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To the Graduate Council:

I am submitting herewith a thesis written by R. Steven Garris entitled "Habitat Utilization and Movement Ecology of Black Bears in Cherokee National Forest." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Boyd L. Dearden, Larry Wilson, Ralph Dimmick

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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We have read this thesis
and recommend its acceptance:

Boyd L. Overcash

Gary Wilson

Ralph W. Dimmick

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

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

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

R. Steven Garris

August 1983

ACKNOWLEDGEMENTS

I am grateful to Dr. Michael R. Pelton who made this research possible, served as my major professor, and contributed assistance throughout the project. I also thank the members of my committee--Drs. Boyd Dearden, Ralph Dimmick, and Larry Wilson--for their assistance and review of the manuscript. Dr. William L. Sanders generously provided insight and assistance in the statistical analyses herein. Appreciation is extended to Melinda Pollard and Virginia Patterson (UTCC) for computer assistance.

Appreciation is also expressed to Karen Ackerman, Charles Irvin, Ben Nottingham, Pam Petko-Seus, Alan Rabinowitz, Chuck Villarrubia, and Greg Wathen for assistance with field operations, friendship, and the many invaluable insights shared. A sincere thanks to fellow graduate student, Bruce Hastings who generously provided his time, ideas, assistance with field work, and contributed valuable comments on this manuscript and whose valued friendship will continue as a result of this project. I am also especially grateful to Pat Carr who generously provided his time, ideas, and cooperation while conducting his own project.

I thank Richard Conley, Larry Hunt, and Dick Stark (Pilot) of the Tennessee Wildlife Resources Agency for help with the logistical and collection aspects of the field work. Thanks are extended to Bill Kindy and Bob Shown, Pilots, who provided many hours of aerial radio-tracking.

A deep appreciation goes to my parents (George and Mary Lou) and family (Ann, Wayne, Clark, and Jean), whose unwavering

encouragement and belief in me made the difficult times more tolerable. Also a sincere thanks is expressed to Jane Roscoe and Tom Beroth for their continued support and encouragement.

Finally, a special thanks to Debbie Daws who was always there with understanding and love through the most difficult times of this project.

This study was funded by the Tennessee Wildlife Resources Agency and by McIntire-Stennis Project No. 27, the Agricultural Experiment Station, Department of Forestry, Wildlife, and Fisheries, The University of Tennessee, Knoxville.

ABSTRACT

Home range, movements, and habitat use of black bears in the Cherokee National Forest were monitored from June 1980 through December 1981.

In 1980, home range sizes averaged 192 km^2 for male bears and 23 km^2 for females, whereas the average range in 1981 for males was 60 km^2 and 15 km^2 for females. Larger ranges for males likely reflect a social structure that enhances reproduction. Differences in home range sizes between years was attributed to the availability and abundance of hard mast, especially acorns. Both sexes exhibited seasonal shifts in range use between summer and fall. Males traveled greater distances between summer and fall ranges than female bears.

Diel movements were affected by time of year, different foraging strategies between seasons, and mating activities. Both sexes moved greater distances in diurnal periods than nocturnal periods. Nocturnal movements were extensive only during fall. Increased nocturnal movements in fall were associated with seasonal changes in food sources, preparation for denning, and the influence of human-related activities.

Bears exhibited crepuscular patterns of activity that were modified seasonally. Activities of bears were affected by weather factors, distribution and availability of foods, seasonal changes in foraging strategies, and denning. Sex, age, and reproductive classes also affected activity patterns. Adult male bears were the most active group, whereas females with cubs were the least

active. The pattern of activity for bears in the CNF suggests that breeding may occur in early August.

Factors affecting habitat use included season, individual behavioral differences among bears, reproductive classes, and variations in hard mast production between years. Occurrence of bears in hardwoods increased significantly during 1980 when acorns and hickory nuts were scarce.

Habitat preference was also determined by a utilization-availability analysis. Hardwoods were preferred, although some variations in habitat use were sex related. Male bears used hardwoods (chiefly oaks) more than expected in terms of their availability, whereas females occurred more than expected in softwoods (chiefly pines).

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CHAPTER I

INTRODUCTION

In the eastern United States, human intrusions have forced black bears (Ursus americanus) to recede into diminishing enclaves of former habitat (Pelton and Burghardt 1976). This habitat loss coupled with extensive hunting pressures, low reproductive rates, and low population densities threaten some eastern black bear populations. Information regarding the movements and habitat use of black bears are vital if eastern populations of bears are to be maintained and perpetuated.

In the southern Appalachians the status of black bears ranges from total protection within the Great Smoky Mountain National Park (GSMNP), to management as an important big game species within the Cherokee National Forest (CNF), to total extirpation on adjacent private lands. Black bears are illegally hunted both inside and outside of protected areas in eastern Tennessee and western North Carolina. In the more populated areas bears are frequently shot. A study of harvest characteristics in North Carolina strongly suggested that this population of black bears is being over-harvested (Collins 1974).

In the CNF, alternative resource practices such as logging, hunting, mining, road construction, and various recreational activities also impact the existing bear population. Data regarding movement ecology, and habitat preferences are essential if bear management strategies are to be coordinated with these alternative land uses.

The objectives of this study were: 1) to determine home range size and differentiate seasonal ranges of black bears on the Cherokee National Forest, 2) to delineate hourly movements of the species, 3) to investigate habitat utilization of bears in the CNF, and 4) to determine activity patterns.

CHAPTER II

LITERATURE REVIEW

Research Techniques

In 1970 concern for black bears in Tennessee promoted initiation of essential research. Techniques have since been developed that enabled researchers to capture, handle, and monitor bears (Marcum 1974, Beeman 1975, Eubanks 1976, Eubanks et al. 1976, Eagar 1977, Beeman and Pelton 1978, Garshelis 1978, Burst 1979, Eagle 1979, Johnson and Pelton 1980b, Johnson and Pelton 1980c, Quigley 1982, Villarrubia 1982).

Activity Patterns

Conflicting patterns of activity behavior by black bears have been reported in the literature. The influence of habitat, human-related activities, food, environmental factors, time of year, and method of observation or interpretation contribute to the variation reported.

Direct observation of a few easily visible bears may bias the interpretation of activity behavior (Barnes and Bray 1967). Recent studies of bear activity have therefore relied primarily on radio-telemetry. Distances between sequential radio-locations were used as an index of activity of black bears in Tennessee (Beeman 1975) and Pennsylvania (Alt et al. 1976). The integrity of radio signals have also been interpreted to measure black bear activity (Poelker and Hartwell 1973, Amstrup and Beecham 1976, Lindzey and Meslow 1976,1977). Recent interpretation of bear

activity has been enhanced via the use of specialized activity-sensing monitors incorporated into the transmitter of the radio-collar (Garshelis 1978, Garshelis and Pelton 1980, Quigley 1982, Villarrubia 1982).

Bears were primarily diurnal in Idaho (Amstrup and Beecham 1976) and Washington (Poelker and Hartwell 1973). On the other hand, black bears were mainly nocturnal in Minnesota (Rogers 1977) and North Carolina (Hamilton 1978:79). Hamilton (1978:81) also noted that the highest level of nocturnal activity by bears coincided with the peak in diurnal human-related activities in fall.

In the GSMNP, black bears exhibted crepuscular patterns of activity behavior influenced by season (Beeman 1975, Eubanks 1976, Garshelis 1978, Garshelis and Pelton 1980, Quigley 1982). A similiar pattern of seasonally modified crepuscular activity was reported for bears in the CNF (Villarrubia 1982:35-36). Higher levels of diurnal activity during summer and nocturnal activity during fall was attributed to seasonal availability of food sources (Garshelis and Pelton 1980, Quigley 1982:37-41, Villarrubia 1982:36).

Seasonal discrepancies in bear activities may be attributed to differences in age, sex, and reproductive condition. Adult male black bears are generally more active than females in Wisconsin (Knudsen 1961) and Wyoming (Barnes 1967) over all seasons. Females with cubs were reported less active than adult males or adult females without cubs in Wyoming (Barnes 1967) and

California (Piekielek and Burton 1975). However, in the GSMNP, females with cubs were more active than any other sex-age group (Garshelis 1978). In contrast, Quigley (1982) found that subadult and yearling females were the most active group overall; adult males were the least active group. In West Virginia, female black bears were as active as males in the summer, were more active than males in the spring, and were consistently less active than males in late fall (Brown 1980). Villarrubia (1982) found females with cubs to be the most active sex-age group in the CNF. Diurnal activity peaked during the breeding period for adult males and breeding females in Pennsylvania (Alt et al. 1976), Washington (Lindzey and Meslow 1977), North Carolina (Hardy 1974), GSMNP (Garshelis 1978, Quigley 1982), and the CNF (Villarrubia 1982).

Home Range

Burt (1943:351) is credited with the most generally accepted definition of home range as that area traversed by the individual in its normal daily activities of food gathering, mating, and caring for young. Smith (1974) similiarly defined home range--as the area in which an animal normally lives and is not necessarily associated with any particular type of aggressive behavior. Alt et al. (1976) emphasized the complexity of the home range of black bears and the importance of viewing it as a dynamic spatial requirement.

Home range comparisons among telemetry studies of black bears are hampered by different methodologies of calculation and interpretation. Home range has been represented as the maximum

linear distance between locations, capture points, or recapture points (Erickson and Petrides 1964, Sauer et al. 1969, Jonkel and Cowan 1971, Eveland 1973, Kordek 1973, Piekielek and Burton 1975, Rogers 1977). The minimum polygon or the area enclosed by connecting peripheral points (Mohr 1947) has also been employed to determine home range for black bears (Bernes and Hensel 1972, Poelker and Hartwell 1973, Rieffenberger 1974, Banks et al. 1975, Beeman 1975, Amstrup and Beecham 1976, Eubanks 1976, Lindzey and Meslow 1977, LeCount 1980, Reynolds and Beecham 1980).

Several authors have reported inherent biases found in these methods of calculating home range (Hayne 1949, Davis 1953, Stickel 1954, Brown 1956, Jorgensen and Tanner 1963, Sanderson 1966, Metzgar and Sheldon 1974). Two of the prevalent arguments are that subjectivity is involved and that the actual utilized areas are underestimated (Garshelis 1978).

In an effort to meet difficulties inherent in the minimum area methods, computer programs that measure home range in terms of an animal's total utilization distribution in the habitat were developed (Jennrich and Turner 1969, VanWinkle 1975). Matula et al. (1974) and Alt et al. (1976, 1980) used the bivariate normal probabilistic method to calculate home range size for black bears in Pennsylvania. Koeppl et al. (1975) defined inherent statistical problems in the bivariate normal model and described a program by which home range was calculated as the area which account for a given percentage of this utilization. However, small sample size and varying time intervals between sequential

locations may bias the bivariate normal model (Koeppl et al. 1975). Using the Fortran IV program described by Koeppl et al. (1975), Garshelis (1978) calculated annual and seasonal home ranges of black bears in the GSMNP. The convex polygon or maximum area polygon method was also used to determine home range of black bears in the GSMNP (Quigley 1982) and in the CNF (Villarrubia 1982).

Although different methods of calculation and interpretation restrict direct comparisons of home ranges, several generalizations between home range sizes for black bears may be demonstrated. Typically, male black bears utilized larger areas than females (Kordek 1973, Eveland 1973, Alt et al. 1976, Amstrup and Beecham 1976, Matula 1976, Lindzey and Meslow 1977, Rogers 1977, Garshelis 1978, Novick 1979, Brown 1980, Quigley 1982, Villarrubia 1982). Seasonal availability and concentrations of food sources can cause seasonal shifts and range expansion for black bears (Hatler 1967, Jonkel and Cowan 1971, Piekielek and Burton 1975, Beeman 1975, Amstrup and Beecham 1976, Rogers 1977, Garshelis 1978, Garshelis and Pelton 1981). Increased mortality from illegal and legal hunting often result due to these extensive range expansions (Erickson and Petrides 1964, Beeman and Pelton 1980). Seasonal shifts in elevation have also been noted in black bears (Hatler 1967, Jonkel and Cowan 1971, Amstrup and Beecham 1976). Other patterns of seasonal utilization and their influences on home range are discussed by the above authors.

Social Organization

Analysis of home range overlap provides information regarding intraspecific tolerance, or the territorial behavior of black bears. The social organization of black bears has been debated by many authors (Barnes 1967, Jonkel and Cowan 1971, Kordek 1973, Poelker and Hartwell 1973, Beeman 1975, Amstrup and Beecham 1976, Lindzey and Meslow 1977, Rogers 1977, Garshelis 1978, Brown 1980, Garshelis and Pelton 1981, Quigley 1982, Villarrubia 1982). Extensive home range overlap has been noted by several researchers (Spencer 1955, Sauer et al. 1969, Jonkel and Cowan 1971, Beeman 1975, Amstrup and Beecham 1976, Lindzey and Meslow 1977, Garshelis 1978, Brown 1980, Quigley 1982, Villarrubia 1982). Extensive overlap of home ranges may suggest a relatively high level of intraspecific tolerance among black bears. Beeman (1975:102) indicated that the ritualized threat behavior in bears may supersede actual physical confrontation. The absence of agonisitic behavior or territoriality was reported for bears in Pennsylvania (Kordek 1973) and Idaho (Amstrup and Beecham 1976). In Idaho, the extensive range overlap among bears was attributed to abundant and well-distributed food sources (Amstrup and Beecham 1976).

Other authors have indicated that a highly developed social structure including agonistic behavior may exist among bears (Barnes 1967, Jonkel and Cowan 1971, Poelker and Hartwell 1973, Lindzey and Meslow 1977, Rogers 1977). Female black bears exhibited territoriality in Minnesota (Rogers 1977) and Wyoming

(Barnes 1967). The dispersal of subadults, particularly males, has been related to aggression from adult males (Jonkel and Cowan 1971, Kemp 1976). The fact that adult females often tolerated female offspring in their home range suggested a highly complex social structure among bears (Jonkel and Cowan 1971, Poelker and Hartwell 1973).

Diel Movements

Few studies have directly examined diel, or 24-hour, movement patterns. The need for short sampling intervals in analysis of diel movements was emphasized by Heezen and Tester (1967). In studies of black bears, however, short sampling intervals are often simply not practical (Garshelis et al. 1981) or difficult to achieve (Beeman 1975, Quigley 1982). Several researchers have successfully obtained continuous hourly radio-locations on black bears for 1 to 16 days (Rieffenberger 1974, Rogers 1977, Garshelis 1978, Hamilton 1978, Quigley 1982, Villarrubia 1982). In the GSMNP and CNF, diel movements of bears were affected by habitat, food, time of year, time of day, sex, age, presence of cubs, and social interactions (Garshelis et al. 1981).

Habitat Utilization

Few studies have dealt specifically with habitat use by black bears. In western Oregon, habitat selection by black bears was based on the relative occurrence of tracks and other bear sign (McCollum 1973). Kellyhouse (1980) estimated habitat selection and use by black bears in northern California from the occurrence

of bear sign and limited radio-telemetry. In Montana, habitat selection by black bears was measured by relative trapping success (Jonkel and Cowan 1971).

Radio-telemetry has recently been employed in most studies of habitat use by black bears with varying degrees of success. Such studies have been accomplished in West Virginia (Miller 1975), Idaho (Amstrup and Beecham 1976), Minnesota (Rogers 1976,1977), Washington (Lindzey and Meslow 1977), North Carolina (Hardy 1974, Hamilton 1978, Landers et al. 1979), Georgia (Lentz 1980), West Virginia (Brown 1980), California (Novick 1979), and Tennessee (Beeman 1975, Quigley 1982, Villarrubia 1982).

