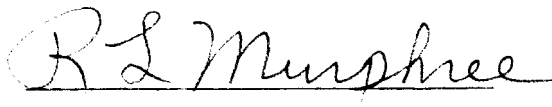
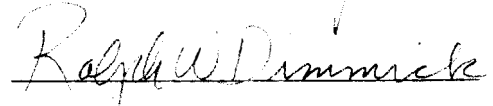
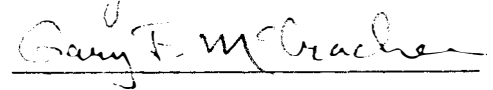


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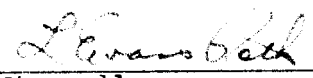
I am submitting herewith a thesis written by John Heinrich Eiler entitled "Reproductive Biology of Black Bears in the Smoky Mountains of Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.


Michael R. Pelton, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

REPRODUCTIVE BIOLOGY OF BLACK BEARS IN
THE SMOKY MOUNTAINS OF TENNESSEE

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

John Heinrich Eiler

June 1981

3051818

ACKNOWLEDGMENTS

I am especially grateful to Dr. Michael R. Pelton who served as my major professor and provided assistance throughout the study. I also thank the members of my committee--Drs. Ralph W. Dimmick, Gary F. McCracken and Robert L. Murphree--for their advice and critical review of the manuscript. Drs. H. Alan Lasater and William L. Sanders generously provided assistance with the statistical analysis.

Deep appreciation is expressed to Tom Burst, Cathy Taylor and Ken Johnson for the many long hours of fieldwork during the winter. I also wish to thank my fellow graduate students, especially Chuck Villarrubia and Howard Quigley, for their friendship, assistance with fieldwork, and willingness to share ideas and insights. Many others helped during this study, and their assistance is greatly appreciated.

Special thanks are extended to my parents, who long ago gave me the freedom to choose my own direction, and supported me in my decisions. My deepest appreciation goes to my wife, Nancy, for helping with fieldwork, typing the rough drafts, and for her continuous support and encouragement.

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

ABSTRACT

Information related to the reproductive biology of female black bears (Ursus americanus) was collected in the Smoky Mountains of Tennessee. Denning and weight information were also collected.

The majority of females utilized tree dens. The denning period averaged 114 days, with most females entering dens during the first 3 weeks of December and emerging from dens between the first and last week of April. Females with newborn cubs denned longer and emerged from dens later than females without offspring. The date of den emergence for females was used to effectively predict reproductive condition (with newborn cubs or without offspring).

Average litter size, determined from den work during 1979-80, was 2.5 cubs, with average litter sizes of 2.2 and 2.7 during 1979 and 1980, respectively. Tape recording in tree dens was an effective method for determining the presence of cubs and estimating litter size.

Most breeding activity was observed during the last week of June and the first 3 weeks of July. The majority of sub-adult females that exhibited signs of estrus were without offspring the following winter. Vaginal smears were useful in verifying estrus in female black bears.

Minimum reproductive age was 4 to 5 years, with most females giving birth for the first time at age 5. The majority of females exhibited a regular pattern of consecutive reproductive cycles: breeding and giving birth during alternate years. However, a substantial number of females skipped a year between reproductive

cycles at some time during their life, probably due to mast availability and the nutritional condition of the female.

Only 1 female was observed lactating during successive years, indicating that losses of whole litters is uncommon. Average litter sizes determined from den work for females with newborn cubs and yearlings were 2.5 and 2.0, respectively, indicating that some cub mortality does occur.

Wild female black bears reached mature weights from 4 to 5 years of age. Panhandler females reached mature weights earlier and weighed more than wild females.

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CHAPTER I

INTRODUCTION

The reproductive biology of a species is extremely important in terms of population dynamics. Natality, mortality, immigration and emigration directly affect the status of a population. When these factors are in balance, the population remains relatively stable; when out of balance, the population expands or declines. Information related to reproduction is essential if wildlife populations are to be managed effectively.

Black bears (*Ursus americanus*) are secretive animals and reproductive information is difficult to obtain. Much of the early information related to reproduction was obtained from captive bears in zoological parks (Baker 1912). Field studies have often relied on information from bears killed by hunters. Reproductive tracts have been collected and examined for corpora lutea and placental scars to estimate litter size and minimum breeding age (Erickson and Nellor 1964, Collins 1973, Kordek and Lindzey 1980). Erickson and Nellor (1964) utilized histological characteristics of reproductive tracts of male and female black bears to determine reproductive activity. Observations of females with offspring have been used to estimate litter size, especially in areas with sufficient visibility. Bears enter dens during the winter and exhibit a period of extended dormancy. With the advent and improvement of radio telemetry equipment and sedation techniques, researchers have been able to locate and

tranquilize bears in winter dens to collect reproductive information (Rogers 1977, Beecham 1980, Hugie pers. comm.).

The reproductive cycle of female black bears is 2 years in length. Black bears generally breed during June or early July (Asdell 1946). The gestation period is approximately 7 to 8 months, with parturition occurring from late January to early February (Erickson and Nellor 1964). Wimsatt (1963) demonstrated that black bears exhibit delayed implantation. Embryonic development is characterized by a period of developmental arrest during the blastocyst stage. The blastocyst remains free in the uterine lumen for approximately 5 months. Implantation and development occur during the last 6 to 8 weeks of gestation (Wimsatt 1963). Cubs are altricial at birth (Baker, 1904) but develop rapidly and are relatively precocial after den emergence (Jonkel and Cowan 1971). Litter sizes of 2 to 3 cubs are most common, but litters of 4, 5 and 6 have been reported (Rowan 1945, 1947, Matson 1952). The cubs remain with the female during the summer and fall and den with her the following winter. Female black bears will not come into estrus during this period, probably due to the physiological effects associated with lactation. However, Baker (1912) reported that estrus would occur if the cubs were removed from the female early in the summer. The family unit breaks up some time after emergence from the den the second winter. The adult female comes into estrus during the summer, and the reproductive cycle is repeated.

In most areas of the country, female black bears become sexually mature at 3 years of age or older (Erickson and Nellor 1964,

Jonkel and Cowan 1971, Raybourne 1976, Rogers 1977). Breeding as early as 2 years has been reported in both captive (Stickley 1961, Ammons 1974) and wild females (Collins 1973, Raybourne 1976, Kordek and Lindzey 1980). Rausch (1961) suggested that sexual maturity may vary with latitude. However, there is substantial information that sexual maturity may be related to the nutritional condition of the animals (Jonkel and Cowan 1971, Rogers 1976).

Bears have one of the lowest reproductive rates of any North American land mammal. They exhibit comparatively slow reproductive maturity, prolonged reproductive cycles and relatively small litter sizes. Changes in these factors can have a profound effect on the productivity of the species within an area. Craighead (1974) illustrated that small changes in reproduction can greatly alter the stability of wildlife populations with low biological potential.

Research has been conducted in the Great Smoky Mountains National Park (GSMNP) related to population density, food habits, movements and the den ecology of black bears; little information has been collected related to reproduction. The main objective of the present study was to collect information from the female segment of the population related to the reproductive potential of the species. Primary interest was centered on determining minimum reproductive age, average litter size, the frequency that parous females will give birth and cub mortality. Of additional interest was how these factors were influenced by changes in environmental conditions, such as mast availability during the fall. Denning information was collected to compare differences between females, with respect to reproductive condition.

CHAPTER II

THE STUDY AREA

Research was conducted within the GSMNP and the adjacent Cherokee National Forest (CNF). The actual study area was limited to the northwestern quadrant of the GSMNP, consisting of the Tennessee portion of the park west of the transmountain road (US Highway 441), and the Tellico Ranger District of the CNF, bounded by the Tennessee-North Carolina state line, the Tellico-Robbinsville Road, and the Tellico River (Fig. 1). The area comprises 994 km² in Blount, Sevier, and Monroe Counties, Tennessee, and is located between 35°20' and 35°47' N latitude and 83°05' and 84°20' W longitude. Access to the study area is limited to 264 km of improved roads, 126 km of unimproved road, 619 km of maintained trails and over 240 km of abandoned trails. Most of the roads are located at lower elevations with the majority of the study area accessible only by foot trails.

The Unicoi and Great Smoky Mountains are part of the Unaka Mountain Range of the Blue Ridge Province in the southern division of the Appalachian Highlands (Fennemans 1938). The main ridge runs in a northeast-southwest direction and for much of its length delineates the Tennessee-North Carolina border. This main ridge connects a series of high peaks, with prominent ridges radiating out to each side. The topography is characterized by steep, rugged mountains and narrow, V-shaped valleys. Over 90% of the area has a slope of greater than 10° (Anonymous 1902). Elevation ranges from 230 m at the

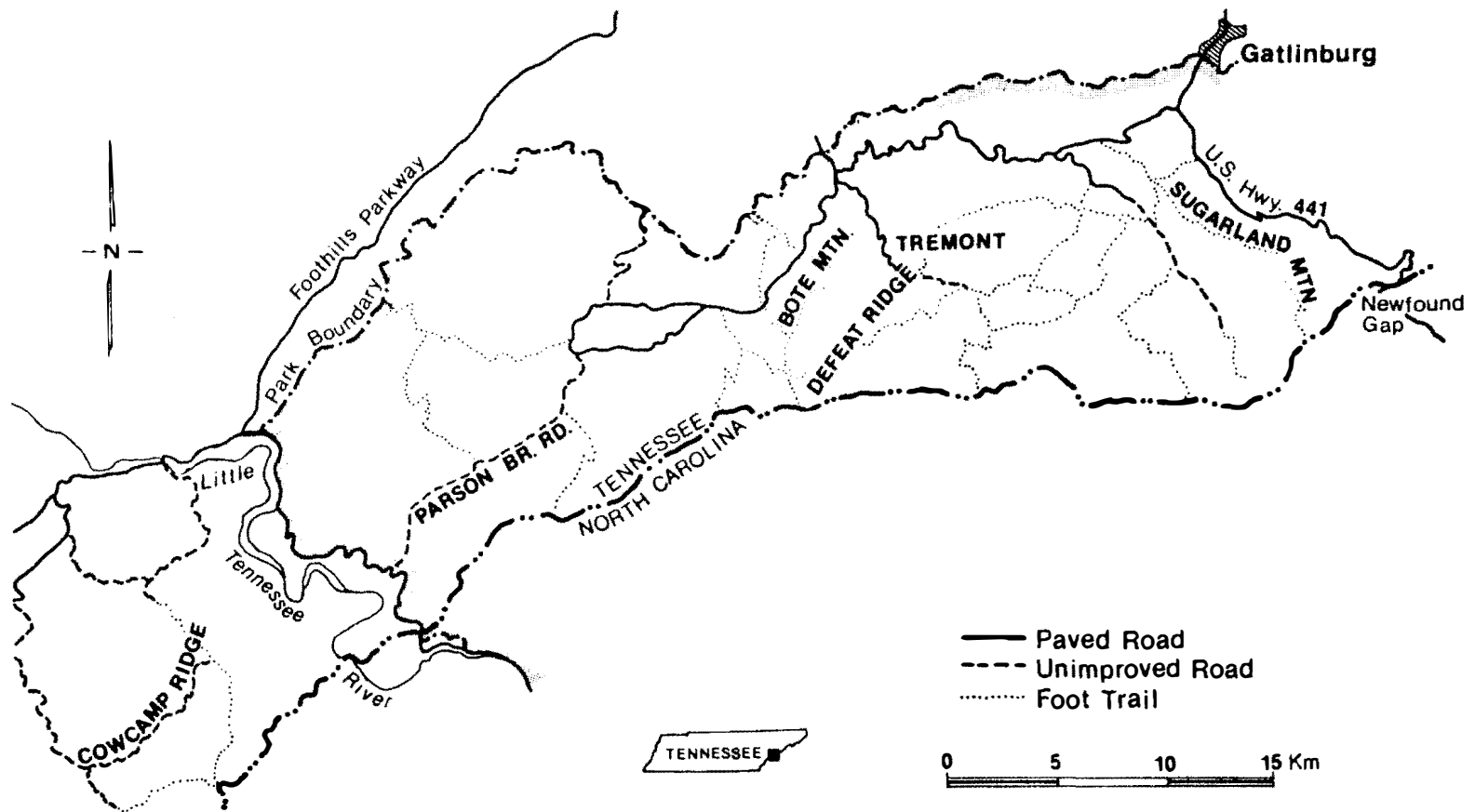


Fig. 1. Map of the study area, the northwestern section of the Great Smoky Mountains National Park and the Tellico Ranger District of the Cherokee National Forest.

confluence of the Tellico and Little Tennessee Rivers, to 2024 m at Clingmans Dome. In general, most of the study area is over 600 m.

Soil types within the area are broadly classified in the Ramsey Association, with most of the higher elevations in the Ramsey Series and the lower slopes in the Jefferson Series. These soils are characterized by low water storage capacity, medium to high acidity and moderate fertility (Anonymous 1945, 1953). The parent material is primarily feldspathic sandstone, siltstone, shale and conglomerate from the Ocoee Series of the late Precambrian (King et al. 1968).

Thorntwaite (1948) classified the climate in the area as mesothermal perhumid (warm-temperate rain forest). Precipitation and temperature vary greatly with differences in elevation and exposure (Shanks 1954a, Tanner 1963, Stephens 1969). Precipitation averages around 140 cm per year at lower elevations while higher elevations may receive over 220 cm. Most precipitation occurs during late winter-early spring and July-August. September and October receive the least precipitation. The average annual temperature is 14C at lower elevations (below 450 m) and 6C at higher elevations (above 1900 m), with a temperature gradient of 4.07C per 1000 m increase in elevation. Lowest temperatures occur during February, with highest temperatures in July (Shanks 1954, Tanner 1963, Anonymous 1972).

The GSMNP and CNF support a large and diverse plant community, including over 1300 species of flowering plants (which includes 131 species of trees), approximately 350 mosses and liverworts, 230 lichens, and more than 2000 species of fungi (Stupka 1960). Thirty species of trees and shrubs are endemic to the Unaka Range in eastern

Tennessee and western North Carolina (Cain 1930). Whittaker (1956) concluded that most of the vegetation within the area was either topographical climax or secondary succession. The varied topographical range, temperature regimen and precipitation levels have resulted in numerous habitat types, ranging from mesic valleys to dry ridges, with a high degree of interspersions. Several authors have categorized various plant associations into forest types. The classification system devised by Shanks (1954b) is the simplest and most widely used (Table 1). The distribution of forest types may be simplified as follows. Spruce-fir is located at the highest elevations. Northern hardwoods occupy the slopes just below spruce-fir and the more exposed slopes within the spruce-fir range. Cove hardwoods occur in the sheltered valleys, while open oak-pine stands and heath thickets occur on dry exposed ridge tops. Closed oak forests occupy slopes with intermediate exposure. Hemlock forest types are found along streams and on sheltered slopes up to 1100 m.

Rhododendron spp., Kalmia latifolia, Smilax spp. and numerous minor associates frequently form nearly impenetrable understory thickets on almost all types of sites, especially on dry ridges. On particularly steep and rocky ridges, these plants form dense heath balds that are essentially treeless. Vaccinium spp. and Gaylussacia spp. are common understory shrubs in the open oak-pine forest.

A few grassy balds are found at higher elevations along the Tennessee-North Carolina border. In addition, 7.3 km² of pastures and fields are maintained in Cades Cove (GSMNP) as a historical site. The Tellico Ranger District is managed for multiple use and sustained

Table 1. Forest associations and their important tree species in the Great Smoky Mountains National Park.

Forest Association Type	Important Species
Cove Hardwood	Eastern hemlock (<u>Tsuga canadensis</u>) Silverbell (<u>Halesia monticola</u>) Yellow buckeye (<u>Aesculus octandra</u>) Tulip poplar (<u>Liriodendron tulipifera</u>) Beech (<u>Fagus grandifolia</u>) Yellow birch (<u>Betula allegheniensis</u>) Black cherry (<u>Prunus serotina</u>) Rhododendron (<u>Rhododendron</u> spp.)
Hemlock	Eastern hemlock (<u>Tsuga canadensis</u>) Yellow birch (<u>Betula allegheniensis</u>) Silverbell (<u>Halesia monticola</u>) Fraser magnolia (<u>Magnolia fraseri</u>)
Northern Hardwood	Beech (<u>Fagus grandifolia</u>) Sugar maple (<u>Acer saccharum</u>) Yellow buckeye (<u>Aesculus octandra</u>) Yellow birch (<u>Betula allegheniensis</u>)
Closed Oak	Chestnut oak (<u>Quercus prinus</u>) White oak (<u>Quercus alba</u>) Black oak (<u>Quercus velutina</u>) Northern red oak (<u>Quercus rubra</u>) Pignut hickory (<u>Carya glabra</u>) Mockernut hickory (<u>Carya tomentosa</u>) Sourwood (<u>Oxydendrum arboreum</u>)
Open Oak and Pine	Sassafras (<u>Sassafras albidum</u>) Scarlet oak (<u>Quercus coccinea</u>) Pitch pine (<u>Pinus rigida</u>) Virginia pine (<u>Pinus virginiana</u>) Mountain laurel (<u>Kalmia latifolia</u>)
Spruce-fir	Red spruce (<u>Picea rubens</u>) Fraser fir (<u>Abies fraseri</u>)

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

yield of timber, wildlife resources and recreation. Timber is managed under an even-aged rotation; 60 years for Virginia pine, 80 years for white and yellow pine, and 100 years for hardwoods. The CNF is considered a wildlife management area, managed in conjunction with the Tennessee Wildlife Resources Agency (TWRA). Approximately 120 km² of the Tellico Ranger District is managed as a bear reserve and no bear hunting is allowed on this area. Other areas of the CNF are periodically open to bear hunting in the fall. Except for poaching, the bear population within the GSMNP is unexploited.

Approximately 59 species of mammals are known to occur in the study area, almost half of which are in the order Rodentia (Linzey and Linzey 1971). Large mammals within the area include white-tailed deer (Odocoileus virginianus), European wild hogs (Sus scrofa), as well as black bears. Sightings of mountain lions (Felis concolor) have been reported, but no substantial evidence has been provided of their existence in the area. Records of over 200 species of birds, 23 species of snakes (2 poisonous), and 72 species of fish are found within the area. In addition, the area contains one of the richest varieties of salamanders in the world (Anonymous 1969).

CHAPTER III

MATERIALS AND METHODS

Capture and Handling Techniques

Black bears were captured using Aldrich spring-activated snares and modified culvert traps consisting of 2 50-gallon oil drums welded together, an angle-iron door frame and a 1 cm thick plywood door. Prebaiting and trapping techniques for Aldrich snares are described by Marcum (1974) and Eagar (1977). Barrel traps are set as illustrated by Fig. 2. An animal attempting to reach the bait placed in the back of the trap dislodges the trip stick which lowers the door over the trap entrance.

Bears were immobilized with an intramuscular injection of M99 (Etorphine hydrochloride, D-M Pharmaceuticals, Inc., Rockville, MD) at dosage levels of 1 mg/45.5 kg body weight. Bears trapped in Aldrich snares were immobilized with a Cap-chur syringe fired from a CO₂-charged pistol (Palmer Chemical and Supply Co., Inc.). A jab stick (a syringe mounted on a plexi-glass rod) was used to immobilize bears caught in barrel traps. M50-50 (Diprenorphine) was used as an antagonist for M99 at dosage levels of 2 mg/45.5 kg body weight. Recovery occurred approximately 5 minutes after an intravenous injection of M50-50.

Black bears were marked with ear tags and lip tattoos to assist in future identification. Basic biological information was collected, including standard measurements, weight, overall condition,

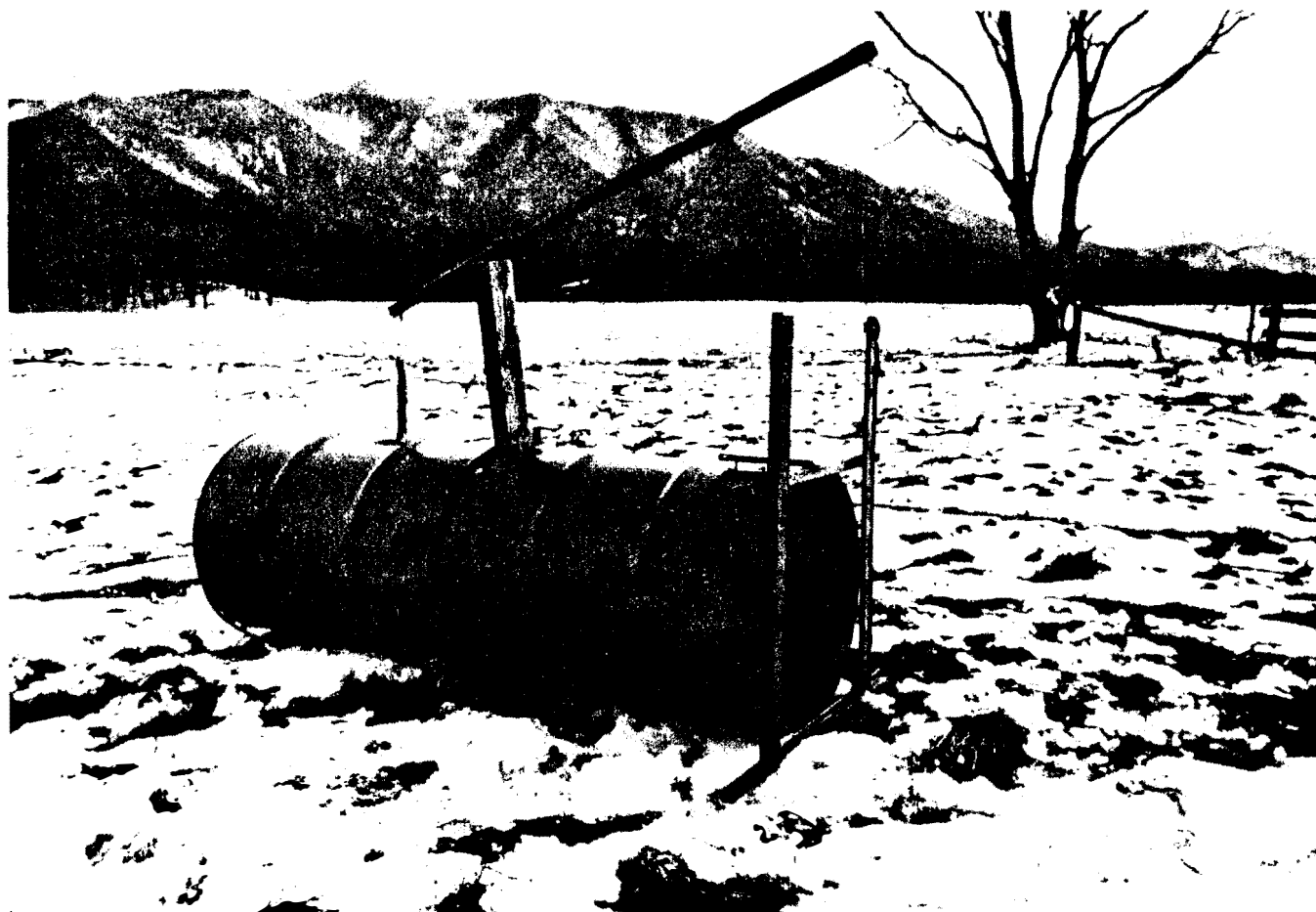


Fig. 2. Culvert trap used in the backcountry of the Great Smoky Mountains National Park and the Cherokee National Forest. Plywood door over entrance not shown.

and a blood sample. Bears were instrumented with radiotransmitters equipped with motion-sensitive activity monitors (Wildlife Materials, Inc., Carbondale, IL and Telonics, Mesa, AZ).

