Aspects of Reproduction and Cub Survival in a Hunted Population of Virginia Black Bears

by

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Abstract

We measured black bear (*Ursus americanus*) reproduction and cub survival during 1994 – 1998, and 1995 – 1999, respectively, in the George Washington and Jefferson National Forests in Virginia to determine age-specific and overall cub production and cub survival. We observed females in estrus between 6 June and 22 August; the mean date of estrus was 17 July. Ages of primiparity ranged between 3 and 5 years with an average of 3.36 years (n=11, SE=0.15). Average litter size for 1995 – 1998 was 2.32 cubs/litter (SE=0.11, n=53) and 85.7% of available females ≥ age 4 (those not accompanied by cubs) reproduced in a given den season. We monitored 98 (48M:50F) black bear cubs equipped with expandable radio-collars (Higgins 1997) or radio transmitters implanted subcutaneously between 1995 and 1999 to estimate cub survival. Kaplan-Meier staggered entry analysis provided 306-day survival rates for 82 cubs. The survival estimates for males and females were 73% (0.49, 0.96) and 91% (0.80, 1.00), respectively. The overall 306-day survival rate for all cubs was 81% (0.67,0.94) using Kaplan-Meier and 76% (0.63, 0.92) using Heisey-Fuller (Mayfield) methods. We also evaluated the utility of radio transmitters implanted subcutaneously in 42 (21M:21F) wild black bear (*Ursus americanus*) cubs from 2 study areas in Virginia between 1996 and 1999 to monitor first year cub survival. More than 64% (27 of 42) of the implants fell out prematurely (2-198 days), and 16.6% (7 of 42) failed for unknown reasons. Less than 5% (2 of 42) of these cubs denned wearing failed implants, and 9.5% (4 of 42) experienced mortality less than 1

month after implant surgery. About 9.5% (4 of 42) of implanted black bear cubs wore working transmitters through to the following den season.

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GENERAL INTRODUCTION

Black bear hunting, specifically hunting using hounds, is a controversial issue in some regions of the country. Some states have held statewide referenda aimed at modifying or completely halting bear hunting. Colorado, California, Florida, Massachusetts, Oregon, Washington, and Wyoming all have outlawed or restricted bear hunting in the past 10 years as a result of state referenda or legal actions taken by citizens groups. Citizens groups at the forefront of these initiatives are concerned about the ethics of certain hunting methods, the impact of hunting on individual bears and the population as a whole, and the impacts of hunting on the environment. Although Virginia's political system is not set up for referendum-type legislation, other means to effect changes are available.

In Virginia, black bear management is accomplished by setting season lengths, bag and weight limits, and by monitoring trends in annual harvests, incidence of miscellaneous kills, and nuisance complaints (D.D. Martin, VDGIF biologist, 1998 unpubl.). Recently, the Department of Game and Inland Fisheries (VDGIF) undertook the task of building a comprehensive and statewide black bear management plan designed to address biological as well as sociological considerations.

The Cooperative Alleghany Bear Study (CABS), of which this research was a part, provides the state with a base of knowledge concerning black bear demographics beyond what harvest data can provide, and allows sound management decisions to be based on actual Virginia black bear biological data. CABS was designed to provide the VDGIF with information that was previously lacking about the exploited population of black bears in Virginia.

This thesis, building upon a baseline of information collected by 4 previous graduate students, was designed to further augment the data gathered on Virginia's hunted bear population. Specific objectives were as follows:

1. To determine the age structure, age of primiparity, interbirth interval, litter size, cub sex ratio, and date of parturition of female black bears in the northwest portion of the George Washington & Jefferson National Forests,

2. To determine the survival rates of male and female black bear cubs during their first year of life, and
3. To evaluate the effectiveness of subcutaneously implanted radio transmitters in black bear cubs as a means to determine cub survival during the first year of life.

Chapter 1: FEMALE BLACK BEAR REPRODUCTION IN VIRGINIA

Abstract:

We measured black bear (*Ursus americanus*) reproduction during 1994 – 1998 in the George Washington and Jefferson National Forests in west-central Virginia to determine age-specific and overall cub production for this population. The average age of females captured during 4 trapping seasons was 5.2 years (SE=0.27, n=174). We observed females in estrus between 6 June and 22 August, but 52.5% of females captured in estrus were captured between 15 June and 31 July; the mean date of estrus was 17 July. Ages of primiparity, based on known reproduction, ranged between 3 and 5 years with an average of 3.36 years (n=11, SE=0.15). Average litter size for 1995 – 1998 was 2.32 cubs/litter (SE=0.11, n=53) and 85.7% of available (those not accompanied by cubs) females ≥ age 4 reproduced in a given den season. There was no difference (W=440.5, P=0.867) in litter sizes between females denned on the ground and females denned in trees or snags. The overall sex ratio was 1.0M:1.04F (53M, 55F; Z=0.037, df=1, P=0.847). The average interbirth interval was 1.50 years (SE=0.10, n=32), for 23 females with known reproductive histories and 2.00 years (SE=0.11, n=64) for females with known reproductive histories combined with data from cementum annuli analysis. Dates of parturition ranged between 19 December and 22 February (Median=17 January, SE=1.73).

INTRODUCTION

The purpose of this study was to measure reproductive performance of black bears subject to harvest in west central Virginia to assist the Virginia Department of Game and Inland Fisheries with bear management. Previous studies conducted on populations of black bears in the Shenandoah National Park and the Great Dismal Swamp National Wildlife Refuge in Virginia (Carney 1985, Hellgren 1988, Schrage 1994, Kasbohm 1994), provided information on reproductive success of Virginia's unexploited populations, but lack of information on the hunted population complicated the state's ability to manage the population and left it vulnerable to public criticism of current black bear management practices.

Bears have one of the lowest reproductive rates of all North American land mammals (Jonkel and Cowan 1971, Bunnell and Tait 1981); their reproductive potential is a function of age of first reproduction, litter frequency, and litter size (Lindzey and Meslow 1980, Bunnell and Tait 1981). Although female black bears have the potential to breed and give birth to cubs every other year, this reproductive capacity is not always realized (Lindzey and Meslow 1980), as the abundance, diversity, and quality of forage may influence reproductive success (Bunnell and Tait 1981, Rogers 1976, Rogers 1987, Elowe 1987, Eiler et al. 1989, Elowe and Dodge 1989).

Bears become sexually mature at different ages depending on birth weights and inheritance of maternal home range (Noyce and Garshelis 1994); age of first reproduction is often influenced by habitat quality (Beecham 1980). The number of litters produced by a population in a given year is a function of the number of potential breeding females and the proportion of these females that attain a nutritional condition capable of sustaining a litter (McLaughlin et al. 1994). Eastern populations of black bears generally tend to breed at an earlier age and more frequently than western populations (Bunnell and Tait 1981, Kolenosky 1990, Eiler 1981, Stickley 1957, Stickley 1961, Hellgren 1988, Hellgren and Vaughan 1989, Kasworm and Thier 1994).

Cub sex ratios differ from litter to litter, but generally do not differ from 50:50 overall (Kolenosky 1986, Reynolds and Beecham 1980, Elowe 1987, Garshelis et al. 1996, Stickley 1957, DuBrock 1980, Schrage 1994); litter sizes of black bears can range from 1 to

6 (Rowan 1945, Rowan 1947, Matson 1952), but more frequently range from 1 to 4. Litter sizes may vary from year-to-year, by age of the sow, and by geographic location (Jonkel and Cowan 1971, Alt 1989, Lindzey and Meslow 1980). In Ontario, Kolenosky (1990) determined litter size to be positively correlated with fall female weights and less so with age.

Although estimates of reproductive parameters are not the only information needed to manage black bears, knowledge of reproductive performance is essential for biologists to make informed decisions about setting bag limits and seasons. These data, combined with accurate information on annual harvests, natural survival and mortality factors, recruitment, and habitat quality and availability information, will permit biologists to manage bear populations effectively and to defend their management decisions.

STUDY AREA

This research was conducted on the 840 km^2 northern study site of the Cooperative Alleghany Bear Study, on the George Washington and Jefferson National Forests (GW&JNF) centered in Augusta and Rockingham Counties in Virginia (Figure 1.1). This site contains portions of the Deerfield and Dry River Ranger Districts in the Ridge and Valley Province of the Appalachian Mountain chain. Elevations ranged between 488 m along the base of Little North Mountain and 1,360 m at the top of Elliott Knob (Kozak 1970). The study area is bordered by Long Run Road (FS Rt. 72) to the north, West Virginia to the west, Virginia route 42 to the south, and the Shenandoah Valley to the east (Godfrey 1996, Higgins 1997a).

Annual rainfall averages 86 cm and annual snowfall averages 71 cm. Temperatures vary between 0.3^{o}C and 22.9^{o}C over the course of the year, with an average temperature of 11.8^{o}C. Temperatures and precipitation amounts were reported as recorded at Dale Enterprise, Virginia, located just east of the mountain range, which typically receives less precipitation and has on average 2.8 - 5.6^{o}C cooler temperatures than the mountains of the GW&JNF (Rawinski et al. 1994).

The study area’s major forest types include eastern hemlock (*Tsuga canadensis*), chestnut oak (*Quercus prinus*), sugar maple-beech-yellow birch (*Acer saccharum-Fagus* *spp.-Betula allegheniensis*), pitch pine (*Pinus rigida*), white oak-black oak-northern red oak (*Q. alba-Q. velutina-Q. rubra*), northern red oak, yellow poplar-white oak-northern red oak (*Liriodendron tulipifera*), eastern white pine (*P. strobus*), and barren and brush cover such as mountain laurel (*Kalmia latifolia*) and scrub or bear oak (*Q. ilicifolia*) (Rawinski et al. 1994, Godfrey 1996).

Soil types are classified in the Hazleton, Lehew, Udorthents, Calvin, and Dekalb, most of which are classified as loamy, mixed, mesic-type soils (Rawinski et al. 1994).

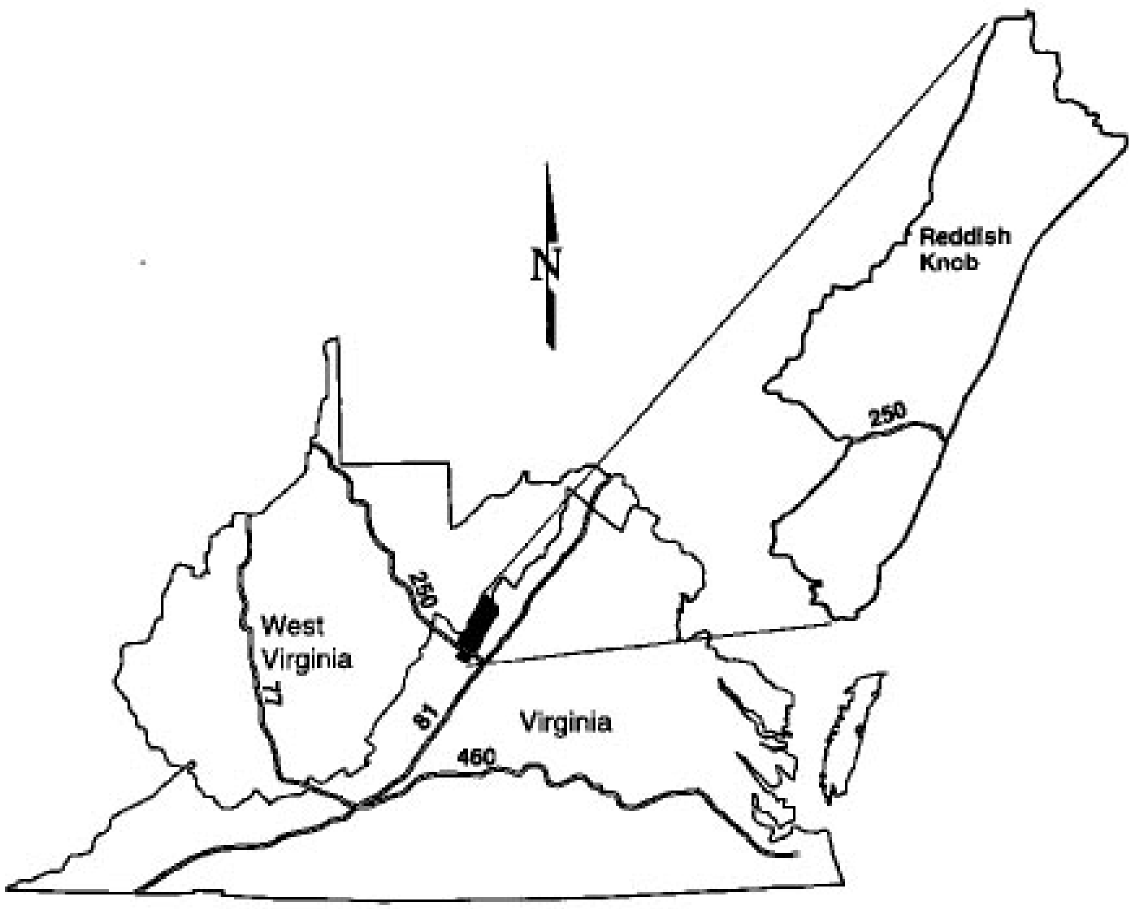

Figure 1.1. Northwest study area of the Cooperative Alleghany Bear Study, Virginia.

METHODS

We trapped black bears during June, July, and August between 1994 and 1997 with spring-activated Aldrich snares and culvert traps. We used a 2:1 mixture of ketamine hydrochloride (Ketaset, Fort Dodge Animal Health, Fort Dodge, IA) and xylazine hydrochloride (Rompun, Bayer Corporation, Shawnee Mission, KS) (concentration 300 mg/ml) at a dosage rate of 1 cc per 45 kg of body weight to immobilize captured bears, and Yobine (yohimbine hydrochloride, Lloyd Laboratories, Shenandoah, IA) (concentration 5 mg/ml; dosage 2 cc per 45 kg) or Antagonil (yohimbine hydrochloride, Wildlife Laboratories, Incorporated, Fort Collins, CO) (concentration 10 mg/ml; dosage 1 cc per 45 kg) as reversal agents to counteract the effects of the xylazine hydrochloride.

We marked captured bears with a uniquely numbered, color-coded ear tag and a correspondingly numbered lip tattoo. We extracted a premolar from all first-time captures and sent them to Matson's Laboratory (Milltown, MT) for cementum annuli analysis (Willey 1974). We collected 4 10 ml blood tubes (2 clot tubes, 1 heparin tube, 1 tube with ethylenediamine tetraacetate (EDTA)) from each bear for genetic and nutritional analysis (Hellgren et al. 1990) and dosed each bear with LA200 (tetracycline; concentration 200 mg/ml; dosage 4 cc per 45 kg) intramuscularly to act as a biomarker to aid in population estimation as well as to combat any infection that may have been introduced during the handling process.

We weighed each bear to the nearest kilogram, and took a series of morphological measurements to the nearest millimeter, including zoological length, total body length, chest girth, neck girth, shoulder height, tail length, ear length, front and hind paw widths and lengths, zygomatic arch widths, and canine breadths and widths. We measured the second thoracic nipple heights and widths on all females and testicle lengths and widths for all males. Reproductive status of captured females was noted based on the presence of cubs at or near the trap site, evidence of lactation and or suckling, and the presence of vulval swelling (Godfrey 1996).

We placed radio collars (Telonics, Inc., Mesa, AZ or Lotek Engineering, Ontario, Canada) on a sample of bears. Each radio collar had a motion sensitive mortality switch (activity sensor), which operated on a half-hour delay. We systematically located bears wearing radio collars using ground and aerial telemetry surveys to determine location, activity status, den entrance and emergence dates, and to obtain home range estimates and monitor survival.

We monitored radio collared bears regularly until they exhibited evidence of denning (usually November or December) then physically located den sites during December, January and February. We entered the dens of females with yearlings and lone females during January and February and delayed entering the dens of females with newborn cubs until March and early April to avoid encountering cubs less than 8 weeks old. We determined litter size and cub sex ratio. We recorded weight of cubs to the nearest 0.01 kilogram and measured total length, chest and neck girths, front and hind paw lengths and widths, ear length, and length of hair on top of the head between the ears to the nearest millimeter.

We used 2 regression models developed by Godfrey (1996) from growth rate data on captive born cubs to determine cub ages and dates of parturition for cubs born during the 1997 and 1998 den seasons. We used Godfrey's (1996) first model to determine cub ages and dates of parturition for cubs born during the 1995 den season because measurements for one of the variables needed for the second model were not taken during this first den season.

We compared ages of captured females between years 1996 and 1997 using the Student's T-test and the Mann-Whitney test; the data did not follow a normal curve. We also analyzed the 4-year data set from 1994-1997 (data combined with Godfrey 1996) using the ANOVA and Kruskal-Wallis tests. We also compared the ages with other Virginia studies using both ANOVA and Kruskal-Wallis tests. We used the Student's T-test to compare interbirth intervals between 1995 – 1996 and 1997 – 1998 data sets. We tested cub sex ratios against the expected 1:1 ratio using the Z-test of proportions. We evaluated the correlation of litter size and sow age using both Pearson's correlation and regression analysis. We tested for differences between litter sizes of sows denned on the ground against those denned in trees using the Mann-Whitney test. We used the chi-square analysis to test for proportion of males by litter size being different from the expected 1:1

ratio. Cub growth measurements were compared between and among years using linear contrasts of the least squared means.

RESULTS

Age Structure

We captured 81 females aged 0 (cub) to 20 years 128 times during summers 1996 and 1997 (Figure 1.2). The average age of females captured during summer 1996 ($\bar{X}$=4.8, SE=0.46, n=45) was not different (T=-1.74, P=0.085, df=96 / W=2063.0, P=0.1449) from the average age of females captured during the summer of 1997 ($\bar{X}$=6.0, SE=0.56, n=55).

Including data collected as part of previous studies, we captured 122 different females aged 0 (cub) to 20 years 207 times during summers 1994, 1995, 1996, and 1997 (Figure 1.3). The average age of females captured during these 4 summers differed between years (H=10.62, df=3, P=0.014). Females captured in 1994 were younger on average than females captured in 1997. The average age of females captured was 3.7 years (SE=0.37, n=35) in 1994, 5.7 years (SE=0.64, n=39) in 1995, 4.8 years (SE=0.46, n=45) in 1996, and 6.0 years (SE=0.56, n=55) in 1997.

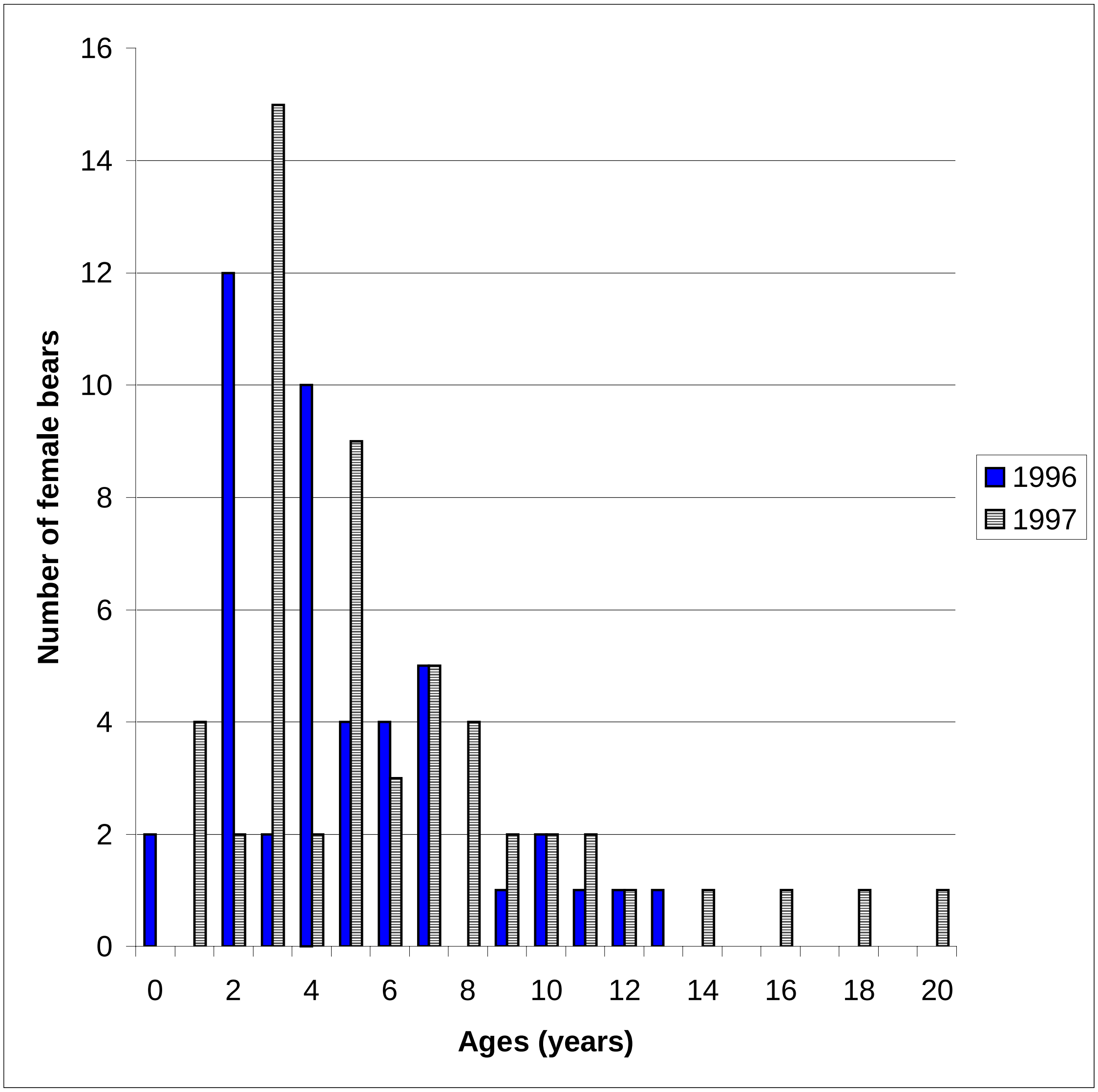

Figure 1.2. Age structure of female black bears captured on the George Washington & Jefferson National Forests, Virginia, during summers 1996 – 1997.

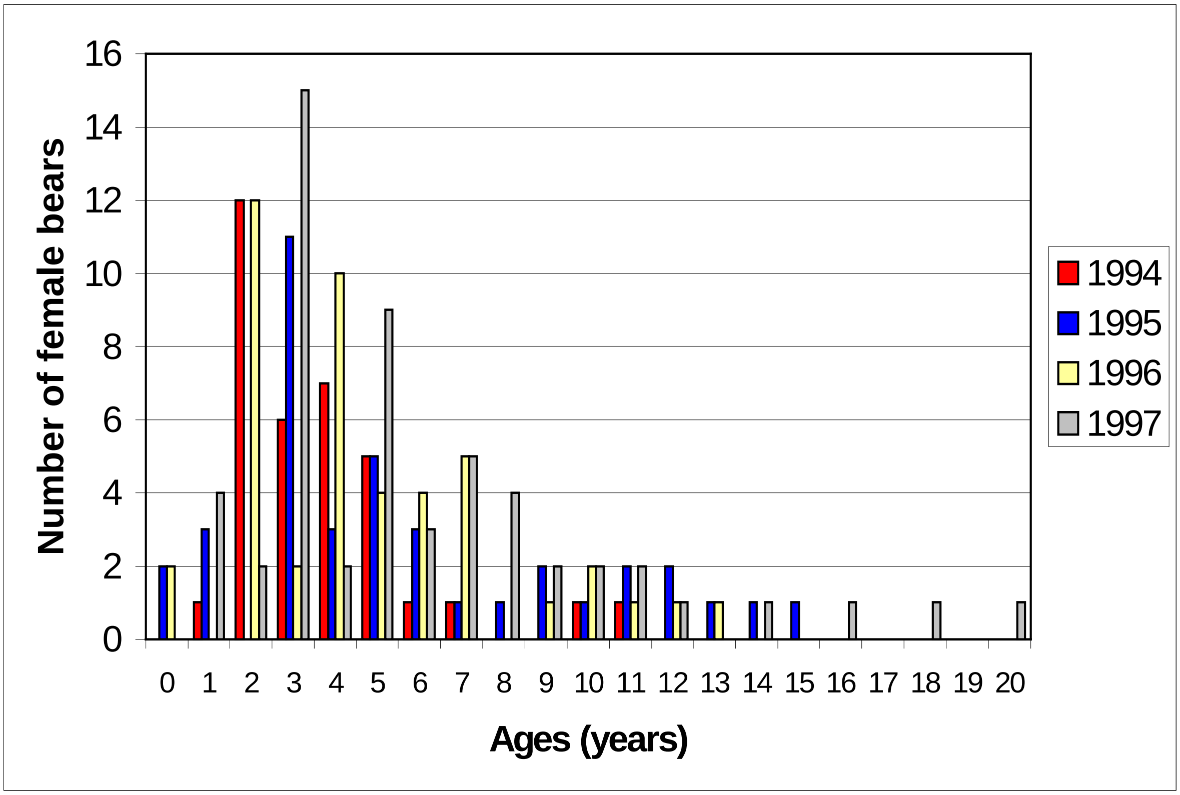

Figure 1.3. Age structure of female black bears captured on the George Washington & Jefferson National Forests, Virginia, during summers 1994 – 1997.

