Survival, Home Range and Spatial Relationships of Virginia's Exploited Black Bear Population

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SURVIVAL, HOME RANGE, AND SPATIAL RELATIONSHIPS OF VIRGINIA'S EXPLOITED BLACK BEAR POPULATION

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(Abstract)

Eighty-three (21M, 62F) of 194 black bears captured during 1994-1996 were equipped with radio collars. Annual survival rates estimated with Kaplain-Meier staggered entry approach for radio collared adult females, adult males, subadult females, and subadult males were 95.3, 100.0, 90.4 and 50.0% respectively. Hunting, handling, vehicle collisions, and natural causes accounted for 81.0, 11.1, 3.2, and 1.6% of mortality. Twenty, 9.8, and 70.6 % of bears harvested were harvested in the deer firearm season, the deer archery season, and the bear firearm season, respectively.

Twenty-three cubs were equipped with expandable radio collars (11M,10F) or transmitters implanted subcutaneously (2M,0F) in 1995-1996. Six cubs (4M, 2F) died, 6 (3M,3F) survived their first year, and the status of 11 cubs (6M, 5F) was unknown. Survival rates (date marked until 4 December) estimated with Kaplain-Meier and Heisey-Fuller were 64.3 and 64.7% respectively. Interval survival rates were 71% (15 March to 31 May), 100% (1 June to 31 July), 92% (1 August to 31 August), and 100% (1 September to 4 December). Intraspecific aggression (33.3%), starvation (16.7%), unknown causes (16.7%) and predation (16.7%) were the causes of mortality.

Total home range size for males and adult, subadult, and transitional age females were 7.2, 5.5, 5.6 and 7.2 km^2 (95% MCP) and 11.2, 6.8, 9.0, and 10.0 km^2 (95% normal kernel). Females with cubs had larger fall ranges than spring and summer ranges. Seasonal ranges of solitary females did not differ when estimated with MCP. Bears exhibited home range overlap among and within sex classes.

Acknowledgments

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INTRODUCTION

Management of black bears (*Ursus americanus*) for sport hunting is a controversial issue. Once managed primarily as a nuisance species, black bears are now a valued game species and attention has been focused on their management, particularly in western states. Generally, the public trusts state agencies to protect black bears from overexploitation, and supports hunting as a valid wildlife benefit, but some aspects of hunting are unpopular (Beck et. al. 1993). The public is concerned with the sportsmanship of certain hunting methods, the physiologic impact of hunting on the individual bear and the population, the impact to non-target wildlife, the effect of hunter access on environmental quality, and the cost of regulating different methods of take (Beck et. al. 1993). Hunting bears with dogs, hunting over bait, and hunting in the spring season are the primary concerns of special interest groups. These groups were successful in closing bear hunting in California, spring bear hunting in Utah and Oregon and closing bear hunting with dogs, bear hunting over bait and the spring bear season in Colorado through separate ballot initiatives (Beck pers. comm.). Recently, on separate ballot initiatives, Massachusetts and Washington hunters lost their privilege to hunt bears with dogs, while Idaho and Michigan maintained this method of harvest. Beck et. al. (1993) believed most western management agencies were ill-prepared to deal with the issue of black bear hunting techniques. The ballot initiative in Colorado was not a response to the welfare of the black bear population, but a loss in credibility of the agency, because agency personnel failed to listen to all constituents (Beck et. al. 1993).

As the bear hunting issue has gained momentum, some state agencies have begun to prepare for the debate in their states. In Virginia, unexploited black bear populations in the Shenandoah National Park (SNP) and in the Great Dismal Swamp National Wildlife Refuge (GDSNWR) were studied intensively beginning in the early 1980s (Carney 1985; Garner 1986; Hellgren 1988; Kasbohm 1994; Schrage 1994). Although, these studies described the demographics and ecology of Virginia's unhunted population, similar information for Virginia's hunted black bear population is not available. Limited data on Virginia's hunted bear population and severe alternate year fluctuations in annual harvest (26%-75%) that began in 1989 are of particular concern to the Virginia Department of Game and Inland Fisheries (VDGIF). Current management of black bears in Virginia involves manipulating the timing and length of the bear season based on harvest trends. Estimates of black bear population size and growth in Virginia are based on monitoring trends in harvest rates, nuisance complaints, and incidence of road kills, but these data may be inadequate, and biased. Changes in bear population dynamics, hunter dynamics, weather, and food availability can affect productivity and survival of bear populations. These parameters are not identified in harvest, road kill, and nuisance data. A better understanding of hunter dynamics, bear population dynamics, and effects of proximate and ultimate factors on Virginia's bear population are needed if the VDGIF management strategy is to be based on sound biological information.

