light-cut, 1905 (WPLR watershed)
R 31	Under root system of red maple sprout	Red maple-sweet birch	Dense rhododendron	36	76	354	50	50	1098	Heavily logged, 1930's (MPLR watershed)
Y 30	Cavity in red maple	Eastern hemlock-yellow birch	Dense rhododendron	39	271	10	8	20	1334	Virgin (Anthony Creek watershed)
Y 3[illegible]	Cavity in eastern hemlock	Eastern hemlock-yellow birch	Dense rhododendron	22	259	up	50	50	1318	Virgin (Anthony Creek watershed)
Y 52a	Cavity in eastern hemlock	Cove hardwood	-	-	SE	-	-	-	1189	Virgin (WPLR watershed)

Table 10 (Continued)

Bear No.	Den Type	Vegetation Type	Understory	Slope Degree	Slope Aspect Degree	Den Entrance Aspect Degree	Position on Slope: Micro Percent	Position on Slope: Macro Percent	Elevation (m)	History of Land Use
P 53[a]	Cavity in eastern hemlock	Cove hardwood	-	-	E	-	-	-	1207	Virgin (WPLR watershed)
Y 60[a]	Under dead tree stump	Closed oak	-	-	NE	-	-	-	823	Light-cut, 1905 (WPLR watershed)
R 56[a]	Cavity in red maple	Northern hardwood	-	-	SW	-	-	-	1341	Virgin (WPLR watershed)
Average for tree dens				31			28	46	1244	
Average for ground dens				36			35	43	964	
Average for both				33			31	44	1104	

[a]Not used in statistical analysis due to a lack of measured parameters.

A pattern in slope aspects of tree dens existed with 73% occurring in the 135° area from 247.5° (W) to 22.5° (N). Due to the general topography of the study area, with the major (state-line) ridge running northeast to southwest, the steep upper coves that harbor den trees are generally facing northwesterly (247.5° to 22.5°). The same northerly trend exists for ground dens but their slope aspects are much more scattered.

No patterns or differences are evident for aspects of den entrance for tree or ground dens. The presence of a suitable den is probably the stimulus for selection rather than the aspect of entrance or slope since snow cover is usually insiginficant and bears located below entrances ($\bar{x}$ = 219 cm) in tree cavities are adequately protected from wind and moisture.

The macro-topographic position of dens on slopes was generally lower (44%) than the micro-topographic position (31.5%). The lower macro-position insures sufficient soil depth, moisture and protection for growth of large trees while the higher micro-position results in greater susceptibility of these areas to wind damage leading to den formation. The lack of differences on slopes between the positions of tree and ground dens again reveals the importance of large trees (p. 53) and wind damage to both den types.

Vegetation Around Dens

Vegetation analysis of the area around den sites further elucidates differences between tree and ground dens (Tables 10, page 56, 11 and 12). Forest types of tree dens included northern hardwoods

Table 11. Phytosociological data (Bitterlich method) for active den sites and random sites.

Tree Species	Random Vegetation Samples (n = 115) Basal Area m²/ha	Random Vegetation Samples (n = 115) Percentage Composition	Random Vegetation Samples (n = 115) Percentage Species Freq.	Den Sites (n = 30, 15 Tree and 15 Ground Dens) Basal Area m²/ha Tree	Basal Area m²/ha Ground	Basal Area m²/ha Both	Percentage Composition Tree	Percentage Composition Ground	Percentage Composition Both	Percentage Species Frequency Tree	Percentage Species Frequency Ground	Percentage Species Frequency Both
Red maple	2.44	10.71	46.96	2.30	4.06	3.17	8.72	26.77	15.31	60.00	55.56	46.67
Yellow poplar	1.78	7.81	24.35	-	-	-	-	-	-	-	-	-
Spruce	1.74	7.64	8.70	-	-	-	-	-	-	-	-	-
Yellow birch	1.43	6.28	22.61	5.43	1.45	3.44	20.64	9.60	16.61	60.00	22.22	36.67
Chestnut oak	1.36	5.97	20.87	-	.61	.31	-	4.04	1.48	-	22.22	3.33
Fraser magnolia	1.27	5.58	23.48	.92	.61	.76	3.49	4.04	3.69	20.00	33.33	20.00
Eastern hemlock	1.21	5.31	23.48	3.14	.61	1.88	11.92	4.04	9.04	40.00	22.22	26.67
Fir	.90	3.95	8.70	-	-	-	-	-	-	-	-	-
Pitch pine	.88	3.86	7.83	-	-	-	-	-	-	-	-	-
Sweet birch	.84	3.69	16.52	2.14	2.30	2.22	8.14	15.15	10.70	33.33	44.44	30.00
Silverbell	.83	3.64	17.39	.31	.15	.23	1.16	1.01	1.11	6.67	11.11	6.67
Northern red oak	.78	3.42	14.78	1.84	.31	1.07	6.98	2.02	5.17	26.67	22.22	20.00
Virginia pine	.68	2.99	9.57	-	-	-	-	-	-	-	-	-
Sourwood	.67	2.44	15.65	.61	.69	.65	2.33	4.55	3.14	6.67	44.44	16.67
Scarlet oak	.66	2.90	11.30	-	.15	.08	-	1.01	.37	-	11.11	3.33
Black gum	.54	2.37	13.04	.15	-	.08	.58	-	.37	6.67	-	3.33
White pine (*Pinus strobus*)	.50	2.20	8.70	-	-	-	-	-	-	-	-	-
Black locust (*Robinia pseudo-acacia*)	.45	1.98	16.52	-	.15	.08	-	1.01	.37	-	11.11	3.33
Basswood	.43	1.89	6.09	2.14	-	1.04	8.14	-	5.17	20.00	-	10.00
Sassafras	.37	1.62	8.70	-	-	-	-	-	-	-	-	-
White oak	.36	1.58	6.96	-	-	-	-	-	-	-	-	-
Serviceberry (*Amelanchier arborea*)	.30	1.32	4.35	.15	-	.08	.58	-	.37	6.67	-	3.33
Shortleaf pine (*Pinus echinata*)	.30	1.32	3.48	-	-	-	-	-	-	-	-	-

Table 11 (Continued)

Tree Species	Random Vegetation Samples (n = 115) Basal Area m²/ha	Percentage Composition	Percentage Species Freq.	Den Sites (n = 30, 15 Tree and 15 Ground Dens) Basal Area m²/ha Tree	Ground	Both	Percentage Composition Tree	Ground	Both	Percentage Species Frequency Tree	Ground	Both
Dead pine	.26	1.14	4.35	-	-	-	-	-	-	-	-	-
Pignut hickory	.24	1.05	7.83	.15	.31	.23	.58	2.02	1.11	6.67	11.11	6.67
Table mountain pine	.22	.97	3.48	-	1.84	.92	-	12.12	4.43	-	11.11	3.33
Fire cherry	.21	.92	3.48	1.99	.23	1.11	7.56	1.52	5.35	33.33	11.11	20.00
Sugar maple	.18	.79	5.22	1.38	.15	.76	5.23	1.01	3.69	26.67	11.11	16.67
Black cherry	.18	.79	5.22	.15	.46	.31	.58	3.03	1.48	6.67	11.11	6.67
White ash (*Fraxinus americana*)	.30	.53	2.61	-	-	-	-	-	-	-	-	-
Black oak	.44	.44	3.48	-	-	-	-	-	-	-	-	-
Mockernut hickory	.10	.44	1.74	-	-	-	-	-	-	-	-	-
Southern red oak (*Quercus falcata*)	.26	.26	1.74	-	-	-	-	-	-	-	-	-
Dead angiosperm	.06	.26	2.61	.46	.31	.38	1.74	2.02	1.85	20.00	11.11	13.33
Ironwood (*Ostrya virginiana*)	.04	.18	.87	-	-	-	-	-	-	-	-	-
Dogwood (*Cornus florida*)	.04	.18	1.74	-	-	-	-	-	-	-	-	-
Striped maple (*Acer pensylvanicum*)	.04	.18	1.74	-	-	-	-	-	-	-	-	-
Beech	.04	.18	.87	1.22	-	.61	4.65	-	2.95	20.00	-	10.00
Cucumber tree (*Magnolia acuminata*)	.04	.18	1.74	-	-	-	-	-	-	-	-	-
Yellow buckeye	.02	.09	.87	1.87	-	.92	6.98	-	4.43	20.00	-	10.00
Mountain holly (*Ilex montana*)	-	-	-	-	.76	.38	-	5.05	1.85	-	11.11	3.33

Table 12. Phytosociological data (Point-quarter method) for active den sites and random sites.