The average age of females captured on the George Washington and Jefferson National Forests during 1994-1997 ($\overline{X}$ =5.2, n=174, SE=0.27) was not different (H=3.09, df=2, P=0.213) from those captured in the unexploited populations of the Shenandoah National Park during 1982-1992 ($\overline{X}$ =4.6, n=127, SE=0.30; Carney 1985, Kasbohm 1994, and Schrage 1994) or the Great Dismal Swamp National Wildlife Refuge during 1985-1988 ($\overline{X}$ =4.03, n=30, SE=0.47; Hellgren 1988).

Timing of Estrus

We captured 21 females exhibiting signs of estrus (i.e. vulval swelling) 22 times during the summer of 1996 and 20 females exhibiting signs of estrus 22 times during the summer of 1997 (Figure 1.4). We also captured 31 and 34 other females that did not show signs of estrus during summers 1996 and 1997, respectively. Dates females were captured with vulval swelling ranged between 6 June and 22 August for 1996 and 1997. The mean date of estrus was 16 July (SE=3.0, median=15 July). Two females (ID 20 and 298) captured with swollen vulva twice were captured for the second time within 10 days of their initial captures (Appendix 1.2). A third female (ID 263), was captured for a second time 23 days after her first capture and exhibited vulval swelling at both captures. The majority (65.9%) of females captured while and exhibiting signs of estrus was captured between 15 June and 31 July.

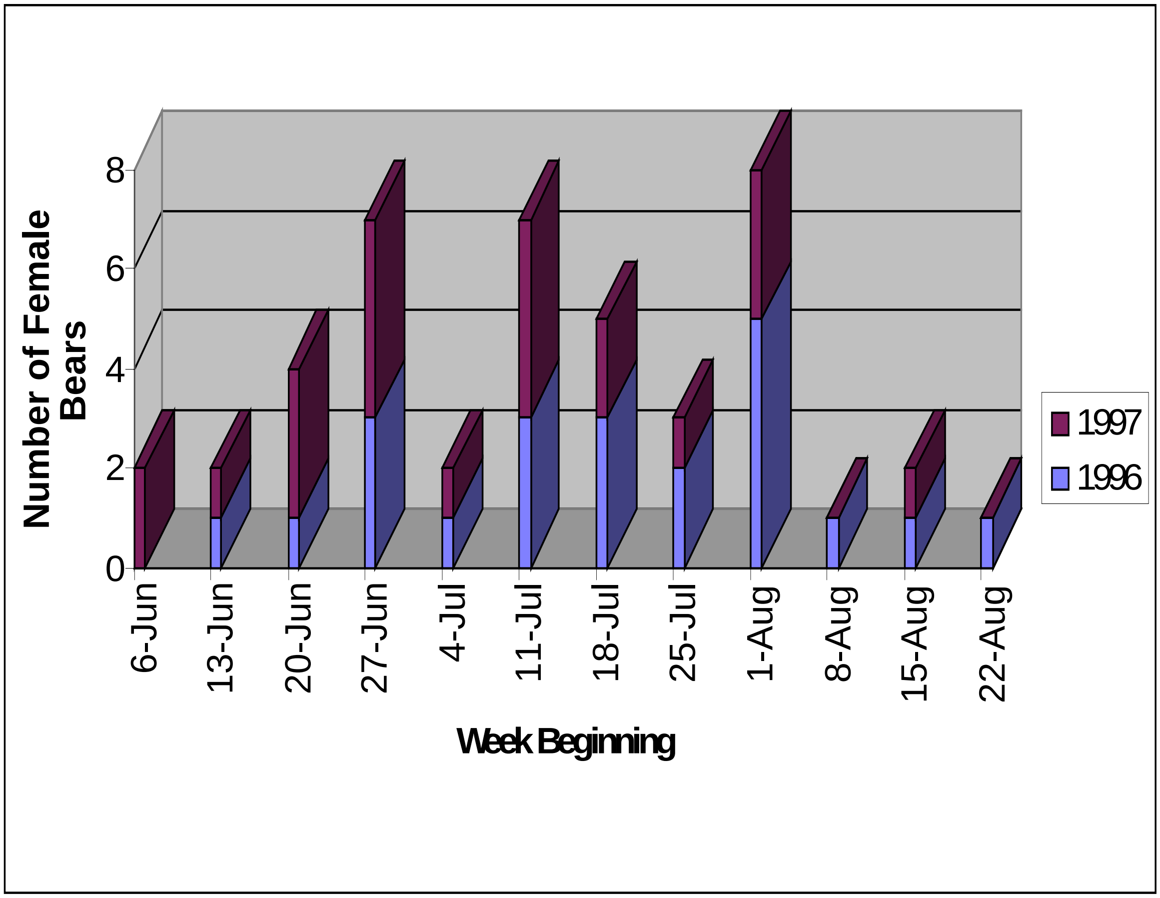

Figure 1.4. Number of female black bears showing evidence of estrus by week during summers 1996 and 1997 in the George Washington & Jefferson National Forests, Virginia.

Adding 1994 – 1995 data (Godfrey 1996) to our data changed the mean date of estrus to17 July (SE=2.3, median=17 July; range = 6 June – 22 August). Fifty-two percent (32 of 61) of the females showing evidence of being in estrus during summers 1994 – 1997 were captured between 1 July and 31 July. More than 73% of the females captured during the week of July 11-17 exhibited signs of estrus (Table 1.1).

Table 1.1. Percent of females captured exhibiting signs of estrus during summer trapping on the George Washington & Jefferson National Forests, Virginia, 1994 – 1997.

Week of	# Exhibiting estrus[1]	% Exhibiting estrus	# Exhibiting no sign of estrus[2]	% Exhibiting no sign of estrus	# Unknown status[3]	Total # females captured
6 - 12 June	2	28.6	5	71.4	1	8
13 - 19 June	2	15.4	11	84.6	4	17
20 - 26 June	5	29.4	12	70.6	1	18
4 - 10 June	4	57.1	3	42.9	2	9
27 June - 3 July	8	44.4	10	55.6	2	20
11 - 17 July	11	73.3	4	26.7	4	19
18 - 24 July	7	53.8	6	46.2	1	14
25 - 31 July	8	57.1	6	42.9	3	17
1 - 7 August	11	42.3	15	57.7	4	30
8 - 14 August	1	8.3	11	91.7	2	14
15 - 21 August	2	11.8	15	88.2	2	19
22 - 28 August	1	7.7	12	92.3	1	14
29 August - 5 September	0	0.0	3	100.0	4	7

[1,2] Used to compute estrus percentages.
[3] Not used to compute estrus percentages.

Litter Size

The average litter size of radio-collared females during winters 1997 and 1998 was 2.6 cubs per litter (SE=0.12, n=27). During winters 1997-1998, 1 female had a litter of 1, 9 females had litters of 2, 16 females had litters of 3, and 1 female had a litter of 4. We found no correlation between sow age and litter size for the 1997 and 1998 den seasons using either Pearson's correlation (r=0.017, P=0.939) or linear regression analysis (P=0.551) and the regression equation was a poor predictive model (adj. $R^2 = 0.00$). Three sows reproduced for the first time at age 4; two of these 4-year-old sows gave birth to 2 cubs, but the other litter size could not be confirmed. Another female, followed since age 2, had not successfully reproduced at the completion of this study when she was 4 years old. None of the 5 marked 3-year old sows reproduced during either winter. We did not compare first and subsequent litter sizes because of insufficient data.

Litter sizes of sows that denned on the ground ($\bar{X}$=2.6, n=11, SE=0.15) and sows that denned in a tree or snag ($\bar{X}$=2.6, n=16, SE=0.18) during the 1997 and 1998 den seasons were not different (T=0.05, P=0.96, df=24/W=153.5, P=1.000).

The 1997 cub sex ratio of 1M:1.14F (14 males, 16 females) was not different from the 1M:2F sex ratio (10 males, 20 females) in 1998 (Z=1.107, P=0.27). The overall sex ratio for 1997 – 1998 was 1M:1.5F and was not different (Z=2.400, P=0.121) from 1:1. Males constituted 0.0 % of all single cub litters (n=9), 50.0 % of all litters of 2 (n=16), 41.0 % of all litters of 3 (n=21), and 0.0% of all litters of 4 (n=1). The proportion of males by litter size did not differ (χ^2=4.02, P=0.260) from 1:1.

When we combined new data (1997 – 1998) with data from 1995 – 1996 (Godfrey 1996), 9 sows gave birth to litters of single cubs, 19 sows had litters of 2 cubs, 24 sows had litters of 3 cubs, and 1 sow gave birth to 4 cubs (Table 1.2). The average litter size for 1995-1998 was 2.3 (SE=0.11). Average litter size by age class, was 1.5 (SE=0.14, n=13) for sows ages 3 and 4, 2.3 (SE=0.19, n=15) for sows ages 5 and 6, and 2.7 (SE=0.12, n=25) for sows ages 7 and older. Pearson's correlation indicated that litter size increased with sow age (r=0.513, P<0.001), but the regression equation (P<0.001) was a poor predictive model (adj. R^2=0.25).

The overall sex ratio of litters during 1995 – 1998 was 1.00M:1.04F (53 males, 55 females) and did not differ (Z=0.037, P=0.847) from 1:1. Males composed 33.3% of all single litters, 56.3% of all litters of 2, 50.8% of litters of 3, and 0.0% of litters of 4. The proportion of males by litter size did not differ (χ^2 =5.48, P=0.140) from the expected 1:1 ratio.

There was no difference (T=0.37, P=0.71, df=38/W=440.5, P=0.867) in litter sizes of sows denned on the ground and those denned in tree structures for the pooled 1995-1998 sample (Table 1.2). Sows denned on the ground averaged 2.4 (n=16, SE=0.15) cubs per litter, while those denned in trees or snags averaged 2.3 (n=37, SE=0.14) cubs per litter.

Table 1.2. Black bear litter size, litter sex ratio, and sow age of all females captured in dens in the George Washington & Jefferson National Forests, Virginia, 1995 – 1998.

Sow ID	Den Year	Sow Age	Den Type	Litter Size	Sex Ratio
4	1995	4	Tree	2	1M:1F
15		12	Snag	3	2M:1F
31		4	Tree	1	0M:1F
50		5	Ground	2	2M:0F
63		3	Tree	1	0M:1F
75		3	Tree	1	0M:1F
77		3	Tree	1	0M:1F
88		5	Tree	3	1M:2F
90		7	Tree	3	3M:0F
94		3	Tree	1	1M:0F
101		6	Tree	2	1M:1F
110		4	Snag	1	0M:1F
6	1996	7	Snag	3	2M:1F
51		7	Ground	2	-
63		4	Tree	2	1M:1F
73		4	Tree	2	2M:0F
85		5	Tree	2	1M:1F
94		4	Ground	2	-
110		5	Ground	2	1M:1F
136		16	Tree	3	1M:2F
138		5	Ground	1	1M:0F
139		6	Tree	3	3M:0F
153		15	Tree	3	3M:0F
154		14	Tree	3	1M:2F
156		6	Snag	1	1M:0F
165		4	Tree	2	1M:1F
13	1997	4	Snag	2	-
15		14	Ground	3	1M:2F
62		13	Ground	2	1M:1F
72		8	Ground	2	2M:0F
85		6	Tree	3	1M:2F
89		7	Tree	3	1M:2F
95		5	Ground	3	2M:1F
138		6	Ground	3	-
152		14	Ground	3	-
161		8	Tree	2	2M:0F
165		5	Tree	2	0M:2F

Table 1.2. Continued.

Sow ID	Den Year	Sow Age	Den Type	Litter Size	Sex Ratio
172		8	Snag	3	2M:1F
174		5	Tree	3	1M:2F
187		7	Tree	1	0M:1F
204		12	Tree	3	1M:2F
307	1997	13	Ground	3	-
15		15	Ground	2	1M:1F
31		7	Snag	3	2M:1F
49		8	Tree	3	2M:1F
95		6	Ground	2	1M:1F
143	1998	10	Ground	3	1M:2F
161		9	Tree	2	0M:2F
169		4	Snag	2	1M:1F
181		8	Tree	3	0M:3F
298		12	Ground	3	1M:2F
300		8	Tree	4	0M:4F
389		6	Snag	3	1M:2F
		$\overline{X}$ =7.34		$\overline{X}$ =2.32	53M:55F

Interbirth Interval

The average interbirth interval for 16 radio-collared female bears with known reproductive histories was 1.4 years (SE=0.12) during 1996 and 1997. Nine females gave birth in consecutive years (4 of these may have been negatively impacted due to our research). One of these 9 sows devoured her litter in 1996, but successfully produced a single cub in 1997. The other 8 sows were not first time mothers, but had not successfully raised a litter yet.

Matson's Laboratory (Milltown, MT) provided reconstructed reproductive histories for 11 females captured but not radio-collared during 1996 and 1997. The average interbirth (or inter-lactation) interval for female bears captured and aged using cementum annuli analysis was 2.19 years (SE=0.14, n=16) for low certainty observations and 2.27 years (SE=0.20, n=11) for high certainty observations. Combining the high certainty observations with the known reproductive histories of radio-collared black bears resulted in the same average of 2.27 years (SE=0.20, n=16) because no additional information was available beyond that provided by the cementum analysis data and known reproductive events for any of these females.

When we combined new data (1996 – 1997) with data from 1994 – 1995 (Godfrey 1996) and updated data on radio-collared females, we obtained an average interbirth interval of 1.50 years (SE=0.10, n=32) for 23 females with known reproductive histories (Table 1.3). When we combined both the known reproductive histories with the high certainty cementum annuli reconstructed reproductive histories for all 4 years (Table 1.4), we obtained an average interbirth interval of 2.00 years (SE=0.11, n=64). An analysis of

Table 1.3. Ages of cub production for female black bears captured and radio collared in the George Washington & Jefferson National Forests, Virginia, during the summers 1994 – 1997, based on summer observations of cubs/lactation and den season observations.

Sow ID	Age at first capture	Ages of cub production[1]
6	5	5 7 9
15	11	11 12 14[2] 15
31	3	4[2] 5 7
62	10	11 13
63	2	3 4 5
72	5	6 8
75	2	3 5
85	3	3 5[2] 6
89	4	4 7
94	2	3 4 6
95	2	5 6
110	3	4 5
138	4	5[2] 6
152	12	12 14
161	6	7 8 9
165	3	3 4 5[2]
176	9	9 10
181	5	6 8
187	5	6 7
204	10	10 12
293	5	5 6
298	10	10 12
300	6	6 8

[1]sequential years of cub production indicate reproductive failure.
[2]research activities may have influenced the survival of this litter.

Table 1.4. Ages of cub production for female black bears captured in the George Washington & Jefferson National Forests, Virginia, during the summers 1994 – 1997, based on dental cementum analysis and known parturition events.

Sow ID#	Age at first capture	[1]Ages of cub production
6	5	3?[2] 5[3] 7 9
15	11	3 5 7 9? 11 12 14 15
49[5]	4	4?
49[6]	6	5? 8[3]
59	7	4 6
72	5	4? 6 8
87	4	4
88	4	3 5
90	6	4 ??[4] 7
101	5	3 5 6
111	4	4
136	15	3? 5 9 11 15
139	5	5? 6
143	7	4 7
154	13	4 6 8 10 14
161	6	3 ?? 7 8 9
168	9	4 6
172	6	4? 6?
175	12	5 7 9 ?? 13
176	9	5 ?? 9 10
272	4	3
295	7	3 ??
299	7	5? 7
371	20	4 6 10 12 14? ??
374	9	4 6 8?
380	3	3
396	18	5 7 9 11 14 16 ??
401	10	4 6 ??
402	3	3?
405	11	5 7 9? ??
419	7	4? 6?

[1]reported as ages when females gave birth to cubs.

[2](?) indicates likelihood of cub production that year, although Matson's criteria were not met.

[3](_) indicates age at which females were known to produce cubs during this study.

[4](??) indicates Matson's Laboratory was unable to determine reproductive history beyond this point.

[5]Matson's report for ID 49 in 1994.

[6]Matson's report for ID 49 in 1997.

all high certainty, low certainty, and known intervals revealed an average interbirth interval of 1.97 years (SE=0.09, n=72). The average interbirth intervals computed using these 2 methods were not different (T=0.19, P=0.85, df=127). The information on #49 provided by Matson's Laboratory was not included in the analysis because 1997's report conflicted with the report provided for the same female in 1994.

Reproductive Success

We followed 44 different bears for 71 bear winters between 1997 and 1998 (Table 1.5). Twenty sows were accompanied by yearlings, the reproductive status of 7 sows was unknown, and 43 were available to produce cubs based on summer reproductive status or previous den season reproductive status. One bear was not of reproductive age. Four 3-year-old sows, considered to be among the 43 available to produce cubs failed to reproduce.

Table 1.5. Percent of radio collared female black bears that produced cubs in the George Washington & Jefferson National Forests, Virginia, during 1997 – 1998.

Age	# of females	# with yearlings	# with unknown status	# available to produce cubs	# producing cubs	Average litter size	% of available females with cubs
2	1	0	0	0	0	0.0	N/A
3	4	0	0	4	0	0.0	0.0
4	5	0	0	5	3[1]	2.0[2]	60.0
5	12	4	1	7	6	2.8	100.0
6	12	4	1	7	5	2.7	71.4
7	8	3	1	4	3	2.3	75.0
8	8	1	1	6	6	2.8	100.0
9	4	2	0	2	2	2.0	100.0
10	2	1	0	1	1	3.0	100.0
11	1	1	0	0	0	0.0	N/A
12	3	0	1	2	2[1]	3.0	100.0
13	3	1	0	2	2	2.5	100.0
14	4	1	1	2	2	3.0	100.0
15	2	1	0	1	1	2.0	100.0
UNK	2	1	1	0	0	0.0	N/A
Total	71	20	7	43	33	2.6	76.7

[1] Reproductive status of the other sow(s) is not known.
[2] Litter size for 1 of 3 litters (other 2 litter sizes are unknown).

Thus, 76.7% (n=33) of females ≥ 3 and available to reproduce reproduced successfully. When we considered only females older than 3, 85.0% of females available to reproduce reproduced successfully.

We followed 68 different radio-collared females for 141 bear winters between 1995 and 1998 (Table 1.6). Thirty-three sows were accompanied by yearlings, 16 were of undetermined reproductive status, 2 bears were not of reproductive age, and 72 of 90 (80.0%) bears available to produce cubs, did so. When we considered only females older than 3, 86.0% of females available to reproduce reproduced successfully.

Table 1.6. Percent of radio collared female black bears that produced cubs in the George Washington & Jefferson National Forests, Virginia during 1995 – 1998.

Age	# of females	# with yearlings	# with unknown status	# available to produce cubs	# producing cubs	Average litter size	% of available females with cubs
2	2	0	0	0	0	0.0	0.0
3	15	0	2	13	6	1.0[2]	46.2
4	22	4	2	16	13[1]	1.8[2]	81.3
5	20	4	3	13	12	2.2[2]	85.7
6	24	6	3	15	10	2.4[2]	66.7
7	15	4	1	10	8	2.5[2]	80.0
8	8	1	1	6	6	2.8	100.0
9	5	2	0	3	3	2.0	100.0
10	3	1	0	2	2	3.0	100.0
11	3	2	0	1	1	UNK	100.0
12	6	2	1	3	3[1]	3.0	100.0
13	6	3	0	3	3	2.5[2]	100.0
14	5	2	1	2	2	3.0	100.0
15	4	1	0	3	3	2.7	100.0
UNK	3	1	2	0	0	0.0	0.0
Total	141	33	16	90	72	2.3	80.0

[1] Reproductive status of the other sow(s) is not known.
[2] Sample size used to compute average litter size does not equal that of # producing cubs.

Age of Primiparity

During 1997-1998 the average age of primiparity for female bears wearing radio collars was 3.75 years (n=4, SE=0.25) based on den season observations and the presence of cubs during the summer. Three females gave birth to their first litter at age 4 and 1 nonradio collared 3-year-old female was observed with cubs at capture during the summer of 1997. Apart from these 4, a 3.5-year-old lactating sow was captured in 1996, indicating she gave birth at age 3. None of the 5 radio-marked 3-year-old females from 1997 – 1998 gave birth to cubs.

The average age of primiparity for bears whose reproductive histories were reconstructed from cementum annuli analysis was 3.86 years (n=8, SE=0.30), and ranged between 3 and 5 years of age. The average age of primiparity did not differ (T=-0.32, P=0.75 df=9 / W=25.0, P=0.926) between the 2 methods. Six of 12 2-year-old females were in estrus when captured during the summer of 1996, which suggests that many of these bears give birth to their first litter at age 3.

The average age of primiparity for 11 non-parous females during 1994-1998 was 3.36 years (SE=0.15) based on den season observations and summer lactation, or presence of cubs at capture. Seven of the 11 produced their first litters at age 3, while 4 produced their first litters at age 4. Six additional 3.5 year-old females were lactating when captured, indicating they had given birth at age 3, although it is not possible to confirm this as their first litter. Tooth analysis would not likely confirm this because, if they failed to raise their first litter, the annual growth ring on their tooth would not be affected. The average age of primiparity for 21 female bears captured during 1994-1998 whose reproductive histories were determined from cementum annuli analysis was 3.86 years (SE=0.16), no different (T=2.25, P=0.033, df=27 / W=138.5, P=0.064) than that of known ages of primiparity.

Cub Age/Date of Parturition

We used the 2 most accurate regression models developed by Godfrey (1996) to determine cub age and dates of parturition for 1997 and 1998. Estimated birth dates ranged between 31 December and 21 January for 1997 (n=12) and between 19 December and 30 January for 1998 (n=11) (Appendix Table 1.3). Average dates of parturition for 1997 and 1998 were 9 January (Median=9 January, SE=2.18) and 13 January (Median=13 January, SE=4.24), respectively.

In 1997, we confirmed the presence of cubs for sow #15, a 14-year-old, on 8 January through field observation. Using the regression model, the birth date of her litter was estimated as 31 December. Sow #62, a 13-year-old sow, had cubs by 14 January and the regression equation estimated a birth date of 1 January.

The average date of parturition for all years combined (1995 – 1998) was 16 January (Median=17 January, SE=1.73, n=47) and ranged between 19 December and 22 February (Appendix Table 1.3).

Cub Growth Measurements

Average cub body measurements for male and female cubs in 1997 and 1998 are presented in Tables 1.7 and 1.8. Cub growth measurements for the 1997 and 1998 den seasons (Table 1.11) were analyzed together with data from Godfrey (1996) to provide a 4-year analysis. Male cubs weighed more than female cubs overall (F=8.74, P=0.0039) and among years (F=6.18, P=0.0007), and male cubs born in 1997 weighed more than male cubs born in 1998 (F=4.44, P=0.0377). Differences in cub weights were detected between 1995 and 1996 and between 1995 and 1998. Cub total lengths differed by year (F=3.34, P=0.0225). Chest girths differed by year (F=5.54, P=0.0015), neck girths differed by year (F=8.84, P=0.0001) and by sex (F=4.46, P=0.0373), front paw lengths differed by year (F=16.78, P=0.0001), front paw widths differed by sex (F=4.49, P=0.0366), and hair

Table 1.7. Body measurements ($\overline{X}$ ± SE) of male black bear cubs captured at den sites during March of 1997 and 1998 in the George Washington & Jefferson National Forests, Virginia.

	Average					
Measurement	1997	SE	n	1998	SE	n
Weight (Kg)	2.11	0.12	14	2.19	0.25	10
Total length (mm)	465.6	13.2	14	472.2	18.7	10
Chest girth (mm)	261.8	5.3	14	253.6	8.2	10
Neck girth (mm)	177.8	4.1	14	174.8	7.2	10
Front paw length (mm)	32.4	1.1	14	37.5	2.8	10
Front paw width (mm)	34.0	0.8	14	36.7	1.8	10
Hind paw length (mm)	53.2	2.0	14	55.1	1.8	10
Hind paw width (mm)	31.8	0.8	14	33.0	1.3	10
Hair length (mm)	27.1	1.2	14	32.3	2.8	10
Ear length (mm)	40.5	1.4	14	43.1	3.6	10

lengths of cubs differed only by year (F=3.39, P=0.0211) (Tables 1.9 and 1.10). Front paw lengths, hind paw lengths, and ear lengths did not differ between males and females or among years (Tables 1.9, 1.10, and 1.11).

Table 1.8. Body measurements ($\overline{X}$ ± SE) of female black bear cubs captured at den sites during March of 1997 and 1998 in the George Washington & Jefferson National Forests, Virginia.