In Virginia, black bears are a valued game species, and bear hunting with dogs is a long held tradition and a very popular activity. There is no spring bear season, and hunting over bait is not a legal method of take. Under Virginia's current licensing structure, hunter effort and success rate can not be determined, because bear, deer (*Odocoileus virginianus)*, and turkey (*Meleagris gallopavo*) hunters purchase the same license. In addition, bears can be harvested by deer hunters during part of the deer archery season, and during the second week of the deer rifle season. In the bear firearm season, hunters can pursue bears with hounds, still-hunt with a rifle, or harvest bears with a muzzleloader in the late deer muzzleloading season (during the last week of the bear firearm season). During the bear firearm season, pursuit with hounds is the most common method used to harvest bears, and the VDGIF considers all bears killed in that season as taken with hounds. Ratio of deer hunter to hound hunter take of bears remains nearly 50:50 throughout the state (Martin file data).

In May 1994, the VDGIF and Virginia Polytechnic Institute and State University (VPI&SU) initiated the Cooperative Alleghany Bear Study (CABS). The objectives of this study were as follows: to determine age specific birth rates, death rates and population growth rates, determine regional density levels, estimate the number of black bears in Virginia's exploited bear population, assess the relative importance of factors that affect population birth and death rates, assess potential indices of population size, develop population models, determine habitat use patterns, assess the quality of bear habitat, determine seasonal distribution patterns, and recommend a strategy for the long-term management of black bears in Virginia. The objectives of the research reported here were to (1) determine age and sex specific survival rates, (2) assess the relative importance of factors that affect survival, and (3) estimate home range size and spatial relationships. Emphasis was placed on cub survival, because their survival represents recruitment into the population, and cub survival data are limited.

Study Area

The 860 km^2 study area is located on the Dry River and parts of the Deerfield Ranger Districts of the George Washington-Jefferson National Forests (GWJNF), formerly the George Washington National Forest. These districts are located in Augusta and Rockingham counties, the two largest counties in Virginia. The study area is bounded by the Shenandoah Valley to the east and West Virginia to the west (Figure 1) and is dominated by mountainous terrain of the Appalachian Mountains. Elevations range from 488 m to 1,360m (Koazk 1970). The study area consistently experiences the largest bear harvest in the state (Martin, VDGIF file data), which may be attributed to the size of these counties and availability of public land allowing access to hunters.

The average winter temperature is 0.3 °C and the average summer temperature is 22.9 °C. Annual precipitation is 86 cm, with 60% of it occurring during April-September. The average seasonal snowfall is 71 cm at Dale Enterprise, Virginia. The study area is typically cooler and receives more precipitation than Dale Enterprise in the adjoining Shenandoah Valley (Rawinski et. al. 1994).

The Shenandoah Valley was first explored in 1716 and settled by farmers of Scottish-Irish and German descent. The area later known as the George Washington National Forest was cut, burned and farmed, which led to erosion and siltation. The United States Forest Service (USFS) purchased the Shenandoah Unit, now the Dry River Ranger District, in 1911 to suppress fire and improve land and water quality. It wasn't until 1924 that timber management was an objective for the USFS with the passing of the Clark McNary Act (Satterthwait 1993). Currently 1/4 of 1% of timber forest wide (1.1 million acres) is harvested annually. The study area is characterized by poor soils and poor site index as a result of the previous destructive forest practices (Bourgeois, (VDGIF) regional biologist pers. comm.). The major forest cover types are 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. valutina, Q. rubra*), Northern Red Oak, Yellow Poplar-White Oak-Northern Red Oak (*Liriodendron tulipifera*), Eastern White Pine (*Pinus strobus*), and barren and brush cover (*Q. ilicifolia*, *Kalmia latifolia*) (Rawinski et. al. 1994, Godfrey 1996).