Tree Species	Importance Value (Sum of Relative Density, Dominance and Frequency) Tree	Ground	Both	Relative Density (Percent) Both	Relative Dominance (Percent) Both	Relative Frequency (Percent) Both
Active Den Sites (n = 30, 15 Tree and 15 Ground Dens)						
Yellow birch	104.70	53.58	85.52	20.83	31.36	33.33
Red maple	61.82	76.46	68.74	13.54	17.70	37.50
Eastern hemlock	53.44	-	37.86	5.21	15.98	16.67
Northern red oak	51.07	-	35.40	6.25	12.48	16.67
Basswood	30.74	-	19.80	5.21	2.09	12.50
Sweet birch	29.72	90.20	50.40	14.58	2.49	33.33
Fraser magnolia	27.96	49.25	34.42	7.29	2.13	25.00
Yellow buckeye	21.67	-	14.75	2.08	4.34	8.33
Beech	18.96	-	16.18	3.13	.55	12.50
Sugar maple	17.63	24.83	13.76	3.13	2.30	8.33
Black gum	13.16	-	9.39	1.04	4.18	4.17
Sourwood	10.46	43.62	22.54	5.21	.66	16.67
Fire cherry	8.50	15.31	10.73	2.08	.32	8.33
Pignut hickory	8.48	17.25	10.98	2.08	.57	8.33
Mountain holly	8.40	-	5.26	1.04	.05	4.17
Chestnut oak	27.01	27.01	6.96	1.04	1.75	4.17
Table mountain pine	23.46	23.46	7.84	3.13	.54	4.17
Black locust	16.60	16.60	5.57	1.04	.36	4.17
Silverbell	-	14.79	5.33	1.04	.12	4.17
Scarlet oak	-	14.30	5.64	1.04	.43	4.17
Mean distance (m)	6.12	5.14	5.75			
Mean area (m^2)	37.45	26.42	33.06			
Density (trees/ha)	267	379	303			
Basal area per tree (m^2)	.3508	.0899	.2530			
Total basal area (m^2/ha)	93.7	34.1	76.7			

Table 12 (Continued)

Tree Species	Importance Value (Sum of Relative Density, Dominance and Frequency) Tree	Ground	Both	Relative Density (Percent) Both	Relative Dominance (Percent) Both	Relative Frequency (Percent) Both
Random Vegetation Samples (n = 115)						
Red maple	53.88			12.07	7.55	34.26
Yellow birch	42.09			7.89	13.83	20.37
Eastern hemlock	37.55			6.27	14.61	16.67
Yellow poplar	34.90			8.59	9.64	16.67
Fraser magnolia	29.78			6.96	5.23	17.59
Silverbell	26.55			5.57	4.31	16.67
Spruce	21.46			3.71	9.42	8.33
Chestnut oak	21.33			4.41	5.81	11.11
Sweet birch	21.28			6.03	2.29	12.96
Northern red oak	16.61			3.48	4.80	8.33
Scarlet oak	13.33			3.48	1.52	8.33
White pine	12.93			2.32	4.13	6.48
Fir	12.71			3.71	1.59	7.41
Black gum	12.52			2.32	2.79	7.41
Sourwood	12.21			2.32	.63	9.26
Virginia pine	11.20			2.55	1.24	7.41
Black locust	9.27			1.62	1.17	6.48
Pitch pine	8.06			1.86	.64	5.56
Sassafras	7.85			1.86	.43	5.56
White oak	6.51			1.39	1.42	3.70
Pignut hickory	6.28			1.16	.49	4.63
Fire cherry	6.08			1.62	.76	3.70
Black cherry	5.51			.70	2.03	2.78
Table mountain pine	4.86			1.39	.69	2.78
Basswood	4.75			.93	1.04	2.78
Sugar maple	4.08			.70	.60	2.78
Serviceberry	3.39			1.39	.15	1.85
White ash	2.62			.46	.31	1.85
Beech	2.59			.46	.28	1.85
Dogwood	2.39			.46	.08	1.85
Yellow buckeye	2.38			.46	.07	1.85
Cucumber tree	2.36			.46	.05	1.85
Shortleaf pine	1.86			.46	.47	.93
Black oak	1.29			.23	.13	.93
Southern red oak	1.22			.23	.06	.93
Mountain holly	1.21			.23	.05	.93
Striped maple	1.18			.23	.02	.93

Table 12 (Continued)

Tree Species	Importance Value (Sum of Relative Density, Dominance and Frequency)			Relative Density (Percent)	Relative Dominance (Percent)	Relative Frequency (Percent)
	Tree	Ground	Both	Both	Both	Both
Mean distance (m)	4.44					
Mean area (m^2)	19.72					
Density (trees/ha)	507					
Basal area per tree (m^2)	.0922					
Total basal area (m^2/ha)	46.8					

(39%), cove hardwood-hemlock associations (44%) and red maple, sweet birch, fire cherry and sourwood associations (17%). All of the tree dens in the red maple associations were likely "culls" skipped during early logging operations in these areas. Forest types of ground dens included wild grape and greenbrier thickets (33%), red maple associations (28%), closed oak (17%), cove hardwood-hemlock associations (11%), table mountain pine (6%) and northern hardwoods (6%). Forest types of ground dens exhibited a more xeric tendency than tree dens.

The understory vegetation was significantly more dense ($P < .0038$) around ground dens than around tree dens. The most common understory associations were rhododendron and mountain laurel and wild grape and greenbrier. No ground dens were devoid of understory but 33% of tree dens had no understory. Factor analysis revealed an inverse relationship between understory density and distance of the den cavity above ground. Whether this "trade-off" between understory density and distance above ground is a "seclusion-seeking" behavior or an anomaly of the data is unclear.

Phytosociological comparison of community parameters at den sites and random sites is presented in Tables 11 and 12. The total basal area on sites was greater ($P < .0112$) for tree dens than ground dens. Also the basal area per tree was much larger ($P < .0003$) at tree den sites than ground den sites. Density of trees was lower ($P < .0044$) and the mean distance between trees was greater ($P < .0033$) at tree den sites than at ground den sites.

Phytosociological data reveal that tree dens most commonly occur (83%) in climax communities dominated by a small number of

widely spaced individuals of a very large size. Cull trees skipped during logging operations represent the remainder. The majority of ground dens (72%) occur in disturbance communities characterized by stumps and treeless thickets or earlier succession stages characterized by high densities and low basal areas per tree. The discreteness of community and site parameters between tree and ground dens will be later applied to delineating availability of denning habitat from random plots (p. 78).

Sex and Age Differences

Den site selection varied in response to differing requirements of sex and age classes with adult females and sub-adults of both sexes more often ($P < .0780$) selecting tree cavities above ground than adult males. The present study provides the strongest evidence yet of more careful selection of dens by females and sub-adults which was also observed by Calahane (1947), Erickson (1964), and Lindzey and Meslow (1976b). The differences in site, vegetation and physical characteristics of ground and tree dens discussed previously exemplify these sex and age differences. Earlier denning dates (p. 35) by females and smaller body size of females and sub-adults allows them to select the more protected tree cavities.

In addition to differential selection of den types, there was also a separation in vegetation types selected for denning among the sex and age groups. Sub-adults more commonly denned ($P < .054$) in northern hardwoods and adult females denned in cove hardwood-hemlock associations at high elevations and wild grape and greenbrier thickets

at low elevations where tree dens were less abundant. This difference was also reflected in the average elevations of dens for sub-adults (1157 m) and adult females (1077 m). Furthermore, the separation in denning habitat was more distinct between adult females and adult males. Adult males denned more commonly ($P < .005$) in red maple associations and adult females in cove hardwood-hemlock or wild grape associations.

A similar separation in selection of vegetation types for denning was observed in Washington by Lindzey and Meslow (1976b). They postulated such a separation would lessen the chance of contact between adults and sub-adults. Also by selection of northern hardwoods, sub-adults would not compete with adult females for dens and would be insured tree dens (due to their later denning dates, p. 35) which better conserve winter fat stores (Johnson and Johnson 1978). This is particularly important to sub-adults since they are generally in poorer physical condition than other segments of the population (Jonkel and Cowan 1971). Separation in denning habitat and den types between adult males and adult females would lessen the chance of intraspecific predation on cubs. Such a case was recorded in Michigan where a large black bear killed and ate a mother and two cubs at a den in mid-April 1963 (unpublished report in the files of the Michigan Department of Natural Resources at Crystal Falls, Michigan _in_ L. L. Rogers, 1977). Intraspecific predation has also been reported for male brown bears (Troyer and Hensel 1962).