A first premolar was extracted for age determination by the cementum-annuli technique described by Willey (1974). Tooth sections were prepared and stained as described by Eagle and Pelton (1978).

Collection of Reproductive Data

Determination of reproductive condition during summer. Female black bears were checked for signs of reproductive condition: lactation, the presence of cubs, or signs of estrus. Swelling of the external genitalia occurs during estrus and this condition was noted when observed. Vaginal smears were taken from female black bears to determine if changes in vaginal epithelium can be used to detect the onset or occurrence of estrus. Epithelial cells from the vagina were collected using cotton swabs, transferred to microscope slides and stained with Wright-Giemsa stain. Tests to determine the vaginal pH and electrical resistance of the vaginal tract were conducted on female bears trapped in 1979. A Hickok LX303 digital volt-ohm meter and a 1 cm diameter probe were used to record vaginal resistance. The pH paper, sensitive to 1 unit increments, was used to obtain pH readings.

Lactation was determined by attempting to induce milk let-down by manual stimulation of the mammary glands. During 1979, inter-muscular injections of Oxytocin (Parke-Davis, Inc.) were given to

adult females prior to manual stimulation to minimize the possibility of not detecting lactation.

Family group observations. Observations of family groups (adult females with offspring) collected by the National Park Service and bear project personnel from 1970 through 1979 were compiled. Similar information was collected from hikers and backpackers from 1970 through 1977. These data were analyzed separately and used to estimate changes in average litter size. Summer trapping records (1972-79) were reviewed for information related to litter size, minimum reproductive age, and the reproductive cycle.

Determination of reproductive condition during winter. Female black bears denning on the ground were sedated to determine reproductive condition. Since parturition is thought to occur around the end of January and the first of February, bears in dens were sedated after the second week of February. Initially M99 was used to sedate black bears during the winter, particularly because of the existence of the antagonist M50-50. An animal experiencing some difficulty under sedation could be revived quickly with an intravenous injection of M50-50. However, M99 appears to have physiological effects that are incompatible with winter conditions. One female died after an initial injection of M99. Two females sedated with M99 displayed strong vital signs when placed back in the den, but died some time later. Females given intramuscular injections of M50-50 to aid in recovery apparently revived too quickly and abandoned the den. A combination of Ketaset (Ketamine hydrochloride) and Rompun (Xylazine hydrochloride) was used

as a replacement because of its wide latitude of tolerance. Under most conditions, the immobilizing drug was administered with a jab stick. A dart pistol was used when the animal was positioned out of reach in the den, or was too active to get close enough to use the jab stick.

Reproductive information was obtained concerning the presence or absence of cubs or yearlings, the size and sex ratio of the litter, and the weight of the offspring. Yearlings had to be sedated prior to handling and were marked with ear tags and lip tattoos. Small radio-collars, designed to break away after approximately 12 months, were placed on selected yearlings. Information related to the condition of the adult female was also collected: weight, standard measurements, general condition, and a blood sample. Radio-collars and other markings (ear tags and lip tattoos) were replaced when necessary.

Except in one instance, female black bears using tree dens were too inaccessible to make sedation possible. Climbing ropes or aluminum ladders were used to climb to the cavity entrance for the purpose of making visual observations (Appendix A). Adult females and yearlings are distinguishable in tree dens. Newborn cubs are small and often underneath the female, making direct observations and accurate counts impossible. However, newborn cubs emit vocalizations that are easily detected. A Marantz EC-3S microphone was lowered into the tree cavities to record sounds within the den. Recording sessions usually lasted 45 minutes. When time permitted, 90-minute recordings were made. Recorded vocalizations were used to verify the presence of cubs and assist in estimating the number present. A Series 700 Voice Identification Spectrograph was used to produce spectrograms (voice

prints) from selected vocalization recordings to aid in estimating litter size. Estimated litter size based on the tape recordings were considered minimum estimates. One 9-hour recording session was made on a female known to have newborn cubs to provide an estimation of the frequency of vocalizations.

Denning Information

Radio-collared females were monitored during the fall, winter and spring to determine den entry and emergence. Bears were located every 3 days, starting in mid-November, by radio-tracking from the ground or aircraft. Ground locations were determined by triangulation from a series of prominent points. These points were used systematically when tracking from the ground to standardize error due to topography and signal bounce. Procedures for radio-tracking are described by Garshelis (1978). Activity was determined from radio signals as described by Quigley et al. (1979). Radio locations were plotted on 7.5 minute USGS quadrangle maps using a 1.3 cm circle to account for error. An animal was considered in the den when the plotted locations consistently fell within the same area. A similar procedure was used to determine den emergence. In addition, during the spring of 1980, den sites were visited to determine if the bears were out of the dens. Females, especially those with newborn cubs, might stay within the general vicinity of the den after emergence; this would not be detected from radio-tracking information.

Winter dens of radio-collared females were located by following the radio signals into the den sites. Dens were located after 1 January to minimize disturbance; by that time, most bears had denned

and activity had decreased significantly. Dens were classified into 2 general categories: ground dens and tree dens. Any structure utilized at ground level was designated as a ground den. Tree dens consisted of cavities in large trees that were located higher than 2 m above the ground.

Mast Yield

Information on hard mast yield was obtained from annual state-wide mast surveys by the Tennessee Wildlife Resources Agency (TWRA). Information from the Tellico Wildlife Management Area, CNF, was used to estimate mast production within the study area.

Statistical Analysis

Comparisons of when female black bears entered and emerged from winter dens, and the length of the denning period were made between years of the study, reproductive condition and age of the female, and the intervals used to determine entry and emergence dates (3-day versus 5-day intervals) using Student's t-distribution. Vaginal pH and electrical resistance test results for estrous and anestrus females were compared using Student's t-distribution. The 10% level of significance was used to determine variance equality for the F-test of the 2 samples being compared. A significance level of 0.05 was used to determine differences between samples.

Multiple regression analysis was used to determine the relationships between den entry and emergence for age, reproductive condition and climatic factors: total precipitation, the number of days with precipitation, minimum and maximum temperature, minimum and maximum

temperature range, and the average and maximum daily wind. Weather conditions were compiled for 5 days prior to the date bears entered and emerged from winter dens. Weather data for the central and eastern part of the study area were taken from the U.S. Weather Station in Gatlinburg, Tennessee. Records kept by the U.S. Forest Service in Tellico, Tennessee were used for bears in the western section of the GSMNP (Parsons Branch area) and the CNF. Information related to daily wind was taken from the Knoxville International Airport. Factors found significant were used to set up a predictive model for reproductive condition using two class discriminate analysis. The equation used for the model was $\hat{Y} = b_0 + b_1X$ where $\hat{Y}$ is the predicted value (approximating 1 or 0 depending on the reproductive condition), b_0 the Y intercept, b_1 the slope of the regression line, and X the factors that effectively predict reproductive condition. Predicted values falling close to 1 would indicate a female with cubs. Values falling closer to 0 would indicate a female with yearlings or without offspring.

Chi square contingency tables were used to compare yearly changes in litter size determined from family group observations, monthly changes in the number of wild lactating females caught during the summer, and the number of lactating females observed in relation to age (with respect to the total number of that age trapped). Comparisons were made between average litter size (determined from family group observations) and estimated mast yield for the previous year using simple correlation.

Weight information was compiled by age and grouped into 4 categories based on sex and status (wild versus panhandler bear).

Growth curves were constructed from weight-age data using the equation $W = A - Be^{-kt}$ where W is weight, A is the asymptote (where the slope of the line approaches 0), B is an integration constant, e is the base of the natural log, k is the instantaneous relative growth rate, and t is age (Brody 1964). Weight estimates based on the data were weighted so that small sample sizes within certain age classes would not bias the results. Differences between growth curves and mean weight values were inspected to determine how well weight-age data for the black bear reflected the parameters of Brody's model. Comparisons between seasonal weights of lactating and non-lactating females were made using analysis of variance. Differences in cell means were partitioned using Duncan's multiple range test at a significance level of 0.05.

CHAPTER IV

RESULTS

Denning Chronology

Radio-collared females entered dens between 21 November and 4 January 1978-79, and 2 December and 23 January 1979-80 (Table 2 and Appendix B), with no significant difference between the 2 years of the study ($n=24$). Denning information collected over 3-day and 5-day intervals showed no significant differences and were combined. Most females (19, 79%) denned within the first 3 weeks of December, with the majority (14, 67%) denning between 2 and 15 December. Only 4 females (3 sub-adults and 1 adult female with cubs) denned after this period. One female with cubs denned before 22 November, which was the earliest record of denning in the GSMNP and the only incident of denning observed prior to the first week of December. During the winter of 1979-80, 1 sub-adult female had not denned as of 20 February. It is not known whether she denned that winter.

Female black bears emerged from their dens between 30 March and 3 May 1979, and 19 March and 26 April 1980 (Table 2 and Appendix B), with no significant difference between the 2 years of the study ($n=24$). Most females (20, 83%) left their dens during April ($\bar{x}=14$ April). Three females (2 sub-adults and 1 female with yearling cubs) left the dens during March. One female with newborn cubs remained in the den until the first week of May.

Table 2. Dates of den entry and emergence, and length of the denning period for female black bears in the Great Smoky Mountains National Park and Cherokee National Forest, with respect to years of the study and reproductive condition, 1978-80.

Year/Condition	Den Entry	Den Emergence	Denning Period
1978-80	21 Nov - 23 Jan $\bar{x}$ = 14 Dec (n = 24)	19 Mar - 3 May $\bar{x}$ = 17 Apr (n = 24)	79 - 145 days $\bar{x}$ = 114 days (n = 15)
1978-79	21 Nov - 4 Jan $\bar{x}$ = 11 Dec (n = 15)	30 Mar - 3 May $\bar{x}$ = 17 Apr (n = 9)	85 - 135 days $\bar{x}$ = 120 days (n = 7)
1979-80	2 Dec - 23 Jan $\bar{x}$ = 19 Dec (n = 9)	19 Mar - 26 May $\bar{x}$ = 12 Apr (n = 15)	79 - 145 days $\bar{x}$ = 109 days (n = 8)
Females with newborn cubs in winter dens	2 Dec - 17 Dec $\bar{x}$ = 9 Dec (n = 5)	19 Apr - 3 May $\bar{x}$ = 25 Apr (n = 9)	127 - 145 days $\bar{x}$ = 136 days (n = 3)
Females with yearling cubs in winter dens	20 Nov - 23 Jan $\bar{x}$ = 13 Dec (n = 8)	19 Mar - 18 Apr $\bar{x}$ = 12 Apr (n = 4)	79 - 130 days $\bar{x}$ = 109 days (n = 4)
Females without offspring in winter dens	2 Dec - 4 Jan $\bar{x}$ = 18 Dec (n = 10)	30 Mar - 18 Apr $\bar{x}$ = 6 Apr (n = 10)	85 - 127 days $\bar{x}$ = 108 days (n = 8)

The denning period ranged in length from 85 to 135 days in 1978-79 and 79 to 145 days in 1979-80 (Table 2 and Appendix B). No significant difference between years was detected. The average denning period for the study was 114 days (n=15).

Pregnant females (n=5) were the first to enter dens ($\bar{x}$ =9 December). Females with cubs (n=8) entered an average of 4 days later (13 December). Non-pregnant females without offspring (n=10) were the last to enter dens, with an average entry date of 18 December (Table 2). Sub-adult females made up 83% of this category. The differences observed between these groups were not significant.

Females without offspring (n=10) were the first to emerge from dens ($\bar{x}$ =6 April). Females with yearling cubs (n=4) left an average of 6 days later (12 April). Females with newborn cubs (n=9) emerged last with an average emergence date of 25 April (Table 2). Females with newborn cubs emerged significantly later ($P < 0.0001$) and denned significantly longer ($P < 0.029$) than females without offspring. The significant difference in the length of the denning period was probably due to the later emergence of females with cubs, since differences in den entry were not significant. Differences in when females with cubs and females with yearlings left their dens were not significant ($P < 0.094$), but this was possibly due to the small number of females with yearlings in the sample).

Differences in when adult and sub-adult females entered dens were not significant. Sub-adults emerged from dens significantly earlier than adult females ($P < 0.003$).

Four females left their initial den sites during the study. Emergence occurred an average of 32 days after den entry (Appendix B) and was not related to our research activities. All 4 females denned in different locations, ranging from 0.5 km to 2.2 km from the original site. In a separate incident, one adult female located on 15 December 1979 became extremely active when we approached the den. An aerial location obtained on 18 December indicated that she had left the den and moved to the other side of a prominent ridge. In January, this female was located in the same den that she had occupied initially.

During spring 1980, 9 den sites were visited repeatedly to assist in determining den emergence. Two of the 5 females with newborn cubs and 2 of the 4 sub-adult females remained within the general vicinity of the den after emergence. The emergence date would not have been accurately detected based solely on radio-tracking data.

No significant relationship existed between age, reproductive condition, climatic factors and when females entered dens. Total precipitation, minimum temperature and reproductive condition showed the strongest linear relationship to when females left dens ($R^2=0.94$). Females tended to leave after periods of heavy rainfall and low minimum temperature, regardless of reproductive condition. Females with yearlings reflected this less, possibly due to small sample size ($n=4$).

Predictive Model for Reproductive Condition

A predictive model was developed to determine reproductive condition for female black bears based on total precipitation, minimum

temperature (compiled for 5 days prior to emergence) and the date of emergence from dens ($R^2=0.74$). Total precipitation and minimum temperature were not reflective of reproductive condition when emergence information was not included ($R^2=0.09$). The date of emergence from dens was a significant predictor of reproductive condition when considered separately ($R^2=0.74$). For this reason, the equation used for the model was $\hat{Y} = -5.4859 + 0.041X$ where $\hat{Y}$ is the predicted value approximating 0 or 1, and X the den emergence date (days were given a numerical value, with 20 November equal to 1). A cut-off point of 0.5 was used to separate the $\hat{Y}$ values into 2 categories. Predicted values less than 0.5 indicated females without offspring, greater than 0.5 indicated females with cubs. Predicted values were obtained for the 19 females of known reproductive condition used in this analysis (Table 3). The predicted value for 1 female in the sample did not reflect the actual reproductive condition; therefore, 5.3% of the females in the sample were misclassified by the model. The probability of error in predicting reproductive condition from den emergence using this model ranges from 0% to 15% with 95% confidence.

Den Utilization

Tree dens were utilized more frequently than ground dens. A total of 34 (79%) females used tree dens during the study, with 16 (73%) and 18 (86%) denning in trees during 1978-79 and 1979-80, respectively (Appendix B). The proportion of den types used (ground versus tree den) varied within different sections of the study area (Table 4). Tree dens ranged from approximately 4.6 m to 18.3 m

Table 3. Predicted values estimating reproductive condition based on den emergence for female black bears of known reproductive condition, using 0.5 as a cut-off point ($\hat{Y} > 0.5$ indicates female with cubs, $\hat{Y} < 0.5$ indicates female without offspring).

Bear No.	Predicted Value ($\hat{Y}$)	Reproductive Condition
307	0.3773	Without offspring
316	0.6215*	Without offspring
320	1.2323	With cubs
321	-0.1521	Without offspring
403	-0.1113	Without offspring
414	1.0694	With cubs
306	0.7844	With cubs
316	0.7844	With cubs
321	0.9473	With cubs
343	0.7844	With cubs
403	0.9473	With cubs
454	0.0108	Without offspring
459	-0.0299	Without offspring
471	-0.0299	Without offspring
486	0.0108	Without offspring
498	0.2551	Without offspring
487	0.6623	With cubs
476	0.5401	With cubs
426	0.2958	Without offspring

*Predicted value does not reflect actual reproductive condition.

Table 4. Den utilization for female black bears during 1978-80 and timber practices for different areas of the Great Smoky Mountains National Park and Cherokee National Forest.

Area	Tree Den	Ground Dens	Ground Den Type	Timber Practices
Sugarland Mt., GSMNP	0	3	Rock crevice (n=3)	Logged heavily during 1920's
Smokemont Area, GSMNP	0	1	Basal fire scar (n=1)	Logged heavily during 1920's
Tremont Area, GSMNP	3	1	Up-turned stump (n=1)	Logged heavily during 1930's
Bote Mt./Defeat Ridge, GSMNP	13	4	Root system (n=2) Fallen timber (n=2)	High grade thinning 1905, virgin timber at higher elevations
Parsons Br., GSMNP	9	0		Virgin timber
Citico Area, CNF	9	1	Root system (n=1)	Timber managed under even-aged logging system

above the ground, with the majority (28, 82%) higher than 9.1 m. Chestnut oak (Quercus prinus) and northern red oak (Quercus rubra) were the most common tree species utilized.

Ground dens were categorized into 4 basic groups: cavities formed underneath fallen timber, under the root systems of fallen trees or up-turned stumps, at the base of standing trees, and within rock outcrops. The types of ground dens varied in relation to area of the GSMNP and CNF (Table 4). Ground dens formed by rock outcrops were observed only in the Sugarland Mountain area of the GSMNP. This was the only type of den observed within this area; however, the sample size is small. Ground dens formed by fallen timber or under root systems were the most common den type observed in other areas.

Three instances were observed during this study of black bears utilizing dens that had been used previously; 2 females used the same ground dens during successive winters and 1 female denned in a tree den that had been used several years earlier. All 3 den sites were in areas that had been logged extensively.

Litter Size

Litter size based on den work. Ten females were sedated in dens during the study. Five females had given birth, with an average litter size of 2.6. Five females were observed with yearlings, with an average litter size of 2.4. One female within this group was a panhandler bear and was observed with 4 yearlings. Average litter size for females with yearlings was 2.0 when only backcountry bears were considered.

Visual observations and tape recordings were made for 28 females denning in trees (Appendix C). Tape recordings detected the presence of newborn cubs for 9 females. A minimum estimated litter size of 2.4 was determined from analysis of the recordings. Cub vocalizations consisted mainly of continuous nursing with an occasional crying or grunting sound. Nursing vocalizations produced a distinctly regular pattern when analyzed on the spectrograph, ranging from 0 to 7 KHz but centered between 0 and 2 KHz (Fig. 3). Nursing averaged 12 vocalizations per second. Crying sounds generally occurred at higher frequencies, with grunting vocalizations at the lower ranges. Differences between 1 and 2 cubs nursing were distinguishable audibly and with electronic analysis (Fig. 4). It was not possible to distinguish between 2 and 3 cubs nursing, due partly to the lack of a control sample where 3 cubs were known to be nursing. Estimates of 3 cubs were obtained when a combination of nursing and crying occurred that enabled the sounds of a third cub to be isolated.

Nursing frequency was obtained for a female with 3 cubs over a continuous 9-hour period from 0900 to 1800 hours (Table 5). All of the 1-hour recordings were made between 0900 and 1800 hours. The recordings were analyzed by 1 minute segments for the presence of nursing vocalizations and crying/grunting sounds. Minute segments with both types of vocalizations were categorized as nursing. Hourly nursing frequency ranged from 5% (3 minutes) to 100% (60 minutes), with an average frequency of 29% (155 minutes/540 minutes). Minute segments with crying or grunting vocalizations occurred an average of 26% (140 minutes/540 minutes) of the time, with hourly frequencies

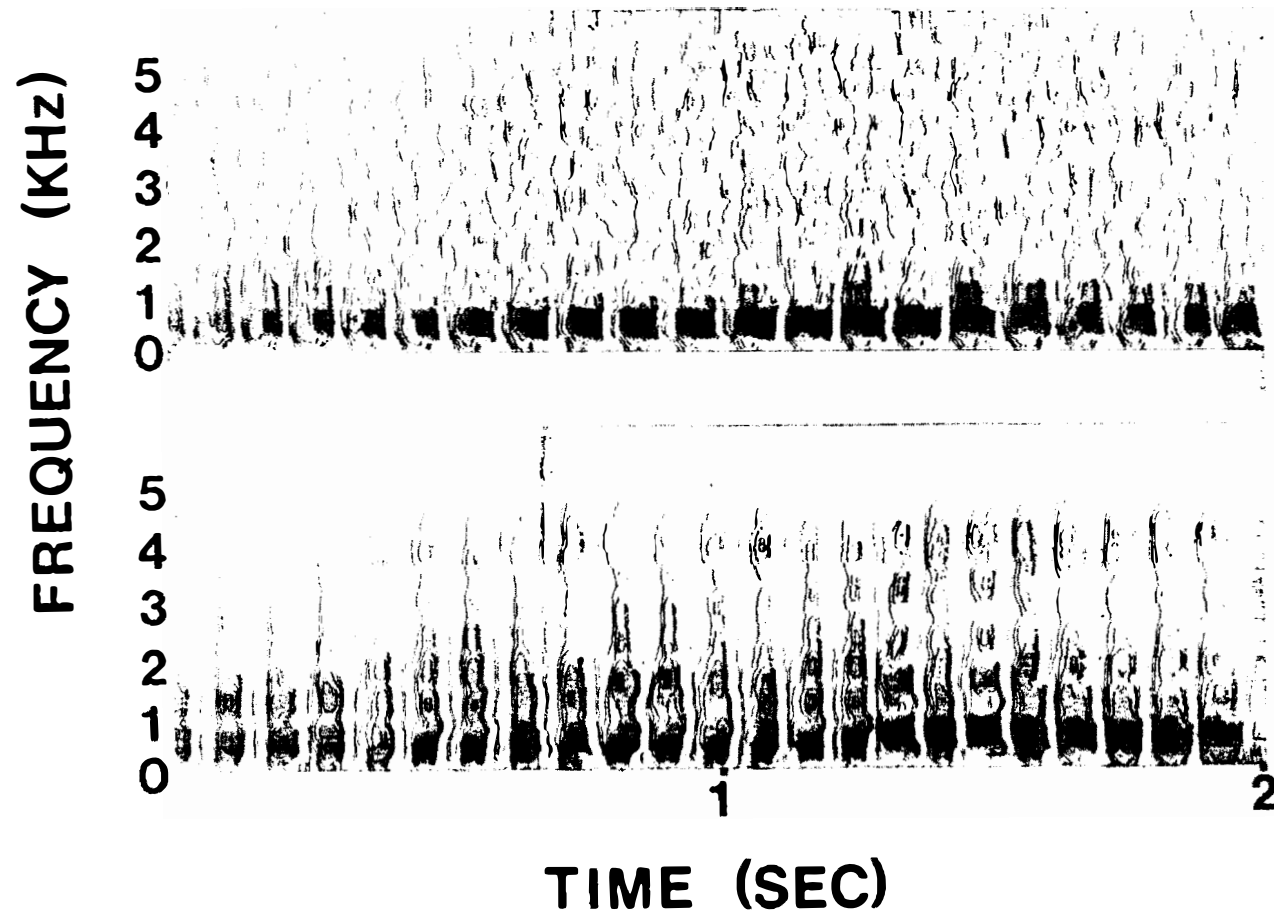


Fig. 3. Spectrographs of 1 cub nursing from recordings of 2 females with cubs in the Great Smoky Mountains National Park. The entire range of vocalization is shown. The darker areas represent greater sound amplitude.