CHAPTER III

STUDY AREA

Location

Research was conducted on a 760 km^2 area in the Tellico Ranger District of the Cherokee National Forest (4,905 km^2) roughly bordered by the North Carolina-Tennessee state line, the new Tellico-Robbinsville Road, the Tellico River and the Little Tennessee River (Fig.1). Land ownership included both public (United States Forest Service or USFS) and private property in Monroe County, Tennessee. In addition, the area encompassed portions of the South Cherokee Management Area (Tennessee Wildlife Resources Agency or TWRA) and the Tellico Bear Sanctuary. To the east and north are located the Great Smoky Mountain National Park, the Joyce Kilmer Memorial Forest, and the Nantahala National Forest (Fig.2). Knoxville, approximately 113 km to the north, and Chattanooga, approximately 121 km to the southwest, are the 2 nearest and largest population centers. Detailed descriptions of the area are found in Strickland (1972), Belden (1972), and Villarrubia (1982).

Topography and Geology

The study area lies within the Unaka Mountain Range of the southern Blue Ridge Province (Fenneman 1938). Elevations in the Unaka Mountains range from 305 to 1524 m above mean sea level (AMSL). High narrow ridge crests and steep, rugged mountains dissected by narrow meandering streams characterize the area.

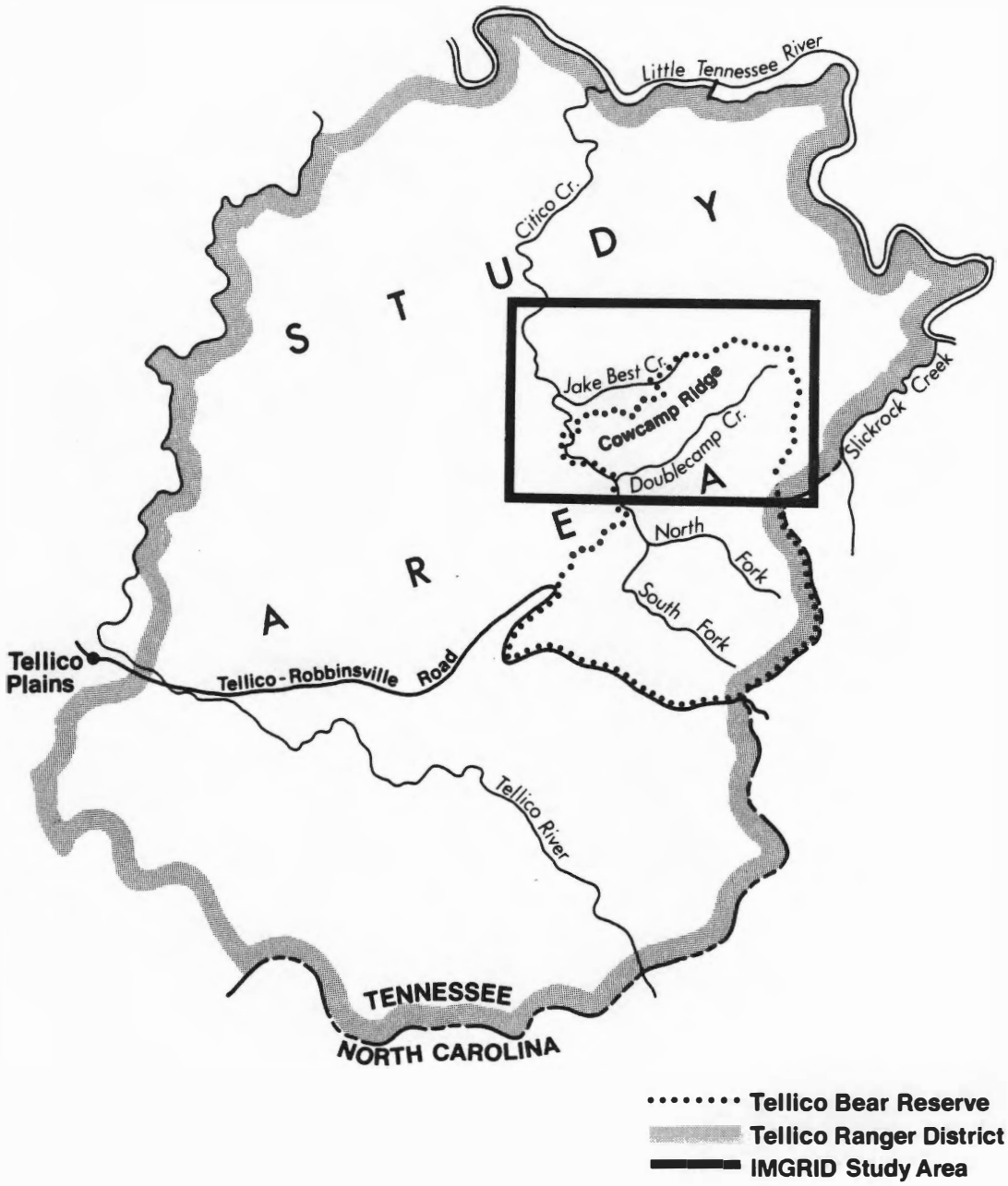


Figure 1. The location of study area within the Tellico Ranger District, Cherokee National Forest.

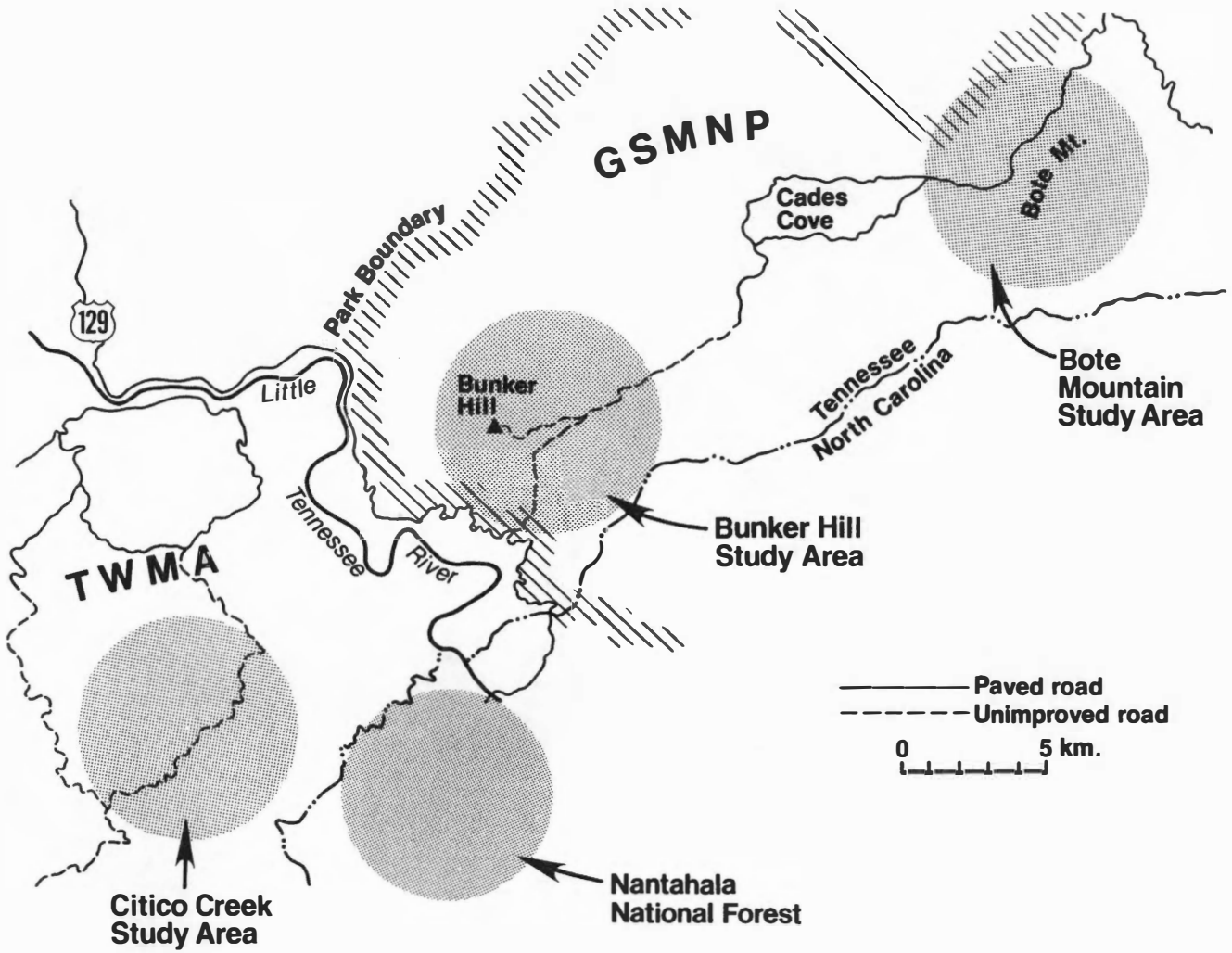


Figure 2. Relationship of study area to the Great Smoky Mountains National Park and the Nantahala National Forest.

The soil association of Ditney-Brookshire Jeffrey (Soil Survey 1981:12) is found predominately on the narrow ridgetops, steep mountainsides, and in the deep coves. Soils are formed in material underlain by slate, phyllite, graywacke, arkosic sandstone, and conglomerate in some places (Soil Survey 1981:12). Slopes vary from 10 to 70 %, but are mainly 40 to 60 %. Additional details regarding physiographic features are discussed by Villarrubia (1982:10).

Climate

Thornthwaite (1948) categorized the climate as mesothermal prehumid or a warm-temperate forest. Alternating cold air currents moving south from Canada and warm moist air currents moving north from the Gulf of Mexico frequently cause daily and seasonal variations in the weather. Local temperature and precipitation also vary greatly with differences in elevation and aspect (Shanks 1954a, Tanner 1963, Stephens 1969).

Average annual precipitation ranges from 140cm in the lower elevations to over 230cm at the highest elevations (Quigley 1982). Precipitation patterns of the southern Appalachians have been classified as orographic in summer and cyclonic in winter (Dickson 1960, Trewartha 1966). Two rainfall maxima occurred annually; the largest in late winter-early spring and a secondary one in early summer primarily from the result of thunderstorm activity (Soil Survey 1981). In all seasons, periods of excessive dry and wet weather are experienced. Annual snowfall averages approximately 63cm, less than 3 % of the annual rainfall.

Annual temperature averages 14°C at elevation below 450m to 8°C at elevations over 1,900m. Shanks (1954a) reported a temperature gradient of 4°C per 1000m change in elevation. The greatest change in average daily maximum and minimum temperature is during October and November, and again in February and March. The average growing season in the CNF is approximately 151 days (USFS 1976).

Average annual humidity and relative annual humidity for Monroe County are estimated at approximately 70 % (Soil Survey 1981). Diurnal cloud cover averages less than 0.6 % resulting in abundant sunshine (Soil Survey 1981).

Flora

A rich diversity of flora is found within this region. Unfortunately, no quantitative studies of vegetation are available for the Tellico Ranger District. King and Stupka (1950), however, noted that the adjacent GSMNP supports over 1,300 species of flowering plants, within which are 131 species of native trees. In addition, Cain (1935), Shanks (1954b), Whittaker (1956), and Golden (1974) have conducted vegetative studies in the neighboring Smokies. Both Shanks (1954b) and Whittaker (1956) defined 6 major forest types (Table 1). In contrast, Golden (1974) categorized 20 different forest types and related vegetation patterns to elevation, aspect, and topography.

In the Cherokee National Forest the forest cover types have been delineated and mapped. Five major forest types are recognized within the CNF (Table 2). Additional information

Table 1. Forest types and their important tree species in the Great Smoky Mountains.

Forest Type	Important Species
Cove hardwood	Yellow-poplar (*Liriodendron tulipifera*) Eastern hemlock (*Tsuga canadensis*) Yellow buckeye (*Aesculus octandra*) Silverbell (*Halesia carolina*) Beech (*Fagus grandifolia*) Yellow birch (*Betula allegheniensis*) Black cherry (*Prunus serotina*)
Hemlock	Eastern hemlock Yellow birch Silverbell Fraser magnolia (*Magnolia fraseri*)
Northern hardwood	Beech Sugar maple (*Acer saccharum*) Yellow buckeye Yellow birch
Closed oak	Chestnut oak (*Quercus prinus*) White oak (*Q. alba*) Black oak (*Q. velutina*) Northern red oak (*Q. rubra*) Pignut hickory (*Carya glabra*) Mockernut hickory (*C. tomentosa*) Sourwood (*Oxydendrum arboreum*)
Open oak and pine	Pitch pine (*Pinus rigida*) Scarlet oak (*Q. coccinea*) Virginia pine (*P. virginiana*)
Spruce-fir	Red spruce (*Picea rubens*) Fraser fir (*Abies fraseri*)

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

Table 2. Five major forest types and their important tree species in the Tellico Ranger District.

Forest Type	Important Species
Cove hardwood	Yellow-poplar Eastern hemlock White oak Northern red oak
Northern hardwood	Sugar maple Beech Yellow birch Basswood (*Tilia* spp.) Red maple (*A. rubrum*) Hemlock Northern red oak Black cherry Sweet birch (*B. lenta*)
Mesic hemlock	Yellow birch Yellow-poplar Basswood Blackgum (*Nyssa sylvatica*) Northern red oak Cucumbertree (*M. acuminata*) White pine (*P. strobus*) Hemlock
Pine	White pine (*P. strobus*) Virginia pine Pitch pine Shortleaf pine (*P. echinata*) Table-mountain pine (*P. pungens*)
Oak-hickory	Chestnut oak Post oak (*Q. stellata*) Black oak Southern red oak (*Q. falcata*) Scarlet oak (*Q. coccinea*) Hickories White oak Shortleaf pine Virginia pine Pitch pine

Source: USFS 1976.

regarding forest cover types is presented in the Society of American Foresters (1954, 1958).

Fauna

Fifty-nine mammalian species are reported for the GSMNP (Linzey and Linzey 1971). Some of the larger mammals that are found on the Tellico Ranger District include: black bear, white-tailed deer (*Odocoileus virginianus*), European wild hog (*Sus scrofa*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), gray fox (*Urocyon cinereoargenteus*), cottontail rabbit (*Sylvilagus floridanus*), oppossum (*Didelphis virginiana*), woodchuck (*Marmota monax*), gray squirrel (*Sciurus carolinensis*), red squirrel (*Tamiasciurus hudsonicus*), and others. In addition to the mammalian fauna, over 80 species of reptiles and amphibians, 200 species of birds, and 80 species of fishes inhabit the Great Smokies (King and Stupka 1950). Ecology and life history of the European wild hog has been intensively investigated on the Tellico Ranger District (Matschke 1964, Henry and Conley 1972, Strickland 1972, Tennessee Game and Fish 1972, Belden and Pelton 1975).

History

In the early 1920's, logging and wildfires were the dominant influences on the area. A disastrous wildfire burned much of the area causing loggers to discontinue operations. A few inaccessible stands of timber were left untouched. The Forest Service purchased the land in the early 1930's from Babcock Lumber Company and Tellico River Lumber Company. Management of the area has

since been for mutiple use such as sustained yield of timber, outdoor recreation, watershed protection, and wildlife resources (D. Conley, pers. com.).

CHAPTER IV

MATERIALS AND METHODS

Capture

Field work was conducted from June 1980 to January 1982. Inaccessibility of the area and earlier failures with culvert traps in the CNF (D. Conley, pers comm.) necessitated the use of Aldrich spring-activated snares (Aldrich Animal Trap Co., Clallam Bay, WA). Each snare consisted of a steel spring, a trigger mechanism, steel loop cable, and an anchor cable. The possibility of major injuries to bears was minimized by the use of an automobile hood spring as a shock absorber (Johnson and Pelton 1980b). All snares were baited with sardines.