Black bears utilize a variety of den types across their range (Table 13). As the use of radiotelemetry has expanded, location of

Table 13. Types of winter dens used by black bears.

Den Type	Area	Reference
Open nest or shallow depression	Minnesota	Morse (1937)
	Mexico	Leopold (1959)
	Michigan	Erickson (1964)
	North Carolina	Hamilton and Marchinton (1977)
Depression under boughs of coniferous tree	Maine	Smith (1946)
Depression under tree roots or stump	Minnesota	Morse (1937)
	Minnesota	Aldous (1937)
	North Carolina	Clodfelter (1943)
	Alaska	Hock (1951)
	Pennsylvania	Matson (1946)
	Washington	Lindzey and Meslow (1976b)
Depression under boulders	New York	Schoonmaker (1938)
	Pennsylvania	Matson (1946)
	Mexico	Leopold (1959)
	Montana	Jonkel and Cowan (1971)
Depression under fallen log	Pennsylvania	Matson (1946)
	Michigan	Erickson (1964)
	Montana	Jonkel and Cowan (1971)
	Washington	Lindzey and Meslow (1976b)
Base of a hollow tree	Montana	Jonkel and Cowan (1971)
	USSR	Bromlei (1973)
	Washington	Lindzey and Meslow (1976b)
Drainage culvert	Yellowstone Nat'l. Park	Barnes and Bray (1966)
Under cabin	Montana	Jonkel and Cowan (1971)
Tree cavities high above ground	Michigan	Switzenberg (1955)
	Louisiana	Taylor (1971)
	Washington	Lindzey and Meslow (1976b)
	North Carolina	Hamilton and Marchinton (1977)
	Tennessee (Nat'l. Forest)	Conley (1976)
	Georgia	Ernst (1972)
	USSR	Bromlei (1973)
	Tennessee (GSMNP)	Present Study

tree cavities high above ground as winter dens for black bears has increased, thus fulfilling predictions by Beeman (1975).

Results from the GSMNP indicate the importance of tree dens to black bears. The small entrances, dry cavities, superior heat insulation and isolation from ground disturbances result in tree cavities being the most advantageous dens.

Protected den sites such as tree cavities are particularly important to adult females since parturition and maternal care occur in winter dens. The extremely altricial cubs must be nursed for up to 2.5 months of dormancy without intake of food or water. Dry and well insulated tree cavities allow the female to expend less energy (15.05%) for body maintenance and more for parturition and lactation (Johnson and Johnson 1978). Seclusion above ground level lessens the chance of arousal and subsequent increases in energy consumption and possible cub abandonment.

Areas of abundant tree dens may serve as important maternity denning areas and centers of dispersal. Population data from the area with the majority of the active tree dens (WPLR) suggest a higher concentration ($P < .0102$) of adult females than for the study area wide population of wild bears. Also the population density of this area is much higher than the overall population (Eagar 1977). The same remoteness that protected tree dens from logging undoubtedly protects bears from people-related mortality.

Preservation of tree dens and denning habitat should be implemented in forest management practices outside the confines of the National Park. Indications are that black bears also utilize tree

dens in the national forest of the Southern Appalachians (Ernst 1972, Conley 1976). Identification and classification through discriminant function analysis of the site and vegetation characteristics of tree dens provide the means for such preservation (p. 78). Tree dens may afford the extra protection necessary to maintain viable black bear populations in islands of dwindling and often marginal habitat.

IV. DEN SITE AVAILABILITY

Availability of Dens

Thirty random transects (60 ha) were searched to determine the availability of dens, denning habitat, and large trees to bears (Figure 7). Sixty-one percent (36.6 ha) fell in uncut or light cut areas and 39% (23.4 ha) fell in heavy cut areas. Seventeen potential dens were located: five were in the base of large, hollow trees; four were root dens; three were stump dens; three were tree cavities above ground; and two were rock dens (Table 14). Four were dens that had been used by bears, as evidenced by bedding material, claw marks inside the cavity, and bear hair in the bedding material. One additional den was located in a plot but this tree did not meet the pre-established minimum size (dbh > 84 cm) for "large" trees. Potential dens in the logged plots consisted of three stump, two root and two rock dens whereas the potential dens in the unlogged plots consisted of five dens in the base of large, hollow trees, three in tree cavities above ground and two root dens. Ground dens proved to be 4.7 times more abundant than tree cavities above ground.

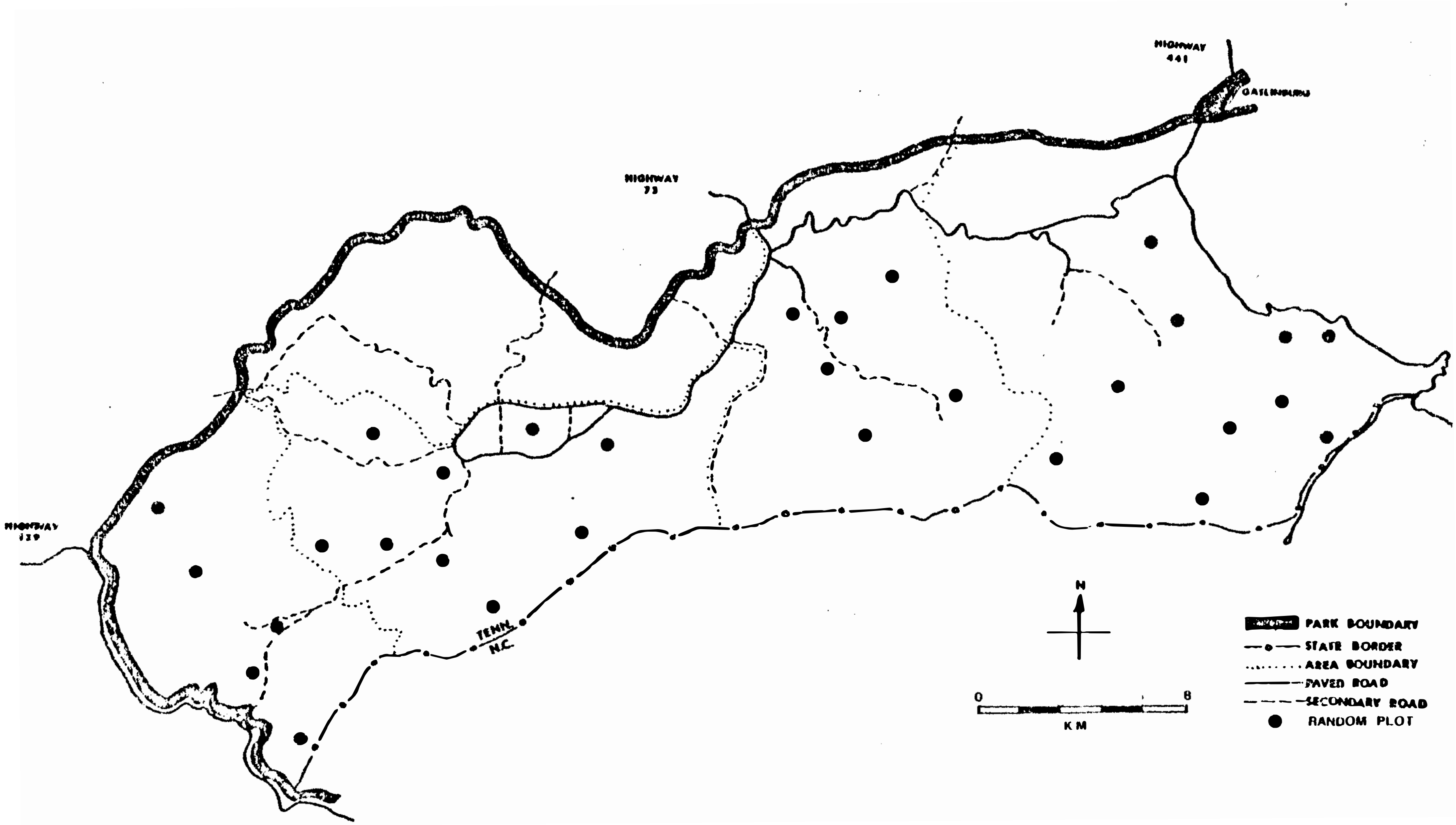

Figure 7. Distribution of random vegetation plots in the study area.

