To the Graduate Council:

I am submitting herewith a thesis written by Charles Rene Villarrubia entitled "Movement Ecology and Habitat Utilization of Black Bears in Cherokee National Forest, Tennessee." I have examined the final 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

Michael R. Pelton, Major Professor

We have read this thesis
and recommend its acceptance:

Boyd L. Dearden

David K. Smith

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

MOVEMENT ECOLOGY AND HABITAT UTILIZATION OF BLACK BEARS IN CHEROKEE NATIONAL FOREST, TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
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Charles Rene Villarrubia

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ABSTRACT

Forty-five captures of 28 black bears (*Ursus americanus*) were made in Cherokee National Forest (CNF), Tennessee between June 1978 and December 1979. Twenty-two bears were fitted with radio-collars.

Bears exhibited a crepuscular activity pattern which was modified seasonally. Higher levels of activity during the day in summer and at night in fall is attributed to bears feeding on available berry and acorn crops. Females with cubs were the most active sex-age group; this is likely related to the high energy demands of raising cubs.

Larger home ranges of males (30.1 km^2) than females (11.6 km^2) reflects the greater mobility and less attachment to specific areas of males; their greater mobility likely enhances their reproductive success with females in the population. Use of larger areas in the fall than in spring/summer reflects the more active feeding by bears prior to winter denning. High home range overlap among bears likely indicates the relatedness of bears in the study area.

Radio-telemetry data indicate that bears were rarely located on private land. The Tellico Bear Sanctuary and the areas immediately adjacent to it accounted for 96% of radio-locations. Short-term movements by subadult males to Nantahala National Forest, North Carolina, likely reflected exploratory movements by these animals. No bears were documented moving to Great Smoky Mountains National Park; however, 3 bears radio-tracked in a concurrent study in the Park moved to CNF for brief periods. Subadult bears were located in hunted areas more

frequently than any other sex-age group. No bears were killed illegally during the study; however, 4 subadult bears were killed within 2 km from the Tellico Bear Sanctuary. Movement and reproductive data collected during this study indicated that the bear sanctuary is providing refuge for a breeding nucleus of females while allowing for dispersal of subadults into surrounding areas.

The IMGRID computer system was used to determine habitat utilization. Pine vegetation types were preferred during all seasons; this is attributed to the abundant berry crops and scattered large oaks in these types. The oak-hickory vegetation type was used more in fall than in any other season due to available mast in this type. Generally, mesic hemlock, cove hardwood, and oak-hickory types were used less than expected. Less food (berries and acorns), greater access, and fewer tree dens are probable reasons the lower elevation hemlock and cove hardwood types were used less.

Telemetry data indicated that bears did not cross the Tellico-Robbinsville highway. An avoidance of roads by female bears and by all bears during fall was determined and reinforces the supposition that bears avoid roads; their avoidance is likely related to the degree of harassment of bears by people.

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CHAPTER I

INTRODUCTION

Black bears in the Cherokee National Forest (CNF) are an important natural resource of the region. Some black bear populations in the East are restricted and threatened by human activities (Pelton and Beeman 1975). Land-use practices such as timber, mining, and commercial development impact black bear habitat and influence management decisions. Information regarding movement and activity patterns of bears as well as site-specific, quantitative data on the components of black bear habitat is needed to coordinate bear management policies with alternative land uses.

Activity and movement patterns of bears reflect their responses to seasonal differences in food supply, intra-specific interactions, environmental influences and disturbances by man. Black bears are classified as mainly diurnal in Washington (Poelker and Hartwell 1973, Lindzey and Meslow 1977) and Idaho (Amstrup and Beecham 1976) and as nocturnal in Minnesota (Rogers 1977) and North Carolina (Hamilton 1978). In East Tennessee, Eubanks (1976) and Garshelis and Pelton (1980) indicated that bears exhibited a crepuscular activity pattern although this pattern was modified seasonally (Garshelis and Pelton 1980). Hamilton (1978) noted that bears were more nocturnal in fall, when human activities were highest, than in other seasons.

Home range and movement patterns of bears have been reported by many authors. Male bears occupied larger areas than females in

Pennsylvania (Alt et al. 1976), Idaho (Amstrup and Beecham 1976), Washington (Lindzey and Meslow 1977) and Tennessee (Garshelis and Pelton 1981). Considerable home range overlap has been reported in several studies (Lindzey and Meslow 1977, Reynolds and Beecham 1980, Garshelis and Pelton 1981) although Rogers (1977) believes that lack of kinship relationships exaggerates overlap. Home range size, overlap, and movement patterns, especially regarding subadults and adult females, are important factors in establishing sanctuaries for bears (Sanders et al. 1978). In addition, accessibility to the area (roads) affects the vulnerability of bears to hunters (McIlroy 1972, Landers et al. 1979) and may restrict movement patterns (Brown 1980).

The fundamental components of wildlife habitat include food, cover, and water. The spatial arrangement and temporal relationships of these components as well as special requirements of the species (i.e., breeding, denning) are important in determining the number of animals an area will support (King 1938, Treadwell 1979). Specific habitat components such as the distribution and abundance of food sources, cover, and den availability affect black bear reproduction, movements, dispersal, and mortality. During periods of food scarcity, fewer offspring are produced, starvation occurs, and the age of first breeding increases (Jonkel and Cowan 1971, Rogers 1976, 1977, Beeman and Pelton 1980, Eiler 1981). Scarcity of food also causes increased movements, dispersal, and bear mortality from increased human-bear interactions (Rogers 1976, 1977, Garshelis 1978, Beeman and Pelton 1980). Increased amounts of refuge cover and remoteness have been documented in decreasing the vulnerability of bears to hunting (McIlroy 1972, Landers et al. 1979) and den sites appear to be important as maternity areas for females and focal points of dispersal (Johnson and Pelton 1979, 1980a, 1981). Decisions regarding black bear management would be enhanced if these components of habitat could be quantitatively identified and coordinated with other land uses.

Traditionally, an animal's utilization of various habitats was compared to the availability of those habitats within the animal's home range. The simplest application of this method involves classifying animal locations into habitat types via a habitat map and comparing the proportion of locations in each type to the availability of the type. Habitat utilization by black bears in Washington (Lindzey and Meslow 1977), California (Kellyhouse 1980, Novick 1979), North Carolina (Hardy 1974, Landers et al. 1979), Montana (Jonkel and Cowan 1971), West Virginia (Miller 1973), East Tennessee (Beeman 1975), and Idaho (Amstrup and Beecham 1976) has been determined by this method. Other methods of obtaining and manipulating habitat information to meet specific objectives have been reported. These include digitized habitat maps (Nichols and Warner 1972, Gilmer et al. 1973), overlay techniques (Crozier et al. 1974, Gysel and Lyon 1980), LANOSAT imagery (Brabander and Barclay 1977), and computer techniques (Wilcott and Gates 1977, Beeman 1977, Davis 1980, Exum 1981). As land uses increase in complexity and size, computer-assisted techniques become more practical. These techniques are used as inventory systems to store and retrieve site-specific quantitative information. Also, delineation of the proximity and coincidence of resources and traditional habitat utilization-availability is also possible (Beeman 1977, Davis 1980, Exum 1981). The ability of these systems to manipulate and graphically display large amounts of geographic data has broad management implications when assessing alternative uses of the natural resources of an area.

Research on various aspects of black bear ecology has been conducted in the Great Smoky Mountains National Park (GSMNP or Park); however, little information on habitat utilization is available for this area. The main objectives of the present study were to determine movement and activity patterns of black bears in Cherokee National Forest and to relate their movements to selected habitat parameters.

CHAPTER II

THE STUDY AREA

Location

The Cherokee National Forest comprises 4,905 km^2 in Carter, Cocke, Greene, Johnson, McMinn, Monroe, Polk, Sullivan, Unicoi, and Washington counties, Tennessee, of which 2,503 km^2 are in public ownership administered by the U.S. Forest Service (USFS). This investigation was conducted on that portion of the Tellico Ranger District (approximately 760 km^2) bordered by the Tellico-Robbinsville Road, the North Carolina-Tennessee state line, the Little Tennessee River, and the Tellico River (Fig. 1). This administrative area, between 35°20' and 35°37' N latitude, 83°55' and 84°20' W longitude, encompasses approximately 500 km^2 in Monroe county and is adjacent to the Great Smoky Mountains National Park (GSMNP or Park) (Fig. 2). Approximately 285 km^2 of the 500 km^2 study area are owned by the USFS, the remainder being private land. A portion of the 500 km^2 study area was chosen for habitat analysis. This 71 km^2 area (all USFS land) is designated as the IMGRID study area (Fig. 1). In addition the Tellico Bear Sanctuary comprises approximately 121 km^2 of the main study area and 38 km^2 of the IMGRID study area (Fig. 1).

The major drainages within the area include Citico Creek (including North and South Forks), Slickrock Creek, Doublecamp Creek, and Jake Best Creek. On the Tellico Ranger District there are 200 km

Figure 1. The location of the study area within the Tellico Ranger District, CNF.

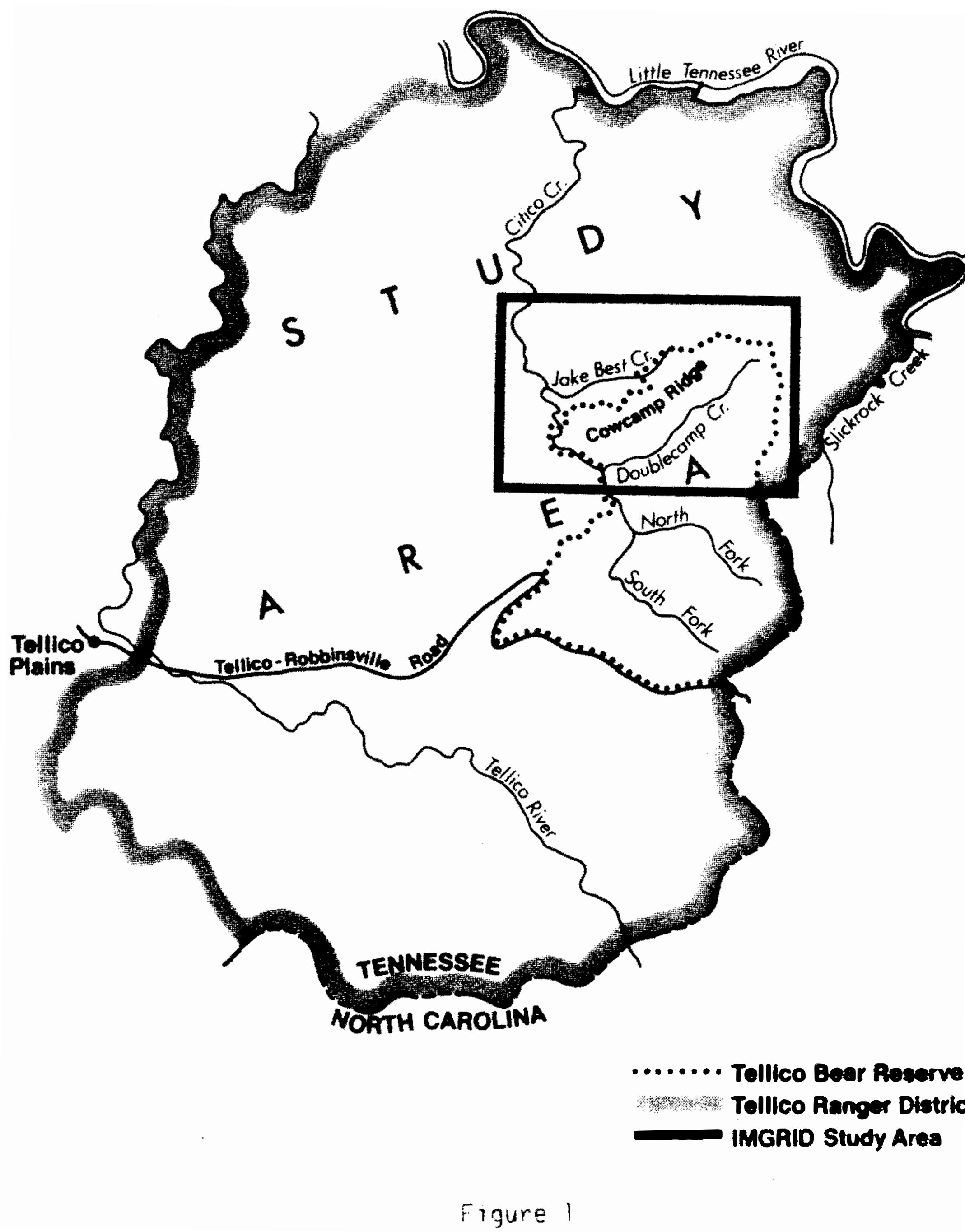

Little Tennessee River
Citico Cr.
S T U D Y
Jake Best Cr.
Cowcamp Ridge
Doublecamp Cr.
Slickrock Creek
A R E A
North Fork
South Fork
Tellico Plains
Tellico-Robbinsville Road
Tellico River
TENNESSEE
NORTH CAROLINA
Tellico Bear Reserve
Tellico Ranger District
IMGRID Study Area

Figure 1

Figure 2. The relationship of the study area and the Great Smoky Mountains National Park.

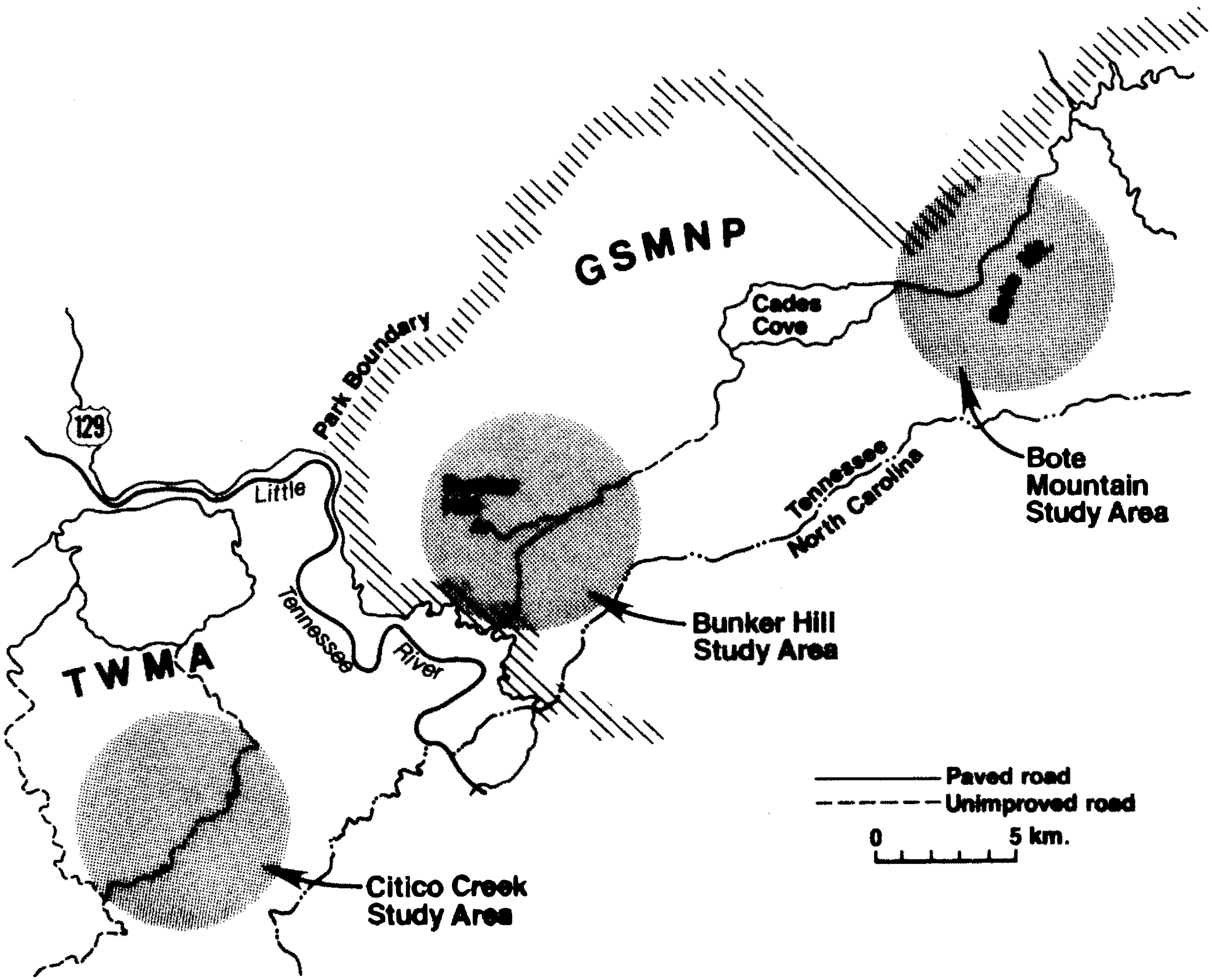

GSMNP
Park Boundary
Cades Cove
129
Little
Tennessee
River
TWMA
Tennessee
North Carolina
Bote Mountain Study Area
Bunker Hill Study Area
Citico Creek Study Area
Paved road
Unimproved road
0
5 km.

Figure 2

of all-weather roads, 38 km of primitive roads, 61 km of motorcycle routes, and 158 km of foot trails.

Physiography and Geology

The Unicoi Mountains are part of the Unaka Mountain Range of the Blue Ridge Province in the southern division of the Appalachian Highlands (Fenneman 1938). The Unicoi Ridge is situated in a north-south direction and, for much of its length, delineates the North Carolina-Tennessee border. Numerous spur ridges radiate from this main ridge; the most prominent being Sassafras and Pine Ridges, and Salt Spring Mountain, which lie in an east-west direction. The topography is characterized by steep, rugged mountains dissected by numerous fast-flowing streams. Less than 10% of the area has less than 10 degrees slope (Message from the President 1902). On the Tellico Ranger District elevations range from 230 m, at the confluence of the Tellico and Little Tennessee Rivers, to 1667 m, at Haw Knob.

Most of the area is composed of feldspathic sandstone, siltstone, conglomerate, and shale of the Ocoee Series, which dates to the late Precambrian Period. However, metamorphosis has changed the form of the rocks to phyllite, slate, quartzite, and schist. The Ocoee Series includes the Great Smoky, Snowbird, and Walden Creek Groups (King and Stupka 1950, King et al. 1968).

Soils of the Ramsey, Matney, Jefferson, and Barbourville series occur throughout the area. The deeper soils occur along drainageways as local alluvial deposits at the base of slopes; shallow soils are associated with narrow ridges and southern aspects (TVA et al. 1972).

Climate

Generally, the climate of the area is characterized as mesothermal perhumid (warm-temperate rain forest) (Thornthwaite 1948). Precipitation maxima generally occur in late winter-early spring and in July-August; a minimum occurs in October. Precipitation patterns are cyclonic in winter and orographic in summer (Dickson 1960, Trewartha 1966). Average monthly temperatures are usually highest in July and lowest in February.

Temperature and precipitation vary greatly with differences in elevation, exposure, and topography (Shanks 1954a, Tanner 1963, Stephens 1969). Shanks (1954a) reported a 4.07 C decrease in temperature per 1000 m rise in elevation in the Great Smoky Mountains. Precipitation averages 140 cm per year at low elevations; whereas, high elevations can receive over 230 cm per year. The average number of frost-free days per year in the mountains on the CNF is 151 (USFS 1976). Temperature and precipitation data for the study period are presented in Appendix A.

Fauna

Linzey and Linzey (1971) listed 59 species of mammals for the GSMNP; an additional 6 species are considered extirpated. On the Tellico Ranger District, large mammals other than black bears include white-tailed deer (*Odocoileus virginanus*) and European wild hogs (*Sus scrofa*). From 1959 to 1972, the Tennessee Wildlife Resource Agency conducted an intensive study of the life history and ecology of European wild hogs on the Tellico Ranger District (Tennessee Game and

Fish Commission 1972). Other studies on the ecology of wild hogs on the Tellico District include Matschke (1964), Henry and Conley (1972), Strickland (1972), and Belden and Pelton (1975). Also more than 200 species of birds, 80 reptiles and amphibians, and 80 fishes inhabit the Great Smokies (King and Stupka 1950).

Flora

The Cherokee National Forest supports a variety of plant communities due to differences in soil types, moisture and temperature patterns, topography, elevation, and man-caused disturbances. Whittaker (1956) stated that almost all vegetation is either topographic climax or secondary succession.

For the Citico Creek Wilderness Study Area, Malter (1977) collected 536 species of vascular plants. The GSMNP supports over 1,300 species of flowering plants, 131 being native trees, 50 fern and fern allies, 330 mosses and liverworts, 230 lichens and 1,800 fungi (King and Stupka 1950). Cain (1930) reported that 30 species of woody plants are endemic to the Unaka Mountain Range.

No quantitative vegetation studies are available for the Tellico Ranger District. However, Cain (1935), Shanks (1954b), Whittaker (1956), and Golden (1974) have conducted vegetation studies in the GSMNP. Whittaker (1956) and Golden (1974) have analyzed the relationships among certain environmental parameters and forest cover types; they listed 15 and 17 forest cover types, respectively. Golden (1974) found that the vegetation patterns are most likely related to elevation, topography, and aspect.

The Cherokee National Forest is divided into compartments and stands which have been mapped into forest cover types. Definitions of these terms (Society of American Foresters 1954, 1958) and detailed descriptions of forest cover types are given in Appendix B. Age distribution of forest cover types on the Tellico Ranger District is presented in Appendix C.