Prospective trapsites were usually prebaited (Marcum 1974, Eagar 1977, Johnson and Pelton 1980b, Villarrubia 1982:16) to determine areas of concentrated bear activity. Traplines were opened intermittently from June through October of 1980 and 1981. Black bears were trapped using the snares as described by Marcum (1974) and Eagar (1977).

Handling

Captured bears were immobilized with intramuscular injections of M-99 (Etorphine hydrochloride, D-M Pharmaceuticals, Rockville, MD). Dosage administered was approximately 1 mg/45 kg (1 cc/100 lbs) of estimated body weight. The drug was injected using a projectile syringe fired from a CO_2 pistol (CAP-CHUR, Palmer Chemical Equipment Co., Douglasville, GA) or a jab stick (a

plexi-glass rod fitted with a syringe). Intravenous injection of M50-50 (Diprenorphine, D-M Pharmaceuticals, Rockeville, MD) with a hand-held syringe resulted in quick recovery of the animal. M50-50 was administered at the rate of 2 mg/45 kg (2 cc/100 lbs) estimated body weight.

Marking

While bears were immobilized, several markings were employed to insure identification of individual animals. A color coding system using 1 metal ear tag and 1 yellow-colored ear tag (National Band and Tag Co., Newport, KY) discriminated sexes by position (e.g., for males the metal tag was attached in the right ear and the yellow in the left, while for females the procedure was reversed). To insure against tag loss, tattoos were placed on the inside of the upper lip.

Examination

Each bear was weighed, measured (Cherry and Pelton 1976:32), sexed, examined for ectoparasites, and noted for general body condition. A blood sample was collected (Eubanks et al. 1976:29, Beeman and Pelton 1978:127-129) and reproductive condition was examined (Eiler 1981:12-13).

The first premolar was extracted for age determination (G. Wathen pers. comm.). Premolars were prepared using techniques described by Eagle and Pelton (1978) and age was determined by the cementum-annuli technique (Willey 1974).

Telemetry

Selected bears were fitted with radio-collars (Telonics, Telemetry-Electronics Consultants, Mesa, AZ). Breakaway collars, designed to fall off in 12 to 16 months, were placed on younger and smaller bears. All collars transmitted in the 150-152 MHz range.

Instrumented bears were frequently monitored to determine locational and activity information. The basic radio-tracking techniques employed were ground and aerial tracking. Information regarding cloud cover, temperature, precipitation, ground condition, date, and time of day were collected along with locational and activity data.

A portable receiver (Telonics, Inc., Mesa, AZ); elevated 8-element antennas (Hy-Gain Electronics, Lincoln, NB); hand-held 3-element and 2-element (H-antenna) antennas (Telonics, Inc., Mesa, AZ) were used to obtained ground azimuths on instrumented bears. Ground azimuths were determined by the loudest signal method as described by Springer (1979:928) and with the use of a TDP2 (Telonics, Inc., Mesa, AZ). The locations of individual bears were then triangulated using from 2-10 acceptable azimuths.

The accuracy of ground locations was tested with reference transmitters placed in known locations at periodic intervals during the study. The tests indicated that radio-locations in error of less than 150m in any direction were acceptable. These tests were also used by Garshelis (1978:14-16) and Quigley (1982:14-16) to verify accuracy of acceptable locations.

Periodically, 24 hr diels were conducted to determine hourly movements and activities. Two elevated fixed mast antennas were used to increase tracking capabilities and to improve the accuracy of radio-locations. Researchers recorded simultaneous hourly azimuths by orienting a fixed compass rosette at the base of each mast antenna. Communication was facilitated between tracking stations with the use of field radios. Availability of equipment and manpower coupled with seasonal distribution of bears limited the use of diels.

Because of rugged topography, inaccessibility of many areas, and the extensive range of some bears, ground tracking often proved inefficient or impossible. Aerial support proved invaluable and extremely efficient, enabling researchers to pinpoint bear locations in remote inaccessable areas.

Aerial radio-tracking was performed from a Cessna 170 or 172. On each of the airplane's wing struts, an 'H' antenna was mounted. The antennas were connected through a switch box in the cabin. The switch box enabled researchers to use each antenna individually or both simultaneously. Both antennas were used until a radio-signal was encountered. The animal's position was then determined by flying parallel lines noting intensity of signals from different sides of the plane. Perpendicular flight lines were subsequently flown, while noting the increasing or decreasing signal intensity from alternate antennas. This procedure was repeated until the bear's location was accurately plotted. The location was finally pinpointed by flying tighter

and tighter circles, while decreasing altitude. The above flying procedure was essentially the same as used by Quigley (1982:15-16) and Villarrubia (1982:20).

The accuracy of aerial locations was repeatedly substantiated by visual observations (n=9) of instrumented bears from the plane and the retrieval of dropped collars (n=6) from aerial locations. The accuracy of aerial telemetry locations was influenced by width of transect, cruising speed, and altitude (Caughley 1974). Differences in the pilot's attitude, interest, and experience were felt to strongly influence the error (Hoskinson 1976, pers. obser.). Overall, aerial tracking was an irreplaceable asset in this study.

All locations were plotted on 1:24000 scale United States Geological Survey (USGS) topographical maps. A transparent overlay grid was then used to assign each location an Universal Transverse Mecator (UTM), 6-digit coordinate (Strahler 1969:58-59, 625-627).

Activity

To monitor activity, all transmitters were equipped with a reset motion sensor (Telonics, Inc., Mesa, AZ) with a 5-minute reset period. These motion sensitive devices are commonly referred to as 'mortality monitor sensors' (Franzman et al. 1980). Movements cause these motion sensitive transmitters to register the active or alternate transmission (100 bpm or 80 bpm pulse rate). After cessation of movements and elapsing of the 5-minute

reset period, the transmitter would revert to a slower base pulse rate (75 bpm or 40 bpm).

In the field, an animal was always recorded as active or inactive depending on the transmission rate. However, the programmed timing mechanism may overestimate the active behavior of bears (Garshelis 1978:71-74, Quigley et al. 1979). A notation system was devised to compensate for this overestimation of activity as described by Quigley et al. (1979). For example, a signal initially heard in the active mode or a signal that changed from inactive to active was rechecked after the reset period had elapsed (4-6 min). During the second check, an active signal was recorded as such and an inactive signal recorded as being inactive. The assumption was that the bear's initial activity was only a temporary head movement while the animal was resting. Additional discussion of this system for noting activity is presented by Quigley et al. (1979), Quigley (1982:12-13), and Villarrubia (1982: 18-19). Active signals were often rechecked a third time in the field to insure accurate interpretation of activity in this study.

Data Analysis

Home range. Seasonal and annual home range sizes were calculated using the maximum convex polygon method. Peripheral radio-locations were connected to determine the area of a convex polygon as described by Brinker (1969:248-250). The convex polygon method was utilized because of its simplicity, graphical

application, and prominence in black bear literature. The use of convex polygons to determine the range of black bears is also discussed by Villarrubia (1982:50) and Quigley (1982:17-18).

Accurate estimations of home range for black bears in the CNF are difficult to determine. The cryptic nature of the black bear, mountainous topography, and the inaccessibility of some areas affect the consistency and success of radio-tracking. In this study, however, the regular use of aerial tracking enhanced the probability of locating bears throughout their range and reduced inconsistencies in sampling.

Seasonal divisions of home range were categorized as spring-summer (den emergence through Aug) and fall (Sept through den entrance). Statistical differences in seasonal and annual home range sizes were determined using the t-test and the Student's t-test (Mendenhall and Ott 1976:225-230).

Activity centers. Most animals utilize segments of their home range area with differential intensity. The conspicuous geographical points of the animal's greatest activity have been termed 'centers of activity.' The ecological importance of concentrated activity areas was originally introduced by Seton (1909). Hayne (1949) referred to the center of activity as a two-dimensional average of a group of points. Later, the center of activity was described as a two-dimensional average or geographic center, of the points of capture (Hayne 1950). Several authors have termed the arithmetic mean center as the geometric center of activity (Harrison 1958, White 1964, Tester and Siniff

1965, Sanderson 1966, VanWinkle et al. 1973, VanWinkle 1975). Recently, a new method of calculating centers of animal activity based on the harmonic mean of an areal distribution has been described (Dixon and Chapman 1980).

The seasonal displacement of activity centers and home range boundaries were investigated for 18 radio-collared bears in the CNF. Directional movement and distinct clusters of consecutive activity centers indicated temporal use of the annual home range. These distinct clusters of sequential radio-locations were partitioned into groups formed by connecting the peripheral radio-locations of each group. Discrete seasonal activity centers were used mainly in the summer during breeding season (Jun-Aug) and in the fall during prime mast availability (Sept-Nov).

The mean seasonal activity centers were calculated for both summer and fall. Seasonal shifts in the use of annual home range were then compared among bears and years, using the mean distance between summer and fall activity centers. The t-test and approximate t-test (Sokal and Rohlf 1969:376) were used to ascertain statistical significance.

Diel movements. Diel data were analyzed with respect to diurnal and nocturnal mean hourly rates of travel. Diurnal movements were defined as occurring between 0500-2000 hrs and nocturnal movements as occurring between 2100-0500 hrs. The t-test was used to determine statistical significance when appropriate.

Activity patterns. Reset activity monitors were used to determine activity patterns by 18 different bears from June 1980 through December 1981. Quigley (1982:24) and Villarrubia (1982:26) earlier assessed the reliability of reset motion sensors in determining the % of activity for black bears.

Audible variations in signal integrity were not recorded in this study; however, changes in the intensity of some inactive signals were observed. Villarrubia (1982:27) and Quigley (1982:26) reported similar variations. These variations indicate that the use of signal quality as an index of activity may be biased toward activity (Lindzey and Meslow 1977, Sunquist 1981, Quigley 1982:26, Villarrubia 1982:27). Position of the radio-collar, fluctuations in environmental factors (e.g., wind, temperature, humidity, precipitation), topography, and vegetation may impact signal integrity.

Activity was recorded as active or inactive as determined by the field recording system devised to compensate for the bias toward activity (Quigley et al. 1979, Quigley 1982:27-28). Ground and weather conditions, including temperature, precipitation, and cloud cover were recorded with each activity reading. The least-square analysis of variance procedure was used to investigate relationships between activity and environmental factors, reproductive associations, time of day, and time of year. Using this procedure, activity is designated as the probability of being active under the stated conditions rather than as an actual percentage (Garshelis and Pelton 1980).

Time of year was divided into months and categorized as seasons. Time of day was divided into hours (beginning on the hour), cloud cover was assessed as percent coverage (i.e., 0, 25, 50, 75, or 100%), and temperature was delineated in $3^{o}C$ increments. Ground conditions were classified as wet or dry, while precipitation was categorized as none, drizzle, or snow. Statistical significance in comparisons other than with the analysis of variance was determined with the t-test.

Habitat utilization. Habitat parameters (Table 3) for the Citico Creek study area had previously been coded (Villarrubia 1982:21-22) and used in the computer-based IMGRID (Information Management on a Grid Cell System) system (Sinton 1976) to evaluate the relationships of bear locations to habitat features. The IMGRID system, however, proved time-consuming (Villarrubia 1982:110), inefficient (Quigley 1982:115), and limited in analysis of habitat utilization by black bears (Quigley 1982:67). To facilitate a more complete analysis of habitat use, data previously encoded in the IMGRID area were reassigned UTM (Universal Transverse Mercator) coordinates (x, y). Using a transparent grid overlay, each bear location was also assigned coordinates and later merged (SAS 1979) with the habitat information. Bear locations outside the original IMGRID area were assigned coordinates along with respective habitat parameters. Forest cover types were obtained from compartment and stand maps of the Cherokee National Forest and the Nantahala National Forest.

Table 3. Habitat parameters and description used in analysis of habitat utilization by black bears in the CNF, 1980-1981.

Habitat Parameter	Description	Coding Procedure
Forest cover type	Pitch pine White pine White pine-hemlock Hemlock White pine-upland hwd Pitch pine-oak Virginia pine-oak Shortleaf pine Virginia pine Sugar maple-beech-yellow birch Table mtn. pine Cove hwds-white pine-hemlock Upland hwds-white pine Chestnut oak-scarlet oak-yellow pine Bottomland hwd-yellow pine White oak-black oak-yellow pine N. red oak-hickory-yellow pine Yellow-poplar Chestnut oak White oak-red oak-hickory Yellow-poplar-white oak-N. red oak Scarlet oak	Type in which radio-locations were found
Water	(USGS topos)	Presence-absence
Elevation	Coded in meters	Center
Aspect	North (315-45) East (45-135) South (135-240) West (240-315)	Center
Slope	Upper (1/3) Middle (1/3) Lower (1/3)	Center
Construction	Campground Public access road Limited access road Gated road Trail Wildlife food plot	Presence-absence

The FUNCAT procedure (SAS Institute 1982:257-292) was used to evaluate habitat utilization with regard to the influences and interactions of time of year, time of day, individual variation among bears, age, and reproductive condition (Dr. W. L. Sanders, pers. comm.). The FUNCAT procedure, similar to an analysis-of-variance except that reponses are categorical rather than continuous, models the functions of reponses as a linear model. This procedure permitted the measurement of relationships between habitat use and associated factors, independent of compounding effects. Minimum chi-square values were produced according to methods described by Grizzle et al. (1969). Forest cover types were categorized into 2 major habitats: (1) hardwoods (chiefly oaks) defined as any cover type producing hard mast in fall; and (2) softwoods or pines including any of the softwood cover types.

Habitat preference. The FUNCAT procedure does not consider preference or avoidance of a given habitat in terms of its availability to the animal. Therefore, a chi-square analysis and the Bonferroni approach (Neu et al. 1974, Miller 1966:67-69) were used to determine if bears use hardwoods or softwoods in proportion to their availability to bears. The hardwoods and softwood habitat categories were grouped as previously discussed.

CHAPTER V

RESULTS AND DISCUSSION

Movements

Home range. The convex polygon method was used to determine annual and seasonal home ranges for 1980 (Table 4) and 1981 (Table 5). A total of 2,900 radio-locations from 18 different black bears was used in the analysis. Nine of the 18 were tracked during both years.

Mean annual home range in 1980 for female bears (22.7 km^2) was significantly smaller than the mean annual range for males (192.4 km^2). In 1981, males (60.1 km^2) also occupied significantly larger annual ranges than females (15.0 km^2). Male bears inhabited considerably ($p<0.05$) larger seasonal ranges than females in both summer and fall during both years (Tables 4 and 5).

Direct comparisons of home range from different black bear populations are confusing and often meaningless due to the discrepancies in sampling techniques and methods of calculation. Regardless of the methodologies, however, male bears occupied larger annual ranges than females (Table 6) in Pennsylvania (Eveland 1973, Kordeck 1973, Alt et al. 1976, Matula 1976, Alt et al. 1980), Michigan (Erickson and Petrides 1964), Montana (Jonkel and Cowan 1971), West Virginia (Rieffenberger 1974, Brown 1980), Washington (Lindzey and Meslow 1977), Idaho (Amstrup and Beecham 1976), California (Novick 1979), Minnesota (Rogers 1977), North

Table 4. Annual and seasonal home ranges (km^2) for radio-collared bears in the CNF, 1980. Range size calculated by the convex polygon method.