Table 14. Potential dens located on random transects in the Great Smoky Mountains National Park, 1976-78.

Den Type		Tree Species	Dbh (cm)	Cause of Damage	Signs of Use	Watershed
Base of a hollow tree	1.	Yellow poplar	91.99	Basal fire	Claw marks, bedding and bear hair	Abrams Creek
	2.	Eastern hemlock	126.69	Basal fire	None	Abrams Creek
	3.	Northern red oak	116.82	Basal fire	Claw marks, bedding and bear hair	Abrams Creek
	4.	Yellow birch	106.63	"Stilt growth"	None	EPLR
	5.	Northern red oak	109.18	Basal fire	Claw marks, bedding and bear hair	Abrams Creek
	*	Chestnut snag	74.17	Chestnut blight and basal fire	Claw marks, bedding and bear hair	Abrams Creek
Root dens	6.	Fire cherry	41.33	Wind tilt	None	EPLR
	7.	Sweet birch	45.61	Wind tilt	None	EPLR
	8.	Eastern hemlock	72.26	Natural cavity	None	EPLR
	9.	Eastern hemlock	153.43	Natural cavity	None	EPLR
Stump dens	10.	-	111.41	Logging	None	MPLR
	11.	-	87.54	Logging	None	MPLR
	12.	-	92.63	Basal fire and logging	Claw marks, bedding and bear hair	MPLR

Table 14 (Continued)

Den Type		Tree Species	Dbh (cm)	Cause of Damage	Signs of Use	Watershed
Rock dens	13.	-	-	-	None	MPLR
	14.	-	-	-	None	EPLR
Tree cavities above ground	15.	Yellow birch	120.96	Wind	Climb marks	EPLR
	16.	Yellow birch	90.08	Wind	None	EPLR
	17.	Sugar maple	91.67	Wind	None	EPLR

*Not tallied as a potential den since the tree did not meet the pre-established minimum size requirement (dbh > 84 cm) for dens in tree cavities or the base of trees.

The extensive utilization and survival implications of tree dens warranted further investigation into their availability to bears. Expansion of the random transect data with the aid of the Poisson distribution yielded an estimate of 2140 $\pm$ 92 (two standard deviations) tree dens in the study area which has an estimated population of 129 bears (Eagar 1977). Due to the relatively small sample size, two alternative methods were used to evaluate the accuracy of the estimate. Intensive investigation in WPLR yielded a direct count of 29 active and potential den trees available to bears. Expansion of this minimum number of tree dens in an area of known size and land use history (virgin) to the virgin proportion of the study area (39%) produced an estimate of 30,046 available tree dens. A minimum of 29 known tree dens indicated an abundant supply available to bears in this watershed at present population levels (Eagar 1977) and sex and age ratios (Beeman 1975). Since the population density is high (one bear/.8 km^2 or 50 bears in the watershed) in this area (Eagar 1977), no possible shortage of tree dens is apparent.

Information from other virgin and heavy cut areas which were mapped and potential dens counted translates to an estimate of 7587 available tree dens in the study area. The density of tree dens in these five areas ranged from one tree den/2.2 ha to 0; the extremes being represented by a virgin and heavily logged stand. Again an abundance of tree dens is apparent.

A few scattered den trees do occur in heavy cut areas either because they were "culls" at the time of logging or were simply too large to be harvested with the technology of the day. Eleven percent

(11) of the large trees in random plots and 17% (3) of active den trees occurred in heavy cut areas. Low den tree densities precluded an absolute estimate of their availability in heavy cut stands due to the necessary sampling intensity which was beyond the scope of the present study. Low densities of den trees were further evidenced by the more frequent selection of ground dens in heavy cut areas ($P < .005$).

In conjunction with food availability and mark tree studies, 103 plots totaling 28 ha along index routes were searched. One chestnut oak (75.8 cm dbh) was located which had been used as a den. The cavity was above ground level but could easily be climbed and inspected. Transects run through the fall home ranges of radio-collared bears resulted in searching 18.4 ha and producing a potential stump and rock den.

A total of 101 trees > 84 cm dbh were located in the 30 random samples (Table 15). Eastern hemlock, yellow birch, chestnut oak and yellow poplar were the most numerous large trees. Eleven trees (11%) occurred in logged plots and 90 trees (89%) occurred in unlogged plots. This, plus the disproportionate availability of den types in logged and unlogged plots (p. 71) and the more frequent selection of ground dens in heavy cut areas reveals the clustered and uneven distribution of tree dens across the study area.

A large carnivore as sparse in numbers as black bears would not likely experience a shortage of den cavities above ground level in a climax ecosystem consisting of a large proportion (39%) of virgin forest. In absolute numbers there appears to be a sufficient supply

Table 15. Large trees (dbh > 84 cm) located on random transects in the Great Smoky Mountains National Park, 1976-78.

Species	Percent of Sample (No.)	Avg. dbh (cm)	Percent Damaged (No.)	Percent Potential Tree Dens	Percent Potential Ground Dens	Percent with Climb Marks
Eastern hemlock	35 (35)	114	20 (7)	0	3 (1)	3 (1)
Yellow birch	14 (14)	99	50 (7)	14 (2)	7 (1)	7 (1)
Chestnut oak	11 (11)	92	64 (7)	0	0	36 (4)
Yellow poplar	10 (10)	100	40 (4)	0	10 (1)	70 (7)
Yellow buckeye	6 (6)	97	17 (1)	0	0	0
Spruce	6 (6)	96	0	0	0	0
Northern red oak	5 (5)	104	40 (2)	0	40 (2)	40 (2)
White pine	4 (4)	88	0	0	0	0
Red maple	4 (4)	116	50 (2)	0	0	25 (1)
Sugar maple	3 (3)	89	67 (2)	33 (1)	0	0
Chestnut snag	1 (1)	89	100 (1)	0	0	0
Black cherry	1 (1)	99	100 (1)	0	0	100 (1)
Silverbell	1 (1)	96	100 (1)	0	0	0
Totals	101 (101)	103	35 (35)	3 (3)	5 (5)	17 (17)

of tree dens available to bears. However, the clumped distribution of available tree dens resulting from the pre-Park logging history results in tree cavities being less available to bears in certain watersheds (e.g., MPLR) and especially at low elevations. Other den types are consequently utilized (bears 89, F5, B18, B10, A45, A42, E7) and indications are that black bear densities are generally lower in these areas (Eagar 1977). Social pressures (Rogers 1977) may prevent female black bears from migrating to prime maternity denning areas as polar bears (*Ursus maritimus*) do (Jonkel et al. 1972).

Availability of Den Habitat

The discrete differences of site and vegetation parameters at tree and ground dens can be identified and described in quantitative terms and used to classify areas with the highest den potential. One hundred and fifteen random plots with identical parameter measurements to those taken at den sites were accumulated for classification. Discriminant function analysis placed 7.8% (9) of the random sites in a tree den habitat category (Table 16). Twenty-one (18.3%) of the random sites were classified as potential ground den habitat (Table 16).

This analysis confirms the disproportionate availability of ground dens over tree dens (p. 71) and the clumped distribution of tree dens in the virgin areas (p. 76). Only one plot overlapped both categories. Re-examination of the vicinity of plots classified as tree or ground den habitats often showed the actual location of a potential or active den or abundance of large trees in the area along the transect.

Table 16. Number of random vegetation plots classified as denning habitat or non-denning habitat by the discriminant function analysis.

	Den Type	Predicted Group Denning Habitat	 Non-Denning Habitat	Total
		Tree Dens		
Actual group	Denning habitat (Actual den sites)	13	2	15
	Non-denning habitat (Random plots)	9	106	115
		Ground Dens		
Actual group	Denning habitat (Actual den sites)	11	4	15
	Non-denning habitat (Random plots)	21	94	115

Results from the GSMNP provide the methodology and indicate the feasibility of identification and classification of areas with the highest tree den potential. The habitat itself could then be preserved, as well as the specific den sites. Preservation of denning habitat could then be incorporated into forest management practices outside the confines of the Park. However, the diverse and often unique ecological conditions of the GSMNP limit direct application of data from this study to the surrounding national forest of the Southern Appalachians. Extrapolations should be made with caution. But if a population of known tree dens is located and a vegetation survey possible, the process could be duplicated. A productive approach for the future would be to coordinate black bear sanctuary and wilderness establishment with areas identified as having high tree den potential.