Basically 5 major forest types are recognized (USFS 1976). The cove hardwood type consists primarily of yellow-poplar (*Liriodendron tulipifera*), white oak (*Quercus alba*), northern red oak (*Q. rubra*), and hemlock (*Tsuga canadensis*). This type occurs between elevations 152 m and 1,219 m on lower slopes, northerly slopes, coves, and moist flats. The oak-hickory type includes southern red oak (*Q. falcata*), white oak, hickories (*Carya spp.*), post oak (*Q. stellata*), black oak (*Q. velutina*), chestnut oak (*Q. prinus*), scarlet oak (*Q. coccinea*), shortleaf pine (*Pinus echinata*), Virginia pine (*P. virginiana*), and pitch pine (*P. rigida*). This type occurs in coves, mountain slopes, and flat ridge tops. The pine type consists of white pine (*P. strobus*), shortleaf pine, Virginia pine, and Table-mountain pine (*P. pungens*). This type occurs in old fields, relatively infertile ridges, dry flats, and slopes. The mesic hemlock type includes white pine hemlock, yellow birch (*Betula alleghaniensis*), yellow-poplar, basswood (*Tilia* sp.), blackgum (*Nyssa sylvatica*), northern red oak, and cucumbertree (*Magnolia acuminata*). This type occurs above 457 m elevation in moist coves and northern slopes. The northern hardwood type includes sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), yellow birch, basswood, red maple (*A. rubrum*), hemlock, northern red oak, black cherry (*Prunus serotina*), and sweet birch (*B. lenta*). This type occurs above 1,066 m elevation on sites with adequate moisture and relatively high fertility.

Land Use Patterns

Little information is available documenting land use practices on the Tellico Ranger District before the establishment of Cherokee National Forest in 1936. Early logging practices were probably similar to those used in GSMNP. During the late 1800's, logging was restricted to accessible areas and selective cutting of black cherry, black walnut (*Juglans nigra*), and ash (*Fraxinus sp.*), and yellow-poplar was predominant. Logging operations relied heavily on stream and oxen transportation of logs. These operations removed choice poplar from the lower creeks; accessible cherry, walnut, and ash were removed from the upper drainages. However, no large areas above streams were denuded of timber. Also fires due to logging were rare (Lambert 1961).

Mechanized logging techniques brought an end to selective cutting practices; it enabled loggers to cut any merchantable timber tree. These techniques were more destructive of timber and decreased its capacity for reproduction. Also the frequency of fires due to logging increased (Lambert 1961).

Much of the Citico drainage was logged by the Babcock Land and Lumber Company around 1920-1925. A large fire, which started in fresh logging slash, burned a portion of the upper Citico watershed in 1925 (TVA et al. 1972).

Current forest practices for the CNF are described in USFS (1976). Basically the plan proposes even-aged management on that part of the forest that is suitable. Proposed rotations are 60 years for Virginia pine, 80 years for white and yellow pines, and 100 years for hardwood groups.

The Tellico Ranger District is administered and managed in various ways and for various purposes. Being a national forest, the district is managed under the multiple use-sustained yield philosophy for its outdoor recreation, timber, watershed, and wildlife resources (Multiple Use-Sustained Yield Act, 12 June 1960, PL 86-517). The entire CNF is considered a wildlife management area and its wildlife resources are administered in cooperation with the Tennessee Wildlife Resources Agency. A portion of the study area is administered as the Tellico Bear Sanctuary, 124 km^2 (Fig. 1, page 6); no bear hunting is allowed on this area, although small and big game hunting are allowed. Dogs are allowed for raccoon and grouse hunting (see Sanders et al. 1978 for a discussion on bear sanctuaries).

A part of the main study area is managed as wilderness (Joyce Kilmer-Slickrock Wilderness area (16 km^2) and Citico Creek Wilderness study area (6 km^2)) as proposed by the Wilderness Act (3 September 1964, PL-88-577) and the Eastern Wilderness Act (3 January 1975, PL93-622).

CHAPTER III

MATERIALS AND METHODS

Trapping

Field work for this study was conducted from June 1978 through December 1979. Prebaiting techniques (Marcum 1974, Eagar 1977, Johnson and Pelton 1980b) were used to locate sites of black bear activity. This technique involved hanging 3 open sardine cans from a tree branch approximately 2.5 m above the ground. Bear claw marks on the tree and the absence of the bait indicated that a bear had visited the site.

Trap lines were established in areas of bear activity as indicated by the prebaiting, primarily on Cowcamp Ridge and Jake Best Creek drainage (Fig. 1, page 6). These lines, located on old logging roads, were opened intermittently from May through October depending upon the availability of equipment and personnel. Black bears were captured using Aldrich spring-activated foot snares (Aldrich Animal Trap Co., Clallam Bay, WA) and barrel traps fabricated from 2, 50-gallon oil drums welded together (Marcum 1974, Eagar 1977, Johnson and Pelton 1980b, Eiler 1981). Sardines were used as bait and were replaced every 3-4 days.

Tagging and Handling

Bears were immobilized with an intramuscular injection of M99 (Etorphine hydrochloride, D-M Pharmaceuticals, Inc., Rockville, MD) administered with a projectile syringe and fired from a CO2-charged pistol (CAP-CHUR, Palmer Chemical Equipment Co., Douglasville, GA).

The dosage of M99 was 1 mg/45.5 kg of estimated body weight. M50-50 (Diprenorphine, D-M Pharmaceuticals, Inc., Rockville, MD) was used as a M99 antagonist at a dosage of 2 mg/45.5 kg of estimated body weight. Usually recovery occurred 2-5 minutes after intravenous injection of M50-50; intramuscular injections resulted in longer recovery times.

After immobilization, bears were marked with a numbered, silver (metal), Monel cattle tag in 1 ear; a numbered, colored (yellow), cattle tag in the other (National Band and Tag Co., Newport, KY), and a lip tattoo for future identification (Johnson and Pelton 1980c). Also the statement "Return for Reward, Dept. Forestry, UT" and phone number was printed on the ear tags. Biological information collected from each bear included: sex and weight, blood (Eubanks et al. 1976:29, Beeman and Pelton 1978:127-129), a premolar tooth, a series of body measurements (Cherry and Pelton 1976:32), and reproductive condition (Eiler 1981:12-13).

Age Determination

A first premolar was extracted for age determination. Bears were aged using the cementum-annuli technique (Willey 1974); tooth sections were prepared using methods described by Eagle and Pelton (1978). Bears were placed in 2 age classes: adult ≥ 4 yrs, subadult < 4 yrs.

Radio-Telemetry

Most (79%) of the bears captured were instrumented with radio-collars (Telonics, Inc., Mesa, AZ). The transmitters (150-152 mhz) had an expected life of 3 years. Radio-collars designed to fall off in 9-12 months after application were also used. A brass plate was attached to the radio-collar with the statement "Return for Reward, Dept. of Forestry, UT" and phone number.

All radio-collars were equipped with a reset motion sensor commonly known as mortality sensors (Telonics, Inc., Mesa, AZ). To detect activity patterns, the timing interval was reduced. Movement by the animal causes the monitor to change from a base (inactive, 75 bpm) to an alternate (active, 100 bpm) pulse rate and any subsequent activity causes the timing mechanism to reset. The timing interval was programmed for 5 minutes. If the animal did not move in 5 minutes the pulse rate automatically returned to the inactive mode. Due to the timing mechanism the reset motion sensor may overestimate activity when discrete sampling is used. The inactive mode indicates the animal is not moving; the active mode indicates activity has occurred within 5 minutes. The following system was used to compensate for the overestimation of activity:

INITIAL MODE	SECOND CHECK	RECORDED
I		I
I-A	I	HM
I-A	A	A
A-I		HM
A	I	HM
A	A	A

A=Active

I=Inactive

HM=Head movement

If the signal initially is heard in the active mode while the researcher is listening, a second check is made on the mode 3-8 minutes later (Quigley et al. 1979).

The radio-receiving equipment consisted of a portable receiver (Telonics, Inc., Mesa, AZ) and a hand-held 2-element "H" antenna (Telonics, Inc., Mesa, AZ). The receiver operated in the 150-152 mHz range. Also 2, 8-element antennas (Hy-Gain Electronics Corp., Lincoln, NE) erected on 9 m masts were used for the diel tracking periods and to increase the accuracy of the daily radio-tracking efforts.

Triangulation stations were established at known locations along ridges throughout the study area. Radio-locations of instrumented bears were established by the intersection of 2 or more azimuths taken with a hand-held compass (Silva, Inc., LaPorte, IN). Azimuths were determined by the loudest signal method (Springer 1979:928) and were triangulated on 1:24000 scale United States Geological Survey (USGS) topographical maps. All radio-locations were given a Universal Transverse Mercator (UTM) coordinate (Strahler 1969:58-59, 625-627) to the nearest 100 m. A transparent overlay grid, which divided the 1000m by 1000 m (km^2) UTM cells into 100 hectare (100 m by 100 m) cells, facilitated this procedure. The grid was the size of a topographic map and was oriented to grid north. Locations were recorded in Zones 16 and 17 of the UTM system. Attempts were made to locate instrumented animals 3 times per week and to vary the time of locations. Periodically, instrumented bears were monitored for diel activity and movement patterns. Two 8-element mast antennas with a compass rose at the base were used for this purpose. Approximately twice a month aerial searches were conducted in a Cessna 140, 170, or 172 aircraft. Two "H" antennas, mounted on the airplane's wing struts and connected through the cabin by a switch box, were used for the aerial tracking. Both antennas were used until a signal from an instrumented bear was heard. Then, while switching from left to right antennas, parallel flight lines were flown approximately 0.5-1 km apart to determine the approximate location of the bear. This procedure was repeated by flying parallel lines perpendicular to the first ones. Thus the approximate location of the bear could be "boxed in." When this was established, tighter and tighter circles were flown with the loudest signal on the inside of the circle. The pilot and researcher usually listened to the signal. When a location was established, it was marked on a 1:24000 scale map to the nearest 100 m. Once a signal was heard it usually took 5-8 minutes to establish a location.

Information collected with each azimuth reading included time of day, date, temperature, cloud cover, precipitation, and activity of the bear. Garshelis (1978) describes other aspects of the radio-tracking procedure.

Data Analysis

Activity. Activity of instrumented bears was recorded as active or inactive. Other information recorded with each activity reading included the date, time, temperature, cloud cover, precipitation; the sex, age, and presence of cubs with females was known from trapping records. Activity readings were taken at least 10 minutes apart, except on diels (1 hr apart). For the analysis, time of year was divided into months, time of day divided into hours (beginning on the half hour), temperature grouped into 3 C increments, cloud cover grouped into classes of 25%, and precipitation classified as drizzle, rain, or snow.

A least-squares analysis of variance procedure (SAS Institute 1979) was used to investigate the relationships among weather, time of day, time of year, sex, age, presence of cubs, and activity. Using this procedure the relationships between activity and each factor could be measured independent of the confounding effects of all other factors. Therefore, activity is reported as a probability of being active under the stated condition(s) rather than as an actual percentage of the observations where noted (Garshelis and Pelton 1980).

Movements and home range. Home ranges (the area traversed by the individual in its normal activities of food gathering, mating, and caring for young (Burt 1943:351)) were determined by connecting the outermost radio-locations of a convex polygon and determining its area (Brinker 1969:248-250). The Mann-Whitney-Wilcoxon U test (Sokal and Rohlf 1969:391-395) was used to determine differences in home range size (P=0.05). Convex polygons were used to determine home range overlap.

Diel movements were analyzed with respect to total daily movement (sum of distances between consecutive hourly locations), net daily movement (distance between locations obtained 24 hrs. apart, i.e., distance between beginning and end points in a 24 hr sequence of locations), daily range length (maximum distance between radio-locations in a 24 hr period), and circuity. Circuity was calculated by dividing net movement over a period of 12 or more hours by the total distance traveled in that period. A value of 1 indicated straight line movement, whereas a value of 0 indicated that the animal returned to the original location. Relatively stationary animals were deleted from the analysis of circuity (Garshelis et al. 1981). Mann-Whitney-Wilcoxon U tests were used to test significance among these parameters ($P=0.05$).

Hourly rates of travel were computed by dividing total movement measured between consecutive hourly locations by the number of recorded hourly locations. Rates of travel during daylight hours were determined only for diel data including 8 or more hourly movements; nocturnal rates of travel were tabulated for diel data including at least 4 consecutive hourly movements. Diurnal movements were defined as occurring between 0600-2000 hr and nocturnal movements as occurring between 2100-0500 hr (Garshelis et al. 1981). Mann-Whitney-Wilcoxon U tests were used to test differences in hourly movement parameters ($P=0.05$). Due to lack of movement and home range data in spring, seasons were grouped as: Spr/Summer = March-August, Fall = September-December.

Habitat. IMGRID (Information Management on a Grid Cell System) is a computer system developed by Sinton (1976). In this study, IMGRID version 3.5 was used (Holmes and Jolly 1980). A portion of the study area which included 96% of bear radio-locations was chosen as the IMGRID study area (Fig. 1, page 1). The IMGRID analysis area (130 km^2) is a rectangular array of 100m by 100m (ha) cells; the IMGRID study area is an irregularly-shaped area within the IMGRID analysis area for which habitat information and radio-locations were encoded. The IMGRID analysis area was needed for input of data into the computer. The base maps were USGS 1:24,000 scale topographical maps; the coordinate system was UTM. The transparent overlay grid, described earlier, was used in this process.

Habitat and radio-location data were then obtained for each cell in the IMGRID study area. All data were obtained from or encoded on USGS maps. The following habitat components were encoded for each cell in the IMGRID study area:

(1) elevation (recorded to the nearest 6 m),

(2) water (permanent streams),

(3) roads (public access, 4-wheel drive, gated roads, trails),

(4) position on slope (upper 1/3, middle 1/3, lower 1/3 of the slope),

(5) aspect (N=315-45, E=45-135, S=135-240, W=241-315) (Mark Harmon, The University of Tennessee, Knoxville, pers. comm.),

(6) concave/convex topography (ridge or valley topography),

(7) forest cover types (US Forest Service cover maps),

(8) bear locations (recorded as age by sex by season, i.e., adult male locations in summer.

Forest cover types were placed into 4 groups:

(1) cove hardwoods = cove hardwoods-white pine-hemlock, upland hardwoods-white pine, white pine-upland hardwoods;

(2) mesic hemlock = white pine, white pine-hemlock, hemlock, bottomland hardwood-yellow pine, yellow poplar;

(3) pine = pitch pine-oak, Virginia pine-oak, shortleaf pine, pitch pine, Virginia pine, Table-mountain pine;

(4) oak-hickory = white oak-red oak-yellow pine, northern red oak-hickory-yellow pine, chestnut oak, scarlet oak, white oak-red oak-hickory, yellow poplar-white oak-northern red oak, sugar maple-beech-yellow birch.

Using IMGRID, proximity searches were conducted from roads to determine if bears were located near (<0.1 km) or far (>0.1 km) from roads). Due to the preponderance of roads on the study area, any corridor around roads larger than this resulted in most of the study area being "near" roads.

To determine habitat utilization, comparisons were made among different subsets of radio-locations and habitat data. The following subsets of radio-locations were used:

(1) all radio-locations;

(2) season (spring = March-May, summer = June-August, fall = September-December;

(3) sex;

(4) age.

Chi-square goodness of fit tests were used to detect differences in habitat utilization (P=0.10) (Sokal and Rohlf 1969), except for the

IMGRID-generated elevation data. Then to determine which categories within the habitat component contributed most to the chi-square statistic, the Bonferroni approach (Neu et al. 1974) was used. When necessary, or to compare categories of interest, categories within habitat components were lumped to increase cell frequencies. If this was not possible, the chi-square statistic was considered invalid if any expected cell frequency was less than 2. Duncan's multiple range test (SAS Institute 1979) was used to determine differences (P=0.05) in elevation means. Other aspects of the IMGRID system are described in Appendix I.

CHAPTER IV

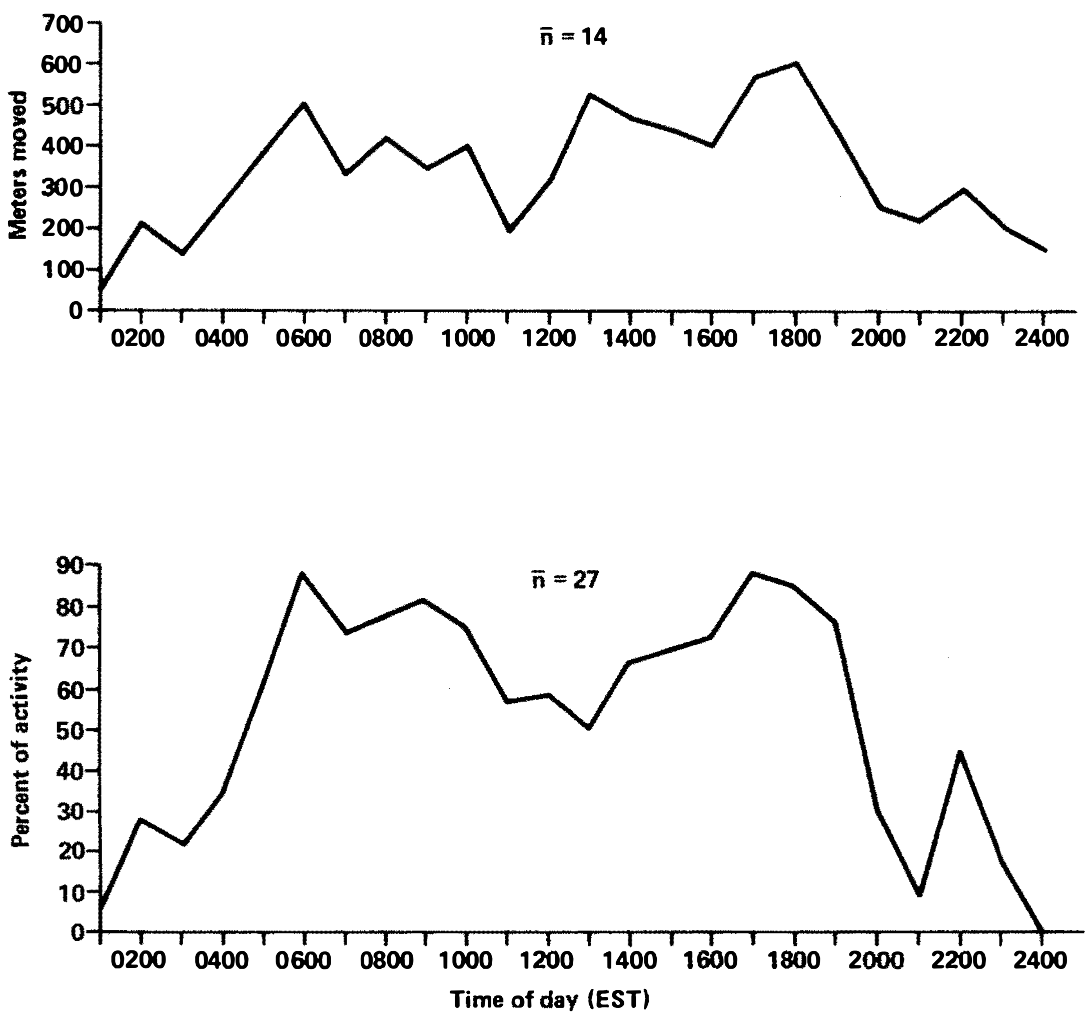
RESULTS AND DISCUSSION

Assessment of Reset Motion Sensors

A high correlation ($r=0.84$, $n=24$, $P>0.001$) existed between mean distance moved per hour and percentage activity as indicated by the reset motion sensors (Fig. 3). Using tip-switch motion sensors, Garshelis (1978) also found a high correlation between these 2 measures of activity. Individual variation among bears (due to age, sex, and reproductive status), weather, and time of day affect the activity pattern of the population as a whole (Garshelis and Pelton 1980, pp. 30-33). The above relationship exists despite the variation in activity caused by these factors. Audible changes in signal strength and frequency were not recorded; therefore, no comparison could be made between distance moved and signal quality. However, changes in signal quality were noted while the motion sensor indicated inactivity. Slight movements by bears, temperature fluctuations, and attenuation of the signal by terrain and vegetation may cause changes in signal strength and frequency. Lindzey and Meslow (1977) felt that using signal qualities as an indicator of activity was biased toward activity.

An analysis was performed to test the criteria used to differentiate head movements (Garshelis 1978:74, pp. 19-20) from actual activity by bears with reset motion sensors. When a head movement was recorded by an observer ($n=64$), a head movement was

Figure 3. Comparison of 2 measures of activity for 13 radio-collared black bears during 1978-1979 in Cherokee National Forest. The upper dotted curve represents mean distance moved per hour. The lower solid curve represents corresponding percentage activity observed during the same hours using reset motion sensors. Mean sample size for the points on each curve are shown (n=); activity determined using reset motion sensors was sampled twice per hour whereas movements were sampled hourly.



n̄ = 14
Meters moved
700
600
500
400
300
200
100
0
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
n̄ = 27
Percent of activity
90
80
70
60
50
40
30
20
10
0
Time of day (EST)

Figure 3

recorded by the second observer 20% of the time, inactivity was recorded 53% of the time, and activity recorded 27% of the time. There was a significant association (sign test P>0.01 Siegel 1956:68-75) between what was called head movement and inactivity. Garshelis (1978) reported that head movements were recorded by both observers only 4 times which indicated that the head movement is brief. Head movements recorded by the 5-min reset motion sensor "lasted longer" but were still associated with inactivity. This supports the assumption that the reset motion sensor is biased toward activity and some recording method is needed to compensate for this (Quigley et al. 1979, pp. 19-20). However comparison of mean distance moved per hour when 2 independent observers recorded head movements ($\bar{x}$=362 m, n=13), when both observers recorded inactivity ($\bar{x}$=252 m, n-74), and when both observers recorded activity ($\bar{x}$=429 m, n=153), indicated that movements during periods when head movements were recorded were not significantly different (P=0.5) from active periods or inactive periods (P=0.2). These figures give no clear indication whether the criteria used to separate head movements from activity were valid. The small sample size when head movements were recorded and high variation within means of all groups may account for this difference.

Factors Affecting Activity

Time of year (Month) and time of day (Hour) were significantly correlated with activity patterns of black bears in Cherokee National Forest (Table 1). Also individual differences among bears (Bear) and the differing responses of some individuals to time of year and time

Table 1. Analysis of variation in activity patterns of black bears in the CNF with respect to time of year, time of day, and differences among bears.

Source of variation	df	SS	MS	F
Total	4411	1079.7905		
Bear	20	41.6950[a]	2,0848	9.67*[b]
Month	9	141.8906[a]	15.7656	73.1243*[b]
Season	2	108.0333[a]	54.0167	250.5413*[b]
Hour	23	91.0818[a]	3.9601	18.3678*[b]
Month x Hour	111	66.2597[a]	0.5969	2.7686*[b]
Season x Hour	33	78.2143[a]	2.3701	10.9930*[b]
Other interactions involving bear	1196	257.8739	0.2156	1.3794*[c]
Variation of observations within bear-month-hour	3052	477.1082	0.1563	

[a]Partial sum of squares.

