Reproduction, Survival, and Denning Ecology of Black Bears in Southwestern Virginia

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(Abstract)

Thirty-four (6 M, 28 F) of 93 black bears (*Ursus americanus*) captured during summers 1995 and 1996 were equipped with radio-collars. The mean age of male and females captured was 2.5 (n = 63; 2 males not aged) and 4.4 (n = 28) years, respectively. The mean date of females in estrus was 24 July, and we observed one 1.5-year old female in estrus. The average age of primiparity of radio-collared females was 3.0 years; however, we documented fetuses present in a 2-year old noncollared female's reproductive tract. The average interbirth interval was 1.6 years and 95.4% of females without yearlings produced cubs. The mean litter size was 2.2 and the cub sex ratio was 1.3M:1F.

Hunting, vehicle collisions, poaching, research, and euthanasia accounted for 80.5%, 5.5%, 5.5%, 5.5%, and 2.8%, respectively of the adult and juvenile male mortalities (n = 36). Hunting, vehicle collisions, and research each accounted for 2 of the adult and juvenile female mortalities (n = 6). Annual harvest rates for males in 1995 and 1996 were 36.1% and 45.5%, respectively; corresponding harvest rates for females were 0.0%, and 5.9%. Annual survival rates estimated with Kaplan-Meier for adult females, juvenile females, and cubs were 100.0%, 93.3%, and 70.3%, respectively. Maximum juvenile male survival rates were 52.0% in 1995 and 51.7% in 1996. Maximum adult male survival rates were 50.0% and 80.0% in 1995 and 1996, respectively.

We monitored 31 bears for 39 bear winters with 100% of the known bears denning. Bears denned in trees (41%), rock cavities (32%), excavations (14%), snags (8%), and ground nests (5%). Chestnut oak (*Quercus prinus*; n = 9), red oak (*Q. rubra* ;n = 8), and tulip-poplar (*Liriodendron tulipifera*; n = 1) were used as tree dens. Habitat characteristics did not differ between ground dens and tree dens; however, older bears used ground dens more frequently (Z = -2.484, P = 0.013) than tree dens. Fifty-seven percent of bears denned on public land, and we documented one instance of den reuse.

Acknowledgments

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Introduction

Black bear (*Ursus americanus*) hunting has been under close scrutiny throughout much of the country for the past 10 years. Ethical questions surrounding springtime hunting, hunting over bait, and the use of hounds to hunt bears are issues that have been raised by the public. In California, Burton (1994) noted that the public was interested in black bear bag limits, season length, and the use of hounds to pursue or hunt bears. Public opinion (Burton 1994) and insufficient biological data for some bear populations has stopped or altered methods of bear hunting in a number of states including California, Oregon, Washington, Colorado, and Massachusetts.

In Virginia, where hunting bears with dogs is traditional, black bears are managed by setting bag limits, weight limits, season lengths, and controlling access on public lands (through closed gates; Martin, 1991). Bear harvests in Virginia generally have increased since records were kept in the late 1920s, and harvest data have been the major informational tool to manage bear populations. However, because Virginia does not have a separate bear license, the number of hunters pursuing bears is unknown. Thus, hunter effort and success is not fully considered in Virginia's bear management strategy.

Virginia state biologists began tagging bears in 1957 (Strickley 1961). Early studies (Raybourne 1977) provided some background information, but did not give specific information on reproductive rates, cub survival, dispersal, nonhunting moralities, or denning ecology of the black bear. More recent studies (Carney 1985, Garner 1986, Hellgren 1988, Kasbohm 1994, Schrage 1994) of nonexploited populations in the Shenandoah National Park (SNP) and Great Dismal Swamp National Wildlife Refuge (GDSNWR) provided some insight into the demographic characteristics of black bears in Virginia.

Data from the exploited black bear population are essential to ensure proper management of the resource. In 1994, the Virginia Department of Game and Inland Fisheries (VDGIF) and Virginia Polytechnic Institute and State University began research on the exploited black bear population. The long-term goal of the project (Cooperative Allegheny Bear Study; CABS) was to construct a population model and provide data crucial to the management of bears in Virginia. The first goal of CABS was to conduct a demographic analysis of the black bear population. This thesis is the first in a series of studies designed to provide baseline demographic and ecological data for bears in the southwestern study area of CABS. The specific objectives of this thesis were to

1. determine the timing of estrus, age of primiparity, percent reproducing, litter size, date of parturition, and cub sex ratio in the southern portion of the George Washington and Jefferson National Forests (GWJNF).
2. determine the age structure, age and sex specific survival rates, sex specific harvest rates, and causes of mortality in the southern portion of the GWJNF.
3. determine den types, habitat characteristics, and den reuse in the southern portion of the GWJNF.

General Methods

Live Trapping and Handling Techniques

Black bears were trapped from June until the first Saturday in September in 1995 and 1996. Culvert traps and modified Aldrich foot snares were used to capture bears. The number and location of trap lines within the study area were selected to distribute the capture sample and maximize use of personnel. Trap lines and areas trapped were divided among VDGIF personnel and Virginia Tech graduate students.

Trap lines were prebaited for 4-8 days before snares were set. Bait and trap sites were determined in the field based on bear sign, accessibility of site, and safety of site to personnel and trapped bears. We used meat scraps, pastries, bread with molasses, and carrion as bait. Call bags (cloth sacks with meat scraps and molasses in it) were hung a minimum of 3 meters high in a tree to attract bears and determine use of site. We checked bait sites and put out new bait every other day; snares were set shortly after a bear visit. Trap lines of 6-15 snares were run for 2 weeks before shifting to a new area. Captures per trap night and number of trap nights were recorded for each trapping crew. The Global Positioning System (GPS) was used to identify Universal Transverse Mercator (UTM) grid coordinates of successful trap sites.

A 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride was used to immobilize black bears caught in snares (Schrage 1994). A jab stick, blow gun, or dart gun or pistol was used to administer the drug at a dosage rate of 1cc of ketamine hydrochloride and xylazine hydrochloride per 44 kilogram (kg) of estimated live weight. Each captured bear was marked with a numbered ear tag in each ear and a tattoo in the upper lip; both ear tags and the lip tattoo bore the same number.

We removed one of the upper first premolars for age determination (Willey 1974), took a hair sample for genetic analysis, and drew blood from each bear. One blood tube with EDTA anticoagulant for hematological and genetic analyses to be used by a current student and 2 for blood serum analyses were drawn from the femoral vein. The bear's ear tag number, date of collection, sex, and ID were placed on the blood and hair sample containers. Each bears' ID in the southwestern study area began with an S.

We recorded the weight of each bear to the nearest kg. Morphological measurements were taken to be used by a current student. Each bear's canine length and breadth, forepaw (length and width), hindpaw (length and width), ear length, tail length, shoulder height, body length (zoological and actual length), zygomatic circumference, and chest and neck circumference were measured to the nearest millimeter (mm). On males, we measured testicle length and width and on females we measured the second thoracic nipple. For females, we also determined whether cubs were present and checked for lactation and estrus. Overall condition such as scars, parasites, wounds, teeth and coat condition, injuries, and any abnormalities was entered onto the data sheet.

Radio Telemetry

Telonics (Telonics Inc., Mesa, AZ) receivers and H-antennas were used for ground telemetry. Compass bearings were taken from at least 3 fixed telemetry stations, and locations were estimated through triangulation. Readings more than 30 minutes apart (unless transmitter was on mortality mode) or angles less than 30 degrees were not used for analysis. Aerial telemetry was used specifically for missing bears, den locations, dropped collars, and to supplement ground telemetry. Dennis Martin (VDGIF), a hired pilot, or a graduate student conducted aerial telemetry. GPS was used for determining aerial locations.

Accuracy of both aerial and ground telemetry was assessed. Den locations and dropped collars were used to determine the accuracy of each pilot. The dens were chosen at random so that the pilots did not know they were being tested. Den locations and placed collars were used to rate the accuracy of graduate students and volunteers. Students and volunteers located the collars from the ground and percent error was calculated. Volunteer accuracy was combined into one rating for all volunteers.

Study Area

Research was conducted from May 1995 through December 1997 on the Blacksburg and Newcastle Ranger Districts of the GWJNF (Figures 1 and 2). The 1,544 sq. km study area was in the Southern Appalachian Ridge and Valley Province (United States Department of Agriculture [USDA] 1965) of Giles, southern Craig, and northwestern Montgomery counties. Major valleys and ridges run parallel to the New River (Soil Conservation Service [SCS] 1985). The southern study area was bordered by West Virginia to the northwest, Bland County to the southwest, route 624 to the southeast, and route 311 to the northeast.

Average yearly temperatures at Mountain Lake Meteorological Station, in the middle of the study area, were 8.3^0C and 6.9^0C in 1995 and 1996, respectively with a range of -23.8^0C to 29.2^0C. Total precipitation was 119 cm and 153 cm in 1995 and 1996, respectively; the monthly range was 7 cm to 246 cm.

Mountain bedrock on the study area is generally sandstone and shale (SCS 1985). The elevation ranges from 492 m along the Craig Creek drainage to 1,378 m at Mountain Lake. Soils are typically from the Gilpin, Nolichucky, Jefferson, and Lily series and are sloping to very steep and are well drained (SCS 1985).

Chestnut oak, white oak (*Quercus alba)*, scarlet oak (*Q. coccinea*), northern red oak, and black oak (*Q. velutina*), are the important tree species in the southern study area (USDA 1985). In addition, red maple (*Acer rubrum*), pignut hickory (*Carya glabraI*), bitternut hickory (*C. cordiformis*), pitch pine (*Pinus rigida*), eastern white pine (*P. strobus*) were also common overstory species. Sassafras (*Sassafras albidum*), mountain laurel (*Kalmia latifolia*), downy serviceberry (*Amelanchier arborea*), flowering dogwood (*Cornus florida*), witch hazel (*Hamamelis virginia*), and rhododendron (*Rhododendron maximum*) were the common understory species.

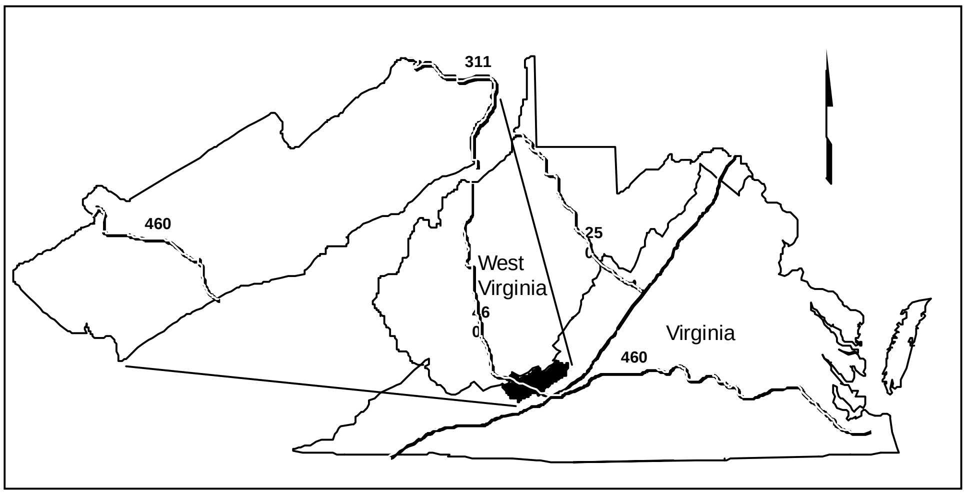

Figure 1. Southwestern study area of the Cooperative Alleghany Bear Study, Virginia.

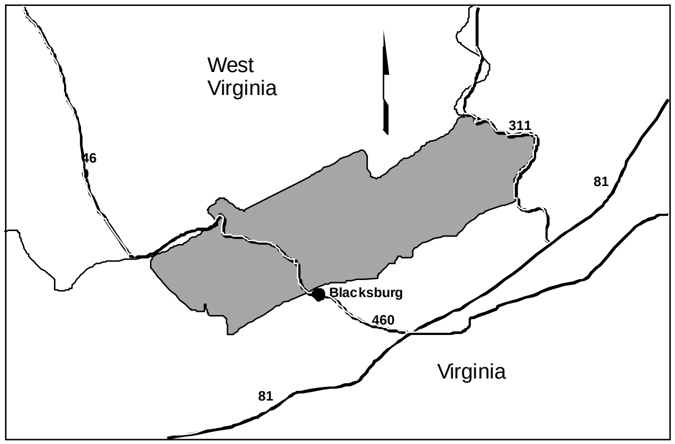

Figure 2. Southwestern study area of the Cooperative Alleghany Bear Study, Virginia.

Chapter 1: Reproduction

Introduction

With delayed sexual maturity, small litter sizes, and a prolonged birth interval (Eiler et al. 1989), black bears have one of the lowest reproductive rates of mammals in North America; thus small changes in reproduction may severely alter population levels (Craighead et al. 1974). Reproduction in black bears may be affected by physical condition (Samson and Hout 1995) and age (Alt 1982) of reproducing females, and fall mast availability (Elowe and Dodge 1989). The number of cubs produced in any given year is largely a function of the number of breeding females in the population and of habitat quality. Beecham (1980), LeCount (1987), and Rogers (1977) hypothesized that cub production is density-independent, with most females producing at or near maximum potential, but LeCount (1987) stated that social regulation (density dependent) was a factor in cub survival in Arizona.

Black bears typically breed from late May through August. In most regions, the peak of breeding occurs during late June and July (Alt 1989, Eiler 1981, Jonkel and Cowan 1971, Kohn 1982, Rogers 1987). Breeding periods apparently are longer in southern black bear populations because reproductive cycles in males are triggered by photoperiod (Garshelis and Hellgren 1994). Bears give birth from mid-January to mid-February (Alt 1989, Carney 1985, Godfrey 1996). Cubs remain with their mother for 1.5 years, at which time the family group breaks up and the female breeds again.

Female black bears typically breed every other year, but will breed in consecutive years if they lose their entire litter before late summer (Carney 1985); thus the interbirth interval depends on cub survival and nutritional condition of the female. Research has shown that the mean interbirth interval for the eastern United States is 1.9 - 2.3 years (Alt 1989, Carney 1985, Eiler et al. 1989, Elowe and Dodge 1989, Godfrey 1996, Hellgren and Vaughan 1989, Kolenosky 1990). Kasworm and Thier (1994) reported a mean interbirth interval of 3.2 years for black bears in Montana. In Alaska, the mean interbirth interval was 2.0 years (Miller 1994).

Female black bears typically first give birth between 3 and 7 years of age (Alt 1989, Carney 1985, Eiler et al. 1989, Elowe and Dodge 1989, Kasworm and Thier 1994, Lindzey and Meslow 1977, McLaughlin et al. 1994, Rogers 1987, Schwartz and Franzmann 1991). Age of first reproduction varies geographically, depending on size and condition of the bears (Alt 1989, Elowe 1987), and food availability (McLaughlin et al. 1994). However, Alt (1989) in Pennsylvania, where greater than 80% of the females give birth by age 3, reported reproduction in one 2-year old female. In Virginia, Carney (1985) and Hellgren (1988) reported an average breeding age of 3 years (giving birth at 4 years) for unexploited populations, and a minimum breeding age of 2 years. However, Godfrey (1996) showed the mean age of primiparity for an exploited population in the northern GWJNF to be 3.14 years. The mean age for first litters of bears in the southern Appalachian Mountains was 4.6 years (Eiler et al. 1989). In Washington, Lindzey and

Meslow (1977) observed that black bears on average gave birth as 4-year olds. In Alaska, the average age at first reproduction in black bears ranged from 4.6 to 5.1 years (Schwartz and Franzmann 1991). In Maine, black bears began reproducing as 6-year olds when beechnuts (*Fagus grandifolia*) were scarce and 4 years when they were plentiful (McLaughlin et al. 1994). In Montana, black bears were greater than 6-years old when they began to reproduce (Kasworm and Their 1994).

Age, weight, food availability, and nutritional condition (Alt 1989, Noyce and Garsheils 1994, Samson and Hout, 1995) influence litter size of female black bears. The largest reported mean litter sizes were in Pennsylvania ($\bar{x}$ = 2.9 - 3.0; Alt 1982, Alt 1989) and West Virginia ($\bar{x}$ = 2.87; Kraus et al. 1988). Carney (1985), Schrage (1994), and Godfrey (1996) reported mean litter sizes of 2.0 - 2.3 in Virginia. In Maine (McLaughlin et al. 1994), Alaska (Miller 1994), and Montana (Kasworm and Thier 1994) average litter sizes were 2.5, 2.1, and 1.8, respectively. Litters of 5 have been reported in Michigan (Matson 1952), Saskatchewan (Rowan 1945), and Pennsylvania (Alt 1982).

First time mothers typically have smaller litters than older adult females (McLaughlin et al. 1994, Noyce and Garshelis 1994). Miller (1994) reported that all first litters in south central Alaska were 2 cubs. In Maine, the average first litter size was 2.1 (McLaughlin et al. 1994). Alt (1982) and Godfrey (1996) found a direct correlation between age of mother and litter size, with young mothers producing smaller litters. In Minnesota, Noyce and Garhelis (1994) reported a significant difference between first litter size and subsequent litters.

Sex ratios of black bear cubs tend to be 1:1 (Godfrey 1996, McLaughlin et al. 1994, Miller 1994, Schwartz and Franzmann 1991). However, in Pennsylvania, males made up 51% of small litters ($\leq$3), but 63% of larger litters (4-5; Alt 1982). Samson and Hout (1995) in Quebec reported a sex ratio of 2.5M:1F. In Maine, the sex ratio of cubs was 1.2M:1F (McLaughlin et al. 1994) and in Virginia it was 0.89M:1F (Hellgren 1988, Kasbohm 1994).

Methods

Upon capture, female bears were examined for signs of lactation and estrus (see live trapping and handling). Vulval swelling indicated the timing of estrus, and dates of estrus were tested between younger and older females with a Wilcoxon Rank Sum test. Lactating females exhibiting loss of hair around their nipples were assumed to have successfully reproduced that year. Adult females ($\geq$ 3 years) not showing signs of lactation were considered available to reproduce, whereas juvenile females ($\leq$ 2 years) were not considered available to reproduce. Percent available to reproduce was tested between years with a z-test for proportions (α = 0.05 was the significance level for all statistical tests).

Female reproductive success was determined during the denning season. Percent of successfully reproducing females that were available to reproduce was tested between years with a z-test for proportions. Cub sex ratio, litter size, age of primiparity, and cub and sow physical measurements (see live trapping and handling) were determined in the den season or shortly after den emergence. Cub sex ratio was tested between years with a z-test for proportions. A Chi-square goodness of fit test was used to determine if the cub sex ratio differed from 1:1. The relationship between age of female and litter size was tested with a Spearman's Correlation. Litter size by age classes (3 and 4 years vs. $\geq$5 years), between years, and for females that denned in trees versus ground dens were tested with a Wilcoxon rank sum.

Body measurements, sex, markings (blazes), and overall condition were recorded for each cub. Weight of each cub was determined to the nearest 0.5 kg. Measurements of each cub's total length, neck and chest girth, forepaw (length and width), hindpaw (length and width), and hair length at the crown of the head were determined to the nearest millimeter (mm). Selected cubs were fitted with radio transmitters to determine cub survival (Chapter 2). Cub growth measurements were tested between years and sexes with analysis of covariance (covariant = cub age). Regression equations (Godfrey 1996) from physical characteristics and growth rates of captive bear cubs at Virginia Tech were used to calculate date of parturition. Hair, measured between the ears, and ear length measurements were averaged per litter for multiple cub litters. The regression used from Godfrey (1996) was

$$\text{Age} = -5.98 + (1.28 * \text{hair length}) + (0.75 * \text{ear length})$$

$$\underline{n} = 56, \text{Cp}=48.52, \text{Adjusted } R^2=0.983, \text{MSE}=11.006$$

Date of parturition was tested between years and age classes with a Wilcoxon rank sum.