Dynamics of Tree Den Formation and Destruction

To aid in delineation of den dynamics, 92 damaged trees were catalogued using a standard data form (Appendix B). Fifty-one percent (47) were tree cavities, 32% (29) were cavities at the base of trees, 5% (5) were stump and root dens, 3% (3) were cavities in dead snags, 2% (2) were at the base of dead snags and 1% (1) was a cavity at the base of a tree with the entrance above ground level. Thirty-six (39%) of the catalogued trees occurred on random transects.

Table 17 summarizes the information recorded by species. Chestnut oak (19), yellow birch (16), yellow poplar (13) and eastern hemlock (11) were the most numerous tree species with the average dbh

Table 17. Summary of damaged trees catalogued to delineate dynamics of den formation and destruction.

Species (No.)	Avg. dbh	Den Types (%)	Signs of Use (%)	Type Damage (%)	Age of Damage (%)	Degree of Damage (%)
Chestnut oak (19)	88	Tree cavities (84) Base of tree (16)	Climb marks (55) Bear hair (5) None (40)	Wind (58) Lightning (32) Basal fire (5) Other (5)	Developing (26) Developed (58) "Overdeveloped (16)	Entire top broken (58) Localized to entrance (16) Damaged trunk (11) Other (11)
Yellow birch (16)	100	Tree cavities (63) Base of tree (37)	Climb marks (31) Bear hair (8) None (61)	Wind (56) Basal fire (6) Natural deformities (32) Other (6)	Developing (12) Developed (88)	Entire top broken (6) Localized to entrance (56) Damaged trunk (38)
Yellow poplar (13)	118	Tree cavities (38) Base of tree (62)	Climb marks (46) Bear hair (8) None (46)	Wind (23) Basal fire (54) Other (23)	Developing (46) Developed (54)	Entire top broken (15) Localized to entrance (54) Damaged trunk (23) Other (8)
Eastern hemlock (11)	110	Tree cavities (64) Base of tree (18) Root dens (18)	Climb marks (27) Bear hair (9) None (64)	Wind (55) Basal fire (18) Natural cavity (18) Lightning (9)	Developing (36) Developed (27) "Overdeveloped (36)	Entire top broken (36) Localized to entrance (55) Other (9)
Yellow buckeye (7)	99	Tree cavities (71) Base of tree (29)	Climb marks (29) None (71)	Wind (71) Basal fire (14) Other (14)	Developing (43) Developed (57)	Localized to entrance (86) Damaged trunk (14)

Table 17 (Continued)

Species (No.)	Avg. dbh	Den Types (%)	Signs of Use (%)	Type Damage (%)	Age of Damage (%)	Degree of Damage (%)
Northern (6) red oak	112	Tree cavities (33) Base of tree (67)	Climb marks (17) Bear hair (33) None (50)	Wind (33) Basal fire (67)	Developing (17) Developed (83)	Entire top broken (17) Localized to entrance (67) Damaged trunk (17)
Stumps (5)	106	Base of stump (100)	Bear hair (20) None (80)	Man-made (100)	Developed (100)	Hollow from top (80) Stump solid, entrance at base (20)
Red (4) maple	103	Tree cavities (25) Base of tree (75)	Climb marks (25) None (75)	Basal fire (75) Lightning (25)	Developing (50) Developed (50)	Localized to entrance (75) Damaged trunk (25)
Others (11)	76	Tree cavities (18) Base of tree (55) Root dens (27)	Bear hair (9) None (91)	Wind (46) Basal fire (27) Lightning (9) Natural deformity (18)	Developing (9) Developed (73) "Overdeveloped (18)	Localized to entrance (36) Entire top broken (18) Damaged trunk (9) Other (36)

being 88, 100, 118 and 110 cm, respectively. Eight potential dens had been used by bears. Seventeen developed tree cavities had bear climb marks on the trunk but these trees were not climbed and inspected for bear hair and bedding material.

Wind damaged 48% of the catalogued trees, basal fire 27%, lightning 12%, natural limb rot 2%, natural deformity 15%, and man-induced damage occurred on 5% of the catalogued trees. Ten trees incurred two types of damage with wind and basal fire being the most frequent combination. The frequency of wind and lightning damage in random samples was 57 of 294 sites (19%) and seven of 294 sites (2%), respectively. Wind appeared to be the most important force in den formation as well as destruction. Four of the five active tree dens no longer available to bears succumbed to high winds. Lightning damage was generally more severe resulting in a decrease in den potential and longevity. Lightning damage also occurred more often on dry exposed sites which do not support suitable tree dens, thus further diminishing the importance of lightning in tree den dynamics. Wind damage was well dispersed over all vegetation types. As trees reach a large size, the frequency of damage and natural decay leading to cavity formation increases significantly ($P < .005$). Thirty-five percent of the large trees in random plots, 28% of the large hemlocks investigated in the WPLR and 34% of the large trees found in mapped areas incurred damage. Only 5% of trees < 84 cm dbh measured and inspected in application of the quarter method incurred damage.

With the exception of the chestnut oak, site data analysis of catalogued trees and various den types yield a consistent pattern

with active dens and random transect data. Catalogued chestnut oaks generally occurred at lower elevations, higher on slopes and exhibited a more xeric tendency with southerly slope aspects than other species of den trees. This pattern is particularly pronounced in the Abrams Creek watershed. These site factors also facilitate the increasing importance of basal fire damage and den formation at the base of large trees (p. 17). Indications are that chestnut oaks play an increasingly important role in den selection of bears outside the Park (Ernst 1972, Conley 1976).

Early observations of the high attrition rate of den trees (Pelton et al. 1977) were likely the result of a small sample size (n = 7). Of the 18 active tree dens now located in the Park, five (28%) are no longer available to bears due to falling of the tree (4) or rotting away of the cavity (1). However, 13 (72%) of the den trees are sturdy and can be expected to provide useable cavities in the future. A chestnut snag near the ridge top is the only active den tree with its longevity in immediate doubt. Also, 76% of the catalogued potential den trees are sturdy and appear to have an extended longevity as available cavities.

It appears that more den trees will be developing than will be destroyed as the forest community matures. Thirty-five percent of the catalogued tree dens were developing, 50% were fully developed and 15% were in the dead or fallen category. Data from random transects showed that 50% were developing, 25% developed and 25% dead or fallen. Den dynamics apparently present no problem in availability of tree dens since the absence of logging and timber stand

improvement allows a natural balance to occur between development and destruction of tree dens.

Reuse of Dens

Seventeen active and nine potential dens (13 tree and 13 ground dens) were monitored for use or reuse by bears. Eight dens (four tree and four ground dens) were monitored for two consecutive winters. No ground dens were reused by bears during the study. Eleven (85%) tree dens were not revisited by bears but two (15%) had fresh climb marks. Due to the seclusion of cavities above ground and to avoid possible disturbances, the presence of a bear was undetermined. Multiple climb marks on the trees indicated a bear may not have been present. One of the potential den trees was a large chestnut oak which may have been climbed while foraging for acorns.

Monitoring of five radio-instrumented bears (all females) with previous den locations revealed no reuse of dens (four tree and one ground den). Three bears were monitored for two consecutive winters. New dens were usually within one km of the previous den.

Bromlei (1973) reported a high incidence of reuse of hollow tree dens by the Asiatic black bear. Some dens were occupied every winter but always by different bears. He further observed the number of hollow trees suitable for dens was limited. Ernst (1972) also found evidence of reuse of den trees in Georgia where the availability of tree dens is undoubtedly low.

Strong preferences for tree dens were confirmed in the GSMNP since 50% of all radio-instrumented bears utilized tree dens (p. 50)

and ground dens proved to be 4.7 times more abundant than tree dens (p. 71). Low use or reuse of potential and active tree dens further indicate an abundant supply of tree cavities available to bears in the virgin portions of the GSMNP.

CHAPTER V

SUMMARY AND CONCLUSIONS

The denning period averaged 94 days with most bears entering dens between the last week in December and the first week in January and emerging from dens between the last week in March and the first week in April. Bears exhibited a strong fidelity to dens after entrance and did not intermittently leave and return to dens. The denning period in the GSMNP was shorter than reported in other studies with the difference being in the late dates of den entrance. This is probably related to a milder climate which allows the food supply to influence the denning period.