Bear No	Age	Reproductive Class	Summer Area (n)[1]	Fall Area	Annual Area
317	3	Subadult male	47.4 (25)	88.4 (25)	137.5 (50)
322	5	Adult male	21.1 (20)	231.2 (21)	244.5 (41)
328	4	Adult male	16.2 (45)	234.6 (37)	238.7 (82)
335	5	Adult male	13.5 (30)	51.1 (24)	58.5 (54)
344	4	Adult male	6.4 (06)	244.0 (28)	282.6 (34)
Subaverage			20.9	169.9	192.4
310	3	Estrous female[2]	3.0 (34)	12.4 (80)	12.8 (114)
306	5	Female w cubs	5.6 (21)	27.7 (104)	28.7 (125)
316	4	Estrous female	8.5 (48)	29.0 (98)	29.3 (146)
320	9	Estrous female	7.0 (53)	20.1 (98)	26.1 (151)
326	2	Subadult female	3.6 (31)	18.0 (70)	19.3 (101)
346	2	Subadult female	4.1 (21)	6.4 (53)	8.2 (74)
349	4	Female w cubs	4.0 (20)	31.6 (95)	37.6 (115)
352	2	Subadult female	--------	10.5 (86)	---------
356	5	Female w cubs	1.5 (10)	18.8 (37)	19.9 (47)
Subaverage			4.7	19.4	22.7
Total average			12.8	94.6	107.6

[1]Sample size (radio-locations) used in the home range calculation.

[2]Estrous females are in estrous only in summer.

Table 5. Annual and seasonal home ranges (km^2) for radio-collared bears in the CNF, 1981. Range size calculated by the convex polygon method.

Bear No	Age	Reproductive Class	Summer Area (n)[1]	Fall Area	Annual Area
317	4	Adult male	16.7 (38)	---------	--------
322	6	Adult male	28.1 (84)	39.4 (45)	57.8 (129)
328	5	Adult male	49.8 (87)	73.8 (35)	85.3 (122)
335	6	Adult male	29.7 (63)	29.6 (25)	63.3 (88)
344	5	Adult male	35.3 (38)	47.2 (32)	53.1 (70)
501	4	Adult male	9.3 (22)	40.8 (23)	41.1 (45)
Subaverage			28.1	46.2	60.1
310	4	Female w cubs	8.9 (171)	7.8 (71)	11.6 (242)
306	6	Estrous female[2]	10.6 (122)	5.1 (36)	12.6 (158)
305	9	Estrous female	9.8 (49)	7.9 (71)	10.9 (120)
506	1	Yearling	3.5 (52)	7.6 (89)	8.3 (141)
507	1	Yearling female	4.2 (28)	12.7 (45)	14.5 (73)
326	3	Estrous female	8.1 (144)	4.2 (90)	9.7 (234)
349	5	Estrous female	10.8 (135)	31.5 (84)	37.5 (219)
Subaverage			8.0	11.0	15.0
Total average			18.1	28.6	33.8

[1]The number of radio-locations used in home range calculations.

[2]Estrous females are in estrous only in summer.

Table 6. Mean annual home ranges of black bears from various areas in the United States.

Source	Location	Male (km^2)	Female (km^2)	Calculation Method
Alt et al. (1976)	Pennsylvania	196	37	Covariance matrix
Lindzey and Lindzey (1977)	Washington	5	2[1]	Convex polygon
Garshelis (1978)	GSMNP	21	8	Convex polygon
Quigley (1982)	GSMNP	32	5	Convex polygon
Villarrubia (1982)	CNF	30	12	Convex polygon
Brown (1980)	West Virginia	204	49	Bivariate normal model
Erickson and Petrides (1964)	Michigan	52	26	Recapture techniques
Jonkel and Cowan (1971)	Montana	31	5	Recapture techniques
Amstrup and Beecham (1976)	Idaho	112	49	Minimum area
Hamilton (1978)	N. Carolina	91	8	Minimum area
Poelker and Hartwell (1973)	Washington	52	5	Convex polygon
Novick (1979)	California	22	17	Convex polygon

[1]Richness of habitat on the island presumably allowed smaller home ranges.

Carolina (Hamilton 1978), the GSMNP (Garshelis and Pelton 1981, Quigley 1982), and the CNF (Villarrubia 1982). Regional variability in the size of home ranges for black bears may be attributed to the varying influences of human-related activities, climate, topography, and differences in quantity, quality, availability, and distribution of food sources. In addition, the estimation of home range sizes is affected by sampling techniques and methods used in home range calculations.

The fact that male bears traverse larger areas than females is partially a function of reproduction. The reproductive success of males depends primarily on their ability to breed with several females (Orians 1969). Hence, it is advantageous for promiscuous males to be mobile, less attached to specific areas, and occupy large areas that overlap the range of many females. The reproductive success of females, on the other hand, is not improved by breeding with many males so females are less mobile, occupying areas only extensive enough to ensure adequate food for self maintenance and the development of young (Amstrup and Beecham 1976).

The sexual dimorphism of body size and weight in black bears has also been related to the larger range of males (Quigley 1982:50). The larger size of males may create the need for increased food intake and nutrition. Body weight for omnivores including black bears is strongly correlated with home range size (Harestad and Bunnell 1979).

Home range size of males may also be affected by social interactions, whereas the larger males dominate the bear population and influence the distribution of bears, particularly younger and smaller males. Extensive home range overlap of males was observed in this study; however, bears avoided each other through different temporal use patterns of the same areas. The dispersal of subadults, especially males, has been related to aggression from larger adult males (Jonkel and Cowan 1971, Kemp 1976). Garshelis and Pelton (1981) reported that dominant (heavier) males exclude subordinate males and females from preferred ranges in the fall. Other authors have suggested that the distribution of bears is affected by a highly developed social structure including agonistic behavior (Poelker and Hartwell 1973, Lindzey and Meslow 1977, Rogers 1977).

Significant differences in annual and seasonal ranges were evident between the 2 years of this study. In 1980, males established annual ranges ($x=192.4$ km^2) that significantly exceeded those occupied in 1981 ($x=60.1$ km^2). Summer ranges of males in 1980 ($x=20.9$ km^2) did not differ statistically from 1981 ($x=28.1$ km^2). However, the fall home ranges of males in 1980 ($x=169.9$ km^2) were significantly larger than those of males in 1981 ($x=46.2$ km^2).

Annual home ranges for females did not differ statistically between 1980 ($x=22.7$ km^2) and 1981 ($x=15.0$ km^2) despite an apparent decrease in range size. The summer ranges of females also did not differ appreciably between years. However, the

average fall range of 9 females in 1980 ($x=19.4$ km^2) significantly ($p<0.10$) exceeded the average fall range of 7 females ($x=11.0$ km^2) in 1981. No significant difference in home range size was apparent among breeding females, females with young, or subadult females.

Bears of both sexes occupied significantly ($p<0.10$) larger ranges in the fall of 1980. Acorns are the staple food item of black bears in the GSMNP during the fall (Beeman and Pelton 1980). In 1980, acorn production was rated poor to fair (2.8 numerical rating), whereas in 1981, acorns were more abundant (4.2 numerical rating) and more evenly distributed (TWRA 1981, pers. observ.). The average numerical rating for acorn production from 1970-1981 was 3.91 in the CNF (TWRA 1981). The availability and distribution of acorns apparently influenced the home range sizes of black bears in the CNF. Garshelis and Pelton (1981) suggested that the availability of acorns may affect the magnitude of fall home range shifts. Other authors have reported that the concentration and availability of food sources may provide stimuli for seasonal expansions of home range boundaries (Hatler 1967, Sauer et al. 1969, Beeman 1975, Piekielek and Burton 1975, Rogers 1977).

Activity centers. Extensive seasonal displacement between summer and fall centers of activity was observed for all radio-collared bears in 1980 and to a lesser extent in 1981. Mean distances between conspicuous summer and fall centers were determined in order to examine the magnitude of seasonal shifts

(Table 7). Displacement of the activity center from summer to fall differed significantly ($p<0.10$) between 1980 and 1981 when ranges for both sexes were combined. However, the yearly shift in summer and fall activity centers for females did not differ statistically between 1980 ($\bar{x}=2.0$ km^2) and 1981 ($\bar{x}=0.6$ km^2) despite an apparent decrease.

In view of the magnitude of the shift in seasonal activity centers for all bears in 1980, it is likely that movements were affected by mast availability and distribution. Bears may simply move in response to the phenological development of their surroundings (Amstrup and Beecham 1976, Reynolds and Beecham 1980). Garshelis and Pelton (1981) suggested that learning may influence the development of regionally characteristic movements. Similiar perennial movements have been observed for members of the same family of bears in northeastern Minnesota (Rogers 1977:113-114).

Males traversed greater distances between summer and fall ranges than females (Table 7). Learning and/or instinct may affect the development of these characteristic movements between the sexes. Young females often continued to utilize a part of their mother's home range after family breakup (Jonkel and Cowan 1971, Rogers 1977:131-134, Reynolds and Beecham 1980, Garshelis and Pelton 1981). Information regarding the distribution of food resources is likely transmitted to the young females, affecting seasonal movements within the range of their mother.

Table 7. Mean distance between summer and fall activity centers for black bears in the CNF, 1980-1981.

Sex (N)	Dist (km)	SD	Min	Max
		1980		
Male (5)	12.9	10.1	2.6	26.1
Female (10)	2.0	3.0	0.3	10.4
Average (15)	7.4	6.6	0.3	18.3
		1981		
Male (6)	1.8	0.6	0.4	2.0
Female (5)	0.6	0.3	0.2	0.9
Average (11)	1.2	0.5	0.3	1.5
		Combined 1980 and 1981		
Male (11)	6.5	8.9	0.4	26.1
Female (15)	1.5	2.5	0.2	10.4
Average (26)	4.0	5.7	0.2	26.1

On the other hand, young males rarely settle in their mother's range (Rogers 1977:144) and are less likely to retrace their mother's movements between seasonal ranges.

Diel movements. Diel data were collected from 14 and 12 radio-collared bears in 1980 and 1981, respectively. A total of 1,576 sequential hourly movements was recorded via 16 diels from June 1980 through December 1981.

In 1980 bears traveled greater distances ($p<0.05$) per hour than in 1981 (Table 8). In summer, mean hourly distances moved by males and females did not differ significantly between years. However, the mean distance traveled hourly by bears in the fall differed significantly between 1980 and 1981.

Differences in mean hourly rates of travel in the fall between years were attributed to hard mast availability and distribution, primarily acorns. In 1980, the scarcity of acorns, hickory nuts, and beech mast may have forced bears to forage over larger areas. The high nutritive value of acorns (Eagle 1979:62,68) indicates the importance of acorns to bears as a fall food item. In the GSMNP, bears made greater fall movements in years when acorns were scarce than when they were abundant (Garshelis 1978:35, Garshelis et al. 1981).

In 1981 the mean distance traveled by male and female bears per hour was considerably different between summer and fall ($p<0.05$). The difference between rates of travel in summer and fall may indicate the use of different foraging strategies as the chief food items change from squawroot (*Conopholis americana*)

Table 8. Mean distance moved per hour by black bears in the CNF, 1980-1981.

1980				1981			
Category (n)	Dist (N)[1]	SD	Max[2]	Category (n)	Dist (N)[1]	SD	Max
Summer				Summer			
Male (4)	0.8 (62)	0.8	4.1	Male (5)	0.8 (142)	0.8	3.5
Female(8)	0.5 (122)	0.5	3.9	Female(7)	0.6 (492)	0.5	2.8
Average	0.7 (184)			Average	0.7 (634)		
Fall				Fall			
Male(4)	1.0 (59)	1.2	6.1	Male(4)	0.7 (26)	0.6	2.0
Female(9)	0.7 (426)	0.6	4.3	Female(7)	0.4 (247)	0.4	3.0
Average	0.8 (485)			Average	0.5 (273)		
Annual				Annual			
Male(4)	0.9 (121)			Male(5)	0.8 (168)		
Female(9)	0.6 (548)			Female(7)	0.5 (739)		
Average	0.8 (669)			Average	0.6 (907)		

[1]Sample size (number of hourly movements) used in analysis.

[2]The minimum distance moved per hour was always 0.

in spring to blackberries (Rubus spp.), huckleberries (Gaylussacia spp.), and blueberries (Vaccinium spp.) in summer to acorns (Quercus spp.) and hickory nuts (Carya spp.) in fall (Beeman and Pelton 1980). Bears may restrict foraging to smaller areas when food supplies are abundant; hence, travel rates would consequently be reduced. In both summers, hourly movements remained consistently high (Table 8). This consistency may reflect the influence of breeding activities and continuous foraging for dispersed berry patches.

Diurnal-nocturnal movements. A total of 1,326 consecutive hourly locations were recorded via sixteen 24-hour radio-tracking periods. Diurnal movements were defined as occurring between 0500-2100 hrs and nocturnal movements as occurring between 2200-0400 hrs. Seasonal comparisons were restricted to summer (Jun-Aug) and fall (Sept-Dec) due to insufficient diel data in spring (Table 9).

Bears overall moved greater ($p<0.05$) distances per hour during the diurnal period than the nocturnal period. However, seasonal differences in nocturnal and diurnal movements were evident (Table 9). In summer, the diurnal movements of both sexes exceeded ($p<0.05$) diurnal movements in fall. In contrast, nocturnal travel rates in summer were significantly lower than fall nocturnal movements. In addition, whereas diurnal movements of bears in summer were considerably ($p<0.05$) greater than summer nocturnal rates, the diurnal and nocturnal movements in fall did not differ appreciably.

Table 9. Diurnal and nocturnal hourly movements (km/hr) by black bears in the CNF, 1980-1981.

Diurnal Movements (0500-2100)				Nocturnal Movements (2200-0500)			
Category (n)	Dist (N)[1]	SD	Max	Category (n)	Dist (N)[1]	SD	Max
Summer				Summer			
Male(8)	0.8 (100)	0.6	2.8	Male(8)	0.5 (54)	0.7	4.1
Female(15)	0.6 (361)	0.5	2.8	Female(15)	0.3 (162)	0.3	1.4
Average	0.7 (461)			Average	0.3 (216)		
Fall				Fall			
Male(5)	0.7 (42)	0.7	3.6	Male(5)	0.8 (22)	1.2	5.2
Female(16)	0.5 (400)	0.5	3.0	Female(16)	0.6 (185)	0.6	3.3
Average	0.5 (442)			Average	0.6 (207)		
Annual				Annual			
Male	0.8 (142)			Male	0.7 (76)		
Female	0.6 (761)			Female	0.4 (347)		
Average	0.7 (903)			Average	0.6 (423)		

[1]Sample size (number of hourly movements) used in analysis.

Seasonal differences in diurnal and nocturnal movements by bears in the CNF may result from the varying influences of increased social interactions associated with breeding (Rogers 1977, pers. obser.), changes in the availability, distribution, and types of foods utilized (Beeman and Pelton 1980), preparation for winter dormancy (Garshelis 1978), and differential intensity of human-related activities (Hamilton 1978:81, pers. obser.). Predominate diurnal movements in summer may reflect breeding activities and a subsequent increase in social interactions between breeding animals and/or mutual avoidance between nonbreeding and breeding animals (Rogers 1977). The significant decrease in diurnal movements between summer and fall may also indicate temporal utilization of different foods and feeding habits. For example, Eagle (1979:82) attributed an increase in hourly movements by bears in August to a high consumption of insects. Orientation by bears to small prey is visual and the catching of prey involves primarily the forepaws (Bacon 1973:137-139). Similarly, in summer bears may rely essentially on vision while feeding on berries (Bacon 1973), thereby limiting foraging to the diurnal period, whereas the larger-sized and more evenly dispersed acorns may be perceptible at night, allowing increased nocturnal foraging (Garshelis and Pelton 1980).

Increased nocturnal movements of bears in fall may partially be a function of denning preparation, whereas the heavy ingress of hunters (i.e., those seeking raccoon, squirrel, deer, hog, ruffed grouse, bear) and other recreationists (i.e., hikers, bikers,

campers, fishermen) into bear habitat may limit the diurnal movements by bears. In the southern Appalachians, bears circumvent the critical winter months of food shortages and severe weather conditions by becoming dormant (Johnson and Pelton 1980a:653, pers. obser.). Increased activities, movements, and accelerated fat deposition in early fall are considered important constituents in preparation for denning (Beeman 1975, Rogers 1977, Garshelis 1978, Johnson and Pelton 1980a:658). The importance of mast availability in the GSMNP to denning chronology has been suggested by Beeman (1975), Garshelis (1978), and Johnson (1978). Eiler (1981:73) also suggested that mast abundance affects the litter size of bears in the Smokies.