[b]Tested against other interactions involving bear.

[c]Tested against variation of observations within bear-month-hour.

*$P<0.01$.

of day (Other interactions involving bear) contributed significantly to the variation in the level of activity. Garshelis and Pelton (1980) reported essentially these same results and noted that sex, age, and family associations influence activity patterns. Using mean distance moved per hour as a measure of activity, Brown (1980) noted that activity patterns of black bears in West Virginia were influenced by time of year and time of day. Mech et al. (1966) found that variation in and among individual cottontail rabbits (*Sylvilagus floridanus*) obscured the relationship of seasonal or sex differences to the activity patterns.

Weather factors were also related to activity patterns although the relationship was not as distinct (Table 2). Garshelis and Pelton (1980) felt that interactions among environmental and biological conditions obscure these relationships. Hayes (1976), studying woodchucks (*Marmota monax*), and Sunquist and Montgomery (1973), studying three-toed sloths (*Bradypus infuscatus*), also found that environmental factors and activity patterns of these animals were not well correlated. Other mechanisms (metabolic or endogenous) may account for more of the variation.

Seasonal and Hourly Effects on Activity

In spring, after emergence from their dens, bears were inactive most of the time (Fig. 4). The level of activity then increased rapidly during the June-July breeding season and reached a peak in August. Activity then decreased but remained high until October. In the months prior to denning most of the bears were inactive. Garshelis

Table 2. Analysis of variation in activity patterns of black bears in the CNF with respect to time of year, time of day, differences among bears, and weather factors.

Source of variation	df	SS	MS	F
Total	4001	974.1069		
Bear	20	39.2648	1.9632	11.07*
Month	9	63.5171	7.0575	39.78*
Hour	23	62.4800	2.7165	15.31*
Weather	24	7.3924	0.3080	1.74*
Temperature	14	5.5222[a]	0.3944	2.22*
Cloud cover	3	1.2265[a]	0.4088	2.30[ns]
Precipitation	7	1.1534[a]	0.1648	0.93[ns]
Residual	3925	696.2417	0.1774	

[a]Partial sum of squares.

*P<0.05.

Figure 4. Relationship between time of year and probability of activity of black bears in the Cherokee National Forest 1978-1979.

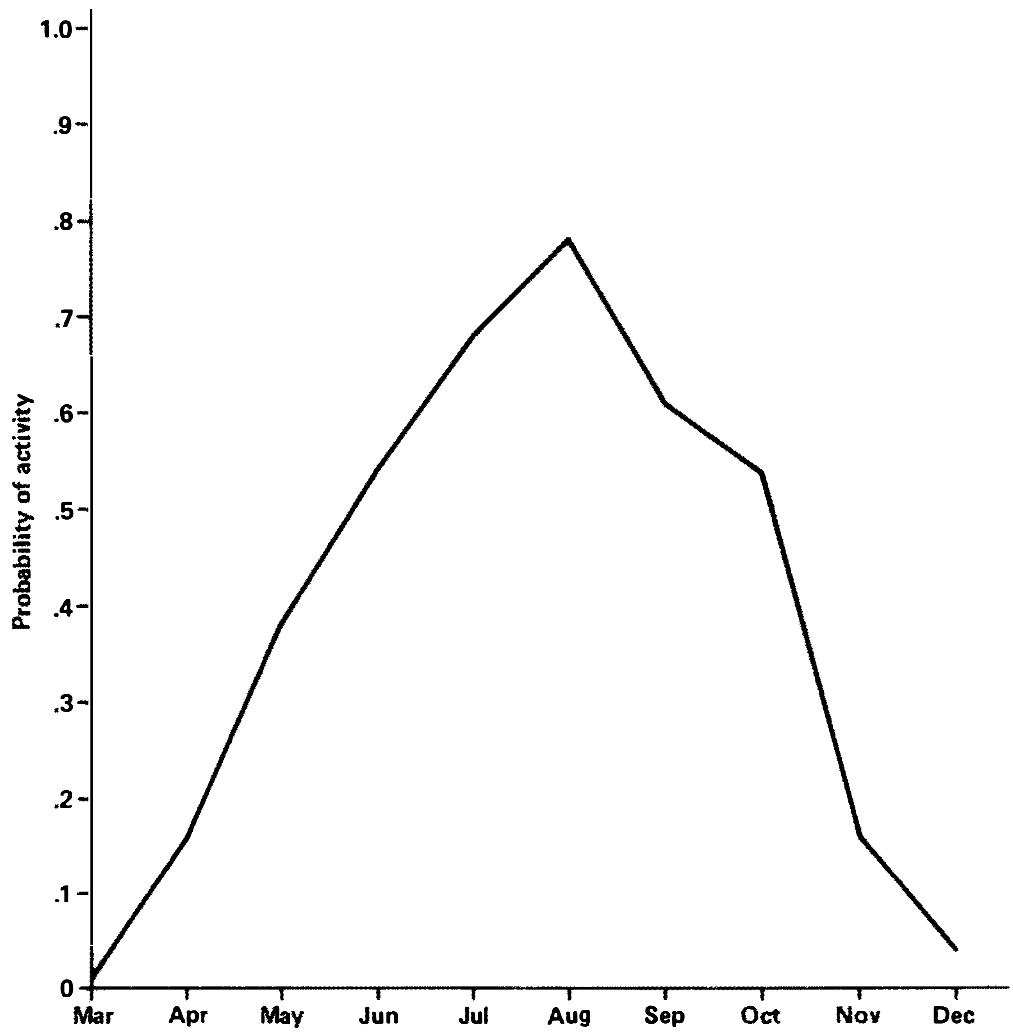

1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Probability of activity
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 4

and Pelton (1980) noted a similar pattern in the phenology of activity in GSMNP; however, the level of activity peaked in June. Trapping records (1975-1979) indicate that the mean age of radio-collared bears in CNF, and for the population as a whole, is significantly ($P<0.01$) less than for those in GSMNP. Eiler (1981:50) found that 2 3-year-old females in CNF had young and that 3-year-old females may breed later in the season than the older females (Eiler 1981:43,82). The difference in age composition between these 2 areas may account for the differences in the activity pattern. Alt et al. (1976), Amstrup and Beecham (1976), Hamilton (1978), and Brown (1980) reported similar annual activity patterns for bears in Pennsylvania, Idaho, North Carolina, and West Virginia, respectively. Johnson and Pelton (1979) and Lindzey and Meslow (1976) noted decreased levels of activity by bears in pre- and post-denning periods.

The daily activity pattern averaged over the entire year indicated that bears in CNF were generally crepuscular, with peaks at 0700 h and 2000 h. Also activity was higher during the day than it was at night. Diurnal or crepuscular activity patterns are reported for bears in western Washington (Poelker and Hartwell 1973, Lindzey and Meslow 1977), Idaho (Amstrup and Beecham 1976), and eastern Tennessee (Eubanks 1976, Garshelis and Pelton 1980). Nocturnal activity patterns have been reported for bears in North Carolina (Hamilton 1978). However, because time of year had a significant effect on hourly activity (MonthXHour Table 1, page 30), months were grouped into seasons (Spring = March-May, Summer = June-September, Fall = October-December) and least square means calculated for each hour of each season rather than each hour of each month. Factors believed to affect activity, namely phenological development of the food sources (Beeman and Pelton 1980), seasonal range shifts (Garshelis 1978), and the breeding cycle, were used to delineate seasons. These groupings accounted for an appreciable portion of the yearly variation in activity (Season, Table 1, page 30) and showed an influence on hourly activity patterns (SeasonXHour, Table 1).

In this study no diels were conducted during spring; therefore, a 24 h activity pattern for this season could not be assessed (Fig. 5). Also intensive radio-tracking was not conducted during spring; therefore, the information presented may not be representative for that season. However, the level of activity is low during the day and sharply increases from 1600 h to 1900 h.

During the summer, the level of activity is low during the early morning hours, increases between 0500-0600 h, reaches a peak at 0700-0800 h, remains high during the day, peaks again at 1900-2000 h, then declines to a low level during the night (Fig. 5). Garshelis and Pelton (1980) reported a similar activity pattern in the summer for bears in GSMNP. It appears that the extent of activity during the middle of the day is greater in summer than in spring. Also the evening activity peak may occur earlier in spring than in summer due to earlier sunset during this season.

The activity pattern in autumn is characterized by a high level of activity during the night and a low level during the day (Fig. 5). Maximum and minimum activity occurred at 2000 h and 1300 h, respectively. The activity level during midday (1000-1500 h) was

Figure 5. Seasonal differences in the daily activity pattern of black bears in the Cherokee National Forest 1978-1979.

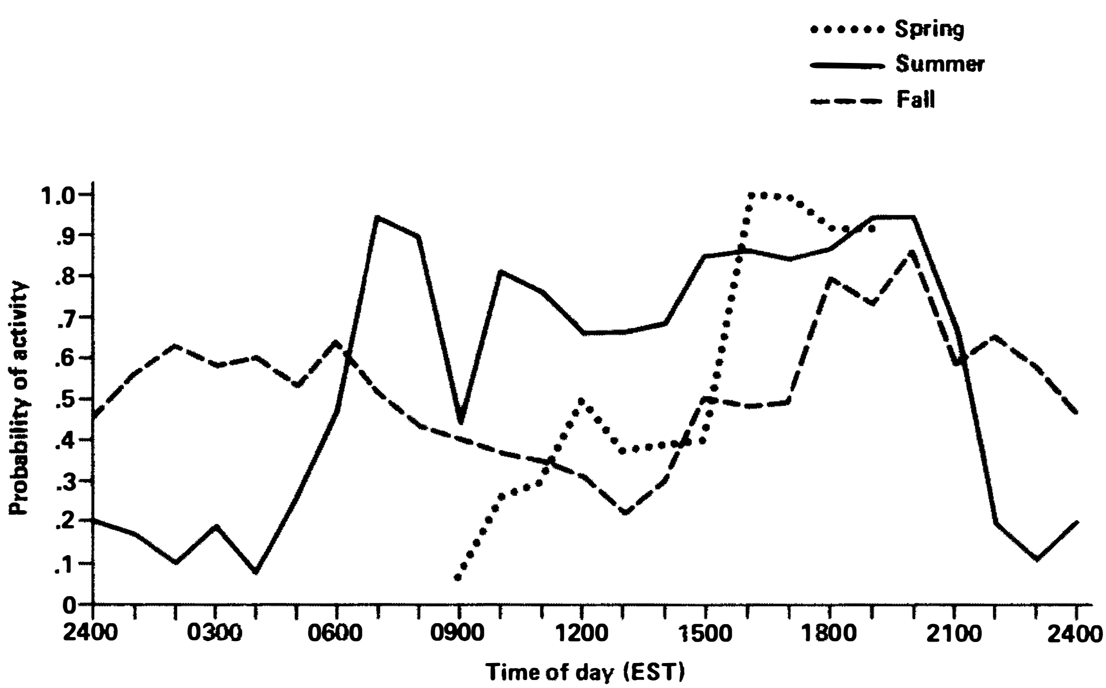

Spring
Summer
Fall
Probability of activity
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
2400
0300
0600
0900
1200
1500
1800
2100
2400
Time of day (EST)

Figure 5

similar to the spring level but lower than the summer level. Amstrup and Beecham (1976) and Hamilton (1978) observed greater nocturnal activity by bears in the fall.

Seasonal and daily activity patterns of bears may be influenced by the physiological condition of the bears, the distribution and abundance of the food supply, and weather patterns. In spring bears lose weight (Jonkel and Cowen 1971:45, Poelker and Hartwell 1973:116, Beeman 1975:1959) due to a diet low in nutritional value and food energy (Eagle 1979). During this season Garshelis and Pelton (1980) reported a distinct crepuscular pattern of activity for bears in GSMNP and postulated that it may represent an optimal foraging strategy for bears on a low energy diet. In CNF, it appears bears may exhibit a similar pattern in spring but insufficient data precluded this comparison.

In summer bears in CNF exhibited an activity pattern similar to that reported by Garshelis and Pelton (1980). Shrub-borne fruits, which are high in energy value, constitute the main part of the bear's diet (Eagle 1979). This transition from a negative to a positive energy balance enables bears to maintain a high level of activity during the day. An increased level of activity during the summer may be attributed also to breeding activity. In the Smoky Mountains, breeding occurs mainly in June-July (Eiler 1981). Rogers (1977) reported increased movements of both males and females during the breeding season.

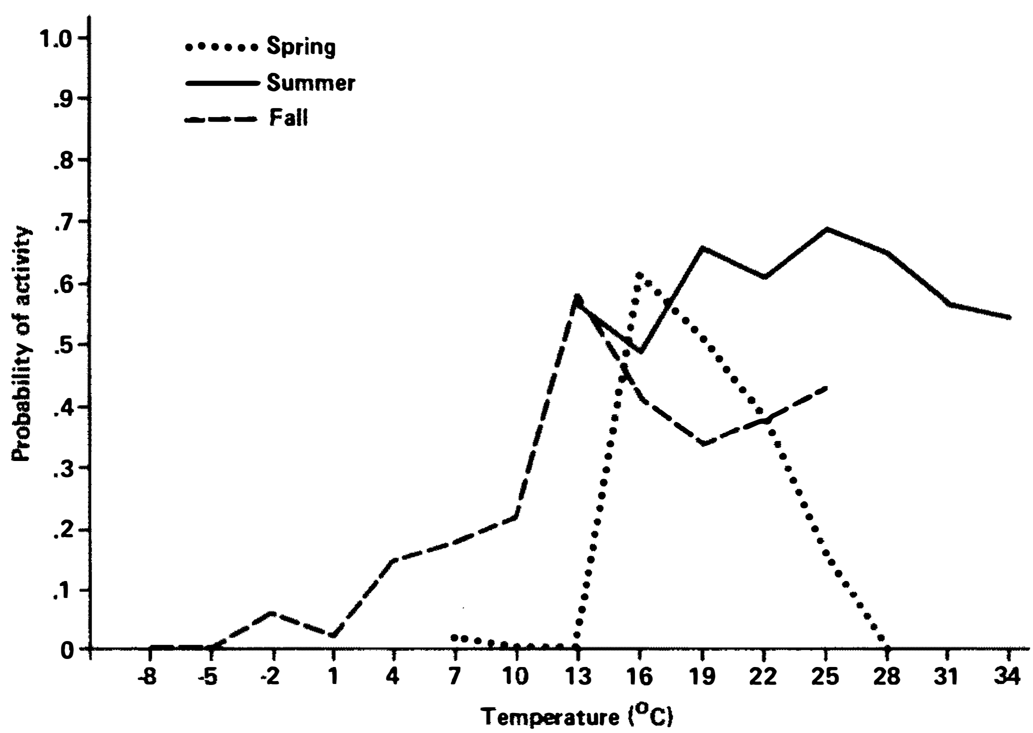
In autumn, bears in the CNF exhibited an activity pattern similar to that reported by Garshelis and Pelton (1980). The distribution and abundance of the food supply (acorns) and the need for bears to increase fat reserves before denning may explain why nocturnal foraging is necessary. Also human-related activities such as hunting may contribute to the increase in nocturnal activity in the fall (Hamilton 1978:81).

The variation in seasonal activity patterns of bears in CNF reflects their opportunistic feeding behavior to differences in food supply and to their physiological needs during different seasons. Comparison of the seasonal activity patterns of this study with those reported by Garshelis and Pelton (1980) suggests that endogenous and climatic patterns interact to produce similarities between seasonal activity patterns of the 2 areas.

Effects of Weather on Activity

Temperature had a significant effect on the level of activity of black bears in CNF (Table 2, page 32). In spring, the level of activity was low at temperatures below 13 C and above 25 C; activity was high at temperatures between 16-22 C (Fig. 6). Garshelis and Pelton (1980) found that activity increased with increasing temperature but it seemed to stabilize between 20-26 C. Because bears are in a negative foraging period in the spring (Beeman 1975:159), there may be an "optimum" range of temperatures conducive to activity by bears. In summer the level of activity was higher than in spring and exhibited a direct relationship with temperature up to 25 C. Above 25 C activity decreased but remained high. This pattern is similar to that reported by Garshelis and Pelton (1980). In autumn the level of

Figure 6. Seasonal effects of temperature on activity patterns of black bears in Cherokee National Forest 1978-1979.



Spring
Summer
Fall
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Probability of activity
-8
-5
-2
1
4
7
10
13
16
19
22
25
28
31
34
Temperature (°C)

Figure 6

activity was relatively high at temperatures above 13 C and low at temperatures below 10 C; during this season bears in GSMNP exhibited decreased levels of activity below 0 C and above 20 C (Garshelis and Pelton 1980).

Activity of black bears in CNF was not related to the extent of cloud cover or to precipitation (Table 2, page 32). Sunquist and Montgomery (1973) and Hayes (1976) found that activity patterns were not well correlated with environmental factors. They felt that factors relating to the physiology of the animal may be more important in determining activity patterns. This may also be true for black bears. Movements and activities of bears are affected by the nature of the food supply (Amstrup and Beecham 1976, Rogers 1976, 1977, Garshelis et al. 1981), the breeding cycle (Rogers 1977), onset and cessation of lethargy (Lindzey and Meslow 1976, Johnson and Pelton 1979, 1980a) and reflect the different physiological conditions experienced by bears within and between years.

Sex, Age, and Family Effects on Activity

Differences in activity patterns among different sex and age groups and between females with and without cubs were tested using orthogonal contrasts. Overall, females with cubs were more active ($P<0.05$) than any other sex or age group. All other comparisons were not significant ($P>0.05$). Garshelis and Pelton (1980) found that subadults of both sexes were more active than the adults of their respective sex and that adult males were more active than solitary females.

On a seasonal basis, the patterns of activity between different sex and age groups was altered somewhat (Fig. 7). In spring females with cubs were most active but no significant differences ($P>0.05$) were observed among the different groups. Also the level of activity for all groups was lower than in the summer. Amstrup and Beecham (1976) noted that a higher level of spring activity by females with cubs may reflect their need for adequate nutrition at this time. Nursing and play behavior by cubs may also affect the level of activity of the female. In summer the general level of activity increased among all sex and age groups. Females with cubs were more active ($P<0.05$) than any other group and no differences ($P>0.05$) were observed between adult males and solitary adult females or between subadults of both sexes and adults of their respective sex. In autumn the general level of activity was diminished from that of summer. Females with cubs, subadult males, and adult males had similar levels of activity ($P<0.05$), but were different (P 0.05) from solitary adult females and subadult females (Fig. 7).

In CNF, no overall differences were observed in the activity patterns of different sex and age groups, except for females with cubs. However, these patterns changed seasonally. The differences in activity patterns of bears in CNF and those in GSMNP (Garshelis and Pelton 1980) may be due, in part, to the younger age structure of bears in CNF. Subadult male bears exhibit different movement patterns (Rogers 1977, Reynolds and Beecham 1980) than adult bears, relating mainly to dispersal and establishment of a home range. Adult female

Figure 7. Seasonal differences in activity among different sex and age groups and between females with and without cubs. Symbols denote significant differences at the 0.05 level.

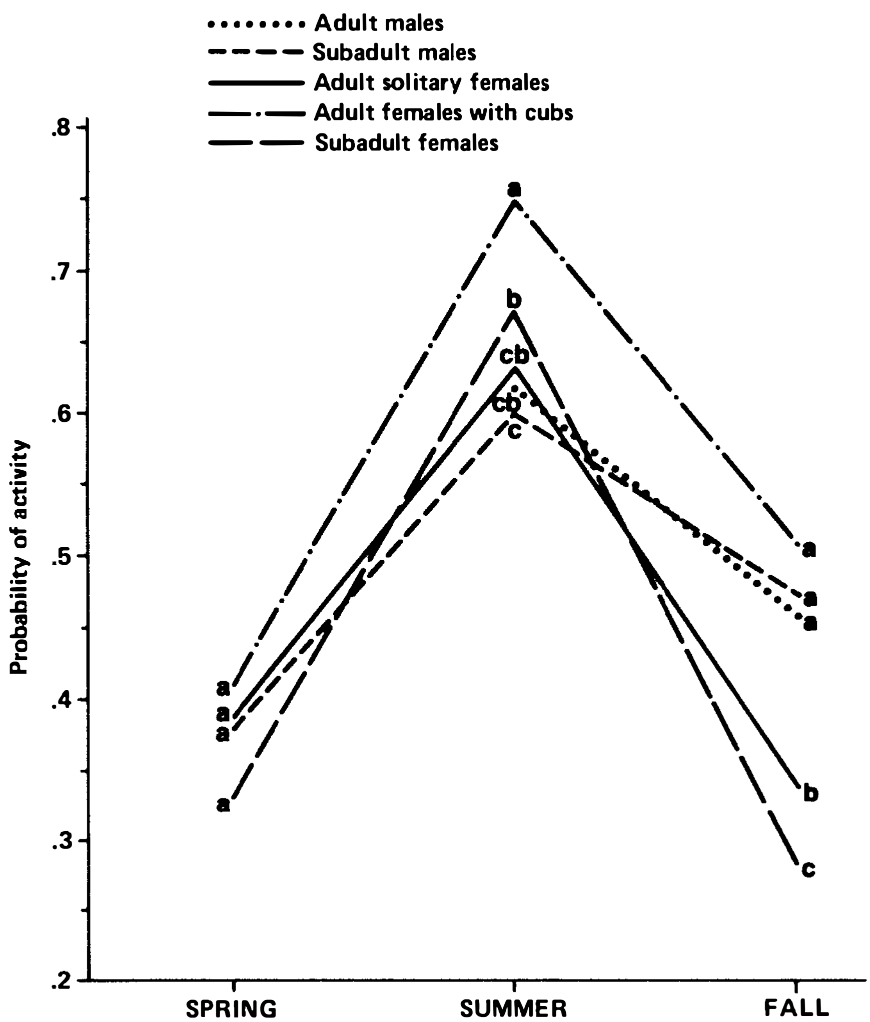

Adult males
Subadult males
Adult solitary females
Adult females with cubs
Subadult females
Probability of activity
.8
.7
.6
.5
.4
.3
.2
SPRING
SUMMER
FALL
a
b
cb
cb
c
a
a
a
a
a
a
a
b
c

Figure 7

bears allow their female offspring to remain in their home range (Rogers 1977). This may explain differences observed seasonally in the activity levels of subadult males and females. Also differences in the distribution and abundance of food sources between CNF and GSMNP, both temporally and spatially, may account for the dissimilar activity patterns. Garshelis et al. (1981) noted that differences in diel movement patterns between CNF and GSMNP were due, in part, to the differences in food supply.