Adult females entered dens first, adult males next and subadults of both sexes denned last. Emergence was in the reverse sequence. Females with newborn cubs exited dens significantly later and denned significantly longer than other females. Sex and age data in relation to the denning period from the GSMNP are in general agreement with other studies. Reproductive condition of females, variations in fat deposition, and different tolerances of weather factors are believed to account for these sex and age differences in the denning period.

Weather, principally increased precipitation, lower maximum, and higher minimum daily temperatures associated with a low pressure front, provided the proximate stimulus to den. Food availability also apparently influences entrance of bears into dens since bears denned significantly earlier in years (1972-74) with a fair to poor

mast yield than in years (1976-78) with excellent mast yields. Weather factors exhibited a much weaker relationship to den emergence. A circannual (endogenous) rhythm as the ultimate mechanism encompasses the observed variations in environmental factors affecting the denning period of bears over their broad geographic range and diverse ecological conditions.

Denning behavior was characterized by a reduction in sensitivity with females being much more lethargic than males. Arousal was accompanied by shivering, slow movement of the head from side to side and extremely slow body movements. Bears did not appear to focus their eyes very effectively. Bears apparently sleep in a curled position with the forehead pressed to the floor of the den and the extremities underneath the body. All dens contained bedding material, but only one bear carried bedding material from the ground into a tree den.

Significant increases in inactivity occurred in the pre- and postdenning periods with the transition into and out of dormancy occurring gradually over a period of about one month. This pre- and postdenning behavior may be a physiological transition period. The frequency of head movements increased significantly prior to den emergence indicating movements within dens and readjustment to normal behavior. Four fecal plugs were described, but most bears retain the plug and may not feed for some time after emergence.

Preferred den sites were cavities high above ground ($\bar{x}$ = 11.15 m) in large ($\bar{x}$ dbh = 94.8 cm) trees. Yellow birch, eastern hemlock, red maple and northern red oak were the most common tree dens. Den

cavities were formed by wind (82%) or lightning (18%) damage and natural decay. The majority of ground dens (78%) were cavities under root systems of wind-tilted trees or in association with stumps.

Dens generally occurred on steep slopes ($\overline{z}$ = 33°) at high elevations ($\overline{z}$ = 1104 m). This is probably related to the inaccessibility of these areas to pre-Park logging activities and the importance of wind damage to den formation. Lower macro-topographic position of dens on slopes ($\overline{z}$ = 44%) insured sufficient soil depth, moisture and protection for growth of large trees while the higher micro-topographic position of dens on slopes ($\overline{z}$ = 31%) resulted in greater susceptibility of these areas to wind damage leading to den formation.

Forest types of tree dens included northern hardwoods (39%), cove hardwood-hemlock associations (44%) and red maple associations (17%). Forest types of ground dens included wild grape and greenbrier thickets (33%), red maple associations (28%), closed oak (17%), cove hardwood-hemlock associations (11%), table mountain pine (6%) and northern hardwoods (6%). The understory vegetation was significantly more dense around ground dens than around tree dens.

Phytosociological data reveal that tree dens most commonly occurred (83%) in climax communities dominated by a small number of widely spaced individuals of a very large size. The majority of ground dens (72%) occurred in disturbance communities characterized by stumps and treeless thickets or earlier successional stages characterized by high densities and low basal areas per tree.

Adult females and sub-adults of both sexes more often selected tree cavities above ground than adult males. Tree dens offered

seclusion from ground disturbances and superior energy conservation over ground dens. Protected dens are particularly important to adult females since parturition and maternal care occur in winter dens. Areas of abundant tree dens may serve as important maternity denning areas and centers of dispersal. Population data from the watershed with the majority of active tree dens showed a significantly higher concentration of adult females and higher population density than the study area wide population of wild bears. Tree dens may afford the extra protection necessary to maintain viable black bear populations in islands of dwindling and often marginal habitat.

Seventeen potential dens, four of which had been used by bears, were located on 30 random transects (60 ha). Ground dens proved to be 4.7 times more abundant than tree cavities above ground. The Poisson frequency distribution yielded an estimate of 2140 $\pm$ 92 (two standard deviations) tree dens in the study area which has an estimated population of 129 bears. Direct counts of potential tree dens in virgin areas of known size further indicated no absolute shortages of tree dens. However, the clumped distribution of available tree dens resulting from the pre-Park logging history results in tree cavities being less available to bears in certain watersheds and especially at low elevations. Consequently ground dens are more frequently selected and indications are that bear densities are generally lower in these areas.

Ninety-two damaged trees were catalogued and the longevity of all active tree dens monitored to delineate the dynamics of tree den formation and destruction. Seventy-two percent of the active den

trees are sturdy and can be expected to provide usable cavities in the future. Thirty-five percent of the catalogued tree dens were developing, 50% were developed and 15% were in the dead or fallen category. Data from random transects showed that 50% were developing, 25% developed and 25% dead or fallen. Den dynamics apparently presents no problem in availability of tree dens since the absence of logging and timber stand improvement allows a natural balance to occur between development and destruction of dens.

Seventeen active and nine potential dens were monitored for use or reuse. Strong preferences for tree dens were confirmed since 50% of all radio-instrumented bears utilized tree dens and ground dens proved to be 4.7 times more abundant than tree dens. Low use or reuse of potential and active tree dens further indicated an abundant supply of tree cavities available to bears in the virgin portions of the GSMNP.

Factor analysis showed discrete differences of site and vegetation parameters at tree and ground dens and extracted six variables for classification of areas with the highest den potential by discriminant function analysis. Eight and 18% of 115 random vegetation plots with identical parameter measurements to those taken at den sites were classified as potential tree and ground den habitat, respectively. Results from the GSMNP provide the methodology and indicate the feasibility of identification of areas with the highest tree den potential. Preservation of tree den habitat, as well as the specific den sites, could then be incorporated into forest management practices outside the confines of the Park. A productive approach for the

future would be to coordinate black bear sanctuary and wilderness establishment with areas identified as having high tree den potential.

LITERATURE CITED

LITERATURE CITED

Aldous, S. E. 1937. A hibernating black bear with cubs. J. Mammal. 18:466-468.

Alt, G. L. 1977. Dynamics of home range and movements of black bears in northeastern Pennsylvania. Proc. 4th Int'l. Conf. on Bear Manage. and Res. Kalispell, Montana. (In press.)

Bacon, E. S. 1973. Investigation on perception and behavior of the American black bear (*Ursus americanus*). Unpublished Ph.D. Dissertation, The University of Tennessee, Knoxville. 161 pp.

Barnes, V. G., Jr., and O. E. Bray. 1966. Black bears use drainage culverts for winter dens. J. Mammal. 47:712-713.

Barr, A. J., J. H. Goodnight, J. P. Sall, J. T. Helwig. 1976. A user's guide to SAS-76. SAS Institute Inc., Raleigh, North Carolina. 329 pp.

Beeman, L. E. 1971. Seasonal food habits of the black bear (*Ursus americanus*) in the Smoky Mountains of Tennessee and North Carolina. Unpublished M.S. Thesis, The University of Tennessee, Knoxville. 62 pp.

__________. 1975. Population characteristics, movements and activities of the black bear (*Ursus americanus*) in the Great Smoky Mountains National Park. Unpublished Ph.D. Dissertation, The University of Tennessee, Knoxville. 218 pp.

Bromlei, F. G. 1973. Bears of the south far-east USSR. Publ. for U.S. Dept. of Int., Washington, D. C., by Indian National Scientific Documentation Centre, New Delhi. 138 pp.

Cahalane, V. H. 1947. Mammals of North America. Macmillan Co., New York. 682 pp.

Cain, S. A. 1930a. Certain floristic affinities of the trees and shrubs of the Great Smoky Mountains and vicinity. Butler Univ. Bot. Studies 1:129-150.

__________. 1930b. An ecological study of the heath balds of the Great Smoky Mountains. Butler Univ. Bot. Studies 1:177-208.

__________. 1935. Ecological studies of the vegetation of the Great Smoky Mountains. II. The quadrat method applied to sampling spruce and fir forest types. Amer. Midland Nat. 16:566-584.

Clodfelter, F. 1943. Shot of a lifetime; in front of a hibernating black bear. Nature 36:43.