Age and sex also contributed to variance in diel movements. Males traversed greater ($p<0.05$) diurnal and nocturnal distances than females in both seasons of both years, except in the fall of 1980. The distances traveled by females and males during nocturnal periods in the fall of 1980 did not differ appreciably ($p>0.10$). The fact that the nocturnal movements of female bears are similar to those of males in years of poor fall mast production may reflect the necessity of foraging for acorns in preparation for denning. Villarrubia (1982:64) noted that overall diurnal and nocturnal movements were similar for male and female bears in the CNF (1978-1979); however, insufficient diel data may have influenced these results.

Movements outside the bear sanctuary. Radio-monitored bears that were trapped within the Citico bear sanctuary often moved

into surrounding areas. Overall male bears (n=6) were found over 52% of the time and females (n=9) about 16% of the time in hunted areas. Males generally traveled greater distances from the sanctuary's periphery than females. However, 3 instrumented females were killed in the 1980 Tennessee bear hunts. Telemetry data indicated that of the 3, 2 were likely driven from the sanctuary to just outside its periphery and shot.

In autumn, bears (6 males, 1 female) sometimes moved into hunted areas within the NNF, North Carolina (Fig. 2). The extent of movements was related to the phenological variation between years and areas. In fall 1980, when the acorn crop in the CNF was limited, bears (4 males, 1 female) were located in the NNF over 30% of the time. However, in 1981 acorns were more abundant in the CNF and bears' (2 males, 1 female) occurrences in NNF during fall were less than 2%.

Male bears were located on private inholdings less than 3% of the time, whereas females never occurred on these private properties. No bears were documented moving to the GSMNP; however, 3 bears instrumented in the Bunker Hill area of the Park moved to the CNF and NNF for brief periods.

Activity Patterns

Over 17,000 activity readings were field recorded for 18 different black bears from June 1980 through December 1981, via the use of reset monitors. Ultimate activity readings were recorded as determined by a notation system to compensate for the

bias toward activity (see Materials and Methods). A total of 5,745 activity readings was used in the analysis of activity patterns. For comparative purposes, the format of activity analysis and results are the same as presented by Garshelis and Pelton (1980:8-19), Quigley (1982:24-47), and Villarrubia (1982:26-47).

Factors affecting activity. The activities of bears in the CNF (1980-1981) were significantly ($p<0.05$) affected by time of year (month), time of day (hour), season (summer-fall), and the individual behaviorial differences among bears (bear) (Table 10). Similar results were reported for bears in the GSMNP (Garshelis and Pelton 1980, Quigley 1982:28-30) and CNF (Villarrubia 1982:29-31). Inconsistencies in activity among bears were attributed to differences in sex, age, and family associations, as well as individual peculiarities (Garshelis and Pelton 1980, Quigley 1982:30, Villarrubia 1982:31). The effects of each of these factors are discussed in detail later in this paper.

Weather factors were also highly correlated with the activity patterns of bears (Table 11). Garshelis and Pelton (1980) suggested that environmental and biological conditions obscured the relationships between individual weather factors and bear activity. However, temperature, precipitation, and cloud cover distinctly ($p<0.05$) affected the activities of bears (Table 11). The influences of weather factors on bear activity are discussed in greater detail later in this section.

Table 10. Analysis of variance in the activities of bears in the CNF, 1980-1981 with respect to time of year (month), time of day (hour), season (summer and fall), and individual differences among bears (bear).

Source of variation	df	MS	F	PR>F
Total	5560			
Bear	17	3.2959	18.61	.0001
Month	10	3.7183	21.00	.0001
Hour	23	6.9367	36.92	.0001
Month X Hour	162	1.7918	10.12	.0001
Bear X Hour	410	0.6479	22.73	.0001
Season	1	19.5705	99.26	.0001

Table 11. Analysis of variance in activity of black bears in the CNF, 1980-1981 with respect to differences among individual bears (bear), time of year (month), time of of day (hour), weather factors, and differences between years.

Source of Variation	df	MS	F	PR>F
Total	5562			
Bear	17	3.0291	16.10	0.0001
Month	6	2.2872	12.16	0.0001
Year	1	3.7728	20.05	0.0001
Hour	23	6.2891	33.43	0.0001
Temperature	12	1.3204	7.02	0.0018
Precipitation	6	0.6622	3.52	0.0001
Cloud cover	3	0.5476	2.91	0.0327

Seasonal Effects. Bears were less active in early spring and late fall than any other time of the year (Fig. 3). During June and July, activity escalated rapidly reaching a peak in early August (01 Aug-14 Aug). The level of activity then gradually diminished until denning in December or early January (pers. obser.).

A similar pattern of activity was reported for bears in the Bote Mountain area within the GSMNP, except that the peak of activity was observed in June (Garshelis and Pelton 1980). Bears in the Bunker Hill area of the Park (Quigley 1982:31-35) and earlier in the CNF (Villarrubia 1982:31-35), however, exhibited low levels of activity in the pre- and post-denning periods, rapid increases in activity levels in June and July, and an August peak in activity. The temporal difference in activity peaks with respect to the Bote Mountain area was attributed to varying age composition (Quigley 1982:33, Villarrubia 1982:35). Trapping records indicated a significantly lower mean population age for bears in the CNF and the neighboring Bunker Hill area.

Subadult females may exhibit prolonged or reoccurring estrus causing breeding to occur later in the year than originally suspected (Eiler 1981:43,95). Hence, the higher activity levels in August may reflect the breeding activities of younger bears. The younger age of bears in the CNF and the adjacent Bunker Hill area may be a result of accessibility and an associated increased human-related bear mortality (pers. obser.).

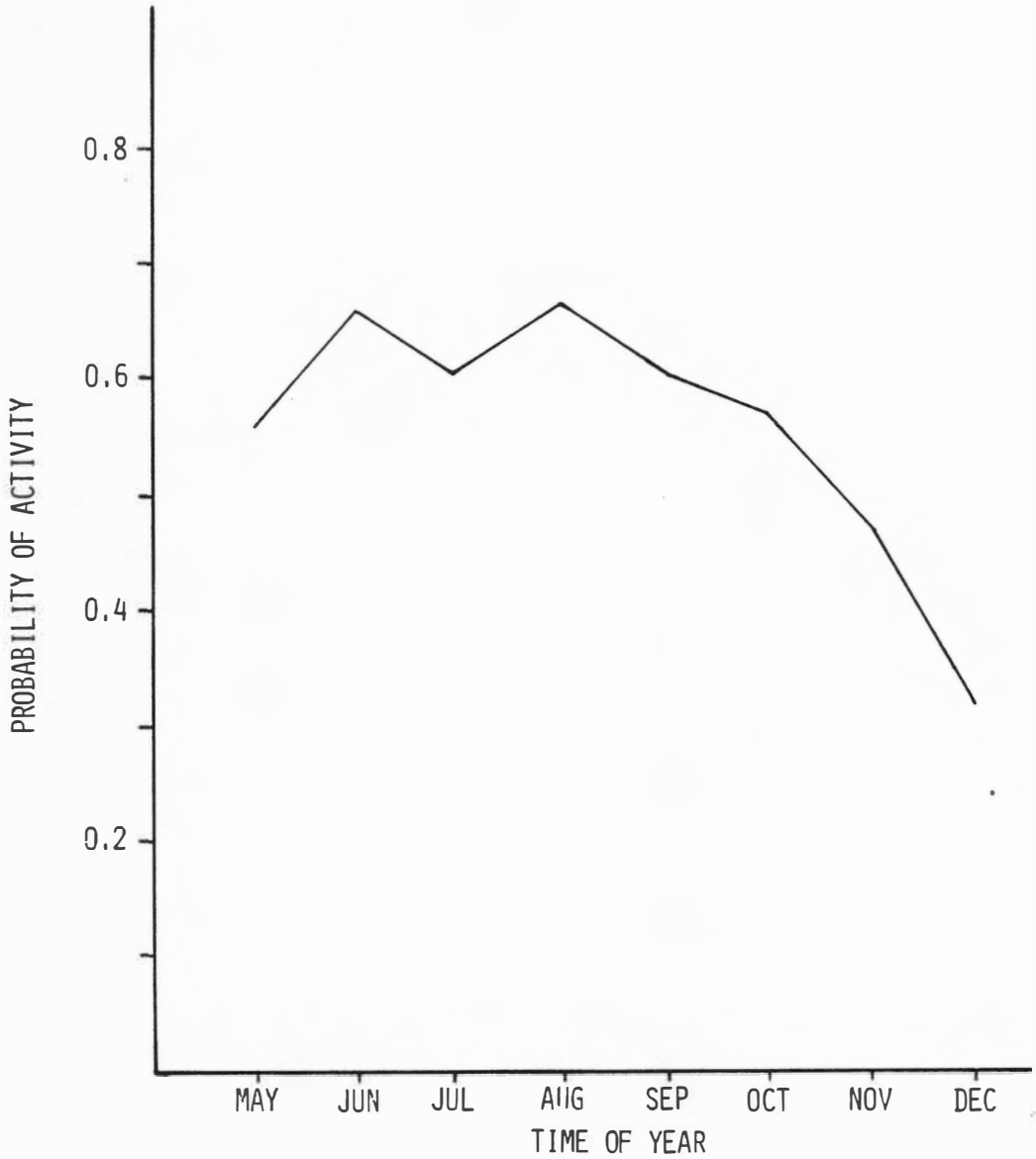


Figure 3. Relationship between time of year (month) and the mean monthly activity probability for black bears in the Cherokee National Forest, 1980-1981.

Diel effects. Daily activity, averaged over the entire year, indicated that bears were generally crepuscular in the CNF. Peaks of activity occurred at 0700h and 1900h. Bears were significantly ($p<0.001$) more active during diurnal ($x=0.7$ $n=4660$) than nocturnal ($x=0.3$ $n=1031$) periods, combining both sexes, years, and seasons. Using different techniques, researchers found that black bears were primarily diurnal in west-central Idaho (Amstrup and Beecham 1976), southwestern Washington (Lindzey and Meslow 1977), and western Washington (Poelker and Hartwell 1973). On the other hand, bears were mainly nocturnal in coastal North Carolina (Hamilton 1978:79), Minnesota (Rogers 1970,1977), GSMNP (Beeman 1975:89), and Alaska (Erickson 1965).

Since time of year significantly affected the activities of bears in the CNF, months were grouped into seasons and seasonal effects were analyzed. In summer, diurnal activity remained high, nocturnal behavior was low (especially 2100-0400h), and a distinct crepuscular pattern was evident (Fig. 4). The level of bear activity increased rapidly between 0400-0600h, reached a peak at 0600-0800h, remained relatively high during the middle of the day, peaked again between 1700-2000h, and declined sharply to levels of low activity at 2100h and 0200hr. Almost identical patterns of activity were described for bears in the GSMNP (Garshelis and Pelton 1980, Quigley 1982:37) and CNF (Villarrubia 1982:36) during summer, except that morning and evening peaks were less discernible.

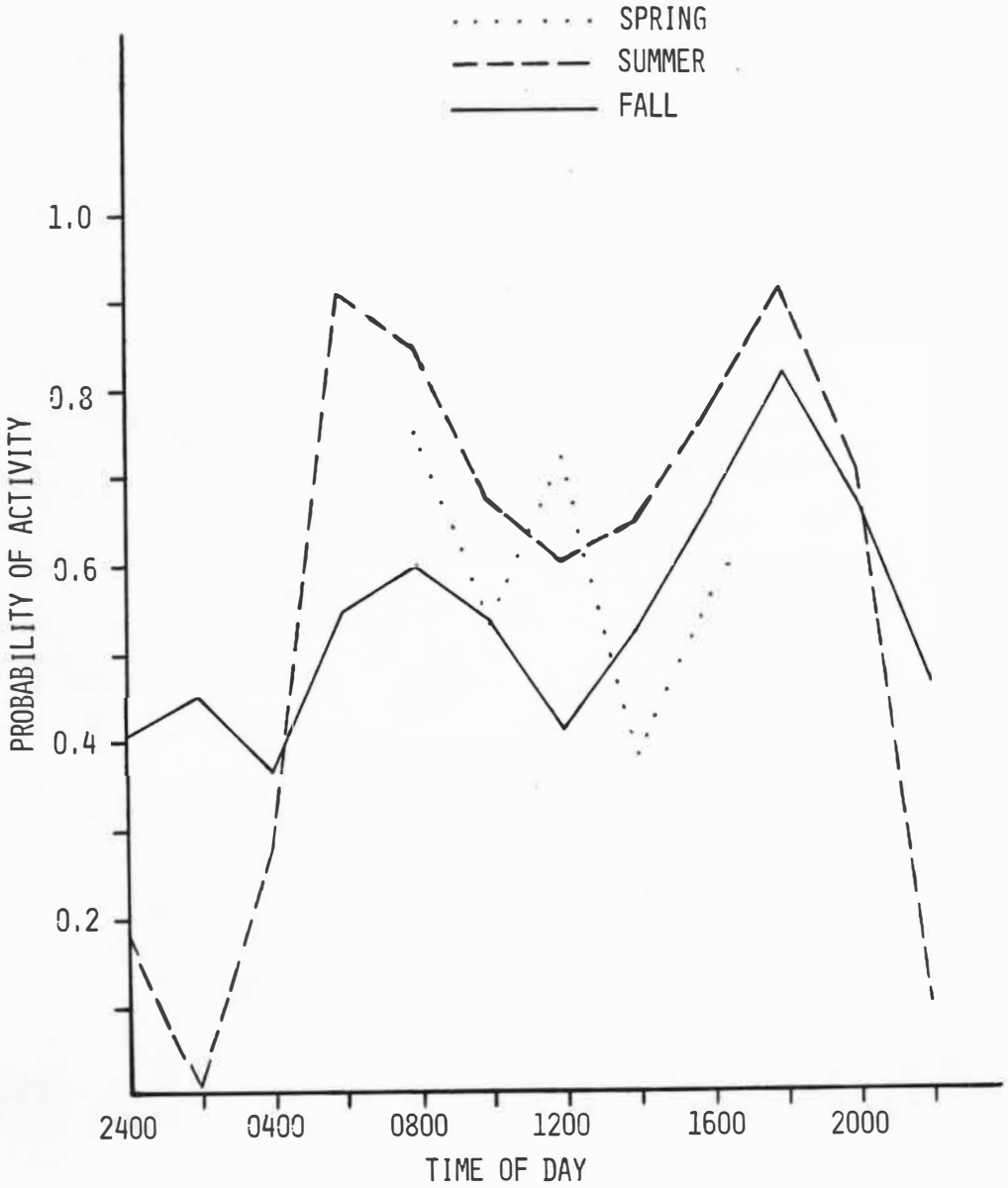


Figure 4. Seasonal variation in the daily activity patterns of black bears in the Cherokee National Forest, 1980-1981. Spring information includes only the 0800-1600 hr time interval.

Diurnal activities of bears decreased in fall, while their nocturnal activities increased (Fig. 4). Diurnal activity and increased nocturnal activity peaks in the fall were less pronounced and bears of both sexes were virtually as active during nocturnal ($\bar{x}$=0.4 n=494) periods as during diurnal ($\bar{x}$=0.5 n=2221) periods. Villarrubia (1982:39-40) reported a similar pattern of bear activity in the CNF (1978-1979), although levels of increased nocturnal activity were not as discernible.