	Average					
Measurement	1997	SE	n	1998	SE	n
Weight (Kg)	1.92	0.11	16	1.89	0.14	20
Total length (mm)	461.4	10.8	16	454.5	10.6	20
Chest girth (mm)	254.0	6.1	16	241.3	6.4	20
Neck girth (mm)	167.9	2.9	16	163.7	4.6	20
Front paw length (mm)	32.0	0.8	16	34.2	1.6	20
Front paw width (mm)	33.0	0.7	16	34.0	0.9	20
Hind paw length (mm)	51.7	1.3	16	53.5	1.5	20
Hind paw width (mm)	30.3	0.8	16	31.5	1.0	20
Hair length (mm)	28.2	1.5	16	31.9	1.4	20
Ear length (mm)	43.2	1.9	16	43.0	1.8	20

Table 1.9. Body measurements accounting for sex and age covariates ($\overline{X}$ ± SE) and P-values for the linear contrasts of the measurement LSMeans of black bear cubs captured during March of 1997 and 1998 in the George Washington & Jefferson National Forests, Virginia.

	Average						
Measurement	1997	SE	n	1998	SE	n	P-value
Weight (Kg)	2.00	0.08	30	1.97	0.12	30	0.0286
Total length (mm)	463.3	8.3	30	460.4	9.3	30	0.0259
Chest girth (mm)	257.6	4.1	30	245.4	5.1	30	0.0015
Neck girth (mm)	172.5	2.6	30	167.4	3.9	30	0.0083
Front paw length (mm)	32.2	0.7	30	35.3	1.4	30	0.1817
Front paw width (mm)	33.5	0.5	30	34.9	0.9	30	0.7509
Hind paw length (mm)	52.4	1.2	30	54.1	1.1	30	0.5220
Hind paw width (mm)	31.0	0.6	30	32.0	0.8	30	0.5251
Hair length (mm)	27.7	1.0	30	32.0	1.3	30	0.0644
Ear length (mm)	41.9	1.2	30	43.0	1.7	30	0.0454

Table 1.10. Body measurements accounting for age and year covariates ($\overline{X}$ ± SE) and P-values for the linear contrasts of the measurement LSMeans of male and female black bear cubs captured during March of 1997 and 1998 in the George Washington & Jefferson National Forests, Virginia.

	Average						
Measurement	Males	SE	n	Females	SE	n	P-value
Weight (Kg)	2.14	0.12	24	1.89	0.09	36	0.0039
Total length (mm)	468.3	10.7	24	457.6	7.5	36	0.3614
Chest girth (mm)	258.4	4.6	24	246.9	4.5	36	0.1560
Neck girth (mm)	176.5	3.7	24	165.6	2.8	36	0.0373
Front paw length (mm)	34.6	1.4	24	33.2	1.0	36	0.4128
Front paw width (mm)	35.1	0.9	24	33.6	0.6	36	0.0366
Hind paw length (mm)	54.0	1.4	24	52.7	1.0	36	0.3192
Hind paw width (mm)	32.3	0.7	24	31.0	0.7	36	0.0997
Hair length (mm)	29.3	1.4	24	30.3	1.0	36	0.2424
Ear length (mm)	41.6	1.7	24	43.1	1.3	36	0.0799

Table 1.11. Body measurements accounting for sex and age covariates ($\overline{X}$ ± SE) and least-squares means of black bear cubs measured during March 1995, 1996, 1997, and 1998 in the George Washington & Jefferson National Forests, Virginia.

Measurement	Mean	SE	n	Year	LSMean	SE	P-value
Weight (Kg)	1.95	0.06	108	1995	2.25	0.09	0.0007
				1996	1.82	0.08	
				1997	2.03	0.07	
				1998	1.79	0.08	
Total length (mm)	457.4	4.9	108	1995	474.7	7.7	0.0225
				1996	454.3	6.9	
				1997	464.9	6.2	
				1998	444.1	6.7	
Chest girth (mm)	252.5	2.6	108	1995	264.5	5.0	0.0015
				1996	254.5	4.4	
				1997	258.5	4.0	
				1998	239.2	4.3	
Neck girth (mm)	171.2	1.9	108	1995	185.3	3.3	0.0001
				1996	170.3	2.9	
				1997	173.3	2.6	
				1998	162.9	2.8	

Table 1.11. Continued.

Measurement	Mean	SE	n	Year	LSMean	SE	P-value
Front paw length (mm)	36.8	0.7	108	1995	39.7	1.4	0.0001
				1996	43.0	1.2	
				1997	32.3	1.1	
				1998	34.5	1.2	
Front paw width (mm)	34.0	0.4	108	1995	34.7	0.6	0.2655
				1996	34.7	0.5	
				1997	33.6	0.4	
				1998	33.8	0.5	
Hind paw length (mm)	52.7	0.6	108	1995	53.5	0.9	0.4716
				1996	53.6	0.8	
				1997	52.6	0.8	
				1998	51.9	0.8	
Hind paw width (mm)	31.2	0.4	108	1995	32.2	0.6	0.3009
				1996	31.4	0.5	
				1997	31.1	0.5	
				1998	30.7	0.5	
Hair length (mm)	29.0	0.6	108	1995	30.7	0.7	0.0211
				1996	28.8	0.7	
				1997	27.8	0.6	
				1998	29.5	0.6	
Ear length (mm)	41.6	0.9	88	1996	42.0	0.9	0.1287
				1997	42.8	0.8	
				1998	40.3	0.9	

DISCUSSION

Sex and Age Structure

Not all studies report the age structure of black bear populations at capture. Schrage (1994) and Kasbohm (1994) reported that female black bears captured in Shenandoah National Park during 1990-1993 and 1985-1989, respectively, were older, on average, than male bears captured during the same time intervals ($\overline{X}$=2.4 for males vs. $\overline{X}$=4.3 for females). Hellgren (1988) reported a highly variable sex ratio, but similar average age for male and female ($\overline{X}$=4.3 vs. $\overline{X}$=4.0, respectively) black bears captured in the Great Dismal Swamp National Wildlife Refuge during 1984-1986. During 1982-1984 in the Shenandoah

National Park, the sex ratio at capture was skewed toward males (Carney 1985), but by the conclusion of the study did not appear different from the expected 50:50. Kolenosky (1986) in Ontario and Beecham (1980) in Idaho reported similar sex and age structures in their trapping results.

We experienced difficulty in capturing females during the onset of CABS during 1994-1995 in the northern study area of the GW&JNF (Godfrey 1996). The ratio of female to male black bears captured in the first 2 summers was low (1.00:0.38 in 1994 and 1.00:0.54 in 1995 compared to 1.00:0.66 in 1996 and 1.00:0.94 in 1997). Differences in capture rates of the sexes may be explained by the inexperience of trappers during the initial years of this study, as males are typically much easier to capture than females because of their larger home ranges and dispersal tendencies (Bunnell and Tait 1980).

Godfrey (1996) reported an unexplainable difference ($\underline{T}$=-2.66, $\underline{P}$=0.01, $\underline{df}$=51/$\underline{W}$=1104.0, $\underline{P}$=0.0228) in the average age of female bears captured during the 1994 and 1995 trapping seasons, $\bar{X}$=3.7 and $\bar{X}$=5.7, respectively, but the average age of female bears captured in 1996 and 1997 was similar ($\underline{T}$=-1.74, $\underline{P}$=0.085, $\underline{df}$=96/$\underline{W}$=2063.0, $\underline{P}$=0.1449), $\bar{X}$=4.8 and $\bar{X}$=6.0, respectively. Differences were detected among all 4 years which, given the high number of female recaptures in 1996 and 1997 ($\underline{n}$=51), was expected. Each female that was recaptured in successive years would have been a year older and contributed to the increase in average age. The high average age of females captured in the GW&JNF ($\bar{X}$=5.2, SE=0.27, $\underline{n}$=174) suggests an unexploited population, although the comparably low age of capture for males ($\bar{X}$=2.9, SE=0.14, $\underline{n}$=254), suggests a heavily exploited population (Garshelis 1990).

Houndsmen who hunt bears within the study area claim they refrain from harvesting bears they believe may be females (Higgins 1997b, Virginia Bear Hunters Association members, pers. comm.), which may explain why female bears may experience greater longevity and exhibit higher average ages than males. While young males constitute a large portion of our trapped sample, they also constitute a large portion of the hunter harvest. Males accounted for 65% of Virginia's annual bear harvest between 1995 and 1998 (D. D. Martin, VDGIF biologist, 1998 unpubl.) This is likely because younger males are more vulnerable to being trapped and harvested due to dispersal, intra-specific aggression with larger males, and their constant search for a food (Bunnell and Tait 1980). These factors increase the home range size, and thereby males' potential for trap or hunter contact. A disproportionate number of males in the harvest annually will suppress the average male age while allowing the average female age to increase.

Timing of Estrus

The timing of estrus (or evidence of estrus) in our study area generally coincided with that reported for other black bear populations, although it appeared to last longer and exhibit a less definite peak over a 4-year period. Estrus in black bears reportedly occurs between late May and mid-September (Alt 1989, Eiler et al. 1989, Jonkel and Cowan 1971, Rogers 1987, Reynolds and Beecham 1980, Barber and Lindzey 1986), and most frequently peaks sometime in mid- to late June. Earlier studies in Virginia, e.g. DuBrock (1980), Godfrey (1996), and Ryan (1997), reported estrus occurred primarily between mid- and late-July. Data from this study for summers 1996 and 1997 is in agreement with the latter.

Study participants in the GW&JNF experienced less success capturing females during the first 2 summers of trapping than in later years. Additionally, their ability to definitively recognize signs of estrus improved over the course of the study.

Though estrus peaked in late June and July in the GW&JNF, several bears captured in August were recorded with vulval swelling. This could be in response to total litter loss late in the summer while there is still time to breed; however, there are no data to suggest such an unusual loss occurred in late summer during any given year on this study. Rogers (1987) indicated bears in Minnesota were receptive to males for just 2-3 days, based on behavioral observations, but the literature is inconclusive on how long a breeding female may appear to be in estrus. We observed females with vulval swelling for up to 23 days.

Further, Rogers (1987) believed that the timing of the breeding season was influenced more by food availability than the optimization of the date of parturition. Most bear biologists agree that there is no relationship whatsoever between the time of breeding and parturition due to delayed implantation. If the occurrence of estrus is nutritionally related, that may explain the lack of a distinct "peak" in our study, because variable weather conditions from year-to-year affect the timing of ripening of such foods as blueberries and grapes.

Eiler (1981) reported a bimodal distribution in the peak of estrus for bears in Tennessee with an initial peak in late June and another peak in mid-July. We observed a similar distribution for bears captured on the GW&JNF for the 1996 – 1997 summers combined (Figure 1.4), but did not observe this distribution for the 1994 – 1995 data (Godfrey 1996). Godfrey's (1996) sample size ($\underline{n}$=17) was small and may have been insufficient to demonstrate this pattern. Black bears are thought to be mono-estrus (Erickson and Nellor 1964), but a quiescent period similar to that exhibited in brown bears (Craighead et al. 1969) may explain the bimodal distribution observed. It is also likely that our ability to detect a distinctly bimodal distribution is affected by our shutting down of snares during the week of 4 July every summer due to greater public use of trapping areas during this holiday.

Litter Size

Average litter size ($\overline{X}$=2.6) for 1997 – 1998 on GW&JNF was numerically higher than most other studies in Virginia, which have ranged from 2.0 to 2.6 cubs per litter (Carney 1985, Stickley 1961, Godfrey 1996, Kasbohm 1994, Schrage 1994, Ryan 1997, Hellgren 1988). Alt (1982, 1989) reported average litters of 2.9 and 3.0 for unexploited bear populations in Pennsylvania, while Reynolds and Beecham (1980) reported 1.9 cubs per litter ($\underline{n}$=16) in Idaho. The average litter size of radio-collared females during winters 1997 and 1998 ($\overline{X}$=2.6, SE=0.12, $\underline{n}$=27) was greater ($\underline{P}$=0.001) than the average litter size ($\overline{X}$=2.0, SE=0.16, $\underline{n}$=26) reported by Godfrey (1996) for winters 1995 and 1996. The average age of reproducing females, however, also was significantly lower ($\underline{P}$=0.012) in 1995 – 1996 ($\overline{X}$=6.2, SE=0.74, $\underline{n}$=26) than 1997 – 1998 ($\overline{X}$=8.4, SE=0.63, $\underline{n}$=27). This is the result one would expect if the relationship between age of sow and litter size reported by Godfrey (1996) is valid.

Alt (1989), Fuller (1993), Kolenosky (1993), and Godfrey (1996) reported that litter size appears to be influenced by sow age. The trend Godfrey (1996) saw for 1995 – 1996 in the GW&JNF is not readily apparent for the 1997 – 1998 data. The age structure of radio-collared females increased over the years as did the average litter size, but the number of older sows giving birth to smaller litters also increased. Godfrey (1996) never observed a sow aged 7 years or older with a litter of less than 3 cubs. This held true for sows as old as 15 and 16 years of age. Since 1996, 2 sows, aged 13 and 15, each had litters of 2, and an 8-year-old gave birth to a litter of 4 cubs. The absence of this relationship may be explained in part by annual fluctuations in the quality of habitat and availability of food resources and their effect on nutritional condition. According to Noyce and Garshelis (1994), litter size is the first reproductive parameter to be affected by nutritional condition.

Every year since 1959, Virginia has monitored its hard and soft mast production by region (D. D. Martin, VDGIF biologist, 1997 unpubl.). Mast production was considered to be generally good in the western regions of Virginia during 1995 and 1996. It was rated between good and fair for 1994, and considered to be a complete failure during 1997. The mast crop in 1997 was the worst recorded in 10 years and among the 4 worst recorded since the survey was standardized in 1973. This may help explain why some females failed to reproduce, but only serves to further confuse the issue about the otherwise good cub production experienced by other sows during that den season. The patchiness of certain natural foods augmented by supplemental foods supplied by bear hunters in certain areas may account for some of this reproduction, although we cannot document that the feed in 1997 exceeded that of any other given year. Additionally, natural food source availability may dictate how much these supplemental food sources are utilized.

Hellgren and Vaughan (1989) reported an average litter size of 2.1 ($\underline{n}$=48) for black bears in the Great Dismal Swamp in Virginia and North Carolina. Schrage (1994) and Kasbohm (1994) reported litters of 2.3 ($\underline{n}$=12), and 2.3 ($\underline{n}$=26), respectively, for Shenandoah National Park, and Stickley (1957) reported an in utero litter size of 2.5 ($\underline{n}$=20) for all of Virginia, based on examination of female reproductive tracts. The 4-year average for the northern GW&JNF ($\overline{X}$=2.3) falls nicely into these previously reported average litter sizes for Virginia, although average litter size appears to fluctuate substantially from year-to-year.

In Pennsylvania, Alt (1982) found a male-biased sex ratio in large litters produced by large females. Males composed 63% of offspring in litters of 4 or more, but only 51%

in litters of 3 or less. The only litter of 4 cubs observed in the northern GW&JNF was 100% females. Alt (1982), Kasworm and Their (1994), McLaughlin et al. (1994), Noyce and Garshelis (1994), and Schrage (1994) all reported a non-significant preponderance of males in the overall sex ratios of black bear litters. Noyce and Garshelis (1994) reported that the sex of cubs was "related to maternal weight and litter size, with the proportion of males increasing with increasing maternal weights and in litters of 3 or fewer, decreasing with increasing litter size." Samson and Huot (1995) unsuccessfully tried to relate a highly male-biased sex ratio in litters of black bears in Quebec to a superior maternal nutritional condition. No such sex ratio bias could be detected in the data for the northern GW&JNF, in part because the majority (69.8%) of pregnant females denned in trees and could not easily be removed and weighed at the time the den was worked, nor were there enough chest girth measurements to use a regression equation to relate chest girths to weight. Sex ratios each year were skewed to one sex or the other for 2 of 4 years, but remained approximately 1:1 for the other 2 years, and resulted in an approximately 1:1 overall ratio.

Interbirth Interval

Noyce and Garshelis (1994) suggested that litter frequency is the least sensitive parameter to female nutritional condition, but Reynolds and Beecham (1980) believe nutrition accounts for most of the variability in the rates of reproduction. Nutritional factors are the predominant factor regulating black bear reproduction according to Rogers (1976), Beecham (1980), and Bunnell and Tait (1981).

Habitat quality and quantity are factors that influence the frequency of litters (Eiler et al. 1989, Jonkel and Cowan 1971, Alt 1982 , Rogers 1976, Elowe 1987). In Minnesota, the interbirth interval was 2.28 years and ranged from 2 to 4 years (Rogers 1987); the 4-year interval between cub production occurred following a 3-year period of food scarcity. Eiler et al. (1989) reported an interbirth interval of 2.2 years, which included 23 skips in expected reproduction by radio-collared female black bears. Nine of 10 skips were observed following fair-to-poor fall hard mast ratings.

Hellgren and Vaughan (1989) suggested a mean interval of 2 years based on a small sample of bears in the Great Dismal Swamp National Wildlife Refuge in Virginia and North Carolina. Jonkel and Cowan (1971) documented 9 female black bears that did not have litters for 3 years in northwestern Montana. Noyce and Garshelis (1994) reported that greater than 93% of consecutive litters in Minnesota occurred at least 2 or more years apart; 5 females experienced complete litter failures and reproduced in consecutive years. The average interbirth interval in east central Ontario was a litter every 2.7 years, but was as low as 2.1 for well established reproducing females (Kolenosky 1990).

We would expect a sow's age and experience to influence interbirth intervals because an older, more experienced sow is more likely to raise a partial or complete litter than a younger, inexperienced sow. Younger, inexperienced sows that lost a litter likely would come into estrus in consecutive years, lowering the average interbirth interval. Seguin (1992) and LeCount (1983) however, reported single instances of sows rearing consecutive litters in consecutive years in Saskatchewan and Arizona, respectively, resulting in an interbirth interval of 1.0 year. This would maximize reproductive output, but such events are thought to be rare and therefore would not affect the population substantially.

Percent Reproducing

The percentage of bears in the northern GW&JNF available to reproduce who did so during the 1997 and 1998 den seasons remained similar (84.6% versus 82.6%) to that reported by Godfrey (1996) for 1995 and 1996. Ryan (1997) reported an unusually high percentage (95.4%) of females available to reproduce who actually did so for the southern GW&JNF for 1996 and 1997.

During the fall of 1997, the study area experienced a mast failure (D. D. Martin, VDGIF biologist, 1997 unpubl.), which may have influenced the reproduction of at least 5 of our marked females. Based on their reproductive status during the 1997 den season and their status at capture during summer 1997, all 5 of these females were expected to reproduce in 1998 but were barren. A 15-year-old sow that previously gave birth to litters of 3 (1995, 1997), had a litter of 2 in 1998. Godfrey (1996) speculated that 3 females failed to reproduce in 1996 due to poor mast conditions in the localized area of Elliott Knob, but there was no such localization of bears that failed to reproduce in 1998. Ratings for red, black, white, and chestnut oaks ranged between complete failure and fair, while bear oak, hickory, grape, dogwood, and black gum productions ranged between complete failures and excellent ratings. The soft mast production appears to have been patchy while the hard mast was more evenly poor throughout most of the study area. Supplemental food provided by local bear hunters may have augmented the patchy natural foods in certain areas and broken up any pattern that may have existed.

Rogers (1976) found that female bears in Minnesota weighing less than or equal to 67 kg (n=16) by October failed to produce cubs. In Canada, females weighing less than 56 kg in late December were never observed with newborn cubs (Samson and Huot 1995). We did not capture bears in the GW&JNF after late August or early September so weights just prior to denning were not available. We do not rule out the possibility of having missed the birth of and the subsequent consumption of any newborn cubs in the den, but also acknowledge that sows are only likely to devour their young in the event they have insufficient nutritional reserves to raise them (M. R. Vaughan, VPI&SU, pers. comm.).

Age of Primiparity

Black bears in the eastern United States have reportedly reproduced for the first time at 2 years (Alt 1989), and 3 years of age (Stickley 1957, Hellgren and Vaughan 1989, Kordek and Lindzey 1980, McLaughlin et al. 1994, Alt 1981, Alt 1982, Rogers 1976, Godfrey 1996), but Jonkel and Cowan (1971) reported that no black bear in Montana gave birth before reaching age 6. Most studies in North America report age of primiparity between 3 and 4 years. Kolenosky (1990) reported a female producing her first litter of cubs at age 9 in Ontario. High age of primiparity reportedly is influenced by low habitat quality and reduced female nutritional condition (Jonkel and Cowan 1971, McLaughlin et al. 1994, Beecham 1980). Average age of primiparity for bears in the GW&JNF falls within the normal range reported by most eastern states with the exception of that reported by Ryan (1997), who documented 2 instances of bears that had bred at 1.5 years for the southern GW&JNF, suggesting that the age of first reproduction may be as early as 2 years.

Cub Age/Date of Parturition

Though only a few studies in Virginia have estimated dates of parturition, Carney (1985) estimated that parturition dates for bears in Shenandoah National Park, Virginia ranged between 9 January and 2 March. Godfrey (1996) estimated parturition dates between 1 January and 14 February, and Ryan (1997) reported dates of parturition between

5 January and 8 February, for northern and southern GW&JNF, respectively. The mean date of parturition was 22 January for both study areas on the GW&JNF. Godfrey (1996) and Ryan (1997) based parturition dates on a regression equation developed from cub measurements taken from captive born cubs of known age. Dates of parturition in Pennsylvania ranged between 1 and 27 January ($\overline{X}$ =15 January) (Alt 1989).

Noyce and Garshelis (1994) reported that individual cub weights were influenced by maternal weight, litter size, and litter order, but their sample size was too small to measure the influence of each variable. The regression equation developed by Godfrey (1996) did not account for variances due to sow age, nutritional condition, or litter size, all of which inevitably influence the growth rate of cubs in a given year. For instance, sow #94, a 3-year-old, gave birth to a male cub that appeared extremely malnourished and small when observed in the den in March. According to Godfrey's (1996) equation he was 3 weeks old, but was known to be at least 5 weeks of age because his eyes were completely open (Butterworth 1969) at the time the den was worked, and we heard him vocalize in the den 5½ weeks before working the den. His poor nutritional state, probably influenced by his mother's age or nutritional condition, prevented the regression from producing an accurate estimate of age.

Godfrey's (1996) regression equations were developed using data from cubs aged 1 to 60 days old, however, cub ages calculated with the equation during 1997 and 1998 ranged between 21 and 105 days old. Thirty-six (4 of 11) and 61 (22 of 36) percent of litter ages computed with equations A and B, respectively, were estimated to be older than 60 days. This growth curve may change significantly outside of the 0-60 day range, and may result in erroneous estimates of ages and dates of parturition for cubs older than those of the cubs used in its development.

Despite the potential problems with these regression equations, no alternate method of determining cub ages and parturition dates exists using the data that were collected. I was able to confirm the birth of 2 litters in the field during 1997, but have no way of verifying their exact dates of birth. The estimates provided by the regression equations are consistent with the "known" dates of parturition.

Cub Growth Measurements

We suspect that some cub growth measurements taken between years and among observers were somewhat inconsistent, and may have compromised the value of these data. However, cub ages and dates of parturition calculated based on cub hair and/or ear length are probably more reliable than some of the other measurements taken. Differences in morphological measurements among litter mates may be due to differential timing of individual births of litter mates (personal observation in captive study) and differences in aggressiveness at feeding times and resulting growth rates. Inherent physiological and genetic differences also may explain some of the variation. These differences may become more obvious as the cubs grow older with their siblings in a confined den space.

It is impossible to explain why differences in morphological features such as front paw lengths would not also result in differences in other features like front paw widths, hind paw widths or hind paw lengths. Differences in cub weights, chest girths, and neck girths were detected between 1995 and 1998. Differences in male weights and male neck girths were detected between 1997 and 1998. Male and female front paw widths differed during the 1998 den season.

MANAGEMENT IMPLICATIONS

Management decisions about black bears in many states often are based on the previous years harvest levels, but harvest level alone is insufficient information upon which to base management decisions. Wildlife managers should take into account information on reproductive parameters and sex specific survival rates that vary geographically. Setting bag limits and season limits for different harvest methods must be adjusted according to each population's level of production because the reproductive potential of a population becomes increasingly important as hunting pressure and natural mortality factors increase (Beecham 1980). Knowledge of habitat parameters as they change throughout the year is lacking for the state of Virginia. Future study should focus on the relationship between the bears and their habitat, food preferences, availability and quality in relation to reproductive success.

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APPENDIX

Appendix Table 1.1. Den site descriptions and reproductive status of radio-collared female black bears during the 1995 – 1998 den seasons in the George Washington & Jefferson National Forests, Virginia. Year is denoted by first 2 digits in the Den ID#.