Conley, R. H. 1976. Tennessee state report on black bear management and research. In J. Rieffenberger, ed., pp. 78-80. Third Eastern Workshop on Black Bear Manage. and Res. 82 pp.

Cottam, G. and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Craighead, F. C., Jr. 1972. Discussion, p. 136. In S. Herrero, ed., Bears--their biology and management. IUCN New Ser. Publ. 23. Int'l. Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 371 pp.

__________ and J. J. Craighead. 1972a. Grizzly bear prehibernation and denning activities as determined by radiotracking. Wildl. Monogr. 32. 35 pp.

__________ and __________. 1972b. Data on grizzly bear denning activities and behavior obtained by using wildlife telemetry, pp. 84-106. In S. Herrero, ed., Bears--their biology and management. IUCN New Ser. Publ. 23. Int'l. Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 371 pp.

Craighead, J. J., F. C. Craighead, Jr., J. R. Varney and C. E. Cote. 1971. Satellite monitoring of black bear. Bioscience 21: 1206-1211.

Dickson, R. R. 1960. Climates of the states: Tennessee. U.S. Dept. Commerce, Weather Bureau, Climatology of the U.S., No. 60-40. 16 pp.

Eagar, D. C. 1977. Radioisotope feces tagging as a population estimator of black bear (Ursus americanus) density in the Great Smoky Mountains National Park. Unpublished M.S. Thesis, The University of Tennessee, Knoxville. 89 pp.

Eagle, T. C. 1978. A simplified tooth sectioning and staining technique for aging black bears. Proc. 4th Eastern Workshop on Black Bear Manage. and Res. Greenville, Maine. (In press.)

Erickson, A. W. 1964. An analysis of black bear kill statistics for Michigan, pp. 68-102. In The black bear in Michigan. Michigan State Univ. Agric. Exp. Sta. Res. Bull. 4. 102 pp.

__________. 1965. The black bear in Alaska. P-R Job Proj. Rep., Proj. W-6-R-5, Alaska Dept. Fish and Game, Juneau.

Ernst, R. 1972. A pilot study of the black bear (Ursus americanus). Georgia Job Completion Rept. W-37-R. 22 pp.

Ewer, R. F. 1973. The carnivores. Cornell Univ. Press, New York. 494 pp.

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

Floody, O. R. 1974. Ultrasonic communications and the hormonal modulation of aggressive behavior in the female hamster. Unpublished Ph.D. Dissertation, Rockefeller University, New York. 158 pp.

Folk, G. E., Jr., M. A. Folk and J. J. Minor. 1972. Physiological condition of three species of bears in winter dens, pp. 107-124. In S. Herrero, ed., Bears--their biology and management. IUCN New Ser. Publ. 23. Int'l. Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 371 pp.

__________, A. Larson and M. A. Folk. 1976. Physiology of hibernating bears, pp. 373-380. In M. R. Pelton, J. W. Lentfer and G. E. Folk, eds., Bears--their biology and management. IUCN New Ser. Publ. 40. Int'l. Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 467 pp.

__________, J. M. Hunt and M. A. Folk. 1977. Hibernating bears: further evidence and bioenergetics. Proc. 4th Int'l. Conf. on Bear Res. and Manage. Kalispell, Montana. (In press.)

Garshelis, D. L. 1978. Movement ecology and activity patterns of the black bear in the Great Smoky Mountains National Park. Unpublished M.S. Thesis, The University of Tennessee, Knoxville. 117 pp.

Golden, M. S. 1974. Forest vegetation and site relationships in the central portion of the Great Smoky Mountains National Park. Unpublished Ph.D. Dissertation, The University of Tennessee, Knoxville. 275 pp.

Grosenbaugh, L. R. 1952. Plotless timber estimates--new, fast, easy. J. Forestry 50:32-37.

Hamilton, R. J. and R. L. Marchinton. 1977. Denning activity of black bears in the coastal plain of North Carolina. Proc. 4th Int'l. Conf. on Bear Res. and Manage. Kalispell, Montana. (In press.)

Harmon, H. H. 1960. Modern factor analysis. Univ. of Chicago Press, Chicago. 469 pp.

Heller, H. C. and T. L. Paulson. 1970. Circannian rhythms II. Endogenous and exogenous factors controlling reproduction and hibernation in chipmunks (Eutamias) and ground squirrels (Spermophilus). Comp. Biochem. Physiol. 33:357-383.

Herrero, S. 1972. Aspects of evolution and adaptation in American black bears (Ursus americanus Pallas) and brown and grizzly bears (Ursus arctos Lenne') of North America, pp. 221-231. In S. Herrero, ed., Bears--their biology and management. IUCN New Ser. Publ. 23. Int'l. Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 371 pp.

Hock, R. J. 1951. Rectal temperatures of the black bear during its hibernation. Proc. Alaska Sci. Conf. 2:310-312.

__________. 1957. The metabolic rates and rectal temperatures of active and hibernating black bears. Fed. Proc. 16:440.

__________. 1960. Seasonal variations in physiologic functions of arctic ground squirrels and black bears. Harvard Univ. Museum of Comp. Zoo. Bull. 124:155-173.

Johnson, K. G. and D. O. Johnson. 1978. A simulation model of winter heat loss for a black bear in a closed tree den. Proc. 4th Eastern Workshop on Black Bear Manage. and Res. Greenville, Maine. (In press.)

Jonkel, C. J. and I. McT. Cowan. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27. 57 pp.

__________, G. B. Kolenosky, R. J. Robertson and R. H. Russell. 1972. Further notes on polar bear denning habits, pp. 142-149. In S. Herrero, ed., Bears--their biology and management. IUCN New Ser. Publ. 23. Int'l. Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 371 pp.

Kayser, C. 1961. The physiology of natural hibernation. Pergammon Press, New York. 325 pp.

King, P. B. and A. Stupka. 1950. The Great Smoky Mountains--their geology and natural history. Sci. Month. 61:31-43.

__________. 1964. Geology of the central Great Smoky Mountains, Tennessee. U.S. Geol. Surv. Prof. Pap. 349-C. 148 pp.

__________, R. B. Neuman and J. B. Hadley. 1968. Geology of the Great Smoky Mountains National Park, Tennessee and North Carolina. Geol. Sur. Prof. Pap. 587. 23 pp.

Kolb, V. A. 1977. Wie erkennen shich Motter und Junges des Mausohrs, Myotis myotis, bei der Rückkehr von Jagdflug? Z. Tier Psychol. 44:423-431.

Lambert, R. S. 1958. Logging in the Great Smoky Mountains. Report to the Park Superintendent. Typewritten manuscript. 12 pp.

Le Count, A. L. 1977. Some aspects of black bear ecology in the Arizona chaparral. Proc. 4th Int'l. Conf. on Bear Res. and Manage. Kalispell, Montana. (In press.)

Leopold, A. S. 1959. Wildlife in Mexico. Univ. of Calif. Press, Berkeley and Los Angeles. 545 pp.

Lindzey, F. G. and E. C. Meslow. 1976a. Winter dormancy in black bears in southwestern Washington. J. Wildl. Manage. 40:408-415.

__________ and __________. 1976b. Characteristics of black bear dens on Long Island, Washington. Northwest Science 50:236-242.

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

Lundberg, D. A., R. A. Nelson, H. W. Wahner and J. D. Jones. 1976. Protein metabolism in the black bear before and during hibernation. Mayo Clinic Proc. 51:716-722.

Marcum, L. C. 1974. An evaluation of radioactive feces tagging as a technique for determining population densities of black bear (Ursus americanus) in the Great Smoky Mountains National Park. Unpublished M.S. Thesis, The University of Tennessee, Knoxville. 95 pp.

Mark, A. F. 1958. The ecology of the southern Appalachian grass balds. Ecol. Monogr. 28:293-336.

Matson, J. R. 1946. Notes on the dormancy in the black bear. J. Mammal. 27:203-212.

__________. 1954. Observations on the dormant phase of a female black bear. J. Mammal. 35:28-35.

Message from the President. 1902. A report to the Secretary of Agriculture in relation to the forests, rivers, and mountains of the southern Appalachian Region. U.S. Government Printing Office, Washington, D. C. 201 pp.

Morrison, D. F. 1967. Multivariate statistical methods. McGraw-Hill, New York. 338 pp.

Morrison, P. 1960. Some interrelations between weight and hibernation function. Harvard Univ. Museum of Comp. Zoo. Bull. 124: 75-91.