Differences in activity patterns of bears are likely influenced by the physiological condition of bears, weather conditions, changes in the availability and distribution of foods, and the influence of denning (Garshelis and Pelton 1980, Quigley 1982:37-41, Villarrubia 1982:39-40, this study). The activities of bears may also be affected by human-related activities. In coastal North Carolina, increased nocturnal activity of bears in the fall was attributed to a diurnal increase in human-related activities, primarily hunters and their dogs (Hamilton 1978:78-80). Fall nocturnal activities of bears in the CNF may also be influenced by the increased influx of hunters and dogs and other recreationists into bear habitat.

Effects of weather. Temperature, precipitation, and cloud cover significantly influenced ($p<0.05$) the activities of black bears (Table 11). Using similar techniques, Garshelis and Pelton (1980), Quigley (1982:41-43), and Villarrubia (1982:40-43) attributed a significant portion of the variance in bear activities to the influence of temperature.

The relationship between temperature and activity in spring was nebulous due possibly to limited sample size. In the GSMNP, increased spring temperatures were associated with an increase in bear activity (Garshelis and Pelton 1980). In summer, bear activity increased steadily as the temperature climbed from 16¹C to 31¹C (Fig. 5). If the temperature exceeded 31¹C, the active behavior of bears decreased. In fall, activities of bears decreased as temperatures dropped below 31¹C. The decrease in bear activity with lower temperatures might also reflect the influence of denning activities.

Although the activities of bears in CNF were significantly related to the extent of cloud cover, the relationship between the cloud cover and bear activity was not clear. The significance of cloud cover to bear activity may be a function of its relationship to other weather factors.

The level of activity and precipitation was also significantly ($p<0.05$) correlated. Bears were slightly more active immediately after a rainfall. Bears were the least active when there was a snow cover coupled with sleeting ($n=70$); however, this relationship between snow and activity may be affected by the concurrent effects of freezing temperatures (Garshelis and Pelton 1980) and the influence of denning.

Sex, age, and family effects. Orthogonal contrasts were used to determine differences in activity patterns among various sex and age groups, and between females with and without cubs (Garshelis and Pelton 1980:17, Quigley 1982:44,

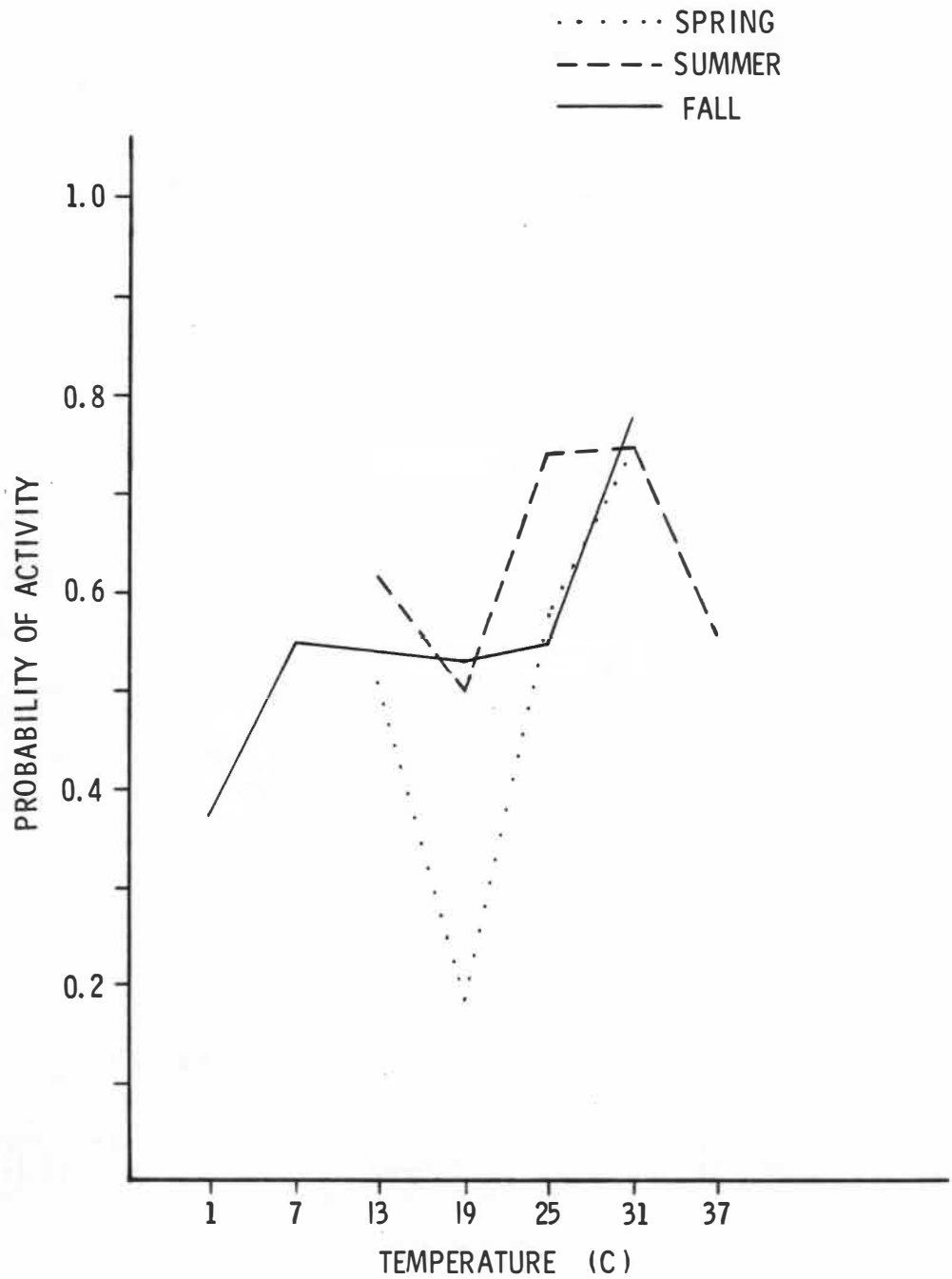


Figure 5. Seasonal relationships between temperature and activity patterns of black bears in the Cherokee National Forest, 1980-1981.

Villarrubia 1982:43). In the Bote Mountain area of the GSMNP, adult males were more active than solitary adult females; and subadults of both sexes were more active than solitary adults of their respective sex (Garshelis and Pelton 1980). Subadult females exhibited the highest overall activity of any sex-age group in the Bunker Hill area of the Park (Quigley 1982:44). In the CNF, Villarrubia (1982:43) concluded that females with cubs were the most active sex or age group.

In this study, adult males were more active ($p<0.05$) than females with cubs, solitary adult females, and subadult and yearling females. The activity of subadult and yearling females exceeded ($p<0.05$) that of solitary adult females and females with cubs. The only subadult male tracked in this study was apparently less active than the adult males; however, this contrast was not tested statistically and was hampered by small sample size. Females with cubs were the least ($p<0.05$) active group when compared with adult males, solitary adult females, and subadult females.

Seasonal changes in activity patterns were evident among different reproductive groups (Fig. 6). In the spring, females with cubs were the least active ($p<0.05$) group. In contrast, several authors have suggested that nursing and play behavior by cubs and the subsequent need for adequate nutrition may stimulate spring activity by the mother (Amstrup and Beecham 1976, Garshelis and Pelton 1980, Quigley 1982:46, Villarrubia 1982:44-46). The stimulated activity by the mother, however may be head

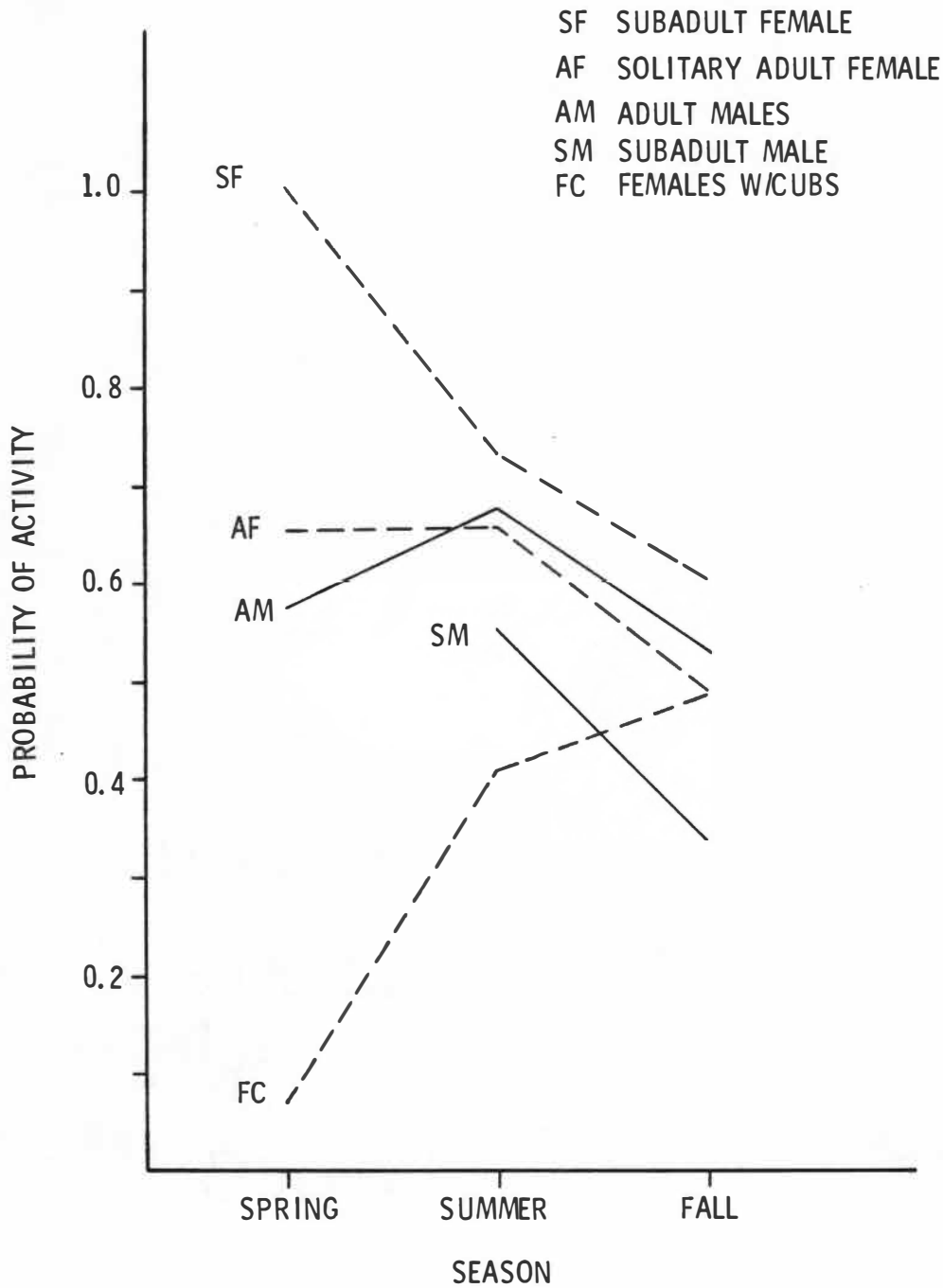


Figure 6. Seasonal relationships among activity patterns of different sex, age, and family groups of black bears in the Cherokee National Forest, 1980-1981.

and body movements rather than actual locomotion (Alt et al. 1976, Rogers 1976).

Activity levels of females with cubs in spring are difficult to explain. Low levels of spring activity, following den emergence, may reflect the restricted mobility and small size of young cubs as well as the need for prolonged resting periods. Individual peculiarities among females with cubs may also affect the variation in activity patterns.

Females with cubs gradually increased activity from spring to summer to fall; increased size, mobility, and exploratory ability of cubs, coupled with an expanding need to assure adequate nutrition for both self maintenance of the mother and development of the young, may stimulate this activity continuum. In all other sex and age groups, bears are most active in the summer, with activity diminishing in the fall.

In spring, adult males were less active than any group ($p<0.05$) except females with cubs. This pattern was observed for males in Idaho (Amstrup and Beecham 1976) and GSMNP (Garshelis and Pelton 1980, Quigley 1982:46).

Adult males and breeding females coincided their highest level of activity during summer (breeding season) enhancing the probability of successful breeding. In northeastern Pennsylvania, Alt et al. (1976) found that adult males and solitary adult females also synchronized activity peaks in the breeding season. They suggested that synchronization of activity may be important

in increasing the probability of successful breeding, particularly in sparsely populated bear range.

Habitat Utilization

Radio-monitored bears (n=18) were located over 3,000 times in 1980 and 1981. Habitat use by black bears was examined utilizing the FUNCAT procedure.

Factors affecting habitat use. Time of year (season) and year contributed significantly ($p<0.05$) to the variation in habitat use by bears in the CNF. Individual differences among bears, reproductive condition, age, and the differing responses of these to time of year also affected ($p<0.05$) bears' use of habitat. Habitat utilization by bears was not significantly affected by time of day (hour).

Differential use of habitat. Although bears were found in over 20 different forest cover types (Table 12), 85-90 % of bear locations occurred in pine or oak-hickory types. Bear locations were grouped into 2 habitat categories, hardwoods (i.e., cove hardwoods, oak-hickory, northern hardwood) and softwoods (i.e., mesic hemlock, pines). Differential use of these 2 habitat categories was then determined using the FUNCAT procedure.

Hardwoods (chiefly oak-hickory) were used significantly more than softwoods (chiefly pines) by all bears overall (Fig. 7). Males occurred over 63 % and females almost 52 % of the time in hardwood areas.

Table 12. Habitat categories, associated forest cover types, and the frequency that black bears occurred in each, 1980-1981.