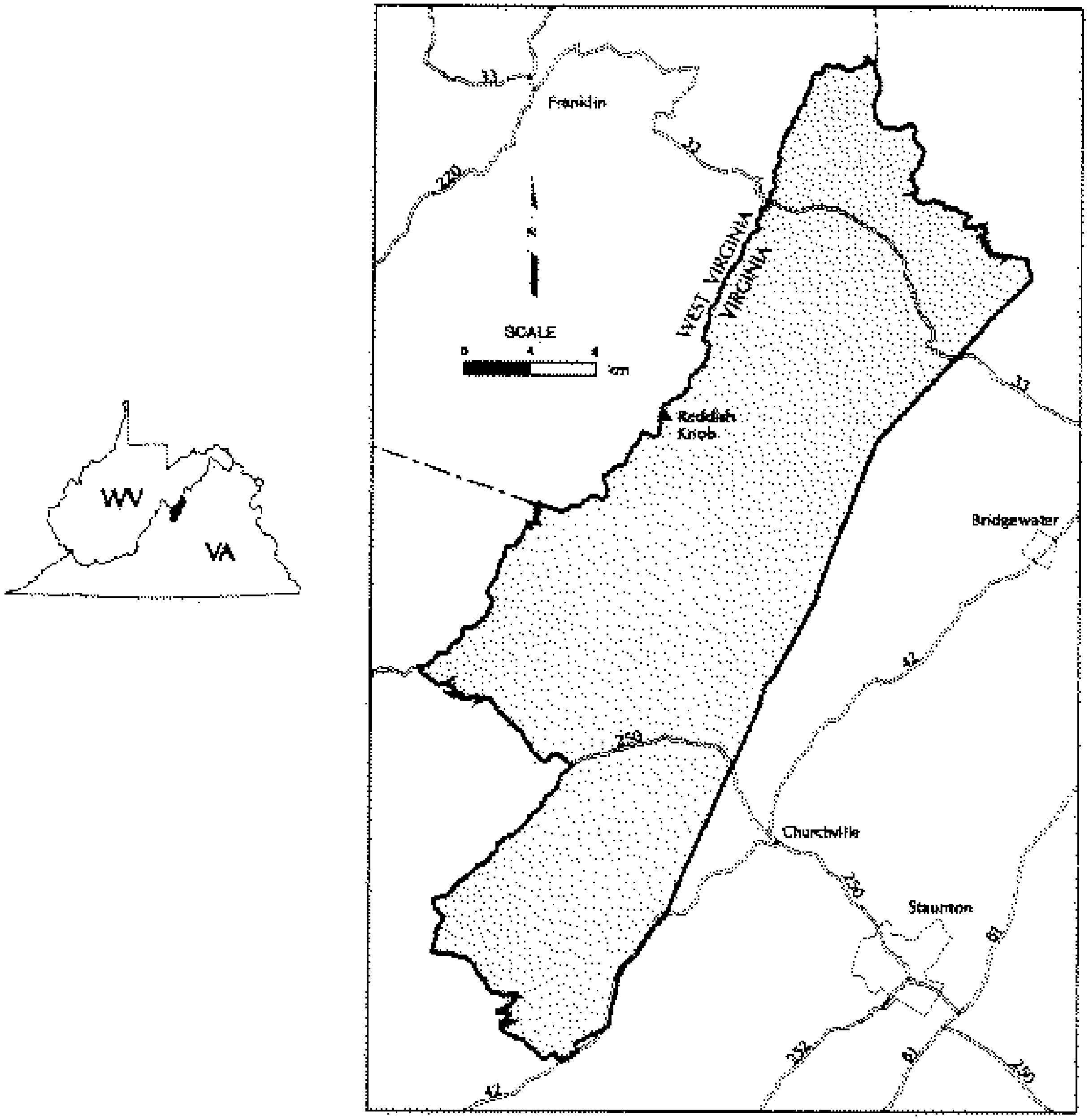

Figure 1. Study area in the George Washington-Jefferson National Forests, Virginia

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Chapter 1: Adult and Subadult Survival

Humans cause 34-100% of the mortality in hunted black bear populations throughout North America (Bunnell and Tait 1985; LeCount 1987; Elowe and Dodge 1989; Beck 1991; Schwartz and Franzmann 1991; Doan-Crider and Hellgren 1996), which are easily depleted by harvest and are slow to recover (Taylor et. al. 1987; DeRocher and Stirling 1995). Male bears usually are harvested at a higher rate than females, because they have larger home ranges, hunters select them and they are more vulnerable to some methods of take (e.g. bait sites) (Rogers 1976; Beecham 1980; Bunnell and Tait 1980; Lindzey and Meslow 1980; Carney 1985; Beck 1991; Kasworm and Their 1994). In addition, subadult males experience greater mortality than adult males (Bunnell and Tait 1985; Elowe and Dodge 1989; Schwartz and Franzmann 1992), likely because their extensive dispersal movements bring them into contact with people (dumps, hunters, roads) and unrelated bears (Rogers 1977; Clevenger and Pelton 1990; Schwartz and Franzmann 1992). Human induced mortality was the major source of mortality for dispersing male bears in Massachusetts and Alaska (Elowe 1987; Schwartz and Franzmann 1992).

Female offspring usually remain in their mother's home range; thus, subadult females are more likely to survive to adulthood than males (Elowe 1987; Schwartz and Franzmann 1992, Clevenger and Pelton 1990). In Alaska, for instance, subadult females were 2 to 3 times more likely to survive to adulthood than subadult males (Schwartz and Franzmann 1992). However, in general, rates of survival for subadult black bears are poorly documented in North America (Rogers 1977; Alt 1978; Clevenger and Pelton 1990; Schwartz and Franzmann 1992).

Survival of female bears is essential to the maintenance of a bear population (Taylor et. al. 1987; DeRocher and Stirling 1995; Eberhardt 1990; Beck 1991), particularly survival of adult females. Older females typically produce larger litters with a higher rate of survival than younger females (Elowe and Dodge 1989). A knowledge of sex and age-specific survival rates is vital to understanding the dynamics of hunted bear populations.