Corpora lutea, placental scars, or fetuses per female were determined from reproductive tracts collected from road-killed and harvested females (Carney 1985). To assist in the collection of reproductive tracts, diagrams with instructions on reproductive tract removal and storage were distributed to bear hunters, law enforcement officers, and game check-in stations. Reproductive tracts were labeled and frozen until further dissection. Number of fetuses and corpora lutea present was determined by dissection of the reproductive tracts. Placental scars were counted for each reproductive tract (Tsubota et al. 1990).

Age of primiparity was determined by following radio-collared juvenile females ($\leq$ 3 years) until they produced their first litter. Interbirth interval was calculated by counting the number of years between successive litters for the same bear.

Results

Timing of Estrus

Ten females with swollen vulvas were captured 11 times between 20 June and 21 August 1995 and 1996 (Figure 1). Mean date for females exhibiting signs of estrus was 24 July (SE = 6.49, $\underline{n}$ = 10, median = 25 July). Five of 10 females with swollen vulvas were captured between 11 July and 3 August. Four of 9 non-lactating females captured between 11 July and 30 July exhibited signs of estrus. Timing of estrus did not differ ($\underline{Z}$ = 1.358, $\underline{P}$ = 0.175) between younger females ($\leq$ 3.5 years) and older females ($\geq$ 4.5

years). One 6.5-year old female exhibited signs of estrus when captured on 18 July 1996 and recaptured on 25 July 1996. We captured a 1.5-year-old female exhibiting signs of estrus on 21 August 1995.

Age of Primiparity

Average age of primiparity was 3.0 years (SE = 0.00, n = 6; Table 1). Five of 6 females captured when they were $\leq$ 3 produced their first litters at 3 years. Average summer weight of 3-year old females producing cubs was 44.9 kg (SE = 2.50, n = 5). The mean date weights of 3-year old females was taken was 5 July (SE = 9.86, median = 27 June, range = 6 June to 10 August). All (n = 3) radio-collared females 3 years of age and observed in estrus, produced cubs. One female was observed in her den with yearlings at 4 years of age, indicating she gave birth at 3 years. In addition, the reproductive tract of a nonmarked 2-year old female, harvested within the study area, contained 2 fetuses.

Percent Reproducing

Twenty-seven female bears were monitored for 35 bear winters. Twenty-two females were available to reproduce, 7 were accompanied by yearlings, 3 were subadults, and the reproductive status of 3 females was unknown. Ten of fifteen (66.7%) and 12 of 17 (70.5%) females were available to reproduce in 1996 and 1997, respectively (Z = 0.460, P = 0.645). One hundred percent (10 of 10) and 91.6% (11 of 12) of females available to reproduce successfully gave birth to cubs in 1996 and 1997, respectively (Z = 1.04, P = 0.296). During both years combined, 95.4% of available females produced cubs (Table 2). Five of 6 (83.3%) 3-year old females had cubs present at their den sites.

Interbirth Interval

The average interbirth interval was 1.6 years (SE = 0.24, n = 5). Two bears, both first time mothers, produced cubs in 1996 and 1997 and exhibited interbirth intervals of 1 year. Three females captured with yearlings in their dens in 1996 gave birth to cubs in 1997. Two of 2 females, excluding first time mothers, that produced cubs in 1996 and were still wearing their collars in 1997, did not produce cubs in 1997.

Litter Size

Litter size averaged 2.5 (SE = 0.31, n = 10) in 1996 and 1.9 (SE = 0.31, n = 11) in 1997 (Z = 1.4, df = 1,20, P = 0.162). Average litter size for both years combined was 2.2 (SE = 0.22, n = 21; Table 3). Older females ($\geq$ 5 years; SE = 0.31, $\bar{x}$ = 2.5, n = 13) did not have greater (Z = 1.440, P = 0.150) litter sizes than younger females (3 and 4 years; SE = 0.25, $\bar{x}$ = 1.7, n = 8), nor was there a relationship between age and litter size (coefficient = 0.326, P = 0.149). First time mothers had average litter sizes of 1.4 (SE = 0.244, n = 5). Six females, including 3 first time mothers, had 1 cub; 8, including 2 first time mothers, had 2 cubs; 4 had 3 cubs; and 3 had 4 cubs. Females producing cubs ranged from 3 to 17 years of age. Females denning in trees ($\bar{x}$ = 1.4, SE = 0.202, n = 7) had smaller (Z = 2.33, P = 0.020) litters than females that denned on the ground ($\bar{x}$ = 2.5, SE = 0.291, n = 13). Weight of females denning in trees is unknown in the southern GWJNF because we were unable to remove adult bears from tree dens to weigh them (Chapter 3).

Table 1. Age of first successful breeding for black bears in North America.

	Age at first successful breeding		
Area	Mean	Min-Max	Citation
Southern GWJNF	2.5	1.5-2.5	Present Study
Northern GWJNF	2.6	2.5-3.5	Godfrey 1996
SNP	3.0	2.5-3.5	Kasbohm 1994
Tennessee	4.4	2.5-8.5	Eiler 1989
Pennsylvania	2.7	1.5-4.5	Alt 1989
Massachusetts	3.2	2.5-4.5	Elowe 1987
Maine	4.6	3.5-5.5	McLaughlin et al. 1994
Ontario	5.1	4.5-6.5	Kolenosky 1990
Minnesota	5.0	2.5-7.5	Rogers 1987
Idaho	4.3	3.5-5.5	Reynolds 1977
Arizona	4.2	3.5-5.5	LeCount 1984
Alaska	5.6	4.5-7.5	Miller 1987

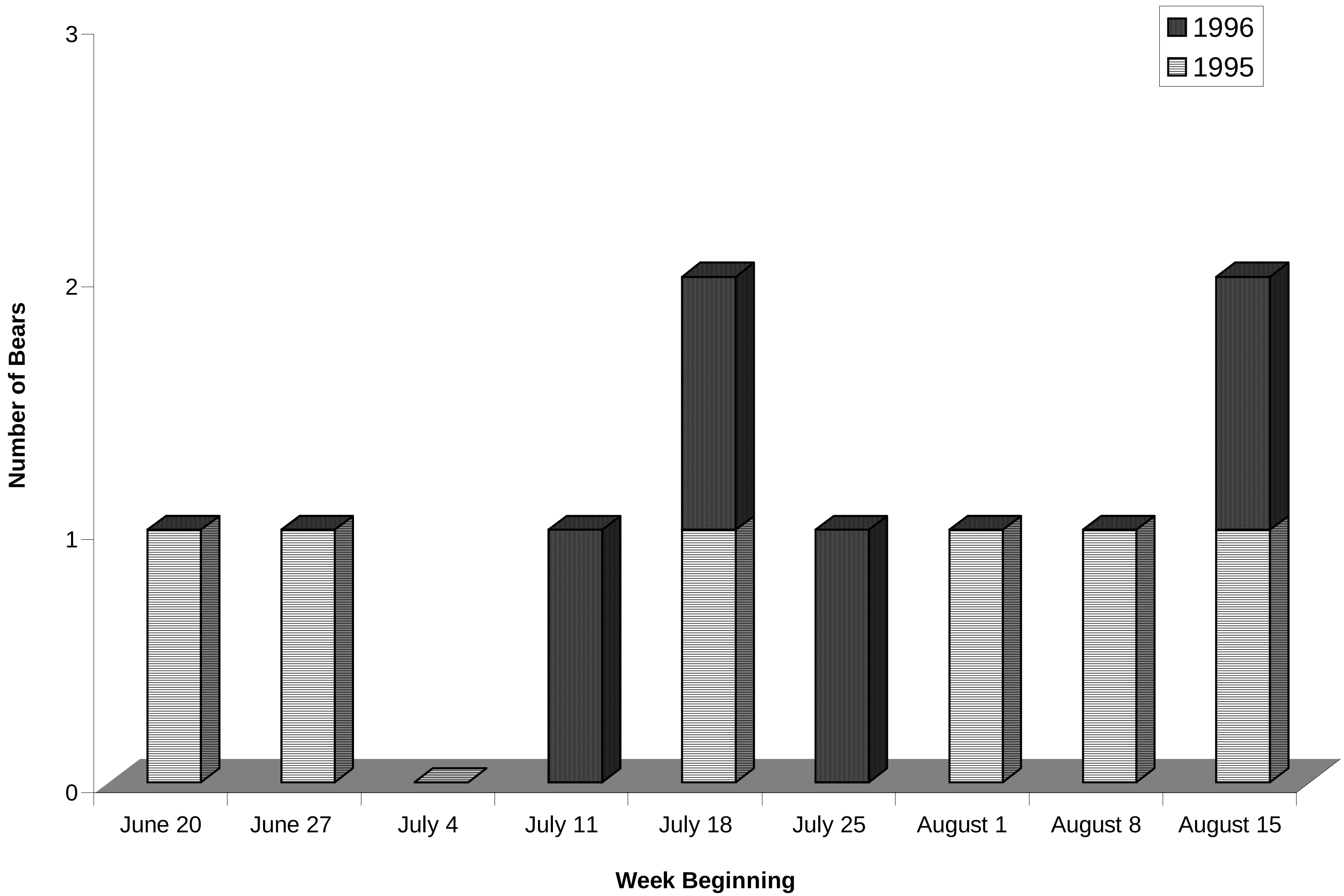

Figure 3. Females captured in estrus during the summer 1995 and 1996 in the southern half of the George Washington and Jefferson National Forests.

Table 2. Reproductive success of female black bears in the southern George Washington and Jefferson National Forests, Virginia, 1996-1997.

Age	# of female	# with yearlings	# with unknown status	# Available to produce cubs	# Producing cubs	Average litter size	% of Available females with cubs
2	3	0	0	0	0	0.0	N/A
3	9	0	3	6	5	1.4	83.3%
4	4	1	0	3	3	2.3	100%
5	4	1	0	3	3	2.0	100%
6	1	0	0	1	1	4.0	100%
7	5	1	0	4	4	2.0	100%
8	2	1	0	1	1	4.0	100%
9	1	0	0	1	1	3.0	100%
10	0	0	0	0	0		N/A
11	0	0	0	0	0		N/A
12	1	1	0	0	0		N/A
13	2	1	0	1	1	3.0	100%
14	0	0	0	0	0		N/A
15	1	0	0	1	1	2.0	100%
16	0	0	0	0	0		N/A
17	1	0	0	1	1	2.0	100%
18	1	1	0	0	0		N/A
Total	35	7	3	22	21		N/A

Table 3. Average litter sizes and hunting status of black bears in North America.

Location	Hunting Status	Average Litter Size	Citation
Southern GWJNF	Exploited	2.2	Present Study
Northern GWJNF	Exploited	2.0	Godfrey 1996
SNP	Unexploited	2.5	Carney 1985
GDS	Unexploited	2.1	Hellgren 1988
Pennsylvania	Unexploited	3.0	Alt 1989
Tennessee	Exploited	2.6	Eiler et al. 1989
Massachusetts	Exploited	2.4	Elowe 1987
West Virginia	Exploited	2.8	Kraus et al. 1988
Idaho	Exploited	2.1	Reynolds and Beecham 1980
Montana	Exploited	1.8	Kasworm and Their 1994
Alaska	Exploited	2.1	Miller 1994
Ontario	Exploited	2.5	Kolenosky 1990
Minnesota	Exploited	2.5	Noyce and Garshelis 1994
Maine	Exploited	2.5	McLaughlin et al. 1994
Quebec	Exploited	2.5	Samson and Hout 1995

One of 4 reproductive tracts collected from harvested and roadkilled bears contained fetuses and corpora lutea. Three of the reproductive tracts were from marked females and 1 was from an unmarked harvested 2-year old female. The unmarked female, killed on 16 December, had 2 fetuses and 2 corpora lutea present. One fetus had implanted in each uterine horn; however both corpora lutea came from the same ovary. The fetuses were 15.2 mm and 15.8 mm in length. An average of 3 placental scars was observed in marked females. Females S-19, SN-1, and SN-4, produced 4, 3, and 2 cubs in the spring and had 4, 3, and 2 placental scars at time of death, respectively. An average of 2.3 (SE = 0.211, $\underline{n}$ = 6) yearlings was observed in dens. Four females had 2 yearlings present and 2 had 3.

Cub Sex Ratio
The cub sex ratio of 1.3 M:1F (23 males, 18 females; 5 unknown) did not differ (χ^2 = 0.610, $\underline{P}$ = 0.435) from 1:1. Cub sex ratios were 1.6M:1F (13 males: 8 females; 4 unknown) and 1M:1F (10 males: 10 females; 1 unknown) in 1996 and 1997, respectively, (Z = 0.773, $\underline{P}$ = 0.439).

Date of Parturition
Estimated average dates of parturition were 20 January (SE = 3.56, $\underline{n}$ = 8, median = 23 January) in 1996 and 24 January (SE = 2.75, $\underline{n}$=9, median = 22 January) in 1997 ($\underline{Z}$ = 0.868, $\underline{P}$ = 0.385). Dates of parturition ranged from 5 January to 1 February and 12 January to 8 February in 1996 and 1997, respectively (Table 4). The average date of parturition for both years combined was 22 January (SE = 2.19, $\underline{n}$ = 17, median = 22 January). Mean parturition dates for older females ($\geq$ 5 years) did not differ ($\underline{Z}$ = 1.902, $\underline{P}$ = 0.057) from younger (3 or 4 years) females.

Mean estimated litter age at time of cub measurements was 62.1 (SE = 3.03) and 58.3 (SE = 1.64) days in 1996 and 1997, respectively. Litter age varied from 52 to 72 days in 1996 and 49 to 66 days in 1997.

One female provided 2 estimated dates of parturition and at least one female provided an incorrect estimated date of parturition. Bear S-30's estimated dates for parturition were 27 January 1996 and 28 January 1997. The estimated date of parturition for female S-19 was 28 January 1996. However, cubs were heard at her den site on 23 January 1996. This is the only known discrepancy in estimated date of parturition and when cubs were heard at den sites. However, cubs were not heard at all den sites.

Cub Growth Measurements
Male cubs had greater neck girth ($\underline{F}$ = 5.70, df = 1,34, $\underline{P}$ =0.023) and front paw width than female cubs ($\underline{F}$ = 7.59, df = 1,34, $\underline{P}$ = 0.009; Tables 5, 6, and 7). Cubs weighed more ($\underline{F}$ = 10.72, df = 1,35, $\underline{P}$ = 0.002) in 1997, but had greater front paw length ($\underline{F}$ = 11.74, df = 1,34, $\underline{P}$ = 0.002) in 1996 (Table 8).

Table 4. Estimate dates of parturition for bears in the southern George Washington and Jefferson National Forests, Virginia in 1996 and 1997.

Bear ID #	Age of Sow	Date handled	Estimated litter age	Estimated date of parturition
S-5	7	3/22/96	56	1/27/96
S-11	7	3/15/96	70	1/5/96
S-19	6	3/21/96	53	1/28/96
S-20	7	3/19/96	72	1/7/96
S-25	17	3/24/96	52	2/1/96
S-30	3	3/23/96	56	1/27/96
S-47	5	3/26/96	69	1/17/96
SN-4	9	3/28/96	69	1/19/96
S-30	4	3/28/97	59	1/28/97
S-39	13	3/27/97	55	1/31/97
S-41	8	3/19/97	66	1/12/97
S-42	5	3/24/97	63	1/20/97
S-82	7	3/17/97	59	1/17/97
S-87	3	3/25/97	55	1/29/97
S-92	3	3/29/97	49	2/8/97
S-94	3	3/24/97	59	1/22/97
S-99	15	3/21/97	60	1/20/97

Table 5. Average measurements and ± SE of male cubs captured in the southern George Washington and Jefferson National Forests in March 1996 and 1997.

	Average	
Measurement	1996 (n)[1]	1997 (n)[1]
Weight (kg)	2.06±0.11 (13)	2.40±0.15 (10)
Total length (mm)	459.5±12.3 (13)	459.2±7.8 (10)
Chest girth (mm)	277.7±7.2 (13)	269.5±9.9 (10)
Neck girth (mm)	189.7±6.8 (13)	188.3±6.3 (10)
Front paw length (mm)	47.5±3.0 (13)	37.5±1.9 (10)
Front paw width (mm)	38.5±1.2 (13)	38.8±1.3 (10)
Hind paw length (mm)	56.4±2.5 (13)	59.7±1.2 (10)
Hind paw width (mm)	35.1±1.6 (13)	37.4±1.6 (10)
Hair length (mm)	39.5+2.4 (13)	26.0±0.4 (10)
Ear length (mm)	32.2+1.2 (13)	39.7±1.2 (10)

[1] sample size

Table 6. Average measurements and ±SE of female cubs captured at den sites in southern George Washington and Jefferson National Forests in March 1996 and 1997.

	Average	
Measurement	1996 (n)[1]	1997 (n)[1]
Weight (kg)	1.67±0.13 (8)	2.24±0.09 (7)
Total length (mm)	438.6±16.4 (7)	462.3±12.1 (7)
Chest girth (mm)	251.6±11.0 (7)	274.7±3.6 (7)
Neck girth (mm)	166.8±7.7 (7)	183.6±7.3 (7)
Front paw length (mm)	44.4±2.8 (7)	36.4±1.7 (7)
Front paw width (mm)	33.3±2.2 (7)	36.7±1.7 (7)
Hind paw length (mm)	54.1±6.2 (7)	55.3±3.2 (7)
Hind paw width (mm)	35.7±2.5 (7)	34.7±1.2 (7)
Hair length (mm)	29.7±1.6 (7)	31.9±2.0 (7)
Ear length (mm)	38.3±4.2 (7)	38.3±1.7 (7)

[1] sample size

Table 7. Average measurements and ±SE of male and female cubs captured at den sites in the southern George Washington and Jefferson Forests during March 1996 and 1997.

	Average		
Measurement	Males (n)[1]	Females (n)[1]	P-value[2]
Weight (kg)	2.21±0.09 (23)	1.94±0.11 (15)	0.069
Total length (mm)	459.4±7.6 (23)	450.4±10.3 (14)	0.316
Chest girth (mm)	274.1±5.8 (23)	263.1±6.4 (14)	0.136
Neck girth (mm)	189.1±4.6 (23)	175.2±5.6 (14)	0.023
Front paw length (mm)	43.2±2.1 (23)	40.4±1.9 (14)	0.331
Front paw width (mm)	38.6±0.8 (23)	35.0±1.4 (14)	0.009
Hind paw length (mm)	57.8±1.5 (23)	54.7±3.3 (14)	0.428
Hind paw width (mm)	36.1±1.1 (23)	35.2±1.3 (14)	0.561

[1] sample size
[2] Analysis of covariance (covariate – cub age)

Table 8. Average measurements and ±SE of cubs at den sites in the southern George Washington and Jefferson National Forest in March 1996 and 1997.

	Average		
Measurement	1996 (n)[1]	1997 (n)[1]	P-value[2]
Weight (kg)	1.91±0.09 (21)	2.33±0.10 (17)	0.002
Total length (mm)	452.2±9.9 (20)	460.5±6.5 (17)	0.362
Chest girth (mm)	268.6±6.5 (20)	271.6±5.9 (17)	0.569
Neck girth (mm)	181.7±5.6 (20)	186.4±4.6 (17)	0.335
Front paw length (mm)	46.5±2.1 (20)	37.1±1.3 (17)	0.002
Front paw width (mm)	36.6±1.2 (20)	37.9±1.0 (17)	0.297
Hind paw length (mm)	55.6±2.6 (20)	57.8±1.5 (17)	0.579
Hind paw width (mm)	35.3±1.3 (20)	36.3±1.1 (17)	0.503

[1] sample size
[2] Analysis of covariance (covariate – cub age)

Discussion

Timing of Estrus

Timing of estrus in the GWJNF was slightly later than in other populations. Most studies reported a peak in the timing of estrus (breeding) during the first week of July (Alt 1989, Eiler 1981, Barber and Lindzey 1986). In this study, 4 of 9 nonlactating females, captured between 11 July and 30 July were in exhibited signs of estrus. However, trapping effort may be not be the same over all studies; therefore the dates that bears were observed in estrus may not be comparable between studies.