Home Range Size

Male bears occupied significantly larger ($P<0.05$) annual home ranges than females (Table 3). The average area occupied by males and females was 30.1 km^2 (n=9) and 11.6 km^2 (n=12), respectively. Male and female bears occupied areas of 295.5 and 50.8 km^2 in Pennsylvania (Alt et al. 1976), 5.05 and 2.35 km^2 in Washington (Lindzey and Meslow 1977), and 21.2 and 8.4 km^2 in GSMNP (Garshelis 1978). The method used in all home range comparisons was the convex polygon.

Seasonally, males used larger ($P<0.05$) home ranges than females in spring/summer and fall. In addition, fall ranges of both males and females were larger (P 0.05) than areas occupied in spring/summer (Table 3 and Appendix D).

Home ranges of male bears are typically larger than females (Alt et al. 1976, Amstrup and Beecham 1976, Rogers 1977). Males may exhibit less attachment for specific areas and therefore roam over larger areas; however, this varies among individuals. Amstrup and Beecham (1976) felt that males increased their reproductive success by being more mobile.

Table 3. Mean annual and seasonal home ranges of 21 black bears in CNF, 1978-1979.

Category	Annual home range[a]		Spr/summer range[c]		Fall home range[d]	
	1978(n)[b]	1979(n)	1978(n)	1979(n)	1978(n)	1979(n)
Subadult males	11.2(1)	36.5(6)	9.3(1)	10.1(8)	6.8(2)	33.6(6)
Adult males	--	20.1(2)	3.2(1)	11.3(3)	--	15.6(2)
Males	11.2(1)	32.4(8)	6.3(2)	10.2(11)	6.8(2)	29.1(8)
Subadult females	14.7(4)	8.0(5)	2.0(4)	4.0(2)	13.9(4)	4.6(5)
Adult females	22.7(1)	8.8(2)	4.2(1)	4.2(2)	17.1(2)	7.1(2)
Females	16.3(3)	8.2(7)	2.4(5)	4.0(4)	15.0(6)	5.3(7)

[a]Home ranges determined by connecting the outermost radio-locations for each animal (convex polygon) and reported in km^2.

[b]Number of bears.

[c]Spr/summer = March-August.

[d]Fall = September-December.

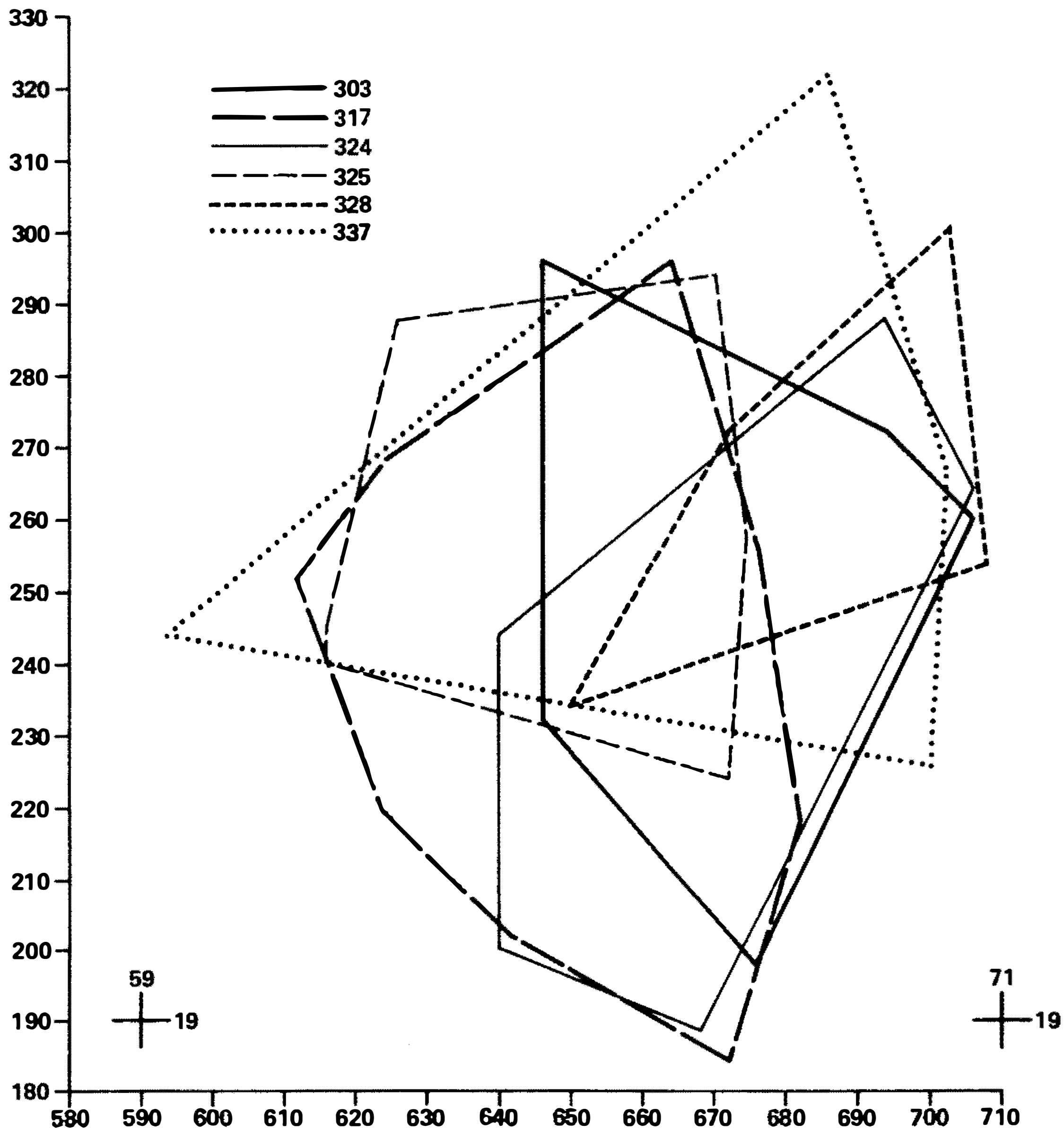
Distribution of food sources, learning, and social interactions influence the areas occupied by bears. In CNF, summer food sources (berries) are locally abundant and clumped; whereas, fall foods (acorns) tend to be more dispersed (pers. obser.). Thus bears likely have to travel further in the fall for food. Rogers (1977) and Garshelis and Pelton (1981) documented bears moving to areas of local food abundance, mainly during the fall, in Minnesota and GSMNP, respectively. Also, Amstrup and Beecham (1976) and Rogers (1977) believed that a knowledge of alternative food sources increased an individual bear's fitness. Knowledge of foraging areas may be passed from mother to offspring (especially her female offspring) or through dispersal or range expansion movements. Rogers (1977) and Garshelis and Pelton (1981) presented evidence for this in Minnesota and GSMNP, respectively. However, variation among individual bears tends to obscure the relationship among factors influencing home range size.

The estimation of home range size is influenced by sampling frequency, activity patterns of the animal, topography, and method of calculation. Smith et al. (1981) noted that inconsistency in sampling frequency, observation period, and method of calculation decrease the ability to correlate home range size with other ecological factors. Comparability would be enhanced if the sampling procedure and method of calculation are standardized and also if a large proportion of the area utilized is estimated. However, the probability of locating individual bears and of locating a particular bear equally throughout its range is influenced, in mountainous terrain, by topography. Some bears are more observable or accessible than others. Aerial radio-tracking, if done on a regular basis, may reduce these biases when an estimate of home range size is the main objective. Overall, the convex polygon is an acceptable method of calculation because of its graphical applications, simplicity, and prominence in the literature. Statistical methods of calculation (Jennrich and Turner 1969, Koeppl et al. 1975) assume that an animal's use of an area conforms to some probability distribution; this may be an unrealistic assumption (Waldschmidt 1979). The above violation especially may apply to data obtained when radio-tracking animals that roam over large areas of inaccessible terrain. Statistical methods (Waldschmidt 1979) and polygon methods (Rogers 1977) may indicate areas of use where no use was observed. However, the convex polygon method seems adequate when a determination of size and relative position of home ranges is the main objective.

Home Range Overlap

As determined by the convex polygon method, extensive home range overlap occurred among subadult males, among subadult females, among adult males, among adult females, and between adult males and adult females (Figs. 8-12). Lindzey and Meslow (1977) and Reynolds and Beecham (1980) also reported extensive home range overlap for bears in Washington and Idaho, respectively. However, Rogers (1977) noted that objective determination of home range and a lack of kinship relationships, especially among females, may give an appearance of overlap when actually there is none (i.e., polygon methods may include areas the bears do not use and female offspring may establish a range within their mother's range). Rogers (1977) believed that mature females were

Figure 8. Home range overlap among 6 subadult male bears in Cherokee National Forest, 1979.



Distance between UTM grid tics = 12 km.

Figure 8

Figure 9. Home range overlap among 5 subadult female black bears in Cherokee National Forest, 1979.

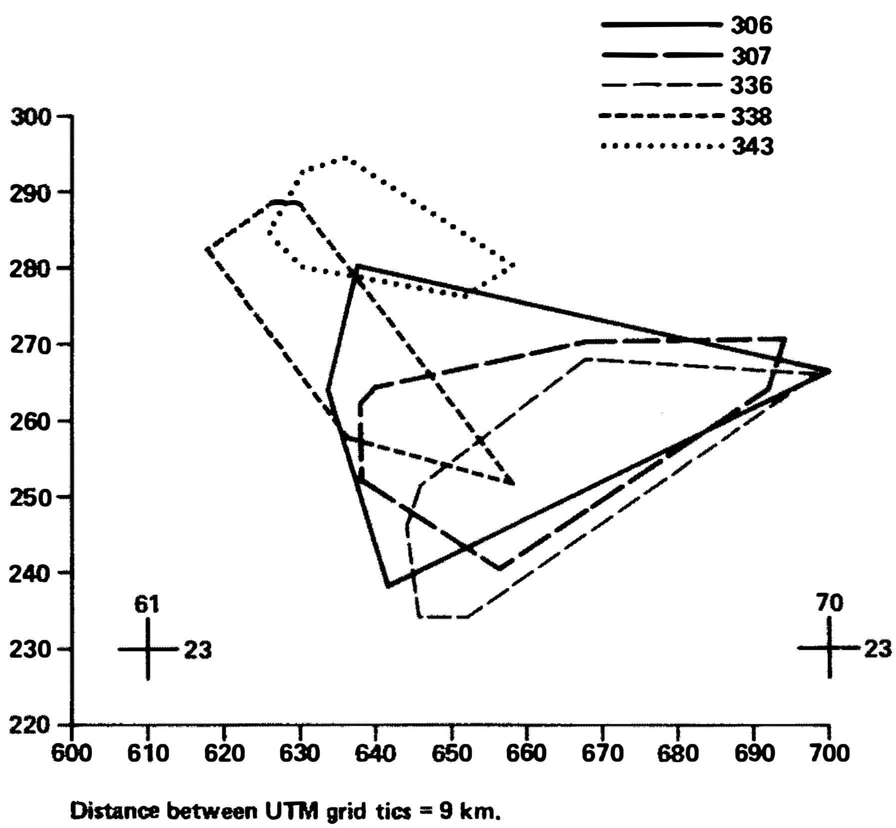
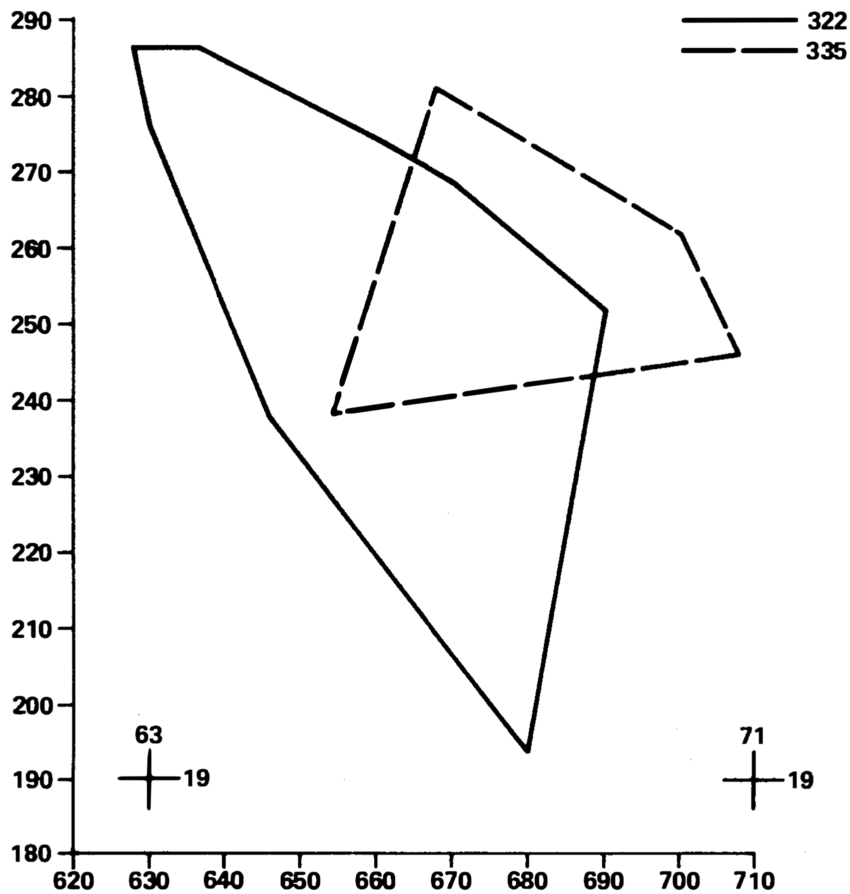

306
307
336
338
343
300
290
280
270
260
250
240
230
220
600
610
620
630
640
650
660
670
680
690
700
61
23
70
23
Distance between UTM grid tics = 9 km.

Figure 9

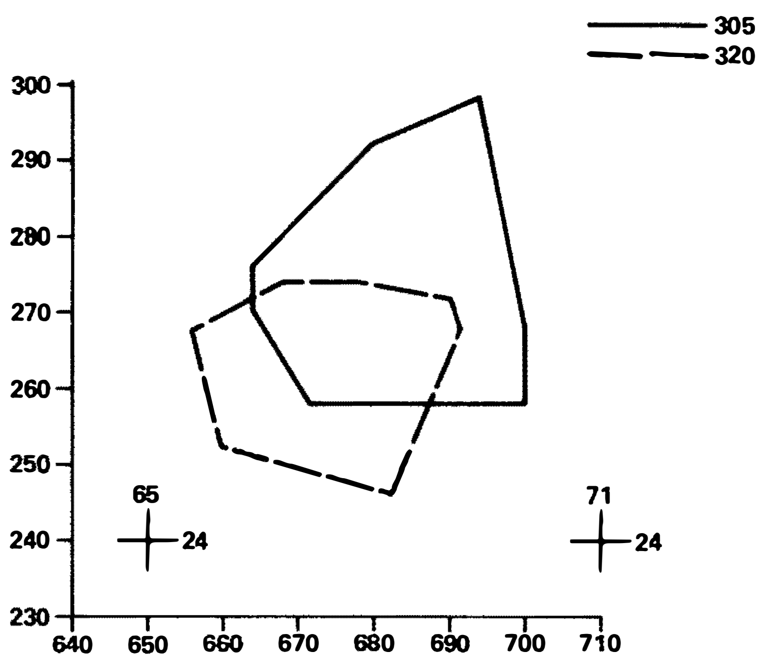
Figure 10. Home range overlap between 2 adult male black bears in Cherokee National Forest, 1979.



Distance between UTM grid tics = 6 km.

Figure 10

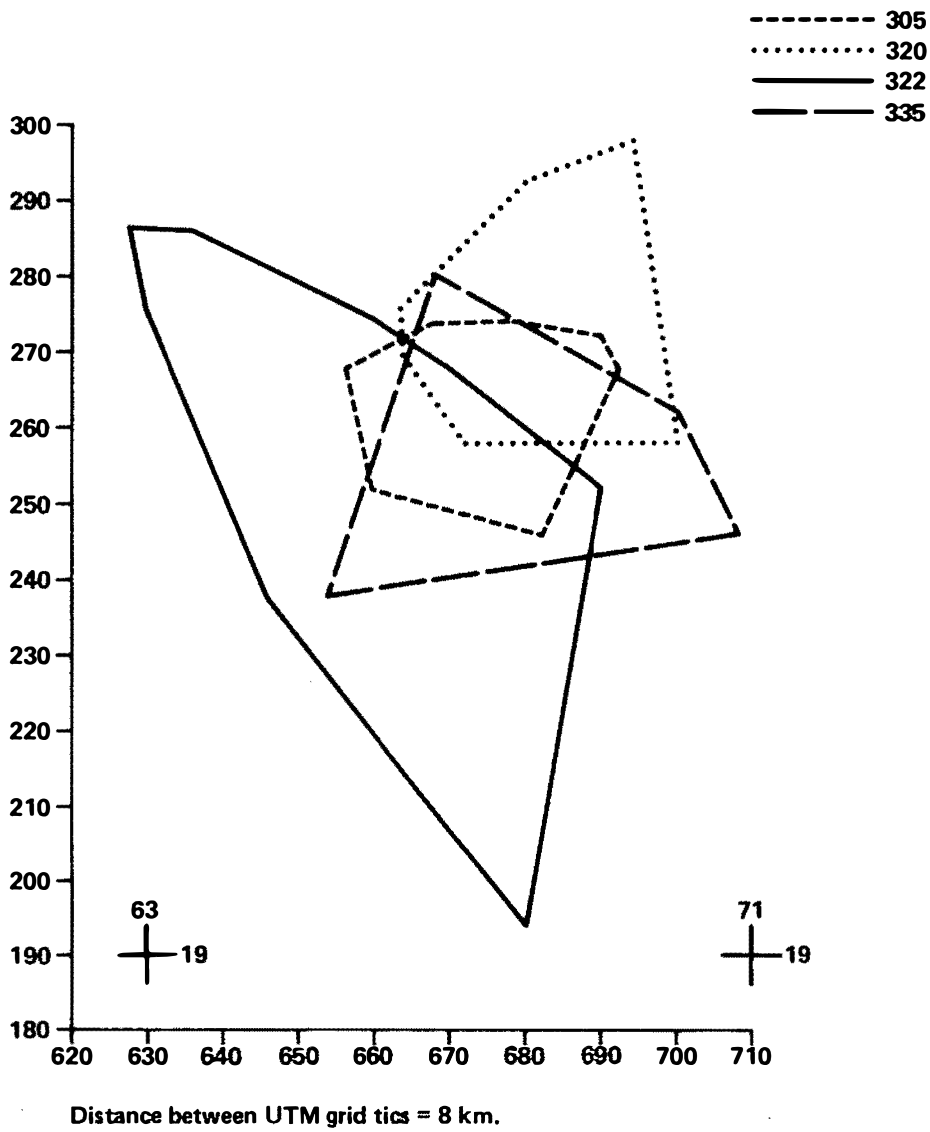
Figure 11. Home range overlap between 2 adult female black bears in Cherokee National Forest, 1979.



Distance between grid tics = 6 km.

Figure 11

Figure 12. Home range overlap among 2 adult female and 2 adult male black bears in Cherokee National Forest, 1979.



Distance between UTM grid tics = 8 km.

Figure 12

territorial (i.e., they occupied areas more or less exclusively), at least most of the year. Despite these biases, the scatter of locations for bears in CNF does not indicate that a strictly spatial exclusion occurs. The high overlap of home ranges may indicate the relatedness of bears in this area, especially females. High overlap and postulated relatedness was also observed for bears in Montana (Jonkel and Cowen 1971) and Washington (Lindzey and Meslow 1977). It is more likely that a spatio-temporal exclusion occurs. Garshelis and Pelton (1981) noted that bears in GSMNP mutually avoided each other; spatio-temporal exclusion was also noted for bears in Washington (Lindzey and Meslow 1977).

Diel Movements

Hourly movements of bears were monitored on a periodic basis (Tables 4 and 5). In all comparisons sample sizes were too small for statistical tests or were not significant (P 0.05); however, some trends are noteworthy.

Females exhibited shorter total daily movement, net daily movement, and daily range length than males during spring/summer and fall. Other studies noted that females restrict their movements to smaller areas (Alt et al. 1976, Amstrup and Beecham 1976).

Diel movement patterns differed from those reported for bears in GSMNP (Garshelis et al. 1981). Nocturnal and diurnal hourly rates of travel, and total daily movements for both sexes in CNF were significantly higher ($P>0.05$) than in GSMNP in spring/summer. Also spring/summer travel rates were more circuitous ($P<0.05$) in CNF than

Table 4. Daily movement parameters of black bears in CNF, 1978-1979 (distance in kilometers).

Category	Total daily movement				Net daily movement			Circuity			Daily range length			
	$\bar{x}$	SD	Max	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	Range	n
Spr/Summer														
females	6.1	1.5	7.1	2	0.6	0.4	2	0.1	0.0	2	2.0	0.8	1.2-3.1	4
males	8.4	1.5	10.0	6	1.3	0.5	5	0.2	0.1	5	2.5	0.4	1.9-3.2	6
total	7.8	1.8	-	8	1.1	0.5	7	0.2	0.1	7	2.3	0.6	1.2-3.2	10
Fall														
females	4.5	1.6	5.6	2	1.6	-	1	0.3	0.4	2	1.6	0.5	1.0-2.0	3
males	8.6	-	-	1	-	-	-	0.2	-	1	1.9	-	-	1
total	5.4	2.3	-	3	1.6	-	-	0.3	0.3	3	1.7	0.4	1.0-2.0	4

Table 5. Hourly movement parameters of black bears in CNF, 1978-1979 (km/h).