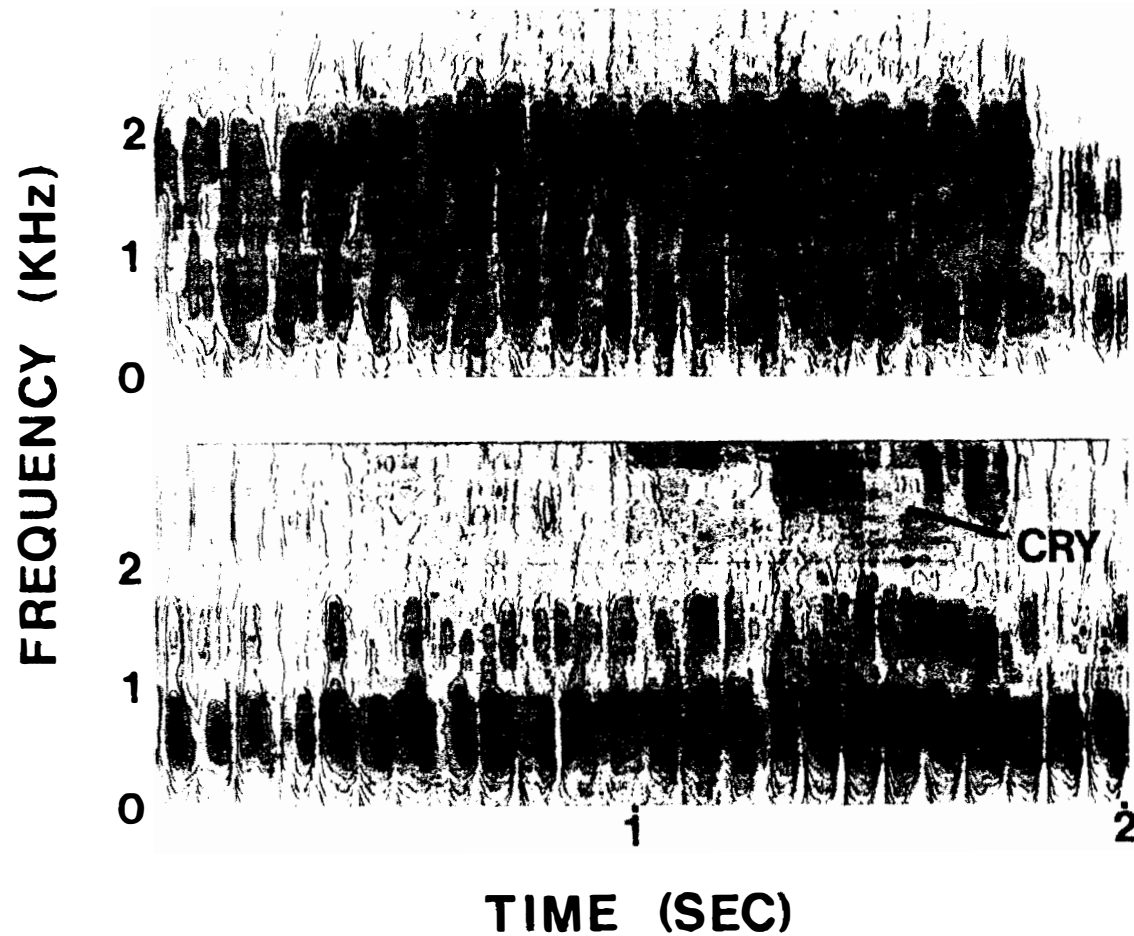


Fig. 4. Spectographs of 2 cubs nursing (above) and 1 cub nursing with another cub crying (below) from recordings of 2 females with cubs in the Great Smoky Mountains National Park. A regular pattern is observed when only 1 cub is nursing; the pattern is not distinguishable when 2 or more cubs are nursing.

Table 5. Nursing frequency over a continuous 9-hour period for a female black bear with 3 newborn cubs in the Great Smoky Mountains National Park, recorded on 4 April 1980.

Hour	Nursing Vocalizations	Only Crying or Grunting Sounds	Combined Vocalizations
0900	17 (28%)	18 (30%)	35 (58%)
1000	16 (27%)	16 (27%)	32 (54%)
1100	60 (100%)	--	60 (100%)
1200	--	28 (47%)	28 (47%)
1300	24 (40%)	8 (13%)	32 (53%)
1400	3 (05%)	29 (48%)	32 (53%)
1500	28 (47%)	12 (20%)	40 (67%)
1600	--	8 (13%)	8 (13%)
1700	7 (12%)	21 (35%)	28 (47%)
Total	155 (29%)	140 (26%)	295 (55%)

ranging from 13% (8 minutes) to 48% (29 minutes). No nursing vocalizations were recorded from 1200 to 1300 hours and 1600 to 1700 hours. Cub vocalizations of at least 1 category occurred during all hourly periods.

Three females were observed in tree dens with yearlings; 1 female with 2 yearlings, 1 female with at least 2 yearlings and possibly 3, and 1 female with an undetermined number of yearlings.

Sixteen females were without offspring in dens. Fourteen (88%) females in this group were 4 years old or younger. One old-age female (10 years or greater) was observed for 2 successive winters without offspring.

A comparison of all den work on backcountry females showed an average minimum litter size of 2.5 and 2.0 for females with newborn cubs and yearlings, respectively (Table 6). A comparison between age and minimum litter size was made from information obtained from summer trapping and winter den work. Average litter sizes for young (3 to 4 years), mid (5 to 9 years) and old age (10 years or older) females were 2.2, 2.5 and 2.5, respectively (Table 7).

Litter size based on family group observations. Family group observations made by backpackers were compiled from 1970-77. A total of 153 family units were reported. Sixty-two (41%), 57 (37%) and 31 (20%) observations were reported for litter sizes of 2, 3 and 1 cubs, respectively. Two observations were made of litters with 4 cubs. One litter reportedly had 5 cubs. Average overall litter size from observations submitted by backpackers was 1.9. Yearly estimates ranged from 1.6 in 1973 to 2.4 in 1974 (Table 8).

Table 6. Minimum estimated litter size of black bears obtained from winter den work in the Great Smoky Mountains National Park and Cherokee National Forest, 1979-80.

Reproductive Condition	No. of Family Groups	No. of Offspring	Females with 1 Cub	Females with 2 Cubs	Females with 3 Cubs	Average Litter Size
Females with cubs	13	32	0	7	7	2.5
Females with yearlings	6	12	1	4	1	2.0

Table 7. Minimum estimated litter size in relation to age for backcountry female black bears from summer trapping and winter den work in the Great Smoky Mountains National Park and the Cherokee National Forest, 1972-80.^a

Age	Age Class	Females with 1 Cub	Females with 2 Cubs	Females with 3 Cubs	Average Litter Size	Average Litter Size for Age Class
3	Young		2		2.0	2.2
4	Young		2	1	2.3	
5	Mid		3	1	2.3	2.5
6	Mid		2	1	2.3	
7	Mid	1 ^b		2	2.3	
8	Mid		1		2.0	
9	Mid		1	2	2.7	
10	Old		2		2.0	2.5
11+	Old		1	3	2.8	

^aFemales with yearlings included as females with cubs for previous year.

^bFemale with 1 yearling.

Table 8. Family group sightings of black bears reported by backpackers and hikers in the Great Smoky Mountains National Park, 1970-77.

Year	Number of Family Groups	Number of Cubs	Females with 1 Cub	Females with 2 Cubs	Females with 3 Cubs	Females with 4 Cubs	Average Litter Size
1977	10	19	2 (20%)	7 (70%)	1 (10%)		1.9
1976	27	49	10 (37%)	12 (44%)	5 (19%)		1.8
1975	12	28	3 (25%)	4 (33%)	4 (33%)	1* (9%)	2.3
1974	14	34	1 (8%)	8 (57%)	3 (21%)	2 (14%)	2.4
1973	15	24	6 (40%)	9 (60%)			1.6
1972	51	89	25 (49%)	14 (27%)	12 (24%)		1.8
1971	--	--	--	--	--	-	---
1970	24	44	10 (42%)	8 (33%)	6 (25%)		1.8
Total	153	287	57 (37%)	62 (41%)	31 (20%)	3 (2%)	1.9

*Female with 5 cubs.

A total of 152 family units were sighted by bear project and NPS personnel from 1970-79. Litters of 2 cubs were most common (79, 52%). Thirty-four (22%) and 32 (21%) litters were observed with 3 and 1 cubs, respectively. Average overall litter size was 2.1, with yearly litter size ranging from 1.5 in 1972 to 2.6 in 1974 (Table 9). NPS and bear project observations were categorized into 2 groups: backcountry and panhandler bears (bears that habitually come into developed areas to obtain food). The panhandler category included backcountry panhandlers around backcountry campsites and shelters, and front country panhandlers around picnic areas, campgrounds and roadsides. Litter sizes of 2 cubs were observed most often for all categories. Average litter size was 2.2 for panhandler bears, with 2.2 and 2.3 for front country and backcountry observations, respectively. Wild backcountry females had an average litter size of 2.0.

Chi square analysis indicated that differences in litter sizes observed between years were not significant. Correlation analysis failed to show any relationship between litter size (based on observations of family groups by backpackers and NPS/bear project personnel) and estimated mast yield.

Scattered observations of panhandler females with yearlings were made from 1978-80 by NPS personnel, with an average litter size of 2.2 (Appendix F).

Reproductive Tracts

Six reproductive tracts were collected from female black bears killed during the 1979 bear hunts on the CNF and losses within the GSMNP (road kills, etc.). Corpora lutea were observed in the ovaries

Table 9. Family group sightings of black bears reported by National Park Service and The University of Tennessee bear project personnel in the Great Smoky Mountains National Park, 1970-79.

Year	Number of Family Groups	Number of Cubs	Females with 1 Cub	Females with 2 Cubs	Females with 3 Cubs	Females with 4 Cubs	Average Litter Size
1979	30	64	4 (13%)	19 (63%)	6 (20%)	1 (3%)	2.1
1978	22	52	5 (23%)	7 (32%)	7 (32%)	3 (13%)	2.4
1977	11	18	5 (45%)	5 (45%)	1 (10%)		1.6
1976	8	16	1 (13%)	6 (75%)	1 (13%)		2.0
1975	--	--	-	--	-	-	---
1974*	13	34		6 (46%)	6 (46%)	1 (8%)	2.6
1973*	13	23	5 (39%)	6 (46%)	2 (15%)		1.8
1972*	21	39	5 (24%)	14 (67%)	2 (9%)		1.5
1971*	15	33	2 (13%)	8 (54%)	5 (33%)		2.2
1970*	19	41	5 (26%)	8 (42%)	4 (21%)	2 (11%)	2.2
Total	152	320	32 (21%)	79 (52%)	34 (22%)	7 (5%)	2.1

*Beeman (1975).

of 3 females (3, 3 and 2). One of the 3 tracts without corpora lutea was from a female known to have given birth the previous winter; 3 placental scars were visible. The 2 remaining females were judged to be immature based on the size of the reproductive tract. Three implantation sites were found in the uterus of a female killed 8 December during the fall hunts. Three corpora lutea were observed, all present on 1 ovary; implantation sites were present on both uterine horns, indicating migration of the blastocyst within the uterus.

Characteristics of Offspring Examined in Winter Dens

Weights were obtained for 6 litters of newborn cubs and 3 litters of yearlings examined in dens (Appendix E). Cubs estimated to be 2 to 3 weeks old weighed an average of 0.5 kg. Cubs from 1 litter, known to be between 46 and 49 days old, weighed 1.8 kg and had their eyes open. Four backcountry yearlings (from 2 litters) weighed an average of 10 kg, ranging from 7.7 kg to 14 kg. Weights of 4 pan-handler yearlings (from 1 litter) ranged from 14 kg to 28 kg, with an average weight of 21 kg (Appendix E).

Pronounced differences were observed in the weights and development of newborn cubs examined during a 10 day period (8 March to 17 March) in 1979 and 1980. The cubs of 1 litter examined on 17 March 1979 weighed 1.1 kg; cubs of another litter examined a week earlier (10 March 1979) weighed 1.8 kg. Both sets of cubs had their eyes closed. However, the cubs examined on 10 March were much more mobile in the den. All of the cubs observed in the winter of 1980

had their eyes open; cubs examined during 1979 had their eyes closed (Appendix E).

One male cub examined during the winter of 1980 was distinctly marked with a chest blaze and 4 white paws (Fig. 5). The adult female and the 2 male siblings were solid black.

On 25 March 1980, 4 male yearlings were sedated in the den and examined. A first upper premolar was extracted for comparative purposes in aging tooth sections. One yearling had a double canine; a permanent canine pushing up behind the deciduous canine. The adult female and 3 yearlings were recaptured on 11 May 1980. Two of the yearlings had a full set of premolars, indicating that the premolars pulled on 25 March were deciduous.

A preponderance of male offspring was observed in litters of backcountry females examined in dens, with a sex ratio (male:female) of 2.5:1. Control actions initiated during the summer by the National Park Service on panhandler females with offspring produced a sex ratio for the litters of 1.7:1. The overall sex ratio for both of these groups combined was 2.1:1 (Appendix F).

Cub Mortality

Limited information was available on cub mortality. Information was collected for 10 females known to have had cubs the previous year to determine the presence or absence of yearlings (Table 10). Nine females were observed with yearlings in dens or early in the spring before the family unit broke up. One female was observed with only 1 yearling in the den. One female was observed with newborn cubs during 2 successive winters, indicating the complete loss of the first litter.



Fig. 5. Black bear cub with chest blaze and 4 white paws, observed during the winter of 1980 in the Great Smoky Mountains National Park.

Table 10. Status of litters for female black bears in the Great Smoky Mountains National Park and Cherokee National Forest with 2 successive years of reproductive information, 1978-80.

Bear No.	Comments
305	Lactating summer 1978, with yearlings in winter den, 1979
308	Lactating summer 1978, with yearlings in winter den, 1979
320	With cubs in winter den 1979, with yearlings in winter den, 1980
463	Lactating summer 1979, with yearlings in winter den, 1980
476	With cubs in winter den 1979, with cubs in winter den, 1980*
549	Observed with yearlings before family unit split up in spring, 1979
577	Lactating and observed with 4 cubs during 1979, with 4 yearlings in winter den, 1980
A45	With cubs in winter den 1978, with yearlings in winter den, 1979
B10	With 1 yearling in winter den, 1979
E7	With cubs in winter den, 1978, with yearlings in winter den, 1979

*Loss of litter in 1979 possibly due to disturbance in den that winter.

However, this mortality was possibly due to disturbance of the female the first winter, causing her to abandon the den prematurely. No other adult females were observed lactating during successive years from 1973-79. Average litter sizes (determined from den work) for females with cubs and yearlings were 2.5 and 2.0, respectively, which suggests that some cub mortality occurs. Average litter size based on observations of females with yearlings reported by NPS and bear project personnel was 2.10, with average litter sizes of 2.2 and 1.9 for pan-handler and backcountry females, respectively.

Estrous Period

Sign of estrus (swelling of the external genitalia) were observed in 36 females trapped from 1972-79. Females with prominent swelling of the genitalia (Fig. 6) were observed from 21 June to 31 August (n=25). Females with less prominent swelling were observed as early as 5 June and as late as 12 September (n=11). Most observations of estrus (76%) were made between 25 June and 21 July (Fig. 7).

Determination of Estrus

Vaginal pH was recorded for 21 females trapped during the summer of 1979 (Appendix G). Readings of pH averaged 6 for estrous females and 6.2 for anestrus females, with ranges of 5 to 8 and 5 to 7, respectively. No significant difference existed between estrous and anestrus females.

Electrical resistance of the vaginal tract was recorded for 17 females (Appendix G). Readings for estrous females ranged from 0.03 to $0.7 \times 100 \text{ K ohms}$, with an average of $0.22 \times 100 \text{ K ohms}$. Anestrus



Fig. 6. Comparison of the external genitalia of female black bears during anestrus (above) and estrus, with pronounced vulval swelling (below), in the Great Smoky Mountains National Park and the Cherokee National Forest, 1978-79.

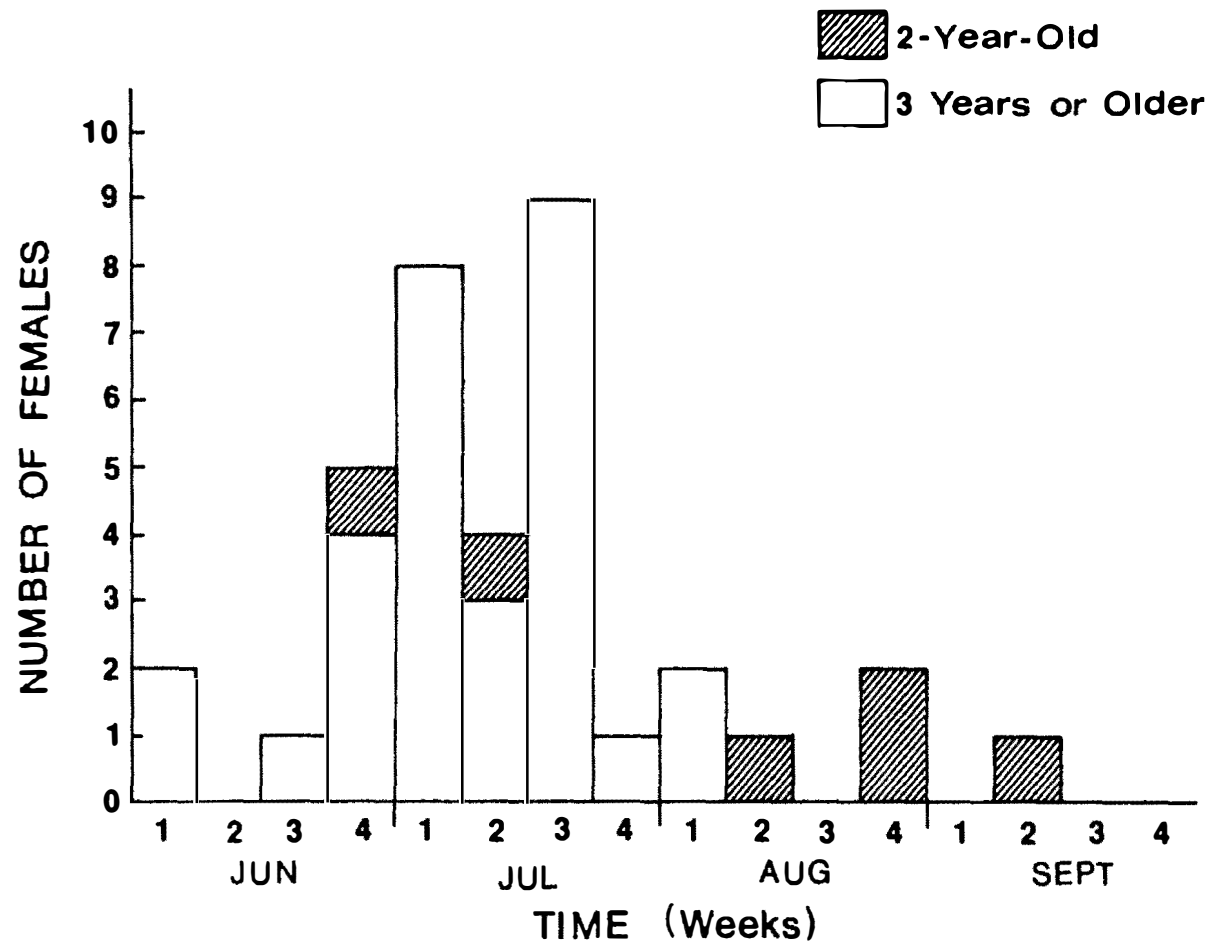


Fig. 7. Observation of female black bears in estrus in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

females ranged from 0.03 to 0.8 x 100 K ohms, with an average of 0.25 x 100 K ohms. No significant difference was found between the 2 groups.

Vaginal smears were taken from 54 females (including 6 recaptures) trapped during 1978 and 1979 (Appendix G). The cell types observed were compared with the presence or absence of external signs of estrus, age and reproductive condition observed the following year (Table 11). Twelve females displayed prominent signs of estrus (distinct swelling of the external genitalia). Cornified cells (Fig. 8) were found in the smears of 6 of these females, including 3 adults and 3 sub-adults. Two of the adult females gave birth the following winter. The third was killed later in the summer; examination of the reproductive tract revealed the presence of 3 corpora lutea. One of the sub-adults from this group was killed during the fall bear hunts on the CNF; 3 corpora lutea and 3 implantation sites were found when the reproductive tract was examined. The remaining sub-adults were without offspring when observed in dens. Cornified cells were not detected in smears obtained from 6 females (1 adult and 5 sub-adults) with pronounced vulval swelling. The adult female and 1 sub-adult gave birth the following winter. The 4 other sub-adults were without offspring in the dens. Two adults and 2 sub-adults exhibited only slight swelling of the external genitalia. Cornified cells were not present in the smears taken from these females. One of the adults had newborn cubs the following winter; 1 sub-adult was without offspring. The reproductive status of the two remaining females is unknown. Cornified cells were not detected in smears

Table 11. Comparison of external signs of estrus in relation to age, changes of vaginal epithelium, and reproductive condition of female black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1978-79.

External Condition	Condition of Vaginal Epithelium	Age	Reproductive Condition of Females
12 females with prominent vulval swelling	6 females with cornified cells	3 adults	2 with cubs the following winter 1 road kill, with corpora lutea on reproductive tract
		3 immature	2 without cubs the following winter 1 killed in fall hunts, with corpora lutea and implantation sites on reproductive tract
	6 females without cornified cells	1 adult	1 with cubs the following winter
		5 immature	1 with cubs the following winter 4 without cubs the following winter
	4 females without cornified cells	2 adult	1 with cubs the following winter 1, reproductive status unknown
		2 immature	1 without cubs the following winter 1, reproductive condition unknown
38 females without signs of estrus	3 females with cornified cells	3 adult	1 with cubs the following winter 2, reproductive condition unknown

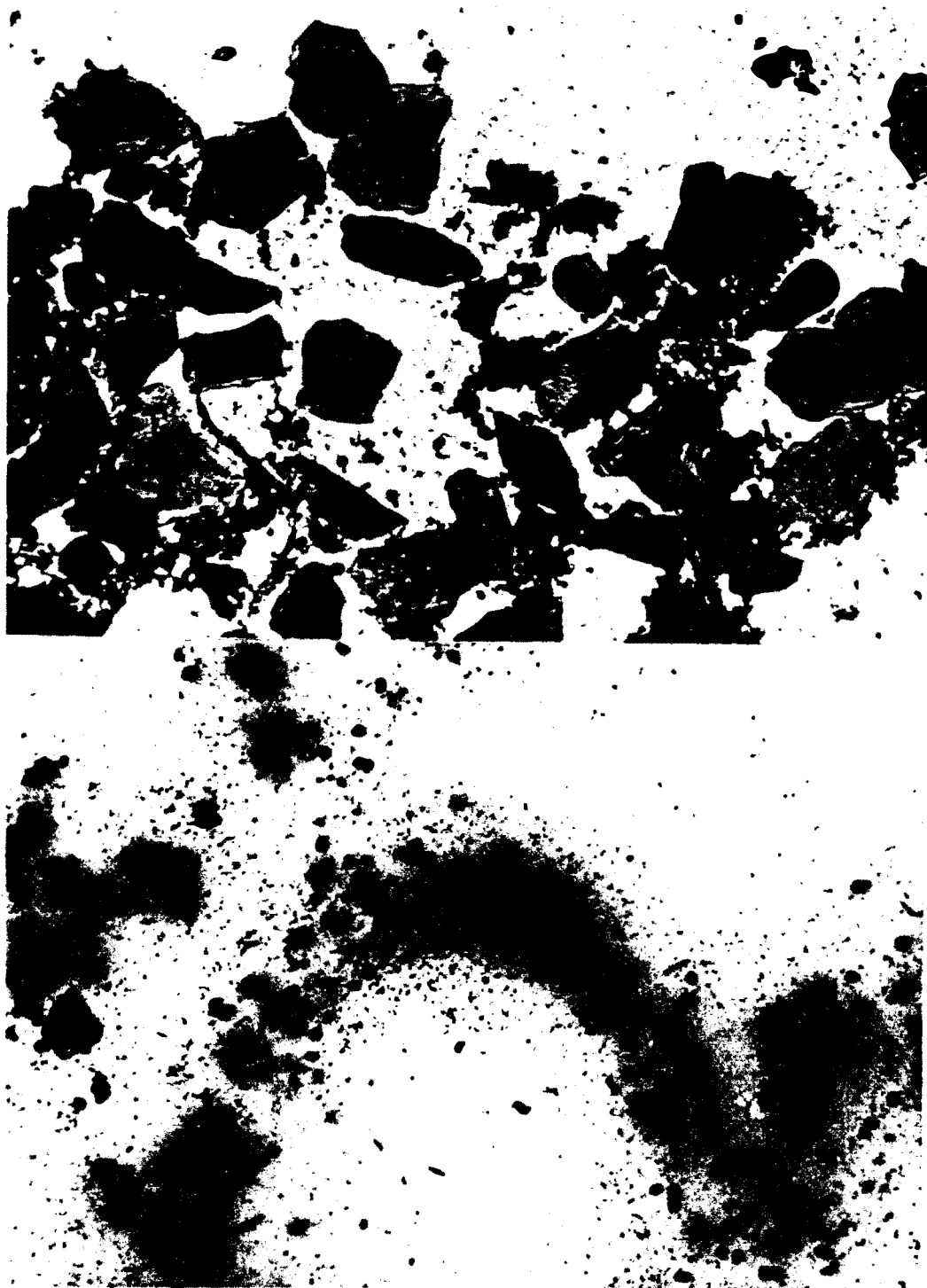


Fig. 8. Cells observed in vaginal smears taken from black bears in the Great Smoky Mountains National Park and the Cherokee National Forest, 1978-79. A predominance of cornified epithelium (above) indicates an estrous condition. Leucocysts (below) predominate for a short time following estrus.

obtained from 35 of 38 females that exhibited no external signs of estrus. One of the 3 females that exhibited cornified cells gave birth the following winter; the reproductive status of the other 2 is unknown.