Timing of estrus in this study supports data from other bear populations in Virginia. Five of 10 females in the present study were observed in estrus during 11 July – 3 August (range 20 June – 21 August). Godfrey (1996) and DuBrock (1980) reported similar dates in northern GWJNF and SNP, respectively. A later and longer breeding season in the GWJNF may be influenced by localized food sources, nutritional condition of the females (Eiler et al. 1989, Godfrey 1996, Jonkel and Cowan 1971, Rogers 1987), a lower age of reproduction, and the variability in dates of estrus for young females.

Age of Primiparity

Age of primiparity ($\bar{x}$ = 3.0) in the current study was numerically lower than many other reported populations (Alt 1989, Eiler et al. 1989, Elowe and Dodge 1989, Kasworm and Their 1994, Kolenosky 1990, Lindzey and Meslow 1977, McLaughlin et al. 1994, Rogers 1987, Schwartz and Franzmann 1991). In addition, within Virginia, age of primiparity in the present study was numerically lower than for nonexploited populations (Carney 1985, Hellgren 1988), but numerically similar to exploited populations (Godfrey 1996).

In the present study, 5 of 6 radio-marked 3-year old females gave birth. This was numerically similar to Pennsylvania, where more than 80% of females gave birth by age 3 (Alt 1989). However, this was a much higher numerical proportion than other populations. Godfrey (1996) and Clark (1991) reported that 66.7% of 3-year old females gave birth in exploited populations. In unexploited Virginia populations, fewer than 40% of females gave birth by age 3 (DuBrock 1980, Hellgren 1988, Kasbohm 1994). Fewer than 33.3% of 3-year olds gave birth in Tennessee, Ontario, and Arkansas (Eiler 1981, Kolenosky 1990, Smith 1985).

In Minnesota, no females produced cubs unless they weighed at least 41 kg the preceding March or 67 kg on 1 October of the preceding year (Rogers 1977, Noyce and Garshelis 1994). Beecham (1980) reported that females in Idaho did not reproduce until they weighed at least 52 kg. If female bears in the southeastern United States have to reach a minimum weight to reproduce, it is much lower than western populations. I could not accurately estimate a minimum weight for females producing cubs in the GWJNF. In the present study, the only female available to reproduce that was not known to produce cubs was a 3-year old female that had a summer weight of 53.5 kg. The minimum summer weight of a female known to produce cubs was 36.4 kg.

Minimum breeding age increases from east to west and south to north (DuBrock 1980). The lowest and highest reported minimum breeding ages were 1.5 in the southern GWJNF (present study) and Pennsylvania (Alt 1989) and 5.6 in Alaska (Miller 1987). Other populations (Alt 1989, Elowe 1987, Godfrey 1996, McLaughlin et al. 1994) near the same longitude increased as latitude increased from south to north. Minimum breeding age for female bears near the same latitude typically increased as longitude increased (LeCount 1984, Miller 1987, Reynolds 1977, Rogers 1987) from east to west. Females in the Smoky Mountains of Tennessee were the only exception ($\bar{x}$ = 4.4). In Tennessee, the high age of minimum breeding was attributed to extreme mast failure (Eiler 1981).

A high average weight ($\bar{x}$ = 44.9 kg in summer) and small sample sizes of 3-year old females might have been the main factors for the low age of primiparity in this study. No females were documented giving birth at age 4. One radio-collared female did not give birth at age 3 and will produce her first litter at a later age. The reproductive status of 3 3-year old females was unknown because of early den emergence. It is unlikely that any of these females had cubs. If this is true and these females produce their first litters at age 4, the average age of primiparity likely will rise to that reported by other studies in the eastern United States.

Alt (1989), in Pennsylvania, reported one case of a 2-year old female producing cubs. In the present study, no radio-collared 2-year old females produced cubs. However, the reproductive tract of a non-collared 2-year old female contained 2 fetuses, indicating that she bred at 1.5 years of age. In addition, we captured one 1.5-year-old female in estrus.

Percent Reproducing

Small litter sizes, a prolonged interbirth interval, and delayed sexual maturity make it necessary for the maximum number of females to reproduce to sustain population levels. Percentage of reproductive tracts containing corpora lutea (Hellgren 1988) and interbirth intervals have been used to index the percent of the population that reproduces each year (Carney 1985, Kasbohm 1994, Kasworm and Their 1994, McLaughlin et al. 1994, Schrage 1994)

Percent reproducing was numerically higher in this study than other exploited populations of Virginia. Godfrey (1996) reported that 82.6% of available females in the northern GWJNF produced cubs. Twenty-one of 22 (95.4%) available females in this study reproduced. Small geographic effects probably influenced the percent reproducing in the northern GWJNF. Godfrey (1996) reported that all females in the Elliot Knob area failed to reproduce in 1996, possibly because of localized mast conditions. In the present study, there were not any specific geographical areas that showed a lack of reproduction.

In Maine, 80% of available females reproduced at the Spectacle Pond study site during good mast years, but only 13% of available females reproduced during bad mast years (McLaughlin et al. 1994). The mast conditions in the southern GWJNF were fair to good and good (VDGIF unpublished doc.) in 1995 and 1996, respectively. As length of the present study increases, further insight will be gained on how mast conditions and different food sources affect reproduction in the southern GWJNF.

Interbirth Interval

Female black bears normally breed every 2 years unless there is poor mast production (Eiler et al. 1989, McLaughlin et al. 1994) or an entire litter is lost (Carney 1985). In Tennessee, skips in the every-other-year breeding cycle were caused by extreme mast failure (Eiler 1981). Females in the Spectale Pond region of Maine did not reproduce because of a failure in the beechnut crop even if entire litter loss occurred in the spring (McLaughlin et al. 1994).

Interbirth interval in the southern GWJNF was numerically lower than reported in other studies (Alt 1989, PA; Eiler et. al. 1989, TN; Elowe and Dodge 1989, MA; Hellgren and Vaughan 1989, VA and NC; Kasworm and Their 1994, MT; Kolenosky 1990, ON; Miller 1994, AS; Noyce and Garshelis 1994, MN). Carney (1985) reported that age and experience of the mother heavily influenced entire litter loss and cub survival. A small sample size of females followed in consecutive winters and entire litter loss by first time mothers greatly influenced the interbirth interval in this study. Godfrey (1996) also attributed a low interbirth interval to litter loss by first time mothers. Extreme mast failures did not occur during the present study. All (n = 3) the adult females $\geq$5 years old in this study exhibited interbirth intervals of 2.0 years. As length of the study increases and a greater number of mature females are followed for consecutive years the interbirth interval likely will approach 2.0.

Litter Size

Average litter size in this study ($\bar{x}$ = 2.2) was numerically smaller than for other exploited populations in the eastern United States ($\bar{x}$ = 2.4-3.0; Alt 1989, Eiler et al. 1989, Elowe 1987, Kraus et al. 1988, McLaughlin et al. 1994, Rogers 1987, Smith 1985). However, it was similar to other populations in Virginia ($\bar{x}$ = 2.0-2.3; Carney 1985, Godfrey 1996, Hellgren 1988). The numerically smaller average litter size was influenced by the higher proportion of young (3 and 4 years) mothers.

Average litter sizes have been correlated with age (Alt 1989, Fuller 1993, Godfrey 1996, Kolenosky 1990) and weight of the female (Alt 1989, Kolenosky, 1990), but in this study, age of female and litter size were not closely related. Young females ($\leq$ 4 years) in the southern GWJNF had a numerically higher average litter size ($\bar{x}$ = 1.7, n = 8) than those in the northern GWJNF ($\bar{x}$ = 1.4, n = 16). The relationship between weight of females in the southern GWJNF and litter size could not be evaluated because we were unable to remove adult bears from tree dens to weigh them (Chapter 3).

Immobilizing bears in tree dens has been a problem with bear studies in the past. Studies have reported litter sizes without knowing the litter size of female bears denning in trees (Eiler 1989). Females that used ground dens in the southern GWJNF (present study) had a larger average litter size ($\bar{x}$ = 2.5) than females in tree dens ($\bar{x}$ = 1.4). Godfrey (1996) reported that there was no difference in litter sizes or age and weight of females using ground dens and tree dens in the northern GWJNF. A scarcity of large tree dens could force larger females to den on the ground, but enable smaller females to den in trees (Chapter 3). Some studies may overestimate average litter sizes if there is a correlation between litter size and den type, but only ground den information is reported.

Some studies have used reproductive tracts to estimate mean litter size (Collins 1973, Strickley 1961, Harlow 1961, Hellgren 1988), percent reproducing, percent available to reproduce, minimum breeding age (Collins 1973, Hellgren 1988), and interbirth intervals (Hellgren 1988). Collins (1973) noted that 16 of 48 reproductive tracts in North Carolina contained placental scars. Three of 4 (75%) reproductive tracts in this study contained placental scars and 1 contained fetuses and corpora lutea. Tsubota et al. (1990) reported that all female grizzly bears with new placental scars had produced cubs that year. In the present study, all of the females with new placental scars were marked females that produced cubs that year. However, the high proportion of females with new placental scars is not a representative sample of the population. Two of the 3 females were nuisance bears that had been introduced to our study area and later died from car collisions (Chapter 2). If they had not been wearing eartags, I probably would not have been contacted about their deaths. One unmarked female's reproductive tract contained 2 fetuses and 2 corpora lutea. Each uterine horn contained 1 fetus; however both corpora lutea came from 1 ovary. Collins (1973) in North Carolina and Eiler (1981) in Tennessee noted one instance each of egg migration between the horns of the uterus from 48 and 6 reproductive tracts, respectively.

Cub Sex Ratio

Some studies have reported a higher proportion of males than females in black bear litters (Alt 1982, Fuller 1993, Noyce and Garshelis 1994, Samson and Hout 1995). However, most studies have reported that cub sex ratios did not differ from 1:1 (Carney 1985, Godfrey 1996, Hellgren 1988, McLaughlin et al. 1994, Miller 1994, Schwartz and Franzman 1991). Cub sex ratio in the southern GWJNF did not differ from 1:1. Inadequate sample sizes prohibited cub sex ratio testing between litter size, weight of females, and age of mother. As the length of the study increases, sample sizes should provide enough power to detect long-term differences in cub sex ratios.

Date of Parturition

Few studies have reported dates of parturition for black bears. Alt (1989) and Carney (1985) located dens in late December and early January and returned to listen for sounds of newborn cubs. Cubs were estimated to have been born (± 2 days for Alt and ±3 days for Carney) at the midpoint from the date cubs were not heard until first sounds of newborn cubs were heard. Godfrey (1996) developed regression equations of cub growth, using hair and ear length from cubs of captive bears in Virginia, to predict dates of parturition for bears in the GWJNF. In Pennsylvania, Alt (1989) used regression from hair length of wild cubs with known dates of parturition to predict cub age.

In the present study, the estimated average date for parturition was 22 January (20 January 1996 and 24 January 1997). This is numerically similar to other populations in the GWJNF, but slightly earlier than the SNP. Godfrey (1996) reported average dates of parturition for the northern GWJNF ranged from 22 January to 26 January. Average dates of parturition for bears in SNP were 20 January, 5 February, and 2 February (Carney 1985).

In Pennsylvania, older females gave birth earlier than younger females (Alt 1989). Godfrey (1996) in the northern GWJNF and Carney (1985) in SNP both reported that females $\geq$ 5 years old and females $\leq$ 4 years old gave birth during a similar time interval. Females $\geq$ 5 years old, in the present study, appeared to give birth earlier (10 days) than females $\leq$ 4 years old; however the differences were not significant ($\underline{P}$ = 0.057). The SNP and northern GWJNF are closer geographically to each other than to the southern GWJNF. Localized food sources, condition of adult females, and small sample sizes of dates of parturition for young females may be the reason that they appeared to have given birth later in the southern GWJNF, but not in the northern GWJNF and SNP.

Estimated date of parturition for female S-19 was 28 January 1996; however, cubs were heard at her den site on 23 January 1996. This was the only known discrepancy between estimated date of parturition and when cubs were heard at the den sites. Variability surrounding the regression equation is unknown for wild bears because the data used to develop the equation is from captive bears at Virginia Tech. There should be little observer bias in the measurements used because hair length (Alt 1989) and ear length are easy to measure. Hair length showed low variation, it was easy to measure, and growth appears less influenced by nutritional status (Alt 1989). Alt (1989) concluded that hair length would be an excellent predicator of date of parturition when cubs are less than 50 days. However, the accuracy in predicting parturition dates decreases after 50 days because hair growth is more variable. All females, except bear S-92, provided estimated litter ages over 50 days. Incidentally, female S-92 provided the latest date of parturition, 8 February. One person, with the exception of 1 litter, took all of the cub measurements in the southern GWJNF; therefore observer bias in the southern GWJNF cub measurements should be minimal. Estimated dates of parturition (using regression equation) should be tested with known parturition dates in the southern GWJNF to show evidence that the regression is correct for wild populations. A random selection of easily accessible dens of females available to reproduce could be located before 1 January. Observers could return to the dens every 4 days and listen for newborn cubs (Alt 1989). Regression equations could then be used to predict the estimated date of parturition and a Signed Rank test performed to tell if there is a difference between known parturition dates and estimated parturition dates.

Cub Growth Measurements

Bears are generally uniform in size and weight at birth, but experience sexual dimorphism later in life. Alt (1989), in Pennsylvania, reported that weights of cubs did not differ at birth, but differed in March. However, most of Pennsylvania's cubs were measured before they were 50 days old and had a chance to show large variation. Males, in the present study, had a greater neck girth and front paw width and appeared to weigh more than females, but the differences were not significant ($\underline{P}$ = 0.069). Cubs were measured at an average of 62.1 and 58.3 days after birth in 1996 and 1997, respectively.

Sexual dimorphism was probably more pronounced in the southern GWJNF than Pennsylvania because of the cub's ages.

Cub growth measurements are difficult to compare across studies because there is variation in date of birth, litter sizes, nutritional condition of the female, and in the time the cubs are handled. Cubs in the GWJNF (northern and southern) during 1996 were born and handled at approximately the same time. Cub measurements in the southern GWJNF were slightly higher than measurements in the northern GWJNF (Godfrey 1996). The mast conditions in both areas were "fair to good" (VDGIF unpublished doc.).

Cub weight is heavily influenced by the weight of the mother, litter order (first or subsequent litter for the mother), and litter size (Alt 1989, Noyce and Garshelis 1994). In Minnesota, 40% of the variation in total litter weight and 28% of variation of individual cub weight was accounted for by the weight of the mother. However, no other cub body measurements were different (Noyce and Garshelis 1994). Mast conditions in the southern GWJNF were "fair to good" and "good" in 1996 and 1997, respectively (VDGIF unpublished doc.). Average litter size was numerically larger in 1996 ($\bar{x}$ = 2.5) than 1997 ($\bar{x}$ = 1.9), but the two were not statistically different. However, cubs weighed more in 1997 than 1996. Smaller litter size and a better mast crop in 1997 might explain why cubs weighed more that year.

Summary and Recommendations for Future Study

The mean dates for females captured in estrus and estimate dates of parturition were 24 July and 22 January, respectively. The average age of primiparity of radio-collared females was 3.0 years; however, we documented fetuses present in a 2-year-old noncollared female's reproductive tract. The mean litter size was 2.2 with a cub sex ratio of 1:1. The average interbirth interval was 1.6 years with 95.4% of available females producing cubs.

Future work should focus on the reproductive rates over an extended period of time with respect to food availability, female survival rates, and the reproductive input of young females. We can not explain why females in the southern GWJNF breed at an unusually early age and why a higher proportion of them bred than would be expected. However, natural foods are adequate and an unknown amount of supplemental food is provided almost year round by hunters. Future reproductive research should focus on determining the relationship between supplemental feeding and reproductive performance within the population.

Chapter 2: Survival

Introduction

Black bears are at the top of the food chain throughout much of their range and humans are the only predators that have an appreciable impact on black bear populations. Major causes of mortality come from hunting (Carney 1985, Kasworm and Thier 1994, Wooding and Hardisky 1994), car collisions (Wooding and Brady 1987), and cannibalism (Mattson et al. 1992).

Hunting is the major cause of mortality in adult black bears (Carney 1985, Higgins 1997, Kasworm and Thier 1994, Wooding and Hardisky 1994). Due to their large home ranges, males are more likely to come into contact with humans and thus are more susceptible to human induced mortality (Carney 1985). Kasworm and Thier (1994) found an annual survival rate of 73% for adult males and 79% for adult females in Montana. In Ontario, overall survival of adults ranged from 74%-83%, but the survival rate of adult males in a nonhunted population was 90% (Kolenosky 1986). In SNP, Virginia, the annual survival rate of adult males was 57%-60%, and 90-95% for females (Kasbohm 1994). In Alaska, females were 2-3 times more likely to survive to adulthood than males (Schwartz and Franzmann 1992).

Subadults have higher mortality rates than adults (Elowe and Dodge 1989). Males disperse from their natal areas as yearlings or 2-year olds, whereas many females tend to stay in their natal areas (Schwartz and Franzmann 1992). Dispersal directly affects survival by putting bears at a higher risk of mortality from car collisions and cannibalism from larger bears (Schwartz and Franzmann 1992). Carney (1985) reported that yearlings had the highest mortality rate (54%) of any age class. Female bears 3-6 years old and males 2-6 years old in Ontario were more vulnerable to hunting than older age classes (Kolenosky 1986).

Cub survival is one of the most important demographic parameters to black bear population growth. Long interbirth intervals, low reproductive rates, and high parental investment cause cub survival to become crucial to bear populations. Black bear cub mortality can be caused by cannibalism (Higgins 1997), predation (Higgins 1997), disease, hunting (LeCount 1987), interactions with humans (Elowe and Dodge 1989), and natal den flooding (Alt 1984a). Social regulation (LeCount 1987) and habitat quality (Rogers 1976) may play an important role in cub survival. Miller (1994) reported a 41% mortality rate of black bear cubs in Alaska during their first year. In Virginia, the estimated annual survival rate of black bear cubs was 65-76% (Carney 1985, Carney and Vaughan 1987, Higgins 1997, Kasbohm 1994, Hellgren 1988, Schrage 1994). Alt (1982) reported a survival rate of 72% for Pennsylvania. Arizona cubs experienced the lowest reported survival rate (52%, LeCount 1987).

The majority of cub deaths occur while they are in the den or shortly after emergence from dens. In Ontario, black bear cubs had a higher mortality rate in the first 5-8 months of life than later in the year (Kolenosky 1990). LeCount (1987) and Higgins (1997) reported that most cub moralities occurred within 60 days of den emergence. Alt (1984a) reported cases of black bear cub moralities due to natal den flooding in Pennsylvania. In Massachusetts, 76% of cub mortality occurred between 1.5 and 5 months of age (Elowe 1987).

Black bear cubs of first time mothers experience a higher mortality rate than cubs of older females. In Pennsylvania, 55% of litters of first time mothers experienced some mortality, but only 15% of experienced females' litters had any mortality (Alt 1982). Similarly, Elowe (1987) found that 57% of first litters were lost, whereas only 7% of subsequent litters did not survive. In Maine, 29% and 6% of first and subsequent litters were lost, respectively (McLaughlin et al. 1994). Carney (1985) attributed the deaths of 2 cubs to the inexperience of first time mothers. Alt (1982) hypothesized that the higher mortality rate of young mothers' litters may result from inability and inexperience to raise and nourish cubs.