Category	Mean diurnal (0600-2200) rate of travel		Mean nocturnal (2300-0500) rate of travel		Maximum hourly rate
	$\bar{x}$	n	$\bar{x}$	n	
Spr/Summer					
females	0.4	4	0.3	4	1.3
males	0.5	6	0.2	6	2.0
total	0.5	10	0.2	10	-
Fall					
females	0.4	3	0.2	3	1.6
males	0.3	1	0.3	1	1.1
total	0.4	4	0.2	4	-

in GSMNP. In contrast, movements during fall were similar between the two areas. Differences in age structure and food supply between the 2 areas likely influences these movement patterns.

Mean hourly rates of travel were similar for males and females in spring/summer and fall (Table 5). Hourly rates of travel were less during nocturnal periods of both seasons. The maximum hourly rates of travel were similar to those reported in other studies (Rogers 1977, Garshelis 1978).

Movements Among Land Use Classes

Radio-locations of the different sex-age groups were categorized into different land use classes (Table 6). From an administrative standpoint bears occasionally roam over areas subject to various management and political policies. However, based on radio-locations, bears rarely left the administrative boundaries of the national forest. The USGS maps do not include a description for private inholdings. Consequently, a few (<3%) locations may have occurred on private property. However, based on my knowledge of the study area, such occurrences were rare.

Also bears were located and presumably seldom left the defined study area. More precisely, the Tellico Bear Sanctuary and the areas adjacent to it (mainly east and west, Fig. 1, page 6) accounted for 96% of radio-locations. Bears not in the study area (Table 6) (1%) generally moved eastward to the Joyce Kilmer-Slickrock area of Nantahala National Forest, North Carolina. These movements likely reflect exploratory or dispersal behavior because all bears (n=3) were

Table 6. Percentage of radio-locations in various land use classes for 21 black bears trapped in CNF 1978-1979.

	Land class							
Sex-age group(n)[b]	National forest	vs Private[a]	Study area	vs Outside study area	Hunted area	vs Bear Sanctuary	Tennessee	vs N. Car.
Subadult males (373)	100	0	96	4	27	73	96	4
Adult males (137)	100	0	100	0	22	78	100	0
Males (510)	100	0	97	3	25	75	97	3
Subadult females (394)	100	0	100	0	21	79	100	0
Adult females (219)	100	0	100	0	8	92	100	0
Females (613)	100	0	100	0	16	84	100	0
All bears (1123)	100	0	99	1	20	80	99	1

[a]See text, p. 64.

[b]Number of locations.

subadult males and the movements were short-term and during different seasons. However, one of these bears (#303) denned in North Carolina in winter 1978-79, returned to the study area (where it was initially trapped) in summer, 1979, then returned to North Carolina in early winter 1979 where it was killed. It is unknown whether this bear would have established a home range in North Carolina.

No bears were documented moving to GSMNP, although 1 bear (#320), which was radio-tracked in 1976 prior to the present study, moved to the Park for 2 weeks and returned to CNF (R. H. Conley, Tennessee Wildlife Resources Agency, pers. comm.). Three bears (subadult males), which were radio-tracked in a concurrent study in the southwest corner of GSMNP, moved to CNF for a brief period and moved back to the Park (H. Quigley, The University of Tennessee, Knoxville, pers. comm.). Also an additional subadult male from the Park moved to the Snowbird Mountain area of Nantahala National Forest, North Carolina, where it was killed (H. Quigley, The University of Tennessee, Knoxville, pers. comm.). Although movements between CNF and GSMNP appear to be minimal, the Park may act as a reservoir to areas along its periphery.

Subadult bears were located in hunted areas most frequently; adult females were located least frequently in these areas (Table 6). When located in hunted areas, bears were generally east or west of the Tellico Bear Sanctuary (Fig. 1, page 6). No bears were documented crossing the Tellico-Robbinsville road. This road may restrict bear movements between the Citico and Tellico drainages. In West Virginia, bears generally avoided roads, especially paved roads (Brown 1980).

Also, the areas north and south of the bear sanctuary are known for illegal hunting activities; bears may learn to avoid such areas if social pressures and food shortages do not prompt movements into these areas. In North Carolina, bears exhibited decreased movements, increased nocturnal activity, and aversion to roads in fall, when hunting activities were highest (Hamilton 1978). No radio-collared bears were killed illegally during this study; however, 4 (2 subadult males, 2 subadult females) were killed legally during the 1979 statewide hunts. Additionally, an instrumented subadult male, which moved to the Santeetlah Creek area of North Carolina, was killed during the 1979 North Carolina hunts. Four of the 5 instrumented bears killed were within 2 km from the bear sanctuary. Although females tend to roam less than males, the vulnerability of both sexes to hunting appears equal on national forest lands in Tennessee (194 of 399 bears killed were males, harvest data, Tennessee 1949-1979, Tri-State Black Bear Project, Progress Report, W-48-R). The accessibility of national forest lands and the hunting methods (4-wheel drive, dog hunting) probably offset differences in vulnerability due to behavioral differences between the sexes. However, when protection is afforded to a population (GSMNP), wide-ranging males or young bears tend to be more vulnerable (Pelton and Burghardt 1976) if their movements take them outside the Park.

The prebait-trapping-reproductive data collected in this study (Appendixes E and H and Eiler 1981) and the movements data presented above indicate that the study area (primarily the bear sanctuary area) supports a viable population of bears. In 2 years of trapping 28 bears were captured (6 adult males, 10 subadult males, 3 adult females, 9 subadult females). Also during the study period 12 young were born from 6 different females (Appendix H). The small home ranges and movements of bears (Table 6, page 65) (especially adult females) indicate that the bears killed in Tennessee do not likely represent dispersal from the Park or North Carolina. In addition, the bears killed in the statewide hunts represented dispersal of younger bears from the sanctuary. It appears that the sanctuary is providing refuge for a breeding nucleus of females while allowing for dispersal of subadults into surrounding areas. However, as mentioned above, the Tellico-Robbinsville road may inhibit dispersal into the Tellico drainage.

Utilization of Forest Cover Types

A total of 1,131 radio-locations on 21 black bears was obtained during 1978-1979. Of this total 1,089 (96%) locations occurred in the 7,100 ha IMGRID study area (Fig. 1, page 6). The IMGRID study area is located predominately (56%) in the Tellico Bear Sanctuary. Because radio-locations in a particular 1 ha cell (the basic encoding unit used in this study) were encoded as presence-absence, the frequency of radio-locations in these cells could not be determined. As a result, 874 radio-locations are actually encoded in the IMGRID system. Furthermore, in specific analysis in which locations were lumped by season, sex, or age, the sample size was reduced further by the overlay process.

Forest cover types were placed into 4 groups: cove hardwood type (666 ha), mesic hemlock type (290 ha), pine type (2,917 ha), and oak-hickory type (3,166 ha) and were overlaid, using IMGRID, with bear locations. Although 7,100 ha were encoded with IMGRID, 7,039 ha had forest cover type data (Tables 7-14).

Overall, chi-square analysis indicated a differential use of cover types by bears ($P<0.10$) (Table 7). Using the Bonferroni approach (Neu et al. 1974) to determine preference, certain habitats were used more and others less than expected. Confidence intervals (90% simultaneous, 97.5% individual) were constructed around the proportion of locations in each type and compared to the expected proportion of radio-locations assuming the bears occurred in each type in proportion to its availability.

Bears used the pine type more than expected; mesic hemlock and oak-hickory were used less than expected ($P<0.10$, Table 7). Bears utilized the cove hardwoods in proportion to its availability ($P>0.10$, Table 7). Locations in the pine and oak-hickory type accounted for 52.8% and 33.2% of the radio-locations, respectively.

Preference or avoidance of the forest cover types changed seasonally. In spring, the pine type was used greater than expected ($P<0.10$); all other types were used proportional to their availability ($P>0.10$, Table 8). The pine type accounted for 61% of the locations. Use of types in summer was the same as the overall utilization; pine type was used more ($P<0.10$), mesic hemlock and oak-hickory less ($P<0.10$), and cove hardwood proportional ($P>0.10$), to their

Table 7. Utilization of forest cover types by 21 black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	88	74	0.113	(0.087,0.139)
Mesic hemlock	290	0.041	21	32	0.027	(0.013,0.040)
Pine	2917	0.414	412	323	0.528	(0.486,0.570)
Oak-hickory	3166	0.450	259	351	0.332	(0.293,0.371)
Total	7039		780	780		

[a]See methods for descriptions of forest cover types.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 780=74).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

Table 8. Utilization of forest cover types in spring by 21 black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	4	4	0.098	(-0.010,0.206)
Mesic hemlock	290	0.041	2	2	0.049	(-0.029,0.127)
Pine	2917	0.414	25	17	0.610	(0.433,0.787)
Oak-hickory	3166	0.450	10	18	0.244	(0.088,0.400)
Total	7039					

[a]See methods for description of forest cover types.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 41-4).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

Table 9. Utilization of forest cover types in summer by 21 black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	38	32	0.113	(0.072,0.153)
Mesic hemlock	290	0.041	6	14	0.018	(0.001,0.035)
Pine	2917	0.414	205	139	0.612	(0.550,0.674)
Oak-hickory	3166	0.450	86	151	0.257	(0.201,0.312)
Total	7039		335	336		

[a]See methods for description of forest cover type.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 335=32).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

Table 10. Utilization of forest cover types in fall by 21 black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	53	42	0.120	(0.084,0.156)
Mesic hemlock	290	0.041	15	18	0.034	(0.014,0.054)
Pine	2917	0.414	198	183	0.448	(0.393,0.503)
Oak-hickory	3166	0.450	176	199	0.398	(0.344,0.452)
Total	7039		442	442		

[a]See methods for description of forest cover types.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 442=42).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

Table 11. Utilization of forest cover types by 15 subadult black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	47	48	0.093	(0.063,0.123)
Mesic hemlock	290	0.041	12	21	0.024	(0.008,0.040)
Pine	2917	0.414	272	210	0.535	(0.483,0.586)
Oak-hickory	3166	0.450	177	229	0.348	(0.299,0.397)
Total	7039		508	508		

[a]See methods for description of forest cover types.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 508=48).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

Table 12. Utilization of forest cover types by 6 adult black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	42	26	0.156	(0.105,0.207)
Mesic hemlock	290	0.041	9	11	0.033	(0.007,0.058)
Pine	2917	0.414	140	112	0.519	(0.448,0.594)
Oak-hickory	3166	0.450	79	122	0.293	(0.228,0.357)
Total	7039		270	271		

[a]See methods for description of forest cover types.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 270=26).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

Table 13. Utilization of forest cover types by 12 male black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	31	33	0.088	(0.053,0.123)
Mesic hemlock	290	0.041	10	14	0.028	(0.007,0.048)
Pine	2917	0.414	188	145	0.536	(0.474,0.598)
Oak-hickory	3166	0.450	122	158	0.348	(0.289,0.407)
Total	7039		351	350		

[a]See methods for description of forest cover types.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 351=33).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

Table 14. Utilization of forest cover types by 9 female black bears in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
Cove hardwoods	666	0.095	57	41	0.133	(0.095,0.171)
Mesic hemlock	290	0.041	11	18	0.026	(0.008,0.048)
Pine	2917	0.414	224	178	0.522	(0.465,0.578)
Oak-hickory	3166	0.450	137	193	0.319	(0.266,0.371)
Total	7039		429	430		

[a]See methods for description of forest cover types.

[b]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[c]Calculated by multiplying proportion of total area x total locations (i.e., 0.095 x 429=41).

[d]90% simultaneous, 97.5% individual (Neu et al. 1974).

availability (Table 9). Again locations in the pine type accounted for 61% of the radio-locations. Chi-square goodness of fits indicated a differential use of types in the fall ($P<0.10$); however, individual confidence limits did not indi-ate which types were preferred or avoided (Table 10), although the pine type was used less than in spring or summer and the oak-hickory was used more. Chi-square independence tests also indicated a differential use ($P<0.10$) of cover types among the seasons.

Independence chi-square indicated that adults and subadults exhibited different preferences of forest cover types ($P<0.10$, Tables 11-12). Subadults preferred the pine types ($P<0.10$) and used mesic hemlock and oak-hickory less frequently ($P<0.10$, Table 11), whereas adults preferred cove hardwoods and pine type ($P<0.10$) and used oak-hickory less frequently (Table 12). However, adults and subadults were primarily located in the pine and oak-hickory types.

Differential use of forest cover types was not significant ($P>0.10$) between males and females (Tables 13-14). Both sexes, individually, exhibited preference for certain types ($P<0.10$) with pine type preferred and the oak-hickory type used less (Tables 13-14). Females may prefer cove hardwoods as it was a borderline situation.

In CNF, bears utilized all forest cover types; however, some types were used more than others. On a percentage basis most locations were in the pine or oak-hickory types. The pine type appears important to bears in CNF. Huckleberries (Gaylussacia sp.) and blueberries (Vaccinium sp.) comprise most of the bear's diet in summer (Eagle 1979) and these species are commonly associated with pine types (Shanks 1954b, USFS 1976). Pine types generally have a well developed shrub layer which can provide cover for bears while feeding. Lindzey and Meslow (1977) noted the importance of the juxtaposition of food and cover to bears in Washington. Pine types may also provide sources of acorns for bears in fall. Large oaks, left as cull trees when the area was logged, were noted in most pine types (pers. obser.) especially at higher or more inaccessible locations. Also in CNF bears denned primarily in large oak trees located in pine types. In 1978, 5 of 6 females denned in oak trees in pine types and 1 denned in oak-hickory type. The pine type may provide important summer food sources, denning areas, as well as complement the oak-hickory type with sources of acorns.

Conversely, the oak-hickory type was used less than expected based on its availability, except during fall when it was used in proportion to its availability. Overall, however, 25-40% of radio-locations were in this type. Several reasons may account for the lower utilization of this type in CNF than reported in other studies (Beeman 1975, Garshelis 1978). Although 45% of the IMGRID study area is oak-hickory, some of this is not mast producing age or size. In addition, areas of oak mast in CNF appear to be dispersed (pers. obser.) and the pine type provides sources of mast for bears (pers. obser.). Bears in CNF exhibited increased nocturnal activity in fall (Fig. 5, page 37) which may be related to foraging activity. This was also documented for bears in GSMNP (Garshelis 1978). Because bears may feed more at night during fall and radio-tracking was conducted primarily during daylight hours, the results may be biased.

The oak-hickory type provides sources of acorns for bears, which are the primary food item in bear's diet in fall (Eagle 1979). Beeman (1975) found that bears in GSMNP preferred the closed type in fall. Garshelis and Pelton (1981) noted that male bears (primarily adult males) moved to areas of abundant oaks in fall in GSMNP.

Both cove hardwoods and mesic hemlock were used generally in proportion to their availability. Most of the forest cover types which comprise the cove hardwood and mesic hemlock types do not offer much foraging opportunities for bears in CNF. However, some of the cove hardwood types may be locally important to bears and availability of dens in these types should be good. In GSMNP, many tree dens are located in hemlock and cove hardwoods associations (Johnson 1978).

Many factors influence the utilization or choice of habitats by bears; however, the clues by which bears recognize "good habitat" are largely unknown. Bears probably recognize the spatial distribution of food sources and, by experience, return to areas which they have associated with food in the past. Herrstein (1971) demonstrated that positive reinforcement influences the behavior of animals and prompts them to repeat the experience. Rogers (1977) documented that bears in Minnesota moved out of their home ranges more frequently when food is more abundant outside of these areas. Beeman and Pelton (1980) also noted increased movements of bears, mainly males, out of GSMNP during years of food scarcity.

Learning probably plays an important role in locating food sources. Rogers (1977) found that female bears with an extraterritorial knowledge of food sources had higher reproductive success, especially in years of scarce food, than females who did not exploit other food sources. Also females with tendencies to roam had offspring with similar tendencies. Nelson and Mech (1981) have suggested that learning by deer played an important role in migration patterns and affinity for certain areas, especially when predation by wolves (*Canis lupus*) is considered. Deer prefer familiar areas, where they are less vulnerable to predation, to areas of "better habitat."

Thus, many interacting factors influence habitat utilization by bears. The distribution, abundance, phenology, and quality of the food supply have been shown to influence population density, dispersion, reproduction, and social behaviour of black bears (Rogers 1976, Amstrup and Beecham 1976, Beeman and Pelton 1980, Lindzey and Meslow 1977, Landers et al. 1979) and therefore are important in determining habitat utilization. Diversity of cover types or alternate food sources has also been documented as important to bears (Jonkel and Cowan 1971, Rogers 1977, Landers et al. 1979). In CNF bears were located primarily in areas that provided foraging, breeding, and denning opportunities while subject to the constraints imposed by social interactions and human-related disturbances. Any major change in human-related activity or land modification may have adverse effects on the bear population in the area.

Relationship of Bears to Roads

Accessibility of bears to human activities is an important factor in maintaining viable bear populations in an area (McIlroy 1972, Miller 1975, Hamilton 1978, Landers et al. 1979, Brown 1980). My experience in the study area suggested that all types of access (public access roads, 4-wheel drive roads, gated roads and trails) influenced bears in some way. Therefore, all types of access roads were considered in analyzing the relationship of bears to roads in the IMGRID study area.

Overall, chi-square analysis indicated a significant difference (P<0.10, Table 15) in the proximity of bears to roads. It appears that bears were located less than expected near a road (<0.10 km from road) and more than expected further from roads (>0.10 km from road). Although the confidence intervals were not significant (P>0.10), they were borderline cases for both of the categories. Approximately 11% of locations were less than 0.1 km from roads and 89% were greater than 0.1 km from roads. Both Miller (1975) and Brown (1980) reported similar results for bears in West Virginia.

On a seasonal basis, no significant differences (P>0.10) were noted in the proximity of bears to roads during spring or summer (Tables 16-18). However, in fall bears were located less than expected (P<0.10) close to roads and more than expected further from roads (P<0.10, Table 18). Hamilton (1978) also reported that bears avoided roads during fall in North Carolina.

Adults and subadults exhibited no preference or avoidance of roads (P 0.10, Tables 19-20). Males and females, however, did exhibit

Table 15. Proximity of 21 black bears to roads in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
<0.1 km from roads	940	0.132	87	103	0.111	(0.089,0.133)
>0.1 km from roads	6161	0.868	697	681	0.889	(0.867,0.911)
Total	7101		784	784		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 784=103).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

Table 16. Proximity of 21 black bears to roads in spring in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
<0.1 km from roads	940	0.132	5	6	0.119	(0.021,0.219)
>0.1 km from roads	6161	0.868	37	36	0.881	(0.783,0.979)
Total	7101		42	42		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 42=6).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

Table 17. Proximity of 21 black bears to roads in summer in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
<0.1 km from roads	940	0.132	42	44	0.125	(0.090,0.160)
>0.1 km from roads	6161	0.868	293	291	0.875	(0.840,0.910)
Total	7101		335	335		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 335=44).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

Table 18. Proximity of 21 black bears to roads in fall in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
< 0.1 km from roads	940	0.132	43	59	0.096	(0.069,0.123)
> 0.1 km from roads	6161	0.868	403	387	0.904	(0.877,0.931)
Total	7101		446	446		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 446=59).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

Table 19. Proximity of 6 adult black bears to roads in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
<0.1 km from roads	940	0.132	28	36	0.103	(0.067,0.139)
>0.1 km from roads	6161	0.868	243	235	0.897	(0.861,0.933)
Total	7101		271	271		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 271=36).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

Table 20. Proximity of 15 subadult black bears to roads in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
<0.1 km from roads	940	0.132	60	67	0.117	(0.089,0.145)
>0.1 km from roads	6161	0.868	451	444	0.883	(0.855,0.911)
Total	7101		511	511		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 511=67).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

differences in relation to proximity of roads. Females preferred to be further from roads ($P<0.10$); males exhibited no preference or avoidance of roads ($P>0.10$, Tables 21-22). Brown (1980) found that female bears were more tolerant of roads than males.

As indicated in Tables 15-22 (pages 83-88, 90-91), 940 ha in the IMGRID study area have some type of road. This includes public access, 4-wheel drive, logging roads, and trails. Many logging roads were not on USGS maps and therefore were not recorded. Computer-generated maps of the IMGRID study area (7,100 ha) revealed that only 150 ha are greater than 1 km from some type of road. Most of CNF is accessible by vehicle or foot.

Use of roads (or proximity to roads) by bears is influenced by cover and food sources along the road, bear density, social interactions, human traffic along the road, and learning. Bears may learn to use or avoid roads based on the positive or negative reinforcements associated with roads. In some situations bears are attracted to roads. In some national parks the behavior and distribution of bears is influenced by artificial food sources along roads and trails. The positive reinforcement due to attractive food sources and the protection afforded to bears in parks has enabled the behavior of panhandling to develop in some individuals (Harms 1977, Tate 1981).

However in areas where bears are hunted, Miller (1975), Hamilton (1978), and Brown (1980) have documented that bears generally avoid roads, especially hard-surface roads, probably due to human-related activities associated with roads. This also appears true in CNF. No bears ($n=21$) were documented crossing the Tellico-Robbinsville road

Table 21. Proximity of 12 male black bears to roads in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
<0.1 km from roads	940	0.132	44	46	0.125	(0.090,0.160)
>0.1 km from roads	6161	0.868	308	306	0.875	(0.840,0.910)
Total	7101		352	352		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 352=46).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

Table 22. Proximity of 9 female black bears to roads in CNF, 1978-1979.

Forest cover type[a]	Total area (ha)	Proportion of total area[b]	# locations in type	# expected in type	Proportion of locations in type	Confidence interval[d]
<0.1 km from road	940	0.132	43	57	0.100	(0.072,0.128)
>0.1 km from road	6161	0.868	389	375	0.900	(0.872,0.928)
Total	7101		432	432		

[a]Proportion of total area represents expected bear locations as if bears occurred in each type in proportion to its availability.

[b]Calculated by multiplying proportion of total area x total locations (i.e., 0.132 x 432=57).

[c]90% simultaneous, 95% individual (Neu et al. 1974).

and generally, bears either avoided roads or used roads in proportion to their availability in the area.