One sub-adult female, trapped initially in June and recaptured in late August, exhibited prominent signs of estrus on both occasions. Cornified cells were not detected in the vaginal smear taken in June but were present during August. This female was without offspring when observed the following winter.

Lactation

The majority (31, 58%) of females lactating or observed with cubs in winter dens were within the mid-age class (5-9 years), with 7 (13%) and 15 (29%) in the young (3-4 years) and old (10 years and older) age classes, respectively (Table 12). However, in relation to the total number of females trapped within the respective age classes, 40% (15/38) of the old age females were lactating or observed with cubs, compared to 31% (31/99) and 14% (7/50) for mid-age and young age classes, respectively. Twenty-three percent (22) of the total number of mature backcountry females trapped from 1973-79 were lactating (Table 13).

The number of lactating females observed during the trapping season (mid-June through mid-September) was compared by months for 1972-79. Panhandler females were not included in this analysis since control actions were initiated sporadically during the summer; trapping of the wild segment of the population was relatively continuous throughout this period. Chi square analysis indicated that

Table 12. Age differences observed for lactating female black bears determined from trapping data and den work in the Great Smoky Mountains National Park and the Cherokee National Forest, 1972-80.

Age Class	Age	No. of Lactating Females	Total No. of Females	Percent of Total Lactating Females within Age Class	Percent of Total Lactating Females for Age	Percent of Females Lactating Within Age Class	Percent of Females Lactating for Age
Young	3	2	31	13	4	14	7
	4	5	19		9		26
Mid	5	7	22	58	13	31	32
	6	9	23		17		39
	7	5	21		9		24
	8	6	20		11		30
	9	4	13		8		31
Old	10	5	10	29	9	40	50
	11	2	10		4		20
	12	3	9		6		30
	13	3	5		6		60
	14	-	1		--		--
	15	2	3		4		67
Totals		53	187				

Table 13. Number of wild lactating female black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

Categories	Year						
	1979	1978	1977	1976	1975	1974	1973
Number of lactating females	2	4	6	3	3	4	0
Number of adult females	8	11	16	18	20	11	14

no significant variation existed between the observed and expected frequencies at the 0.05 level ($\chi^2 = 1.16$, $P < 7.81$), indicating that the number of females observed lactating during August and September was on a comparable level with June and July.

Milk let-down could not be induced by manual manipulation of the mammary glands for 8 females known to have cubs (Appendix C). Four of these females were observed later in the summer or in winter dens with offspring. Two of these females were trapped late in the fall and may have already weaned their cubs. The status of 2 females and their litters is unknown. Three females sedated in winter dens with newborn cubs were also unresponsive to attempts to initiate milk let-down. Suppression of lactation was not observed when oxytocin was administered to females known to have cubs.

Minimum Reproductive Age

Two 3-year-old females gave birth during the study, indicating successful breeding at 2 years of age. Both instances were observed on the CNF. Only 7% (2/28) of the females in this age class gave birth. Twenty-nine percent (5/17) of the 4-year-old females were lactating or had cubs when trapped or observed in winter dens (Table 12). Comparisons of the number of lactating females observed between ages 4 through 9 (with respect to the total number of females trapped within these ages) indicated that there was no significant difference in the number of females that gave birth at 4 through 9 years of age ($\chi^2 = 0.93$, $P(0.05) < 11.1$).

Minimum reproductive age was determined for 18 females, based on recapture information: 2 at 3 years, 5 at 4 years, 6 at 5 years,

3 after 4 years, and 2 after 5 years of age (Table 14). An extreme mast failure may have been a factor in delaying minimum reproductive age for 1 female that gave birth for the first time at 6 years. Females that were known to have given birth after 4 years of age were combined with females that gave birth initially at 5, since only a small percentage gave birth for the first time after age 5. This combined group made up the majority (9/18) of the total sample.

Reproductive Cycle

Information related to the reproductive status of females trapped during the summer and observed in winter dens was compiled by age for 1973-80 (Table 15). One hundred (60%) of the 165 females trapped during the summer were in non-lactating anestrus, 32 (19%) were lactating and 33 (20%) showed signs of estrus. Information was compiled by age for females recaptured over successive years (Table 16). Ten females were lactating that had been observed in estrus the previous year. Eight females were not lactating even though they had been in estrus the year before. Six females in this group were 4 years or younger; 2 females were 5 years or older and therefore considered sexually mature. Fifteen females trapped the previous year in non-lactating anestrus were lactating; 12 of these females were 5 years or older. Seventeen females were not lactating even though they had been in non-lactating anestrus the previous year. The majority (10) were 5 years or older. In all, a total of 13 (38%) females 5 years or older were not lactating after showing signs of estrus or non-lactating anestrus the previous year, indicating a skip in the reproductive cycle.

Table 14. Minimum reproductive age determined for 18 female black bears from trapping data and den work in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-80.

Category	Age					
	3	4	5	6	7	> 4
No. of females giving birth for the first time	2	5	6	1	1	3
Percent of total	11%	28%	33%	5.5%	5.5%	17%

Table 15. Reproductive status of female black bears determined from summer trapping and winter den work in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-80.

Categories	Age				Total
	2	3	4	5+	
No. of females in estrus	4	6	4	19	33
No. of females lactating	0	2	4	41	47*
No. of females in non-lactating anestrus	15	19	7	59	100

*Includes winter den work, 32 females lactating or observed with cubs during summer.

Table 16. Reproductive information for female black bears trapped over successive years and observed in winter dens in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-80.

Categories	Age				Total
	3	4	5	6+	
No. of females lactating, in estrus previous year	1	1	2	6	10
No. of females not lactating, in estrus previous year	3	3	1	1	8
No. of females lactating, in non-lactating anestrus the previous year	0	2	1	12	15
No. of females not lactating, in non-lactating anestrus the previous year	3	3	1	10	17

Thirty-three mature females were recaptured over a sufficient period of time to provide information related to the reproductive cycle. Fourteen (45%) females in this sample displayed skips in the reproductive cycle. Ten of these 14 females were within the mid-age class, with only 3 old-age females exhibiting skips in the cycle. One old-age female displayed skips in the cycle over 2 successive years.

A comparison was made between estimates of mast yield (Fig. 9) and skips in the reproductive cycle for 12 females where the skips could be pinpointed to the exact year (Table 17). Skips were observed during 1974, 1976, 1979 and 1980. The years 1974 and 1979 were preceded by years with extremely poor mast crops. The availability and quality of mast that preceded 1976 was fair. The year 1980 was preceded by a medium mast crop; however, the female that skipped during this year had also skipped the year before and some other factor may be involved.

Weight

Growth curves based on Brody's model were used to estimate the population parameters relative to weight gain and maturity for wild female bears (Fig. 10), panhandler females (Fig. 11), wild males (Fig. 12), and panhandler males (Fig. 13). Differences between mean weights and weight estimates from the growth curves were compared with respect to age. Wild and panhandler males were substantially heavier than their female counterparts. Panhandler females were heavier than wild females, with an estimated asymptotic weight of 68 kg and 54 kg, respectively (Fig. 14). A similar pattern was observed between panhandler and wild males, with panhandler males exhibiting higher

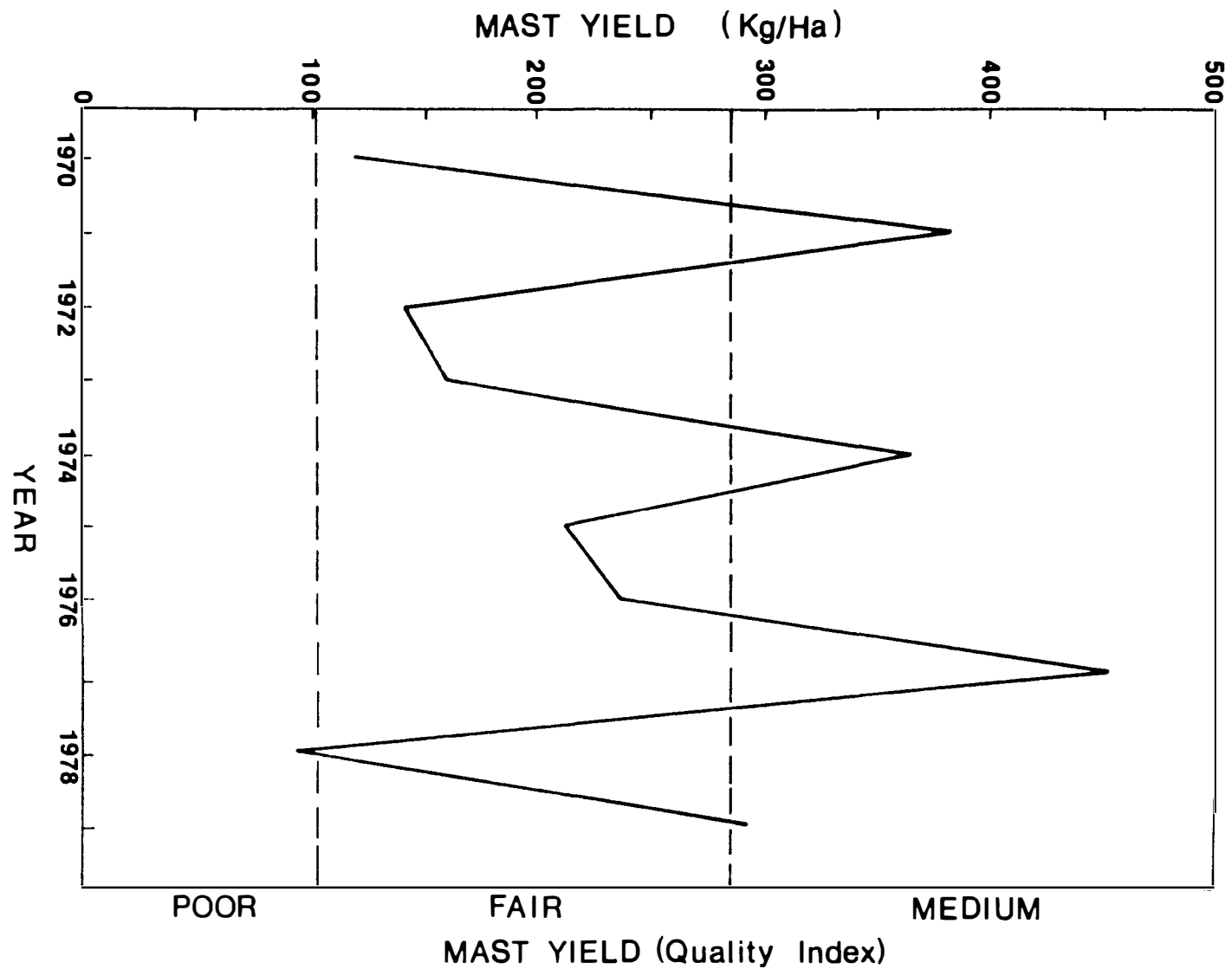


Fig. 9. Estimated mast yields (kg/HA and in reference to quality index) for the Tellico Wildlife Management Area, Cherokee National Forest, 1970-79.

Table 17. Relationship between skips in the reproductive cycle of female black bears in the Great Smoky Mountains National Park and the Cherokee National Forest and the estimated mast yield for the previous year, 1974-80.

Year	No. of Females with Skips	Females with Skips Compared to Total No. of Females	Estimated Mast Yield for Previous Year (kg/ha)
1980	1	1/14 (7%)	292
1979	4	4/14 (29%)	91
1978	0	0/9 -	452
1977	0	0/8 -	237
1976	5	5/8 (63%)	212
1975	0	0/7 -	364
1974	2	2/6 (33%)	160

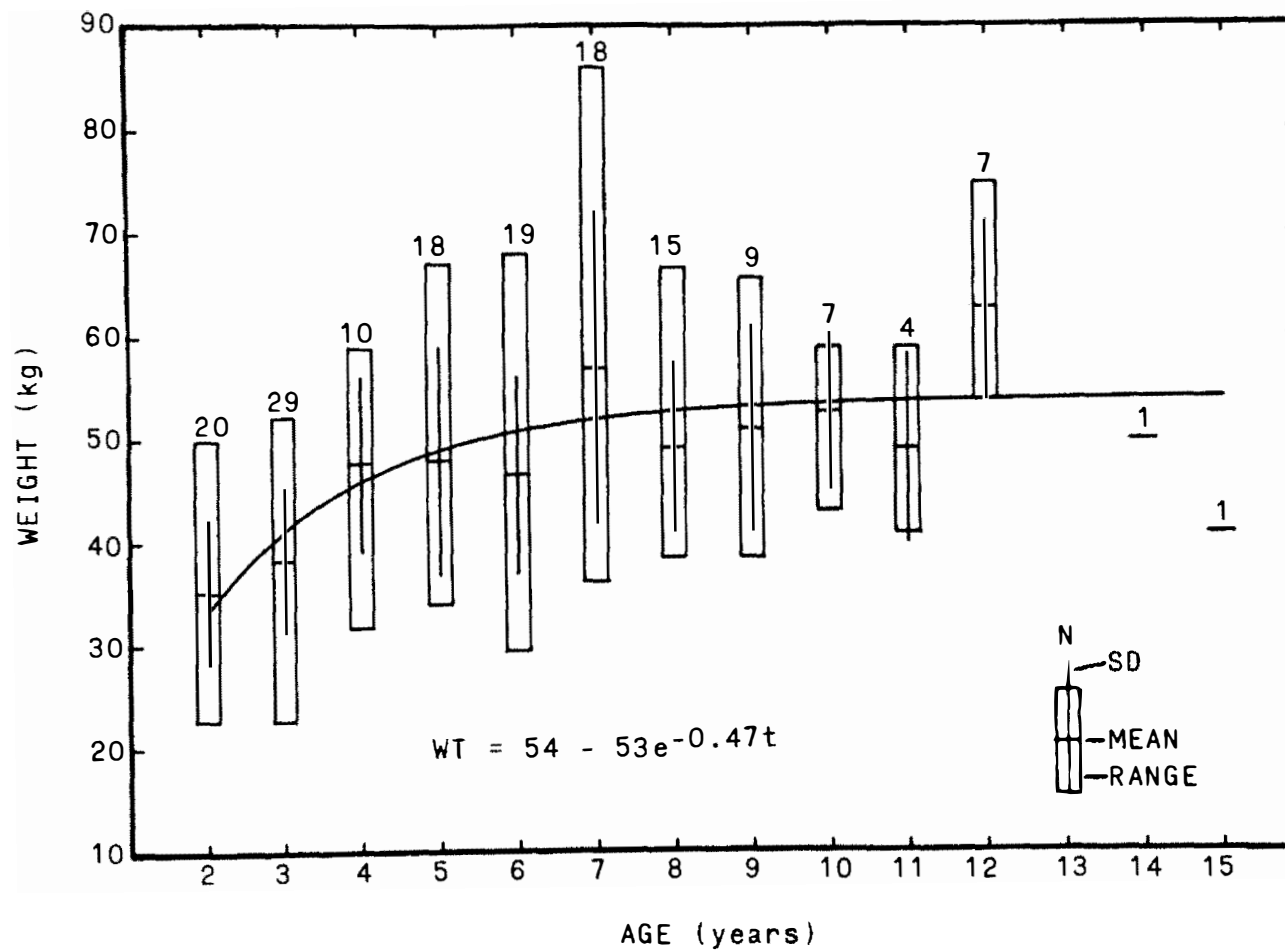


Fig. 10. Mean, standard deviation (SD), range, and logistic growth curve of weight data, by age, for wild female black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

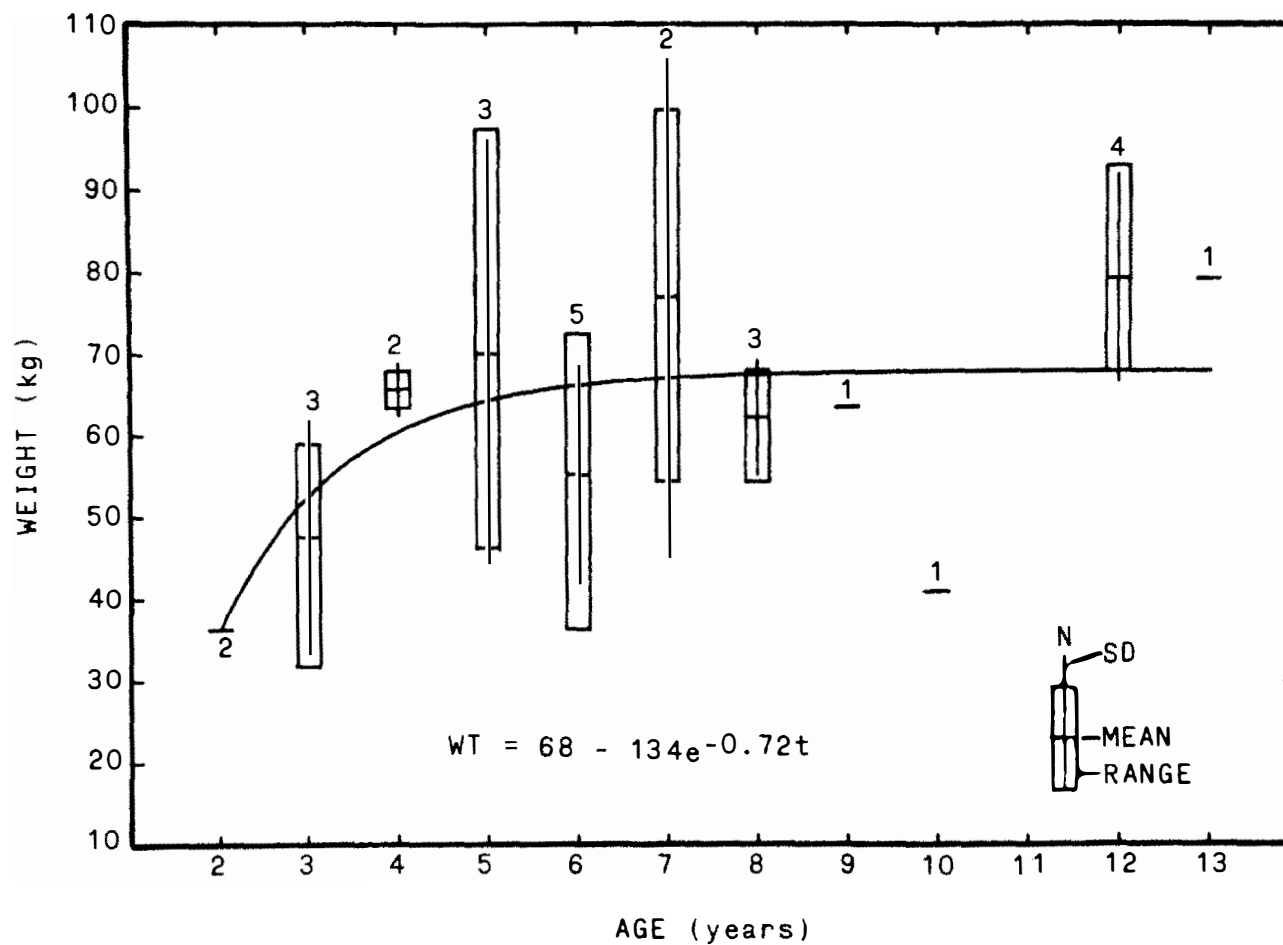


Fig. 11. Mean, standard deviation (SD), range, and logistic growth curve of weight data, by age, for panhandler female black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