Den ID#	Bear ID#	Age	Litter Size	Sex Ratio	Den Type	Status and comments
9501	15	12	3	2M:1F	Snag	Female with cubs
9502	13	2	0	--------	Tree	Lone Female
9503	101	6	2	1M:1F	Tree	Female with cubs
9504	110	4	1	0M:1F	Snag	Female with cubs
9505	65	4	Unknown		Tree	Female with cubs
9506	63	3	1	0M:1F	Tree	Female with cubs
9507	77	3	1	0M:1F	Tree	Used 2 dens in 1995
9508	85	4	---	--------	Tree	Female and yearlings
9509	94	3	1	1M:0F	Tree	Female with cubs
9510	31	4	1	0M:1F	Tree	Female with cubs
9511	72	6	2	Unknown	Tree	Female with cubs
9512	38	3	Unknown		Tree	Female with cubs
9513	95	3	Unknown		Snag	Female with unknown status
9514	20	4	Unknown		Tree	Female with cubs
9515	23	3	Unknown		Snag	Female with cubs
9516	89	5	0	--------	Tree	Lone Female
9517	49	5	---	--------	Tree	Female and yearlings
9518	50	5	2	2M:0F	Slashpile	Female with cubs
9519	4	4	2	1M:1F	Tree	Female with cubs
9520	90	7	3	3M:0F	Tree	Female with cubs
9521	62	11	Unknown		Tree	Female with cubs
9523	75	3	1	0M:1F	Tree	Female with cubs
9524	88	5	3	1M:2F	Tree	Female with cubs
9525	36	3	0	--------	Tree	Lone female
9527	51	6	0	--------	Rock Cavity	Lone Female
9528	77-2	3	---	--------	Tree	Female moved to new den
9601	15	13	---	--------	Tree	Female and 1 F yearling
9602	137	4	0	--------	Tree	Lone Female
9603	13	3	0	--------	Tree	Lone Female
9604	187	6	0	--------	Tree	Female devoured litter
9605	85	5	2	1M:1F	Tree	Female with cubs
9606	6	7	3	2M:1F	Snag	Female with cubs
9607	168	9	Unknown		Tree	Female with unknown status
9608	139	6	3	3M:0F	Snag	Female with cubs
9609	175	13	Unknown		Tree	Female with cubs
9610	63	4	2	1M:1F	Tree	Female with cubs

Appendix Table 1.1. Continued.

Den ID#	Bear ID#	Age	Litter Size	Sex Ratio	Den Type	Status and comments
9611	155	7	Unknown		Tree	Female with cubs
9612	154	14	3	1M:2F	Tree	Female with cubs
9613	23	4	---	--------	Snag	Female and 1 M yearling
9614	73	4	2	2M:0F	Tree	Female with cubs
9615	169	2	0	--------	Tree	Lone female
9616	165	4	2	1M:1F	Tree	Female with cubs
9617	156	6	1	1M:0F	Snag	Female with cubs
9618	153	15	3	3M:0F	Tree	Female with cubs
9619	172	7	0	--------	Tree	Lone female
9620	136	18	3	1M:2F	Tree	Female with cubs
9621	161	7	Unknown		Tree	Female with cubs
9622	194	4	0	--------	Snag	Lone Female
9623	181	6	Unknown		Tree	Female with cubs
9624	75	4	---	--------	Tree	Female with 1 F yearling
9625	31	5	Unknown		Tree	Female with unknown status
9626	204	11	---	--------	Snag	Female with yearling(s)
9627	174	4	0	--------	Excavation	Lone female
9628	94	4	2	Unknown	Open nest	Female with cubs
9629	138	5	1	1M:0F	Open nest	Female with cubs
9630	172-2	7	0	--------	Tree	Lone female
9631	110	5	2	1M:1F	Stump	Female with cubs
9632	176	10	Unknown		Open nest	Female with unknown status
9636	95	4	Unknown		Tree	Female with unknown status
9637	51	7	2	Unknown	Slashpile	Female with cubs
9638	178	4	Unknown		Open nest	Female with cubs
9701	221	1	0	--------	Tree	Lone female
9702	175	14	0	--------	Snag	Lone female
9703	235	1	0	--------	Snag	Lone female
9704	204	12	3	1M:2F	Tree	Female with cubs
9706	165	5	2	0M:2F	Tree	Female with cubs
9707	85	6	3	1M:2F	Tree	Female with cubs
9708	187	7	1	0M:1F	Tree	Female with cubs
9709	172	8	3	2M:1F	Tree	Female with cubs
9710	152	14	3	Unknown	Open nest	Female with cubs
9711	174	5	3	1M:2F	Tree	Female with cubs
9712	75	5	Unknown		Snag	Female with cubs
9713	161	8	2	2M:0F	Snag	Female with cubs
9714	89	7	3	1M:2F	Tree	Female with cubs
9715	293	6	Unknown		Tree	Female with cubs
9716	169	3	0	--------	Snag	Lone female
9717	13	4	2	Unknown	Snag	Female with cubs

Appendix Table 1.1. Continued.

Den ID#	Bear ID#	Age	Litter Size	Sex Ratio	Den Type	Status and comments
9718	110	6	---	--------	Tree	Female with yearling(s)
9719	194	5	Unknown		Tree	Female with unknown status
9720	23	5	Unknown		Tree	Female with unknown status
9721	178	5	0	--------	Tree	Female with unknown status
9722	176	11	---	--------	Slashpile	Female with 2 yearlings
9724	94	5	---	--------	Open nest	Lone female (w/ yearlings?)
9725	95	5	3	2M:1F	Slashpile	Female with cubs
9726	307	13	3	Unknown	Open nest	Female with cubs
9727	72	8	2	2M:0F	Excavation	Female with cubs
9728	138	6	3	Unknown	Open nest	Female with cubs
9729	15	14	3	1M:2F	Rock Cavity	Female with cubs
9730	265	3	0	--------	Open nest	Lone female
9731	198	10	---	--------	Open nest	Female and 2 yearlings
9732	62	13	2	1M:1F	Rock Cavity	Female with cubs
9733	233	1	0	--------	Tree	Lone female
9734	115	2	0	--------	Tree	Lone female
9735	155	8	Unknown		Snag	Female with unknown status
9737	63	5	Unknown		Tree	Female with cubs
9801	75	6	---	--------	Tree	Female and 2M yearlings
9802	172	9	---	--------	Snag	Female and 1M yearling
9804	63	6	---	--------	Tree	Female and 1M yearling
9806	72	9	---	--------	Open nest	Female and 1M yearling
9807	152	15	---	--------	Slashpile	Female and 3 yearlings
9808	138	7	---	--------	Open nest	Female and 3 yearlings
9809	329	1	---	--------	Tree	Lone female
9810	204	13	---	--------	Tree	Female with unknown status
9811	293	7	0	--------	Tree	Female with unknown status
9813	194	6	Unknown		Snag	Female with unknown status
9817	389	6	3	1M:2F	Tree	Female with cubs
9819	299	9	0	--------	Snag	Female with unknown status
9820	169	4	2	1M:1F	Snag	Female with cubs
9821	62	14	---	--------	Tree	Female and 1 F yearling
9822	161	9	2	0M:2F	Snag	Female with cubs
9823	31	7	3	2M:1F	Snag	Female with cubs
9825	73	6	0	--------	Tree	Lone female-barren
9826	341	6	---	--------	Open nest	Female with 3 yearlings
9827	300	8	4	0M:4F	Tree	Female with cubs
9828	165	6	0	--------	Tree	Lone female-barren
9829	13	5	---	--------	Snag	Female with 2 yearlings
9830	15	15	2	1M:1F	Rock Cavity	Female with cubs
9831	412	Unk.	0	--------	Tree	Female with 1 F yearling

Appendix Table 1.1. Continued.

Den ID#	Bear ID#	Age	Litter Size	Sex Ratio	Den Type	Status and comments
9832	298	12	3	1M:2F	Slashpile	Female with cubs
9833	181	8	3	0M:3F	Tree	Female with cubs
9834	143	10	3	1M:2F	Slashpile	Female with cubs
9835	110	7	0	--------	Tree	Lone female-barren
9836	49	8	3	2M:1F	Tree	Female with cubs
9837	353	Unk.	0	--------	Tree	Female with unknown status
9838	95	6	2	1M:1F	Slashpile	Female with cubs
9839	176	11	Unknown		Snag	Female with unknown status
9840	304	4	0	--------	Rock Cavity	Lone female
9841	265	4	Unknown		Snag	Female with cubs
9842	6	9	Unknown		Excavation	Female with cubs
9843	94	6	Unknown		Open nest	Female with cubs
9844	285	4	Unknown		Unknown	Female with unknown status
9845	300-2	8	---	---------	Tree	Female's first den site-moved
9846	15-2	15	---	---------	Rock Cavity	Female's first den site-moved

Appendix Table 1.2. Female black bear capture data for summers 1994 – 1997 in the George Washington & Jefferson National Forests, Virginia.

Bear ID#	Date captured	Age	Lactating	Estrus	Cubs	Weight (kg)	Total length (mm)	Chest girth (mm)
4	6/6/94	3	N	N	N	23.6	1330	645
	8/29/95	4	Y	N	Y	57.7	1556	770
6	6/7/94	5	Y	N		68.2 (est)	1560	700
	6/14/96	7	Y	N	Y-3	82.3	1650	837
	6/6/97	8	Y	Y	N	70.5 (est)		881
13	6/13/94	1				23.6	1100	560
	4/10/96	3	N	N	N			
	8/2/96	3	N	Y	N	56.8	1470	707
	8/21/96	3		N				
	8/9/97	4	Y	N	N	61.4	1590	801
15	6/14/94	11	Y			72.7 (est)	1610	900
17	6/15/94	2	N	N	N	59.1	1414	855
20	6/16/94	3	Y	N	N	45.9	1440	760
	7/10/97	6	N	Y	N	58.2	1575	745
	7/20/97	6		Y	N			
22	6/17/94	2	N	N	N	46.4	1165	605
23	6/18/94	2	N	N	N	43.2	1451	694
	8/29/94	2				38.6		
31	6/23/94	3	N		N	72.7	1340	770
	4/24/97	6			N	77.3 (est)	1670	892
36	6/30/94	2	N	N	N	33.6	1370	690
	8/2/95	3	N	N	N	50.0		763
38	7/9/94	2	N	N	N	39.1	1290	680
49	7/15/94	4	Y	N	N	45.5	1500	750
	7/17/97	7	N	Y	N	47.3		
50	7/15/94	4	N	unk	N	50.5	1528	724
51	7/16/94	5	N	Y	N	54.1	1510	760
59	7/29/94	7	Y			65.9	1610	760
61	7/30/94	2	N	N	N	52.3	1272	660
62	7/31/94	10	N	Y	N	76.4	1490	820
	8/22/95	11	Y	N	Y	62.3	1606	842
63	7/31/94	2	N	Y	N	22.7	1350	700
	8/3/94	2						
	7/7/95	3	N	Y	N	57.7	1521	752
	7/9/96	4	Y	N	N	53.6	1482	716
65	8/1/94	3	N	N	N	38.6	1280	630
	7/31/96	5	Y	N	N	51.4	1456	751
72	8/4/94	5	N	Y	N	77.3	1441	809
	6/13/96	7	N	Y	N	52.3	1157	723

Appendix Table 1.2. Continued.

Bear ID#	Date captured	Age	Lactating	Estrus	Cubs	Weight (kg)	Total length (mm)	Chest girth (mm)
73	8/5/94	2	N	N	N	29.5	1270	640
	7/15/95	3	N	Y	N	44.1	1418	713
75	8/7/94	2	N	Y	N	33.2	1320	620
	8/25/95	3	Y	N	Y	43.2	1420	719
75	8/5/96	4	N	Y	N	46.8	1570	704
	8/22/97	5	N	N	N	50.9	1435	775
77	8/8/94	2	N		N	27.3	1263	630
80	8/9/94	5	Y	N	N	59.1	1430	818
85	8/12/94	3	Y	N	Y	47.7	1405	735
	8/16/95	4	N	N	N	67.7		
87	8/10/94	4	Y		Y	51.4	1570	760
88	8/16/94	4	N	N	N	54.1	1460	820
89	8/19/94	4	Y	N	Y	63.6	1461	794
	7/31/95	5	N	Y	N	65.5	1390	845
	8/20/96	6	N	Y	N	77.3	1538	888
90	8/19/94	6	N	N		59.1 (est)	1490	908
94	8/22/94	2	N	N	N	40.9	1389	696
	8/20/95	3			N	40.9	1462	765
	8/5/96	4	Y	N	Y-1	50.0	1560	720
	6/11/97	5	N	Y	N	50.5		
95	8/23/94	2	N	N	N	40.9	1489	725
98	8/25/94	4	Y	N	Y		1465	760
101	8/27/94	5	N	N	N	51.4	1420	700
110	8/31/94	3	N	N	N	46.8	1410	690
111	9/1/94	4	Y		N	64.1	1670	820
115	7/16/95	0.5				9.1	840	414
127	8/29/95	0.5				15.9 (est)		
133	5/11/95	unk	N	N	N	74.1	1660	780
134	5/11/95	11	Y	N	Y			
136	6/20/95	15	Y	N	N	88.6	1710	965
137	6/21/95	3	Y	N	N	43.2		
138	6/21/95	4	N	N	N	70.5	1500	830
	8/5/96	5	N	Y	N	81.8	1530	855
139	6/21/95	5	N	Y	N	52.3	1372	723
143	6/22/95	7	Y	N	N	84.1	1520	1022
	8/17/97	9	N	N	N	97.7	1630	930
152	6/27/95	12	Y		N	68.2		
	6/26/96	13	N	Y	N	61.4 (est)	1400	790
	6/24/97	14	Y	N	Y	56.8	1514	770
153	6/28/95	14	N	N	N	78.6		868

Appendix Table 1.2. Continued.

Bear ID#	Date captured	Age	Lactating	Estrus	Cubs	Weight (kg)	Total length (mm)	Chest girth (mm)
153	7/3/97	16	N	N	N	63.6	1585	803
	8/1/97	16		Y	N	53.2	1510	710
154	6/28/95	13	N		N	72.7 (est)	1560	855
	7/7/95	13				66.8		
155	7/10/95	6	N	Y	N	49.1	1540	695
156	7/12/95	5	N	Y	N	71.4	1570	845
161	7/14/95	6	N	Y	N	66.8	1555	793
	8/6/96	7	N	Y	N	55.9	1387	689
	6/29/97	8	N	N	N	72.7 (est)	1483	866
165	7/18/95	3	Y			67.3	1530	855
	7/11/96	4	Y	Y	N	59.1	1680	810
	8/17/97	5	N	N	N	72.7	1590	817
168	7/19/95	9	N	Y	N	90.9	1162	810
169	7/19/95	1	N	N	N	34.1	1188	622
	6/6/96	2	N	N	N	36.4		
	8/14/96	2	N	Y	N			
	8/2/97	3	N	N	N	70.5	1490	747.5
172	7/22/95	6	N	N	N	72.7	1538	884
	8/2/95	6						
174	7/24/95	3	N	Y	N	43.2	1429	706
175	7/25/95	12	N	Y	N	66.8	1540	793
176	7/25/95	9	Y	Y	N	63.6	1520	830
178	7/27/95	3	N	M	N	61.4	1580	805
	8/18/96	4	Y	N	N	59.1	1580	760
	7/16/97	5	N	Y	N	81.8	1670	870
181	7/30/95	5	N		N	61.4	1250	786
	6/12/97	7	N	N	N	59.1	1527	799
184	8/3/95	3	Y	N	N	61.4	1460	832
187	8/5/95	5	N	Y	N	60.9	1530	830
	6/19/96	6	N	N	N	68.2		
	7/24/96	6	N	Y	N	53.6	1593	795
194	8/15/95	3	N	N	N	47.7	1541	732
	8/6/96	4	N	Y	N	34.1	1370	686
	7/12/97	5	N	Y	N	55.0	1527	769
198	8/19/95	8	N	N	N	75.0	1610	906
	7/13/96	9	N	N	Y-2	54.5	1760	780
	6/25/97	10	N	Y	N	65.9	1650	830
199	8/20/95	1	N		N	29.5	1310	695
	6/25/96	2	N	N	N	30.9	1320	740
	6/22/97	3	N	N	N	62.3	1550	787

Appendix Table 1.2. Continued.

Bear ID#	Date captured	Age	Lactating	Estrus	Cubs	Weight (kg)	Total length (mm)	Chest girth (mm)
204	8/28/95	10	Y	N	N	59.1	1436	774
	7/20/96	11	N	N	N	72.3	1432	839
	7/27/96	11	N	N	N			
	8/26/97	12	N		N	66.8	1460	857
206	8/29/95	1	N	N	N	46.4	1402	683
	8/7/96	2	N	N	N	50.5	1566	697
	8/6/97	3	N	N	N	60.0	1586	800
246	6/8/96	2	N	N	N	52.3	1484	675
	6/13/96	2						
	7/9/97	3	N	N	N	53.2	1528	814
253	6/15/96	2	N	N	N	52.7	1504	733
	8/13/96	2	N	N	N	59.1 (est)		
257	6/22/96	2	N	N	N	38.6	1345	610
	7/25/96	2		Y				
259	6/26/96	2	N	N	N	45.5	1412	715
263	6/27/96	2	N	Y	N	40.9	1400	722
	7/19/96	2	N	Y	N	43.2	1424	624
264	6/27/96	5	Y	N	Y-1	57.7	1520	710
	6/16/97	6	Y	N	N	53.6	1583	799
265	6/28/96	2	N	Y	N	36.4	1400	730
	6/24/97	3	N	N	N	84.1		
	8/4/97	3						
267	6/30/96	4	N	Y	N	68.2	1585	745
269	7/10/96	4	N	Y	N	54.5	1470	780
270	7/10/96	3	Y		Y	43.2	1350	730
	8/13/96	3	N	N	N	35.5	1383	732
	8/1/97	4	N	N		60.5	1560	854
	8/4/97	4						
272	7/11/96	4	N	Y	N	57.7	1520	713
273	7/11/96	10	Y	Y	N	65.9	1434	874
283	7/24/96	6	N	Y	N	50.0	1460	742
	8/25/96	6	N	N	N	36.4 (est)		
284	7/25/96	0				6.8 (est)	810	410
285	7/26/96	2	N	Y	N	47.7		840
	8/19/97	3	N	N		66.8		
289	8/2/96	0.5				11.4	910	410
	8/30/96	0.5				15.9		
293	8/4/96	5	Y	N	N	58.2	1620	790
	6/18/97	6	Y	N	N	56.8	1560	758
295	8/7/96	7	Y	N		51.4	1480	767

Appendix Table 1.2. Continued.

Bear ID#	Date captured	Age	Lactating	Estrus	Cubs	Weight (kg)	Total length (mm)	Chest girth (mm)
295	7/15/97	8	Y	N	N	50.0	1553	793
297	8/9/96	2	N	N	N	34.1	1175	650
298	8/9/96	10	Y	N	Y-4	53.6	1390	822
	8/18/96	10	Y	N	Y-4		1495	807
	6/18/97	11	N	Y	N	59.1	1532	791
	6/28/97	11	N	Y	N	59.1		
299	8/14/96	7	Y	N	N	59.1 (est)	1500	747
	8/4/97	8	N	N	N	67.3	1580	812.5
300	8/16/96	6	Y	N	N	68.2	1470	777
	6/25/97	7	N	Y	N	89.5	1551	943
304	8/22/96	2	N	Y	N	47.7	1430	699
305	8/24/96	4	N	N	N	47.7	1330	692
307	9/5/96	12	Y	N		59.1	1460	731
338	4/11/97	1				20.0 (est)	1330	660
	7/16/97	1				36.4 (est)		
341	5/27/97	4	Y	N	Y		1550	960
344	5/27/97	8	Y	N	Y	93.2	1679	814
353	6/12/97	unk	N			55.5	1750	770
	7/2/97	unk	N	Y	N			
357	6/14/97	unk	N	N	N	58.2	1588	774
358	6/17/97	unk	N	N	N	37.3	1400	670
359	6/18/97	1	N			20.9	1157	533
364	6/23/97	5	Y	Y	N	53.2	1604	728
366	6/24/97	2	N	N	N	31.8	1258	629
	8/6/97	2	N	N	N	34.1	1343	647
367	6/25/97	3	N	N	N	38.6 (est)	154	722
371	6/27/97	20	Y	Y	N	71.4	1640	826
	8/15/97	20	N	Y	N	65.0	1621	814
372	6/28/97	3	N	N	N	52.3	1348	743
	8/10/97	3	N	N	Y	43.2		
374	7/2/97	9	N	N	N	81.8	1490	814
377	7/2/97	5	N	Y	N	77.3	1562	829
378	7/2/97	1	N	N	N	34.1	1260	640
380	7/1/97	3	N	N	N	40.5	1300	650
381	7/2/97	2	N	N	N	44.1	1412	749
388	7/11/97	1				21.4	1198	554
389	7/14/97	5	N	Y	N	47.3	1458	745
390	7/16/97	3	N	N	N	54.5 (est)	1473	764
	7/25/97	3	N	N	N	51.4		
394	7/19/97	3	N	N	N	40.9	1442	689

Appendix Table 1.2. Continued.

Bear ID#	Date captured	Age	Lactating	Estrus	Cubs	Weight (kg)	Total length (mm)	Chest girth (mm)
396	7/20/97	18	Y	Y		79.5	1650	884
399	7/22/97	3	N	N	N	45.5	1420	641
	8/24/97	3	N	N	N	41.8	1440	614
401	7/22/97	10	N	N	N	75.0	1527	578
402	7/25/97	3	N	N	N	38.6	1480	678
405	7/31/97	11	N	Y		42.3	1420	699.5
406	8/3/97	7	Y	N	N	64.1	1568	796
407	8/3/97	unk	Y	Y	N	50.9	1495	745
408	8/4/97	3	N	Y	N	34.1	1365	627
410	8/10/97	3	N	N	N	36.4	1390	657
412	8/12/97	unk	N	N	N	38.2	1340	694.5
413	8/17/97	unk	Y	N	Y-3	63.2	1492	870
415	8/17/97	5	N	N	N	70.5	1550	749
419	8/23/97	7	Y	N	N	76.4	1627	825
421	11/20/97	unk	N	N	N	72.7		

Appendix Table 1.3. Estimated dates of parturition and litter age for female black bears in the George Washington & Jefferson National Forests, Virginia during winters 1995 – 1998.

Sow ID#	Sow age	Date handled	Litter Size	Litter age range (days)	Estimated litter age (days)	Estimated date of parturition
4	4	3/26/95	2	53-55	55[1]	1/30/95
15	12	3/8/95	3	53-69	59[1]	1/8/95
31	4	3/7/95	1	65	65[1]	1/1/95
50	5	3/16/95	2	65-69	67[1]	1/8/95
63	3	3/28/95	1	67	67[1]	1/20/95
75	3	3/9/95	1	27	27[1]	2/10/95
88	5	3/27/95	3	59-78	66[1]	1/20/95
90	7	3/12/95	3	55-57	56[1]	1/15/95
94	3	3/15/95	1	21	21[1]	2/22/95
101	6	3/17/95	2	53-57	56[1]	1/20/95
110	4	3/14/95	1	44	44[1]	1/29/95
6	7	3/6/96	3	38-46	44[2]	1/22/96
63	4	3/14/96	2	46-61	54[2]	1/20/96
73	4	3/20/96	2	39-50	45[2]	2/4/96
85	5	4/11/96	2	66-69	68[2]	2/3/96
94	4	3/29/96	2[3]	59	59[2]	1/31/96
110	5	3/28/96	2	69-72	71[2]	1/17/96
136	15+	4/5/96	3	64-75	69[2]	1/27/96
138	5	3/31/96	1	90	90[2]	1/1/96
139	6	3/8/96	3	46-54	52[2]	1/16/96
153	15	3/24/96	3	62-67	65[2]	1/19/96
154	14	3/16/96	3	47-61	55[2]	1/21/96
156	6	3/23/96	1	70	70[2]	1/12/96
165	4	3/22/96	2	54-59	57[2]	1/25/96
15	14	3/4/97	3	58-71	63[2]	12/31/96
62	13	3/10/97	2	67-68	67[2]	1/1/97
72	8	3/12/97	2	62-67	64[2]	1/6/97
85	6	3/11/97	3	45-51	48[2]	1/21/97
89	7	3/26/97	3	76-80	77[2]	1/8/97
95	5	3/8/97	3	48-55	50[2]	1/16/97
161	8	3/17/97	2	61-64	62[2]	1/13/97
165	5	3/13/97	2	61-75	68[2]	1/4/97
172	8	3/14/97	3	60-84	68[2]	1/5/97
174	5	3/15/97	3	45-62	53[2]	1/21/97
187	7	3/13/97	1	70	70[2]	1/2/97
204	12	3/3/97	3	48-51	49[2]	1/12/97
15	15	3/22/98	2	80-105	92[2]	12/19/97
31	7	3/16/98	3	77-88	82[2]	12/24/97
49	8	3/27/98	3	55-57	56[2]	1/30/98
95	6	3/31/98	2	65-72	68[2]	1/21/98

Appendix Table 1.3. Continued.