Accessibility of bears to hunters is an important factor in determining hunter success. In Alaska, bears feeding in more accessible tidal marshes were more vulnerable to hunters (McIlroy 1972). In CNF roads appear important in determining hunter success. The 4 instrumented bears killed in the study area during the Tennessee statewide hunts were within 0.5 km from roads. Bear 337 was located approximately 0.2 km from a paved road prior to being shot in the hunts. Although many factors interact to affect the vulnerability of bears to hunters, accessibility appears to be an important factor in east Tennessee.

Relationship to Elevation

In CNF, bears were not located at significantly different ($P>0.05$) elevations seasonally (Fig. 13). In GSMNP, Beeman (1975) found that bears did not use different elevations seasonally; whereas, Garshelis (1978) found that bears were located at lower elevations in fall, presumably due to a greater abundance of oaks at lower altitudes. In the mountains of the western U.S., bears are generally located at higher elevations in summer and fall, depending on seasonal food availability and the phenological development of food plants and snowmelt (Amstrup and Beecham 1976, Novick 1979). In southern California, bears used higher elevations on southern exposures than on northern ones (Novick 1979). In CNF, sources of both summer foods (berries) and fall foods (acorns) occur generally at mid- to upper

Figure 13. Mean, standard deviation, and range of elevation (m) at which 21 radio-collared black bears were located in Cherokee National Forest 1978-1979. Means are not significantly different ($P>0.05$). Sample sizes within each category were: spring=42, summer-335, fall=445.

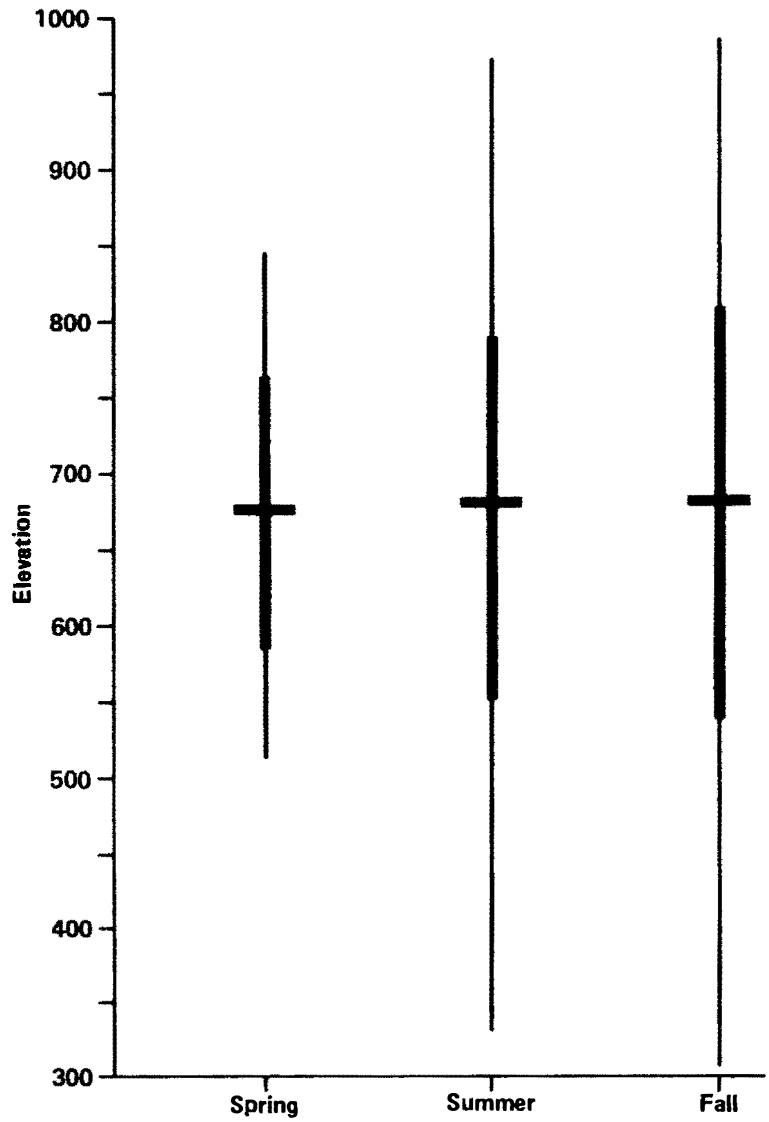

1000
900
800
700
600
500
400
300
Elevation
Spring
Summer
Fall

Figure 13

elevations (pers. obser.). The elevation range for the CNF study area (274-1,158 m) is less than the study area in GSMNP (approximately 400-1,500 m, Garshelis 1978). Therefore bears may not have to move as far with respect to elevation in CNF.

However, differential use of elevations by bears ($P<0.05$) was observed between age and sex groups with adults and males, respectively utilizing higher elevations (Figs. 14-15). Garshelis (1978) found that males used lower elevations than females during fall which substantiated their use of prime feeding areas. In CNF this also appears true. Food sources for bears tend to be distributed at the higher, more inaccessible, locations (pers. obser.). Also roads are generally located near creeks in the lower elevations. Males and adult bears may compete successfully for these "better" areas of habitat over females and subadults.

Bears in CNF used the upper portions of the ridge systems in their home ranges regardless of the elevation. The Cowcamp ridge system is higher ($\bar{X}$ approx. 670 m) than the west slope of Salt Spring Mountain ($\bar{x}$ approx. 480 m); however, bears in both areas were located in the upper portions of the respective ridge systems. This supports the conjecture that the more favorable habitat for bears is located in the upper portions of respective ridge systems. Also the upper portions of ridge systems tend to be more remote and supports the hypothesis that bears prefer areas of remote terrain.

Figure 14. Means, standard deviations, and ranges of elevation (m) at which 12 male and 9 female black bears were located in Cherokee National Forest 1978-1979. Sample sizes were: male=347, female=432. Means are significantly different (P>0.05).

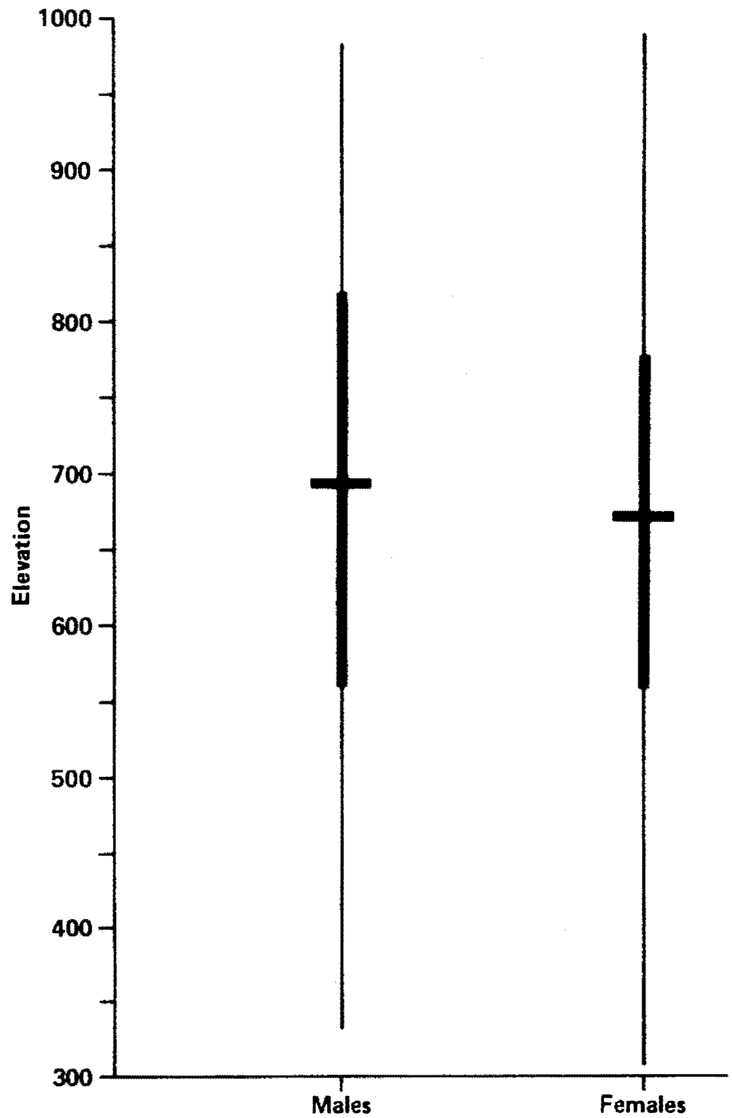


Figure 14

Figure 15. Means, standard deviations, and ranges of elevations (m) at which 6 adult and 15 subadult black bears were located in Cherokee National Forest 1978-1979. Sample sizes were: adults=270, subadults=506. Means were significantly different ($P>0.05$).

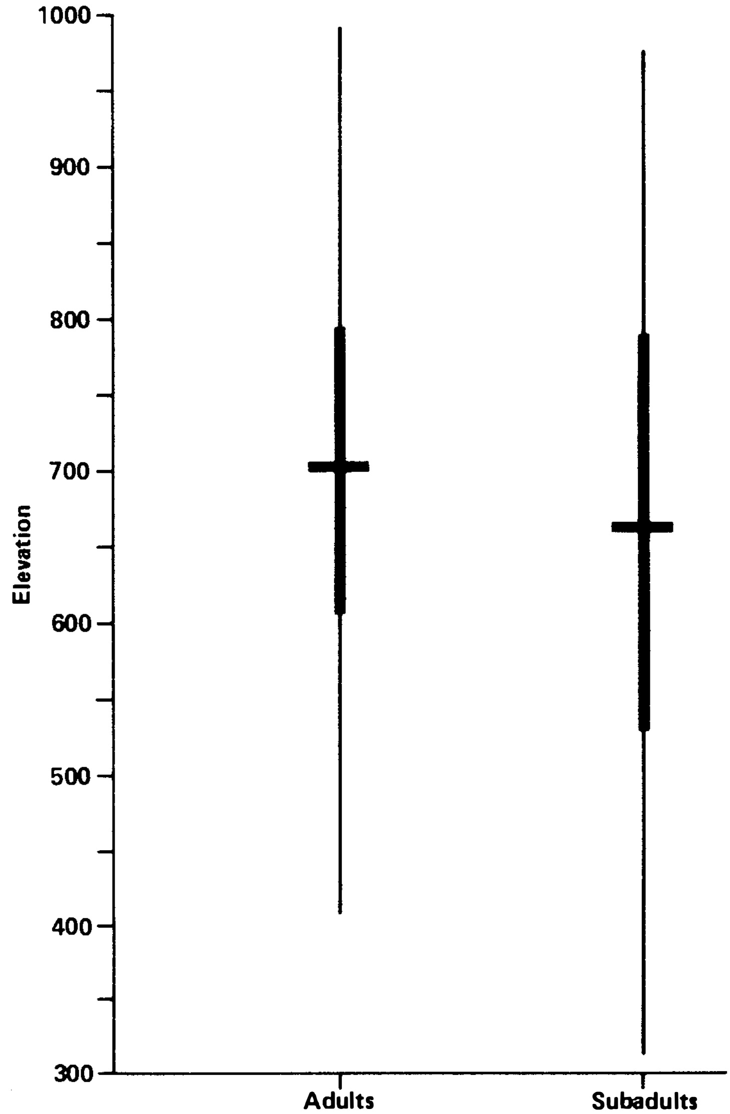


Figure 15

Evaluation of IMGRID

Design and capabilities of IMGRID. The IMGRID computer system was developed initially at Harvard University as a teaching tool (Sinton 1976). Subsequently other capabilities were incorporated into IMGRID version 3.5 (Holmes and Jolly 1980). The system was designed to assist land-use planners in evaluating the physical, biological, cultural, and economic resources of an area. The information generated using IMGRID is similar to that obtained with overlay maps (Crozier et al. 1976). However, as land area increases in size, complexity, and land-use potential, computer-assisted techniques become more practical (Beeman 1977). The IMGRID system is user-oriented and it allows for site-specific interpretations of resource data.

Any geographically-referenced data is inputed into the computer system. Each mutually-exclusive set of data (i.e., forest cover type) is encoded into a grid cell format for input into the system (Appendix I). IMGRID is used to store and retrieve geographically-referenced information. These data are updated easily by individual grid cells, by row of grid cells, or by an entire element. This capability is useful for updating of documenting land-use changes (i.e., clearcuts).

Data analysis usually consists of restructuring data, locating coincidence and proximity of resources, and using mathematical functions (i.e., addition, multiplication). Data encoded into the system are usually nominal scale; however, it can be rescaled to ordinal (i.e., assign a higher value to mast-producing hardwoods when evaluating an area for fall food sources for bears). Data are combined to locate the coincidence of different resources (i.e., forest cover types and locations of animals obtained with telemetry are overlaid to determine which forest cover type the animals are using). The spatial relationship of different resources can be determined (i.e., proximity of animal locations obtained with telemetry to roads). Finally various mathematical functions can be performed on the data. For example, in a model predicting areas of mast production, areas with older mast producing trees are given a higher value than areas of younger trees. Thus a weighting of different factors is incorporated into the model.

The computer is used to create maps of the analysis or of the data stored in the system. For example, forest cover type data is displayed alone or the coincidence of forest cover types and animal locations can be mapped. Thus only relevant information from any analysis is displayed. Textual information and a histogram which summarizes the frequency of each item on the map is also displayed.

Comparison of techniques of habitat evaluation. Many techniques in habitat utilization-availability studies involve the categorization of animal locations (obtained through radio-telemetry, visual observation capture-recapture) into various habitat components (i.e., cover types). Then, the observed distribution of locations in specific cover types is compared to an "expected" distribution or availability of the specific cover types based on the hypothesis that the animal uses the various types in proportion to availability.

The simplest application of this method involves classifying animal locations into cover types via a habitat map and comparing the proportion of locations in each type to the available area of each type. A good habitat map is essential for this process. Jonkel and Cowan (1971), Hardy (1974), Lindzey and Meslow (1977), Landers et al. (1979), and Novick (1979) have documented availability and utilization of forest cover types by black bears using this method. In a similar manner, Nichols and Warner (1972) and Gilmer et al. (1973) have used digitized habitat maps to determine availability and use of cover types by barred owls (*Strix varia*) and mallards (*Anas platyrhynchos*), respectively. If good habitat maps are not available, a non-mapping technique (Marcum and Loftsgaarden 1980) can determine the availability of the various habitat components. This technique is especially useful in inaccessible terrain and when a diversity of habitat components makes delineation of the types difficult. The main advantage of these techniques is their ease of application, especially when a small number of variables are considered. Also, more powerful statistical techniques such as ANOVA can be easily incorporated into the design of these studies.

However, as land uses increase in size and complexity, computer-assisted techniques become more practical. These techniques enable storage and retrieval of quantitative information on the proximity and coincidence of resources. Beeman (1977), Wilcott and Gates (1977), Davis (1980) and Exum (1981) have demonstrated the uses of computer-assisted geographic information systems in wildlife and land-use planning. Beeman (1977) and Exum (1981) have demonstrated the use of 1 technique, IMGRID, in evaluation of wildlife habitat.

Computer techniques yield the same information (utilization-availability data) as do the more traditional methods. However, once important habitat parameters are delineated, models can be devised to determine the juxtaposition of these habitats and their relative importance to each other. Thus techniques such as IMGRID serve as inventory systems with broad management implications.

The choice of an appropriate technique depends on the objectives of the project. The availability-utilization data obtained in this study could have been obtained easier and faster (IMGRID is time-consuming) with the non-mapping technique (Marcum and Loftsgaarden 1980). However, for long-term projects with many habitat variables to consider and when decisions regarding alternative land uses are desired, the value of IMGRID becomes evident.

CHAPTER V

MANAGEMENT CONSIDERATIONS

The Cherokee National Forest is administered and managed for its outdoor recreation, range, timber, watershed, and wildlife resources. The wildlife resources are managed in cooperation with the Tennessee Wildlife Resources Agency. These competing land uses and administrative policies may be beneficial, detrimental, or have no influence on the black bear population inhabiting the region.

Rogers (1976, 1977) felt that the density of bears in Minnesota is limited by human-caused mortality, starvation, and reproductive failures all of which depend on the distribution and abundance of food sources. In CNF, these factors also appear important in regulating bear numbers. Although no radio-collared bears were killed in 1978, 5 were killed legally in 1979. No radio-collared bears were killed illegally during the study although poaching of bears in and around the Tellico Bear Sanctuary was documented (R. H. Conley, Tennessee Wildlife Resources Agency, pers. comm.) during the study. Foods utilized by bears were more abundant in 1979 than 1978 (pers. obser.) and reproductive success appeared higher in 1979 (Eiler 1981).

In CNF bears used primarily the pine and oak-hickory forest types. These types provided the foods necessary for bears seasonally. Also, past logging practices tended to leave large, cull trees at the higher, more inaccessible elevations in the forest types which bears used as dens (Johnson and Pelton 1981). In certain situations or areas logging may be beneficial to bears (Rogers 1976, Lindzey and Meslow 1977). However, the size, shape, and juxtaposition of clearcuts or other timber removal and reproduction systems influence the magnitude of beneficial or detrimental effects on bears inhabiting the area. Shrub-borne mast producing species should be encouraged during the regeneration period and subsequently in the understory after establishment of the overstory (in ecological situations which support these species) to provide for summer foods for bears. The conversion of large acreages to white pine type will likely be detrimental to bears as indicated by the low utilization of the cove hardwood and mesic hemlock types (primarily white pine). These types provide little food or denning opportunities for bears in CNF. The oak-hickory type provides important food energy sources for bears prior to the denning period. Fall food shortages are important in determining reproductive success of females (Eiler 1981) and bear mortality due to increased movements and interactions with humans (Beeman and Pelton 1980). Although weather factors largely influence mast failures (Strickland 1972), species composition and distribution, of red and white oaks mainly, is important in minimizing the effect of mast failures on wildlife (Beck 1977). In CNF the availability of den trees is unknown; however, in the Tellico Bear Sanctuary their availability may be suitable for the current population level (11 of 12 dens located with radiotelemetry were tree dens). These trees appear important in sustaining viable bear populations (Johnson and Pelton 1981) and should be maintained when possible.

Remote, inaccessible areas are important as escape cover for bears (Landers et al. 1979) and affect the vulnerability of bears to hunters (McIlroy 1972). Roads can affect bear movements (Miller 1975, Brown 1980) and in CNF may restrict bear movements. Male bears, especially subadults, moved primarily to the Joyce Kilmer-Slickrock areas. However, radio-collared bears were documented crossing Highway 129 and Little Tennessee Rivers to the Slickrock and Citico areas but not the reverse. The GSMNP may act as a reservoir to areas along the periphery of the Park. In addition, data collected in this study indicate that the Tellico Bear Sanctuary supports a viable population of bears. It appears that the sanctuary is providing refuge for a breeding nucleus of females while allowing for dispersal of subadults into surrounding areas (Appendixes E and H). The bear sanctuary concept is a valuable management policy, especially in areas of dwindling bear habitat.

It is common knowledge in the Tellico area that more bears inhabit the Citico drainage than the Tellico drainage. The Tellico drainage is more intensively managed and used, both commercially and recreationally, than the Citico drainage. Whether biotic factors (food or den availability) or increased bear mortality due to increased accessibility and use is reducing the bear population as compared to Citico is unknown. More comparative research is needed to determine these factors and to further the integration of bear management policies and practices with competing land uses.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. This study was conducted from June 1978 to December 1979 in the Citico Creek drainage of the Tellico Ranger District, Cherokee National Forest. Objectives of this study were to determine habitat utilization, movement and activity patterns of black bears in CNF.

2. In 2 seasons of trapping 28 (16 males and 12 females) different bears were captured 45 times. Radio-collars were attached to 22 bears which were radio-tracked periods ranging from 1 day to 531 days. Five instrumented bears were killed during the 1979 Tennessee and North Carolina bear hunts.

3. Reset motion sensors provided a reliable measure of activity patterns of bears.

4. Factors affecting activity included time of year, time of day, individual variation among bears, and temperature.

5. Activity increased rapidly after bears emerged from dens, reached a peak in August, and declined to a low level prior to denning.

6. Bears exhibited crepuscular activity pattern; however, this was modified seasonally. The level of activity was higher during the day in summer and higher at night in fall.

7. Weather factors were not well correlated with activity of black bears. Temperature exhibited a significant influence on activity; activity was depressed below 10° C and above 25° C depending on the season.

8. Females with cubs were the most active sex-age group.

9. Home ranges of male bears were significantly larger than female bears averaging 30.1 km^2 and 11.6 km^2, respectively. Males used significantly larger ranges than females in spring/summer and fall. The fall ranges of both males and females was significantly larger than areas occupied in spring/summer. Males exhibit less attachment for specific areas and, therefore, roam over larger areas than females. Fall food sources (acorns) in the study area appear more dispersed and bears likely travel further in fall for food.

10. As determined by the convex polygon method, extensive overlap occurred among subadult males, among subadult females, among adult females, and between adult males and adult females. The high overlap of home ranges may indicate the relatedness of bears in the area.

11. Females exhibited smaller values of total daily movement, net daily movement, and daily range length than males during spring/summer and fall. Mean hourly rates of travel were similar for males and females in spring/summer and fall.

12. Locational data indicated bears rarely moved outside the study area and more precisely, the Tellico Bear Sanctuary bears not in the study area generally moved eastward to the Joyce Kilmer-Slickrock area of Nantahala National Forest, North Carolina. These movements by subadult males probably reflect exploratory or dispersal behavior by these individuals. No bears were documented moving to GSMNP.

13. Trapping, reproductive, and movement data collected during the study indicate that the Tellico Bear Sanctuary supports a viable

population of bears and provides refuge for a breeding nucleus of females while allowing for dispersal of subadults into surrounding areas.

14. The IMGRID computer system was used to determine habitat utilization by black bears. The system can store, retrieve, and update geographically-referenced information, restructure data, locate the coincidence and proximity of resources, and perform mathematical functions.

15. Overall chi-square analysis indicated differential use of cover types by bears. Using the Bonferroni method to determine preference, the pine type was used more than expected; mesic hemlock and oak-hickory were used less than expected and cove hardwood used in proportion to its availability.

16. Use of cover types by bears changed seasonally. However, pine was the preferred type in all seasons and oak-hickory was used more in the fall than in any other season.