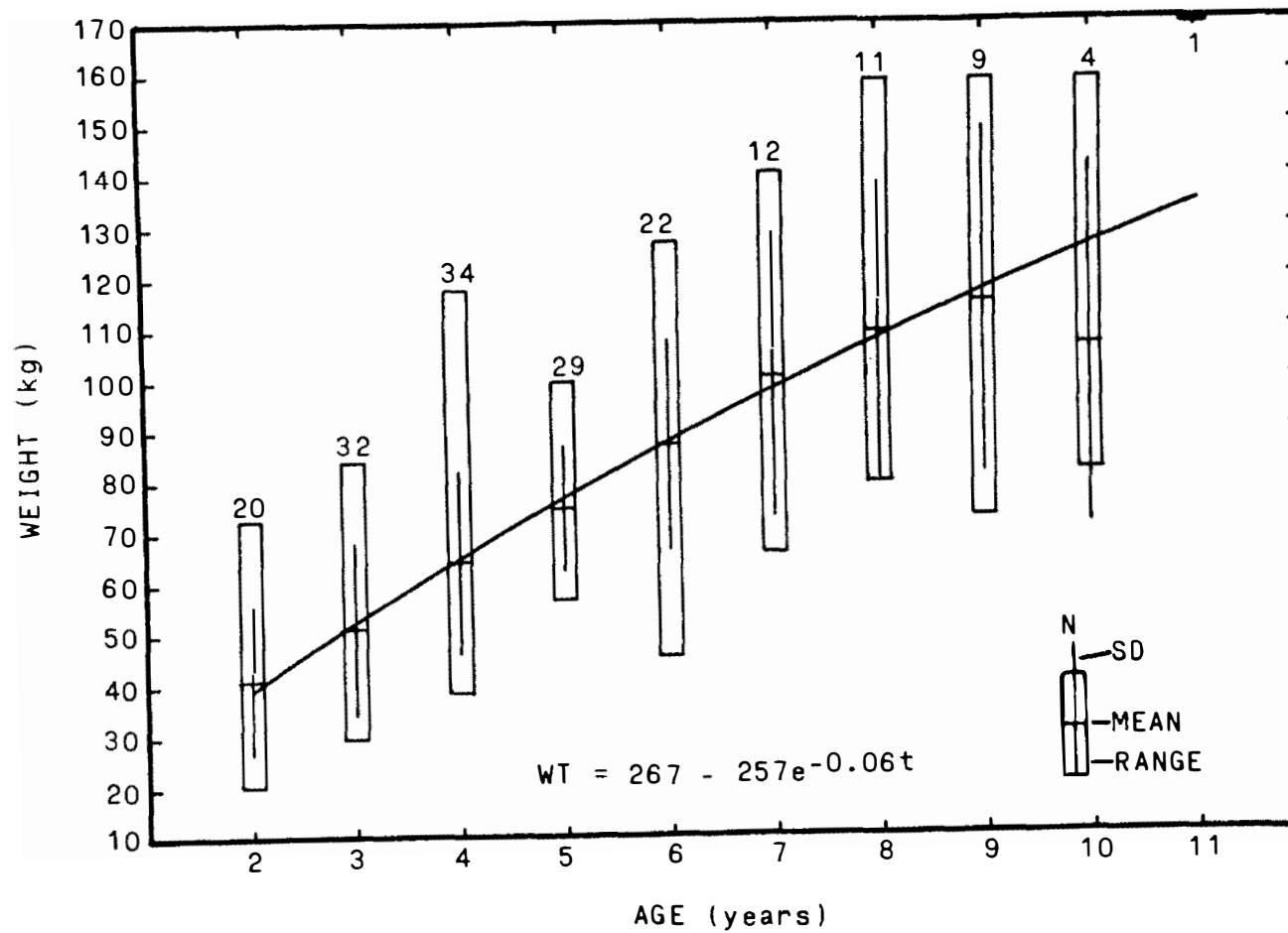


Fig. 12. Mean, standard deviation (SD), range, and logistic growth curve of weight data, by age, for wild male black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

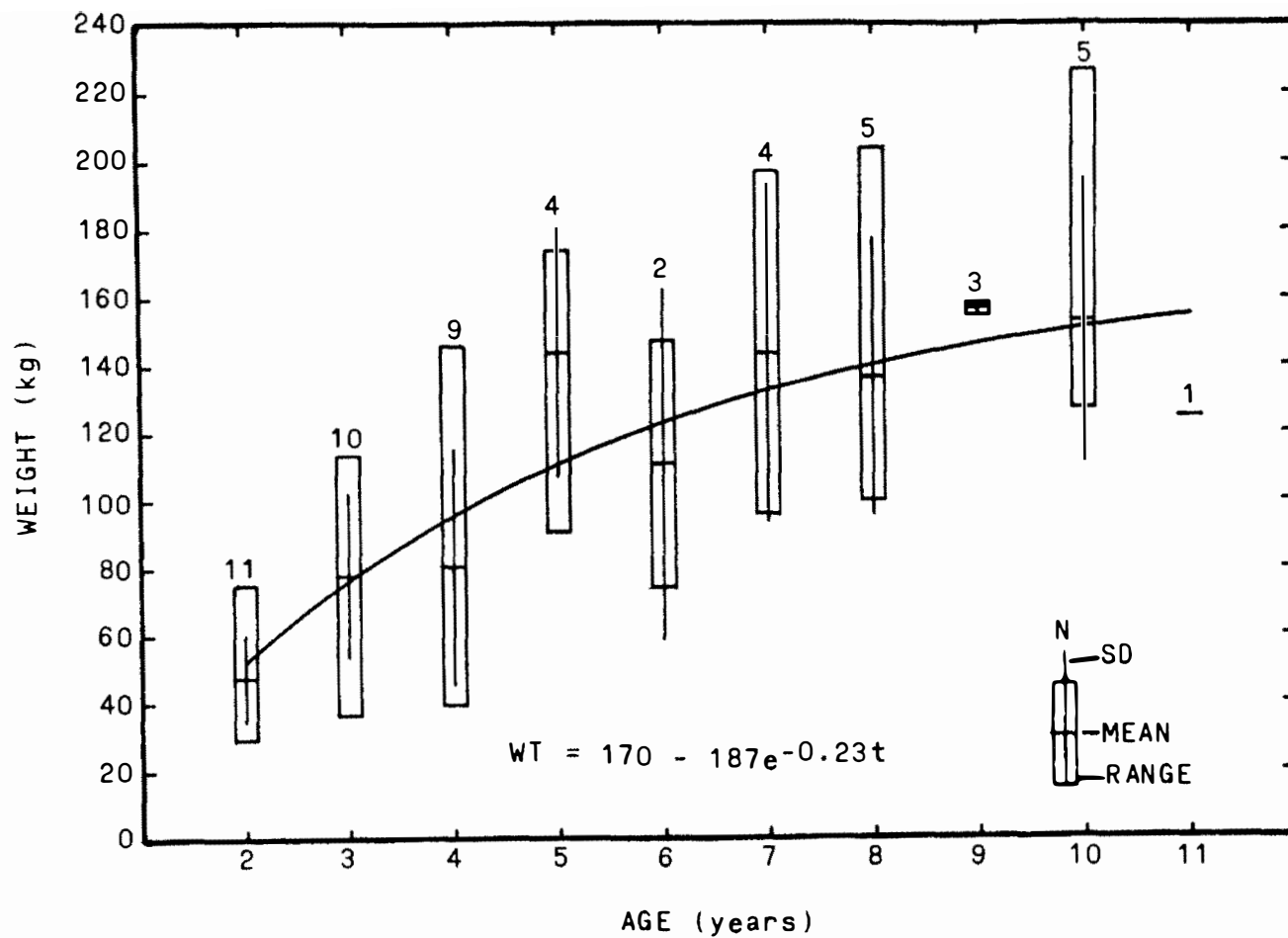


Fig. 13. Mean, standard deviation (SD), range, and logistic growth curve of weight data, by age, for panhandler males trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

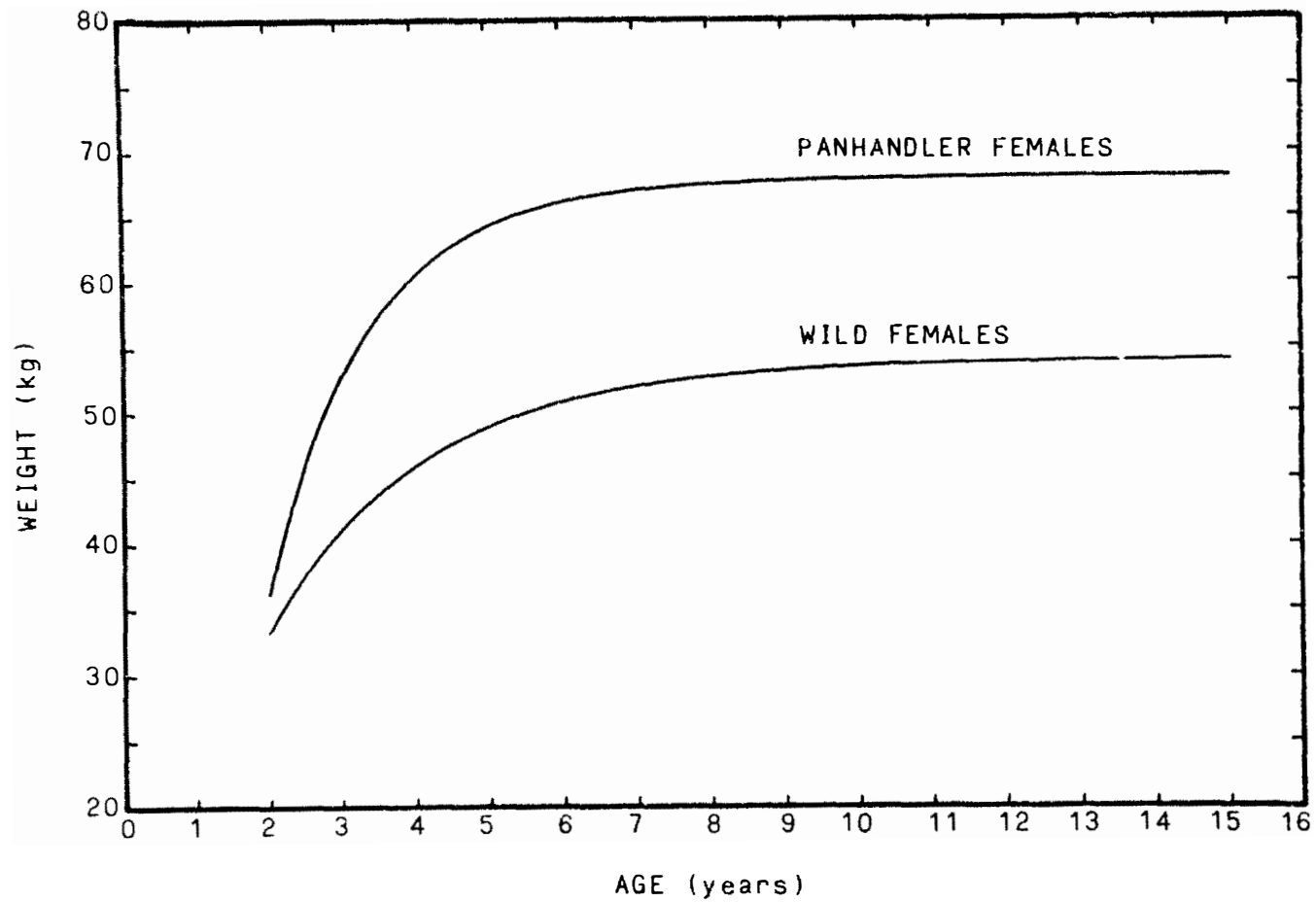


Fig. 14. Difference in weight-age data, based on the logistic growth curve, for wild and panhandler female black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

weights (Fig. 15). However, since weights for wild males never level off, the asymptote for that group was actually higher. Mean weights compiled by age reflected similar patterns between the 4 groups.

The instantaneous relative growth rate (K) derived from the data by Brody's model was highest for panhandler females (-0.72), followed by wild females (-0.47), panhandler males (-0.23) and wild males (-0.06). The extremely low K value for wild males was related to the fact that weight for this group does not level off.

Weights for panhandler and wild females tended to level off at 5 and 6 years of age using Brody's model. Mean weight values for panhandler and wild females leveled off at 4 years.

Differences in weights were observed between lactating and non-lactating females (Fig. 16). Females with newborn cubs weighed significantly more during the winter than females that had given birth the previous year; weight differences observed from June through September were not significant. Lactating females were significantly heavier during the winter than in the following September. Non-lactating females (that had given birth the previous year) weighed significantly less during the winter than in the following September. No significant differences were observed between September weights of mature non-lactating females and winter weights of lactating females; the same was true for September weights of lactating females and winter weights of non-lactating females that had given birth the previous year. Immature females (2-3 years) weighed significantly less than mature females, regardless of reproductive condition.

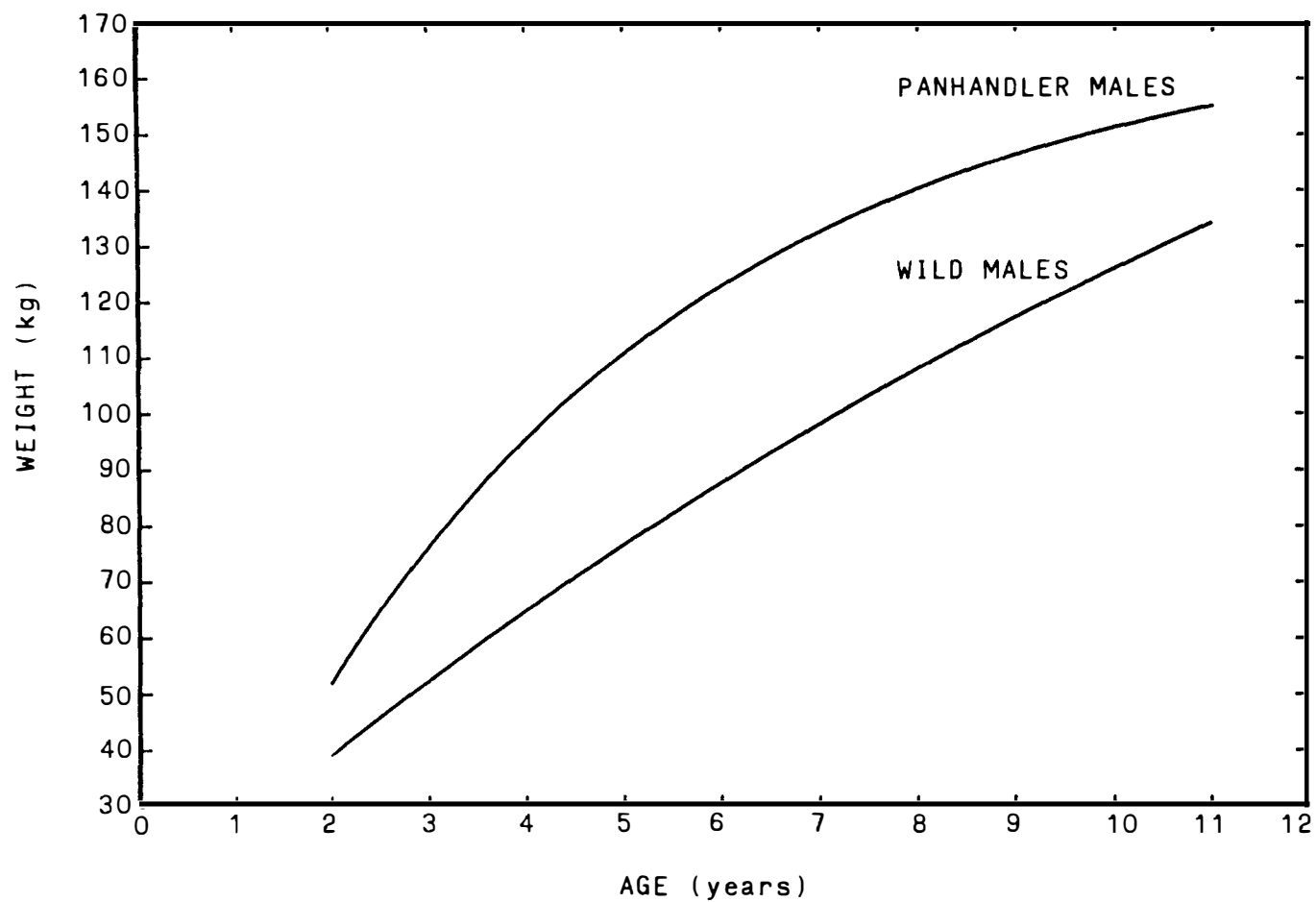


Fig. 15. Difference in weight-age data, based on the logistic growth curve, for wild and panhandler male black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79.

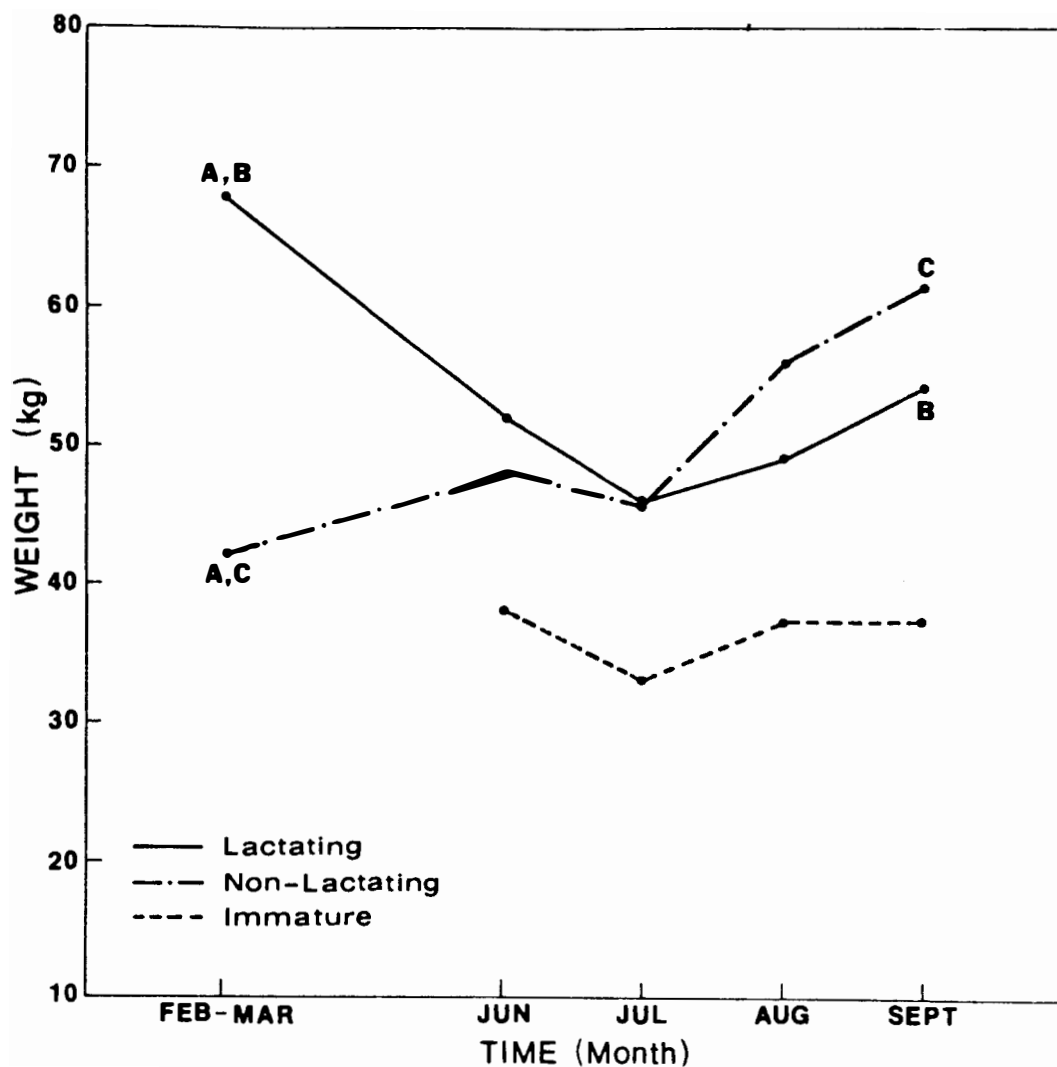


Fig. 16. Comparisons of seasonal weight changes, in relation to reproductive condition, for sub-adult and adult female black bears trapped in the Great Smoky Mountains National Park and the Cherokee National Forest, 1973-79. Points with the same letter (A, B, or C) indicate significant differences between weights of mature females. Immature females weighed significantly less than mature females at all times.

CHAPTER V

DISCUSSION

Denning Chronology

Factors influencing den entry. Denning during the winter has been reported for black bears throughout their range in North America (Johnson and Pelton 1980). Bears generally enter dens from mid to late fall. However, the proximate factors that initiate denning are not well understood. Den entry has been attributed to inclement weather (Erickson 1964, Jonkel and Cowan 1971, Lindzey and Meslow 1976, Johnson and Pelton 1980), physical condition of the animals (Matson 1946, Spencer 1955, Lindzey and Meslow 1976) and the availability of mast during the fall (Johnson and Pelton 1980).

During the winters of 1978-79 and 1979-80, no significant relationship was observed between den entry and weather conditions. Johnson and Pelton (1980) found a linear relationship between den entry and total precipitation, number of days with precipitation, minimum and maximum temperature for 3 days prior to entry ($R^2 = 0.70$) for male and female black bears in the GSMNP. During this period (1976-78), den entry occurred significantly later (last week of December and first week in January) than was observed during the present study (first 3 weeks of December, with the majority of bears denning during the first 2 weeks). It is possible that bears denning later in the fall were influenced to a greater extent by weather

conditions, whereas bears that denned earlier were more responsive to factors other than weather.

Johnson and Pelton (1980) suggested that food availability during the fall influenced den entry, based on the fact that bears denned significantly earlier (first 2 weeks of December) in years (1972-74) with fair to poor mast yields and exceptionally mild weather (Beeman 1975) than in years (1976-78) with medium mast yields and unusually severe weather. Mast availability seemed to have little influence on den entry during 1978-79. Denning occurred during the first 3 weeks of December for both 1978 and 1979 (with no significant differences observed) even though mast yields were rated as poor (mast failure) in 1978 and medium during 1979 (Fig. 9, page 55). In addition, females entered dens significantly earlier in 1979 than in 1976-78 (years of comparable mast yield). The differences observed in den entry (1979 compared with 1976-78) suggest that the influence of mast availability on when bears enter winter dens may vary. During the fall of 1978, greater amounts of hard mast were observed on Sugarland Mountain than in other parts of the study area. A female collared in this area denned at a time comparable to females in other areas.

A small number of females with cubs and sub-adult females (non-pregnant) entered winter dens much later (late January to mid-February) than other females of similar reproductive condition. Johnson (1978) observed similar occurrences. Sub-adults weigh significantly less than adult females, and females with cubs from the previous year weigh significantly less during the winter than females

with newborn cubs. The poor condition of sub-adults and females with yearlings may influence them to delay denning if sources of food are readily available. However, other factors are clearly involved since differences in den entry between these 2 groups and pregnant females were insignificant. In addition, the earliest record of denning in the GSMNP was for a female with cubs.

It is suggested that a number of factors influence den entry, including weather conditions, food availability (or other factors related to habitat quality), and condition of the animal. The extent of influence exhibited by any particular factor may vary from year to year. The absence of 1 factor may allow another to take effect. A combination of several factors may cause a previously influential factor to become insignificant.

Factors influencing den emergence. Den emergence in the spring was associated with increasing precipitation and decreasing minimum temperature. Periods of adverse weather probably cause conditions in the den to become unsuitable. If the animal is physiologically ready to emerge, these conditions may stimulate it to leave. Black bears in Minnesota left after ground dens became saturated with moisture from melting snow (Aldous 1937, Rogers 1976). Three females in the GSMNP emerged from ground dens following periods of heavy rainfall (Johnson and Pelton 1980). Johnson and Pelton (1980) observed a linear relationship between emergence from winter den and increases in the maximum and average daily wind ($R^2 = 0.42$). The high winds were possibly associated with weather fronts moving into the area.

Reproductive condition was a major factor related to emergence from dens. Females with newborn cubs stayed in dens significantly longer than females without offspring, probably due to the altricial nature of the cubs. Later emergence allows more time for the cubs to develop and protects them from the heavy rains and low temperatures associated with early spring.

Lindzey and Meslow (1976) reported that black bears in Washington exhibited strong fidelity to dens following entry. During this study, 4 females (ranging from 4 to 13 years of age) left initial dens and denned in different sites. One female denned initially in a tree den. The actual den sites of the remaining females had not been pin-pointed prior to emergence, but all 3 were located in areas where substantial utilization of tree dens was observed (Defeat Ridge and the Parsons Branch area). All 4 females left initial dens after periods of substantial rainfall. The 2 females observed during the winter of 1978-79 left within a few days of each other. Johnson and Pelton (1980) reported that 2 sub-adult females moved to different den sites following heavy rainfall. It appears that winter lethargy in black bears is flexible enough to allow the animals to respond to adverse or changing environmental conditions. The extent of response seems to vary during the winter. One female located in a tree den on 15 December was extremely active and later left the den, probably due to our activity near the site. Females located during January did not exhibit this type of response. Certain females were extremely active prior to sedation in winter dens, while others displayed little reaction to our presence.