Sow ID#	Sow age	Date handled	Litter Size	Litter age range (days)	Estimated litter age (days)	Estimated date of parturition
143	10	3/25/98	3	69-78	72[2]	1/12/98
161	9	3/14/98	2	62-65	63[2]	1/9/98
169	4	3/25/98	2	56-62	59[2]	1/25/98
181	8	3/26/98	3	57-71	62[2]	1/23/98
298	12	3/24/98	3	67-73	70[2]	1/13/98
300	8	3/20/98	4	71-81	77[2]	1/1/98
389	6	3/3/98	3	36-38	37[2]	1/25/98

[1]Regression model (Godfrey 1996): Age=1.48 + (1.93*hair length).
[2]Regression model (Godfrey 1996): Age=-5.98 + (1.28*hair length) + (0.75* ear length).
[3]Litter size of 2 cubs – measurements available for 1 cub only.

Appendix Table 1.4. Definitions of morphological measurements taken on black bear cubs at den sites in the George Washington & Jefferson National Forests, Virginia, 1995 – 1998.

Measurement	Definition
Total length	Total length along the backbone 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 ear lobe
Front paw length	Length of paw from bottom of main pad to anterior tip of middle toe pad
Front paw width	Width of large pad on front paw at widest point
Hind paw length	Length of paw from bottom of pad at heel to anterior tip of middle toe pad
Hind paw width	Width of pad on hind paw at widest point
Hair length	Length of longest hair on top of head midway between the ears

Chapter 2: BLACK BEAR CUB SURVIVAL IN VIRGINIA

Abstract:

Cub survival is one of the most important yet one of the most difficult to obtain demographic parameters for black bear (*Ursus americanus*) populations. Because cubs grow from less than 0.5 kg to greater than 20 kg during their first year, equipping them with telemetry devices to monitor first year survival is difficult and risky. During 1995 – 1999, we monitored 98 (48M:50F) black bear cubs equipped with expandable radio-collars (Higgins 1997) or radio transmitters implanted subcutaneously. We computed survival rates for 82 cubs using the Kaplan-Meier staggered entry design (Pollock et al. 1989) and the method described by Heisey and Fuller (1985). Kaplan-Meier estimated 306-day survival rates ranged from 33% (0.00, 0.87) to 100% for male cubs and 50% (0.00, 1.00) to 100% for female cubs. Combined 5-year 306-day survival estimates using Kaplan-Meier were 73% (0.49, 0.96) for males and 91% (0.80, 1.00) for females. Survival estimates for male and female cubs were not different for Kaplan-Meier (P=0.240) or Heisey-Fuller (P=0.326) methods. The overall 306-day survival rate for all cubs was 81% (0.67,0.94) using the Kaplan-Meier method and 76% (0.63, 0.92) using the Heisey-Fuller method.

INTRODUCTION

Wildlife scientists in AZ (LeCount 1987), MN (Rogers 1987, Garshelis et al. 1996), MA (Elowe and Dodge 1989), and Ontario (Kolenosky 1990) have tried to acquire reliable estimates of black bear cub survival, but because an effective method to monitor bears through their first year has not been developed, little is known about natural mortality factors and survival rates of cubs. Post-parturition loss of cubs, while the family unit is denned, is also difficult to assess (Jonkel and Cowan 1971), but may play a significant role in population dynamics. Much of what is known about cub survival has been inferred from differences between litter size of cubs soon after birth and yearlings found denned with the sow the following den season (Eiler 1981, Kolenosky 1990, Schrage 1994).

Mortality rates for cubs in the care of their mothers generally are assumed to be low (Bunnell and Tait 1985). In Massachusetts, Elowe (1987) reported that age and experience of the sow had a significant influence on cub survival rates; older sows were more successful raising litters than younger sows. Elowe (1987) and Alt (1981) in PA, also reported that larger litters have a better chance of survival than smaller litters, and sows producing their first litter are less likely to succeed than sows raising a subsequent litter. In Virginia, however, Kasbohm (1994) reported that larger litters suffered greater mortality, though few complete litter losses occurred. Maternal condition also is thought to affect survival of offspring (Elowe and Dodge 1989, Eiler et al. 1989, Samson and Huot 1995).

Cub survival rates reported in the literature differ greatly. In Massachusetts, Elowe and Dodge (1989) reported a 41% mortality rate ($\underline{n}$=41) for cubs from parturition through family break-up at age 1. Sixty-two percent of male cubs ($\underline{n}$=21) did not make it to their second year, versus 20% of female cubs ($\underline{n}$=20). Kolenosky (1990) reported that survival to 1 year for bears in east-central Ontario differed according to sex and age; 58% of male cubs ($\underline{n}$=19) survived to age 1.5 years compared to only 46% of female cubs ($\underline{n}$=13). Erickson (1959) determined that black bears become self sufficient at approximately 5 months of age. Thus, cubs are thought to be less vulnerable to mortality factors after this age. Thirteen of 17 cub mortalities in Massachusetts (Elowe and Dodge 1989) occurred between 1.5 and 5 months of age. Garshelis et al. (1996) reported a 17%

mortality rate for cubs to age 1 (n=128) in Minnesota based on den checks over a 14 year period; mortality for male cubs was twice that of female cubs. Rogers (1987) reported cub mortality rates (unspecified age) between 12% and 41% in Minnesota. Lindzey and Meslow (1980) reported a mortality rate of 13.8% for bears up to age 1 in Oregon, but considered their rate an underestimate. Causes of cub mortality included abandonment, natural accident, presumed disease, predation, cannibalism by sow or other bears, and starvation (Rogers 1976, Lindzey and Meslow 1977, Elowe 1987, LeCount 1987, Elowe and Dodge 1989). In Arizona, cannibalism accounted for 50% of all cub mortalities (LeCount 1987).

LeCount (1987) hypothesized that a high harvest of resident male black bears had the potential to decrease cub survival. A decrease in resident males would allow an influx of non-resident males who would benefit from killing cubs, returning the sow to breeding condition. This idea builds on Rogers' (1977) kinship theory that resident males do not typically kill cubs because of the likelihood of killing their own offspring. It is in a non-resident male's best interest to do so however, to propagate his genes in the population and eliminate those of his competitors.

STUDY AREA

The 840 km^2 study area (see Chapter 1 Figure 1.1) was primarily in Augusta and Rockingham Counties, Virginia in the Ridge and Valley Province of the Appalachian Mountain Range. It encompassed the Dry River and Deerfield Ranger Districts of the George Washington and Jefferson National Forests, formerly the George Washington National Forest.

Annual rainfall averaged 86 cm; snowfall averaged 71 cm. Temperatures varied between 0.3^oC and 22.9^oC, and averaged 11.8^oC over the course of the year. Temperatures and precipitation amounts were recorded at Dale Enterprise, Virginia, 6.5 km east of the mountain range, which typically receives less precipitation and has on average 2.8 - 5.6^oC cooler temperatures than the mountains of the GW&JNF (Rawinski et al. 1994).

Major forest types included eastern hemlock (*Tsuga canadensis*), chestnut oak (*Quercus prinus*), sugar maple-beech-yellow birch (*Acer saccharum-Fagus spp.-Betula* *allegheniensis*), pitch pine (*Pinus rigida*), white oak-black oak-northern red oak (*Quercus alba-Q. velutina-Q. rubra*), northern red oak, yellow poplar-white oak-northern red oak (*Liriodendron tulipifera*), eastern white pine (*Pinus strobus*), and barren and brush cover such as mountain laurel (*Kalmia latifolia*) and scrub or bear oak (*Q. ilicifolia*) (Rawinski et al. 1994, Godfrey 1996)

METHODS

We trapped black bears in successive summers during 1994-1998 and placed radio collars on a select number of adult males and females (Telonics Inc., Mesa, AZ, Lotek Engineering Inc., New Market, Ontario, Canada) so that we could track them throughout the year and locate them in dens during November, December, and January. We visited dens of females suspected of being pregnant in mid-March to early-April to increase the likelihood that cubs handled by us would be greater than or equal to 8 weeks old.

During den visits, we immobilized sows and removed their cubs from the den structure to determine their sex and to count, measure, and weigh them. We tattooed cubs greater than 1.4 kg on their upper lip to help identify individuals at a later date. We placed expandable radio collars (ATS, Isanti, MN) on some cubs (Higgins 1997), while others had radio transmitters surgically implanted subcutaneously (AVM Instruments, Livermore, CA, ATS, Isanti, MN). No cubs weighing less than 1.65 kg (3.6 lbs.) received a radio collar or implanted transmitter. Each cub transmitter package had a mortality sensor with a 4-hour delay.

We sedated cubs selected for implant surgery with a 5:1 mixture of ketamine hydrochloride (Ketaset, Fort Dodge Animal Health, Fort Dodge, IA) and xylazine hydrochloride (Rompun, Bayer Corporation, Shawnee Mission, KS) at 1 cc per 45 kg body weight (see Chapter 3). A licensed veterinarian performed all surgical procedures in the field while at or near the den. Following surgery, we administered an antibiotic (LA200; oxytetracycline, Pfizer, distributed by Animal Health, New York, NY) (4cc/45 kg body weight) to each cub to combat any infections introduced during surgery. We also administered an antagonist (Antagonil, yohimbine hydrochloride, Wildlife Laboratories, Inc., Fort Collins, CO, or Yobine, yohimbine hydrochloride, Lloyd

Laboratories, Shenandoah, IA) to reverse the effects of the xylazine hydrochloride and monitored each cub for vital signs before returning them to their mother in the den.

We monitored cubs equipped with radio telemetry devices (AVM, Livermore, CA; Advanced Telemetry Systems, Inc., Isanti, MN) each day from the day of attachment through the date of their death, collar or implant loss, or censor. Cubs were censored after we lost contact with the radio transmitter due to battery failure or malfunction or other unknown circumstances. Upon detection of a mortality signal, we tracked the signal until we found the dropped transmitter or cub carcass. We recorded mortality information while at the site and collected carcasses for later examination by a veterinary pathologist whenever possible.

We estimated cub survival with both Kaplan-Meier's staggered entry procedure and Heisey and Fuller's staggered entry procedure in their program MICROMORT (Heisey and Fuller 1985, Pollock et al. 1989). Survival estimates were computed from approximately 1 March (first date transmitters were attached) to 31 December. We compared male and female cub survival rates within and between years using the ANOVA test and failed to detect any differences between sexes within years. We then pooled male and female samples within each year and compared survival rates between years. Due to our small sample sizes for individual years, we pooled all 5 years of data to compute an overall survival estimate despite detecting differences between years.

We selected 4 intervals for Heisey-Fuller survival estimates: (1) 1 March to 31 May (pre and post den emergence), (2) 1 June to 31 July (breeding season), (3) 1 August to 31 August (late breeding, no hunting), and (4) 1 September to 31 December (chase and hunt season for black bears) (Higgins 1997). We compared cub survival between years and sexes with the ANOVA test.

We estimated mortality and dropped collar dates as the midpoint between the last time the transmitter signal was detected on active mode and the first date it was detected on mortality mode. We censored radio-marked cubs with which we lost contact (White and Garrott 1990). The censor date was the midpoint between the last date the transmitter signal was detected and the first time it was not heard. During the 1995 den season, a number of cubs were fostered to other females with cubs, confounding our data.

These cubs and the natural cubs of foster mothers were not used in this analysis due to the bias associated with fostering.

RESULTS

We equipped 98 cubs (48M:50F) in 47 litters with either expandable radio collars or subcutaneous implants. We radio collared 61 (27M:34F) cubs and surgically implanted 24 (10M:14F) cubs, for a total of 85 different cubs, during March or April 1995, 1996, 1997, 1998, and 1999 (Appendix Table 2.1). We later radio-collared two implanted females (ID 324 and 325) that lost their implants prior to den emergence. In addition, we radio-marked 11 cubs of females held in captivity over winter at Virginia Tech; 10 (9M:1F) cubs received radio collars and 1 (1F) cub received an implant. During summer trapping, we captured and radio collared 3 (2M:1F) cubs of study females, 1 of which had previously been radio-collared (ID 115) but had slipped her first collar. Radio transmitter ranges varied between 0.5 km and 11.5 km depending upon their geographic location and elevation within the mountainous terrain. In general, subcutaneous implants had substantially less range than radio collars.

Implanted cubs retained their subcutaneous implants for an average of 55.5 days (Median=37.0, $\underline{n}$=21, SE=11.9) before they failed, were rejected, or the cub wearing it died (Figure 2.1A). Collared cubs wore their radios for an average of 150.1 days (Median=127.0, $\underline{n}$=61, SE=16.5) before they dropped off, failed, were removed, the cub died, or the study ended (Figure 2.1B). The minimum total time that black bear cubs wore either cub collars or subcutaneous implants was 125.9 days (Median=76.0, $\underline{n}$=82, SE=13.4) (Figure 2.1C). Maximum length of time collars or implants were worn could not be computed because several cubs were still wearing active collars at the conclusion of this study.

We influenced the survival of 4 litters (6M:4F) in 1995 attempting to foster 3 orphaned cubs (1M:2F) from 2 litters to female study animals. We omitted all of the individuals affected by this fostering from this analysis. Six other cubs were not included because of handling influences. The final analysis included 82 cubs (40M:42F; 61 collars:21 implants) in 40 litters (Table 2.1).

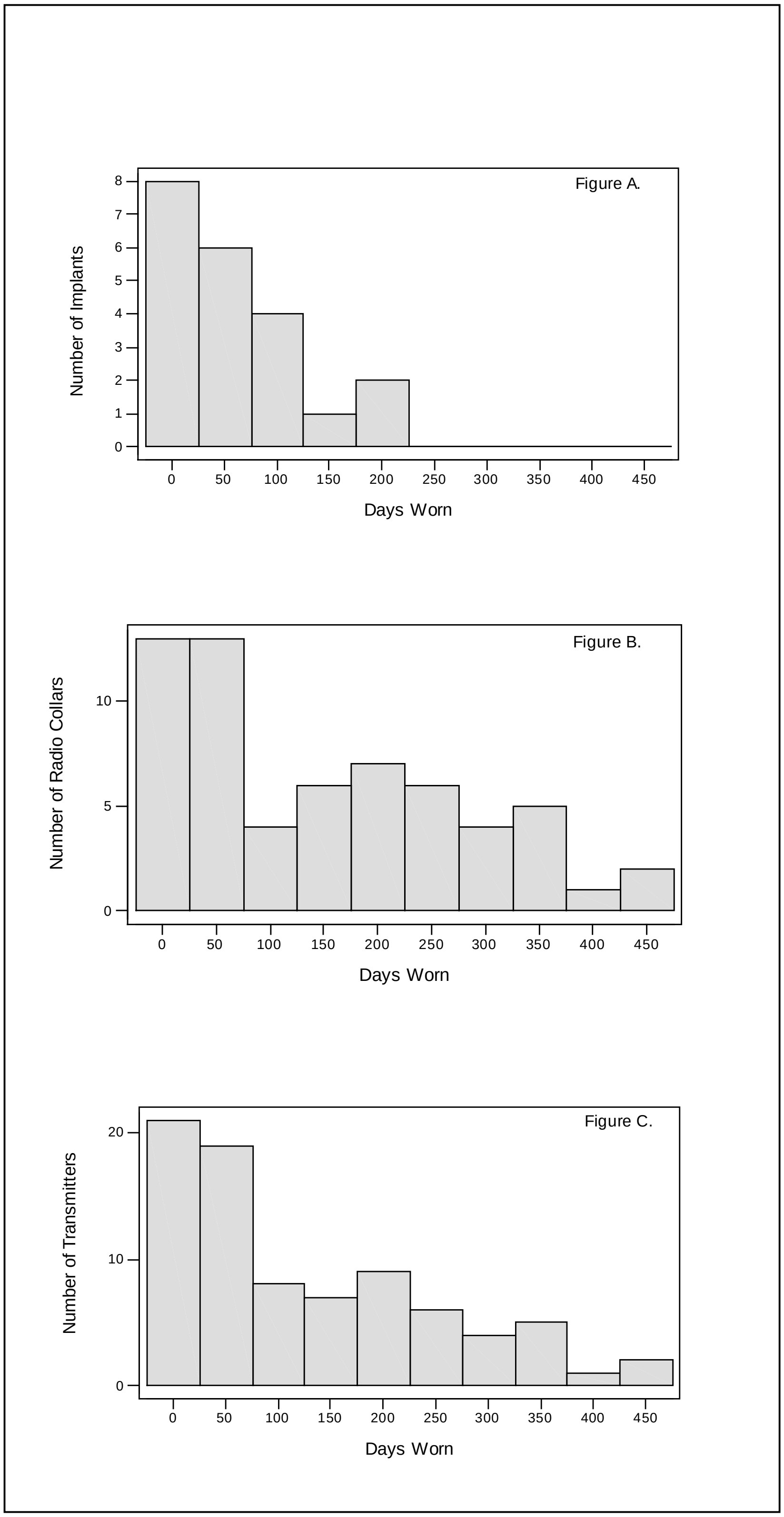

Figure 2.1. Length of time radio transmitters (A. implants, B. collars, C. implants and collars) were worn by black bear cubs in the George Washington & Jefferson National Forests, Virginia, 1995 – 1999.

Table 2.1. Black bear cubs equipped with expandable radio collars and subcutaneous implants on the George Washington & Jefferson National Forests, Virginia, 1995 – 1999.

Id #	Date radioed	Estimated date of death/ drop/censor	# Days worn	Status	Sex	Year Born	Transmitter type
116	4/14/95	8/31/95	139	dropped transmitter	F	1995	collar
122	3/16/95	3/27/95	11	natural mortality	M	1995	collar
123	3/16/95	3/27/95	11	natural mortality	M	1995	collar
126	3/26/95	7/31/95	127	dropped transmitter	M	1995	collar
127	3/26/95	9/14/95	172	dropped transmitter	F	1995	collar
131	3/28/95	4/15/95	18	unknown mortality	F	1995	collar
219	4/10/96	6/18/96	69	dropped transmitter	F	1996	collar
221	3/16/96	2/7/97	328	handling mortality	F	1996	collar
222	3/16/96	10/26/96	224	transmitter failed	M	1996	collar
223	3/16/96	10/6/96	204	transmitter failed	F	1996	collar
224	3/20/96	3/6/97	351	alive	M	1996	collar
225	3/20/96	4/18/96	29	dropped transmitter	M	1996	collar
226	3/22/96	5/2/96	41	dropped transmitter	M	1996	collar
227	3/22/96	5/17/96	56	handling mortality	F	1996	collar
228	3/23/96	8/18/96	148	handling mortality	M	1996	collar
229	3/24/96	4/30/96	37	transmitter failed	M	1996	implant
231	3/24/96	12/30/96	281	transmitter failed	M	1996	collar
232	3/28/96	4/5/96	8	dropped transmitter	M	1996	implant
233	3/28/96	2/18/97	327	natural mortality	F	1996	collar
234	4/5/96	5/28/96	53	starvation	M	1996	collar
235	4/5/96	2/26/97	327	handling mortality	F	1996	collar
236	4/5/96	11/13/96	222	dropped transmitter	F	1996	collar
294	8/5/96	3/23/97	230	alive	M	1996	collar
318	3/10/97	6/2/97	84	dropped transmitter	F	1997	implant
322	3/12/97	7/14/97	124	dropped transmitter	M	1997	collar
323	3/12/97	7/10/97	120	dropped transmitter	M	1997	collar
324	3/13/97	3/27/97	14	dropped transmitter	F	1997	implant
325	3/13/97	3/27/97	14	dropped transmitter	F	1997	implant
326	3/13/97	7/28/97	137	dropped transmitter	F	1997	implant
327	3/14/97	4/19/97	36	dropped transmitter	M	1997	collar
328	3/14/97	5/4/97	51	dropped transmitter	M	1997	collar
329	3/14/97	2/10/98	333	censored	F	1997	collar
330	3/31/97	4/12/97	12	natural mortality	F	1997	collar
331	3/31/97	4/4/97	4	dropped transmitter	F	1997	collar
332	3/31/97	4/9/97	9	dropped transmitter	M	1997	collar
333	3/17/97	3/18/97	1	dropped transmitter	M	1997	implant
334	3/17/97	3/18/97	1	dropped transmitter	M	1997	implant
342	5/27/97	5/17/98	355	unknown mortality	M	1997	collar
343	5/27/97	12/15/97	202	transmitter failed	M	1997	collar
999	5/27/97	6/1/97	5	dropped transmitter	M	1997	collar
345	5/27/97	6/16/97	20	dropped transmitter	M	1997	collar

Table 2.1. Continued.

Id #	Date radioed	Estimated date of death/ drop/censor	# Days worn	Status	Sex	Year Born	Transmitter type
346	5/27/97	7/10/97	44	dropped transmitter	M	1997	collar
347	5/27/97	1/6/98	224	dropped transmitter	M	1997	collar
422	5/27/97	9/8/97	104	dropped transmitter	F	1997	collar
409	8/5/97	6/22/98	321	transmitter failed	M	1997	collar
414	8/17/97	11/29/97	104	legally harvested	M	1997	collar
429	3/14/98	6/1/99	444	transmitter failed	F	1998	collar
430	3/14/98	10/28/98	228	dropped transmitter	F	1998	collar
431	3/16/98	6/1/98	77	dropped transmitter	M	1998	implant
432	3/16/98	5/3/98	48	dropped transmitter	M	1998	implant
433	3/16/98	4/3/98	18	dropped transmitter	F	1998	implant
434	3/20/98	3/30/98	10	dropped transmitter	F	1998	collar
435	3/20/98	12/1/98	256	dropped transmitter	F	1998	collar
436	3/20/98	11/8/98	233	dropped transmitter	F	1998	collar
438	3/22/98	2/7/99	322	dropped transmitter	M	1998	collar
439	3/22/98	9/20/98	182	dropped transmitter	F	1998	collar
444	3/25/98	4/22/98	28	dropped transmitter	F	1998	implant
445	3/25/98	5/24/98	60	transmitter failed	M	1998	implant
446	3/25/98	7/12/98	109	transmitter failed	F	1998	implant
447	3/25/98	5/2/98	38	dropped transmitter	M	1998	collar
458	6/1/98	6/13/98	12	transmitter failed	F	1998	implant
459	6/1/98	9/11/98	102	dropped transmitter	M	1998	collar
460	6/1/98	8/20/98	80	dropped transmitter	M	1998	collar
536	3/1/99	3/2/99	1	dropped transmitter	F	1999	collar
537	3/1/99	4/5/99	35	dropped transmitter	M	1999	collar
544	3/8/99	5/9/00	428	alive	F	1999	collar
545	3/8/99	4/11/99	34	dropped transmitter	M	1999	collar
549	3/11/99	10/13/99	216	dropped transmitter	M	1999	collar
561	3/15/99	4/11/99	27	dropped transmitter	F	1999	implant
562	3/15/99	3/19/99	4	dropped transmitter	F	1999	collar
563	3/15/99	5/2/99	48	dropped transmitter	F	1999	implant
564	3/16/99	9/11/99	179	transmitter failed	F	1999	implant
565	3/16/99	5/30/99	75	dropped transmitter	F	1999	implant
566	3/16/99	9/7/99	175	transmitter failed	M	1999	implant
571	3/17/99	1/4/00	293	transmitter failed	F	1999	collar
572	3/17/99	4/13/99	27	dropped transmitter	F	1999	collar
573	3/17/99	4/24/00	404	alive	F	1999	collar
574	3/17/99	4/5/99	19	dropped transmitter	F	1999	collar
576	3/19/99	11/14/99	240	dropped transmitter	F	1999	collar
567	3/16/99	5/19/99	64	dropped transmitter	M	1999	collar
568	3/16/99	3/29/99	13	dropped transmitter	F	1999	implant
569	3/16/99	3/17/99	1	dropped transmitter	F	1999	collar

Table 2.1. Continued.

Id #	Date radioed	Estimated date of death/ drop/censor	# Days worn	Status	Sex	Year Born	Transmitter type

Note: To compute survival estimates, estimated dates cubs died, dropped transmitters, or were censored were truncated on the last day of the year in which they were radioed.

Survival

Nine (5M:4F) of 61 (14.8%) radio collared cubs and 0 of 21 cubs with transmitters implanted subcutaneously died while still wearing radio transmitters (ID 122, 123, 131, 227, 228, 234, 330, 414 and 536). Fourteen of 82 transmittered cubs (17.1%) were known to survive their first year (ID 221, 224, 233, 235, 294, 329, 342, 347, 409, 429, 438, 544, 571, and 573) with transmitters intact. One of these cubs, a male (ID 342), was found dead of unknown causes 12 months following transmitter attachment. Puncture holes in the skull suggest intraspecific aggression was the cause of death. All other cubs (59 of 82; 72.0%) either rejected their subcutaneous implants (n=15 of 21; 71.4%), slipped their radio collars prematurely (n=34 of 61; 55.7%), or their radio transmitters failed (n=10 of 82; 5 implants:5 collars; 12.2%) prior to reaching 1 year of age. Survival beyond the time radio contact was lost for most of these cubs is unknown (Table 2.1). Four (2M:2F) cubs (4.9%), who had previously slipped their radio collars (ID 122, 123, 331, and 332), died when their families were killed by another bear. Two of the 4 cubs (ID 331 and 332) were cannibalized by a male bear along with their radio collared mother within a week and a half of their den emergence in April 1997.