Kemp (1972), Young and Ruff (1982), and LeCount (1987) documented self-regulation by adult male bears in unexploited populations. In Alberta, Canada, large males controlled population levels by killing or driving off subadults (Kemp 1972; Young and Ruff 1982). However, in Arizona, LeCount (1987) reported that immigrating young males that occupied home ranges formally used by older males, killed cubs and suggested survival of adult males would increase cub survival. However, Miller (1990) suggested there is little data to support these density-dependent relationships in exploited populations.

Current management of Virginia's exploited black bear population consists of monitoring harvest data and trends. This may inaccurately represent the population (age and sex structure) because of differential vulnerability of male and female bears. Tag returns are dependent on hunter cooperation (Carney 1985), and provide minimum estimates of human induced mortalities (road kills, harvest, and nuisance problems). Radio telemetry studies, however, may provide more accurate survival rates and useful information on the timing and cause of death, and can document natural causes of mortality (predation, starvation, disease, accidents, and cannibalism) and their frequency. The goal of this study was to estimate sex and age specific survival rates, and to evaluate the importance of different mortality factors on Virginia's exploited bear population.

METHODS

Black bears were captured with modified Aldrich foot snares in the summers of 1994 and 1995. Bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride. Drugs were administered with a ChapChur pistol (Palmer Chemical Equipment, Douglasville, GA) or a blow pipe (Pneu Dart Inc., Williamsport, PA). A sample of bears was equipped with either 150-151 MHz or 164-165 MHz radio transmitters (Telonics, Inc., Mesa, Az.) on collars with a breakaway cotton spacer (Hellgren et. al. 1988). Each bear was marked with a uniquely numbered ear tag and with a lip tattoo corresponding to the ear tag number. During the 1994 trapping season, female bears were given an additional orange ear tag to identify them as females. In 1995, female bears were not marked differently than males. In addition, orange tags were removed from females when handled in the summer of 1995 and in the winter of 1996. Various morphological measurements were taken (weight, neck and chest girth, total length, zoological length, zygomatic arch, canine width and breath, front and hind paw width and length, ear length and tail length), a premolar was extracted for aging using cementum analysis (Willey 1974), a blood sample was taken for genetic analysis, and reproductive status (lactating, estrus etc.) and body condition were evaluated. Each bear was released at the capture site and monitored until recovery from the drug. The VDGIF, as part of their nuisance bear program, have released nuisance bears into the study area, thus a sample of these nuisance bears (not to exceed 10% of the collared sample) was equipped with radio collars.

Each radio collar was equipped with a motion sensitive mortality sensor. Radio collars on the 150-151 MHz band had a 30-minute delay and radio collars on the 164-165 MHz band had a 5-minute delay. Black bears equipped with radio collars were monitored to detect mortality. Bears observed on mortality mode for an extended period (1-2 hours) were located, and timing and cause of mortality were determined. Hunter tag returns provided additional information on the timing and cause of mortality.

A direct harvest rate was calculated only for bears caught in the summer trapping event and available to be harvested the following fall hunt season. The actual number of bears harvested was higher. The harvest was used to estimate population size with a Lincoln-Peterson population estimator. Bears killed outside the study area were excluded from analysis to avoid violating the assumptions of the Lincoln-Peterson population estimate. None of our marked female bears was harvested outside the study area. To account for movement of male bears, the number of males available for harvest was adjusted by the proportion of males killed outside the study area. Male and female bear harvest rates were calculated separately due to heterogeneity of capture probabilities, and because a higher proportion of female bears were equipped with a radio collar. Harvest rates of female and male bears were combined to estimate the harvest rate for the population. Annual harvest rates were compared using a chi-square test. The Lincoln-Peterson index was used to estimate female and male population size using the summer trapping season as the initial capture event and the fall hunt season as the recapture event.

Survival rates for radio collared bears were estimated using the Kaplan-Meier staggered entry design (Pollock et. al. 1989). The assumptions of the Kaplan-Meier procedure were 1) animals of a particular sex and age class were sampled randomly; 2) survival times were independent for different animals; 3) capturing an animal or carrying a radio collar did not influence its future survival; 4) the censoring mechanism was random (i.e. not related to the animals fate); 5) and newly tagged animals had the same survival probability as previously tagged animals. Yearly survival estimates were calculated from June 1 to May 31. Survival calculations began following a 7-day conditioning period, to allow bears time to adjust to their transmitters and capture. Survival estimates were calculated for subadult bears (between 1 and 4 years of age) and adult bears ($\geq$ 4 years of age). Although 6 3-year old sows produced cubs, these females were still considered subadult bears during analysis. Bears that lost their collars, or bears with collars that failed, were censored from analysis on the date when contact was lost. Bears that died as a result of handling also were censored from analysis on the date of mortality. Mortality dates and dropped/slipped collar dates were estimated as the midpoint between the date they were last heard on active mode and the first date they were observed on mortality mode. The censor date for collars that failed was estimated as the midpoint between the last date observed and first date not observed.