Several females remained in the general vicinity of the den for a short time after emergence. It is possible that females may leave and re-enter dens intermittently prior to final emergence. Aldous (1937) and Matson (1954) determined from tracks around a den site that the female and occasionally the cubs would leave and re-enter the den (staying in close proximity) prior to final emergence. Radio telemetry data collected in the conventional manner is not accurate enough to detect this type of activity; den emergence can be determined only after the female has moved away from the den site. It is possible to continually recheck the den sites to determine emergence, although it is suggested that the inclusion of this restricted activity outside the den as part of the denning period is not a serious error. The restricted activity seems to represent a transition from winter dormancy to normal activity. Nelson (pers. comm.) reported that bears continue to exhibit characteristics of hibernation for a short time following winter dormancy, despite increased activity. During this period, bears are disinclined to feed and urine volume is extremely low. It is probable that some time is needed before the gastrointestinal tract can function normally after 3 to 5 months of inactivity. With the initiation of spring movements (movements away from the den), bears shift into a phase of activity that can be readily distinguished from denning.

Predictive Model for Reproductive Condition

The date of den emergence was an effective indicator of reproductive condition for females with cubs or without offspring. The probability of error exhibited by the predictive model based on

den emergence ranged from 0% to 15% with 95% confidence. Winter den work is time consuming. The extensive utilization of tree dens by female black bears in certain areas of the country further complicates the collection of reproductive information during the winter due to the inaccessibility of such den sites. Lactating and non-lactating females can be differentiated when trapped during the summer; however, there is no way to determine reproductive condition (pregnant versus non-pregnant) for non-lactating females. During most of the summer, information related to breeding activity is not available. In addition, some females that exhibit signs of estrus are without offspring the following winter, especially sub-adult females. The model presented here provides a means to estimate reproductive condition (with newborn cubs or without offspring) of females in winter dens based solely on den emergence dates.

Dates of den emergence are relatively consistent throughout the range of black bears (Johnson and Pelton 1980). Several authors have speculated that this synchrony is due to the widespread scarcity of nutritious sources of food during the spring (Jonkel and Cowan 1971, Rogers 1976). However, yearly changes in environmental conditions could cause shifts in emergence dates, even though the basic pattern (females without offspring leaving before females with cubs) would remain the same. If such an overall shift in emergence was observed, a time component could be included in the model that would compensate for the change: $\hat{Y} = -5.4859 + 0.041 (X + t)$ where t is the overall shift in time (days) in relation to den emergence observed during 1979-80.

Predicted values ($\hat{Y}$) based on den emergence for females with cubs that denned on the ground did not approximate 1.0 (indicating a female with cubs) as strongly as the $\hat{Y}$ values for females with cubs in tree dens, although reproductive condition was accurately predicted in all cases. This is possibly due to the fact that heavy rains may force females on the ground to leave earlier than those in tree dens. For this reason, females denning on the ground should be scrutinized more closely, since weather conditions appear to have more influence on den emergence; the high proportion of females utilizing tree dens in this area minimizes this problem.

Den Utilization

Female black bears preferred tree dens over ground dens during this study. Johnson (1978) found similar denning patterns for female black bears during 1976-78. In areas of virgin timber, where potential tree dens were abundant, all females utilized tree dens. Johnson (1978) found one ground den on Defeat Ridge and in the Parsons Branch area but in terms of the overall sample from the 2 areas these observations were insignificant. Even in areas where tree dens were less abundant, utilization was substantial. The Tremont area was essentially clear-cut during the 1930's. Three of the 4 dens located in this area were in trees. Only 1 of 10 females denned on the ground in the CNF; this area is under intensive even-age timber management and the scattered den trees are probably trees that were too difficult to harvest or not economically valuable. The high utilization of tree dens in spite of their lower abundance in certain areas further indicates their value as den sites. The added seclusion

provided by tree dens is probably a decided advantage to black bears, particularly in areas with greater accessibility and human activity.

Ground dens were observed in areas that had been logged extensively in the past. All of the ground dens observed in the Bote Mountain-Defeat Ridge area were located on Turkeypen Ridge and the northern portion of Bote Mountain, areas that had been logged. By comparison, no ground dens were located on Defeat Ridge; this area was high-graded for lumber at lower elevations, but virgin timber remains at high elevations. Although the sample size is small, all of the dens located on Sugarland Mountain were on the ground in rock outcrops. One den in this area located by Johnson (1978) was also in a rock outcrop.

Black bears appear to be familiar with available den sites within an area. During the winter of 1979, a yearling escaped from its den before it could be sedated. Tracks in the snow indicated that the yearling went straight to a tree den approximately 0.8 km away. Bears probably become familiar with den cavities while foraging in the trees for food. It is probable that bears use these den sites during the year for shelter or escape cover. A radio-collar removed by an adult male during the summer was found in a potential den cavity. Familiarity with potential dens would facilitate locating alternate sites during the winter if conditions in the initial den became unsuitable.

Three instances of den reuse were observed during the study. Johnson (1978) observed no reuse of dens and speculated that this was an indication of the abundance of suitable den sites within the study

area. All 3 instances of reuse were observed in areas that had been logged extensively and possibly reflect reduced availability of suitable den sites in these areas.

Effect of Mast Availability on Litter Size

Litter size determined from den work. Average litter sizes determined from den work for 1979 (mast failure during 1978) and 1980 (moderate mast yield during 1979) were 2.2 and 2.8, respectively. Although these samples are relatively small and the differences difficult to detect (since litter size normally ranges from 1 to 3), these data suggest that litters were smaller in 1979. Only 1 female was observed with 3 cubs in 1979, whereas litters of 3 were common in 1980. Information for 2 females that gave birth in 1978 (moderate mast yield in 1977) indicates that both had 3 cubs.

Reproduction was affected less than expected in 1979, considering the severity of the mast failure in 1978. Estimates of mast yield for this period were similar to those observed in 1972; no females were observed lactating in 1973, indicating that reproduction was severely curtailed. However, although little hard mast was available in 1978, wild grapes (Vitis spp.) were unusually abundant. Scats collected during this period consisted almost entirely of grape seeds and skins. Bears are highly opportunistic feeders and the ability to shift to alternate sources of food possibly cushioned the effect of the shortage of hard mast. However, nutritional differences exist between hard mast and the soft mast available during the fall. While soft mast is moderately high in protein, hard mast is high in

carbohydrates, and in some species, high in fat content (Eagle 1979). Hard mast is a concentrated, highly digestible energy food (Eagle 1979). Mast failures over several continuous years would probably have a substantial effect on reproduction. Jonkel and Cowan (1971) reported that reproduction declined significantly during a 3-year period when huckleberries (Vaccinium spp.), a major fall mast species in western Montana, were unavailable.

Litter size determined from family group observations.

Correlation analysis failed to detect any association between yearly estimates of hard mast yield (for the preceding fall) and family group observations reported by backpackers and NPS personnel. However, the consistency and reliability of such observations over the years may vary and bias the results. In addition, most of the observations of family units consist of panhandler females; observations of wild backcountry females with cubs are uncommon. Limited information is available concerning the differences in productivity between panhandler and wild backcountry females. Panhandler females weigh more (this study) and are able to obtain high quality food during the summer; this may tend to lessen the effect of mast availability during the fall.

Cub Vocalizations

Tape recording in winter dens is an effective method for determining the presence of cubs and estimating litter size. This method is especially useful in areas where a high percentage of females utilize tree dens (making sedation in the den impossible) or

when minimal disturbance is desired for females denning on the ground. A taping session of at least 1 hour is advised to ensure that vocalizations will be detected if cubs are present. Longer sessions sometimes improved estimates of litter size, especially if initial recordings were made during a lull when vocalizations consisted mainly of sporadic nursing and crying.

Estimates of litter size based on tape recordings of cub vocalizations were considered minimum estimates, since there was no way to verify if all the cubs actually present in the den had been accounted for. Estimates were based on combinations of vocalizations. Differences between 1 and 2 cubs nursing were readily distinguishable. However, it was difficult to differentiate between 2 and 3 or more cubs nursing. Estimates of 3 cubs were based on combinations of nursing and crying that enabled the sounds of a third cub to be isolated. In 2 cases, litter sizes estimated as at least 3 cubs based on cub vocalizations were verified the following winter by accurate counts of yearlings. Further refinements in taping and analysis may improve the accuracy of litter size estimates based on recordings of vocalizations.

Most cub vocalizations were centered between 0 and 2 KHz. However, differences between litters were observed. Fletcher (1953) reported that vocalization patterns change with age. Development of the cubs from birth to the time they leave the den may be significant enough to alter vocalizations considerably. Recordings of cub vocalizations taken at regular intervals from mid-February to late April for a female with cubs may show marked changes over time.

Cub Characteristics

Weight and development. Limited information is available on cubs in winter dens because of the relatively small number of litters examined. Differences in weight and development observed during a 10-day period (8 March through 17 March) indicated that birth dates varied between litters; however, no baseline information is available to determine the extent. Cubs in the litters observed in 1980 had their eyes open, while all of the cubs examined in 1979 had their eyes closed. Schoonmaker (1938) and Matson (1954) estimated that cubs open their eyes approximately 40 days after birth (using 1 February as the date of parturition). Butterworth (1969) reported that orphaned cubs began to open their eyes after 28 days. Eye color was a light blue for all of the cubs observed with their eyes open. This probably changes soon after den emergence since no cubs trapped during the summer exhibited blue eye color.

Sex ratio. A preponderance of male offspring was observed in litters of female black bears. No difficulty was encountered in determining the sex of the newborn cubs. Butterworth (1969) reported that external genitalia in the black bear become distinguishable at approximately 2 weeks of age. The sample used to determine sex ratio is relatively small (17 litters for panhandler and wild females combined) and more information is needed. Assuming that additional information supports current trends, the preponderance of male offspring may be related to a behavioral aspect of black bears. Rogers (1977) and Garshelis (1978) reported that female offspring

establish home ranges within the maternal female's home range. Male offspring disperse and establish home ranges in other areas. Mortality is probably higher for the sub-adult males. Females that produce a greater number of male offspring increase the chances that some will survive and become established within the population. Trivers and Willard (1973) suggested that in polygamous systems a female in good condition who produces a son has a higher probability of leaving more offspring than a female that produces a daughter. This would be especially true of black bears. While female black bears can produce 1 litter every 2 years, an established male can breed with several females every year. In addition, since female offspring establish home ranges within the mother's home range, it is possible that a female that produces many daughters would eventually end up competing with her own offspring for resources. Increased competition would possibly result in dispersal and higher mortality for female offspring.

Dentition. Rausch (1961) reported that black bears do not have a deciduous first premolar. The first premolar was considered to be the first permanent tooth to erupt, with eruption beginning late in the third month of life. However, information obtained from yearlings sedated in dens during late March and recaptured in mid-May indicates that the initial first premolar is deciduous with a permanent first premolar coming in between March and May of the second year. The first premolar is therefore one of the last deciduous teeth to erupt instead of the first permanent teeth to come in.

Pelage markings. Special interest was given to the cub with white paws and a chest blaze. Chest blazes have been observed before in the GSMNP and CNF, as well as in other areas of the country. However, the occurrence of white paws has not been previously reported. Even more interesting is the fact that the maternal female and the 2 litter mates were solid black. That one of the offspring was so strikingly different suggests that black bears may exhibit superfecundation (fertilization of eggs during estrus by different males). It is also possible that this simply represents a recessive heterozygous trait or a genetic aberration.

Cub Mortality

Jonkel and Cowan (1971) reported that limited mortality was experienced by bears between 0.5 and 1.5 years of age in northwestern Montana, probably due to maternal care and the precocial nature of the cubs after leaving winter dens. Mortality increased substantially after the offspring left the female, although the extent was difficult to determine since dispersal of the sub-adult males out of the study area could inflate this figure.

Limited information is available related to cub mortality within the GSMNP and CNF. The frequency of lactation observed in the GSMNP and CNF remained relatively constant throughout the summer, suggesting that losses of entire litters were uncommon. Only one incident was observed of a female giving birth in successive years. Although losses of entire litters appear to be uncommon, partial losses may occur. During 1979, one female was observed in the winter

den with only 1 yearling. Litter size determined for 14 females in winter dens with newborn cubs was never less than 2 cubs.

Average litter sizes for females with cubs and yearlings in dens were 2.5 and 2.0, respectively. The difference between these 2 groups indicates that some mortality does occur. Average litter size based on observations of panhandler family units showed no significant difference between females with cubs and yearlings, which suggests that cub survivorship is relatively high. To what extent this reflects the situation within the wild segment of the population is not known. Rogers (1976) speculated that females that feed at garbage dumps have higher cub survival. Observations of wild females with yearlings are uncommon, probably due to limited visibility in the backcountry, the increasing independence of the yearlings, and the short time that females and yearlings stay together. Comparisons of backcountry females with cubs and yearlings in winter dens offer the best means of estimating cub mortality within the wild segment of the population.

Breeding Activity

Breeding activity (based on swelling of the external genitalia) was observed throughout the summer, with the peak of breeding during the last week of June and the first 3 weeks of July. Scattered observations were made as early as the first week of June and as late as mid-September. Erickson and Nellor (1964), Jonkel and Cowan (1971) and Rogers (1977) observed most breeding activity between late June and mid-July. Rausch (1961) felt that the occurrence of estrus for the black bear did not differ significantly between regions.

Limited information is available related to estrus in black bears. Female black bears are thought to be seasonally monoestrous (Erickson and Nellor 1964), with ovulation induced by coital stimulation (Wimsatt 1963, Erickson and Nellor 1964). Nalbandov (1976) stated that estrogen levels tend to drop after ovulation, causing estrous activity to decline. The length of estrus would therefore depend on how soon a female was bred after becoming receptive. Rogers (1977) reported that home ranges of adult male black bears in Minnesota included territories of 7 to 15 females. In addition, home ranges were not defended as territories and overlapped to the extent that no male had exclusive access to any female. Since males within an area are most likely aware of estrus within the female segment of the population, the duration of estrus is probably short. Erickson and Nellor (1964) reported that corpora lutea were observed for the first time on 20 July in reproductive tracts taken from female black bears in Michigan. Reproductive tracts of most adult females examined after this date exhibited functional corpora lutea, indicating that estrus occurred within a short period of time. A captive female black bear in Michigan exhibited extensive breeding activity over a 2-day period, followed by a short post-breeding estrus. Craighead et al. (1969) reported that estrus terminated abruptly in grizzly bears (Ursus arctos), probably due to ovulation. Twenty (44%) of the mature, non-lactating females trapped during the peak of breeding activity in the GSMNP and CNF showed no signs of estrus, suggesting that the estrous period is relatively short. However, Ammons (1974) reported that estrus for captive black bears in North Carolina ranged from 6 to

16 days, with an average estrous period of 9.75 days. (Estrus was designated as the period between the first and last observation of copulation.)

Craighead et al. (1969) observed what appeared to be 2 estrous cycles during the same breeding season for grizzly bears. Intensive breeding activity was followed by a quiescent period, ranging from 4 to 18 days, when the females were unreceptive and the males were not attracted to the females. This was followed by another period of breeding activity. Dittrich and Kronberger (1962) cited by Craighead et al. (1969) reported a similar pattern for captive brown bears. Ammons (pers. comm.) indicated that periods of inactivity were observed between the first and last observation of breeding for captive black bears, which suggests that black bears may exhibit 2 estrous periods. Jonkel and Cowan (1971) did not observe any indication of black bears coming into estrus more than once a year. During the present study, prominent signs of estrus were observed for a sub-adult female trapped in late June and recaptured in August. That this female exhibited prominent sign on 2 separate occasions may indicate that black bears exhibit more than 1 estrous period during a year. However, since this female was a sub-adult, other factors may be involved. Ammons (pers. comm.) reported that a captive sub-adult female exhibited frequent breeding behavior over an extended period of time. Nishikawa (1959) cited by Tyler (1972) stated that a long, so-called continuous estrus is relatively common during the first estrous period of young mares (Equus spp.). During this study, 4 of the 6 females observed in estrus during August and September were 2 years of age. Pearson

(1944) found that ovulation in the short-tailed shrew (Blarina brevicauda) was not induced unless the female was bred approximately 20 times within a period of a few days. It is possible that sub-adult female bears need a greater amount of coital stimulation to induce ovulation, which is why females in this age class are sometimes observed in estrus late in the summer. Erickson and Nellor (1964) found that testicular activity in black bear males did not start to decline until mid-September in Michigan. Assuming this pattern is the same for bears in the southeast, successful breeding of estrous females could occur late in the summer.

Breeding data from 1973-79 (Fig. 7, page 43) produced a bimodal distribution of females in estrus, with an initial peak during the last week of June and the first week of July, and a second peak during the third week of July. Whether this represents the occurrence of 2 estrous periods, sampling error from year to year, or yearly changes in when estrus occurs is not known. Jonkel and Cowan (1971) reported that the occurrence of estrus varied from year to year in northwestern Montana. Craighead et al. (1969) observed similar shifts for grizzly bears. However, severe weather conditions in western Montana during late spring and early summer could affect breeding more drastically than conditions in eastern Tennessee.

Determination of Estrus

Swelling of the external genitalia. Determination of breeding condition for the Ursidae has usually been based on swelling of the external genitalia. Observations of breeding behavior are

occasionally made, but under most field conditions this type of information is not readily available. However, problems exist in attempting to determine estrus based solely on external characteristics. Vulval swelling in the Ursidae is not as distinct as the external signs exhibited by some mammals. Subjectivity and the varied experiences of the researcher can produce significant differences in what external conditions are reported as signs of estrus. In addition, swelling of the genitalia is probably most pronounced during the peak of estrus and less distinct prior to and after this stage. One female trapped in a snare during the present study was observed with a large male. External signs of estrus were extremely pronounced. On other occasions, swelling of the genitalia was much less obvious. Once ovulation occurs, signs of estrus are difficult to detect. Since the duration of estrus is probably short, the chances of observing prominent signs of estrus are reduced.

Electrical resistance and pH of the vaginal tract. Vaginal pH and electrical resistance of the vaginal tract were taken to determine if physiological changes could be used to verify estrous conditions. Quantitative information could supplement observations of vulval swelling. Nalbandov (1976) stated that vaginal pH is alkaline during diestrus and becomes more acidic during estrus due to changes in estrogen levels. The electrical resistance of the vaginal tract has been shown to change with the onset of estrus in some domestic livestock. Gartland et al. (1975) and Foote et al. (1979) found that electrical resistance declined rapidly prior to estrus in dairy cows. Murphree (pers. comm.) reported similar results for domestic pigs.

However, Gartland et al. (1975) showed that differences in resistance between mid-cycle and estrus were only 20% for dairy cows. This small difference coupled with individual variation limited the usefulness of the technique for predicting the condition of individual females from single readings. Similar results were obtained for vaginal pH and electrical resistance recorded for black bears during this study. Readings for estrous and anestrus females showed substantial overlap and no significant differences were observed.

Vaginal smears. Vaginal smears were taken from female black bears to determine if changes in vaginal epithelium can be used to detect the onset or verify the occurrence of estrus. Changes in vaginal epithelium occur during the estrous cycle of all mammals and reflect different stages of the cycle (Nalbandov 1976). In most mammals, as the female approaches estrus, increased levels of estrogen causes rapid growth and cornification of vaginal epithelium. High concentrations of cornified cells indicate an estrous condition (Nalbandov 1976). When estrogen levels drop after ovulation, cornified cells become less abundant and leucocytes predominate (Nalbandov 1976). The vaginal smear technique reflects ovarian changes most accurately in species with short estrous cycles. In species with longer cycles, vaginal changes lag from 1 to several days behind ovarian changes (Nalbandov 1976).

Vaginal smears were an effective means of verifying estrus for female black bears with prominent signs of estrus. The lack of cornified cells for some of the females displaying distinct signs of estrus was attributed to the inexperience of some of the researchers

in taking smears rather than a lack of epithelial changes. In addition, cornified cells were detected in 3 females where vulval swelling was not evident. Cornified cells were not observed in females exhibiting only slight vulval swelling; the absence of cornified cells suggests that epithelial changes lag behind ovarian changes for only a short period of time.

Lactation

The majority of lactating females were observed within the mid-age class. However, in relation to the number trapped, a higher percentage of old-age females were lactating than mid-age females. It is possible that old-age females are in better overall condition and well established within an area, and therefore can maintain a higher level of breeding than younger individuals. Kordek and Lindzey (1980) reported that the potential recruitment from females bred for the first time was significantly less than from later breedings. The high breeding levels of old-age females and the smaller litter sizes of females giving birth for the first time suggests that older aged females contribute significantly to the productivity of the population. Management within an area should attempt to minimize losses from this segment of the population. Female black bears return to denning areas and restrict activities earlier in the fall than males (Johnson 1979). Later hunting seasons would reduce the number of females harvested. Rieffenberger (1976), Collins (1978) and Raybourne (1978) reported that later fall hunting seasons reduced the percentage of female black bears harvested in West Virginia, North Carolina, and Virginia, respectively. The establishment of bear reserves within areas open to

hunting would protect the female segment of the population and create centers of productivity. The establishment of reserves would be particularly beneficial in areas with heavy hunting pressure.

Only 23% of the adult females trapped from 1973-79 were lactating. It is possible that the small number of lactating females trapped is due to the fact that these animals are traveling less because of the cubs and are less likely to come into contact with the traplines.

Occasionally researchers have been unable to detect lactation for females known to be nursing cubs. Nalbandov (1976) reported that stress or anesthesia can sometimes inhibit milk let-down. When oxytocin was injected into a female under deep anesthesia, milk ejection resumed (Nalbandov 1976). Oxytocin was used during the summer of 1979, and researchers were able to induce milk let-down for all females known to be lactating. The half-life in the blood system is 1 to 3 minutes; this minimizes any adverse effects that might occur (Goodman and Gilman 1975).

Minimum Reproductive Age

There is evidence that female black bears have the potential to breed at 2 years of age and give birth at age 3. Most of these observations have been made for captive females (Stickley 1961, Ammons 1974). However, some have been observed in the wild. Collins (1974) found placental scars on the reproductive tract of a 3-year-old female killed in North Carolina, indicating successful breeding at 2 years of age. Collins also reported that 11 of 17 reproductive tracts

from 2-year-old females killed in Tennessee, North Carolina and Georgia had corpora lutea, indicating substantial breeding activity within this age class. However, reproductive tracts for 16 of 19 3-year-old females had corpora lutea (Tri-State Bear Project, unpublished report). The high incidence of 3-year-old females with corpora lutea suggest that few of the females that breed at 2 years of age give birth at 3 years. Raybourne (1976) observed a 2-year-old female in estrus and 1 3-year-old female lactating, but reported that normal breeding age in Virginia appeared to be well established at 3 years of age. Jonkel and Cowan (1971) reported estrus in female black bears as early as 4 years of age, with 6 years the earliest age a female was observed with cubs. Thirty-eight percent of the female black bears in Pennsylvania breed at 2 years of age (Kordek and Lindzey 1980), with 3-year-old females commonly giving birth (Alt pers. comm.).

Signs of estrus were observed for 2-year-old females during this study. However, the percentage of females that gave birth at 3 years of age was low. Information from trapping data and winter den work indicates that minimum reproductive age (defined as the first year that a female gives birth) for female black bears in the GSMNP and CNF is 4 to 5 years, with most giving birth at 5 years of age. Minimum breeding age has limited value in determining the reproductive rate for black bears. The occurrence of sub-adult females breeding without giving birth suggests that minimum reproductive age is in fact more reflective of sexual maturity than the age at which breeding is first observed.