Total mortality of litters is common in black bears. In Arizona, (46%) 6 of 13 litters experienced total mortality (LeCount 1987). Carney and Vaughan (1987) showed that 30% of 10 litters in SNP, Virginia experienced total mortality by the end of their first summer. Alt (1982) reported that 73% of females that lost cubs lost their entire litters.

Mortality rates, with respect to litter size, seem to vary among studies. In Minnesota, larger litters had higher cub mortality (Rogers 1976). Pennsylvania's black bears had a higher cub mortality when litter size was small (Alt 1982).

Methods

Black bears were captured in summers of 1995 and 1996 (see live trapping and handling). Each bear was marked with an uniquely numbered black ear tag and tattooed on the inside lip with a number corresponding to the ear tag. All female bears and a sample of male bears were fitted with radio collars (Wildlife Materials, Inc., Carbondale, IL. or Advanced Telemetry Systems [ATS], Isanti, Mn) with a breakaway cotton spacer. Each radio collar was equipped with a motion sensitive mortality sensor. Each Wildlife Materials collar had a 30-minute delay and ATS collars had an 8-hour delay for activating the mortality switch. We tested total capture sex ratios between years with a z-test for proportions. A Chi-square goodness of fit test was used to determine if the total capture sex ratio differed from 1:1. We tested the age at first capture between years and sexes with a z-test of proportions and a t-test, respectively.

Adult radio-collared bears were checked twice a week to determine age and sex specific survival rates. Aerial telemetry was used when the bears left the study area. Bears with collars on mortality mode for more than 3 hours were located to determine the bear's status (mortality or prematurely dropped collar).

We fitted a sample of black bear cubs with transmitters during 1996 and 1997 to determine cub survival. Den sites of radio-collared female bears were located in January and visited in March (Chapter 3). In 1996 and 1997, we fitted a sample of cubs (weighing at least 1.8 kg) with expandable radio collars (ATS). Also in 1997, a sample of cubs was equipped with radio transmitters implanted subcutaneously (ATS; Moll et al. 1997). Cubs were immobilized with a 3:1 mixture of ketamine hydrochloride and xylazine hydrochloride at dosage rate of 0.045 ml per kg. Cub transmitters were equipped with a 4-hour motion sensitive sensor. Dr. David Moll (Virginia-Maryland Regional Veterinary School) preformed the surgery on all implanted cubs (Moll et al. 1997). In 1996 and part of 1997, each cub was marked with a uniquely numbered green ear tag. We mointered each female and her cubs within 24 hours of immobilizing the sow and again at 72 hours to ensure the cubs were not abandoned.

Radio marked cubs were monitored every 2 days following den emergence until 1 August and twice a week from 1 August until den entrance. We investigated the site of each cub transmitter observed on mortality within 24 hours if the cub was not with the sow. Body condition, position of carcass, method of feeding (if preyed upon), and injuries were determined for each dead cub. All remains were collected and returned to Virginia Tech for further examination.

Total litter loss and minimal cub survival was determined by following females with cubs in consecutive years. Females producing cubs in consecutive years were assumed to have experienced total litter loss.

A direct harvest rate was calculated for bears caught and marked in the summer trapping season and harvested in the next fall hunting season. We tested for differences in harvest rates between sexes with a Chi-square test. To account for bears moving outside the study area, the number of bears available for harvest was reduced by the proportion of marked bears killed outside the study area. We did not document any marked females being harvested outside of the study area. Differences in proportion of bears killed by hunting method were tested with a Chi-square test. In addition, we tested the differences in ages of male bears harvested by deer hunters versus hound hunters with a t-test.

Survival rates for radio collared females were calculated using the Kaplan-Meier staggered entry design (Pollock et al. 1989). Yearly survival estimates were calculated for adult females ($\geq$ 4 years old) and juvenile females (1 to 4 years old) from 1 June to May 31. Bears entered the survival calculations following a 7-day conditioning period to allow for any research-related bias. Bears that prematurely dropped their collars were censored from analysis at the midpoint of when the collar was last heard in active mode and first day it was heard on mortality mode (Higgins 1997).

Annual male survival rates were calculated using MARK. Due to the bias associated with radio collars and visible eartags, only noncollared males marked with black eartags were included in analysis. Yearly survival estimates were produced with program MARK (Burnham 1993). This program accounts for live recaptures and dead recoveries. Maximum and minimal survival estimates were calculated for each age class. All bears with an unknown fate were assumed to have lived through the year for calculated maximum survival estimates and assumed to have died in the year for calculated minimal survival estimates.

Variance and 95% confidence intervals were calculated for each survival estimate. For male bears, an approximate chi-square test statistic was used to compare different survival estimates. Annual survival rates of females were compared with a Z statistic (Pollock et al. 1989, Schwartz and Franzmann 1991). For female bears, survival functions were compared among different age classes with a log rank and approximate chi-square statistic.

Results

Age structure

Ninety-three bears (65 M, 28 F) were captured 141 times. We equipped 34 bears (6 M, 28 F) with radio collars. The average age of males (2 males were not aged) captured was 2.7 (SE = 0.43, n = 39) and 2.1 (SE = 0.33, n = 24) in 1995 and 1996, respectively (t = 0.865, P = 0.390; Figure 4). The average of females was 4.5 (SE = 0.85, n = 19) and 4.0 (SE = 1.33, n = 9) in 1995 and 1996, respectively (t = 0.343, P = 0.735). The average age of females ($\bar{x}$ = 4.4, SE = 0.71, n = 28) was greater (t = 2.950, P = 0.017) than males ($\bar{x}$ = 2.5, SE = 0.30, n = 63). The capture sex ratios were 2.1M : 1F (50 males, 24 females) and 1.6M : 1F (41 males, 26 females) in 1995 and 1996, respectively (Z = 0.790, P = 0.429). The total capture sex ratio of 1.8 M : 1 F (91 males, 50 females) differed (χ^2 = 11.922, P = 0.001) from 1:1.

Adult Mortality

During 1995 and 1996, 42 (36M, 6F) of 92 marked bears were known to have died (Table 9). Of the 36 marked males dying, 29 (80.5%) were harvested, 2 bears (5.5%) were killed by car collisions, 2 (5.5%) were poached, 1 (2.8%) died from euthanasia, and 2 (5.5%) died of research related moralities. Of the 6 marked females dying, 2 were harvested, 2 were killed by car collisions, and 2 died of research related mortalities. Four of the marked bears were equipped with radio collars; two (1M: 1F) died from car collisions, 1 female from handling, and 1 male from hunting.

We documented 2 illegal kills and 1 wounding loss of juvenile male bears during this study. In mid-November 1995, the pelt of a 2-year old male was recovered from a trash bin by game wardens and VDGIF personnel. The ear tags had been removed, but the bear was identified by his tattoo. The bear was poached during the first week of muzzleloader season for deer. In mid-January 1997, VDGIF personnel recovered the carcass of a 3-year old male. The bear had been shot on posted private property. One front paw from the bear had been removed, but the bear was identified by his ear tags. Due to mortal injuries, 1 juvenile male bear captured by VDGIF on a nuisance complaint died from euthanasia under the advice of the Virginia-Maryland Regional Veterinary School. The bear had been shot in the front leg and the bone was completely shattered.

Three (1M: 1F) of 4 bears dying from car collisions were bears moved to our study area after being captured on nuisance complaints. Both (n = 2) harvested females prematurely dropped their collars prior to hunting season. Two females died during den season due to research related moralities. One female, had a tight collar (cub collar did not expand) and died while being immobilized. We suspect the second female died from suffocation after being immobilized at Virginia Tech's bear research facility.

Harvest Rate

Thirty-one marked (29M, 2F) bears were reported harvested in 1995 and 1996. Harvest rates for marked males were 36.1% and 45.5% in 1995 and 1996, respectively (χ^2 = 0.126, P = 0.723, df = 1). Zero percent and 5.9% of marked females were harvested in 1995 and 1996, respectively (χ^2= 1.029, P = 0.310,df = 1). Males were harvested at a greater rate (χ^2 = 10.065, P = 0.002, df = 1) than females. Three male bears were harvested by bowhunters, deer hunters harvested 11 males, and hunters using dogs harvested 15 males and 2 females. Bowhunters harvested less (χ^2 = 9.143, P = 0.002, df = 1) males than dog hunters, but a similar proportion as deer hunters (χ^2 = 3.007, P = 0.083, df = 1). Harvest rates between deer hunters and hunters using dogs did not differ (χ^2 = 2.098, P = 0.147, df = 1). Age structure of harvested male bears did not differ (t = 1.064, P = 0.299) between hunters using dogs and deer hunters (Figure 5). Age structure was not tested between bears harvested by bowhunters and gun hunters or dog hunters because of small sample size. Mean age of captured and harvested males did not differ (t = 0.363, P = 0.718). Females were harvested at the same rate by bowhunters, deer hunters, and dog hunters (χ^2 = 0.986, P = 0.321, df = 2).

Female Survival

Annual adult and juvenile survival rates for radio collared females were 100% (SE = 0.00, n = 1-19, 95% CI = 100.0 % - 100.0%) and 93.3% (SE = 0.06, n = 1-14, CI = 80.7 % - 100.0%), respectively. Survival of juvenile females was lower in 1995 (87.5%) than in 1996 (100.0%; Z = 0.875, P > 0.05); however, survival of adult females did not differ between 1995 and 1996 (Z = 0.00, P > 0.05). Annual survival rates for adult females was not higher than the annual survival rate of juvenile females (χ^2 = 1.25, P > 0.05).

Male Survival

Maximum and minimum annual survival rates for noncollared ear tagged males were 51.6% (SE = 0.089, n = 31, 95% CI = 34.5% - 68.3%) and 32.2% (SE = 0.083, n = 32, 95% CI = 18.3% - 50.2%), respectively in 1995 and 55.9% (SE = 0.085, n = 34, 95% CI = 39.2% - 71.4%) and 12.5% (SE = 0.068, n = 34, 95% CI = 4.1% - 32.3%), respectively in 1996 (Table 10). Annual survival estimates produced by MARK were 34.6% (SE = 0.955, n = 31, 95% CI = 19.0% - 54.9%) and 33.8% (SE = 370.271, n = 34, 95% CI = 0.0% - 100.0%) in 1995 and 1996, respectively. Maximum annual juvenile male survival was 52.0% and 51.7% in 1995 and 1996, respectively (χ^2 = 0.074, P = 0.785). Inadequate sample sizes prevented us from testing differences between adult male and juvenile survival.

Table 9. Mortality causes of black bears in the southern George Washington and Jefferson National Forests, Virginia 1 June 1995 – 31 May 1997.

	Number of bears								
	Males				Females				
	Collared		Noncollared		Collared		Noncollared		
Cause of death	95-96	96-97	95-96	96-97	95-96	96-97	95-96	96-97	Total
Bear hunting with dogs	0	0	8	7	0	0	0	2	17
Bear hunting without dogs	1	0	2	8	0	0	0	0	11
Bear hunting with archery	0	0	2	1	0	0	0	0	3
Vehicle collisions	1	0	1	0	1	0	0	1	4
Poached	0	0	1	1	0	0	0	0	2
Research	0	0	1	1	0	1	0	1	4
Euthanasia	0	0	1	0	0	0	0	0	1
Unknown	0	0	0	0	0	0	0	0	0
Total	2	0	16	18	1	1	0	4	42

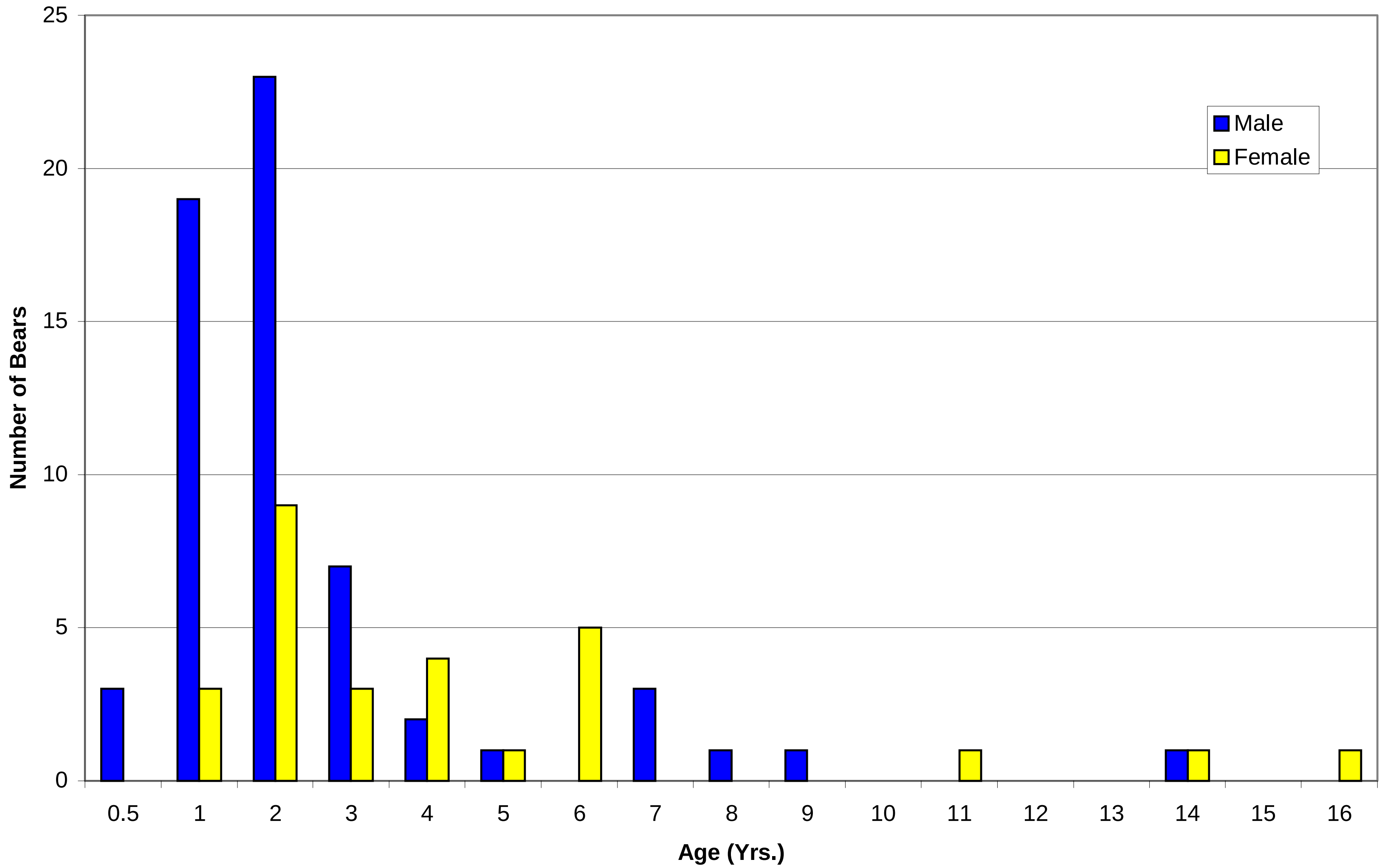

Figure 4. Age structure of male and female black bears captured in 1995 and 1996 on the George Washington Jefferson National Forests, Virginia.

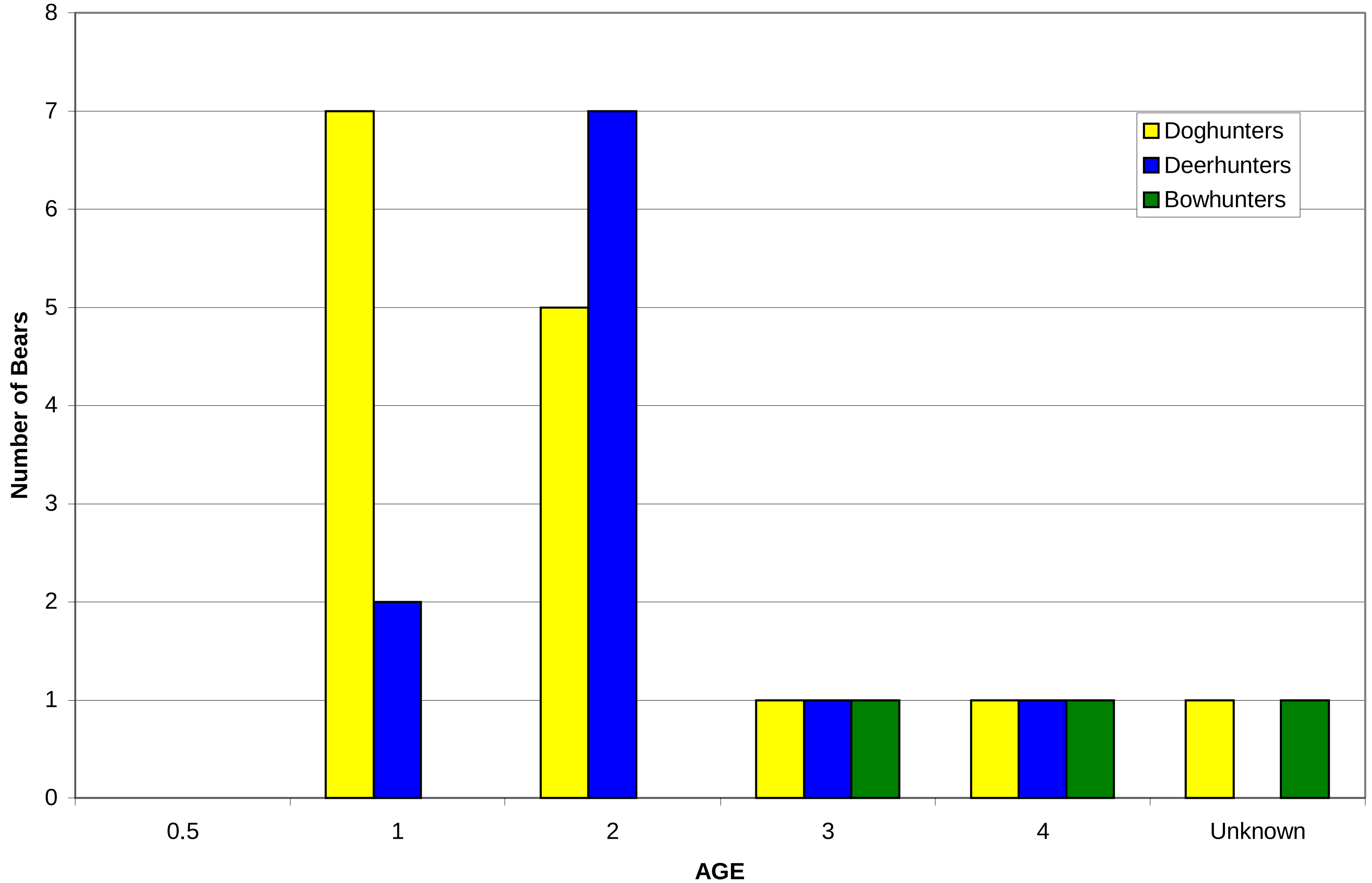

Figure 5. Age structure by method of harvest for male black bears on the southern George Washington Jefferson National Forests, Virginia 1995 and 1996.

Table 10. Minimum, maximum, and program MARK survival estimates from male bears marked with black ear tags in the southern George Washington Jefferson National Forest, Virginias, 1 June 1995 to 31 May 1997.