Variance and 95% confidence intervals were calculated for each survival estimate. Survival functions for different ages and sexes were compared with the log rank and approximate chi-square test statistic. Annual survival rates were compared using a Z statistic (Pollock et. al. 1989; Schwartz and Franzmann 1991).

Hunter harvest of bears may be biased by the presence of a radio collar. We were primarily concerned with reliability of female harvest rates, because most females we captured were radio collared. We believed that a hunter pursuing bears with hounds would be less likely to harvest a collared female bear than a deer hunter who harvested a bear incidentally. Houndsmen were more familiar with the project, knew that female bears were radio collared, preferred not to harvest female bears, and were more likely to see the collar on treed bears. In contrast, we assumed deer hunters would be more opportunistic in their harvest of bears and would be less concerned with size, sex and marking of bears. To determine if deer hunters were more likely than a hound hunters to kill a female bear, we compared the proportion of collared females harvested by deer hunters (no. collared females harvested by deer hunters/total number females harvested by deer hunters) to the proportion of collared females harvested by houndsmen (no. collared females harvested by houndsmen/total number females harvested by houndsmen). A one sample chi-square test was used to test for differences in harvest rate between houndsmen and deer hunters. To estimate the effect of a radio collar on male harvest rate, the harvest rate for collared males and non-collared (but ear tagged) males was compared. A chi-square test was used to test for differences in harvest rate of collared and tagged males. In both analyses, data from 1994 and 1995 were combined because of small sample sizes.

To determine if houndsmen avoided harvesting tagged bears, we compared the proportion of marked bears treed and harvested to the proportion of unmarked bears treed and harvested. These data were from hunters' responses to a CABS survey in 1995 (K. Higgins unpubl. data). The Fisher's exact chi-square test was used to test for differences in harvest rates of treed marked bears vs. treed unmarked bears.

RESULTS

Capture Demographics

During June 1994 to September 1994 and July 1995 to September 1995, 194 different bears (128 M, 66 F) were caught 256 times. Eighty-three different bears (21 M, 62 F) were equipped with radio collars. Sex and age ratio of captured bears were skewed towards younger males (Figure 1.1). The average age of bears captured was 3.4 years (SE=0.20, $\underline{n}$=91). The average age of females and males was 4.9 years (SE=0.43, $\underline{n}$=4) and 2.7 years (SE=0.19, $\underline{n}$=126), respectively. Age of captured females ranged from 0.5-15 years and male ages ranged from 1-12 years.

Mortality

During 1994 and 1995, 63 (53M, 10F) marked bears were confirmed dead. Thirteen (4M, 9F) of the 63 bears wore radio collars. Hunting was the major source of mortality (81.0%) for all marked bears (includes collared and ear-tagged bears). Hunting accounted for 88.7% ($\underline{n}$=47) of male mortality and 4 female mortalities. Vehicle collisions accounted for 2 male and 0 female mortalities. One male and 1 female died of unknown causes (Tables 1.1 and 1.2). No illegal kills or depredation kills were observed.

One adult female with 2 cubs, died from injuries sustained during a fight with another bear. One of the cubs was left unharmed and the other cub was pinned under the sow when she died. This cub was crushed by the weight of the sow (see Chapter 2 for details).

Seven bears died as a result of research and accounted for 3 male mortalities and 4 female mortalities. This high research related mortality rate for female bears was reflective of the low overall mortality rate for female black bears in this study. One subadult male died from heat stress following handling and another subadult male was killed by another bear while caught in a snare set for research activities during the 1994 trapping season. An adult, radio-collared female died following immobilization during the trapping season; a reaction to the drug was suspected. Two adult females and 1 subault female died following immobilization during den work. Two of the 3 appeared to have suffocated in tree dens (one was sitting upright and one's neck and nose were under her body) following immobilization. Another possibility was that the drug lowered the