17. The pine type appears important to bears in CNF; it provides important summer food sources, denning areas, as well as complementing the oak-hickory type with sources for acorns.

18. Overall chi-square analysis indicated a significant difference in the proximity of bears to roads. Preference or avoidance could not be determined although bears tended to be further from roads. During the fall bears were located further from roads. Females also preferred to be further from roads. Accessibility appears to be an important factor affecting vulnerability of bears to hunting in east Tennessee.

Although roads within the study area were not a barrier to bear movements, roads may appear to restrict bear movements, especially that of females. No bears were observed crossing the Tellico-Robbinsville road, the only paved road in the study area.

19. Bears were not located at significantly different elevations seasonally. However, adult and male bears were located at significantly higher elevations. This supports the conjecture that more favorable habitat for bears in this area is the upper portions of ridge systems.

20. IMGRID is a satisfactory technique to determine habitat utilization-preference information. It also has the ability to store, retrieve, update, locate coincidence and proximity of resources, devise habitat models, and map the results. However, use of IMGRID can be time-consuming. The value of IMGRID becomes evident in long-term projects with many habitat variables or when decisions regarding alternative land uses are desired.

21. More comparative research is needed in areas of presumed lower bear densities to determine factors limiting bear populations in these areas.

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LITERATURE CITED

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APPENDIXES

APPENDIX A

Table 23. Monthly average maximum and minimum temperatures, Tellico Ranger District, CNF.[a]

Month	Average maximum temperature C (F) 1978	1979	Average minimum temperature C (F) 1978	1979
January	3.2 (37.8)	5.8 (42.5)	-5.5 (22.1)	-2.7 (27.2)
February	7.1 (44.7)	8.8 (47.8)	-3.8 (25.1)	-0.2 (31.6)
March	16.1 (60.9)	19.3 (66.7)	3.1 (37.5)	6.6 (43.8)
April	22.9 (73.2)	20.8 (69.5)	7.7 (45.8)	6.9 (44.4)
May	24.1 (75.3)	24.7 (76.5)	11.8 (53.3)	11.2 (52.1)
June	30.2 (86.3)	27.2 (80.9)	16.2 (61.1)	14.3 (57.1)
July	32.7 (90.9)	27.2 (80.9)	19.3 (66.7)	18.6 (65.4)
August	31.0 (87.8)	28.6 (83.5)	19.2 (66.5)	17.2 (62.9)
September	30.8 (87.4)	24.9 (76.8)	16.2 (61.2)	15.8 (60.5)
October	23.2 (73.7)	20.2 (68.4)	6.6 (43.8)	7.4 (45.3)
November	19.7 (67.4)	14.6 (58.2)	5.7 (42.3)	3.2 (37.7)
December	12.7 (54.8)	10.8 (51.4)	0.3 (32.5)	-0.7 (30.8)

[a]From U.S. Forest Service records at Tellico Plains, Tennessee (elevation 293 m).

Table 24. Monthly total precipitation, Tellico Ranger District, CNF.[a]

Month	Total precipitation in centimeters (inches) 1978	1979
January	12.88 (5.07)	16.81 (6.62)
February	1.45 (0.57)	13.72 (5.40)
March	10.03 (3.95)	16.66 (6.56)
April	14.68 (5.78)	15.77 (6.21)
May	8.28 (3.26)	19.23 (7.57)
June	6.55 (2.58)	10.41 (4.10)
July	10.44 (4.11)	37.87 (14.91)
August	10.24 (4.03)	6.07 (2.39)
September	2.51 (0.99)	12.90 (5.08)
October	4.98 (1.96)	8.43 (3.32)
November	6.63 (2.61)	22.07 (8.69)
December	16.05 (6.32)	7.04 (2.77)
Annual	104.72 (41.23)	186.69 (73.50)

[a]From U.S. Forest Service records at Tellico Plains, Tennessee (elevation 293 m).

APPENDIX B

Definition and Description of Forest Cover Types on the Tellico Ranger District

A forest type is defined as: "A descriptive term used to group stands of similar character as regards composition and development due to certain ecological factors, by which they may be differentiated from other groups of stands" (Society of American Foresters 1958:91). A cover type is "a forest type now occupying the ground, no implication being conveyed as to whether it is temporary or permanent" (Society of American Foresters 1958:91).

The U.S. Forest Service recognizes 31 forest cover types on the Tellico Ranger District (USFS files, Cleveland, TN). Of these types, 18 are defined by the Society of American Foresters (1954).

1. WHITE PINE--Eastern white pine is pure or predominant. On moist sites in the southern Appalachians, yellow-poplar, hemlock, northern red oak, and white oak are the main associates. On drier sites, chestnut oak, scarlet oak, shortleaf pine, and pitch pine are found. It is found at elevations from 457 m to 1219 m. In the southern Appalachians it occurs on mountain slopes, flats, and valleys varying widely in soil character from sandy to clayey loam and from relatively moist to dry. The type is a long-lived temporary one, usually sub-climax but approaching permanence on sandy soils (Society of American Foresters 1954:13-14).

2. WHITE PINE-HEMLOCK--The type is composed chiefly of eastern white pine and eastern hemlock which are predominant in mixture. The

principal associates are beech, sugar maple, black cherry, basswood, red maple, yellow birch, sweet birch, northern red oak, white oak, yellow-poplar, and cucumbertree. It occurs from 304 m to 1,219 m elevation in Tennessee and North Carolina. The type is found on a wide range of sites from sand plains to heavy upland soils, but favors cool locations, ravines, and north slopes in the southern portion of its range (Society of American Foresters 1954:14).

3. HEMLOCK--Eastern hemlock is pure or predominant over any single associate. Among the associated species are beech, sugar maple, northern red oak, and white oak. It occurs at elevations up to 1,524 m. It prefers cool locations, moist ravines and north slopes. The type is considered climax, but over long periods tends to give way to sugar maple (Society of American Foresters 1954:14-15).

4. RED SPRUCE-FRASER FIR--Red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*) are pure and predominant. Associated in the lower altitudinal portions of the type are hemlock, yellow birch, and less frequently beech, sugar maple, yellow buckeye (*Aesculus octandra*), mountain-ash (*Sorbus americana*), and hawthorn (*Crateagus spp.*). The type occurs at elevations over 1,372 m in the southern Appalachians; it is considered climax (Society of American Foresters 1954:15).

5. HEMLOCK-HARDWOOD--This type is considered a variant of the hemlock type (Society of American Foresters 1954:15).

6. WHITE PINE-COVE HARDWOOD--This type is not defined by the Society of American Foresters (1954).

7. WHITE PINE-UPLAND HARDWOOD--This type is not defined by the Society of American Foresters (1954).

8. SHORTLEAF PINE-OAK--Shortleaf pine predominates, but with oak in mixture. The oaks in the type are scarlet, black, post, and southern red oak. It occurs on the plateaus and foothills of the Appalachian region, but not ascending above 610 m. The type is a transition between shortleaf pine and the hardwood climax (Society of American Foresters 1954:26-27).

9. PITCH PINE-OAK--This type is not defined by the Society of American Foresters (1954).

10. VIRGINIA PINE-OAK--This type is not defined by the Society of American Foresters (1954).

11. LOBLOLLY PINE--Loblolly pine (*P. taeda*) is pure or predominant. Sweetgum (*Liquidambar styraciflua*) is a characteristic associate (Society of American Foresters 1954:28).

12. SHORTLEAF PINE--Shortleaf pine is pure or predominant. Its chief hardwood associates are white oak, southern red oak, scarlet oak, and black oak. In the southern Appalachians it occurs below 732 m. In the mountains the shortleaf pine type occupies low, well-drained ridges to rocky, dry slopes and better drained spur ridges on north slopes (Society of American Foresters 1954:26).

13. VIRGINIA PINE--Virginia pine is pure or predominant. Principal associates are shortleaf pine, white oak, chestnut oak, southern red oak, black oak, sweetgum, red gum, and black gum. It occurs below 610 m in the Appalachians. The type is temporary and is succeeded by shortleaf pine and various hardwoods (Society of American Foresters 1954:27).

14. POND PINE--Pond pine (*P. serotina*) is pure or predominant; it is climax for the site (Society of American Foresters 1954:31-32).

15. PITCH PINE--Pitch pine is pure or predominant. Chief associates are chestnut and scarlet oaks; minor ones include Table-mountain pine, black oak and blackgum. This type occupies relatively infertile ridges, dry flats, and slopes. Sites range from dry to poorly drained. Pitch pine is a temporary type, resulting from fire, in the absence of which hardwoods will gradually become predominant (Society of American Foresters 1954:20).

16. TABLE-MOUNTAIN PINE--This type is not defined by the Society of American Foresters (1954).

17. COVE HARDWOOD-WHITE PINE-HEMLOCK--This type is not defined by the Society of American Foresters (1954).

18. UPLAND HARDWOOD-WHITE PINE--This type is not defined by the Society of American Foresters (1954).

19. SOUTHERN RED OAK-YELLOW PINE--This type is not defined by the Society of American Foresters (1954).

20. CHESTNUT OAK-SCARLET OAK-YELLOW PINE--This type is not defined by the Society of American Foresters (1954).

21. BOTTOMLAND HARDWOOD-YELLOW PINE--This type is not defined by the Society of American Foresters (1954).

22. WHITE OAK-BLACK OAK-YELLOW PINE--This type is not defined by the Society of American Foresters (1954).

23. NORTHERN RED OAK-HICKORY-YELLOW PINE--This type is not defined by the Society of American Foresters (1954).

24. YELLOW-POPLAR--Yellow-poplar is pure or predominant. Associated are black locust (Robinia pseudoacacia), red maple, sweet birch, northern red oak, cucumbertree, sweetgum, and other moist site species. It occurs up to elevations up to 1,219 m in the southern Appalachians. Usually in small scattered stands, the type occupies lower slopes, northerly slopes, moist coves, and flats (Society of American Foresters 1954:23).

25. CHESTNUT OAK--Chestnut oak is pure or predominant. The common associates are scarlet oak, black oak, white oak, post oak, pitch pine, blackgum, sweetgum, and red maple. It occurs at elevations of 457 m to 1,219 m. In the mountains it occupies narrow strips along ridges and warm aspects. The type is permanent in some localities, but it frequently follows fire and clearcutting in types containing a mixture of red and chestnut oaks (Society of American Foresters 1954:20).

26. WHITE OAK-RED OAK-HICKORY--White oak, northern red oak, and hickory predominate. There are many other combinations of oaks, hickories, and other hardwoods in association and these vary from place to place. This type is climax in the central and southern portion of its range (Society of American Foresters 1954:21-22).

27. NORTHERN RED OAK--Northern red oak is pure or predominant. Associates are black oak, scarlet oak, chestnut oak, and yellow-poplar. It occurs at elevations of 914 m to 1,676 m on ridge crests and north slopes (Society of American Foresters 1954:22).

28. YELLOW POPLAR-WHITE OAK-NORTHERN RED OAK--Yellow-poplar, white oak, and northern red oak predominate. Associated are black oak,

hemlock, blackgum, and other moist site species; also hickories occur on drier sites. The type occurs in the southern Appalachians between altitudes of 152 m and 1,219 m on northerly slopes, coves, and moist flats (Society of American Foresters 1954:23).

29. SWEETGUM-YELLOW POPLAR--Sweetgum and yellow-poplar predominate. Associates are red maple, white ash (F. americana), green ash (F. pennsylvanica) and other moist site species. Moisture conditions limit the type to lower slopes and limit its occurrence to belts between stream swamps and upper slopes (Society of American Foresters 1954:29).

30. SCARLET OAK--Scarlet oak predominates, but black oak and southern red oak are coordinate associates. Other associates are chestnut oak, white oak, post oak, hickories, pitch pine, blackgum, sweetgum, black locust, sourwood (Oxydendrum arboreum), flowering dogwood (Cornus florida), with occasional shortleaf and Virginia pine. It occurs below 914 m on dry ridges, south or west-facing slopes (Society of American Foresters 1954:19).

31. SUGAR MAPLE-BEECH-YELLOW BIRCH--Sugar maple, beech, and yellow birch are the component species. Associated are various mixtures of basswood, red maple, hemlock, northern red oak, white ash, white pine, black cherry, yellow buckeye, and cucumbertree. In the southern Appalachians it occurs between elevations of 1,067 m and 1,676 m. The type prefers loamy soils of excellent fertility and good moisture conditions; the type is climax (Society of American Foresters 1954:15).

APPENDIX C

Table 25. Age distribution of regulated[a] forest cover types, Tellico Ranger District, CNF.[b]

Forest cover type	# hectares in age class (years)										
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81+	Unclassed	Total
White pine	411	246	0	9	0	118	194	0	0	8	986
W. Pine-Hemlock	0	0	21	0	0	40	20	0	0	0	81
Hemlock	0	0	0	0	0	0	0	0	10	0	10
R. Spruce-F. Fir	0	0	0	0	0	154	0	0	0	0	154
Hemlock-Hardwood	0	0	0	0	26	47	80	21	0	0	174
W. Pine-Cove Hwd.	0	0	0	0	0	51	0	0	0	1	52
W. Pine-Up. Hwd.	14	18	0	0	37	2	98	0	0	0	169
Shortleaf Pine-Oak	0	0	0	0	0	80	162	153	0	0	395
Pitch Pine-Oak	0	0	0	10	204	401	158	154	13	0	940
Virginia Pine-Oak	71	0	0	32	187	164	0	0	0	0	454
Loblolly Pine	0	5	38	0	0	0	0	0	0	0	43
Shortleaf Pine	550	32	62	0	43	471	192	265	0	0	1615
Virginia Pine	1864	502	249	562	1633	3170	86	61	0	0	8127
Pond Pine	0	0	0	0	0	11	0	0	0	0	11
Pitch Pine	255	84	155	230	762	1102	1130	242	70	0	4030
Table-Mtn. Pine	0	0	23	0	14	72	17	0	0	0	126
Cove Hwd.-W. Pine-Hem.	0	14	0	10	0	1011	798	39	34	0	1906
Up. Hwd.-W. Pine	4	0	0	0	10	0	120	0	0	0	134
S. Red Oak-Y. Pine	28	0	0	0	0	0	0	87	0	0	115
Ch. Oak-Sc. Oak-Y. Pine	24	0	0	0	42	171	93	10	0	0	340
Bt. Hwd.-Y. Pine	0	0	0	0	0	7	0	0	0	0	7
W. Oak-B. Oak-Y. Pine	14	0	0	0	77	0	0	0	0	0	91
N. Red Oak-Hick.-Y. Pine	0	0	0	0	270	571	165	8	0	0	1014
Y. Poplar	0	0	0	43	114	397	119	12	0	0	685
Chestnut Oak	0	0	0	57	133	842	98	71	40	0	1241
W. Oak-R. Oak-Hickory	162	54	142	50	1156	3938	2262	1208	14	35	9021
N. Red Oak	0	0	0	0	0	135	18	0	0	0	153

Table 25 (Continued)

Forest cover type	# hectares in age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81+	Unclassed	Total
Y. Poplar-W. Oak-N. Red Oak	131	0	12	161	1036	2892	1558	265	17	0	6072
Sweetgum-Y. Poplar	0	0	0	0	111	0	0	0	0	0	111
Scarlet Oak	0	0	0	43	0	87	93	12	0	0	235
S. Maple-Beech-Y. Birch	10	12	10	64	102	228	45	4	61	0	536
Total	3538	967	712	1271	5957	16162	7506	2612	259	44	29028
Wildlife Openings											46

[a]Regulated is the commercial forest land and its inventory that can contribute to systemic timber production under sustained-yield principles.

[b]From U.S. Forest Service records, Cleveland, TN.

APPENDIX D

Table 26. Annual and seasonal home ranges of 21 black bears in CNF, 1978-1979.

		Age during radio-		Annual home range[a]		Spr/Summer range[c]		Fall home range[d]		
Bear #	Sex	tracking period[f]	tracking period[e]	1978(n)[b]	1979(n)	1978(n)	1979(n)	1978(n)	1979(n)	Fate of radio-collar/bear[g]
303	M	2-3	28 Jun 78-4 Dec 79	11.2(33)	34.8(70)	9.3(27)	2.6(32)	1.9(6)	24.5(38)	Bear killed 26 Dec 79
309	M	3	18 Jun 79-19 Aug 79	-	-	-	9.9(17)	-	-	Bear removed breakaway collar
317	M	1-2	1 Sep 78-4 Dec 79	-	46.8(31)	-	12.3(14)	11.8(15)	44.6(17)	Functioning
324	M	1	3 Mar 79-4 Dec 79	-	37.7(36)	-	2.2(15)	-	43.7(21)	Functioning
325	M	1	3 Mar 79-27 Nov 79	-	31.2(34)	-	21.2(14)	-	21.1(20)	Bear killed 1 Dec 79
328	M	3	28 Jun 79-4 Dec 79	-	16.4(44)	-	1.9(7)	-	16.4(37)	Functioning
334	M	3	5 Jun 79-12 Sep 79	-	-	-	21.4(11)	-	-	Bear removed breakaway collar
337	M	3	15 Jun 79-1 Dec 79	-	52.3(71)	-	9.0(29)	-	51.3(42)	Bear killed 1 Dec 79
Subadult males average				11.2	36.5	9.3	10.1	6.8	33.6	
301	M	6	28 Jun 78-5 Sep 78	-	-	3.2(12)	-	-	-	Bear removed collar
322	M	4	2 Jun 79-7 Dec 79	-	27.4(31)	-	8.0(15)	-	20.0(16)	Functioning
331	M	4	3 Jun 79-7 Aug 79	-	-	-	18.8(12)	-	-	Bear removed breakaway collar
335	M	4	10 Jun 79-7 Dec 79	-	12.8(77)	-	7.2(31)	-	11.1(46)	Functioning
Adult males average				-	20.1	3.2	11.3	-	15.6	
Males average				11.2	32.4	6.3	10.2	6.8	29.1	

Table 26 (Continued)

Bear #	Sex	Age during radio-tracking period[f]	Radio-tracking period[e]	Annual home range[a] 1978(n)[b]	Annual home range[a] 1979(n)	Spr/Summer range[c] 1978(n)	Spr/Summer range[c] 1979(n)	Fall home range[d] 1978(n)	Fall home range[d] 1979(n)	Fate of radio-collar/bear[g]
306	F	3-4	25 Jun 78-8 Dec 79	17.4(49)	8.2(47)	4.8(26)	3.0(18)	16.3(23)	8.3(29)	Functioning
307	F	2-3	25 Jun 78-3 Oct 79	23.4(71)	9.6(66)	1.9(28)	6.8(45)	23.4(43)	5.0(21)	Collar not functioning; bear killed 1 Dec 79
308	F	3	9 Jul 79-14 Dec 78	7.2(35)	-	0.93(5)	-	5.9(30)	-	Bear died 3 Mar 79
316	F	2-3	24 Aug 78-8 Dec 79	10.7(29)	14.1(43)	0.27(5)	9.6(17)	9.8(24)	6.1(26)	Bear removed collar in 1978; reinstrumented 1979
336	F	3	15 Jul 79-15 Aug 79	-	-	-	1.4(17)	-	-	Bear removed breakaway collar
338	F	3	18 Jul 79-3 Nov 79	-	5.0(15)	-	2.6(6)	-	0.98(9)	Bear removed breakaway collar; Bear killed 1 Dec 79
343	F	2	12 Jul 79-9 Dec 79	-	3.2(26)	-	0.35(7)	-	2.8(19)	Functioning
Subadult females average				14.7	8.0	2.0	4.0	13.9	4.6	
305	F	6-7	24 Jun 78-12 Oct 79	22.7(62)	7.5(71)	4.2(25)	5.2(43)	21.9(37)	4.0(28)	Collar not functioning
320	F	7-8	28 Sep 78-8 Dec 79	-	10.1(72)	-	3.1(18)	12.2(13)	10.1(54)	Functioning
Adult females average				22.7	8.8	4.2	4.2	17.1	7.1	
Females average				16.3	8.2	2.4	4.0	15.0	5.3	

Table 26 (Continued)

[a]Home ranges determined by connecting the outermost radio-locations for each animal (convex polygon) and reported in km^2.

[b]Number of radio-locations used in determining home range.

[c]Spr/Summer = March-August.

[d]Fall = September-December.

[e]Date of capture to date of last radio-location.

[f]Age determined by cementum annuli techniques; Adult $\geq$ 4 yrs., subadult $<$ 4 yrs.

[g]Fate as of 1 Jan 81.

APPENDIX E

PREBAITING INFORMATION

Areas were usually prebaited before they were trapped. In 1978 Cowcamp Ridge exhibited the highest bear activity; in 1979, Jake Best Creek had the highest bear activity. A summary of prebait information for 1978 and 1979 is given in Tables 27 and 28.

Table 27. Prebait data for black bears in CNF, 1978.

Area(date)	# Prebait sites	# Bear visits within 5 days	% Utilization within 5 days
Jeffery'Hell (27 May)	9	3	33.3
Cowcamp Ridge (20 June)	10	6	60.0
Flats Mountain (20 June)	14	4	28.6
McIntyre Ridge (17 July)	9	0	0
Hampton Ridge (17 July)	5	0	0
Miller Ridge	16	4	25.0
Totals	63	17	$\bar{x}$=24.5

Table 28. Prebait data for black bears in CNF, 1979.

Area(date)	# Prebait sites	# Bear visits	% Utilization by bears	% Utilization within 5 days
Jake Beat (1 May-5 May)	8	3	37.5	37.5
Cowcamp Ridge (24 May-9 June)	10	4	40.0	20.0
Jake Best (27 June-17 July)	6	5	83.3	50.0
Totals	24	12	$\bar{x}$=53.6	$\bar{x}$=35.8

APPENDIX F

TRAPPING INFORMATION

In 1978, 15 different bears (7 males, 8 females) were captured on the study area; total captures amounted to 22. Bear 307 (F) was captured 3 times; 5 bears were captured twice, 303 (M), 304 (M), 305 (F), 306 (F), and 308 (F) (Tables 29-30). Cowcamp Ridge was the most productive area for trapping; 11 different bears and 5 recaptures were from that area.

Sex and age structure are shown on page 144. The average age for both males and females was 3.8 years.

Three cub bears were donated by the Knoxville Zoo for release in the study area for restoration purposes. Two cubs were tagged; one was not tagged. Both tagged bears were killed illegally.