Habitat Category	Bear Locations in each type	Forest Cover Types in each habitat
Non-forest	7	
Cove hardwoods	265	cove hwds-white pine-hickory
	7	upland hwds-white pine
	1	white pine-upland hwds
Oak-hickory	697	white oak-red oak-hickory
	9	n. red oak-hickory-yellow pine
	4	chestnut oak-scarlet oak-y. pine
	33	chestnut oak
	12	scarlet oak
	4	northern red oak
	618	yellow-poplar-white oak-n. red oak
	21	sugar maple-beech-yellow birch
Mesic hemlock	55	white pine
	12	white pine-hemlock
	10	hemlock
	2	bottomland hwds-yellow pine
	10	hemlock-hardwoods
	24	yellow-poplar
Pines	26	pitch pine-oak
	31	Virginia pine-oak
	862	Virginia pine
	264	pitch pine
	27	table-mountain pine
	1	shortleaf pine

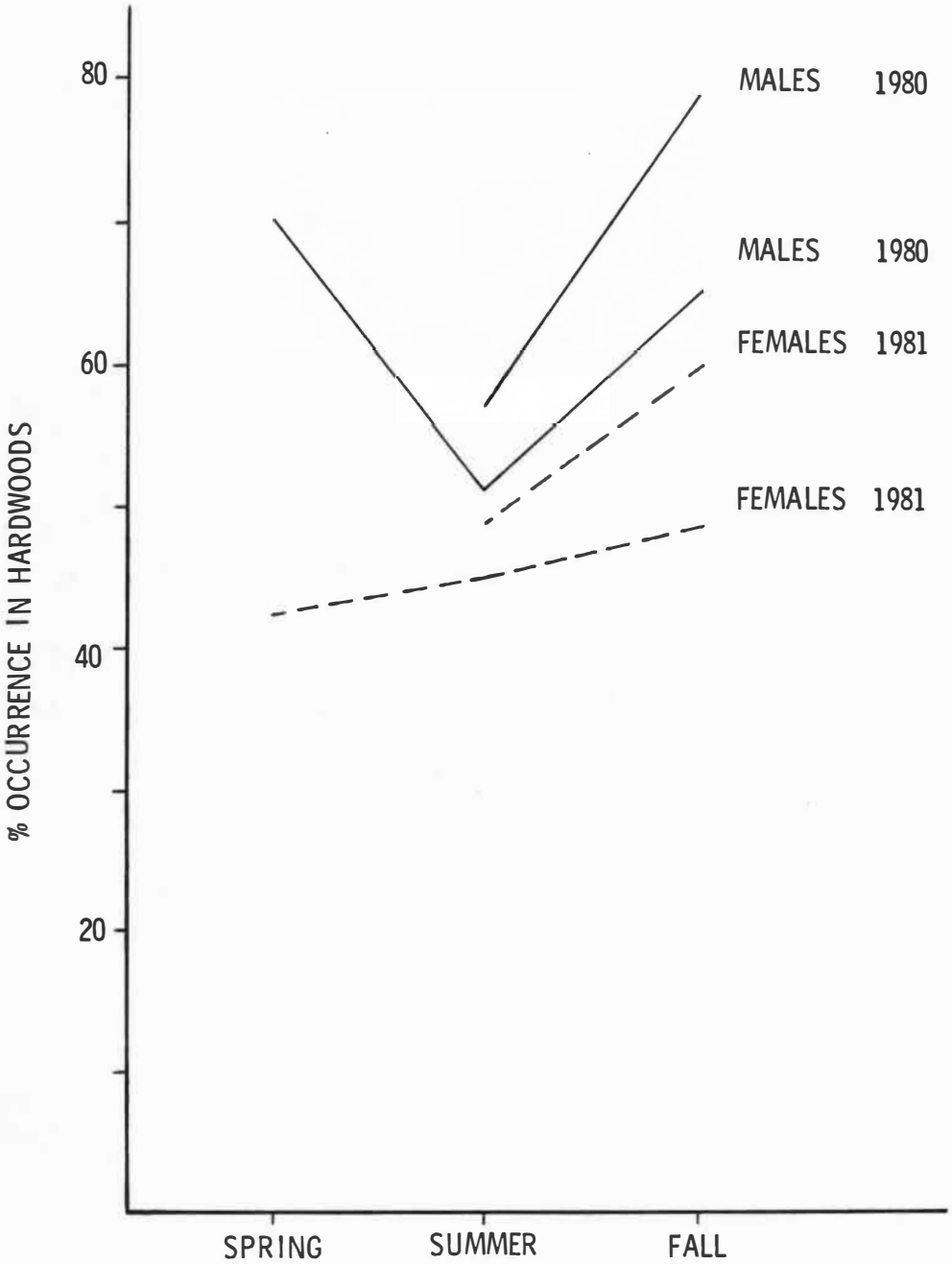


Figure 7. Seasonal use of hardwoods by male and female black bears in the Cherokee National Forest from June 1980 through December 1981.

The importance of hard mast to black bears, primarily acorns has been well recognized in the GSMNP (Eagle 1979:66, Beeman and Pelton 1980, Garshelis and Pelton 1981, Quigley 1982:69), western Virginia (Richards 1968, Barick 1970), and northeastern Georgia (Lentz 1980:25). In contrast, Villarrubia (1982:69), using techniques described by Neu et al. (1974), reported that bears in the CNF (1978-1979) used pines more than expected and oaks less than expected. Individual and small clusters of oaks are distributed throughout pine habitat in the CNF (pers. obser.) and may provide sources of mast for bears (Villarrubia 1982:79), especially in years when acorns are abundant and evenly dispersed (pers. obser.).

Yearly variation. A significant difference ($p<0.05$) existed between the 2 years of this study with respect to the frequency of bears' occurrence in hardwoods (Table 13). In 1980 and 1981, bears were located in hardwood types 59 % and 50 % of the time, respectively. Habitat use by bears between years may vary due to the quality, availability, and distribution of food sources, especially acorns.

Seasonal variation. Seasonal use of hardwood and softwood habitats differed significantly among different sex and age groups. In spring, male bears occurred about 70 % and females over 55 % of the time in areas dominated by hardwoods (Fig. 8). In the GSMNP the spring diet of bears consisted primarily of grasses and herbaceous material (Eagle 1979:29,34).

Table 13. Habitat use (%) by black bears in the CNF, 1980-1981, as determined by radio-telemetry.

Period	Habitat Types	Male (%)	Female (%)	1980 (%) Male-Female	1981 (%) Male-Female
Spring	Cove hwds	26	04	--	15
	Oak-hickory-hwds	41	39	--	40
	Mesic hemlock	04	--	--	02
	Nonforest	--	--	--	--
	Pines	30	58	--	43
Summer	Cove hwds	07	10	14	07
	Oak-hickory-hwds	47	36	38	40
	Mesic hemlock	05	02	03	03
	Nonforest	<1	<1	<1	<1
	Pines	42	52	45	50
Fall	Cove hwds	10	10	07	13
	Oak-hickory-hwds	63	46	57	40
	Mesic hemlock	05	04	05	04
	Nonforest	--	<1	<1	<1
	Pines	23	40	31	43

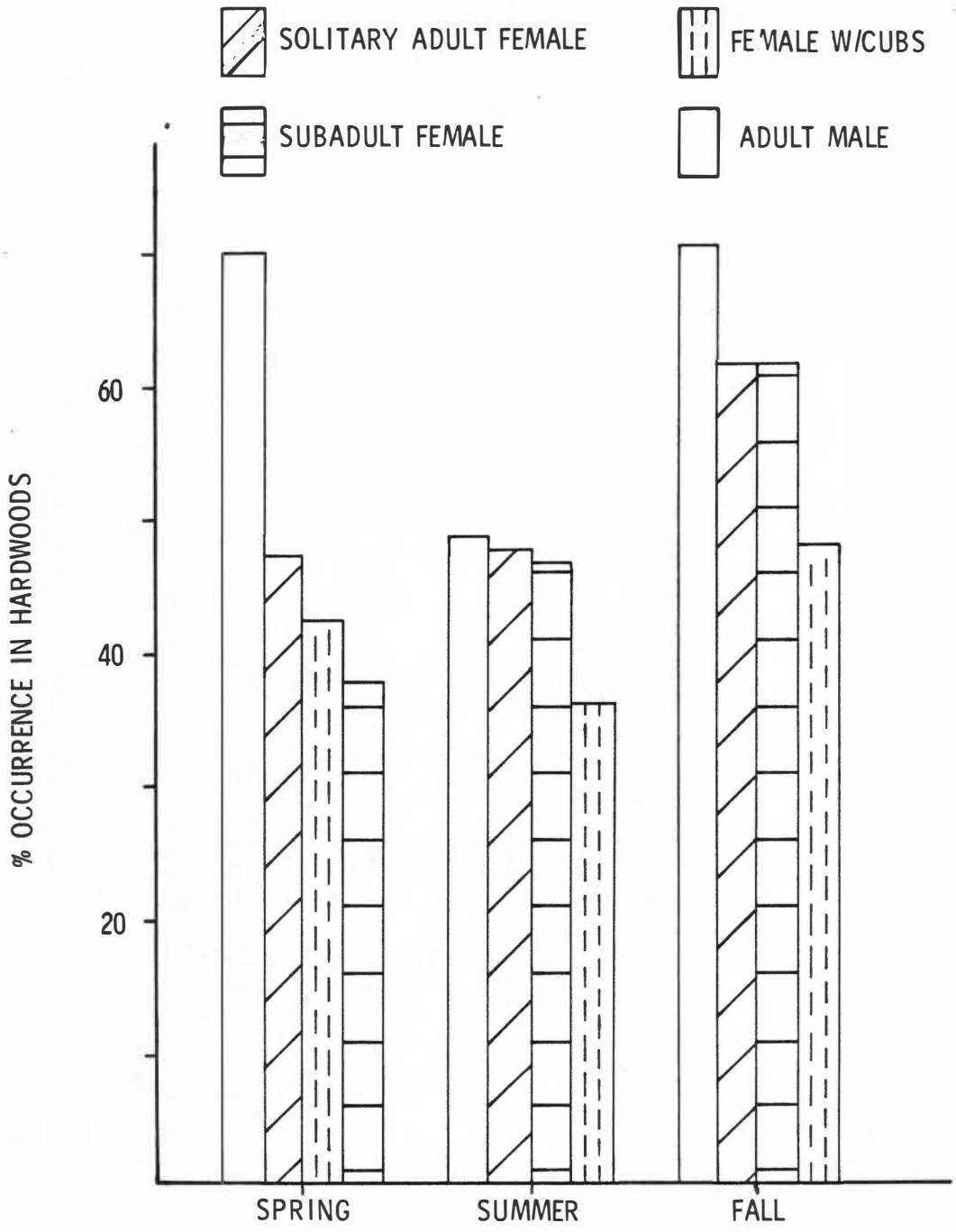


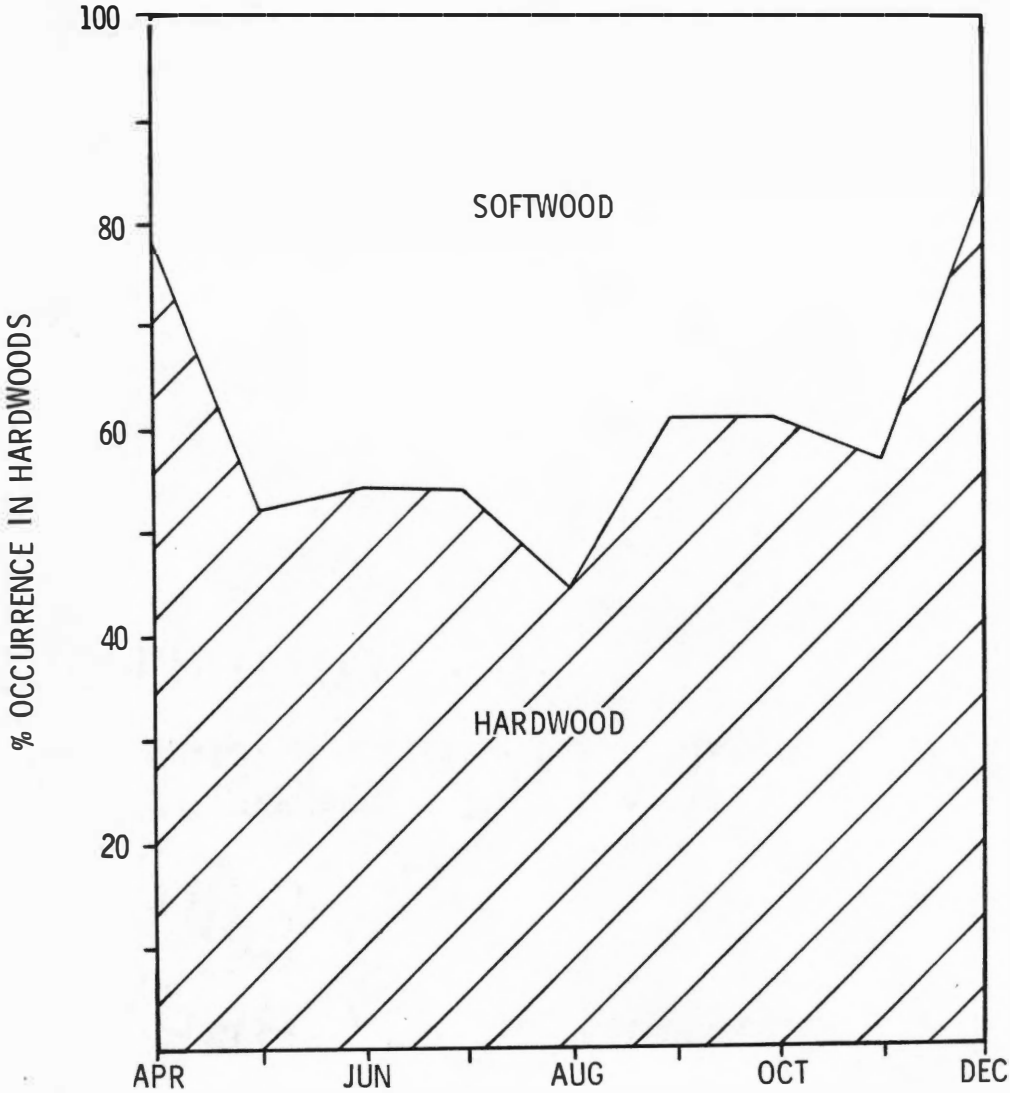
Figure 8. Seasonal use of hardwoods by different reproductive classes of black bears in the Cherokee National Forest, 1980-1981.

Squawroot, a parasite that grows abundantly on the roots of trees (especially oaks) is an important food item for bears in spring (Beeman and Pelton 1980). Bears may occupy hardwoods during spring in order to utilize squawroot.

Except for 1 subadult male, bears occurred more frequently in pines during summer than any other habitat (Fig. 9). Blackberries (Rubus spp.), blueberries (Vaccinium spp.), and huckleberries (Gaylussacia spp.) are generally associated with these drier and more open pine areas (Shanks 1954b, pers. obser.). The fruits from these plentiful plants accounted for the most important constituents of the bears' summer diet (Beeman and Pelton 1980).

The summer shift of adult males into pine habitat overlaps the ranges of several females during breeding season, indicating that the presence of adult males in pine habitat during summer may also be influenced by breeding activities. The dense understory generally associated with pine types could provide critical cover for bears in summer (Villarrubia 1982:79, pers. obser.). Several day beds used by bears in summer were observed in pine habitat during this study. Foraging for insects in summer when they are especially active and available might affect the use of habitat.

Sex, age, and reproductive variation. Although the influence of sex on habitat use was statistically rejected ($p>0.10$), males occurred more frequently in hardwoods than females in both summer and fall. The effects of different reproductive classes (i.e., adult male, breeding female, female with cubs, etc.) may have obscured the relationship of sex to habitat use (Fig. 9).



9. Percentage of Bear Locations in Hardwoods (predominately oaks) and softwoods (chiefly pines) in the CNF, 1980-1981 68

Females generally occupied areas in the fall not commonly used by males. Hardwoods were usually less abundant in these areas. In the Bote Mountain area of the GSMNP, Garshelis and Pelton (1981) also suggested that males exclude females from areas where oaks are most abundant. In general female bears showed less seasonal variation in habitat use than males, a reflection of their more restricted and constant affinity for a specific home range.

Using the Bonferroni approach (Neu et al. 1974), Quigley (1982:69) concluded that males in the Bunker Hill area of the GSMNP used hard mast-producing areas in expected proportion to their availability, whereas females displayed a preference for these areas. Male bears near Bote Mountain within the GSMNP showed a strong preference for hardwoods (Garshelis and Pelton 1981). Lentz (1980:21) reported no statistically significant interaction between habitat use and sex for bears in northeastern Georgia. Likewise, the sexes exhibited no differential use of forest cover types in the CNF (Villarrubia 1982:78). The relationship of sex to habitat use may be obscured by differences in reproductive classes and individual bear behavior.

Bears of different reproductive and age groups exhibited seasonal variation in habitat use (Fig. 9). Subadult females used pine areas considerably ($p<0.10$) more than all other bears in spring, summer, and fall. Differential use of hardwoods by subadult females and adults of both sexes may reflect dispersal of young females. After family breakup, young females often continue to utilize a portion of their mother's home range (Jonkel and

Cowan 1971:35, Rogers 1977:131-134, Reynolds and Beecham 1980). Garshelis and Pelton (1981) suggested that young females utilize the same home range as their mother but avoid each other through different temporal use patterns, rather than by maintaining areas of exclusive use. The adult female's presence in the limited hardwood areas within her home range may confine the movement patterns of her female offspring to the less preferred pine areas. Young males are less likely to restrict their movements within a particular area, because they rarely settle within their mother's range (Jonkel and Cowan 1971). The only subadult male radio-tracked in this study was observed predominately in hardwoods in summer and fall.