Reproductive Cycle

Female black bears have the potential to breed and give birth every 2 years. Although most females in the GSMNP and CNF exhibited this pattern, a substantial number skipped a year between reproductive cycles at some time during their life. Most skips between cycles followed years with low mast production. Only 1 female exhibited a skip in the cycle following a year with good mast production. However, this female also skipped the previous year, following a fall of extremely poor mast production and possibly was in such poor condition that the next year was also skipped.

Breaks in the reproductive pattern are probably caused by a combination of poor mast production and the condition of the female. Females give birth in relatively good condition, but lactation creates a substantial drain on the female's resources. Females with cubs enter dens at weights that are significantly less than pregnant females. After emergence from the den the second winter, the family unit breaks up and the female can again come into estrus and breed. During the summer and fall, body reserves are replenished. Most weight gain occurs during the fall in the form of fat, as a result of foraging on high quality hard mast. A mast failure during the fall probably prevents the female from attaining a body weight necessary to support a litter the following year. Although breeding, ovulation, and conception occur during the summer, implantation occurs during the fall (Wimsatt 1963). The nutritional state of the female during the fall may influence whether the blastocysts implant. Rogers (1976) found a significant relationship between fall weights and reproductive

success for black bears in Minnesota. Females weighing less than 67 kg were observed without cubs. Females greater than 80 kg produced cubs, and females between 67 kg and 80 kg had varied reproductive success. Rogers (1976) also reported that during a 3-year period of food scarcity, females exhibited intervals of as long as 4 years between litters.

Most of the skips between reproductive cycles occurred during mid-age (5 to 9 years of age), while only 3 old-age (10 years or older) females exhibited skips. It is possible that older females are in good condition with suitable reserves, well established within an area and therefore less susceptible to adverse changes in food availability. Younger individuals may be less able to take these changes in stride. For similar reasons, mast failures during the fall probably influence minimum reproductive age, although evidence to support this contention is not available. It is interesting to note that the 2 incidents of 3-year-old females giving birth occurred after falls with good mast production. Rogers (1976) reported that during a 3-year period of food scarcity, females less than 8 years of age did not produce litters.

Reproductive Synchrony

Age data obtained from black bears harvested in New York suggest that reproduction is synchronized in the female segment of the population (Free and McCaffrey 1970). A consistent pattern of high production followed low production during successive years was observed. Synchrony of reproduction during alternate years will be established if first successful mating occurs at an odd numbered year

of age (i.e., 3 or 5 years of age) and subsequent breeding occurs during alternate years (Free and McCaffrey 1970). Information from the GSMNP and CNF suggests that the female segment of the population is not exhibiting reproductive synchrony. Substantial differences were not observed in the number of lactating females trapped from year to year, nor does age data from the animals trapped exhibit a distinctive pattern of high and low production during alternate years. Female black bears within the GSMNP and CNF do not consistently satisfy the basic requirement for reproductive synchrony. A substantial number of females give birth initially at 5 years of age (first successful breeding at age 4). A high percentage of females occasionally exhibit skips in the reproductive cycle. Skips in the reproductive cycle would further break up any pattern of reproductive synchrony that might develop. In 1973, no lactating females were trapped in the study area, probably due to the severe mast failure that occurred during the fall of 1972. It is possible that reproduction would temporarily be synchronized immediately following such an event, but would eventually return to an unsynchronized pattern.

Weight

Logistic growth curves. Growth curves (based on Brody's model) were used to estimate weight-age relationships for 4 categories of black bears examined during the present study. Growth curves have effectively described weight-age relationships for many mammalian species (Brody 1964). Inspection of the differences between growth

curve estimates and mean weights indicates that Brody's model fits the weight-age relationship for black bears extremely well.

Growth curves provide an effective means of comparing growth and weight differences between categories and ages within categories. In addition, it is suggested that growth curves provide estimates that are possibly more reflective of weight-age parameters than mean weight values. Growth curves have the added advantage of weighting information so that extreme variation and small sample sizes are not overly influential. Mean weights compared well with growth curve estimates when sample sizes were relatively large, but were less comparable when sample sizes were small. Weights observed within age classes varied considerably. This variation may be due to several factors: seasonal changes in weight, the reproductive condition of the female, and individual differences. Seasonal differences in weight probably reflect the availability of high quality sources of food during different times of the year. Grasses and herbaceous material make up most of the bears' diet during the early spring (Eagle 1979). Jonkel and Cowan (1971) and Rogers (1976) reported that black bears lose weight or gain slowly during spring and early summer. Weights probably increase as various types of soft and hard mast become available during the summer and fall. Weights differ significantly for adult females in relation to reproductive condition.

Relationship between wild and panhandler bears. Panhandler females reached mature weight levels earlier and weighed more overall than backcountry females. Panhandler females have access to high quality sources of food during the summer in the form of garbage and

handouts from park visitors. This additional source of nutrition probably accounts for the higher weights observed. Captive black bears receive nutritional rich diets and as a result develop more rapidly, weigh more and reach sexual maturity earlier than their wild counterparts (Rogers 1976).

Growth in female black bears with respect to weight is characterized by an initial phase of rapid growth, followed by a distinct leveling off. Brody (1964) stated that the inflection point of the growth curve (the point where the slope stops increasing but has not started to decrease) approximates the onset of puberty. The inflection point for panhandler and wild females occurs between 2 and 3 years of age. Two-year-old females have been observed in estrus within the GSMNP and CNF. Hafez (1968) reported that sexual maturity usually occurs as mature weight levels are approached and developmental growth declines. Weights for panhandler and wild females began to level off around 4 to 5 years, the age when the majority of females in the GSMNP and CNF gave birth for the first time. Sufficient information is not available from this study to compare minimum reproductive age for panhandler and wild females. Panhandler females reach mature weights earlier than wild females which would indicate that panhandler females become sexually mature at a younger age. Sadleir (1969) concluded that most of the differences in wild animals attaining puberty was attributable to differences in growth rate. Beecham (1980) suggested that poorer habitat quality was responsible for slower growth rates for female black bears, causing them to reach sexual maturity later than females in areas with higher quality.

Beecham (1980) believed that the leveling off of weights was associated with puberty and represented the average age at which females become reproductively active. However, breeding activity by sub-adult females suggests that the leveling off of weight is more reflective of the age of first successful breeding. Sadleir (1969) correlated the attainment of a particular minimum body size to successful breeding. It is possible that some sub-adults may be sexually mature, but are unable to reproduce because of body size or condition.

Panhandler males weighed substantially more than their wild counterparts. Weight differences were less within the older age classes, where panhandler weights began to level off while weights of wild males continued to increase. It is possible that panhandler males are beginning to exhibit limits on fat accumulation and given time, wild males would encounter similar limitations.

Relationship between males and females. Male black bears weighed substantially more than females. Similar relationships have been observed in other areas (Jonkel and Cowan 1971, Rogers 1977, Beecham 1980). Weights for males did not level off as observed for female black bears. This continual increase in weight is attributed to accumulation of fat by the males. Although developmental growth stops at some point, it is difficult to detect. A more realistic estimate of condition and actual growth would be obtained if some estimate of fat accumulation was utilized.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. Female black bears entered dens during the first 3 weeks of December and emerged between the first and last week of April. The denning period lasted an average of 114 days. No relationship was observed between den entry and weather conditions or mast availability. Den emergence was strongly correlated with increasing precipitation and low minimum temperatures, indicating that adverse weather may influence emergence if bears are physiologically ready to leave the dens.

2. Females with cubs denned significantly longer and emerged significantly later than females without offspring, possibly due to the altricial nature of the newborn cubs. A predictive model, using the date that females emerged from dens, was effective in predicting reproductive condition. The model could maximize the amount of information obtained from denning observations by providing an estimate of reproductive condition based solely on den emergence.

3. Isolated cases were observed of adult females leaving initial den sites and denning in different areas. This activity was associated with periods of heavy rainfall and suggests that winter dormancy in black bears is flexible enough to allow the animals to respond to adverse or changing environmental conditions. This ability to respond was further demonstrated by the activity of some females when sedated in dens.

4. Female black bears exhibited a significant preference for tree dens. Utilization of tree dens was substantial even in areas that had been logged extensively, where tree dens were less abundant. Ground dens were located in areas that had been logged extensively. Tree dens provide added seclusion, which is probably a decided advantage to black bears, particularly in areas with greater accessibility and human activity. Timber management that specifies that some large cull trees be left in areas that are logged would be beneficial to black bears.

5. Scattered incidents of den reuse were observed in areas that had been logged extensively, possibly reflecting reduced availability of suitable den sites.

6. Most breeding activity was observed during the last week of June and first 3 weeks of July; however, females were reported in estrus as early as 5 June and as late as 12 September. Most of the females observed in estrus late in the summer were sub-adults. One 2-year-old female was observed in estrus on 25 June and 31 August 1978; this suggests that this age class may exhibit prolonged or reoccurring estrus.

7. Vaginal smears were an effective means for verifying estrus in black bears. In several cases, an estrous condition was detected based on epithelial characteristics of the vagina even though external signs of estrus were not pronounced. The use of vaginal smears does not substantially prolong the time that estrus can be detected, since cornified cells do not appear to persist in the vaginal tracts long after ovulation.

8. Relatively little information is available related to the breeding biology of black bears. Field studies can determine the general peak of breeding, but little additional information unless females are observed on a regular basis. Extensive observations and controlled experiments with captive female could answer many questions related to breeding in black bears.

9. Minimum reproductive age (the age a female first gives birth) for female black bears in the GSMNP and CNF was 4 to 5 years, with most giving birth at 5 years of age. Minimum reproductive age in this area is comparable to black bears in Michigan (Erickson and Nellor 1964), somewhat earlier than bears in Minnesota (Rogers 1977) and Montana (Jonkel and Cowan 1971) and slightly later than bears in Pennsylvania (Kordek and Lindzey 1980). The difference in minimum reproductive age between these ages suggests that changes in latitude have limited, if any, effect on age of maturity. Nutritional conditions probably play a greater role in determining when females first give birth.

10. It is suggested that minimum reproductive age for black bears is more reflective of sexual maturity than the age at which breeding is first observed, since sub-adult females observed in estrus were frequently without offspring the following winter.

11. Female black bears have the potential to give birth every 2 years and most females exhibited this pattern. However, a substantial number of adult females exhibited skips between reproductive cycles following years of poor hard mast availability. Most of the skips occurred during mid-age (5-9 years), suggesting that older animals may

be in better condition and less susceptible to adverse change in food availability.

12. Litter size determined from den work for the 2 years of the study was 2.5 cubs, with litter sizes of 2.2 and 2.7 during 1979 and 1980, respectively. The poor mast yield during the fall of 1978 may have attributed to the smaller litters observed in 1979. Considering the severity of the mast failure in 1978, litter size was not affected as much as had been expected. The unusual abundance of alternate food sources that fall may have lessened the effect. It is suggested that successive years of hard mast failure would affect reproduction more dramatically.

13. Tape recording in tree dens is an effective method of determining the presence of cubs and estimating litter size. This method is especially useful in areas where a high percentage of females utilize tree dens or when minimal disturbance is desired for females denning on the ground. Taping sessions should be a minimum of 1 hour in length. Further refinements in taping and analysis may improve the accuracy of litter size estimates.

14. A preponderance of male offspring was observed in litters, possibly an adaptive response to greater mortality of male offspring during dispersal after the family unit breaks up. Losses of entire litters during the first year appear to be uncommon, although evidence of partial mortality within litters was observed.

15. Older aged females appear to have added importance to the population in terms of productivity and should be protected in areas with heavy hunting pressure. Hunting seasons scheduled late in the fall, when females are less active or have started to den, would

minimize the number of females harvested. Bear reserves or areas with limited access established within areas open to hunting would assist in protecting the female segment of the population and create centers of productivity.

16. Additional research on reproduction in black bears is needed within the GSMNP and CNF, especially in reference to cub mortality and the effect of environmental factors, such as mast availability, on minimum reproductive age, litter size and the reproductive cycle.

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APPENDIXES

APPENDIX A

SYSTEM FOR CLIMBING TREE DENS

The inaccessibility of tree dens, in terms of height of the den entrance, necessitated the development of a system for climbing to the cavity entrance to collect reproductive information. During the winter of 1979, aluminum ladders (that could be joined together) were used to climb den trees. However, the distance of most den sites from roads or established trails made this method difficult and time-consuming.

A system was developed during the winter of 1980 based on mountain climbing techniques. An arrow, with a light-weight nylon line attached, was shot over a sturdy limb located above or near the cavity entrance. The nylon line was attached to the end of a mountaineering rope and pulled back over the limb. Once the climbing rope was in place and secured to a stationary object, clog ascenders were used to climb to the cavity entrance (May 1973).

APPENDIX B

Table 18. Den entry and emergence dates, den type and reproductive condition of female black bears in the Great Smoky Mountains National Park and the Cherokee National Forest, 1978-80.

Bear No.	Age	Den Entry	Den Emergence	Den Type	Reproductive Condition	Area
A44	12	2 Dec 78- 4 Dec 78	-	Ground den, cavity under fallen timber.	With newborn cubs	Bote Mt. GSMNP
A45	10	2 Dec 78- 5 Dec 78 5 Jan 79- 9 Jan 79	29 Dec 78- 3 Jan 79 -	Tree den. Redenned in ground den.	With yearlings	Bote Mt. GSMNP
B10	8	1 Dec 78- 7 Dec 78	11 Apr 79- 14 Apr 79	Ground den, under up-turned stump. Abandoned den after winter sedation, redenned in tree den approx. 0.9 km from original den site.	With yearlings	Tremont area GSMNP
E7	8	17 Nov 78- 21 Nov 78	29 Apr 79- 1 May 79	Tree den.	With yearlings	Parsons Branch GSMNP
H1	14	13 Dec 78- 17 Dec 78 9 Jan 79- 12 Jan 79	5 Jan 79- 9 Jan 79 10 Apr 79- 20 Apr 79	Tree den. Redenned approx. 0.5 km from initial denning area.	With yearlings	Defeat Ridge GSMNP
305	7	7 Dec 78- 9 Dec 78	18 Apr 79- 21 Apr 79	Tree den.	With yearlings	Citico Area CNF
306	4	13 Dec 78- 14 Dec 78	21 Apr 79- 1 May 79	Tree den.	Without offspring	Citico Area CNF
307	3	13 Dec 78- 14 Dec 78	12 Apr 79- 17 Apr 79	Tree den.	Without offspring	Citico Area CNF

Table 18 (Continued)

Bear No.	Age	Den Entry	Den Emergence	Den Type	Reproductive Condition	Area
308	4	10 Dec 78- 12 Dec 78	-	Ground den, cavity under root system of fallen tree.	With yearlings	Citico Area CNF
316	3	12 Dec 78- 13 Dec 78	13 Apr 79- 18 Apr 79	Tree den.	Without offspring	Citico Area CNF
320	8	22 Nov 78- 7 Dec 78	3 May 79- 8 May 79	Tree den.	With newborn cubs	Citico Area CNF
321	4	30 Dec 78- 4 Jan 79	26 Mar 79- 31 Mar 79	Tree den.	Without offspring	Parsons Branch GSMNP
403	4	27 Nov 78- 2 Dec 78	31 Mar 79- 3 Apr 79	Tree den.	Without offspring	Parsons Branch GSMNP
414	4	13 Dec 78- 15 Dec 78	29 Apr 79- 5 May 79	Tree den.	With newborn cubs	Parsons Branch GSMNP
454	10	13 Dec 78- 17 Dec 78	30 Mar 79- 7 Apr 79	Tree den.	Without offspring	Defeat Ridge GSMNP
455	-	After 12 Dec 78	15 Apr 79- 20 Apr 79	Tree den.	Not determined	Tremont Area GSMNP
459	2	-	10 Apr 79- 20 Apr 79	Tree den.	Without offspring	Defeat Ridge GSMNP
473	4	After 12 Dec 78	17 Apr 79-	Tree den.	Not determined	Defeat Ridge GSMNP
476	6	Before 17 Dec 78	Before 30 Mar 79	Ground den, cavity under root system of fallen tree.	With newborn cubs	Bote Mt. GSMNP
F5	10	Before 5 Dec 78	-	Ground den, cavity in rock outcrop. Abandoned den after winter sedation, redenned with cubs in den in rock crevice approx. 40 m from original den site.	With newborn cubs	Sugarland Mt. GSMNP

Table 18 (Continued)

Bear No.	Age	Den Entry	Den Emergence	Den Type	Reproductive Condition	Area
F21	5	-	14 Apr 80- 18 Apr 80	Ground den, cavity in rock outcrop.	With newborn cubs	Sugarland Mt. GSMNP
H1	15	12 Dec 79- 15 Dec 79	11 Apr 80- 21 Apr 80	Tree den. Den site located 15 Dec. Aerial location on 18 Dec indicated female out of den. Female in initial den site when located in Jan.	With newborn cubs	Defeat Ridge GSMNP
306	5	-	20 Apr 80- 21 Apr 80	Tree den.	With newborn cubs	Citico Area CNF
316	4	-	20 Apr 80- 21 Apr 80	Tree den.	With newborn cubs	Citico Area CNF
320	9	21 Jan 80- 23 Jan 80	11 Apr 80- 15 Apr 80	Tree den.	With yearlings	Citico Area CNF
321	5	11 Dec 79- 20 Dec 79	4 Jan 80- 8 Jan 80	Tree den, redenned approx. 2.2 km from initial denning area.	With newborn cubs	Parsons Branch GSMNP
		After 8 Jan 80	25 Apr 80- 30 Apr 80			
343	3	-	21 Apr 80- 22 Apr 80	Tree den.	With newborn cubs	Citico Area CNF
403	5	30 Nov 79- 2 Dec 79	25 Apr 80- 30 Apr 80	Tree den.	With newborn cubs	Parsons Branch GSMNP
414	5	2 Dec 79- 7 Dec 79	25 Jan 80- 28 Jan 80	Tree den, redenned approx. 1.9 km from initial denning area.	With yearlings	Parsons Branch GSMNP
		25 Jan 80- 28 Jan 80	Before 19 Mar 80			
423	3	-	-	Had not denned as of 20 Feb 1980.	Without offspring	Parsons Branch GSMNP

Table 18 (Continued)

Bear No.	Age	Den Entry	Den Emergence	Den Type	Reproductive Condition	Area
426	3	After 12 Dec 79	9 Apr 80- 16 Apr 80	Tree den.	Without offspring	Parsons Branch GSMNP
427	4	After 9 Dec 79	Before 9 Apr 80	Tree den.	Without offspring	Parsons Branch GSMNP
454	11	14 Dec 79- 15 Dec 79	2 Apr 80- 9 Apr 80	Tree den.	Without offspring	Defeat Ridge GSMNP
459	3	After 27 Dec 79	Before 2 Apr 80	Tree den.	Without offspring	Defeat Ridge GSMNP
463	13	Before 14 Dec 79	-	Tree den.	With 2 yearlings	Defeat Ridge GSMNP
471	4	27 Dec 79- 3 Jan 80	Before 2 Apr 80	Tree den.	Without offspring	Bote Mt. GSMNP
476	7	5 Dec 79- 10 Dec 79	9 Apr 80- 16 Apr 80	Ground den, cavity under fallen timber.	With 3 newborn cubs	Bote Mt. GSMNP
486	4	27 Dec 79- 9 Jan 80	2 Apr 80- 7 Apr 80	Tree den.	Without offspring	Defeat Ridge GSMNP
483	3	-	11 Apr 80- 21 Apr 80	Tree den.	Without offspring	Bote Mt. GSMNP
487	15	-	18 Apr 80- 21 Apr 80	Tree den.	With newborn cubs	Tremont Area GSMNP
498	3	Before 4 Dec 79	9 Apr 80- 11 Apr 80	Tree den.	Without offspring	Bote Mt. GSMNP

APPENDIX C

Table 19. Natality data 1972-June 1980, Great Smoky Mountains National Park and the Cherokee National Forest.

	Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
112	21 June 80	408	182	X	Parsons Br.	9	115	Lactating, with 3 cubs	X
	21 Jun 80	403	243	X	Parsons Br.	5	110	Lactating	X
	16 Jun 80	321	201	X	Parsons Br.	5	100	Lactating	X
	7 Jun 80	614	205	X	Highway 441	10	90	Lactating, with 2 cubs	
	11 May 80	577	297	X	Smokemont	13	175	4 yearlings observed	X
	2 Apr 80	343	638	+	Citico	3		With at least 2 cubs recorded in den	X
	Mar 80	483		+	Bote Mt.	2		No cubs or yearlings detected in den	X
	26 Mar 80	306	625	+	Citico	5		With at least 3 cubs recorded in den	X
	25 Mar 80	454	250	+	Defeat Ridge	11		No cubs or yearlings detected in den	X
	25 Mar 80	459	242	+	Defeat Ridge	4		No cubs or yearlings detected in den	X
	23 Mar 80	577/576	297	X	Smokemont	13		With 4 yearlings in den	X
	22 Mar 80	H1	100	+	Defeat Ridge	15		With at least 3 cubs recorded in den	X
	19 Mar 80	321	201	+	Parsons Br.	5		With at least 2 cubs recorded in den	X
	18 Mar 80	487	111	+	Tremont	15		With at least 3 cubs recorded in den	X
	14 Mar 80	316	631	+	Citico	4		With at least 3 cubs recorded in den	X

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
14 Mar 80	320	619	+	Citico	9		With at least 1 yearling in den	X
11 Mar 80	498	304	+	Bote Mt.	3		No cubs or yearlings detected in den	X
10 Mar 80	F21	180	X	Sugarland Mt.	6		With 3 cubs in den	X
8 Mar 80	476	266	X	Bote Mt.	7	190	With 3 cubs in den	X
7 Mar 80	471	265	+	Bote Mt.	4		No cubs or yearlings detected in den	X
6 Mar 80	463	040	X	Bote Mt.	13		With 2 yearlings in den	X
3 Mar 80	486	288	+	Defeat Ridge	4		No cubs or yearlings detected in den	X
29 Feb 80	403	243	+	Parsons Br.	5		With at least 2 cubs recorded in den	X
22 Feb 80	423	303	+	Parsons Br.	3		Had not denned as of 22 Feb indicating no offspring	X
22 Oct 79	590	321		Gatlinburg	6	122	With 2 cubs, not lactating	
22 Oct 79	-	322		Gatlinburg	cub	17	Cub of female #590	
22 Oct 79	-	323		Gatlinburg	cub	15	Cub of female #590	
12 Sep 79	471	265	X	Bote Mt.	3	75		X
11 Sep 79	463	040	X	Bote Mt.	12	-	Lactating	X
4 Sep 79	576	297	X	Smokemont	12	205	Lactating, with 4 cubs	X
23 Aug 79	471/470	265	X	Bote Mt.	3	80		
14 Aug 79	427	312		Parsons Br.	3	70		X
13 Aug 79	426	310		Parsons Br.	2	70		X
10 Aug 79	424	309		Parsons Br.	7	95	Lactating	X
8 Aug 79	549	290	X	Chimneys P.G.	12	-		
2 Aug 79	498	304	X	Bote Mt.	2	75		X
31 Jul 79	620	308		Smokemont	12	170		
31 Jul 79	609	186	X	Highway 441	4	140	With 2 cubs	