	MINIMUM SURVIVAL EST.[1]				MARK SURVIVAL EST.[2]				MAXIMUM SURVIVAL EST.[3]			
CLASS	S(x)	SE	LOWER	UPPER	S(x)	SE	LOWER	UPPER	S(x)	SE	LOWER	UPPER
JUV. MALE 95	36.0%	0.096	19.9%	56.0%	36.0%	0.096	19.9%	56.0%	52.0%	0.099	33.1%	70.4%
AD. MALE 95	16.7%	0.152	2.3%	63.1%	18.6%	213.877	0.0%	100.0%	50.0%	0.204	16.8%	83.2%
MALE TOT 95	32.2%	0.083	18.3%	50.2%	34.6%	0.955	19.0%	54.9%	51.6%	0.089	34.5%	68.3%
JUV. MALE 96	6.9%	0.047	1.7%	23.8%	33.7%	468.001	0.0%	100.0%	51.7%	0.093	34.1%	68.9%
AD. MALE 96	20.0%	0.179	2.7%	69.1%	52.4%	0.000	52.4%	52.4%	80.0%	0.178	30.9%	97.3%
MALE TOT 96	12.5%	0.068	4.1%	32.3%	33.8%	370.271	0.0%	100.0%	55.9%	0.085	39.2%	71.4%

[1]Minimum survival using Program MARK; with unknown individuals assumed to have died
[2]Survival estimates from Program MARK (Burhman 1993)
[3]Maximum survival using Program Mark; with unknown individuals assumed to have lived

Table 11. Fate of black bear cubs equipped with radio transmitters in the southern George Washington Jefferson National Forests, Virginia 1996 and 1997.

Cub Id	Sow Id	Transmitter type	Status	Days equipped	Mortality cause
S-60	S-20	COLLAR	DIED	183	UNKNOWN
S-61	S-20	COLLAR	SURVIVED TO DEN[1]	350	RESEARCH
S-68	S-5	COLLAR	DIED	259	POACHED
S-72	S-30	COLLAR	DIED	123	PREDATION
S-73	S-25	COLLAR	SURVIVED TO DEN[2]	335	NA
S-76	S-47	COLLAR	DROPPED	3	NA
S-79	SN-4	COLLAR	DROPPED	103	NA
S-80	SN-4	COLLAR	DROPPED	47	NA
S-114	S-39	COLLAR	DROPPED	2	NA
S-115	S-39	COLLAR	DROPPED	1	NA
S-117	S-30	IMPLANT	SURVIVED TO DEN	257+	NA
S-118	S-30	IMPLANT	SURVIVED TO DEN	257+	NA
S-121	S-41	COLLAR	DROPPED	0	NA
S-123	S-41	COLLAR	DROPPED	13	NA
S-124	S-94	COLLAR	REMOVED	5	NA
S-125	S-99	IMPLANT	SURVIVED TO DEN	250+	NA
S-126	S-99	IMPLANT	SURVIVED TO DEN	250+	NA
S-127	S-82	COLLAR	DROPPED	10	NA
S-128	S-2	IMPLANT	DROPPED	5	NA
S-129	S-2	IMPLANT	DROPPED	11	NA

[1]Collar did not expand [2]Collar expanded

Cub Transmitters
In the winters of 1996 and 1997, we equipped 14 cubs with expandable radio collars and 4 with transmitters implanted subcutaneously (Table 11; Moll et al. 1997). In addition, we equipped 2 cubs with subcutaneous implants in July 1997 and 1 cub in May 1996. Eight cubs dropped their collars prematurely, 2 implants came out of the cubs, 1 collar was removed from a cub that was abandoned in the den season, 3 cubs died, and 6 cubs lived until they were at least 1 year old. We fostered the abandoned cub to an adult female at Virginia Tech's bear pens. Six of 8 cubs that dropped their collars prematurely did so within 150 meters of their den sites. One of 2 expandable collars checked in the den did not expand; it had severely grown into the bear's neck.

Cub Mortality
Three of 14 cubs equipped with transmitters, which were not censored immediately after den emergence, died in 1996 and 1997. One cub was killed by a mammalian predator on 29 May, 1 cub died from unknown causes on 8 July, and 1 cub died from poaching on 12 October. In addition, 1 ear tagged, non-collared cub died from a car collision on 17 May. Age of mortality ranged from 119 – 259 days of age (Table 12).

Cub Survival
Cub survival was lower ($\underline{Z}$ = 2.59, $\underline{P}$ = 0.0048) in 1996 (46.3%, $\underline{n}$ = 1-8, 95% CI = 2.4% - 90.1%) than 1997 (100.0%, $\underline{n}$ = 1-6, 95% CI = 100% - 100%). We combined cub survival between years because of small sample sizes. Cub survival in the southern GWJNF was 70.1% ($\underline{n}$ = 1-14, 95% CI = 41.3% -98.9%).

Five of 9 (55.5%) females lost at least 1 cub in 1996 and maximum cub survival was 70.8% (Table 13). In 1997, as of 10 December, no females were known to have lost 1 cub. Two of three first time mothers in 1996 experienced total litter loss. However, two adult females (> 4 years old), producing cubs in 1996, had an 83.3% cub survival.

Table 12. Estimated age of mortality for black bear cubs in the southern George Washington National Forests, Virginia 1996.

Cub Id	Sow Id	Estimated Date of Birth	Mortality Cause	Mortality Date	Age at Death
S-60	S-20	1-7-96	Unknown	7-8-96	183 Days
S-68	S-5	1-27-96	Poached	10-12-96	259 Days
S-72	S-30	1-27-96	Predator	5-29-96	123 Days
S-78[1]	SN-4	1-19-96	Vehicle collision	5-17-96	119 Days

[1]Bear was not equipped with a radio transmitter

Table 13. Maximum survival of black bear cubs in the southern George Washington and Jefferson National Forests, Virginia 1996.

Sow Id	Sow Age	# of Cubs	Sow Status in 1997	# of Cubs Known Dead	Maximum Survival
S-2	3	2 (2 unknown)	Cubs	2 males	0.0%
S-5	7	2 (1M, 1F)	Dropped Collar	1 male (collared)	50.0%
S-11	7	1 (1M, 0F)*	Dropped Collar		
S-19	6	4 (1M, 3F)	Harvested	Unknown	100.0%
S-20	7	4 (2M, 2F)	Yearlings	1 male (collared)	75.0%
S-25	17	2 (1M, 1F)	Yearlings	0	100.0%
S-29	4	2 (2 unknown)	Harvested	Unknown	100.0%
S-30	3	2 (2M, 0F)	Cubs	2 males (1 collared)	0.0%
S-47	5	3 (2M, 1F)	Dropped Collar	Unknown	100.0%
SN-4	5	3 (3M, 0F)	Car Collision	1 male (not collared)	66.7%
Total/Mean	6.4	25 (13M, 8F, 4 unknown)		7	70.8%

*Cub abandoned at den site and transported to Virginia Tech bear pens

Discussion

Age Structure

Despite the facts that the sex ratio at birth was 1:1, and male bears had a higher mortality rate than female bears, age structure of bears captured was skewed toward juvenile males. Larger home ranges (Carney 1985), dispersal from natal home ranges (Schwartz and Franzmann 1992), and male curiosity make males more susceptible to capture. In addition, our trapping season coincided with breeding season, when adult males increase their movements to find receptive females. Trapping also occurs during family breakup, when juveniles are first dispersing from their natal home range.

The average age of males at first capture in this study is indicative of other exploited populations ($\bar{x}$ = 2.7 years; Higgins 1997), but was numerically lower than the nonexploited population of the GDSNWR ($\bar{x}$ = 4.3 years; Hellgren 1988). The average age of males in 1995 ($\bar{x}$ = 2.7 years) was numerically higher than in 1996 ($\bar{x}$ = 2.1 years), but the difference was not statistically significant. The numerically higher age of males in 1995 was reflective of the first year of trapping in the southern GWJNF, because fewer adult males were available for original capture in 1996. Because young males immigrate and emigrate into and from the study area, and because young males appear to be more susceptible to capture than any other age and sex group the average age of males at first capture is likely to remain around 2 years.

The average age of females at first capture ($\bar{x}$ = 4.4 years) was numerically similar to other nonexploited ($\bar{x}$ = 4.0 – 4.3 years; Hellgren 1988, Kasbohm 1994) and exploited populations ($\bar{x}$ = 4.9 years; Godfrey 1996) of Virginia. The average age of females was numerically higher in 1995 ($\bar{x}$ = 4.5 years) than in 1996 ($\bar{x}$ = 4.0 years), but they did not differ statistically. As the length of the study increases, the average age of females at first capture may decrease because a larger proportion of adult females will be marked, young females are less likely to immigrate into the study area, and female survival is high. Thus, there likely will be fewer adult females not previously captured. The age structure in the southern GWJNF shows evidence that males are killed at a younger age than females.

To assure an unbiased marking of the population, changes could be made in trapping methods. Because most trapping is done from roads in the same areas in consecutive years, bears living in home ranges with roads are more likely to be caught. Therefore, bias could be associated with mark/recapture population estimates, survival estimates (hunters are more likely to kill bears near roads), and age structures, if bears living away from roads have a greater survival. However, in the present study there are few areas that are inaccessible to vehicles and there is probably little bias associated with trapping in the southern GWJNF (unpubl. data). Trails through wilderness areas and areas inaccessible to vehicles could be trapped to improve a random marking of the population.

Adult and Juvenile Mortality
All documented moralities (100%) were human related, closely matching that reported in the northern GWJNF (81%; Higgins 1997), Alaska (88-100%; Schwartz and Franzmann 1991), Arizona (83%; LeCount 1987), Minnesota (> 90%; Rogers 1976), and Tennessee (>95%; Smith 1985). Hunting (80.5%) was the major source of mortality in male bears, with harvest rates skewed to young ($\leq$ 2) male bears. Higgins (1997), in the northern GWJNF, also reported hunting as the major source of mortality. In Virginia, the major causes of mortality in nonexploited populations were cannibalism, vehicle collisions, poaching, legal kills (outside of study area), and damage complaint kills (Hellgren 1988).

In the present study, 4 radio-collared bears (2M: 2F) died from vehicle collisions. Three (1M: 2F) of 4 were nuisance bears that were relocated in our study area. Comly (1993) reported vehicle collisions as a major mortality cause of relocated, nuisance bears. In addition, all 4 were killed during hunting season (1 in October, 1 in November, 2 in December). One male, hit and killed by a vehicle on 24 December, moved more than 40 miles in less than 24 hours, indicating that hunting dogs might have pursued him.

Two juvenile male bears were killed illegally and 1 juvenile male bear died from euthanasia after sustaining mortal injuries from a bullet. In other Virginia populations, Kasbohm (1994), Hellgren (1988), and Higgins (1997) reported 3 illegal kills in the SNP, 4 in the GDSNWR, and 0 in the northern GWJNF, respectively. We do not have an adequate assessment of the percentage of illegal kills or wounding loss in the population.

Harvest Rate
Marked males (mostly ear-tagged) were harvested at a higher rate than marked females (mostly radio-collared). Harvest rates did not differ between deer hunters and bear hunters using dogs; however, bear hunters using dogs harvested a numerically higher proportion of bears.

Hunting as currently practiced in the southern GWJNF is not likely to have a large impact on the female bear population. If the harvest rate of females reported in the present study is accurate, only 2 of 29 (7.1%) tagged (collared and not collared) females were harvested, this should not be large enough proportion to have an effect on the total population. Many pregnant females reduce their movements prior to bear hunting season with dogs (Godfrey 1996); therefore they are less likely to be located by hunting dogs. In addition, many juvenile females (1 and 2 years old; Appendix 1) are below, or only slightly above, the legal harvest weight limit, making them less susceptible to hunting. Some hunters apparently select against harvesting female bears, and most of them knew that the majority of collared bears were females (K. Higgins unpubl. doc.); thus, they may avoid harvesting a collared bear when given the opportunity. The true association with collar bias relating to hunting rates was unknown.

In the southern GWJNF, male harvest rates are numerically higher than other exploited bear populations (Higgins 1997, Kasworm and Their 1994). In the present study, greater than 40% of the marked bears were harvested yearly. The long term effects of harvesting such a high proportion of males is unknown at this time. Population modeling will be done by the current Ph D. student. However, if the reproductive rates remain high and the proportion of available females that reproduces remains constant, then there likely will be enough males to sustain high harvest rates.

Female Survival

The survival rates of females were numerically similar to other populations (Beck 1991, Doan-Crider and Hellgren 1996, Elowe and Dodge 1989, Kasworm and Their 1994, LeCount 1982, Schwartz and Franzman 1991, Waddel 1984). In Virginia, adult female survival (100%) was numerically similar to an exploited population in the northern GWJNF (95%; Higgins 1997), but only slightly higher than unexploited populations in the SNP (92%; Carney 1985) and GDSNWR (87%; Hellgren 1988; Table 14). In addition, juvenile female survival rates were numerically similar in the southern (88%; present study) and northern (90%; Higgins 1997) GWJNF. The reported adult female survival rates may be numerically lower in the SNP (Carney 1985) and GDSNWR (Hellgren 1988) because in those studies all age classes of females were grouped together for survival analysis.

In the present study, reported survival rates of females may not accurately reflect the true survival for the population. All females captured in this study were equipped with a radio collar to obtain reproductive information. Some hunters (especially those using hounds) apparently select against harvesting female bears (per. conversations with hunters). We worked closely with the houndsmen that hunted our study area (Higgins unpubl. doc.), and most of them knew that the majority of collared bears were females; thus, they may avoid harvesting a collared bear when given the opportunity.

To accurately estimate the female survival rate in the southern GWJNF, an unbiased harvest rate must be calculated. Only 2 marked females were harvested in the southern GWJNF and both had prematurely dropped their radio transmitters. In addition, both hunters harvesting the females said they would not have harvested them if they had known they were females (pers. communications with the hunters). Our sample size of ear tagged but noncollared females was inadequate to test for differences in survival rates of collared females versus noncollared females. As the study lengthens, a larger sample of females marked only with black ear tags will be needed if collar bias is to be assessed. Subcutaneous implants (Moll et al.1997) could be used to obtain both survival and reproductive information.

Male Survival

Only bears marked with black ear tags were used to calculate male survival rates; thus bias from visible marks was minimized. Some hunters revealed (per. commun.) that they unknowingly harvested marked bears after looking for, but not discovering the tags. Fifty–six (34 of 60) percent of males marked only with black ear tags were reported dead, suggesting a high reporting rate.

Maximum survival rates for adult (64%; present study; 59%; Carney 1985; 59%; Hellgren 1988; 50%; Kasbohm 1994) and juvenile (52%; present study; 50%; Higgins

Table 14. Reported survival rates of black bears in Shenandoah National Park (SNP), Great Dismal Swamp National Wildlife Refuge (GDSNWR), and the George Washington Jefferson National Forests (GWJNF), Virginia.

Sex and Age Class	Survival	Area	Status	Citation
Adult Female	100 %	Southern GWJNF	Exploited	Present Study
	95 %	Northern GWJNF	Exploited	Higgins 1997
	92 %	SNP	Unexploited	Carney 1985
	89 – 94 %	SNP	Unexploited	Kasbohm 1994
	87%	GDSNWR	Unexploited	Hellgren 1988
Juvenile Female	94 %	Southern GWJNF	Exploited	Present Study
	90 %	Northern GWJNF	Exploited	Higgins 1997
Adult Male	64 %	Southern GWJNF	Exploited	Present Study
	100 %	Northern GWJNF	Exploited	Higgins 1997
	59 %	SNP	Unexploited	Carney 1985
	50 %	SNP	Unexploited	Kasbohm 1994
	59 %	GDSNWR	Unexploited	Hellgren 1988
Juvenile Male	52 %	Southern GWJNF	Exploited	Present Study
	50 %	Northern GWJNF	Exploited	Higgins 1997
	100 %	GDSNWR	Unexploited	Hellgren 1988
Cub	73 %	Southern GWJNF	Exploited	Present Study
	64 %	Northern GWJNF	Exploited	Higgins 1997
	73 %	SNP	Unexploited	Carney 1985
	76 %	GDSNWR	Unexploited	Hellgren 1988

1997) males were numerically similar to survival rates of male bears in other Virginia populations. However, adults in the northern GWJNF (100%; Higgins 1997) and juveniles in the GDSNWR (100%; Hellgren 1988) had a higher survival rate than bears in the present study. In the present study, juvenile male survival was numerically lower than unexploited populations in Mexico (100%; Doan-Crider and Hellgren 1996) and Colorado (76%; Beck 1991), but numerically higher than an exploited population in Massachusetts (25%; Elowe and Dodge 1989). Other survival rates for juvenile males in Arizona (77% - 93%; LeCount 1982, Waddel 1984) and Alaska (38 – 70%; Schwartz and Franzmann 1991) varied among exploited populations. In Virginia, most mortalities of male bears were human caused (Higgins 1997, Hellgren 1988, Kasbohm 1994).

The difference between minimum and maximum survival estimates is the percentage of animals with unknown fates; i.e. natural mortality, bears immigrating from the study area or not recaptured, illegally killed, or wounding loss. As the length of the study increases, the gap between the minimum and maximum survival estimates should narrow. When minimum survival ceases to increase, the difference between the 2 estimates could be used as an index of natural moralities, illegally killed, and wounding loss in the population. The range in the minimum and maximum survival rates for juvenile males was numerically greater in 1996 - 1997 (6.9% - 51.7%) than in 1995 – 1996 (36.0% - 52.0%); however, we had a greater opportunity to account for, recapture, or harvest the animals tagged in 1995. The maximum juvenile male survival estimates did not differ between years, indicating that this might be an accurate reflection of the true maximum survival of the population.

Many bear studies concentrate on the female segment of the population; thus low sample sizes of males equipped with radio transmitters prevent many studies from making accurate estimates of male survival. Juvenile males are difficult to equip with radio-collars because they grow rapidly, and adults' necks are too large to collar. In addition, bears are generally trapped in the summer, but may double their weight in the fall, making tight collars a problem (present study).

Survival estimates of individuals tagged with black ear tags may accurately reflect the true mortality from hunting. However, a large random proportion of the population must be marked to accurately estimate the percentage of bears dying from illegal kills, wounding loss, and natural mortalities. To accurately reflect the true survival rate of the population, the mark (transmitter or ear tag) must not affect the survival of the individual (White and Garrott 1990). Thus, if the mark has an effect on its survival, hunters or poachers must not be able to distinguish that the animal is marked in any manner. A random sample of males could be equipped with subcutaneous implants (Moll et al. 1997) to determine if natural mortality, poaching, or wounding loss has an impact on the population in the southern GWJNF. If natural mortality, poaching, or wounding loss do not have a significant impact on the GWJNF, and tag returns are high, then the true survival of the population is close to the maximum survival of individuals with black ear tags.

Cub Transmitters

To estimate cub survival, we equipped 14 and 6 cubs with expandable radio collars (Higgins 1997) and subcutaneous implants (Moll et al. 1997), respectively. The collars were largely ineffective, because we lacked experience in equipping cubs with expandable collars. I put the majority of expandable collars on cubs in the southwest study area.

Nine of 14 cubs dropped their collars early, 1 collar did not expand, 3 cubs died during the year, and 1 collar had expanded properly when checked in its den. Higgins (1997) noted that without a standardized amount of torque to tighten the bolts to the collar, the cub collar might drop prematurely or not expand. To date, we have been unable to calculate the standardized amount of torque. In addition, weather conditions appeared to have an effect on expandable cub collars. Some of the collars' bolts rusted, preventing the collar from expanding, whereas the material in some collars expanded (or shrunk) making the collar ineffective. To make the collar effective, all of the hardware must be totally rust resistant, collar material must not shrink or expand, and the tightness of the collar must be standardized.

Four of 6 transmitters implanted subcutaneously during March 1997 - July 1997 were still working on 10 December 1997; however 2 implants were dropped prematurely. Cubs may prematurely drop their implants because of sibling or maternal behavior, size of the implant, or physiological rejection (pers. obs.).