First year (306-day) survival for male and female cubs combined (1995-1999) was 81% (n=82; Kaplan-Meier) and 76% (n=8,754 radio days; Heisey-Fuller). The 95% confidence intervals for the Kaplan-Meier estimate were 0.67 – 0.95 and 0.63 – 0.92 for the Heisey-Fuller estimate. These 306-day survival estimates were not different (Z=0.366, P=0.143). Survival estimates (Heisey-Fuller) for intervals 1-4 (Table 2.2) were 80% (n=2,871 radio days), 100% (n=2,184 radio days), 100% (n=993 radio days), and 96% (n=2,706 radio days).

Table 2.2. 306-day survival rates and interval survival rates for black bear cubs on the George Washington & Jefferson National Forests, Virginia, from March 1995 through December 1999.

n	No. of deaths	Survival estimate	95% CI	Survival Intervals	Survival estimator
1-23[1]	8	0.81	0.67-0.95	01 Mar.-31 Dec. [3]	Kaplan-Meier Staggered Entry
8,754[2]	8	0.76	0.63-0.92	01 Mar.-31 Dec. [3]	Heisey and Fuller
2,871[2]	7	0.80	0.68-0.94	01 Mar.-31 May[4]	Heisey and Fuller
2,184[2]	0	1.00	1.00-1.00	01 Jun.-31 Jul. [4]	Heisey and Fuller
993[2]	0	1.00	1.00-1.00	01 Aug.-31 Aug. [4]	Heisey and Fuller
2,706[2]	1	0.96	0.88-1.00	01 Sept.-31 Dec. [4]	Heisey and Fuller

[1] n is a range due to the nature of the staggered entry design.
[2] Total number of radio days that black bear cubs were monitored, 1995 – 1999.
[3] 306-day survival estimate for black bear cubs (date marked – end of year).
[4] Interval periods modified from Higgins 1997.

Interval survival estimates for male cubs (Heisey-Fuller) were 79% (n=1,191 radio days), 100% (n=903 radio days), 100% (n=404 radio days), and 91% (n=1,273 radio days) for intervals 1-4, respectively (Table 2.3). The 306-day male survival rate using the Heisey-Fuller approach was 72%, and 73% using the Kaplan-Meier approach.

Interval survival estimates for female cubs (Heisey-Fuller) were 80% (n=1,680 radio days), 100% (n=1,281 radio days), 100% (n=589 radio days), and 100% (n=1,433 radio days) for intervals 1-4, respectively (Table 2.3). The 306-day survival rate produced using Heisey-Fuller was 80%, and 91% with the Kaplan-Meier approach.

Table 2.3. Heisey-Fuller interval survival rates for male and female black bear cubs on the George Washington & Jefferson National Forests, Virginia, from March 1995 through December 1999.

n[1]	No. of deaths	Survival estimate[2]	95% CI	Survival Intervals[3]
Males				
1,191	3	0.79	0.61-0.92	01 Mar.-31 May
903	0	1.00	1.00-1.00	01 Jun.-31 Jul.
404	0[4]	1.00	1.00-1.00	01 Aug.-31 Aug.
1,273	1	0.90	0.75-1.00	01 Sept.-31 Dec.
Females				
1,680	4	0.80	0.65-1.00	01 Mar.-31 May
1,281	0	1.00	1.00-1.00	01 Jun.-31 Jul.
589	0	1.00	1.00-1.00	01 Aug.-31 Aug.
1,433	0	1.00	1.00-1.00	01 Sept.-31 Dec.

[1] Total number of radio days that black bear cubs were monitored, 1995 – 1999.
[2] Interval survival estimate for black bear cubs.
[3] Interval periods modified from Higgins 1997.
[4] Handling mortality was not included in final survival analysis.

We compared survival rate estimates between sexes within years for Kaplan-Meier using the ANOVA test and found no difference ($P>0.240$). We did detect a difference ($P<0.002$) when we compared estimates among years, however. Duncan's multiple range test revealed differences between 1995 and all other years, between 1996 and 1997 and all other years, and between 1998 and 1999 and all other years at the $\alpha=0.05$ level. The difference in the 1995 estimates likely was due to the small sample sizes (Tables 2.4 and 2.5).

We also compared survival rate estimates between sexes and for both sexes combined within the 4 intervals for Heisey-Fuller using the ANOVA test. There was no difference between male and female survival rates but for both sexes combined the survival estimate for interval 1 (March 1 – May 31) was lower than the other 3 intervals ($P=0.020$).

Table 2.4. Kaplan-Meier yearly (306-day) survival rates for male and female black bear cubs on the George Washington & Jefferson National Forests, Virginia, from March 1995 through December 1999.

n[1]	Year	Survival estimate	SE	95% C.I.
Males				
1-2	1995	0.3333[2]	0.272	0.00-0.87
1-9	1996	0.8000	0.179	0.44-1.00
3-8	1997	0.8000	0.179	0.44-1.00
3-5	1998	1.0000	0.000	1.00-1.00
1-5	1999	1.0000	0.000	1.00-1.00
Females				
1-2	1995	0.5000[3]	0.354	0.00-1.00
2-7	1996	0.8571	0.132	1.00-1.00
1-5	1997	0.8000	0.179	0.44-1.00
2-9	1998	1.0000	0.000	1.00-1.00
1-13	1999	1.0000	0.000	1.00-1.00

[1] Total number of radio collared cubs is a range due to staggered entry design.
[2] 153-day survival estimate.
[3] 195-day survival estimate.

Table 2.5. Kaplan-Meier yearly (306-day) combined survival rates for male and female black bear cubs on the George Washington & Jefferson National Forests, Virginia, from March 1995 through December 1999.

n[1]	Year	Survival estimate	SE	95% C.I.
1-3	1995	0.3333[2]	0.215	0.00-0.76
3-15	1996	0.8333	0.108	0.62-1.00
1-12	1997	0.7500	0.158	0.44-1.00
1-14	1998	1.0000	0.000	1.00-1.00
1-15	1999	1.0000	0.000	1.00-1.00

[1] Total number of radio collared cubs is a range due to staggered entry design.
[2]195-day survival estimate.

Timing and Cause of Mortality

Intraspecific aggression (n=3), starvation (n=1), predation (n=1), legal harvest (n=1), research activities (n=1), and unknown causes (n=2) accounted for the 9 mortalities of transmittered black bear cubs (Table 2.6). All but 2 mortalities (research activities and legal harvest) occurred between 2 and 4 months of age (Figure 2.2).

Table 2.6. Cause and timing of mortality for radio collared black bear cubs on the George Washington & Jefferson National Forests, Virginia, 1995-1999.

Sow ID#	Cub ID#	Sex	Mortality date	# days following den emergence	Mortality factor
63	131	F	4/15/95	0	Unknown
50	122	M	3/27/95	0-11	Intraspecific aggression
50	123	M	3/27/95	0-11	Intraspecific aggression
165	227	F	5/17/96	11	Predation
136	234	M	5/28/96	11	Starvation
156	228	M	8/18/96	111	Research activities/killed in snare by another bear
174	330	F	4/12/97	8	Intraspecific aggression
413	414	M	11/29/98	N/A[1]	Legal harvest (by weight criteria)
176	536	F	3/1/99	0	Unknown

[1]cub was released with sow (nuisance) on 8/17/98 – den emergence date is unknown.

As reported by Higgins (1997), 2 radio-collared cubs, excluded from the analysis, were abandoned by their mother while or shortly after emerging from the den (ID 113 and ID 114). One non-collared cub (ID 121) died of starvation while still in the den, and another non-collared male cub (ID 660), approximately 2 ½ weeks old, died after apparently falling from the sow's (ID 63) den tree in February 1997.

We documented the death of a female yearling (ID 233) denned alone in 1997; she apparently had been separated from the sow the previous September in a chase event during Virginia's bear-dog training season. She appeared severely emaciated when handled in February 1997, and weighed approximately 6.8 kg. She never emerged from her winter den. In 2 other instances, however, cubs separated from the sow during September (ID 224 and 225) and January (ID 329) successfully denned apart from their mother and survived the winter. We also documented 3 female cubs (ID 221, 235, and 429) successfully denning alone following the deaths of their mothers by legal harvest.

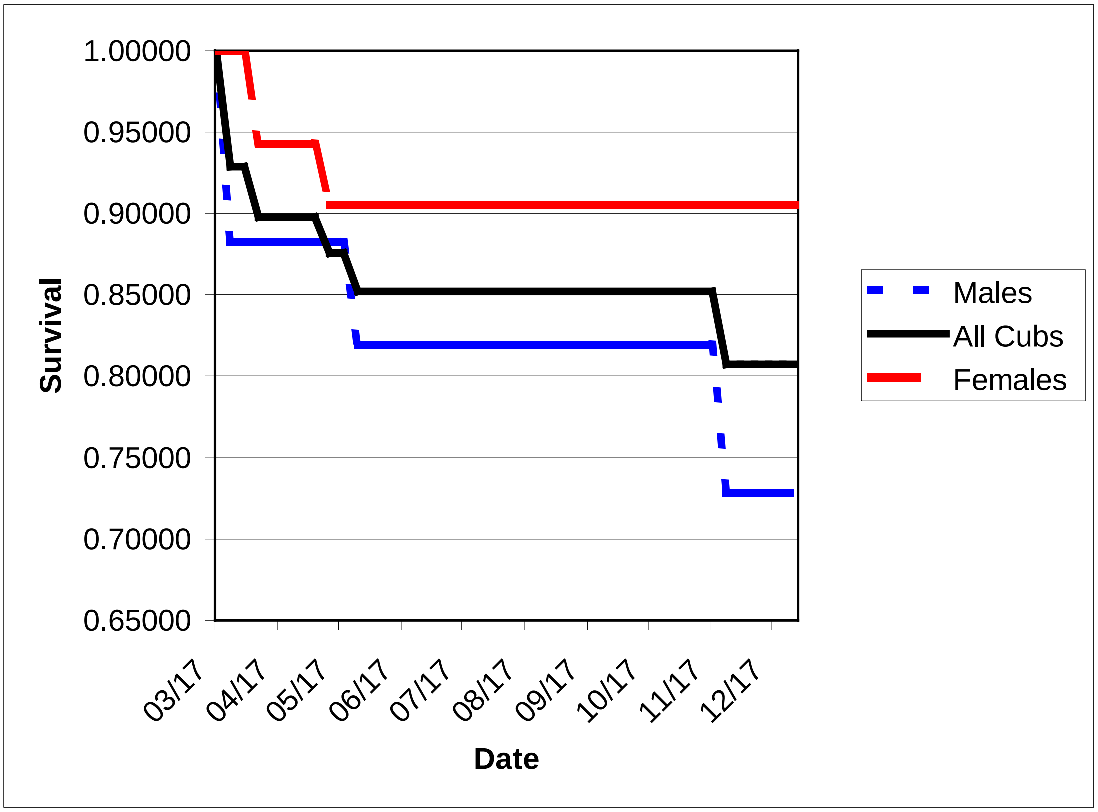

Figure 2.2. Kaplan-Meier combined 5-year cub survival estimates over a 306-day period on the George Washington & Jefferson National Forests, Virginia, 1995 – 1999.

Age and Experience of Females producing cubs

Three of 30 (10%) young sows (3-5 years old) raised complete litters and 7 (23.3%) raised partial litters (Table 2.7). One of the sows raising complete litters was a 3-year old (ID 75) with a litter of 1, 1 was a 4-year old (ID 73) with a litter of 2, and the third was a 5-year old (ID 169) with a litter of 2. One of the 7 sows raising partial litters was a 3-year old (ID 20) that raised at least 1 cub from an unknown litter size, and 1 was a 4-year old (ID 13) that raised at least 2 cubs from a litter size of at least 2. Five of the 7 sows were 5-year olds, including 1 (ID 63) that raised at least 1 cub from a litter of at least 2 cubs in 1997, 1 (ID 110) that raised at least 1 of 2 cubs in 1996, 1 (ID 304) that raised at least 2 of 3 cubs in 1999, 1 (ID 402) that raised at least 1 of 2 cubs in 1999, and a fifth sow (ID 461) that raised at least 1 of 3 cubs in 1999.

Ten young sows lost complete litters, 2 of which were 3-year olds (ID 94, 63) each with a litter of 1 cub. Six of the 10 were 4-year olds (ID 50, 63, 65, 110, 165, and

169) with 4 litters of 2 cubs and 2 litters of 1 cub. The remaining 2 sows were 5-year olds (ID 95, 174), each with litters of 3 cubs. Two of the 10 sows (ID 50, 174) losing entire litters were killed or cannibalized by other bears and their litters died as a result. Litter survival for 4 sows (ID 4, 23, 88, 253) is unknown. Research activities influenced the fate of an additional 6 litters of young sows (ID 77, 31, 94, 85, 138, 165) when the sow died during handling or abandoned the litter. One sow with 1 cub died (ID 77), and 5 more sows abandoned complete or partial litters, affecting 8 cubs. Godfrey et al. (2000) discusses the difficulties associated with handling bears in tree dens.

Seven of 45 (15.6%) older sows (6-16 years old) raised complete litters (Table 2.7); 2 were 6-year old sows (ID 13, 138) with litters of 2 and 3 cubs. Three of the 7 were 7-year olds (ID 61, 165, 187) with 2 litters of 3 cubs and 1 litter of 1 cub. The other 2 sows (ID 161, 299) were aged 9 and 10 with litters of 2 cubs each.

Sixteen of 45 (35.6%) older sows raised at least partial litters. Four of the 16 were 7-year olds (ID 6, 31, 63, 89) that raised 2 of 3 cubs in 1996, 2 of 3 cubs in 1998, at least 2 of 4 cubs in 1999, and 1 (natural) of 5 cubs (3 natural: 2 fostered) in 1997, respectively. Three of the 16 were 8-year old sows (ID 72, 172, 300) that raised at least 1 of 2 cubs in 1997, 2 of 3 cubs in 1997, and at least 1 of 4 cubs in 1998, respectively. One 9-year old (ID 187) and 1 10-year old (ID 143) raised at least 2 of 4 cubs and 1 of 3 cubs in 1999 and 1998, respectively. Two 12-year olds (ID 15, 298) raised at least 1 of 4 cubs (3 natural, 1 fostered) and 2 of 3 cubs, respectively, and 2 13-year olds (ID 62, 176) raised 1 of 2 cubs each. One 14-year old sow (ID 154) raised at least 1 of 3 cubs in 1996. One 15-year old (ID 15) raised at least 1 of 2 cubs in 1998 and 1 16-year old (ID 136) raised at least 1 of 3 cubs in 1996. Hunters legally harvested sows ID 154 and ID 136 in December 1996. Another sow of undetermined age (ID 457) raised 4 of 5 cubs (2 natural:3 fostered) in 1999.

Three of the 45 (6.7%) older sows lost entire litters. These sows, ages 8 (ID 161), 14 (ID 204), and 1 of undetermined age (ID 457) lost litters of 2, 2, and 3 cubs in 1997, 1999, and 1998, respectively. It is likely that research activities influenced the survival of the litter in 1997. The survival of 7 other litters of older sows (ID 90, 90, 95, 152, 153, 204, 389) is unknown because the bears dropped their radio collars or denned in

Table 2.7. Numbers and ages of black bear sows raising complete and partial litters and those losing complete and partial litters on the George Washington & Jefferson National Forests, Virginia, 1995 – 1999.

Sow Age	Number of Sows	Raised complete litter	Raised partial litter	Lost complete litter	Unknown litter survival	Influenced[1]
3	6	1	1	2	1	1
4	11	1	1	6	1	2
5	13	1	5	2	2	3
6	8	2	0	0	2	4
7	10	3	4	0	1	2
8	6	0	3	1	0	2
9	4	1	1	0	0	2
10	2	1	1	0	0	0
11	1	0	0	0	1	0
12	3	0	2	0	1	0
13	2	0	2	0	0	0
14	3	0	1	1	0	1
15	3	0	1	0	2	0
16	1	0	1	0	0	0
UNK	2	0	1	1	0	0
	75	10	24	13	11	17

[1] Influenced by research activities (sow died or abandoned entire or partial litter).

unworkable dens.

Research activities influenced the fate of an additional 10 litters of older sows; 5 sows (ID 85, 101, 139, 181, 269) died while being handled in the den affecting 13 cubs, and 5 more (ID 15, 49, 51, 181, 506) abandoned part or all of their litters, affecting 11 cubs. An eleventh sow's litter (ID 156) was influenced when her only cub was trapped and killed by another bear while in the snare.

We confirmed that at least 10 of 54 different sows (75 total cub dens) raised complete litters between the 1995 and 2000 den seasons. Thirty-two percent of the sows raised at least partial litters and 17.3% lost their entire litter during this same time period. Litter survival could not be determined for 14.6% of the 75 litters. Research activities influenced the survival of 22.7% of the litters. A minimum of 32% of the cubs (53 of 166) born to radio collared sows between 1995 and 1999 were raised to age 1 (Appendix Table 2.2).

DISCUSSION

Survival

Our Kaplan-Meier estimate of cub survival was higher (81%) than survival estimates obtained in other studies (Strathearn et al. 1984, LeCount 1987, Elowe and Dodge 1989, Kasbohm 1994, Hellgren 1988, Doan-Crider and Hellgren 1996). The Heisey-Fuller estimate (76%), viewed by some as the more reliable method for smaller sample sizes (S. Winterstein, Professor of Wildlife, Michigan State University, pers. comm.), was more similar to other estimates. Both estimates, however, had large confidence intervals that overlapped, suggesting they were not statistically different.

Estimated first year cub survival averaged 73% for Shenandoah National Park in western Virginia (Kasbohm 1994) and 76% for the Great Dismal Swamp National Wildlife Refuge in eastern Virginia (Hellgren 1988). Ryan (1997) reported an annual survival rate of 70% for cubs in the southern GW&JNF. Survival estimates from the present study appear similar to those reported in these studies.

Estimated black bear cub annual survival rates in MA (Elowe and Dodge 1989), Ontario (Strathearn et al. 1984), and AZ (LeCount 1987) were 59%, 46%, and 52%, respectively, all lower than that of the present study. Doan-Crider and Hellgren (1996) in Mexico and Schwartz and Franzmann (1991) in Alaska reported 81% and 74-91% black bear cub first year survival rates, respectively. Because of the different methods of estimation, and the small sample sizes, comparison of these survival estimates may not be valid, but they provide valuable insight into the range of values observed for this critical demographic variable.

Heisey-Fuller and Kaplan-Meier Survival Estimates

We used 2 methods to estimate survival, each with a different set of assumptions. The Kaplan-Meier approach assumes that (1) animals of a particular sex and age class have been sampled randomly, (2) survival times are independent for different animals being sampled, (3) capturing and radio marking individuals does not influence their survival, (4) the censoring mechanism is random, and (5) the newly marked animals have the same survival function as the previously marked individuals (Pollock et al. 1989).

We may have violated the first 2 assumptions. Inasmuch as we did not place transmitters on cubs weighing less than 1.65 kg (31.5% of cubs handled weighed less than 1.65 kg), we likely age-biased our sample because there is a direct relationship between weight and age of cubs (Godfrey 1996). Our decision to radio-mark only cubs weighing at least 1.65 kg was made *a priori*, thus we avoided younger/smaller cubs. Additionally, because runts may have different survival probabilities and we often did not collar the runt of the litter due to this same weight criterion, such cubs could not be sampled randomly. We equipped several entire litters with radio transmitters and survival of individual cubs within a litter may not be independent of one another. For instance, the fate of each cub within an entire litter likely would be the same if the sow died for any reason; the survival of a litter is inextricably tied to the sow's survival, at least until the cubs reach a certain age. Pollock et al. (1989) pointed out, however, that a violation of the second assumption only gives the appearance of a smaller variance, but does not bias the estimate.

Violations of the fourth assumption may have occurred where predators killed cubs and also destroyed their transmitter preventing us from determining the circumstances under which it was censored. We censored 20 cubs due to radio failure (or loss of radio contact) in our sample. With regard to the third and fifth assumptions, we assume that marking individuals does not adversely affect their survival and that the survival functions of individuals entering the sample later have the same survival functions as those to first enter the sample; we have no information to contradict these assumptions. The majority of cubs were marked during the same 30-40 day period when cubs were 40-80 days old, and it is unlikely that the survival function changed much during this time period.

Assumptions of the Heisey-Fuller MICROMORT program include (1) the exact date of death is known, (2) the daily survival and agent-specific mortalities remain constant within each defined interval, and (3) all individuals within the same age or sex class have the same survival probabilities (Heisey and Fuller 1985). We monitored cubs very closely after radio marking them so our mortality dates are generally within 72 hours of actual mortality. Careful selection of survival intervals can minimize the likelihood of violating the second assumption; failure to meet this assumption results in the interval with the largest sample size having the most influence on the overall survival estimate (Heisey and Fuller 1985). The third assumption may be violated for the same reason specified under the Kaplan-Meier explanation, namely that since complete litters were marked and the survival of individual cubs within a given litter is not necessarily independent, we cannot assume that the survival of these cubs is independent.

While the assumptions of the Kaplan-Meier staggered entry procedure are less restrictive in nature, the estimate's reliability is highly dependent upon having a large sample size (Pollock et al 1989). Pollock et al. (1989) recommended a sample size of no less than 40 radioed individuals at all times, a sample size no study of cub survival, including ours, has been able to achieve. For this reason, the Heisey-Fuller estimate may be more appropriate because it is less sensitive to sample size of radioed individuals, relying instead on radio days (cumulative number of days radio transmitters were worn).

Timing and Cause of Mortalities

Most mortalities observed during this study occurred when cubs were between 2 and 3 months of age, near the timing of den emergence. Exceptions were a cub killed by another bear during the trapping season in a snare and a cub that was harvested in late November. This is similar to the results of other studies, such as Rogers (1987) in Minnesota, Alt (1982) in Pennsylvania, LeCount (1987) in Arizona, and Elowe (1987) in Massachusetts, who found that black bear cubs are most vulnerable following den emergence when they are still quite small. Inexperience undoubtedly played a role in the death of the 2 families that were cannibalized by adult male bears (sows ID 50 and 174), as well as the cub (ID 227) preyed upon in 1996.

Age and Experience of Female Bears Producing Cubs

Our data lend further evidence to the belief that age and experience of the sow are important components of cub survival. Young and first-time mothers were less likely to raise complete or partial litters to yearling age. Although we could not confirm the survival of complete litters for the older sows, we were able to confirm at least partial litter survival. The 2 family groups (sow and cubs) killed by male bears were young females, age 5. Their inexperience in avoiding aggressive male bears may have led not only to the death of their cubs, but also to their own deaths. An older sow may quickly have treed her offspring and been better able to fend off the approaching male. Admittedly, we may have influenced the survival of 1 of these 2 sows (ID 50) by relocating her den in what may have been an unfamiliar area, after she ran from her original den site. Younger sows (≤ 5 years) in general appear more apt to abandon their cubs when faced with perceived danger, as evidenced by the number abandoning their dens ($\underline{n}$=14 of 51: 27.5%) at our approach compared with that of older sows ($\underline{n}$=7 of 68; 10.3%).

MANAGEMENT IMPLICATIONS

Elowe and Dodge (1989) postulated that bear densities might be limited naturally through fluctuations in recruitment of young into the population. Heavy hunting pressure may actually increase rather than decrease cub mortality from intraspecific aggression according to LeCount (1987). By reducing the number of adult males in a population through harvest, the chances of an immigrant male killing resident cubs in a given area would increase.   LeCount (1987) hypothesized that these males benefit from killing cubs by causing the females to re-enter estrus, allowing the newly immigrating males to breed with them, dispersing their genes in the population while reducing those of competing males. Hunting may then serve to affect population levels in 2 ways, not just through the immediate reduction in numbers. Intraspecific aggression appears to be an important source of mortality in Virginia’s black bear population, which has increased its bear harvest almost 5-fold since 1990 (D. D. Martin, VDGIF biologist, 1998 unpubl.).

Estimates of black bear cub survival have improved since cub survival estimates were based on the presence or absence of cubs denning with sows as yearlings. While many studies continue to try to estimate cub survival based on observational data, the increased success with new radio telemetry equipment eventually will allow for better data collection. A variety of different causes of mortality have been identified in various bear populations around the United States, but the extent to which each factor impacts cub survival and recruitment rates is still largely unknown.

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APPENDIX

Appendix Table 2.1. Black bear cubs handled by the Cooperative Alleghany Bear Study and last known status and date in the George Washington & Jefferson National Forests, Virginia, between March 1995 and December 1999.