Habitat preference. A total of 3,002 bear locations was recorded from June 1980 through December 1981. However, only those locations (n=2,686) that occurred within the original IMGRID study area (Villarrubia 1982:7,68) were used in this utilization-availability analysis. Goodness-of-fit comparisons showed differential use ($p<0.10$) of hardwood and softwood habitats by bears. The Bonferroni approach was used to determine preference or avoidance of these habitats by bears (Neu et al. 1974).

Bears overall occurred more than expected ($p<0.10$) in hardwoods and less than expected in the softwoods (Table 14). Using similar techniques, Quigley (1982:69) reported that bears in the Bunker Hill area within the GSMNP utilize areas of mast-producing trees more than expected and softwood areas

Table 14. Occurrence of 18 black bears in hardwoods and softwoods in the CNF from June 1980 (n=14) through December 1981 (n=12).

Habitat Category	Total Area (ha)	Proportion Total Area[1]	Bear Locations in Habitat	Expected Bear Locations in Habitat[2]	Expected Proportion of Locations in Habitat	Confidence Interval[3]
Hardwood	3832	0.54	1473	1450	0.55	$0.53<p<0.58$
Softwood	3207	0.46	1213	1236	0.45	$0.42<p<0.48$
Total	7039		2686	2686		

[1]Proportion of total area represent expected bear locations as if bears occured in each habitat in exact proportion to its availability.

[2]Calculated by multiplying proportion of total area X total locations (i.e. 0.54 X 2686=1450).

[3]Confidence interval on proportion of occurrence: 90 % simultaneous 97.5 % individual (Neu et al. 1974).

less than expected. Villarrubia (1982:69) concluded that bears in the CNF used pines more than expected, mesic hemlock and oak-hickory less than expected, and cove hardwoods in proportion to their availability.

Differential preference or avoidance of habitats between males and females was also tested. Females apparently selected ($p<0.10$) for the non-mast habitats, predominately pines, and likely avoided ($p<0.10$) some of the hardwood habitats (Table 15). Male bears, on the other hand, exhibited an overall preference ($p<0.10$) for the hardwood areas and may avoid the pine areas in contrast to females who favored them (Table 15). Males appear dominant over females (Lindzey and Meslow 1977, Rogers 1977:103-106, Garshelis and Pelton 1981) and possibly exhibit considerable aggressivness toward females (Rogers 1977:103-106, Garshelis and Pelton 1981:924). Males likely exclude females and subordinate males from prime hardwood areas with abundant white and red oaks (Garshelis and Pelton 1981) in the GSMNP. Hardwoods may be the most critical component of black bear habitat in the CNF and the southern Appalachians.

Male bears exhibited a significant ($p<0.10$) shift among the three seasons with respect to their relative occurrence in hardwoods and softwoods (Tables 14, 15, 16). In spring (April-May), males occurred in hardwoods more than expected and were found less than expected in pines (Table 16). In summer (Jun-Aug), males showed a distinct ($p<0.10$) preference for the pine types (Table 17), whereas in fall they occurred more

Table 15. Occurrence of male and female black bears in hardwoods and softwoods in the CNF, 1980-1981.

Habitat Category	Total Area (ha)	Proportion Total[1] Area	Bear Locations in Habitat	Expected Bears Locations in Habitat[2]	Expected Proportion of Locations in Habitat	Confidence Interval[3]
			MALE			
Hardwoods	3832	0.54	320	299	0.58	(0.53, 0.63)
Softwoods	3207	0.46	234	255	0.42	(0.36, 0.48)
Total	7039					
			FEMALE			
Hardwoods	3832	0.54	1088	1152	0.58	(0.48, 0.53)
Softwoods	3207	0.46	1044	981	0.49	(0.46, 0.52)
Total	7039					

[1]Proportions of total area represent expected bear locations as if bears occurred in each habitat in exact proportion to its availability.

[2]Calculated by multiplying proportion of total area X total locations.

[3]Confidence interval on proportion of occurrence: 90 % simultaneous, 97.5 % individual (Neu et al. 1974).

Table 16. Spring occurrence of male and female black bears in hardwoods and softwoods in the CNF, 1980-1981.

Habitat Category	Total Area (ha)	Proportion of Total Area[1]	Bear Locations in habitat	Expected Bear Locations in habitat[2]	Expected Proportion of Locations in habitat	Confidence Interval[3]
			MALES			
Hardwoods	3832	0.54	18	15	0.67	(0.45, 0.89)
Softwoods	3207	0.46	9	12	0.33	(0.03, 0.64)
Total	7039					
			FEMALE			
Hardwoods	3832	0.54	11	14	0.42	(0.13, 0.72)
Softwoods	3207	0.46	15	12	0.58	(0.33, 0.83)
Total	7039					

[1]Proportions of total area represent expected bear locations as if bears occurred in each habitat in exact proportion to its availability.

[2]Calculated by multiplying proportion of total area X total locations.

[3]Confidence interval on proportion of occurrence: 90 % simultaneous, 97.5 % individual (Neu et al. 1974).

Table 17. Summer occurrence of male and female black bears in hardwoods and softwoods in the CNF, 1980-1981.

Habitat Category	Total Area (ha)	Proportion of Total Area 1	Bear Locations in Habitat	Expected Bear Locations in Habitat 2	Proportion of Locations Expected in Habitat	Confidence Interval 3
			MALE			
Hardwoods	3832	0.54	146	172	0.46	(0.38, 0.54)
Softwoods	3207	0.46	173	147	0.54	(0.46, 0.61)
Total	7039					
			FEMALE			
Hardwoods	3832	0.54	410	485	0.46	(0.41, 0.50)
Softwoods	3207	0.46	488	413	0.54	(0.50, 0.59)
Total	7039					

1Proportions of total area represent expected bear locations as if bears occurred in each habitat in exact proportion to its availability.

2Calculated by multiplying proportion of total area X total locations.

3Confidence interval on proportion of occurrence: 90 % simultaneous, 97.5 % individual (Neu et al. 1974).

frequently in hardwoods (Table 18). Seasonal variation in habitat use by males has been discussed previously.

Female bears showed less seasonal variation in habitat preference than males, preferring pine areas in both spring and summer (Table 17). In fall, however, females did exhibit a slight preference for hardwoods (Table 18). These results probably reflect the smaller and more restricted ranges of female bears as well as the importance of acorns in the fall for bears in the CNF.

Table 18. Fall occurrence of male and female black bears in hardwoods and softwoods in the CNF, 1980-1981.

Habitat Category	Total Area (ha)	Proportion of Tota Area[1]	Bear Locations in habitat	Expected Bear Locations in habitat[2]	Expected Proportion of Locations in habitat	Confidence Interval[3]
			MALE			
Hardwoods	3832	0.54	156	112	0.75	(0.55, 0.95)
Softwoods	3207	0.46	52	96	0.25	(0.19, 0.31)
Total	7039					
			FEMALE			
Hardwoods	3832	0.54	667	653	0.55	(0.51, 0.59)
Softwoods	3207	0.46	542	556	0.45	(0.41, 0.49)
Total	7039					

[1]Proportions of total area represent expected bear locations as if bears occurred in each habitat in exact proportion to its availability.

[2]Calculated by multiplying proportion of total area X total locations.

[3]Confidence interval on proportion of occurrence: 90 % simultaneous, 97.5 % individual (Neu et al. 1974).

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. In this study, 22 bears (13 females and 9 males) were trapped. Radio-collars equipped with activity monitors were attached to 18 different bears.

2. Three instrumented female bears were killed during the 1980 Tennessee bear hunts. Telemetry data indicated that of the 3, 2 were likely driven from within the Citico Bear Sanctuary and shot just outside of its periphery. Although 6 males and 1 female traveled into North Carolina in the fall, none were killed in the North Carolina bear hunts.

3. The convex polygon method was used to determine seasonal and annual home ranges for 14 bears in 1980 (n=1,220) and 13 bears in 1981 (n=1,679). Mean distance between summer and fall ranges was determined to delineate seasonal displacement of ranges.

4. In 1980 annual home ranges averaged 192 km^2 for male bears and 23 km^2 for females. In 1981 annual home ranges averaged 60 km^2 for males and 15 km^2 for females. The ranges of bears were affected by sex, season, and changes in the availability and distribution of acorns between years.

5. Males inhabited larger annual and seasonal ranges than females in both years. Larger ranges for males likely reflect a social structure that enhances reproduction.

6. Mean distances between summer and fall activity centers were affected by sex and yearly variation in the abundance, availability, and distribution of acorns.

7. Male bears traveled a greater distance between summer and fall ranges than females, averaging 6.5 km and 1.5 km, respectively. Learning and behaviorial patterns may contribute to these differences.

8. A total of 1,576 sequential hourly movements were recorded from 14 and 12 radio-collared bears in 1980 and 1981, respectively.

9. Mean hourly movements by bears were significantly greater in summer than in fall. Different foraging strategies and the influence of breeding activities likely affected seasonal hourly movements.

10. In fall, the mean distance traveled per hour by bears differed significantly between 1980 (x=0.7 km) and 1981 (x=0.4 km). The scarcity of acorns, hickory nuts, and beech mast in 1980 probably influenced this variation.

11. A total of 1,326 consecutive diurnal and nocturnal hourly movements were recorded via 16 24-hr radio-tracking periods.

12. Both sexes moved greater distances per hour during diurnal periods (x=0.6 km) than nocturnal periods (x=0.5 km).

13. Diurnal movements of both sexes in summer however, exceeded diurnal movements in fall. Nocturnal movements of both

sexes in fall significantly exceeded nocturnal movements in summer.

14. Seasonal differences in diurnal and nocturnal movements may result from the influences of social interactions associated with breeding, changes in the availability, distribution, and types of foods utilized, preparation for denning, and differential intensity of human-related activities.

15. Age and sex also contributed to the variance in diel movements.

16. A total of 5,745 activity readings was used in the analysis of activity patterns.

17. The activities of bears were significantly affected by time of year (month), time of day (hour), season, individual differences among bears, temperature, precipitation, and cloud cover.

18. Activity levels were low after bears emerged from dens, escalated rapidly in June and July, reached a peak in August, and diminished gradually until denning.

19. Bears exhibited a crepuscular pattern of activity that was modified seasonally.

20. Differences in the activities of bears are likely related to the physiological condition of bears, weather conditions, distribution and availability of food resources, seasonal changes in foraging strategies, and the influence of denning.

21. Sex, age, and reproductive classes also influenced the activities of bears.

22. Adult males were overall the most active group and females with cubs were the least active.

23. Seasonal variation in activity patterns among different age and reproductive classes was evident.

24. Adult males and estrous females coincided their highest level of activity during the breeding season. This synchronization may be important in increasing breeding probability, particularly in sparsely populated bear range.

25. Radio-monitored bears were located over 3,000 times from June 1980 through December 1981. The FUNCAT procedure was utilized to examine habitat use by bears.

26. Factors affecting habitat use included season, year, individual differences among bears, reproductive classes, and age.

27. The use of hardwoods was significantly higher than the use of softwoods.

28. The occurrence of bears in hardwoods was significantly greater in 1980 than in 1981. This difference may be attributed to poor hard mast production in 1980.

29. Seasonal use of habitat differed significantly among the different age and sex groups.

30. Adult male bears moved into softwood areas (chiefly pines) during the summer. Foraging for berries and insects coupled with breeding activities contributed to this selection.

31. In fall, adult males and females were found 64 % of the time in mast habitat.

32. Subadult females used softwood areas considerably more than all other bears in spring, summer, and fall. The dispersal of female offspring within their mother's range may have influenced this difference in habitat selection.

33. A total of 2,686 bear locations was used in an utilization-availability analysis. Preference or avoidance of hardwoods and softwoods was determined using techniques described by Neu et al. (1974).

34. Hardwoods (chiefly oaks) were used more than expected and softwoods (chiefly pines) were used less than expected in terms of their availability to bears.

35. Sex contributed to variation in habitat preference in the CNF. Males overall preferred hardwoods, whereas females preferred the softwood habitats.

36. Season affected habitat selection for both male and female bears. In spring, males used hardwoods more than expected, whereas females used pines more than expected. In summer, both sexes utilized the pine areas more than expected; and both preferred hardwoods in fall.

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APPENDIX

APPENDIX A

Table 19. Capture data for black bears on the Citico Study Area, Cherokee National Forest, 1980.

Ear Tags	Tattoo	Capture date	Capture location	Sex	Age1	Weight (kg)	Tracking period
RM 342 LY 342	342	26 June	Cow Camp Ridge	M	3	41	Radio-collar attached but dropped.
RY 326 LY 326	326	27 June	Cow Camp Ridge	F	2	41	Radio-tracked from 27 June 80 through December 1981
RM 344 RM 304 LY 344	304	29 June	Cow Camp Ridge	M	4	102	Radio-tracked from June 1980 through December 1981.
RM 339 LY 339	None	09 July	Cow Camp Ridge	M	cub	9	One of bear 306's two cubs.
RY 306 LM 306	306	14 July	Cow Camp Ridge	F	5	52	Radio-tracked from July 1980 through December 1981.
RM 347 LY 347	347	15 July	Cow Camp Ridge	M	2	50	Never recovered from M99 injection.
LM 345 RY 345	1	16 July	Cow Camp Ridge	M	cub	9	Excellent condition.
RM 328 LY 328	328	16 July	Flint Branch	M	4	98	Radio-tracked from June 1980 through December 1981.
RM 346 LY 346	346	23 July	Cow Camp Ridge	F	2	36	Radio-tracked from July 1980 through May 1981.

Table 19. (continued).

Ear Tags	Tattoo	Capture date	Capture location	Sex	Age1	Weight (kg)	Tracking period
LM 349 RY 349	None	08 Aug	Double Camp Creek Trail	F	4	36	Radio-tracked from Aug 1980 through December 1981.
LM 333 RY 333	3	10 Aug	Double Camp Lead	F	1	30	No breakaway collars available; too small for static.
LM 314 Ly 318	318	13 Aug	Jake Best Road	M	3	57	No radio-collar attached.
LM 348 RY 310	310	13 Aug	Double Camp Trail	F	3	64	Radio-tracked from Aug 1980 through December 1981.
LM 354 RM 353	354	18 Aug	Cow Camp Ridge	F	cub	11	Excellent condition.
LM 352 RM 351	352	18 Aug	Cow Camp Ridge	F	2	41	Radio-tracked from Aug 1980 through December 1980; shot during Citico Bear Hunt.
LM 356 RM 355	356	19 Aug	Jake Best Road	F	5	61	Radio-tracked from Aug 1980 through May 1981; collar dropped after den emergence.

1Age determined by cementum annuli (Wathen, pers. comm. 1980).

Table 20. Capture data for black bears on the Citico Study Area, Cherokee National Forest, 1981.

Ear Tags	Tattoo	Capture date	Capture location	Sex	Age[1]	Weight (kg)	Comments
RM 501 LY 501	501	18 June	Cow Camp Ridge	M	4	47	Radio-tracked from June 1981 through December 1981.
RM 505 LY 505	505	06 Aug	Cow Camp Ridge	M	2	52	Released without radio-collar.
RY 506 LM 506	506	10 Aug	Cow Camp Ridge	F	1	32	Radio-tracked from Aug 1981 through December 1981.
RY 305 LM 305	305	12 Aug	Cow Camp Ridge	F	9	55	Radio-tracked from Aug 1981 through December 1981.
RY 507 LM 507	507	14 Aug	Cow Camp Ridge	F	1	34	Radio-tracked from Aug 1981 through December 1981.
RY 306 LM 306	306	15 Aug	Cow Camp Ridge	F	6	59	Radio-tracked from July 1980 through December 1981.

[1]Age determined by cementum annuli (Wathen, pers. comm. 1981).

VITA

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