Cub Mortality

Most cub morality is reported to occur between 1 and 5 months of age (Doan-Crider and Hellgren 1996, Elowe and Dodge 1989, Higgins 1997, LeCount 1987); however, in the present study, cub moralities ranged from 4-9 months of age. LeCount (1987) noted that cubs were more vulnerable to predators shortly after den emergence. In the present study, the only cub known to be killed by a predator was killed within 1.5 months of den emergence. Cubs, separated from their mothers before late summer, may not have enough experience to survive their first year. I suspect that one cub, which died of unknown causes in July, died of starvation after being separated from his mother. Human related mortality in the present study accounted for 50% of the total cub mortalities.

Cub Survival

Cub survival is one of the most important, but least understood parameters of black bear biology. Small litter sizes and delayed sexual maturity require high cub survival rates to maintain a stable or increasing bear populations. In the past, researchers have estimated cub survival by counting the number of cubs in a female’s den and then observing how many yearlings den with her the next year (Carney 1985). However, this may underestimate cub survival because yearlings may den separately from their mothers (Higgins 1997). To accurately estimate cub survival, cubs must be equipped with radio transmitters.

In Virginia, cub survival in the southern GWJNF (70%) was numerically similar to populations in the SNP (73%; Kasbohm 1994), GDSNWR (76%; Hellgren 1988), and the northern GWJNF (65%; Higgins 1997). However, it was numerically higher than cub survival in Massachusetts (59%; Elowe and Dodge 1989), Ontario (46%; Strathearn et al. 1984), and Arizona (52%; LeCount 1987) and numerically lower than cub survival in Mexico (81%; Doan-Crider and Hellgren 1996), New York (80%; Simek 1995), and Alaska (74% - 91%; Schwartz and Franzmann 1991). Differing methods of estimation and small sample sizes make it difficult to compare cub survival across different regions. However, even with different methods, all estimations of cub survival in Virginia were numerically similar.

Likely young mothers have a lower cub survival due to inexperience and inability to nourish cubs (Alt 1982, Elowe and Dodge 1989). In the present study, 2 of 3 young mothers experienced total litter loss. Experience gained as a 3-year old mother, even if the entire litter is lost, could help prepare for subsequent litters. Three-year old mothers S-30 and S-2 experienced total litter loss in 1996; however they produced 2 and 3 cubs, respectively in 1997. Female S-2's cubs were observed in late July, indicating that they probably lived through their first year. In addition, female S-30's cubs were both radio-marked and were alive on 10 December 1997.

Summary and Recommendations for Future Study

The average age of male and females at first capture was 2.5 and 4.4 years, respectively. Yearly harvest and maximum survival rates for males ranged from 36%-45% and 52%-56%, respectively. Yearly harvest and survival rates ranged from 0%-6% and 88-100%, respectively for females. In the southern GWJNF, the annual cub survival was 70%.

To accurately estimate survival in the southern GWJNF, bears marked only with black ear tags and bears equipped with radio transmitters should be used in the survival estimates. Unbiased radio transmitter data, from subcutaneous implants, could be combined with data from bears marked only with black ear tags to increase sample sizes and more accurately assess the survival of both male and female bears. As the study lengthens, we should know what, if any, causes of mortality have a detrimental affect on the male black bear population of the southern GWJNF.

By continuing to equip cubs with radio transmitters we should be able to estimate the effects of mortality causes and the timing of mortality for black bear cubs. In addition, a larger sample of cubs from young mothers (3 and 4 years old) should be equipped with transmitters to assess the reproductive contribution of young mothers to the population. Also, a transmitter should be designed so that the cubs may be equipped randomly (i.e. without regard to size and weight). In the present study, no cubs weighing less than 1.8 kg were equipped with a transmitter. If heavier cubs are more likely to survive, we may have overestimated cub survival.

Chapter 3: Denning Ecology

Introduction

Black bears have adapted to decreased food availability and severe winter climatic conditions by denning (Johnson and Pelton 1980). The metabolic state of hibernation and energy-conserving adaptations help bears to survive hard winters (Hellgren and Vaughan 1989, Nelson et al. 1983). Types of dens, time of den entrance and emergence, length of time spent in den, and den availability differ within the black bear's range. Manville (1987) showed that male black bears in Michigan den an average of 1.26 km and females 0.55 km away from human disturbance. In some areas, denning makes bears less vulnerable to hunting (Alt 1984b). Den sites that tend to be successful provide adequate protection from weather, are safe from predation or human disturbances, and are energetically efficient (Oli et al 1997).

Bears prepare for denning by accumulating fat reserves. Schwartz et al. (1987) noted that the amount of fat and rate of fat catabolism is related to how much time a bear may spend in its den. As den entry approaches, bears confine themselves to a small area around their den (Kolenosky and Strathearn 1987). Once the bear enters its den, it does not eat, drink, defecate, or urinate for as long as 7 months (Hellgren et al. 1990). Declines in body temperature, heart rate, and oxygen consumption are characteristic of hibernating black bears (Folk 1967, Hellgren et al. 1990, Watts et al. 1981).

Types of dens vary geographically and depend in part on length and severity of winter, den availability, and human disturbance. Bears den in tree cavities, excavated dens, rock piles or cavities, nest-like depressions, man made structures (culvert pipes), and brushpiles. The majority of dens in Tennessee (Johnson and Pelton 1980, Wathen et al. 1986), Virginia (Godfrey 1996, Kasbohm 1994), Louisiana (Weaver and Pelton 1994), and Prince William Sound, Alaska (Schwartz et al. 1987) were tree dens. Excavated dens were prominent in Alaska (Schwartz et al. 1987), Idaho (Beecham et al. 1983), Montana (Jonkel and Cowan 1971), Ontario (Kolenosky and Strathearn 1987), West Virginia (Kraus et al. 1988), and forested wetlands of Virginia and North Carolina (Hellgren and Vaughan 1989). Ground nests were the most predominant type of den in swamps of Florida (Wooding and Hardisky 1992), Virginia, and North Carolina (Hellgren and Vaughan 1989). Bears in Pennsylvania (Alt 1984b), Arkansas (Hayes and Pelton 1994), and SNP, Virginia, (Carney 1985) denned most frequently in rock cavities. Manville (1987) reported that den selection of upland, swamp, and lowland habitats in Michigan was significantly different between the sexes.

Tree dens are important to successful denning throughout much of the black bear's range. Weaver and Pelton (1994) found that the majority of tree dens in Louisiana were in bald cypress (*Taxodium distichum*), whereas most of the bears in the SNP (Carney 1985, Kasbohm 1994), the northern GWJNF (Godfrey 1996), and the southern Appalachian Mountains (Wathen et al. 1986) denned in chestnut oak or northern red oak. The average distance of the den entrance hole above the ground was 14 meters in Louisiana (Weaver and Pelton 1994), 9.2 m in SNP, Virginia, (Carney 1985) and 12.1 meters in the southern Appalachian Mountains (Wathen et al. 1986). In the northern GWJNF, Godfrey (1996) reported that the average height of entrance holes above the ground were 7.1 m and 9.6 m for chestnut and red oaks, respectively. Wathen et al. (1986), in Tennessee, and Carney (1985), in Virginia, found the mean DBH of tree dens was 100.7 cm and 94.6 cm, respectively. The mean DBH of chestnut and red oaks in the northern GWJNF was 85 cm and 95 cm, respectively (Godfrey 1996). Weaver and Pelton (1994) reported that bald cypress den trees averaged 183 cm DBH. Ground dens had more understory vegetation (Wathen et al. 1986) and a greater slope (Carney 1985) than tree dens.

Rock cavity dens are essential to many black bear populations. They are usually structurally secure and typically on steep slopes far away from any human disturbance (Hayes and Pelton 1994). Den sites with a larger amount of basal area and those found on steeper slopes may offer more protection to the bears from human disturbance. Rock cavities had lower understory stem density and were in larger stands of timber than excavated dens (Hayes and Pelton 1994).

Den availability is one of the least studied, but potentially most important aspects of den ecology. In southern wetlands, den sites, and thus female productivity, may be limited by periodic flooding (Hellgren and Vaughan 1989). Alt (1984a) found that flooding of natal dens caused increased cub mortality. In Arkansas, Hayes and Pelton (1994) reported that the den types used by bears correspond closely to availability.

Early den entry and late emergence may protect vulnerable adult female bears from hunting. In most areas, adult females denned earlier and emerged later than subadults and adult males (Hellgren and Vaughan 1989, Johnson and Pelton 1980, O'Pezio et al. 1983, Tietje and Ruff 1980). In Alberta, Kolenosky and Strathearn (1987) found that yearlings denned before adult females. Weaver and Pelton (1994) in Louisiana and Hellgren and Vaughan (1989) in Virginia reported that pregnant females were typically the first to enter dens and the last to emerge. Schwartz et al. (1987) hypothesized that nonlactating females (assumed to be pregnant) denned first because they had the best opportunity to prepare for the winter. Schooley et al. (1994) hypothesized that when pregnant bears have stored enough fat for reproduction they will den.

Food availability (Schooley et al. 1994), physical condition of bears, above average precipitation (Jonkel and Cowan 1971, Lindzey and Meslow 1976), and overall cumulative effects of winter are all stimuli for den entry (Hellgren and Vaughan 1989, Johnson and Pelton 1980, Lindzey and Meslow 1976, Schwartz et al. 1987). Den entrance dates vary widely throughout the bear's range and appear to be a function of latitude. Mean den entrance dates range from early October in Alaska (Schwartz et al. 1987) to late January in Florida (Wooding and Hardisky 1992). The mean den entrance date was mid-December to early January in eastern Virginia (Hellgren and Vaughan 1989), mid-November in New York (O'Pezio et al. 1983) and Montana (Aune 1994), 27 October in Ontario (Kolenosky and Strathearn 1987), and 15 October in Alberta (Schwartz et al. 1987). The earliest den entrance date was 9 September in Alaska (Schwartz et al. 1987).

Length of time in the den generally decreases from northern to southern latitudes. Schwartz et al. (1987) reported that black bears in Alaska denned 189 - 233 days, but Wooding and Hardisky (1992) showed that bears in Florida denned on average < 90 days. Bears den for approximately 3-4 months in Tennessee (Johnson and Pelton 1980), North Carolina (Hamilton and Marchinton 1980), Mississippi (Smith 1986), and Virginia (Hellgren and Vaughan 1989), 4.5 months in New York (O'Pezio et al. 1983), 5-6 months in Montana (Aune 1994) and Ontario (Kolenosky and Strathearn 1987), and 6-7 months in Alaska (Schwartz et al. 1987). Studies have shown that males and non-pregnant females may remain active throughout the winter in the southern portion of their range (Carney 1985, Godfrey 1996, Hellgren and Vaughan 1989, Smith 1986, Weaver and Pelton 1994). Mild winter temperatures, lack of persistent snow cover, and diverse food items are factors that may contribute to winter activity and lack of denning by black bears (Hellgren and Vaughan 1989).

Den emergence may be associated with photoperiod (Kolenosky and Strathearn 1987, Lindzey and Meslow 1976), snow melt (Rogers 1987, Schooley et al. 1994, Schwartz et al. 1987), cub growth and condition, body condition, and increasing temperature (Kolenosky and Strathearn 1987, Lindzey and Meslow 1976, O'Pezio et al. 1983, Rogers 1987). Emergence dates are probably a combination of these environmental factors. Bears in the middle to southern portion of their range emerge from late March through mid April (Aune 1994, Hellgren and Vaughan 1989, Johnson and Pelton 1980, O'Pezio et al. 1983, Smith 1986). In the northern part of the black bear's range den emergence occurs from mid April to early May (Kolenosky and Strathearn 1987, Schwartz et al. 1987).

Most studies have shown that reuse of dens is low. Kolenosky and Strathearn (1987) found no indication of den reuse in Ontario, but Schwartz et al. (1987) reported den reuse as high as 75% in Alaska. Other studies (Alt 1984b, Jonkel and Cowan 1971, Weaver and Pelton 1994) reported little or no den reuse. Den reuse may be related to den availability (Tietje and Ruff 1980) and types of dens used in that area (Alt 1984b). Alt (1984b) hypothesized that low reuse may increase survival rates of black bears through decreased predation.

Human disturbance (Hellgren 1988) and flooding (Oli et al. 1997) may cause bears to use more than one den during the winter. Weaver and Pelton (1994) reported that at least 45% of bears in Louisiana used more than one den during the winter. Bears in Michigan also occasionally used more than one den (Manville 1987).

Methods

Dens were located in December, January, and February via telemetry (see telemetry). Each den site was photographed or a picture was drawn to aid in the assessment of how to enter the den when researchers returned in late February and March. Height of entrance hole from ground, width of hole, slope of the ground around the tree, and accessibility were estimated for all tree and snag dens when the den site was located.

Width of entrance hole and distance from entrance hole to bear were estimated for each ground den when the den site was located. Researchers listened for cubs (nursing and whimpering; Alt 1989) at each den located after 1 January (Chapter 1).

All accessible dens were visited in February and March. We handled male bears in late February, lone females and females with yearlings in late February to mid - March, and females with cubs in late March. Physical measurements (see live trapping and handling) were taken on adult and yearling bears. We determined reproductive status and took cub measurements in the den (Chapter 1). Ear tags, cotton spacers, and radio-collars were replaced when needed. Dens were classified as tree, snag, rock cavity, ground bed, or excavation.

Den measurements taken at each tree den site included height and width of entrance hole, aspect of den entrance, diameter of cavity inside, distance from ground to entrance hole, distance from bear to entrance hole, and diameter at breast height (DBH) (Godfrey 1996). We measured tree height and height to entrance hole with a clinometer. We tested DBH, tree height, height of entrance hole, slope, and basal area for differences between tree species with a Wilcoxon Rank Sum Test. In addition, we tested these measurements for differences in reproductive status (with cubs or without cubs) with a Wilcoxon Rank Sum test. Cavity length, width, and height were measured for rock cavities and excavations. All dens were measured according to length of nest, width of nest, depth of bedding material, and description of bedding material (Hellgren 1988).

Each den site served as the center of a .04 ha circular plot. We recorded aspect and percent slope for each den site. Basal area around den site, large, medium, and small tree densities, and understory density were estimated for each den. We tested for differences in basal area, large, medium and small tree density, understory density, slope, summer weight of bears, and mean ages of bears in tree versus ground dens with a Wilcoxon Rank Sum test. Rock cavities, excavations, slashpiles, and ground beds were considered ground dens. Den site locations were determined with GPS units and plotted on a topographic map.

Researchers used climbing gear (safety equipment, belay system, ascenders, tree pegs, and climbing rope) to access tree dens (Godfrey unpubl. manuscript). Decisions on whether to enter dens were based upon safety of workers and position of the bear in its den. Bears in tree dens were not immobilized unless they were lying down (bears in a sitting position in tree dens have been reported to suffocate when immobilized; Higgins 1997). Dens were considered workable only if a researcher could safely handle the adult bear.

Results

Denning Status

We mointered 31 bears for 39 bear winters with 100% of the bears denning. The denning status of 2 bears was unknown. We lost radio contact with a relocated nuisance bear in October 1996 and did not locate her until May 1997. Her denning status was unknown; however, it is likely that she denned that winter because we were unable to locate her through aerial telemetry. One female with an unknown denning status was in an inaccessible area from December 1996 to mid March 1997.

Habitat Characteristics

Slope, basal area, large tree density, medium tree density, small tree density, stem density, and summer weight of bears did not differ ($\underline{P} > 0.05$) between ground and tree den sites (Table 15). Average age of bears using ground dens ($\bar{x}$ = 7.1, SE = ± 0.97) was greater ($\underline{Z}$ = -2.484, $\underline{P}$ = 0.013) than bears using tree dens ($\bar{x}$ = 4.4, SE = ±0.91).

Den Type Characteristics

Females denned in tree cavities ($\underline{n}$ = 17, 48.6%), rock cavities ($\underline{n}$ = 11, 31.4%), excavated dens ($\underline{n}$ = 5, 14.3%), and ground nests ($\underline{n}$ = 2, 5.7%). Males denned in rock cavities ($\underline{n}$ = 1) and tree cavities ($\underline{n}$ = 1, Figure 6). Cavity length and width of ground dens were 206.4 cm (SE ± 24.1, $\underline{n}$ = 12) and 120.5 cm (SE ±18.7, $\underline{n}$ = 12), respectively (Table 16). Snags made up three of 17 tree cavities. Den types did not differ ($\underline{Z}$ = -1.298, $\underline{P}$ = 0.1941) between years. Percent of bears denning on public land ($\underline{n}$ = 21, 57%) did not differ (χ^2 = 0.676, $\underline{P}$ = 0.411) from those denning on private property ($\underline{n}$ = 16, 43%; Figure 7).

Tree species used as tree dens included chestnut oak ($\underline{n}$ = 9, 50.0%), red oak ($\underline{n}$ = 8, 44.4%), and tulip-poplar ($\underline{n}$ = 1, 5.6%). Red oaks had higher ($\underline{Z}$ = -2.593, $\underline{P}$ = 0.010) cavity entrances than chestnut oaks (Table 17). Tree height, slope, basal area, and DBH did not differ ($\underline{P} > 0.05$) between chestnut and red oaks or between bears with cubs and bears without cubs (Table 18).

Den Reuse

One of 19 (5.3%) dens was reused in 1997. An ear-tagged male (noncollared) used a ground den that was occupied the previous year by a radio-collared female. No radio-collared bear reused the same den.

Eight of 8 (100%) tree dens had no obvious structural damage after 1 year. However, 1 excavated den had partially collapsed.

Table 15. Den site[1] characteristics of ground and tree dens in the southern George Washington and Jefferson National Forests, Virginia in 1996 and 1997.

Characteristic	Ground Dens	Tree Dens	P-Value
Slope	34.5 ± 3.1 (13)	33.7 ± 3.5 (17)	0.601[2]
Basal area	80 ± 30 (13)	80 ± 10 (17)	0.932[2]
Trees > 50.8cm dbh/ha	70 ± 20 (13)	70 ± 20 (17)	0.833[2]
Trees 25.5-50.8cm dbh/ha	130 ± 30 (13)	90 ± 20 (17)	0.343[2]
Trees 12.7-25.4cm dbh/ha	1200 ± 840 (13)	310 ± 50 (17)	0.672[2]
Stem density (stems/ha)	8300 ± 1900 (13)	5700 ± 900 (17)	0.267[2]
Summer weight of bear (kg)	59.6 (17)	49.8 (16)	0.058[2]
Age of bear using den (mean)	7.1(19)	4.4(18)	0.013[2]

[1] 0.04 ha circular plot centered on den
[2] Wilcoxon Rank Sum

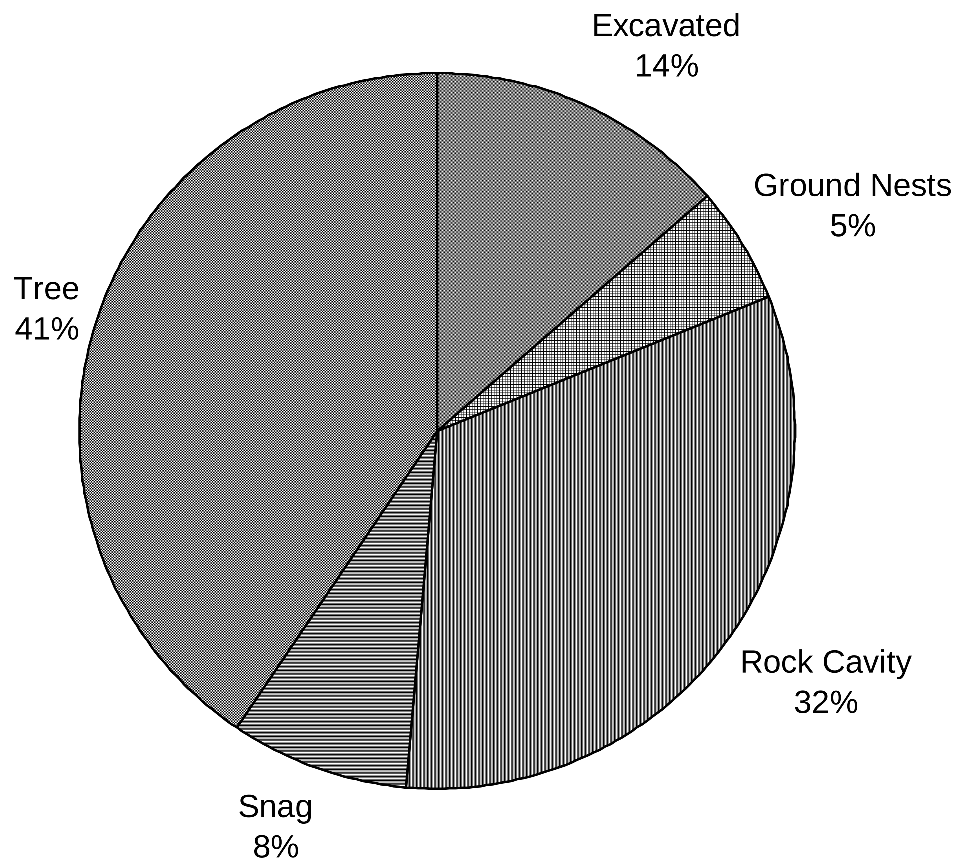

Figure 6. Black bear den types used in the southern George Washinton and Jefferson National Forests, Virginia in 1996 and 1997.