Cub ID#	Sex	Year born	Sow ID#	Sow Age	Litter Size	Date cub last known alive	Status or cause of mortality
		1995	20	3	at least 1	3/31/95	survival unknown
	M	1995	23	3	at least 1	3/18/96	handling mortality in den 96
112	F	1995	31	4	1	4/28/95	fostered to ID90; dropped collar
113	M	1995	15	12	3	4/16/95	separation/abandonment
114	M	1995	15	12	3	4/16/95	separation/abandonment
115	F	1995	15	12	3	7/25/98	dropped collar; survival unknown
116	F	1995	75	3	1	4/22/96	dropped collar; survival unknown
117	M	1995	90	7	3	3/21/95	survival unknown
118	M	1995	90	7	3	4/28/95	survival unknown; eartags/collar in den
119	M	1995	90	7	3	3/21/95	survival unknown
120	F	1995	110	4	1	3/21/95	unknown mortality (seen on ground near den)
121	M	1995	94	3	1	3/15/95	died in den; malnourished
122	M	1995	50	4	2	3/27/95	sow killed; cub starved
123	M	1995	50	4	2	3/27/95	sow killed; cub starved
124	F	1995	101	6	2	6/28/95	fostered to ID15; dropped collar
125	M	1995	101	6	2	8/4/95	fostered to ID88; dropped collar; survival unknown
126	M	1995	4	4	2	7/29/95	dropped collar; survival unknown
127	F	1995	4	4	2	9/13/95	dropped collar; survival unknown
128	M	1995	88	5	3	4/28/95	dropped collar; survival unknown
129	F	1995	88	5	3	4/15/95	dropped collar; survival unknown
130	F	1995	88	5	3	4/15/95	dropped collar; survival unknown
131	F	1995	63	3	1	4/15/95	abandoned in den
132	M	1995	65	4	1	4/23/95	separated from sow; predation
214	F	1995	77	3	1	5/11/95	sow died; fostered; released w/ nuisance sow

Appendix Table 2.1. Continued.

Cub ID#	Sex	Year born	Sow ID#	Sow Age	Litter Size	Date cub last known alive	Status or cause of mortality
		1996	51	7	2	2/15/96	mortality; abandoned; handling related
		1996	51	7	2	2/15/96	mortality; abandoned; handling related
	M	1996	94	4	2	3/26/96	mortality; abandoned; handling related
		1996	94	4	2	3/26/96	survival unknown
215	M	1996	85	5	2	4/13/96	abandoned; fostered to VPI
216	F	1996	6	7	3	7/14/96	survival unknown
217	M	1996	6	7	3	7/14/96	survival unknown
218	M	1996	6	7	3	7/14/96	survival unknown
219	F	1996	63	4	2	6/17/96	dropped collar; survival unknown
220	M	1996	63	4	2	3/14/96	mortality while in den; presumed starvation
221	F	1996	154	14	3	2/7/97	handling related mortality
222	M	1996	154	14	3	10/25/96	collar failed; survival unknown
223	F	1996	154	14	3	10/5/96	collar failed; survival unknown
224	M	1996	73	4	2	6/18/98	captured summer 98; harvested December 99
225	M	1996	73	4	2	6/20/98	captured summer 98; survival unknown
226	M	1996	165	4	2	4/30/96	dropped collar; sow reproduced den 97
227	F	1996	165	4	2	5/15/96	predation
228	M	1996	156	6	1	8/18/96	cannibalism; killed in snare by bear
229	M	1996	153	15	3	4/30/96	transmitter failed
230	M	1996	153	15	3	3/24/96	survival unknown
231	M	1996	153	15	3	12/30/96	transmitter failed
232	M	1996	110	5	2	4/1/96	unknown mortality; suspected mortality while in den 96
233	F	1996	110	5	2	2/18/97	mortality while in den 97; starvation suspected
234	M	1996	136	16	3	5/27/96	starvation/abandonment
235	F	1996	136	16	3	2/26/97	handling related mortality
236	F	1996	136	16	3	11/11/96	dropped collar; survival unknown
237	F	1996	85	5	2	4/13/96	abandoned; fostered; survival unknown

Appendix Table 2.1. Continued.

Cub ID#	Sex	Year born	Sow ID#	Sow Age	Litter Size	Date cub last known alive	Status or cause of mortality
238	M	1996	138	5	1	3/30/96	abandoned; fostered; survival unknown
239	M	1996	139	6	3	3/8/96	fostered; survival unknown
240	M	1996	139	6	3	3/8/96	fostered; survival unknown
241	M	1996	139	6	3	3/8/96	fostered; survival unknown
		1997	138	6	3	1/21/98	survival unknown past 1 year
		1997	138	6	3	1/21/98	survival unknown past 1 year
409	M	1997	138	6	3	6/22/98	survival unknown; collared and dropped
308	F	1997	204	12	3	3/3/97	survival unknown
309	M	1997	204	12	3	3/3/97	survival unknown
310	F	1997	204	12	3	3/3/97	survival unknown
311	F	1997	15	14	3	3/25/97	abandoned; unknown
312	F	1997	15	14	3	3/6/97	unknown mortality
313	M	1997	15	14	3	3/25/97	abandoned; unknown
314	M	1997	95	5	3	3/8/97	unknown mortality-sow reproduced den 98
315	M	1997	95	5	3	3/8/97	unknown mortality-sow reproduced den 98
316	F	1997	95	5	3	3/8/97	unknown mortality-sow reproduced den 98
317	M	1997	62	13	2	3/14/97	unknown mortality near den
318	F	1997	62	13	2	3/13/98	alive den 98; survival unknown
319	F	1997	85	6	3	3/17/98	handling related mortality-sow died
320	M	1997	85	6	3	3/17/98	sow died; fostered
321	F	1997	85	6	3	3/11/98	handling related mortality-sow died
322	M	1997	72	8	2	7/11/97	dropped collar; survival unknown
323	M	1997	72	8	2	7/8/97	dropped collar; survival unknown
324	F	1997	165	5	2	5/5/97	separation/handling related mortality
325	F	1997	165	5	2	5/27/97	separation/handling related mortality
326	F	1997	187	7	1	7/16/99	captured summer 99; ear tag radio installed
		1997	13	4	at least 2	3/22/98	seen in den 98 with sow
		1997	13	4	at least 2	3/22/98	seen in den 98 with sow
327	M	1997	172	8	3	4/18/97	dropped collar; survival unknown

Appendix Table 2.1. Continued.

Cub ID#	Sex	Year born	Sow ID#	Sow Age	Litter Size	Date cub last known alive	Status or cause of mortality
328	M	1997	172	8	3	1/26/98	handling mortality in den 98
329	F	1997	172	8	3	2/10/98	alive den 98; survival unknown
330	F	1997	174	5	3	4/11/97	family cannibalized by bear
331	F	1997	174	5	3	4/4/97	family cannibalized by bear
332	M	1997	174	5	3	4/8/97	family cannibalized by bear
333	M	1997	161	8	2	3/20/97	unknown mortality-sow reproduced den 98
334	M	1997	161	8	2	3/18/97	unknown mortality-sow reproduced den 98
335	F	1997	89	7	3	7/30/99	captured summer 99; radio collared
336	M	1997	89	7	3	4/5/97	survival unknown
337	F	1997	89	7	3	4/5/97	survival unknown
660	M	1997	63	5	at least 2		fell out of tree; found 2/20/97
425	M	1997	63	5	at least 2	8/7/98	dropped yearling implant; captured summer 98
426	M	1998	389	6	3	3/3/98	survival unknown
427	F	1998	389	6	3	3/3/98	survival unknown
428	F	1998	389	6	3	3/3/98	survival unknown
429	F	1998	161	9	2	5/27/99	collar failed; survival unknown
430	F	1998	161	9	2	7/30/99	captured summer 99; ear tag transmitter installed
431	M	1998	31	7	3	5/30/98	implant dropped; survival unknown
432	M	1998	31	7	3	5/3/98	implant dropped; survival unknown
433	F	1998	31	7	3	4/2/98	implant dropped; survival unknown
434	F	1998	300	8	4	3/29/98	dropped collar; survival unknown
435	F	1998	300	8	4	11/29/98	dropped collar; survival unknown
436	F	1998	300	8	4	11/6/98	dropped collar; survival unknown
437	F	1998	300	8	4	3/20/98	survival unknown
438	M	1998	15	15	2	2/2/99	dropped collar; harvested December 1999
439	F	1998	15	15	2	9/11/98	dropped collar; survival unknown
441	F	1998	298	12	3	2/5/99	seen in den 99; survival unknown

Appendix Table 2.1. Continued.

Cub ID#	Sex	Year born	Sow ID#	Sow Age	Litter Size	Date cub last known alive	Status or cause of mortality
442	M	1998	298	12	3	4/26/99	seen in den 99; collared; dropped collar; survival unknown
443	F	1998	298	12	3	3/25/98	survival unknown
444	F	1998	143	10	3	4/22/98	implant dropped; survival unknown
445	M	1998	143	10	3	5/23/98	transmitter failed; survival unknown
446	F	1998	143	10	3	7/20/99	captured summer 99; ear tag transmitter installed
447	M	1998	169	4	2	5/2/98	dropped collar; unknown mortality-sow reproduced den 99
448	F	1998	169	4	2	3/25/98	unknown mortality-sow reproduced den 99
449	F	1998	181	8	3	4/18/98	abandoned; reunited; mortality unknown; sow reproduced 99
450	F	1998	181	8	3	4/18/98	unknown mortality-sow reproduced den 99
451	F	1998	181	8	3	3/26/98	abandoned; died in den
452	M	1998	49	8	3	3/27/98	unknown survival
453	F	1998	49	8	3	3/27/98	abandoned; fostered
454	M	1998	49	8	3	3/27/98	abandoned; fostered
455	F	1998	95	6	2	3/31/98	survival unknown
456	M	1998	95	6	2	3/31/98	survival unknown
458	F	1998	457	UNK	3	6/4/98	unknown mortality-sow reproduced den 99
459	M	1998	457	UNK	3	9/11/98	unknown mortality-sow reproduced den 99
460	M	1998	457	UNK	3	9/11/98	unknown mortality-sow reproduced den 99
532	F	1999	169	5	2	2/25/99	seen in den 00; survival unknown
533	F	1999	169	5	2	2/25/99	seen in den 00; survival unknown
534	F	1999	204	14	2	2/26/99	unknown mortality; sow reproduced 00
535	F	1999	204	14	2	2/26/99	unknown mortality; sow reproduced 00
536	F	1999	176	13	2	3/1/99	unknown mortality; died near den
537	M	1999	176	13	2	4/4/99	dropped collar; survived to den 00; survival unknown

Appendix Table 2.1. Continued.

Cub ID#	Sex	Year born	Sow ID#	Sow Age	Litter Size	Date cub last known alive	Status or cause of mortality
538	M	1999	90	11	3	3/4/99	survival unknown
539	F	1999	90	11	3	3/4/99	survival unknown
540	F	1999	90	11	3	3/4/99	survival unknown
541	M	1999	152	15	3	3/5/99	survival unknown
542	M	1999	152	15	3	3/5/99	survival unknown
543	F	1999	152	15	3	3/5/99	survival unknown
544	F	1999	402	5	2	12/31/99	alive
545	M	1999	402	5	2	4/10/99	dropped collar; survival unknown
546	F	1999	61	7	3	3/9/99	seen in den 00; survival unknown
547	F	1999	61	7	3	3/9/99	seen in den 00; survival unknown
548	M	1999	61	7	3	3/9/99	seen in den 00; survival unknown
549	M	1999	304	5	3	10/12/99	dropped collar; survival unknown
550	F	1999	304	5	3	3/11/99	survival unknown
551	M	1999	304	5	3	3/11/99	survival unknown
554	F	1999	457	UNK	2	3/13/99	survival unknown
555	M	1999	457	UNK	2	3/13/99	survival unknown
556	F	1999	269	7	3	3/26/99	sow died; fostered
557	M	1999	SW			3/14/99	survival unknown
558		1999	506	9	3	3/14/99	unknown mortality; sow reproduced 00
559		1999	506	9	3	3/14/99	unknown mortality; sow reproduced 00
560		1999	506	9	3	3/14/99	unknown mortality; sow reproduced 00
561	F	1999	461	5	3	4/10/99	implant dropped; survival unknown
562	F	1999	461	5	3	3/18/99	dropped collar; survival unknown
563	F	1999	461	5	3	5/1/99	implant dropped; survival unknown
564	F	1999	165	7	3	9/10/99	transmitter failed; seen in den 00; survival unknown
565	F	1999	165	7	3	5/28/99	implant dropped; seen in den 00; survival unknown
566	M	1999	165	7	3	9/6/99	transmitter failed; seen in den 00; survival unknown
567	M	1999	187	9	4	5/18/99	dropped collar; survival unknown

Appendix Table 2.1. Continued.

Cub ID#	Sex	Year born	Sow ID#	Sow Age	Litter Size	Date cub last known alive	Status or cause of mortality
568	F	1999	187	9	4	3/27/99	implant dropped; survival unknown
569	F	1999	187	9	4	3/16/99	dropped collar; survival unknown
570	F	1999	187	9	4	3/16/99	survival unknown
571	F	1999	63	7	4	12/31/99	alive
572	F	1999	63	7	4	4/13/99	dropped collar; survival unknown
573	F	1999	63	7	4	12/31/99	alive
574	F	1999	63	7	4	4/1/99	dropped collar; survival unknown
575	F	1999	299	10	2	3/19/99	seen in den 00; survival unknown
576	F	1999	299	10	2	11/12/99	dropped collar; seen in den 00; survival unknown
577	M	1999	253	5	3	3/20/99	survival unknown
578	F	1999	253	5	3	3/20/99	survival unknown
579	M	1999	253	5	3	3/20/99	survival unknown
580	F	1999	181	9	2	3/25/99	sow died; fostered
581	M	1999	181	9	2	3/25/99	sow died; fostered
582	F	1999	269	7	3	3/24/99	sow died; fostered
583	M	1999	269	7	3	3/26/99	sow died; fostered
584	F	1999	13	6	2	3/27/99	seen in den 00; survival unknown
585	F	1999	13	6	2	3/27/99	seen in den 00; survival unknown

Appendix Table 2.2. Black bear sows and minimum numbers of cubs raised on the George Washington & Jefferson National Forests, Virginia, 1995 – 1999.

Sow ID#	Sow age	Year	# cubs born	Minimum # cubs raised
4	4	1995	2	UNK
15	12		3 (2)[1]	1[2]
20	3		at least 1	UNK
23	3		at least 1	1
31	4		1	---[2]
50	4		2	0
63	3		1	0
65	4		1	0
75	3		1	1
77	3		1	---[2]
88	5		3	UNK
90	7		3	UNK
94	3		1	0
101	6		2	---[2]
110	4		1	0
6	7	1996	3	2
51	7		2	0
63	4		2	UNK
73	4		2	2
85	5		2	---[2]
94	4		2	UNK
110	5		2	0
136	16		3	1
138	5		1	0
139	6		3	---[2]
153	15		3	UNK
154	14		3	1
156	6		1	0
165	4		2	0
13	4	1997	2	2
15	14		3	0[2]
62	13		2	1
63	5		at least 2	1
72	8		2	1
85	6		3	---[2]
89	7		3 (2)[1]	1
95	5		3	0
138	6		3	3
161	8		2	0
165	5		2	0
172	8		3	2
174	5		3	0
187	7		1	1

Appendix Table 2.2. Continued.

Sow ID#	Sow age	Year	# cubs born	Minimum # cubs raised
204	12	1997	3	UNK
15	15	1998	2	1
31	7		3	UNK
49	8		3	UNK[2]
95	6		2	UNK
143	10		3	1
161	9		2	2
169	4		2	0
181	8		3	0
298	12		3	2
300	8		4	1
389	6		3	UNK
457	UNK		3	0
13	6	1999	2	2
61	7		3	3
63	7		4	2
90	11		3	UNK
152	15		3	UNK
165	7		3	3
169	5		2	2
176	13		2	1
181	9		2	---[2]
187	9		4	2
204	14		2	0
253	5		3	UNK
269	7		3	---[2]
299	10		2	2
304	5		3	2
402	5		2	1
457	UNK		2 (3)[1]	4
461	5		3	at least 1[3]
506	9		3	0[2]
			166[4]	53[5]

[1] ( ) represents number of cubs fostered to sow in addition to natural litter.

[2] survival of cubs was influenced by death of sow or other research activity.

[3] number of yearlings could not be counted.

[4] minimum number of cubs in all litters (natural born + fostered) except where sow died or abandoned entire litter.

[5] minimum number of cubs raised in all litters except where sow died or abandoned entire litter.

Chapter 3: EVALUATION OF SUBCUTANEOUS IMPLANTS FOR MONITORING BLACK BEAR CUB SURVIVAL IN VIRGINIA

Abstract:

Implanting radio transmitters in wild animals to monitor physiological processes and survival rates is an accepted practice, but the degree of success or failure rarely is reported, making it difficult to improve the techniques and ideas related to implanted transmitters. We implanted radio transmitters (AVM, Livermore, CA; Advanced Telemetry Systems, Inc., Isanti, MN) subcutaneously in 42 (21M:21F) wild black bear (*Ursus americanus*) cubs from 2 study areas in Virginia during the 1996, 1997, 1998, and 1999 den seasons. We monitored the cubs from the date of implant until the implants fell out, the cubs died, the transmitters failed, or until the cubs denned as yearlings the following den season. More than 64% (27 of 42) of the implants fell out prematurely (2-198 days), 16.6% (7 of 42) failed for unknown reasons, 4.7% (2 of 42) denned wearing failed implants, and 9.5% (4 of 42) experienced mortality less than 1 month after implant surgery. About 9.5% (4 of 42) of implanted black bear cubs wore working transmitters through to the following den season. We discuss the benefits of using subcutaneous implants over visceral implants and radio collars. We experienced limited success using subcutaneous implants, but believe success can be improved with improvements in the surgical procedures, further miniaturization of transmitter and battery technology, a more water-tight transmitter package construction, and a better understanding of the interactions that occur among family members following implant surgery.

INTRODUCTION

Wildlife scientists have been challenged by the difficulty of obtaining unbiased survival data for black bear cubs. Some believe that black bear cubs are most vulnerable during the first 5 months of life (Erickson 1959, LeCount 1987, Elowe and Dodge 1989) while they are still naïve to their surroundings and largely dependent upon their mother's instincts to protect them. However, extensive monitoring of cubs beyond the age of 5 months is rare due to the problems associated with keeping rapidly growing cubs equipped with radio transmitters. Therefore, we know little about the importance of mortality factors beyond this age as well as throughout their first year of life.

Radio transmitters have been implanted in a variety of wildlife species including black bears (Jessup and Koch 1984), grizzly bears (*U. arctos*) (Philo and Follmann 1981), beavers (*Castor canadensis*) (Guynn et al. 1987), mallards (*Anas platyrhynchos*) (Korschgen et al. 1996), deer mice (*Peromyscus maniculatus*), prairie voles (*Microtus ochrogaster*) (Reynolds 1992), montane voles (*M. montanus*), Ord's kangaroo rats (*Dipodomys ordii*), and Townsend's ground squirrels (*Spermophilus townsendii*)(Koehler et al. 1987) and yellow-bellied marmots (*Marmota flaviventris*) (Van Vuren 1989). Researchers have used subcutaneous and/or intraperitoneal implants as a means to monitor animal movements, assess home range size, and monitor physiological processes primarily in the adults of these species. Jessup and Koch (1984) had mixed success with subcutaneous implants in adult black bears. Results ranged from implant rejection to implant failure to complete success, but their sample size was small ($\underline{n}$=10). Little to no information exists in the literature about the success or failure of previous attempts to use subcutaneous implants as a means to monitor black bear cub survival. This paper evaluates the effectiveness of subcutaneous implants in black bear cubs as a tool to monitor survival during their first year of life.

STUDY AREA

Our study area was the northern and southern study areas of the Cooperative Alleghany Bear Study (Figure 3.1). The 840 km^2 northern study area on the George Washington and Jefferson National Forests is centered in Augusta and Rockingham

Counties. It contains portions of the Deerfield and Dry River Ranger Districts in the Ridge and Valley Province of the Appalachian Mountain chain. The northern study area is bordered by Long Run Road (FS rt. 72) to the north, West Virginia to the west, Virginia route 42 to the south, and the Shenandoah Valley to the east (Godfrey 1996, Higgins 1997).

Annual temperatures averaged 10.3^{o}C in 1996, 10.9^{o}C in 1997, and 12.7^{o}C in 1998, and ranged between 33^{o}C and –25^{o}C (NOAA 1996, 1997, 1998). Annual precipitation amounts were 60.7 cm, 33.9 cm, and 39.9 cm, in 1996, 1997, 1998, respectively. Climatological data for 1999 was unavailable. Elevations ranged between 488 m along the base of Little North Mountain and 1,360 m at the top of Elliott Knob (Kozak 1970).

The tree species of importance in the northern study area included eastern hemlock (*Tsuga canadensis*), sugar maple-beech-yellow birch (*Acer saccharum-Fagus spp.-Betula allegheniensis*), chestnut oak (*Quercus prinus*), pitch pine (*Pinus rigida*), white oak-black oak-northern red oak (*Q. alba-Q. velutina-Q. rubra*), northern red oak, yellow poplar-white oak-northern red oak (*Liriodendron tulipifera-Q. alba-Q. rubra*), eastern white pine (*P. strobus*). Predominant understory species include mountain laurel (*Kalmia latifolia*) and scrub oak (*Q. ilicifolia*).

The 1,544 km^2 southern study area includes parts of Giles, Craig, and Montgomery counties in southwest Virginia (Figure 3.1). This study area encompasses parts of the Blacksburg and Newcastle Ranger Districts and is found within the Ridge and Valley Province of the Southern Appalachian Mountain chain (United States Department of Agriculture [USDA] 1965). The southern study area is bordered by West Virginia to the west, Bland County to the south, Virginia route 624 to the east and Virginia route 311 to the north (Ryan 1997). Elevations ranged from a low of 492 m in the Craig Creek Drainage to 1,378 m in the Mountain Lake region.

Annual temperatures averaged 8.3^{o}C and 6.9^{o}C for the 1997 and 1998 seasons, respectively, and ranged between –23.8^{o}C and 29.2^{o}C. Annual precipitation amounts ranged between 119 cm and 153 cm. Information for 1996 and 1999 was unavailable.

The important tree species found within the southern study area include chestnut oak, black oak, white oak, scarlet oak, and northern red oak (USDA 1985). Red maple, pignut hickory (*Carya glabra*), bitternut hickory (*C. cordiformis*), pitch pine, and eastern white pine are fairly common. Understory species include sassafras (*Sassafras albidum*), mountain laurel, downy serviceberry (*Amelanchier arborea*), flowering dogwood, witch hazel (*Hamamelis virginia*) and rhododendron (*Rhododendron maximum*).

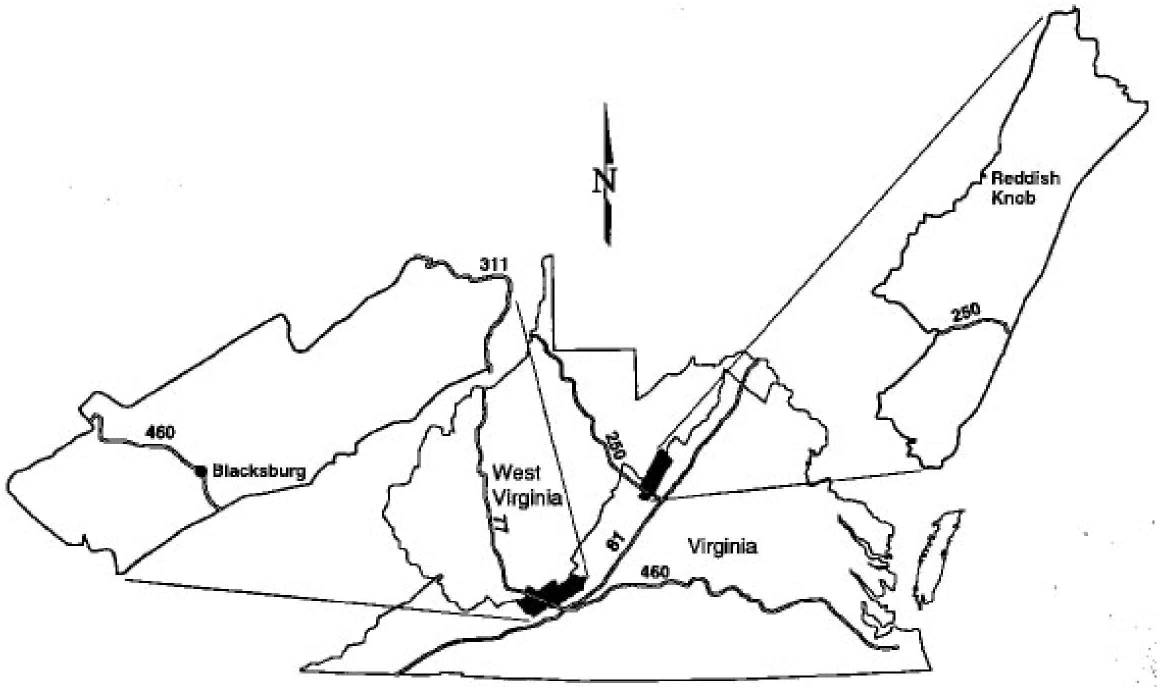

Figure 3.1. Northwest and Southwest study areas of the Cooperative Alleghany Bear Study, Virginia.