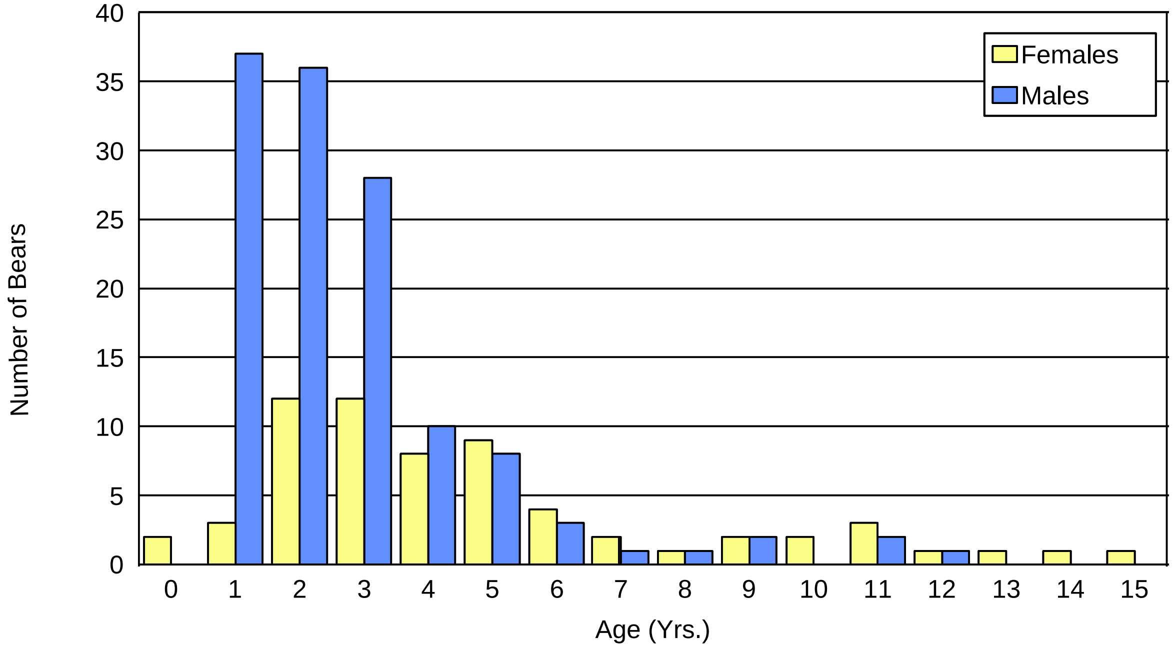

Figure 1.1. Age structure of female and male black bears captured in 1994 and 1995 on the George Washington-Jefferson National Forests, Virginia.

Table 1.1. Source of mortality for male black bears (≥1 years-old) in 1994 and 1995 on the George Washington-Jefferson National Forests, Virginia. The number in parentheses ( ) indicates the number or percentage[a] of collared bears that died from a particular mortality source.

	1994		1995		Total	
Mortality Sources	No.	Percent	No.	Percent	No.	Percent
Hunting	17(0)	85.0 (0.0)	30(3)	90.9(9.1)	47(3)	88.7(5.7)
Vehicle Collisions	1(0)	5.0 (0.0)	1(0)	3.0 (0.0)	2(0)	3.8 (0.0)
Handling	2(1)	10.0(5.0)	1(0)	3.0 (0.0)	3(1)	5.7 (1.9)
Natural	0(0)	0.0 (0.0)	0(0)	0.0 (0.0)	0(0)	0.0 (0.0)
Unknown	0(0)	0.0 (0.0)	1(0)	3.0 (0.0)	1(0)	1.9 (0.0)
TOTAL	20(1)	100.0	33(3)	100.0	53(4)	100.0

[a]Number of collared bears dying due to a particular mortality source/ total bears dying in that year (includes noncollared and collared bears).

Table 1.2. Source of mortality for female black bears ($\geq$1 years-old) in 1994 and 1995 on the George Washington-Jefferson National Forests, Virginia. The number in parentheses ( ) indicates the number or percentage[a] of collared bears that died from a particular mortality source.

	1994		1995		Total	
Mortality Sources	No.	Percent	No.	Percent	No.	Percent
Hunting	2(2)	33.3(33.3)	2(1)	50.0(25.0)	4(3)	40.0(30.0)
Handling	2(2)	33.3(33.3)	2(2)	50.0(50.0)	4(4)	40.0(40.0)
Natural	1(1)	16.7(16.7)	0(0)	0.0 (0.0)	1(1)	10.0(10.0)
Unknown	1(1)	16.7(16.7)	0(0)	0.0 (0.0)	1(1)	10.0(10.0)
TOTAL	6(6)	100.0	4(3)	100.0	10(9)	100.0

[a]Number of collared bears dying due to a particular mortality source/ total bears dying in that year (includes noncollared and collared bears).

bears respiration rate, which was already depressed while hibernating, and the 2 bears were unable to recover (Dr. William Rosolowski DVM and Dr. Robert Martin DVM pers comm.). The other female died from capture myopathy (Dr. Robert Robertson, DVM-VPI&SU). A yearling male also died in the den from dart related injuries (overdose and bad position of the dart; i.e. entered ribcage, but did not puncture his lungs).