In 1979 13 different bears (9 males, 4 females) were captured on the study area; total captures amounted to 22. Three bears were captured twice; 322 (M), 335 (M), 337 (M). Six bears captured in 1978 were recaptured; 316 (F), 306 (F), 305 (F), 309 (M), 303 (M), and 307 (F) (Tables 31-32).

Sex and age structure are shown in Table 33. The average age for both males and females was 2.6 years.

In 2 years of trapping on the CNF, 28 different bears were captured (15 in summer 1978, 2 in winter 1978-1979, 11 in summer 1979). Of these 28 bears, 16 were males and 12 were females. Total captures amounted to 45 (22 in summer 1978, 3 in winter 1978-1979, 20 in summer 1979).

Table 29. Areas trapped and trapping success, CNF, 1978.

Area (date)	# Trap Sites	# Trapnights	# Captures Initials	# Captures Recaptures	Trapnights per Initial Capture	Trapnights per Bear
Head of Doublecamp (31 May-10 June)	6	66	1	-	66	66
Jeffery's Hell (31 May-9 June)	5	48	1	-	48	48
Cowcamp Ridge (20 June-30 June)	11	112	5	-	22.4	22.4
Flats Mountain (20 June-26 June)	5	30	-	-	-	-
Cowcamp Ridge (8 July-11 July)	14	41	2	-	20.5	20.5
Hampton Ridge (19 July-24 July)	4	20	-	-	-	-
Miller Ridge (31 July-14 August)	7	103	2	1	51.5	34.3
Cowcamp Ridge (11 August-24 August)	7	90	2	4	45.0	22.5
Cowcamp Ridge (20 August-5 September)	13	104	1	2	104	52.9
Cowcamp Ridge (25 September-7 October)	7	80	1	-	80	80
Totals	79	694	15	7	$\bar{x}$=46.3	$\bar{x}$=31.5

Table 30. Capture data for black bears captured in CNF, 1978.

Date	Capture area	Sex	Age	Weight (kg)	Tattoo	Ear tags	Comments
6 Jun 78	Jeffery's Hell	M	4	64	-	LY163 RY164	Not radiocollared
6 Jun 78	Head of	F	5	53	-	LY167 RY168	Not radiocollared, one cub seen, broken forearm (trap injury)
23 Jun 78	Cowcamp Ridge	M	6	104	301	LY301 RM301	Radiocollar attached, bear removed radiocollar
24 Jun 78	Cowcamp Ridge	F	6	56	305	LM305 RY305	One cub seen, radiocollar attached, recaptured 24 Aug 78
25 Jun 78	Cowcamp Ridge	F	3	42	306	LM306 RY306	Radiocollar attached, recaptured 13 Aug 78
25 Jun 78	Cowcamp Ridge	F	2	38	307	LM307 RY307	Radiocollar attached, recaptured 12 & 31 Aug 78
28 Jun 78	Cowcamp Ridge	M	2	34	303	LY303 RM303	Radiocollar attached, recaptured 31 Aug 78
9 Jul 78	Cowcamp Ridge	F	3	43	308	LM308 RY308	Lactating, no cubs seen, recaptured 16 Aug 78, radiocollar attached, tranquilized 3 Mar 79 in den, died from drug complications
11 Jul 78	Cowcamp Ridge	M	2	36	309	LY309 RM309	Not radiocollared
3 Aug 78	Miller Ridge	M	2	46	304	LM304 RY304	Not radiocollared, recaptured 11 Aug 78
7 Aug 78	Miller Ridge	F	2	34	313	LM313 RY313	Not radiocollared
17 Aug 78	Cowcamp Ridge	M	10	79 (est)	315	LY129 RY315	Radiocollar attached, bear removed radiocollar
24 Aug 78	Cowcamp Ridge	F	2	48	316	LM316 RY316	Radiocollar attached
1 Sep 78	Cowcamp Ridge	M	1	50	317	LY317 RM317	Radiocollar attached
28 Sep 78	Cowcamp Ridge	F	7	83	320	LY320 RM320	Radiocollar attached

Table 31. Areas trapped and trapping success, CNF, 1979.

Area (date)	# Trap sites	# Trap nights	# Visits	# Captures		Trapnights per visit	Trapnights per	
				Initial	Recapture		Initial capture	Bear
Cowcamp Ridge (29 May-12 Jul)	10	406	52	8	9	7.8	50.8	23.9
Jake Best (5-22 Jul)	5	71	4	3	0	17.8	23.7	23.7
Jake Best (30 Jul-3 Aug)	5	20	0	0	0	-	-	-
Jake Best (6-9 Aug)	5	15	0	0	0	-	-	-
Cowcamp Ridge (24-28 Sep)	6	24	0	0	0	-	-	-
Totals	31	536	56	11	9	$\bar{x}$=9.6	$\bar{x}$=48.7	$\bar{x}$=26.8

Table 32. Capture data for black bears captured in CNF, 1979.

Date	Capture area	Sex	Age	Weight (kg)	Tattoo	Ear tags	Comments
3 Mar 79	Cowcamp Ridge	M	1	8	325	LY325 RM325	Offspring of bear 308 breakaway collar attached
3 Mar 79	Cowcamp Ridge	M	1	14	324	LY324 RM324	Offspring of bear 308 breakaway collar attached
2 Jun 79	Cowcamp Ridge	M	4	82	322	LY322 RM322	Radiocollar attached Recaptured 5 Jul 79
3 Jun 79	Cowcamp Ridge	M	4	73	331	LM331 RY331	Breakaway collar attached Bear removed collar
5 Jun 79	Cowcamp Ridge	M	3	45	334	LY334 RM334	Breakaway collar attached Bear removed collar
7 Jun 79	Cowcamp Ridge	F	1	14	326	LM326 RY326	Not radiocollared
8 Jun 79	Cowcamp Ridge	F	3	41	316	LM327 RY327	Recapture from 1978 New radiocollar attached
10 Jun 79	Cowcamp Ridge	M	4	73	335	LY335 RM335	Radiocollar attached Recaptured 14 Jun 79
11 Jun 79	Cowcamp Ridge	F	4	41	306	LM306 RY306	Recapture from 1978
13 Jun 79	Cowcamp Ridge	F	7	51	305	LM305 RY305	Recapture from 1978
15 Jun 79	Cowcamp Ridge	F	3	45	336	LM336 RM336	Breakaway collar attached Bear removed collar
15 Jun 79	Cowcamp Ridge	M	3	52	337	LY337 RM337	Radiocollar attached Recaptured 4 Jul 79
18 Jun 79	Cowcamp Ridge	M	3	49	309	LY309 RM309	Recapture from 1978 Breakaway collar attached Bear removed collar

Table 32 (Continued)

Date	Capture area	Sex	Age	Weight (kg)	Tattoo	Ear tags	Comments
28 Jun 79	Cowcamp Ridge	M	3	52	328	LY328 RM328	Radiocollar attached
29 Jun 79	Cowcamp Ridge	M	3	41	303	LY303 RM303	Recapture from 1978
7 Jul 79	Cowcamp Ridge	F	3	41	307	LM307 RY307	Recapture from 1978
9 Jul 79	Jake Best	M	2	33	332	LY332 RM332	Not radiocollared
12 Jul 79	Jake Best	F	2	36	343	LM343 RM343	Breakaway collar attached
18 Jul 79	Jake Best	F	3	41	338	LM338 RY338	Breakaway collar attached Bear removed collar

Table 33. Sex and age structure of black bears trapped in CNF, 1978-1979.

Age[a] (years)	Number of bears			
	1978		1979	
	Male	Female	Male	Female
1	1		2	1
2	3	3	1	1
3		2	3	2
4	1		3	
5		1		
6	1	1		
7				
8				
9				
10	1			
Total	7	8	9	4

[a]Ages determined by cementum annuli counts and reported as age at last birthday.

APPENDIX G

RADIOTELEMETRY INFORMATION

In 1978, 10 bears were fitted with radio-collars (Table 34). Bear 315 (M) removed its radio-collar after 1 day; the collar was retrieved. One bear 301 (M) left the study area and had not been located since August 1978, even though several aerial searches were conducted. On 2 November 1979, during a managed deer hunt on the Tellico Bear Reserve, a deer hunter found bear 301's radio-collar. The bear had removed the collar, and it was no longer functioning. Also 2 radio-collared bears (P6, F, 452 M) from the GSMNP were released in the study area. Both of these bears were panhandlers and moved back to the Park. In addition, another radio-collared bear (406 M) from the GSMNP moved into the study area for about 2 weeks and then returned to the Park.

In 1979, 12 bears were fitted with radio-collars (10 during the summer trapping session, 2 during a winter immobilization) (Table 34). Bear 308 (F) died from drug complications during a winter immobilization, and her 2 yearlings (324 M, 325 M) were fitted with break-away collars. Six bears, 309 (M), 325 (M), 331 (M), 334 (M), 336 (F), and 338 (F), removed their break-away collars. Also 5 bears, 303 (M), 307 (F), 325 (M), 337 (M), and 338 (F) were killed during legal bear hunts. Bears 325 and 338 had removed their radio-collars previous to being killed. Bear 303 was killed on 26 December 1979 in the Little Santeetlah drainage, North Carolina. The other 4 bears

Table 34. Bear number, radio-tracking period, and sex of radio-collared black bears, CNF, June 1978-December 1979.

Bear #	Period tracked	# Radio locations	Sex	Comments
301	23 Jun 78-5 Sep 78	12	M	Radio-collared Jun 78, Bear removed collar, Collar not functioning
303	28 Jun 78-4 Dec 79	106	M	Radio-collared Jun 78, Bear killed 26 Dec 79, L. Santeetlah Cr., N.C.
305	24 Jun 78-12 Oct 79	134	F	Radio-collared Jun 78, Radio-collar not functioning
306	25 Jun 78-8 Dec 79	98	F	Radio-collared Jun 78
307	25 Jun 78-3 Oct 79	138	F	Radio-collared Jun 78, Bear killed 8 Dec 79, Radio-collar not functioning
308	9 Jul 78-3 Mar 79	37	F	Radio-collared Jul 78, Died 3 Mar 79 in den
309	18 Jun 79-19 Aug 79	17	M	Radio-collared Jun 79, Bear removed collar Aug 79
315	18 Aug 78-21 Aug 79	1	M	Radio-collared Aug 78, Bear removed collar Aug 78
316	24 Aug 78-8 Dec 79	74	F	Radio-collared Aug 78, Removed collar April 79, Radio-collared Jun 79
317	1 Sep 78-4 Dec 79	47	M	Radio-collared Sep 78
320	20 Sep 78-8 Dec 79	87	F	Radio-collared Sep 78
322	2 Jun 79-7 Dec 79	31	M	Radio-collared Jun 79
324	3 Mar 79-4 Dec 79	42	M	Bear 308 offspring, Radio-collared Mar 79
325	3 Mar 79-27 Nov 79	34	M	Bear 308 offspring, Radio-collared Mar 79, Bear removed collar, Killed 1 Dec 79, Flats Cr., TN
328	28 Jun 79-4 Dec 79	44	M	Radio-collared 79
331	3 Jun 79-7 Aug 79	12	M	Radio-collared Jun 79, Bear removed collar Aug 79
334	5 Jun 79-12 Sep 79	11	M	Radio-collared Jun 79, Bear removed collar Aug 79
335	10 Jun 79-7 Dec 79	77	M	Radio-collared Jun 79
336	15 Jun 79-15 Aug 79	17	F	Radio-collared Jun 79, Bear removed collar Aug 79
337	15 Jun 79-1 Dec 79	71	M	Radio-collared Jun 79, Killed 1 Dec 79, Jake Best Cr., TN

Table 34 (Continued)

Bear #	Period tracked	# Radio locations	Sex	Comments
338	18 Jul 79-3 Nov 79	15	F	Radio-collared Jul 79, Bear removed collar Nov. 79, Killed 1 Dec. 79, Biven Br., TN
343	12 Jul 79-9 Dec 79	26	F	Radio-collared Jul 79
P6[a]	25 Oct 78-29 Oct 78	3	F	Moved back to Park
452[a]	5 Jul 78-13 Jul 78	5	M	Moved back to Park
547[a]	24 Aug 79-25 Aug 79	1	F	Bear removed collar
612[a]	15 Jun 79-16 Jun 79	1	F	Bear removed radiocollar
406[b]	11 Oct 78-1 Nov 78	3	M	Moved back to Park

[a]Panhandler bear released in study area.

[b]Captured in GSMNP.

were killed during the Tennessee statewide bear season (1-8 December 1979) in the Jake Best area of the study area. Two bears, 305 (F) and 307 (F) have not been located since October 1979 although several aerial searches were made. Bear 307 was killed during the Tennessee statewide bear season and the radio-collar was no longer functioning. Bear 305 was trapped in the study area in summer 1981 and the radio-collar was no longer functioning as of October 1979. In addition, 2 radio-collared bears, 547 (F) and 612 (F), were released in the study area; both of these bears were panhandlers and both removed their collars the day after release.

APPENDIX H

DENNING INFORMATION

Winter 1978-1979

All bears entered dens from 1 December-20 December 1978. During January-March 1979, dens were located by radio-tracking instrumented bears to their dens. A total of 10 dens were located in this manner (Table 35). Seven of the 10 dens were tree dens; 3 were ground dens. However, the ground dens used by bears 324 and 325 were a result of the death of their mother, bear 308. Six females were caught on and denned near Cowcamp Ridge. Two subadult males caught on Cowcamp Ridge both relocated and denned in a new location. All bears exited dens between 30 March-10 May 1979. A female (320) with cubs was the last to leave the den (Eiler 1981).

An effort was made to assess the reproductive biology of female bears (Eiler 1981). Since 5 of 6 females denned high in tree cavities, ladders or ropes were used to climb tree dens and observe the bears. If cubs were heard, a microphone connected to a cassette tape recorder was lowered into the den to record cub vocalizations. Bear 308 denned in a root cavity of a fallen tree. She was immobilized and died of drug complications. A subsequent necropsy by University of Tennessee Veterinary Hospital did not determine the specific interaction which led to the bear's death. This bear was accompanied by 2 yearlings (325 M, 325 M); both bears were radio-collared with break-away radio-collars. These yearlings subsequently denned in different locations.

Table 35. Denning data for black bears in CNF, winter 1978-1979.

Bear #	Age[a]	Sex	Den type	Location	Comments
303	3	M	tree den	Joyce Kilmer Memorial Forest	
305	7	F	tree den	Cowcamp Ridge	2 yearlings in den
306	4	F	tree den	Cowcamp Ridge	
307	3	F	tree den	Cowcamp Ridge	
308	4	F	ground den	Cowcamp Ridge	Died of drug complications, 2 yearlings in den
316	3	F	tree den	Salt Spring Mountain	
317	2	M	tree den	Slickrock drainage	
320	8	F	tree den	Salt Spring Mountain	2 newborn cubs
324	1	M	ground den	Cowcamp Ridge	Offspring of bear 308 redenned after death of female
325	1	M	ground den	Cowcamp Ridge	Offspring of bear 308, redenned after death of female

[a]Age as of Feb. 1979.

Of the 6 females captured, 2 had 2 yearlings each and 1 had 2 newborns. The bear with newborns (320) also had cubs in 1977 (Table 36).

Winter 1979-1980

During January-March 1980, dens were located by radio-tracking instrumented bears to their dens. Due to manpower and time constraints only dens of female bears were located. A total of 4 dens were located in this manner; all were tree dens (Table 37). All bears exited dens between 11-22 April 1980. Of 4 radio-collared females tracked to their den, 1 had yearlings and 3 had newborn cubs (Table 38) (Eiler 1981).

Table 36. Reproductive information on black bears in CNF, winter 1978-1979.

Bear #	Age[a]	Estrus in summer 78	Newborns	Yearlings
305	7	no	-	2
306	4	no	none	none
307	3	yes	none	none
308[b]	4	no	-	2
316	3	yes	none	none
320[c]	8	yes	2	-

[a]Age as of Feb. 1979.

[b]Died 3 March 1979.

[c]Had 2 cubs Feb. 1977.

Table 37. Denning data for black bears in CNF, winter 1979-1980.

Bear #	Age[a]	Sex	Den type	Location
306	5	F	tree	Cowcamp Ridge
316	4	F	tree	Cowcamp Ridge
320	9	F	tree	Cowcamp Ridge
343	3	F	tree	Salt Spring Mountain

[a]Age as of Feb. 1980.

Table 38. Reproductive information on black bears in CNF, winter 1979-1980.

Bear #	Age[a]	Estrus in summer 1979	Newborn[b]	Yearlings[b]
306	5	no	2	-
316	4	no	2	-
320	9	-	-	1
343	3	yes	2	-

[a]Age as of Feb. 1980.

[b]Minimal number of offspring.

APPENDIX I

IMGRID

Geographical information is stored in the IMGRID system in a grid cell format. Each cell of the grid has a unique coordinate or row/column position and cells are equal in size. This creates a rectangular array of cells over the study area.

United States Geological Survey 1:24000 scale topographical maps were used as a base map and UTM coordinates were used to reference the cells to the earth. The cell size has 1 ha (100 m by 100 m). The IMGRID analysis area (13,000 ha) is the total rectangular array of cells. The IMGRID study area (7,100 ha) is an irregularly-shaped area within the IMGRID analysis area for which the data (habitat, radio-locations) were encoded. The location of the IMGRID analysis area is:

(1) northwest corner UTM 600310 Zone 16 Rafter Quad;

(2) northeast corner UTM 286309 Zone 17 Tapoco Quad;

(3) southeast corner UTM 280209 Zone 17 Tapoco Quad;

(4) southwest corner UTM 600210 Zone 16 Rafter Quad.

The location of the IMGRID study area (all on Whiteoak Flats Quad, Zone 16) is:

start; northwest corner UTM 610300 then 9000 m east to UTM 700300 then 2000 m south to UTM 700280 then 2000 m east to UTM 720280 then 2000 m south to UTM 720260 then 1000 m west to UTM 710260 then 2000 m south to UTM 710240 then 1000 m west to UTM 700240 then 1000 m south to UTM 700230 then 3000 m west to UTM

670230 then 1000 m south to UTM 671220 then 5000 m west to UTM 620220 then 4000 m north to UTM 620260 then 1000 m west to UTM 610260 then 4000 m north to UTM 610300.

Habitat and radio-location data were encoded on a cell by cell basis for the IMGRID study area. These data were arranged as data elements (a mutually exclusive set of information that describes a natural resource or land-use unit, i.e., forest cover (Beeman 1977:234)). Data elements are composed of data items (descriptive information in each grid cell which collectively make up a data element, i.e., oak-hickory forest type is one data item in the forest cover data element (Beeman 1977:234)).

In this study, 22 elements were encoded. All information was obtained from USGS maps or had been recorded on those maps (radio-locations, forest cover types). The data elements, items, and encoding procedures are shown in Table 39.

Table 39. Data elements, items, and encoding procedures used with IMGRID.

Data element	Data item	Data code	Encoding procedure
Elevation	Elevation in m to nearest 6 m.	-	center-point
Water	Outside study area	0	presence-absence
	land	1	
	water (creek)	2	
Construction	Outside study area	00	presence-absence
	no construction	01	
	public access road	02	
	limited access road	03	
	gated road	04	
	trail	05	
	campground	06	
	wildlife opening	07	
	2 & 3	08	
	2 & 4	09	
	2 & 5	10	
	2 & 6	11	
	2 & 7	12	
	4 & 5	13	
	4 & 7	14	
	5 & 7	15	
	2 & 3 & 5	16	
	2 & 5 & 7	17	
Position on slope	Outside study area	00	predominant type
	lower 1/3 of slope	01	
	middle 1/3 of slope	02	
	upper 1/3 of slope	03	
Aspect	Outside study area	00	center-dot
	north 315-45	01	
	east 45-135	02	
	south 135-240	03	
	west 240-315	04	
Convex/Concave	Outside study area	00	center-dot
	convex	01	
	concave	02	

Table 39 (Continued)

Data element	Data item	Data code	Encoding procedure
Forest cover type	Outside study area	00	predominant type
	non-forest	01	
	white pine	03	
	white pine-hemlock	04	
	hemlock	05	
	white pine-upland hwd.	10	
	pitch pine-oak	15	
	virginia pine-oak	16	
	shortleaf pine	32	
	virginia pine	33	
	pitch pine	38	
	table mtn pine	39	
	cove hwds-white pine-hemlock	41	
	upland hwd-white pine	42	
	chestnut oak-scarlet oak-yellow pine	45	
	bottomland hwd-yellow pine	46	
	white oak-black oak-yellow pine	47	
	northern red oak-hickory-yellow pine	48	
	yellow poplar	50	
	chestnut oak	52	
	white oak-red oak-hickory	53	
	yellow poplar-white oak-northern red oak	56	
	scarlet oak	59	
	sugar maple-beech-yellow birch	81	
Adult female locations in spring	no location	00	presence-absence
	location	01	
Subadult male locations in spring	no location	00	
	location	01	
Subadult female locations in spring	no location	00	
	location	01	
Adult male locations in summer	no location	00	
	location	01	

Table 39 (Continued)

Data element	Data item	Data code	Encoding procedure
Adult female locations in summer	no location location	00 01	presence-absence
Subadult male locations in summer	no location location	00 01	
Subadult female locations in summer	no location location	00 01	
Adult male locations in September	no location location	00 01	
Adult female locations in September	no location location	00 01	
Subadult male locations in September	no location location	00 01	
Subadult female locations in September	no location location	00 01	
Adult male locations in fall	no location location	00 01	
Adult female locations in fall	no location location	00 01	
Subadult male locations in fall	no location location	00 01	
Subadult female locations in fall	no location location	00 01	

VITA

Charles Rene Villarrubia, son of Mr. and Mrs. Richard Villarrubia, was born in Fort Leonardwood, Missouri on April 2, 1955. He attended Rummel High School in Metairie, Louisiana, graduating in 1973. In 1977 he graduated magna cum laude from Louisiana State University, Baton Rouge with a Bachelor of Science in Forestry. He was accepted by the graduate program in Forestry, Wildlife, and Fisheries, The University of Tennessee, Knoxville, in 1978. He received his Master's degree in Wildlife and Fisheries Science in 1982.