METHODS

We trapped and radio collared adult black bears during the summers of 1994, 1995, 1996, 1997, and 1998 using spring-activated Aldrich foot snares and culvert traps. We immobilized bears with a 2:1 mixture of ketamine hydrochloride and xylazine hydrocholoride (concentration of 300 mg/ml) at a dosage of 1 cc per 45 kg of body weight. We weighed immobilized bears to the nearest kg, marked them with a uniquely numbered ear tag and tattooed them with a corresponding number on their upper lip. We also pulled a premolar for aging purposes (Willey 1974). We placed radio transmitter collars on selected adult females (Telonics, Inc., Mesa, AZ; Lotek Engineering, Inc. Ontario, Canada) and monitored them until they denned, at which time we located their dens and listened for cub vocalizations to confirm the presence of cubs at dens of females suspected of being pregnant.

During the month of March, we entered the dens of female bears with newborn cubs. First, we tranquilized the sow and removed cubs from the den structures, counted, measured and weighed them. We selected some individuals to receive subcutaneous implants (AVM, Livermore, CA; Advanced Telemetry Systems Inc., Isanti, MN) based on general health and weight criteria. Cubs weighing less than 1.65 kg (3.6 lbs) did not receive implants. Implants weighed an average of 25.2 g (SE=0.53, n=15) and measured approximately 63.1 mm (SE=0.76, n=16) by 26.2 mm (SE=0.23, n=16) by 11.0 mm (SE=0.20, n=16). Each implant's antenna averaged 132.4 mm (SE=0.73, n=13) in length.

Each cub selected was immobilized with a 5:1 mixture of ketamine hydrochloride (Ketaset, Fort Dodge Animal Health, Fort Dodge, IA) and xylazine hydrochloride (Rompun, Bayer Corporation, Shawnee Mission, KS) (concentration 100mg/ml) at a dosage rate of 1cc per 45 kg of body weight. Once the cub lost consciousness, it was placed in sternal recumbency and its breathing was monitored. We placed a rolled towel under the neck to maintain flexion.

We shaved a section of fur from the base of the neck to the base of the shoulder blades approximately 5.5 cm wide and a second section approximately 2.5 cm^2 and 13.5 cm lower on the back, toward the base of the tail. These areas were scrubbed clean repeatedly with povidone iodine and wiped clean with isopropyl alcohol and then allowed to air dry. We then draped the cub, and cut 2 holes in the drape large enough to expose the proposed incision areas, and secured the drape in place with hemostats.

We made 1-5 cm longitudinal incision through the hide from the base of the neck to the scapular region, and a second 1 cm incision approximately 13.5 cm below the first incision. Using a pair of hemostats in the first incision, we separated the hide from the muscle and fascial tissue and created a pocket to hold the transmitter. We used alligator forceps to tunnel between the caudal incision and the upper incision. We held the tip of the antenna with the forceps that tunneled between the upper and lower incisions, and carefully inserted the transmitter into the pocket drawing the antenna back down through the tunnel toward the base of the tail until the transmitter was completely seated in the pocket. We closed both incisions with double sutures.

Implanted cubs received LA200 (oxytetracycline, Pfizer, distributed by Animal Health, New York, NY) (concentration 200 mg/ml) at a dosage rate of 4cc/45 kg intramuscularly to help combat any infection. Each cub then was administered Yobine (yohimbine hydrochloride, Lloyd Laboratories, Shenandoah, IA), a reversal agent, at a dosage rate of 2 cc per 45 kg (concentration 5 mg/ml) or Antagonil (yohimbine hydrochloride, Wildlife Laboratories, Incorporated, Fort Collins, CO) (concentration 10 mg/ml; dosage 1 cc per 45 kg) to counteract the effects of the xylazine hydrochloride. Licensed veterinarians performed all implant surgeries on cubs.

We also implanted additional cubs born to captive females being held at Virginia Tech's Center for Ursid Research during 1997 and 1998 as part of an ongoing reproduction and nutrition study and monitored their behavioral responses to the implants until their release from captivity in mid-May or early June. We surgically implanted 2 additional wild cubs (0M:2F) at the time of their capture in July 1997. They were released at their capture site following complete recovery from the surgical anesthesia.

We used the Student's T-test to compare the length of time male and female black bear cubs retained their transmitters. To determine if cub sex, cub age, cub weight, sow age, litter size, total length, chest girth, or den type were good predictors in the retention of implanted transmitters, we ran a best subsets regression procedure. We generated Pearson's correlation coefficients to determine which of these factors were highly correlated with one another and therefore, which should be excluded from the final model. Once the best subsets regression was run and the model factors determined, we ran a regular multiple regression with the factors that offered the best fit.

RESULTS

We implanted radio transmitters subcutaneously in 40 wild black bear cubs (21M:19F) during the 1996, 1997, 1998, and 1999 den seasons (Appendix Table 3.1). We implanted transmitters in 10 captive cubs (6M:4F) to observe the interaction between and among implanted cubs, their siblings and the sow. We also implanted 2 (0M:2F) wild cubs captured during trapping efforts in July 1997.

Nine of 12 transmitters implanted in wild cubs during the first 2 years of study were rejected (i.e. fell out, were pulled out, etc.) within the first 5 months; 7 of the 9 were rejected during the first 2 months (Appendix Table 3.1). Two wild cubs died within 5 days of implant surgery of unknown causes. Both cubs had come through the surgical procedures without complications and had recovered from the anesthesia. The twelfth cub's transmitter failed within 2 months of implantation. The 2 female cubs implanted during July rejected their transmitters within 11 days of surgery. Additionally, 2 single female cubs rejected their transmitters after wearing them for 3 months.

During the 1997 den season, we modified the surgical techniques between study areas, changing the incision from a longitudinal cut between the shoulder blades to a lateral incision between the base of the neck and the scapular region. The 10 surgeries on the northern study area using the old technique resulted in rejection of the transmitter. The second 4 surgeries, performed on bear cubs in the southern study area using the new technique, were more successful and resulted in 2 cubs wearing the subcutaneous transmitter until the next den season. Contact with the other 2 cubs was lost at the end of September 1997 and the fate of these cubs remains unknown.

During the 1998 den season, we performed 6 surgeries on the northern study area using the modified technique without improved success. We performed 7 surgeries in the southern study area with mixed success. Four of 7 cubs retained their transmitters until the 1999 den season; the other 3 fell out between 1 and 6 months after surgery.

In 1999, we implanted 6 cubs (1M:5F) in the northern, and 5 (2M:3F) in the southern study areas. During this den season, we used 2 different shapes of transmitters, a cylindrical model and the previous flat model. Additionally, we paid greater attention to the sutures. All but 2 of the transmitters fell out and were recovered before the end of June 1999. The remaining 2 transmitters failed by mid-September 1999.

We observed 10 cubs born in captivity and implanted between 55 and 109 days of age in an attempt to determine what, if any, impact the sow or sibling(s) had on implant retention rates. We made these observations from a distance and therefore were unable to discern individuals. Within 10 days of surgery, 2 cubs in a litter of 4 showed signs of infection and rejection, including drainage and an opening of the incision. Within 3 weeks, these 2 transmitters came out and the 2 other littermates' incisions were beginning to appear infected. The majority of the 10 implants festered to the point of rejection within the first month following implantation. Periodically, we made attempts to intervene, to clean the incision or re-suture, but were largely unsuccessful in keeping the implants in.

The average retention time for all wild cubs was 93.9 days (SE=16.2) (Table 3.1). Male cubs ($\bar{X}$ =134.0, SE=27.0, n=21) retained their transmitters longer (T=2.68, df=27, P=0.013) than female cubs ($\bar{X}$ =53.6, SE=12.0, n=21). We examined the age of the sow (P=0.507, F=0.45, df=41), litter size (P=0.293, F=1.14, df=41), cub age (P=0.186, F=1.81, df=41), cub weight (P=0.740, F=0.11, df =41), cub chest girth (P=0.416, F=0.68, df =37), cub total length (P=0.528, F=0.41, df =41), sex of cub (P=0.011, F=7.16, df =41), and type of den (P=0.585, F=0.30, df =39) in relation to the length of time implants were worn using simple regression analysis. As expected, several predictors revealed a lack of independence because we implanted more than 1 cub within the same litter on several occasions (Table 3.1). The best subsets regression procedure indicated that a model with the 4 predictors of cub weight, cub age, cub sex, and den type, was the best fit. The final relationship of

Days Worn = -21.0 + 138.0*(cub weight) – 4.1*(cub age) – 57.6*(cub sex) + 44.1*(den type)

n=38, Cp=1.3, Adjusted R^2=0.242,

failed to explain most of the variation in the data, however.

Table 3.1. Pearson's correlation coefficients for the number of days implanted transmitters were worn against litter size, sow age, cub weight, cub age, cub chest girth, cub total length, cub sex, and den type for black bear cubs in the George Washington & Jefferson National Forests, Virginia, 1996 – 1999.

	Days Worn	
	Correlation coefficient	P-value
Sow age (years)	0.066	0.686
Litter size	-0.221	0.170
Cub age (days)	-0.098	0.546
Cub weight (Kg)	0.379	0.016
Cub chest girth (mm)	0.136	0.416
Cub total length (mm)	0.121	0.459
Sex	-0.363	0.021
Den type	0.089	0.585

DISCUSSION

Retention of the implanted transmitter was the greatest difficulty we faced. We could not always explain the circumstances under which the implants came out of the bear cubs. Speculation regarding maternal intervention, sibling involvement, and irritation of the implant itself could not be substantiated or refuted. It also was not possible to determine which of these potential factors may have been the most influential. Although male cubs retained their transmitters longer than female cubs ($T=2.68$, df=27, $P=0.013$) we could not easily explain the difference. One possible explanation, however, is that female cubs do not tolerate their implants as well. On several occasions we observed female cubs, immediately following surgery and reversal of their anesthetic, reaching behind their heads and clawing at their sutures. We did not observe male cubs doing this nearly as often. In 3 all-female litters, all implants were quickly rejected. Our sample sizes prevented meaningful statistical comparison to determine the effects of litter size, sex ratio, and the number of cubs in a litter that were implanted.

We encountered a substantial number of transmitter failures. We lost contact with 7 of 42 implanted cubs during the 4 years of implant surgeries. We do not know the circumstances behind all of these failures, but suspect a combination of premature failure of the transmitters due to some inherent flaw in the transmitter, broken antennas which may have compromised the transmitter integrity, destruction of the transmitters by the bear wearing them, or destruction by natural events such as predation. We recovered one of the failed transmitters from 1997 and determined the transmitter had a faulty battery. Female #446, whose transmitter failed on 10 July 1998, was trapped on 20 July 1999 and her subcutaneous implant was detected under the skin at the site of implantation.

The recovery of several of the dropped transmitters and their condition suggests that there may be a failure in the integrity of the transmitter packages. The antennas of at least 5 recovered transmitters had broken off and could not be located. It is not known if the bears retained the antennas, or if they worked their way free of the body prior to the loss of the implant itself. In each case, the antennas broke at the point of attachment to the transmitter. In a few cases, it appeared that this break at the antenna's attachment may have allowed body fluid to enter the electronics of the transmitter. We suspect that this is the reason for transmitter failure in the majority of cases.

The behavioral observations we made of cubs and their siblings in captivity reveal that at a very young age, cubs become very mobile and playful. Their claws are remarkably sharp and are no doubt to blame for some of the infection and possibly some of the suture failures. Sows may influence the retention of these transmitters through grooming the cubs or cleaning wounds. While these observations provided some ideas to help explain the transmitter loss we experienced with wild cubs, we acknowledge some important differences. Captive-born cubs may be more prone to paying attention to their implant due to confinement, and confined cubs may interact more with each other than wild cubs.

Transmitter retention rates varied widely (Figure 3.2). We thought there might be a relationship between the cub's age at the time of implantation and the retention period, but the regression equation was not significant (Figure 3.3). We assumed that the larger the cub, the less intrusive the surgery and therefore the greater chance of acceptance. Each cub, in fact, appeared more capable of reacting to his/her own incisions with increased age and size. On several occasions, implanted cubs were seen reaching behind their backs to scratch at the incision and suturing. Another trend we looked for was that between the age of the sow and the retention time (Figure 3.4); again, the regression equation was not significant. It appears, however, that the older the sow of the implanted cubs, the shorter is the retention period.

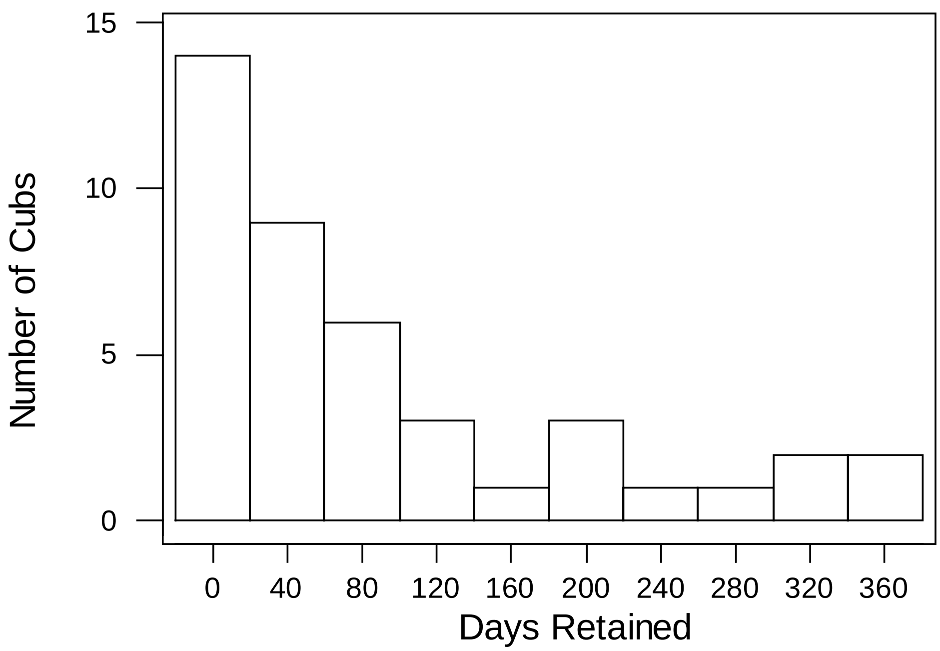

Figure 3.2. Numbers of black bear cubs implanted with subcutaneous transmitters and the length of time they retained them in the George Washington and Jefferson National Forests, Virginia, 1996 – 1999.

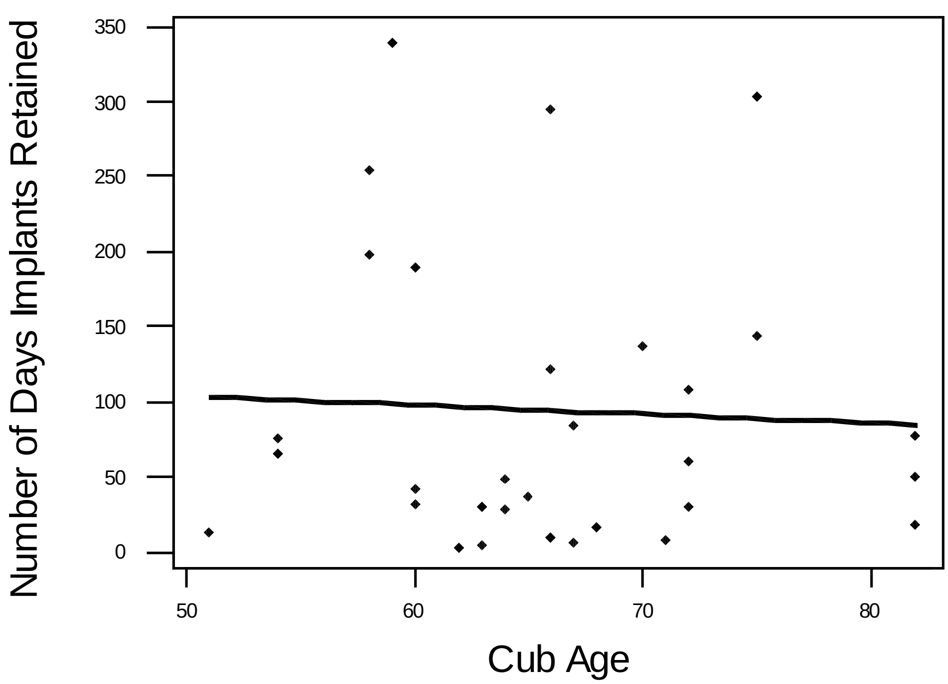

Figure 3.3. Fitted line plot of regression equation relating the number of days subcutaneous implants were worn by black bear cubs in the George Washington and Jefferson National Forests, Virginia, 1996 – 1999 to their age at the time of implant surgery (R^2 = 0.02).

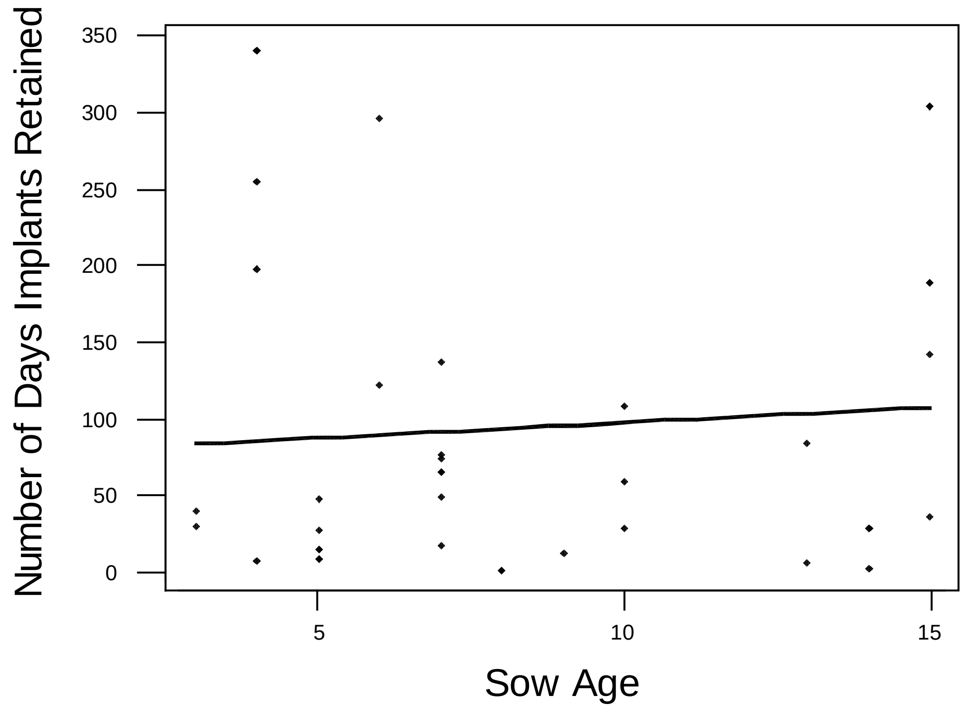

Figure 3.4. Fitted line plot of regression equation relating the number of days subcutaneous implants were worn by black bear cubs in the George Washington and Jefferson National Forests, Virginia, 1996 – 1999 to the sow's age at the time of implant surgery (R^2 = 0.06).

MANAGEMENT IMPLICATIONS

The use of subcutaneous implants to monitor black bear cub survival could be a break-through in our ability to obtain survival data during the first year of life. It is a much more worry-free means of tracking cubs through their first year because the concerns associated with radio collars (e.g. expansion with cub growth) are not present. What we have witnessed with subcutaneous implants is that the wound heals quickly if the implant is rejected, and there is little risk of serious infections that sometimes result from intra-peritoneal implant surgeries (VanVuren 1989, Reynolds 1992). Unfortunately, until such factors as maternal and sibling intervention can be quantified and measures taken to prevent this and other interventions, subcutaneous implants may not be the most feasible, cost-effective, or data-effective options. Subcutaneous implants do not currently offer the ability to obtain consistently longer-running survival data than the expandable radio collars designed for black bear cubs (Higgins-Vashon, CABS, unpubl. data). Although they can provide some of the same valuable data, because they involve the added expense and coordination of a veterinarian, subcutaneous implants may not yet be the method of choice.

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APPENDIX

Appendix Table 3.1. Number of days subcutaneous implants were worn in 42 wild black bear cubs in the George Washington & Jefferson National Forests, Virginia, 1996-1999, and the ultimate outcome of the implant surgery.

Study Area	Bear ID#	Sex	Age (days)	Implant Date	# Days Worn	Results and comments
North	N229	M	65	3-24-96	38	Transmitter failed post den emergence
	N232	M	71	3-28-96	8	Transmitter recovered in den - transmitter rejected or cub consumed?
	N311	F	63	3-4-97	29	Died of unknown causes - sow moved from den
	N312	F	63	3-4-97	2	Cub died of unknown causes in den
	N313	M	63	3-4-97	29	Died of unknown causes - sow moved from den
	N317	M	67	3-10-97	6	Cub died of unknown causes near den
	N318	F	67	3-10-97	84	Transmitter rejected - recovered in sow's home range – cub survived
	N324	F	68	3-13-97	14	Transmitter rejected - recovered in den – cub survived
	N325	F	68	3-13-97	14	Transmitter rejected - recovered in den – cub survived
	N326	F	70	3-13-97	137	Transmitter rejected - recovered in sow's home range – cub survived
	N333	M	62	3-17-97	2	Transmitter rejected - recovered in den – cub survived
	N334	M	62	3-17-97	2	Transmitter rejected - recovered in sow's home range
	N431	M	82	3-16-98	77	Transmitter rejected - recovered in sow's home range
	N432	M	82	3-16-98	48	Transmitter rejected - recovered in sow's home range
North	N433	F	82	3-16-98	18	Transmitter rejected - recovered in sow's home range
	N444	F	72	3-25-98	28	Transmitter rejected - recovered in den
	N445	M	72	3-25-98	60	Transmitter failed post den emergence
	N446	F	72	3-25-98	109	Transmitter failed post den emergence – cub survived – transmitter remained subcutaneous
	N561	F	64	3-15-99	28	Transmitter rejected - recovered in den
	N563	F	64	3-15-99	48	Transmitter rejected - recovered in den
	N564	F	54	3-16-99	179	Transmitter failed

Appendix Table 3.1. Continued.

Study Area	Bear ID#	Sex	Age (days)	Implant Date	# Days Worn	Results and comments
North	N565	F	54	3-16-99	75	Transmitter rejected - recovered in sow's home range
	N566	M	54	3-16-99	175	Transmitter failed
	N568	F	51	3-16-99	13	Transmitter rejected - recovered in den
South	S117	M	59	3-28-97	340	Transmitter failed but worn to den - reimplanted
	S118	M	59	3-28-97	340	Transmitter failed but worn to den - reimplanted
	S125	M	60	3-21-97	189	Transmitter failed
	S126	M	60	3-21-97	189	Transmitter failed
	S128	F	~153	7-3-97	5	Transmitter rejected
	S129	F	~153	7-3-97	11	Transmitter rejected
	S165	M	66	3-23-98	296	Transmitter worn to den
	S166	F	66	3-23-98	124	Transmitter rejected
	S167	M	75	3-23-98	304	Transmitter worn to den
	S168	M	75	3-23-98	304	Transmitter worn to den
	S169	M	75	3-23-98	142	Transmitter rejected
	S170	M	58	3-30-98	254	Transmitter worn to den
	S171	F	58	3-30-98	198	Transmitter rejected - recovered in sow's home range
	S195	M	60	3-18-99	41	Transmitter rejected - recovered in den
	S196	F	60	3-18-99	31	Transmitter rejected - recovered in den
	S198	F	66	3-25-99	9	Transmitter rejected - recovered in sow's home range
	S199	F	66	3-25-99	9	Transmitter rejected - recovered in sow's home range
	S200	M	66	3-25-99	9	Transmitter rejected - recovered in sow's home range

VITA

Kim Needham Echols was born Kim Alexandra Needham on March 2, 1972 in Little Falls, New York. She graduated from Walter Johnson High School in Bethesda, Maryland in 1990. She attended Virginia Polytechnic Institute and State University and earned her Bachelor of Science degree in Wildlife Management in July of 1994. She interned with Dr. William McShea at the Smithsonian Institution and National Zoological Park's Conservation and Research Center between August 1994 and September 1994, working primarily with small mammals and white-tailed deer. In January 1995, she joined the Cooperative Alleghany Bear Study's (CABS) northern study area as a field technician. She became a graduate student of CABS in August 1996. In September 1998, she was hired as a Wildlife Biologist Assistant with the Virginia Department of Game and Inland Fisheries (VDGIF) working with quail under Mike Fies, Small Game Biologist, in Verona. In August 1999, she moved within the VDGIF to another Wildlife Biologist Assistant position to work under Dennis Martin, the Black Bear Program Leader, and Gary Norman, the Upland Game Bird Program Leader. In October 1999, she married Richard F. Echols of Staunton, Virginia.