Harvest Rate

Forty-seven marked males and 4 marked females were reported harvested in 1994 and 1995. Four males and 1 female (9.8%) were harvested in the archery season, 8 males and 2 females (19.6%) were harvested in the deer firearm season, and 35 males and 1 female (70.6%) were harvested in the bear firearm season (typically referred to as the hound season; Figure 1.2). At least 38.9% of marked male bears were harvested in 1995, 1.7 times more than the 22.4% harvested in 1994 (χ^2=3.9, P=0.05). Harvest rates for marked female bears were 5.9% in 1994 and 2.6% in 1995 (χ^2=0.48, P=0.60; Table 1.3). Age and sex ratio of the harvest was skewed towards young males (Figure 1.3).

Population Size

The estimated population size for the study area based on the Lincoln-Peterson estimate was 1,326 bears and 1,434 bears in 1994 and 1995, respectively. The estimated male population decreased 31.3% between years while the estimated female population increased 26.0% (Table 1.3).

Survival

One radio collared bear that did not survive the 7-day conditioning period (handling mortality) and 4 radio collared females that died from research related mortality were censored from analysis. An additional 13 males and 17 females were censored when they dropped their collars.

Annual survival rates for radio collared bears were 95.3% (SE=0.03, n=1-37, CI= ±0.06) for adult females, 90.4% (SE=0.05, n=1-18, CI= ±0.10) for subadult females, and 100.0% (SE=0, n= 1-6) for adult males. Annual survival for subadult males was only 50.0% (SE=0.20, n=1-8, CI= ±0.40; Table 1.4).

Survival of adult females was lower in 1994 (87.5%) than in 1995 (100%; Z=2.73, P=0.004; Appendix Figure A) whereas survival of subadult males was higher in 1994 (66.7%) than in 1995 (33.3%; Z=-2.45, P=0.007; Appendix Figure D). Survival of subadult females in 1994 (88.2%) and 1995 (92.9%) did not differ (Z=0.64, P =0.26; Appendix Figure B), as was the case with adult males (S_x in 1994 and 1995=100.0%; Z=0.00, P =0.50; Appendix Figure E). Annual survival rates were not different for adult females and adult males (χ^2=0.39, P >0.05) or for adult females and subadult females (χ^2=0.17, P >0.05). However, annual survival for subadult

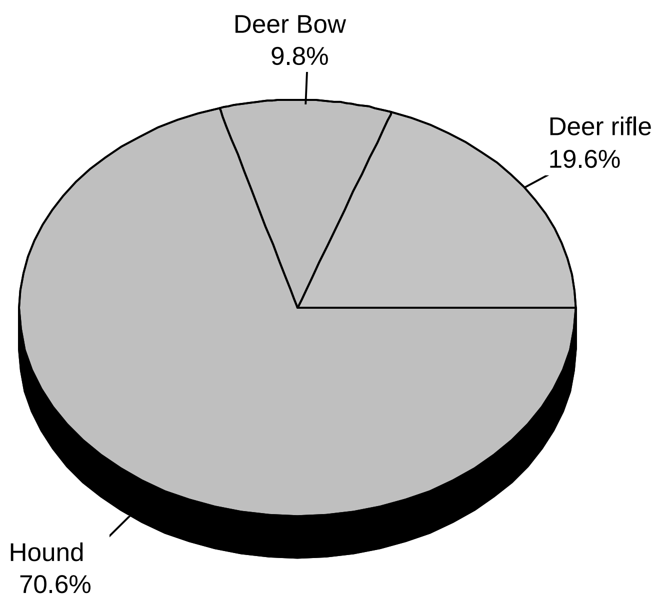

Figure 1.2. Distribution of the black bear harvest by method of take in 1994 and 1995 on the George Washington-Jefferson National Forests, Virgina.

Table 1.3. Harvest rates for Cooperative Alleghany Bear Study animals in 1994 and 1995 and the estimated population size of bears ≥ 1 years-old on the George Washington-Jefferson National Forests, Virginia. The number in parentheses is the number of bears harvested.

	1994					1995				
	Harvest rate	$\hat{n}$	$\hat{N}_C$	$Var(\hat{N}_C)$	CI	Harvest rate	$\hat{n}$	$\hat{N}_C$	$Var(\hat{N}_C)$	CI
Males	22.4(15)	67	475	8,530	±182	38.9(21)	54	362	2,835	±105
Females	5.9(2)	34	851	152,320	±767	2.6(1)	38	1,072	335,331	±1,138
Overall	28.3	101	1,326	160,850		41.5	92	1,434	338,166	

$\hat{n}$ is the estimated number of male bears available for harvest (see text for explanation).

$\hat{N}_c$ is the estimated size of the black bear population, based on the Lincoln Peterson population estimator. $Var(\hat{N}_c)$ is the variation around the estimated population size of black bears. CI is the 95% confidence interval around the population estimate.