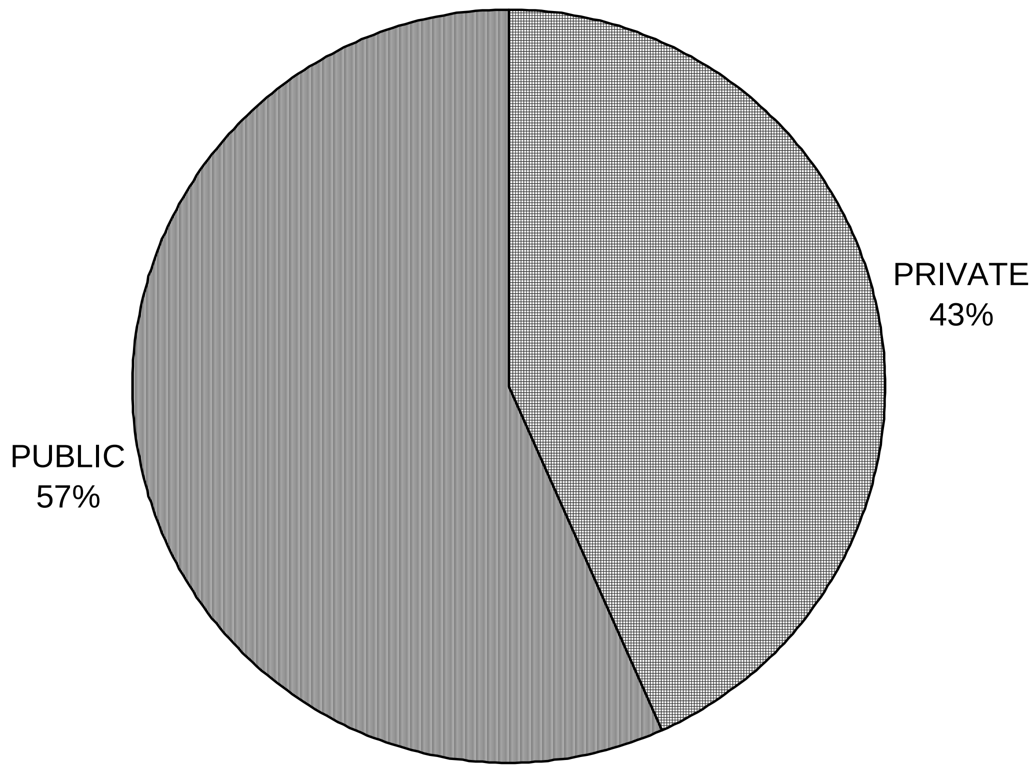

Figure 7. Proportion of bears denned on private and public land in southern George Washington and Jefferson National Forests, Virginia in 1996 and 1997.

Table 16. Ground nest dimensions of black bear den sites in the southern George Washington and Jefferson National Forests, Virginia in 1996 and 1997.

Habitat Characteristic	Mean	Standard error	Number	Minimum	Maximum
Cavity height (cm)	67.6	3.4	12	51.0	82.7
Cavity length (cm)	206.4	24.1	12	102.0	329.0
Cavity width (cm)	120.5	18.7	12	11.4	244.0
Nest length (cm)	106.6	8.9	12	58.0	157.0
Nest width (cm)	79.3	7.9	12	11.4	121.0
Bedding material depth (cm)	12.8	4.8	12	0.0	50.0
Entrance hole height (cm)	64.2	12.3	12	27.0	186.0
Entrance hole width (cm)	96.7	24.8	12	29.3	347.0

Table 17. Characteristics of red and chestnut oaks used as dens in the southern George Washington and Jefferson National Forests, Virginia in 1996 and 1997.

Characteristic	Red Oak	Chestnut Oak	P-Value
Height of tree (m)	23.3 ± 4.1 (6)	13.8 ± 8.0 (9)	0.099[1]
Height of entrance (m)	12.1 ±1.7 (7)	6.6 ± 1.6 (9)	0.010[1]
DBH (m)	1.92 ± 0.16 (8)	1.65 ± 0.16 (8)	0.189[1]
Slope (%)	29.0 ± 3.9 (8)	40.3 ± 5.6 (8)	0.074[1]
Basal area	90 ± 10 (8)	80 ± 10 (8)	0.395[1]

[1]Wilcoxon Rank Sum

Table 18. Characteristics of tree den sites used by black bears with and without cubs in the southern George Washington and Jefferson National Forests, Virginia in 1996 and 1997.

	Reproductive Status		
Characteristic	With cubs	Without cubs	P-Value
Height of tree (m)	18.6 ± 5.8 (6)	16.9 ± 3.9 (9)	0.906[1]
Height of entrance (m)	9.3 ± 1.8 (7)	8.7 ± 1.9 (9)	0.368[1]
DBH (m)	1.87 ± 0.18 (7)	1.72 ± 0.15 (9)	0.458[1]
Slope (%)	39.7 ± 6.6 (7)	30.7 ± 3.7 (9)	0.223[1]
Basal area	80 ± 10 (7)	80 ± 10 (9)	0.789[1]

[1]Wilcoxon Rank Sum

Fidelity to Den Type

Seven female bears were monitored in consecutive winters. Three of 7 (42.9%) switched from ground dens to tree dens. No bears switched from a tree den to ground den.

Eight of 21 (38.1%) and 10 of 16 (58.8%) bears used tree dens in 1996 and 1997, respectively ($\underline{Z}$ = -1.298, $\underline{P}$ = 0.194). However, the proportion of females with cubs using ground dens was higher ($\underline{Z}$ = 2.752, $\underline{P}$ = 0.005) in 1996 (9 of 10) than 1997 (4 of 10). We documented 2 bears using more than 1 den during a winter. Female S-33 emerged from her tree den after being handled and redenned in a tree den. Female S-42 emerged from her initial tree den and redenned in a tree den. We located a dead yearling bear in her initial den and suspect that she emerged after it died.

Discussion

Den Status

Hellgren and Vaughan (1989) reported that bears might show a lesser degree of dormancy or may not den at all when climatic conditions are favorable. In the southern GWJNF (present study), a numerically higher proportion of bears (100%) denned than on the northern GWJNF (81%; Godfrey 1996), SNP (94%; Kasbohm 1994), and the GDSNWR (86%; Hellgren 1988, Hellgren and Vaughan 1989). However, it is difficult to compare the proportion of bears denning between studies because of fluctuations in the annual precipitation and temperatures.

At birth, black bear cubs are uncoordinated, altricial, can not see, and may not be able to smell (Alt 1989); thus pregnant females must den to ensure that their cubs will survive. By denning, females give their cubs more time to grow, which enables them to avoid predators following den emergence. In the present study, the northern GWJNF (Godfrey 1996), SNP (Kasbohm 1994), and GDSNWR (Hellgren 1988) 51%, 47%, 33%, and 20%, respectively of bears monitored throughout the winter produced cubs. Thus, a numerically larger proportion of bears in the southern GWJNF needed to den to ensure successful reproduction.

Den Site Habitat Characteristics

Some studies report that habitat characteristics differ between ground and tree den sites. The habitat around tree dens in the southern Appalachians typically has greater basal area (Godfrey 1996, Johnson and Pelton 1980), a higher proportion of trees with a dbh greater than 50.8 cm (Godfrey 1996), and lower stem density (Godfrey 1996) than ground dens. Ground dens are on steeper slopes with a greater understory than tree dens (Johnson and Pelton 1980, Wathen et al. 1986).

Habitat characteristics of tree dens and ground dens may differ because tree dens may offer more protection from humans and predators. Habitat characteristics in the southern GWJNF did not differ between ground and tree den sites. Godfrey (1996) noted that rock cavity dens and tree dens might have similar habitat characteristics and offer the same protection from predators. However, the habitat around ground nests may have a greater stem density and a greater proportion of trees under 12.5 cm than the habitat around rock cavities because bears using ground nests are more likely to be seen by a human or another bear. In the present study, bears used a large proportion of rock cavity dens (32.4%), but fewer ground nests (5.7%) and excavations (14.3%). We pooled ground dens because of small sample sizes and were unable to test for difference habitat characteristics between ground nests and rock cavities.

Den types used by bears correspond with den availability (Hayes and Pelton 1994). In the northern GWJNF, Godfrey (1996) reported that the age and summer weights of females did not influence selection of den types. In the present study, bears using tree dens were younger than bears using ground dens. Average summer weights of bears using tree dens did not differ ($\underline{P} = 0.058$) from bears using ground dens, but bears in ground dens were on average 9.8 kg heavier. However, we do not know anything about den availability because we did not measure it.

Den Characteristics

Den types vary geographically, with tree dens (Godfrey 1996, Kasbohm 1994, Johnson and Pelton 1980, Schwartz et al. 1987), rock cavities (Alt 1984b, Carney 1985, Hayes and Pelton 1994), and excavations (Hellgren and Vaughan 1989, Jonkel and Cowan 1971, Kraus et al. 1988) being the most predominant in many populations. Tree dens may offer more protection to bears from disturbance by humans, hunters using hounds, and other bears. We expected bears in the southern GWJNF to use tree dens at the same proportion as bears in the northern GWJNF. In the southern GWJNF, use of rock cavities (32.4%) and tree dens (48.6%) did not differ significantly ($\underline{Z} = 1.4404$, $\underline{P} = 0.14975$). Bears in the southern GWJNF (48.6%) used a lower ($\underline{Z} = -3.72393$, $\underline{P} = 0.0002$) proportion of tree dens than the northern GWJNF (82.3%; Godfrey 1996). Bears in the northern GWJNF may have used a higher proportion of tree dens than bears in the southern GWJNF because a larger proportion of tree dens were available, although no measurements of den availability were made on either study area. In addition, bears in the present study used a numerically higher proportion of tree dens than bears in the GDSNWR (Hellgren 1988), a wetland in eastern Virginia, but a numerically lower proportion than bears in SNP (Kasbohm 1994), an oak-hickory forest protected since 1955.

Bears in this study used red and chestnut oaks as dens in numerically similar proportions to bears in the northern GWJNF (Godfrey 1996) and SNP (Kasbohm 1994). Chestnut and red oaks comprised 93% and 79% of the tree species used as den sites in the northern GWJNF (Godfrey 1996) and the SNP (Kasbohm 1994), respectively. Chestnut (McQuilkin 1990) and red oak (Sander 1990) are the major components of their respective forest types in the Appalachian Mountains. The northern red oak is a moderate to fast growing species living on a variety of soils and topography (Sander 1990). The chestnut oak is a slow growing, long-lived tree growing on dry south and west facing slopes, rocky outcrops, and ridge tops at a range in elevation from 450 to 1400 m (McQuilkin 1990). In addition, chestnut oak is at a higher risk to decay and fire damage than other oaks in the Appalachian Mountains (McQuilkin 1990). Sander (1990) reported that northern red oaks are susceptible to oak wilt (*Ceratocystis fagacerum*), carpenterworm (*Prionoxystus robiniae*), Columbian timber beetle (*Corythylus columbianus*), red oak borer (*Enaphalodes rufulus*), and oak timberer (*Arrhenodes minutus*), which may kill or decay their wood. A combination of red and chestnut oak being the most predominant tree species in our study area, and their susceptibility to decay, may indicate why bears choose these species as den types. In the Great Smoky Mountain National Park (GSMNP), Tennessee, only 45% of tree dens were red or chestnut oaks (Wathen et al. 1986); however, Carlock et al. (1983), in Tennessee outside of GSMNP and Georgia, reported that a majority of tree dens were chestnut oak. Oli et al. (1997), in Arkansas, reported that tree den species were comprised of overcup oak (*Q. lyrata*), bald cypress (*Taxodium distichum*), and sycamore (*Platanus occidentalis*) in a bottomland wetland. Patterns of land use (Godfrey 1996) and tree species availability (Carlock et al. 1983) may influence tree species selected as den sites. Topographical features, slopes or amount of moisture, could also influence the tree species available as den sites.

In the southern GWJNF, 43% of radio-collared bears denned on private land; however, all of the marked bears were captured on public land. The large proportion of bears denning on private land may be a function the large amount of land within our study area that is privately owned (roughly 40-50%). Alternatively, it could result from hunters with hounds pressuring bears onto public land (Godfrey 1996), land use patterns on private land, or the similarity between public and private lands in the southern GWJNF. Many private landowners do not permit hunting with hounds on their property; thus the chances for disturbance in a bear's den are reduced in December (during the hound-hunting season) if a bear is denned on private land. In addition, 9 of 11 bears captured on the Virginia – West Virginia State line moved to West Virginia to den. In Mercer and Monroe counties West Virginia (the counties adjacent to the southern GWJNF study area) hunting with hounds is not permitted. Further, the majority of the adjacent land in West Virginia is private and the majority of the land in Virginia, along the state line, is public. Thus, bears that move to West Virginia might experience less hunting pressure and more favorable denning conditions.

Den Reuse

Den reuse in the southern GWJNF was similar to most studies (Alt 1984b, Carney 1985, Godfrey 1996, Jonkel and Cowan 1971, Kasbohm 1994, Kolenosky and Strathearn 1987, Oli et al. 1997, Weaver and Pelton 1994) where den reuse was less than 10%. However, it was numerically lower than populations in Alaska were den reuse was as high as 75% (Kolenosky and Strathearn 1987).

Den reuse may be related to types of den in the area (Alt 1984b), den availability (Tietje and Ruff 1980), the smell of another bear, parasites, or the probability of a bear finding a den that had been used before. In Virginia, Godfrey (1996) and Kasbohm (1994) reported that only tree dens were reused in the northern GWJNF and SNP, respectively. In the southern GWJNF, only a rock cavity den was reused. Godfrey (1996) reported that all cases of reuse occurred by the same bear; however, Kasbohm (1994) reported one instance of an uncollared bear reusing a den that had been used previously by a collared bear. Oli et al. (1997), in Arkansas, reported an unmarked bear reusing a den that had been used previously by a radio marked animal. In the present study, a marked male bear reused a rock cavity den that had been used the previous year by a radio-collared female. Kasbohm (1994), in the SNP, reported that many trees were heavily scarred and may be used frequently as den sites. We located an unmarked female bear in a tree den that had not been used before by a radio-collared bear. The tree had claw marks on its bark and appeared to have been used before. In the southern GWJNF, we observed trees that were heavily scarred with bear claws; however many of the entrance holes were unsafe to check.

Fidelity to Den Type

Four of 7 bears in the southern GWJNF and 11 of 13 bears in the northern GWJNF used the same den types in consecutive years. In the northern GWJNF (Godfrey 1996), both (n = 2) bears that switched, switched from tree dens to ground dens, whereas in the southern GWJNF all (n = 3) bears switched from ground dens to tree dens. In the present study, 2 of 3 females that changed den types also had a different reproductive status the following year. Females S-20 and S- 25 produced cubs in 1996 and had yearlings present in their dens during 1997. Female S-30 (also changed den types) produced cubs in 1996 and again in 1997 (Chapter 1). In the northern GWJNF, both bears that change den types produced cubs during both years (Godfrey 1996).

The use of multiple dens in the same year may be attributed to flooding (Oli et al. 1997) and human disturbance (Hellgren 1988). In the present study, 2 bears used multiple den sites within the same year. One 2-year old female emerged from her den after being handled and 1 bear redenned after 1 of her yearlings died in the den. The actual number of bears using multiple dens may be higher than reported. We located the majority of den sites in January and February. Therefore, we could not document bears that were disturbed from their dens during the hound-hunting season in December.

Summary and Recommendations for Future Study

In the southern GWJNF, 100% of the bears denned. Bears denned in trees (41%), rock cavities (32%), excavations (14%), snags (8%), and ground nests (5%). Chestnut oak (n = 9), red oak (n = 8), and tulip-poplar (n = 1) were used as tree dens. Habitat characteristics did not differ between tree dens and ground dens; however, older bears used ground dens. Fifty-seven percent of bears denned on public land and we documented one instance of den reuse.

Future work should focus on den availability and denning chronology. In the southern GWJNF, understanding the availability of tree dens may reveal why heavier, older bears use rock cavities. In addition, it may assist in understanding why a large proportion of bears den on private land. The importance of denning chronology should be evaluated in the southern GWJNF. If denning chronology is to be understood, a larger number of researcher hours must be devoted to telemetry. However, before an attempt is made to understand denning chronology, an unbiased assessment of telemetry error must be made.

To ensure that den entrance dates are accurate, dens should be located within 7 days after a bear reduces its movements. Also, dens should be checked every 3-4 days in March and April to ensure that bears have emerged from their dens.

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Appendix A:
Tables

Appendix Table 1. Rating scale for signal strength of individual telemetry bearings.

Confidence factor	Description
1	Transmitter signal is picked up using only the receiver
2	Signal is loud, little static
3	Signal is strong, moderate amount of static present
4	Signal is weak but consistent
5	Signal is faint and broken

Appendix Table 2. Rating scale for a telemetry location.

Confidence factor	Definition
1	Visual sighting of animal
2	Very confident in location – animal was close; angle, time, and terrain were favorable
3	Confident in location – most conditions were favorable
4	Weak confidence in location – most conditions were favorable
5	No confidence in location

Appendix Table 3. Definitions of morphological measurements taken on black bear cubs at den sites in the southern George Washington and Jefferson National Forests, Virginia 1996 and 1997.

Measurement	**Definition**
Total length	Length along back bone from tip of nose to tip of caudal bone in tail
Ear length	Length of ear from bottom of notch to outer most edge of the ear lobe
Front paw length	Length of paw from back of main pad to anterior tip of middle tow pad
Front paw width	Width of large pad on front paw
Hind paw length	Length of paw from back of pad to anterior tip of middle toe pad
Hind paw width	Width of large pad on hind paw
Hair length	Length of longest hair on top of head midway between ears

Appendix Table 4. Description of measurements taken at black bear den sites located in the southern George Washington and Jefferson National Forests, Virginia 1996 and 1997.

Measurement	Description
Tree height	Distance form base of tree to the top of the highest branches
Cavity height	Distance from the base of tree to bottom of the cavity entrance hole
Depth to bear	Distance from bottom of entrance hole to the top of the bear inside the cavity
Entrance height	Maximum height of the entrance hole measured from top to bottom
Entrance width	Maximum width of entrance hole taken perpendicular to the entrance height
Depth of bedding material	Depth of material lining bear's nest at the center of the nest
Length of nest	Length of nest at the widest point
Width of nest	Maximum width of nest taken perpendicular to net length
Cavity length	Distance from cavity entrance to the back wall of the cavity for a ground den
Cavity width	Maximum width of ground den cavity
Cavity height	Height of ground den cavity from the center of the nest to the tope of the cavity

Appendix Table 5. Definitions of morphological measurements taken on adult black bear in the southern George Washington and Jefferson National Forests, Virginia 1995 – 1997.