Morse, M. A. 1937. Hibernation and breeding of the black bear. J. Mammal. 18:460-465.

National Park Service. 1969. Resource management plan for the Great Smoky Mountains National Park. Gatlinburg, Tennessee. Sect. III. 21 pp.

Nelson, R. A., H. W. Wahner, J. D. Jones, R. D. Ellefson and P. E. Zollman. 1973. Metabolism of bears before, during and after winter sleep. Amer. J. of Physiol. 224:491-496.

Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner and D. H. Bent. 1975. Statistical package for the social sciences. McGraw-Hill, New York. 675 pp.

Northcott, T. H. and F. E. Elsey. 1971. Fluctuations in black bear populations and their relationship to climate. Can. Field Nat. 85:123-128.

Pelton, M. R., L. E. Beeman and D. C. Eagar. 1977. Den selection by black bears in the Great Smoky Mountains National Park. Proc. 4th Int'l. Conf. on Bear Res. and Manage. Kalispell, Montana. (In press.)

Pengelley, E. L. and S. J. Asmundson. 1972. An analysis of the mechanisms by which mammalian hibernators synchronize their behavioral physiology with the environment, pp. 637-655. In F. C. South, et al., eds., Hibernation and hypothermia perspectives and challenges. Elsevier Publishing Co., New York.

Rogers, L. L. 1974. Shedding of foot pads by black bears during denning. J. Mammal. 55:672-674.

__________. 1977. Social relationships, movements, and population dynamics of black bears in northeastern Minnesota. Unpublished Ph.D. Thesis, University of Minnesota, Duluth. 194 pp.

Sales, G. D. 1972. Ultrasound and mating behavior in rodents with some observations on other behavioral situations. J. of Zoological Society, London 168:149-164.

__________ and D. Pye. 1974. Ultrasonics in communications by animals. J. Wiley and Sons, New York. 281 pp.

Schoonmaker, W. J. 1938. Notes on the black bear in New York State. J. Mammal. 19:501-502.

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

_________. 1954b. Reference list of native plants of the Great Smoky Mountains. Botany Dept., The University of Tennessee, Knoxville. 14 pp. mimeo.

Smith, B. E. 1946. Bear facts. J. Mammal. 27:31-37.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco. 776 pp.

Spencer, H. E., Jr. 1955. The black bear and its status in Maine. Maine Dept. Inland Fish and Game Bull. 4. 55 pp.

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

Stupka, A. 1960. Great Smoky Mountains National Park, natural history handbook number 5. U.S. Government Printing Office, Washington, D. C. 75 pp.

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

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

Thorkelson, J. and R. K. Maxwell. 1974. Design and testing of a heat transfer model of a raccoon (Procyon lotor) in a closed tree den. Ecology 55:29-39.

Trewartha, G. T. 1966. The earth's problem climates. Univ. of Wisconsin Press, Madison. 334 pp.

Troyer, W. A. and R. J. Hensel. 1962. Cannibalism in brown bear. Animal Behavior 13:231.

United States Forest Service. 1970. Tellico district multiple use plan. Chap. 100:150-151.

Whitney, G., M. Alpern, G. Dizzino and G. Horowitz. 1974. Female odors evoke ultrasounds from male mice. Animal Learning and Behavior 2:13-18.

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

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

APPENDIXES

APPENDIX A

DEN SITE AVAILABILITY DATA

Transect #______; Location:____

Observer: _______________; Date:__________________________________

I. Large trees located > 264 cm cir. (if tree has damage, cavity or is hollow, fill in Developmental Den Data sheet).

Species	Cir. bh	Forest Type	Understory	If Area of Many Large Trees--How Many?	Approx. Area	Climb Marks
1.						
2.						
3.						

(Continue on back of page if additional space needed.)

Total large trees (> 264 cm cir.) found:__________
Total large trees found which have damage:________
(wind, lightning, with top broken out, limb missing or ground entrance)
Total large trees found which are hollow:_________
Total potential tree dens with cavity entrances above ground level:_____
Total potential tree dens with entrances at or near ground level:_______

II. Total potential root dens located (Fill in Developmental Den Data sheet).
- A. Cavities under wind tilted tree or stump_____.
- B. Cavities under standing tree or stump where erosion has formed cavity with roots as framework of den_____.
  Above cavities damp or dry:_______

III. Total stump dens (cavity inside hollowed stump) located:______ (Fill in Developmental Den Data sheet).
Top of stump open or closed:____. Cavity damp or dry:____.

IV. Total rock outcrops:_____. Total rock crevices with suitable denning depressions:_____. Distance back to cavity:_______.
Entrance measurements: height_________ width_________
Cavity measurements: length_______ width_______ height_______
Twigs broken off near entrance:_______
Sketch and collect bedding material.

V. Total all other possible denning depressions:_______
Signs of use by bears:_______________________________
Describe, sketch and collect bedding material.

APPENDIX B

DEVELOPMENTAL TREE DEN DATA

Tree #:____; Date:________________; Observer:________________
Location:____________________; If on transect which #:____________

I. Den type: ___Tree cavity, ___Base of tree, ___Stump, ___Base of dead snag, ___Cavity above ground in dead snag, ___Cavity under roots of wind tilted tree, ___Cavity forming in root network, Other (describe):____________________________________
Tree species:____________________; Circumference:____________
Entrance at top of main tree trunk___, or side entrance with limb missing___, or ground entrance___, Other (describe):
____
Distance above ground:____. Entrance dimensions: height_____, width_____. Cavity dimensions: length_____, width_____, height_____.

II. Site data: Forest type:______; Slope:_____; Slope aspect: _____; Den entrance aspect:_____; Micro-position on slope: _____; Elevation:_____. Understory:_____; Macro-position on slope:_____.

III. Signs of use: Climb marks on bole_____; Claw marks present on inside walls of trees_____; Twigs broken off near entrance _____. Collect bedding material.

IV. Type of damage:___wind; ___lightning (charred wood, spiral nature of wound); ___man-made (e.g., logging stump sawed off); ___natural deformity; ___ basal fire; Other (describe):________
____

V. Age of damage (tree dens only):
1. Fresh (no scar tissue, obvious fresh wound)____.
2. Recent (splinters and heartwood easily visible in and around entrance)____.
3. Intermediate (rot well begun but cavity blocked by heartwood, not yet suitable for den)____.
4. Advanced (rot well into tree bole, cavity appears suitable) ____.
5. Dead snag standing: Solid___, Hollow to base___, Only top hollow___.
6. Dead snag on ground: Solid___, Hollow throughout___, Partly hollow___.

VI. Degree of damage (tree dens only):
1. Entire top broken off______.
2. One-half tree trunk split off______.
3. Limb broken clean off______.
4. Limb spiraled off, also damaged bole______.
5. Other (describe):______________________________

VII. Sketch (on back):

APPENDIX C

ULTRASONIC SOUNDS

Recent advances regarding the importance of ultrasonics in communications of mammals (Sales 1972, Sales and Pye 1974) and especially the ultrasonic recognition and location of the young by bats (Kolb 1977) prompted testing of possible emissions from a mother (E7) and three 73-76-day-old cubs in a den on 12 April 1978. Plans were to monitor tree dens for reproductive information, but unfortunately no ultrasonics were detected. Ultrasonics may only be emitted when the mother and cubs are separated. This case along with other possibilities could be easily tested in a control situation such as a zoo. The potential for bears to emit ultrasonics at some time in their development is probably high due to the survival implications for a wide ranging mammal with such a long weaning period (1.5 years). Also, ultrasonics could be beneficial for bringing the normally solitary and aggressive sexes together for breeding. Whitney et al. (1974) and Floody (1974) have shown ultrasonics to play an important role in reproductive and aggressive behavior of the hamster and mouse.

VITA

Kenneth Gregory Johnson was born in Etowah, Tennessee, on February 5, 1952. He attended elementary school in that city and was graduated from Central High School of McMinn County in 1970. In 1970, he entered The University of Tennessee, Knoxville, and in August 1974 received a Bachelor of Science in Business Administration with a minor in the pre-dental sciences. In 1975 he began study at The University of Tennessee, Knoxville, toward a Master of Science degree in Wildlife and Fisheries Science which he received in December 1978.

He is married to the former Debra Joahn Oakley of Gatlinburg, Tennessee. Presently he is employed by The University of Tennessee, Department of Forestry, Wildlife and Fisheries as a research associate.