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
27 Jul 79	498	304	X	Bote Mt.	2	75		X
26 Jul 79	498	304		Bote Mt.	2	-		
22 Jul 79	423	303		Parsons Br.	2	50		X
20 Jul 79	321	201	X	Parsons Br.	4	105	In estrus, vulva swollen	X
18 Jul 79	338	639		Citico	3	90	Vulva slightly swollen	X
18 Jul 79	F21	180	X	Sugarland Mt.	5	85	In estrus, vulva swollen	X
13 Jul 79	494	299		Sugarland Mt.	6	65	Vulva slightly swollen	X
13 Jul 79	305	624	X	Citico	7	110		X
12 Jul 79	458	-	X	Sugarland Mt.	2	55		
12 Jul 79	343	638		Citico	2	80	In estrus, vulva swollen	X
7 Jul 79	307	626	X	Citico	3	90	In estrus, vulva swollen	X
30 Jun 79	614/P8	205	X	Highway 441	9	140		
30 Jun 79	616	298		Rocky Hollow	3	70		
27 Jun 79	576	297		Smokemont	12	-	Lactating, with 4 cubs	
26 Jun 79	575/453	240	X	Smokemont	6	160	Lactating, with 2 cubs	
22 Jun 79	321	201	X	Parsons Br.	4	112		X
15 Jun 79	336	634		Citico	3	100		X
11 Jun 79	549	290		Chimneys P.G.	12	150	With 3 yearlings	X
11 Jun 79	306	625	X	Citico	4	90		X
8 Jun 79	316	631	X	Citico	3	90		
7 Jun 79	326			Citico	1	30		
6 Jun 79	403	243		Parsons Br.	4	95	Vulva slightly swollen	X
6 Jun 79	487/63	111	X	Bote Mt.	14	110		X
5 Jun 79	486	288		Bote Mt.	3	75	Vulva slightly swollen	X
4 Jun 79	609/P3	186	X	Highway 441	4	150	With 3 cubs	
4 Jun 79	-	287		Highway 441	cub	13	Cub of female #609	
28 May 79	606	203	X	Highway 441	8	120		
31 Mar 79	414	269	+	Parsons Br.	4		With at least 2 cubs recorded in den	X

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
31 Mar 79	403	243	+	Parsons Br.	4		No cubs or yearlings detected in den	X
31 Mar 79	321	201	+	Parsons Br.	4		Early den emergence indicating no offspring	X
Mar 79	454	250	+	Defeat Ridge	10		No cubs or yearlings detected in den	X
Mar 79	459	242	+	Defeat Ridge	3		No cubs or yearlings detected in den	X
Mar 79	E7	060	+	Parsons Br.	8		With at least 2 yearlings observed in den	X
17 Mar 79	476	266	X	Bote Mt.	6	120	With 2 cubs in den	X
16 Mar 79	316	631	+	Citico	3		No cubs or yearlings detected in den	X
15 Mar 79	320	619	+	Citico	8		With at least 2 cubs recorded in den	X
15 Mar 79	305	624	+	Citico	7		With 2 yearlings observed in den	X
14 Mar 79	306	625	+	Citico	4		No cubs or yearlings detected in den	X
14 Mar 79	307	626	+	Citico	3		No cubs or yearlings detected in den	X
10 Mar 79	F5	097	X	Sugarland Mt.	10		With 2 cubs in den	X
3 Mar 79	308	628	X	Citico	4	90	With 2 yearlings in den	X
19 Feb 79	480	039	X	Bote Mt.	12	155	With 3 cubs in den	X
13 Feb 79	485/B10	187	X	Tremont	8	93	With 1 yearling in den	X
31 Jan 79	A45	092	X	Bote Mt.	10	95	With 3 yearlings in den	X
23 Oct 78	P6	203	X	Highway 441	7	220		X
28 Sep 78	320	619	X	Citico	7	182		X
10 Sep 78	482	272		Bote Mt.	3	105		

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
9 Sep 78	481/A3	069	X	Bote Mt.	8	130		
7 Sep 78	480/A44	039	X	Bote Mt.	11			X
5 Sep 78	414	269		Parsons Br.	3	100		X
4 Sep 78	476	266		Bote Mt.	5	125		X
4 Sep 78	473	267		Bote Mt.	3	80		X
4 Sep 78	472	268		Bote Mt.	3	65		
3 Sep 78	470	265		Bote Mt.	2	50		
31 Aug 78	307	626	X	Citico	2	95	In estrus, vulva swollen	X
24 Aug 78	316	631		Citico	2	105	In estrus, vulva swollen	X
24 Aug 78	305	624	X	Citico	6	105	Lactating	X
17 Aug 78	408/E60	182	X	Parsons Br.	7	115		X
16 Aug 78	308	628	X	Citico	3	85	Not lactating, with yearling in den (Winter 1978-79)	X
13 Aug 78	E7	060	X	Parsons Br.	7	125	Not lactating, sighted with 3 yearlings in Fall 1978	X
13 Aug 78	306	625	X	Citico	3	80		X
12 Aug 78	307	626	X	Citico	2	80	Vulva slightly swollen	X
9 Aug 78	456	253		Sugarland Mt.	1	45		
9 Aug 78	F5	097	X	Sugarland Mt.	9	140		X
7 Aug 78	313	633		Citico	2	75		
31 Jul 78	455	251		Tremont		70		X
28 Jul 78	454	250		Tremont	9	85		X
17 Jul 78	356	248		Chimneys P.G.	8	150	In estrus, observed copulating	
14 Jul 78	-	246		Highway 441	1/2	18	Cub hit by car	
9 Jul 78	463/A28	040		Crossover	11	130	In estrus, vulva swollen, observed with male	
9 Jul 78	308	628		Citico	3	95	Lactating	X
3 Jul 78	354	245		Walnut Bottoms		100		

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
29 Jun 78	403	243		Parsons Br.	3	84	In estrus, vulva swollen	X
29 Jun 78	404	244		Parsons Br.	3	105	In estrus, vulva swollen	X
29 Jun 78	321/E31	201	X	Parsons Br.	3	95	In estrus, vulva swollen	X
28 Jun 78	459	242		Defeat Ridge	2	60		X
25 Jun 78	307	626		Citico	2	84	In estrus, vulva swollen	X
25 Jun 78	306	625		Citico	3	92		X
24 Jun 78	305	624		Citico	6	123	Lactating, 1 cub observed	X
21 Jun 78	453	240		Smokemont	5	148		
6 Jun 78	-	622		Citico	5	117	1 cub observed	X
22 Mar 78	B18	170	X	Tremont	2	25	No cubs or yearlings in den	
Mar 78	E7	060	X	Parsons Br.	7		With 3 cubs in den	X
Feb 78	H1	100	+	Defeat Ridge	13		Cub vocalizations heard from	
19 Oct 77	P5	220	X	Chimney P.G.	3	130	outside the den	
20 Sep 77	A9	136	X	Bote Mt.	3	115		X
5 Sep 77	A46	213		Bote Mt.	3	80		X
5 Sep 77	H2/17	042	X	Defeat Ridge	13	122	Lactating	
5 Sep 77	H3/48	101	X	Crossover	8	105	Lactating	
4 Sep 77	A45/37	092	X	Bote Mt.	8	120		X
4 Sep 77	H1/47	100	X	Crossover	12	130		X
3 Sep 77	A44/59	039	X	Bote Mt.	10	125	Lactating	X
31 Aug 77	A41	063	X	Bote Mt.	11	90	Lactating, 2 cubs observed	
23 Aug 77	P10	207		Collins Cr.	5	215		
23 Aug 77	P8	205		Highway 441	7	120	Lactating, 1 cub observed	
18 Aug 77	P6	203		Highway 441	6	115	Lactating, 1 cub observed	
10 Aug 77	E31	201		Parsons Br.	2	75		
9 Aug 77	E32	200		Parsons Br.	1	50		
7 Aug 77	E33	199		Parsons Br.	2	70		
7 Aug 77	E34	198		Parsons Br.	7	120		

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
3 Aug 77	P5	220		Chimneys P.G.	3	115		
3 Aug 77	B18	170	X	Tremont	1	28		X
28 Jul 77	B17	195		Tremont	6	95		
28 Jul 77	C22	194		Rabbit Cr.	6	115		
22 Jul 77	B14	191		Tremont	7	90		
18 Jul 77	B10	187		Tremont	6	90		X
11 Jul 77	P3	186	X	Highway 441	2	80		
3 Jul 77	F13	184		Sugarland Mt.	11	105		
2 Jul 77	E60	182		Parsons Br.	6	100	Lactating	
31 Jul 77	F21	180		Sugarland Mt.	3	62		
29 Jun 77	F5	097	X	Sugarland Mt.	8	110	2 cubs observed	X
29 Jun 77	E7	060	X	Parsons Br.	6	110	In estrus, vulva swollen	X
21 Jun 77	D16	176		Bent Arm	8	147	In estrus, vulva swollen	X
14 Jun 77	-	620		Citico	3	86		
18 Mar 77	B18	170		Tremont	1	26	With adult female #89 in den	
11 Sep 76	A9	136	X	Crossover	2	79		X
9 Sep 76	F6	166		Sugarland Mt.	1	60		
8 Sep 76	F5/44	097	X	Sugarland Mt.	7	140		X
8 Sep 76	A29	165		Bote Mt.	1	55		
4 Sep 76	A28/18	040	X	Crossover	10	95		X
22 Aug 76	C13/81	124	X	Highway 441	7	175*		
18 Aug 76	C7/74	118	X	Rabbit Cr.	6	120		
18 Aug 76	C8	158		Rabbit Cr.		110		
11 Aug 76	E5	154		Parsons Br.	8	125		X
5 Aug 76	E1	151		Parsons Br.	5	118	In estrus	
28 Jul 76	D6	150		Bent Arm	5	85	Lactating	
26 Jul 76	D3	146		Bent Arm	7	80		
26 Jul 76	C3	145		Boring Ridge	1	35		
24 Jul 76	D2/43	045	X	Bent Arm	9	100	In estrus, vulva swollen	X

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
21 Jul 76	D1	143		Highway 441	6	132	Vulva slightly swollen	
20 Jul 76	-	615		Citico	4	100*	Lactating, 2 cubs observed	
7 Jul 76	A15/14	037	X	Crossover	5	97	In estrus, vulva swollen	
7 Jul 76	48	101	X	Defeat Ridge	7	115	In estrus, vulva swollen	
7 Jul 76	A14	140		Defeat Ridge	8	90	In estrus, vulva swollen	
1 Jul 76	A10	137		Defeat Ridge	5	75		
30 Jun 76	320	619		Citico	5	125		X
23 Jun 76	A9	136		Bote Mt.	2	65		
22 Jun 76	A8	135		Bote Mt.	10	127	Lactating	
17 Jun 76	A3/08	069	X	Bote Mt.	6	105		
12 Sep 75	89	131		Green Camp Gap	12	165		X
5 Sep 75	87	129		Green Camp Gap	8	120	Lactating	
22 Aug 75	81	124		Highway 441	6	80	Lactating, 2 cubs observed	
21 Aug 75	80	123		Highway 441	2	80		
15 Aug 75	77	120		Ekaneetlee Gap	9	145		
15 Aug 75	76	119		Ekaneetlee Gap	5	135		
1 Aug 75	-	613		Citico	4	135*	In estrus, vulva swollen	
25 Jul 75	74	118		Rabbit Cr.	5	155*		
24 Jul 75	18	040	X	Bote Mt.	9	120		
21 Jul 75	71	115		Rabbit Cr.	5	95	Lactating	
19 Jul 75	64	112		Bote Mt.	15	90		X
19 Jul 75	63	111		Bote Mt.	10	130		X
8 Jul 75	53	105		Rough Cr.	8	85	In estrus	
7 Jul 75	59/01	039	X	Bote Mt.	8	105	Lactating	
5 Jul 75	58/03	062	X	Bote Mt.	6	85	In estrus, vulva swollen	
5 Jul 75	57	108		Bote Mt.	4	70		
28 Jul 75	44	097		Sugarland Mt.	6	115		
22 Jun 75	48	101		Defeat Ridge	6	80		
17 Jun 75	47	100		Defeat Ridge	10	125	1 yearling observed	

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
17 Jun 75	43	045	X	Bent Arm	8	100		
17 Jun 75	41	095		Bent Arm	9	90		
27 May 75	-	610		Citico	5	148		
13 Sep 74	37	092		Bote Mt.	5	65		X
13 Sep 74	09	013	X	Spence Field	3	60		X
5 Sep 74	-	090	X	Highway 441		200		
27 Aug 74	-	089		Highway 441		175	3 cubs observed	
20 Aug 74	33	047	X	Miry Ridge	8	95		
19 Aug 74	32	088		Miry Ridge		130		
18 Aug 74	31	087		Miry Ridge	2	110		
1 Aug 74	21	082		Rough Cr.	9	105	Lactating, 2 cubs observed	
25 Jul 74	29	079		Rabbit Cr.	4	120		
25 Jul 74	28	078		Rabbit Cr.	12	140		
24 Jul 74	26	076		Rabbit Cr.	5	105		
10 Jul 74	18	040	X	Crossover	8	85	Lactating, 1 cub observed	
5 Jul 74	17	042	X	Crossover	10	115*	Lactating	
26 Jun 74	14	037	X	Bote Mt.	3	90		
21 Jun 74	09/99	013	X	Bote Mt.	3	70*		
19 Jun 74	08	069		Bote Mt.	4	130		
15 Jun 74	03	062	X	Bote Mt.	5	75		
14 Jun 74	01	039	X	Bote Mt.	7	100		X
25 Sep 73	01	039	X	Bote Mt.	6	100		X
12 Sep 73	14	037	X	Bote Mt.	2	95	Vulva slightly swollen	X
7 Sep 73	A41	063		Spence Field	7	120*		X
6 Sep 73	-	026	X	Bote Mt.	7	173		X
4 Sep 73	03	062		Bote Mt.	4	75*		
23 Aug 73	E7	060		Parsons Br.	2	85		
9 Aug 73	-	057		Rabbit Cr.	4	120		
8 Aug 73	-	055		Rabbit Cr.	12	119		

Table 19 (Continued)

Date	Bear No.	UT#	Recap	Area	Age	Wt	Reproductive Condition	RC
27 Jul 73	77	009	X	Spence Field	5	140		X
21 Jul 73	-	049		Jakes Gap	8	120	In estrus, vulva swollen	
19 Jul 73	-	048		Jakes Gap	3	40*		
18 Jul 73	33	047		Miry Ridge	7	65*	Vulva slightly swollen	
18 Jul 73	-	046		Miry Ridge		110*	In estrus, vulva swollen	
17 Jul 73	43	045		Bent Arm	6	70*	Vulva slightly swollen	
5 Jul 73	-	043		Crossover	6	100*		
5 Jul 73	17	042		Crossover	9	100*	Vulva slightly swollen	
4 Jul 73	-	041		Crossover	3	35*		
4 Jul 73	18	040		Crossover	7	100*	Vulva slightly swollen	
3 Jul 73	01	039		Bote Mt.	6	71		X
19 Jun 73	14	037		Crossover	2	72		X
17 Jun 73	52	036		Bote Mt.	7	115		X
14 Nov 72	-	034		Highway 441	1/2	16		
7 Nov 72	-	032		Sugarlands V.C.	5	102	Not lactating, 1 cub observed	
6 Sep 72	-	027		Tremont	1/2	12		
28 Aug 72	-	026	X	Spence Field	6	150	Lactating, 1 cub observed	X
25 Aug 72	-	026		Spence Field	6	150	Lactating, 1 cub observed	X
28 Jul 72	-	019		Highway 441	8	142		
27 Jul 72	7	016		Silers Bald		150	Lactating, 3 cubs observed	
12 Jul 72	99	013		Spence Field	1	20		
6 Jul 72	77	009		Spence Field	4	120	In estrus, vulva swollen	X
13 Sep 70	-	090		Collins Gap		185		

*Estimate.

+Visual observation or recording in den.

RC = Radio-collared.

APPENDIX D

Table 20. Observations of panhandler female black bears with yearlings in the front country and backcountry of the Great Smoky Mountains National Park, 1978-80.

Date	No. of Yearlings with Female	Status
5 May 78	3	Front country
24 May 78	2	Front country
7 Jun 78	1	Backcountry
26 Apr 79	2	Backcountry
8 May 79	4	Front country
11 Jun 79	3	Front country
22 Jun 79	1	Backcountry
8 May 80	2	Backcountry
11 May 80	4	Front country
13 May 80	2	Backcountry
23 May 80	1	Front country
30 May 80	1	Backcountry
30 May 80	3	Backcountry
31 May 80	2	Backcountry

APPENDIX E

Table 21. Weights of black bear offspring examined in winter dens in the Great Smoky Mountains National Park and the Cherokee National Forest, 1978-80.

Date	Bear No. of Maternal Female	Litter Size	Weight (kg)	Comments
17 Mar 78	E7	3 cubs	2 males: 1.8 (2)	Cubs between 46 and 49 days old, eyes open
31 Jan 79	A45	3 yearlings	1 male: 9.1 1 female: 9.1	One yearling left den before it could be sedated
19 Feb 79	A44	3 cubs	2 males: 0.5, 0.6 1 female: 0.5	Eyes closed, not well developed
3 Mar 79	308	2 yearlings	2 males: 7.7, 13.6	
10 Mar 79	F5	2 cubs	2 males: 1.8 (2)	Eyes closed
17 Mar 79	476	2 cubs	2 males: 1.1	Eyes closed
8 Mar 80	476	3 cubs	1 male: 2.0 2 females: 2.0 (2)	Eyes closed
10 Mar 80	F21	3 cubs	3 males: 1.8 (2) 1.6	Eyes open
23 Mar 80	577	4 yearlings	4 males: 13.6, 20.4, 23.6, 61.9	Panhandler family unit

APPENDIX F

Table 22. Sex ratio for litters of female black bears trapped by the National Park Service as part of summer control actions or sedated in winter dens by bear project personnel in the Great Smoky Mountains National Park and the Cherokee National Forest, 1978-79.

Date	Bear No. of Maternal Female	Litter Size	Sex Ratio (Male:Female)	Comments
17 Mar 78	E7	3 cubs	2:1	Examined in winter den
Jul 78	606	1 cub	1:0	Summer control action
31 Jan 79	A45	3 yearlings	1:1	Examined in winter den, 1 yearling escaped from den before it could be sedated
12a 13 Feb 79	B10	1 yearling	-	Female and yearling left den after female was sedated
19 Feb 79	A44	3 cubs	2:1	Examined in winter den
3 Mar 79	308	2 yearlings	2:0	Examined in winter den
10 Mar 79	F5	2 cubs	2:0	Examined in winter den
17 Mar 79	476	2 cubs	2:0	Examined in winter den
11 Jun 79	549	3 yearlings	2:0	Summer control action, 1 yearling not captured
18 Jul 79	575	2 cubs	2:0	Summer control action
31 Jul 79	609	3 cubs	1:1	Summer control action, 1 cub not captured
22 Oct 79	590	2 cubs	0:2	Summer control action
6 Mar 80	463	2 yearlings	0:1	Examined in winter den
8 Mar 80	476	3 cubs	1:2	Examined in winter den
10 Mar 80	F21	3 cubs	3:0	Examined in winter den
23 Mar 80	577	4 yearlings	4:0	Examined in winter den, panhandler family unit
7 Jun 80	614	2 cubs	0:2	Summer control action
9 Jun 80	-	1 yearling	0:1	Summer control action

APPENDIX G

Table 23. Vaginal resistance, pH and type of epithelium observed for female black bears trapped during the summer in the Great Smoky Mountains National Park and the Cherokee National Forest, 1978-79.

Date	Bear No.	Age	Vaginal Resistance	Vaginal pH	Vaginal Smear	Reproductive Condition
21 Jun 78	453	5			Nucleated and cornified cells	
24 Jun 78	305	6				Lactating
25 Jun 78	306	3				
25 Jun 78	307	2				In estrus, vulva swollen
28 Jun 78	459	2				
29 Jun 78	321	3			Cornified cells	In estrus, vulva swollen
29 Jun 78	403	3				In estrus, vulva swollen
29 Jun 79	404	3				In estrus, vulva swollen
3 Jul 78	354	-			Leucocytes and mucus strands	
9 Jul 78	308	3				Lactating
9 Jul 78	463	11			Cornified cells	In estrus, vulva swollen
17 Jul 78	356	8			Cornified cells	In estrus, observed copulating
28 Jul 78	454	9				
13 Jul 78	455	-				
17 Aug 78	313	2				
9 Aug 78	F5	9			Cornified cells	
9 Aug 78	456	1				
13 Aug 78	306	3				
13 Aug 78	E7	7				
17 Aug 78	408	7				

Table 23 (Continued)

Date	Bear No.	Age	Vaginal Resistance	Vaginal pH	Vaginal Smear	Reproductive Condition
24 Aug 78	305	6				Lactating
24 Aug 78	316	2				In estrus, vulva swollen
31 Aug 78	307	2			Cornified cells	In estrus, vulva swollen
3 Sep 78	470	2				
4 Sep 78	472	2				
28 May 79	606	8				
5 Jun 79	486	3		5-6		Vulva slightly swollen
6 Jun 79	487	14	0.8 x 100 K	6-7		
6 Jun 79	403	4		6		Vulva slightly swollen
8 Jun 79	316	3		7		
11 Jun 79	306	4		6		
11 Jun 79	549	12				With 3 yearlings
15 Jun 79	336	3				
22 Jun 79	321	4	0.5-0.6 x 100 K	7		
26 Jun 79	575	6				Lactating
27 Jun 79	576	12				Lactating
30 Jun 79	616	3				
30 Jun 79	614	9		6		
7 Jul 79	307	3			Cornified cells	In estrus, vulva swollen
12 Jul 79	343	2	0.03 x 100 K	6		In estrus, vulva swollen
12 Jul 79	458	2	0.48 x 100 K	7		
13 Jul 79	305	7		6		
13 Jul 79	494	6	0.1 x 100 K	7		Vulva slightly swollen
18 Jul 79	F21	5	0.28 x 100 K	6-8		In estrus, vulva swollen
18 Jul 79	338	3	0.01 x 100 K	5		Vulva slightly swollen
20 Jul 79	321	4	0.5-0.9 x 100 K	5-6	Cornified cells	In estrus, vulva swollen
22 Jul 79	423	2	1.14-1.22 x 10 K			
			0.03-0.04 x 100 K			

Table 23 (Continued)

Date	Bear No.	Age	Vaginal Resistance	Vaginal pH	Vaginal Smear	Reproductive Condition
26 Jul 79	498	2	0.03-0.04 x 100 K	6		With 2 cubs
31 Jul 79	609	4		6		
31 Jul 79	620	12				
2 Aug 79	498	2	0.74 x 10 K	6-7		Lactating
8 Aug 79	549	12	0.72 x 10 K	7		
			0.03 x 100 K			
10 Aug 79	424	7		5		
13 Aug 79	426	2	0.13 x 10 K	5		
14 Aug 79	427	3	0.84 x 10 K			Lactating
			0.04 x 100 K			
23 Aug 79	471	3	1.04 x 10 K			
			0.03 x 100 K			
11 Sep 79	463	12				Lactating
12 Sep 79	471	3	1.0 x 10 K	6		
			0.15 x 100 K			

VITA

John Heinrich Eiler, son of Rev. and Mrs. Heinrich Eiler, was born in Youngstown, Ohio on November 26, 1953. He attended Wheaton North High School in Wheaton, Illinois, graduating in 1972. In 1976, he graduated from the University of Montana, Missoula, Montana with a Bachelor of Science in Wildlife Biology. He was accepted by the graduate program in Forestry, Wildlife and Fisheries, The University of Tennessee, Knoxville, Tennessee in 1977. He received his Master's degree in Wildlife and Fisheries Science in June 1981.

John is married to the former Nancy Ann Valach of Missoula, Montana.