Measurement	Definition
Zoological length	-tape held 5cm above bear lying on its side, from tip of nose to the tip of the tail
Actual length	-distance along the spine from tip of the nose to the end of the caudal bone
Chest girth	-circumference of chest directly behind front legs taken on the exhale
Neck girth	-circumference of the neck
Zygomatic arch	-width at the top of the head from one zygomatic arch to the other
Tail length	-from base to the tip of the tail
Ear length	-from notch of ear to tip of the ear
Shoulder height	-along the back of the front leg from the back of the large pad to the top of the scapula
Canine breadth	-buccal to lingual width of the tooth
Canine width	-anterior to posterior length of tooth
Front paw length	-tip of longest toe to the back of large pad
Front paw width	-perpendicular to length at the widest part of the large pad
Hind paw length	-tip of longest toe to back of pad
Hind paw width	-perpendicular to length at the widest part of the pad
Testicle length	-from the anterior to posterior tip
Testicle width	-perpendicular to length at the widest part of testicle
Nipple height	-height of second thoracic nipple
Nipple width	-width at base of the second thoracic nipple

Appendix Table 6. Summer measurements of female black bears captured in the southern study area of the Cooperative Allegheny Bear Study, Virginia 1995 and 1996.

Bear Id#	Date	Sex	Age	Lactating	Estrus	Cubs	Weight (kg)	Chest girth (mm)	Neck girth (mm)
S001	6/20/95	F	4	YES	NO	NO	128	880	495
S001	8/18/95	F	4	YES	NO	YES	130 (est)	735	440
S001	6/24/96	F	5	NO	NO	NO	115	750	480
S002	6/20/95	F	2	NO	YES	NO	97	720	420
S002	7/8/95	F	2						
S005	6/20/95	F	6				121	770	500
S011	6/29/95	F	6	NO	YES	NO	160	910	585
S011	8/23/95	F	6						
S019	7/20/95	F	5	NO	YES	NO	112	740	450
S019	9/1/95	F	5	NO	NO	NO	100		
S020	7/20/95	F	6	NO	NO	NO	168	870	587
S020	8/11/96	F	7	NO	NO	YES	162	875	529
S025	8/3/95	F	16	NO	YES	NO	182	860	520
S025	6/12/96	F	17	YES	NO	YES	148	806	450
S029	8/8/95	F	3	NO	YES	NO	125	758	450
S029	7/30/96	F	4	YES	NO	YES	108	858	480

Appendix Table 6. Cont.

Bear Id#	Date	Sex	Age	Lactating	Estrus	Cubs	Weight (kg)	Chest girth (mm)	Neck girth (mm)
S030	8/10/95	F	2	NO	NO	NO	82	751	465
S033	8/12/95	F	1	NO	NO	NO	60	583	350
S039	8/19/95	F	11	YES	NO	NO	140	793	480
S039	8/22/95	F	11						
S039	7/1/96	F	12	NO	NO	NO	180 (est)	880	489
S039	7/22/96	F	12	NO	NO	NO	170	910	
S041	8/20/95	F	6	YES	NO	YES	142	803	475
S041	7/1/96	F	7	NO	NO	NO		840	51.5
S041	7/12/96	F	7				152		
S042	8/20/95	F	3	YES		NO	115	760	465
S042	8/17/96	F	4	NO	NO	NO	159	872	510
S044	8/21/95	F	1	NO	YES	NO	72	630	380
S047	8/25/95	F	4	NO	NO	NO	148	865	510
S049	8/28/95	F	2	NO			105	792	470
S052	8/30/95	F	1	NO	NO	NO	68	670	425
S082	6/8/96	F	6	NO	NO	NO	103	726	468
S082	7/18/96	F	6	NO	YES	NO	105		

Appendix Table 6. Cont.

Bear Id#	Date	Sex	Age	Lactating	Estrus	Cubs	Weight (kg)	Chest girth (mm)	Neck girth (mm)
S082	7/25/96	F	6	NO	YES	NO	104		
S084	6/9/96	F	4	NO	NO	NO	122	822	598
S084	8/3/96	F	4	NO	NO	NO	135 (est)		
S087	6/17/96	F	2	NO	NO	NO	94	721	463
S092	6/27/96	F	2	NO	NO	NO	95	74	51
S092	8/19/96	F	2	NO	YES	NO	112	685	
S094	7/11/96	F	2	NO	YES	NO	110	750	495
S094	8/9/96	F	2	NO	NO	NO	125		
S094	8/29/96	F	2				118		
S097	7/18/96	F	2	NO	NO	NO	100	700	461
S097	8/7/96	F	2	NO	NO	NO	100	697.5	
S099	8/31/96	F	14	NO	NO	NO	176	859	511
S105	7/30/96	F	2	NO	YES	NO	115	738	469
S112	8/22/96	F	2	NO		NO	115	730	468
SNO3	6/9/95	F	3	YES	NO	YES	130	850	510
SNO4	11/15/95	F	4	NO	NO	NO	230	1080	680

Appendix Table 7. Measurements of black bear cubs captured at den sites in March 1996 and 1997 in the southern George Washington and Jefferson National Forests, Virginia.

WT = weight (kg)
TL = total length (mm)
HPL = hind paw width (mm)
BZ = blaze (yes or no)
NG = neck girth (mm)
FPL = front paw length (mm)
HPW = hind paw width (mm)
EL = ear length (mm)
FPW = front paw width (mm)
HL = hair length (mm)

Cub ID	Sow ID	Date	Sex	WT	NG	EL	TL	CG	FPL	FPW	HPL	HPW	HL	BZ
S-58	S-11	3/15/96	M	2.80	210	50	530	317	64	41	57	42	30	Y
S-60	S-20	3/19/96	M	2.70	210	39	470	328	60	48	65	38	39	Y
S-61	S-20	3/19/96	F	2.20	182	50	500	260	34	36	32	34	25	Y
S-62	S-20	3/19/96	M	2.20	195	56	462	260	32	39	40	37	28	N
S-63	S-20	3/19/96	F	1.80	202	35		270	38	40	62	39	35	N
S-64	S-19	3/21/96	M	1.50	170	32	447	270	40	34	45	30	25	Y
S-65	S-19	3/21/96	F	1.55	151	33	415	230	49	30	50	30	32	Y
S-66	S-19	3/21/96	F	1.65	160	25	420	250	47	30	54	31	32	Y
S-67	S-19	3/21/96	F	1.10	145	34	390	210	45	25	47	47	23	Y

Appendix Table 7. Cont.

Cub ID	Sow ID	Date	Sex	WT	NG	EL	TL	CG	FPL	FPW	HPL	HPW	HL	BZ
S-68	S-5	3/22/96	M	2.50	190	40	516	293	63	40	60	37	35	N
S-69	S-5	3/22/96	F	2.15	175	42	475	300	56	41	85	40	32	N
S-71	S-30	3/23/96	M	1.85	168	28	416	281	43	32	48	32	33	N
S-72	S-30	3/23/96	M	1.95	191	29	485	267	43	38	57	31	31	Y
S-73	S-25	3/24/96	M	1.80	169	30	416	255	57	33	51	35	27	N
S-74	S-25	3/24/96	F	1.40	153	29	397	241	42	31	49	29	29	Y
S-75	S-47	3/26/96	M	1.50	162	39	367	228	39	37	76	29	33	N
S-76	S-47	3/26/96	M	2.00	170	45	500	265	35	37	59	35	35	Y
S-77	S-47	3/26/96	F	1.50										
S-78	SN-4	3/28/96	M	2.15	200	49	475	275	50	40	60	45	39	N
S-79	SN-4	3/28/96	M	1.90	250	35	445	290	41	41	59	40	32	Y
S-80	SN-4	3/28/96	M	2.00	181	41	445	281	51	40	56	25	32	Y
S-113	S-39	3/27/97	M	2.65	207	38	465	307	32	29	61	39	24	N
S-114	S-39	3/27/97	M	2.65	200	40	478	307	31	39	62	38	24	Y
S-115	S-39	3/27/97	F	2.18	216	40	484	276	38	40	61	39	25	N
S-116	S-87	3/25/97	M	1.50	149	39	469	205	38	37	49	31	25	N
S-117	S-30	3/28/97	M	2.55	191	41	444	288	41	42	62	38	27	Y
S-118	S-30	3/28/97	M	2.50	187	40	479	251	42	43	61	49	27	N
S-119	S-92	3/29/97	M	1.80	168	31	399	242	31	39	60	32	25	N
S-120	S-41	3/19/97	F	2.10	171	36	463	264	39	39	60	34	33	Y
S-121	S-41	3/19/97	F	1.85	170	34	402	268	28	29	54	31	36	Y
S-122	S-41	3/19/97	F	2.60	193	39	492	278	33	32	39	35	39	Y
S-123	S-41	3/19/97	F	2.50	192	33	478	292	41	41	58	39	35	
S-124	S-94	3/24/97	F	2.25	185	40	438	278	40	39	51	32	27	N
S-125	S-99	3/21/97	M	2.95	190	42	469	269	49	39	59	39	28	Y
S-126	S-99	3/21/97	M	2.95	219	39	469	288	33	44	61	39	27	Y

Appendix Table 7. Cont.

Cub ID	Sow ID	Date	Sex	WT	NG	EL	TL	CG	FPL	FPW	HPL	HPW	HL.	BZ
S-127	S-82	3/17/97	M	2.00	194	42	444	264	42	38	62	34	26	N
S-130	S-42	3/24/97	F	2.20	158	46	479	267	36	37	64	33	28	N
S-131	S-42	3/24/97	M		178	45	476	274	36	38	60	35	27	N

Appendix Table 8. Den location sheet. Used when the den site is first located in the southern study area of the Cooperative Allegheny Bear Study, Virginia.

Den Location Sheet

Observer (s):________________________________ Date:_________
Bear ID#:__________ Frequency:___________

State:______________ County:____________
Quad Map:__________
Approximate Lat :__________
Long:_________

Den Type: Tree Snag Rock Cavity
Slashpile Excavated Day Bed

Tree and Snag Dens:
Approximate height of entrance hole:________m
Approximate DBH of tree:______cm
Approximate size of entrance hole:_________m
Is tree or snag slanted: Yes No

Rock Cavity or Excavated Dens:
Approximate size of entrance hole:____m
Is bear visible: Yes No

All Dens:
Were cubs heard: Yes No
Pictures taken: Yes No(if no draw picture on back of paper)
Is den workable: 1 2 3 4 5
Yes No

Comments:____
____
____
____
____

Appendix Table 9. Den description data sheet used in the southwestern study area of the Cooperative Allegheny Bear Study, Virginia 1996 and 1997.

Den Data Sheet

Identification/ Location

Bear Id: _____ Radio collar freq: _______

Den Site #: ________ Quad map: ________

UTM East:________ North: ________

County:___________

Den Type

Tree Snag Slashpile Rock Cavity

Day Bed Excavated

Tree den:

1. Live or Dead
2. Total tree height: _______
3. Height to cavity entrance: _______
4. Depth of bear in cavity from entrance: _________
5. DBH of tree: _________
6. Stand type: _______

Den Measurements

Height of entrance hole: _______

Width of entrance hole: ________

Diameter of cavity inside tree: _______

Depth of bedding material: _______

Description of bedding material: ____________________________

Length of nest: __________________

Width of nest: _____________

Cavity length :_____________

Cavity width: ______________

Cavity height: ______________

Macroscopic Site Data

Aspect of den site: __________

Aspect of den entrance: ____________

% Slope of den site: Uphill: _________ Downhill: __________

Basal area around den site: __________

Tree density: ________________

Understory density: ___________

Elevation of site: ____________

Mean stand age:_____________

Appendix Table 10. Physical characteristics of tree den sites used by black bears in the southern George Washington and Jefferson National Forests, Virginia 1996 and 1997.

TS – Tree status (D=dead; A=alive) TH – Tree height (m) CH – Cavity height (m) DB – Depth to bear (m)
DBH – Diameter breast height (m) EH – Entrance height (cm) EW – entrance width (cm) NL – Nest length (cm)
BMD – bedding material depth (cm) NW – Nest width (cm) DSA – Den site aspect DEA – Den entrance aspect

Den Id#	Bear status	TS	Tree species	TH	CH	DB	DBH	EH	EW	BMD	NL	NW	DSA	DEA
96-02	lone	D	C. OAK	2.3	2.3	2.3		0.0	58.4	0.0	63.2	52.9		
96-05	lone	A	C. OAK	40.2	4.1	1.1	1.92	31.0	41.0	0.0	76.0	83.0	N	N
96-10	cubs	D	C. OAK	19.7	6.6	3.1	0.99	49.5	49.0	2.5	77.5	66.0	E	E
96-11	lone	D	C. OAK	9.5	4.9	4.9	0.94	0.0	26.7	2.5	111.8	86.4	NW	NONE
96-18	lone	A	C. OAK	25.6	18.6		2.17						E	SW
96-19	lone	A	R. OAK	18.9	7.7		0.94						S	NONE
96-20	lone	A	C. OAK	10.8	8.2		2.03						S	W
96-21	unknown	A	T.POPLAR	24.7	12.5		4.45						NE	SE
97-02	lone	A	C. OAK	5.7	4.5	3.8	1.82	129.5	63.5	5.1	91.4	88.9	ESE	SSE
97-03	lone	A	R. OAK	20.7	17.1		1.91						SW	NONE
97-04	cubs	A	R. OAK	13.6	9.0	1.5	2.31	130.0	280.0	2.5	87.0	66.0	NE	SW
97-05	cubs	A	C. OAK	5.4	5.4	5.4	1.65	99.5	37.0	1.3	64.0	61.5	ENE	SSW
97-07	cubs	A	R. OAK	25.4	12.2	5.8	1.97	0.0	56.0	2.5	68.0	66.0	NNW	NONE
97-09	cubs	A	R. OAK	.	8.3	4.7	2.17	34.5	26.2	5.1	59.0	65.0	NW	S
97-10	lone	A	R. OAK	.	.	2.2	1.74	80.0	40.0	2.5	48.0	48.0	NNW	SSE
97-11	cubs	D	C. OAK	5.0	5.0	5.0	1.71	0.0	29.0	0.0	96.0	90.0	E	NONE
97-12	lone	A	R. OAK	18.7	11.2	2.7	1.99	60.0	55.0				NW	SW
97-15	cubs	A	R. OAK	42.4	18.9		2.30						E	SE

Appendix Table 11. Physical characteristics of ground dens used by black in the southern George Washington and Jefferson National Forests, Virginia 1996 and 1997.

EH – entrance height (cm)
EW – entrance width (cm)
BMD – bedding material depth (cm)
NL – Nest length (cm)
NW – Nest width (cm)
CL – Cavity length (cm)
CW – Cavity width (cm)
CH – Cavity height
DSA – Den site aspect
DEA – Den entrance aspect

Den ID#	EH	EW	BMD	Bedding Material	NL	NW	CL	CW	CH	DSA	DEA
96-01	47.0	55.5	7.0	LEAVES	157.0	91.0	329.0	131.0	59.5	SSE	SSE
96-03											
96-04	186.0	347.0	16.0	OAK LEAVES	125.0	97.0	275.0	244.0	67.0	N	NE
96-06	83.6	114.2	30.6	OAK LEAVES	113.5	0.96.7	272.8	186.0	82.7	NW	E
96-07											
96-08							.			SE	SW
96-09	29.5	71.0	0.0		78.0	106.0	195.0	124.0	57.0	S	S
96-12	27.0	49.5	2.5	OAK LEAVES	115.6	72.5	115.6	72.5	62.0	NE	NE
96-13	38.0	65.3	4.3	OAK LEAVES	58.0	74.4	325.0	155.0	71.5	E	S
96-14											
96-15											
96-16	69.7	48.9	0.0	NONE	69.3	72.0	132.1	94.3	67.8	NE	NW
96-17											
97-01	83.6	114.2	34.8	OAK LEAVES	129.5	121.0	272.8	186.0	82.7	NW	E
97-06											
97-08	55.9	29.3	50.0	OAK LEAVES	113.0	65.0	136.0	54.0	82.0	SE	E
97-13	46.0	146.1	4.0	OAK LEAVES	146.1	11.4	146.1	11.4	51.0	N	NE
97-16	55.2	68.8	1.9	OAK LEAVES	93.2	72.9	175.2	89.7	54.2	SW	NE
97-18	49.2	50.2	2.2	OAK LEAVES	81.0	72.0	102.0	98.0	74.0	N	E

Appendix Table 12. Habitat characteristics of black bear den sites in the southern George Washington and Jefferson National Forests, Virginia 1996 and 1997.

Type – Den type (G=ground;T=tree)
DSA – den site aspect
DEA – Den entrance aspect
BA - Basal area
LT – Large tree density[1]
MT – Medium tree density[2]
ST – Small tree density[3]
SD – Stem density (stems/ha)

Den Id#	Type	DSA	DEA	Slope	BA	LT	MT	ST	SD
96-01	G			22.5	50	110	110	110	22200
96-02	T								
96-03	G								
96-04	G	N	NE	40	150	110	110	0	2200
96-05	T	N	N	35	120	110	110	340	3800
96-06	G	NW	E	36	80	110	230	110	6100
96-07	G								
96-08	G		SW	22.5	70	110	110	570	7200
96-09	G	S	S	27	80	220	220	110	2000
96-10	T	E	E	25.5	70	0	110	0	5300
96-11	T	NW		28.5	90	110	110	0	6700
96-12	G	NE	NE	44	60	0	220	570	2700
96-13	G	E	S	36	80	0	0	110	7600
96-14	G								
96-15	G								
96-16	G	NE	NW	60	70	110	0	11250	5500
96-17	G								
96-18	T	E	SW	54	50	110	0	0	5300

[1]Large trees had a DBH > 50.8 cm and were reported as (#/ha)
[2]Medium trees had a DBH between 25.5 – 50.8 cm and were reported as (#/ha)
[3]Small trees had a DBH between 12.7 – 25.4 cm and were reported as (#/ha)

Appendix Table 12. Cont.

Den Id#	Type	DSA	DEA	Slope	BA	LT	MT	ST	SD
96-19	T	S		24.5	150	110	110	110	3000
96-20	T	S	W	42	80	110	110	450	6900
96-21	T	NE		19	60	0	110	340	13200
97-01	G	NW	E	36	80	110	230	230	6400
97-02	T			27	50	0	0	680	3100
97-03	T	SW		19	90	110	0	230	13300
97-04	T	NE	SW	47	80	0	0	680	1900
97-05	T	NE	SW	72.5	70	0	230	450	4400
97-06	G								
97-07	T	NW		19.5	80	110	110	110	5300
97-08	G		E	30	100	0	0	1480	4800
97-09	T	NW	S	30.5	60	0	0	450	9700
97-10	T	NW		21.5	60	110	110	340	800
97-11	T	E		38	70	110	0	570	2400
97-12	T	NW	SW	25	70	0	230	340	8600
97-13	G	N	NE	25.5	70	0	0	680	23600
97-15	T	E	.	45	110	230	230	110	2400
97-16	G	SW	NE	46	80	0	230	340	9900
97-18	G	N	E	23	40	0	230	230	7500

Vita

Christopher W. Ryan

Christopher William Ryan was born in Morgantown, West Virginia on December 28, 1972 to William and Carolyn Ryan. He graduated from Morgantown High School in June 1991. He attended West Virginia University where he received his Bachelor of Science Degree in Wildlife and Fisheries Management in 1995. He began work his Master's of Science Degree in Wildlife Science at Virginia Polytechnic Institute and State University in August 1995.