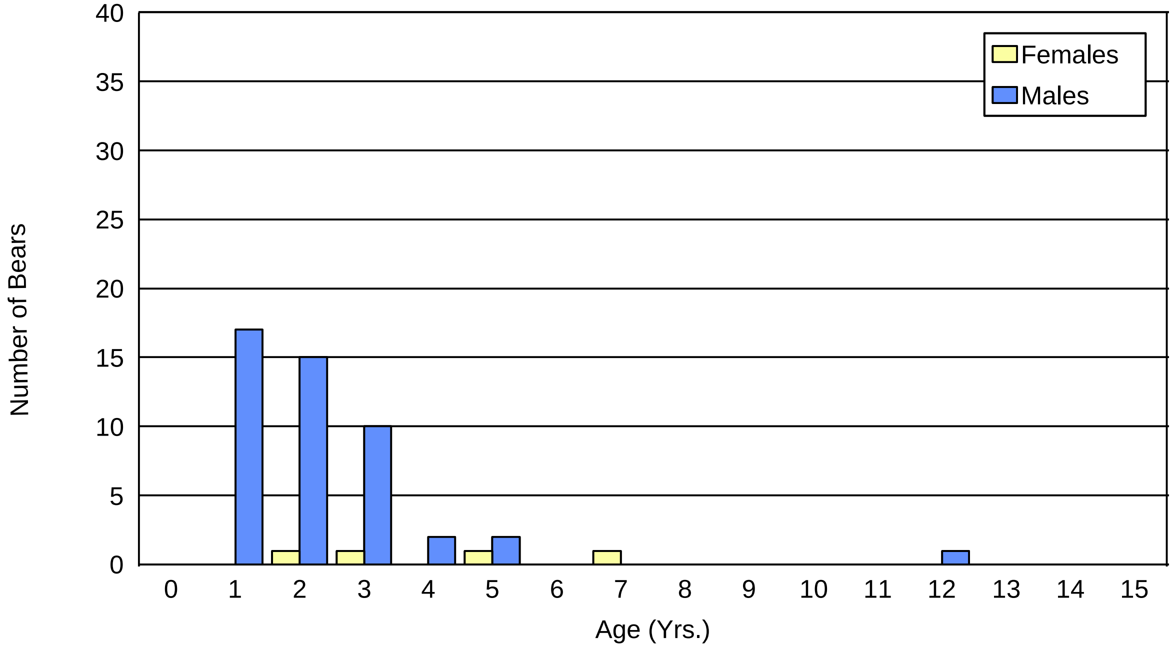

Figure 1.3. Age structure of marked female and male black bears harvested in 1994 and 1995 on the George Washington-Jefferson National Forests, Virgina.

Table 1.4. Annual survival[a] (June 1-May 31) for radio collared black bears in 1994 and 1995 on the George Washington/Jefferson National Forests, Virginia.

	1994				1995			
Age and sex	Survival	n[b]	SE	95% C.I.	Survival	n[b]	SE	95% C.I.
Female adult	0.88	1-21	0.08	0.16	1.00	21-37	0.09	0.19
Female subadult	0.88	1-18	0.08	0.15	0.93	3-14	0.11	0.21
Male adult	1.00	1-6	0.00	0.00	1.00	3-5	0.00	0.00
Male subadult	0.67	2-8	0.27	0.53	0.33	1-3	0.30	0.60

[a] Pollock et. al. 1989
[b] n is number of bears wearing radio collars and is given as a range due to the staggered entry of individual bears into the study population.

females (90.4%; χ^2=4.07, $\underline{P}$<0.05) and adult males (100.0%;χ^2=4.21, $\underline{P}$ <0.05) was higher than annual survival of subadult males (50.0%).

Detecting bias in harvest rates

Hunters pursuing bears with hounds and hunters harvesting bears incidentally during the deer season did not take a significantly different proportion (2/38 and 0/33 (collared females harvested/total females harvested by deer hunters) and 0/34 and 1/21 (collared females harvested/total females harvested by bear hunters) in 1994 and 1995 respectively) of female bears (χ^2=1.45, $\underline{P}$>0.05). In 1994, only 2 collared females were harvested, and both were taken opportunistically by deer hunters. In 1995, the reverse occurred; only one collared female was harvested and she was killed by a houndsmen.

Based on responses to the CABS bear hunter survey in 1995 (K. Higgins unpub. data), harvest rates by houndsmen of treed marked bears and treed unmarked bears were not different (χ^2=3.68, $\underline{P}$=0.096; Appendix Table A). We also found no difference in harvest rates of males with collars and males with ear tags only (χ^2= 0.053, $\underline{P}$=1.0). However, the sex ratios of captured bears (66% males and 34% females) and harvested bears (92% males and 8% females) were different (χ^2=13.6, $\underline{P}$=0.001).

DISCUSSION
Mortality

Hunting was the major source of mortality, and subadult males predominated in the harvest. Natural mortality and other human caused mortality was low. Human induced mortality (81% of total mortality) in this study was similar to that found by Rogers (1976) in Minnesota (>90%), LeCount (1982) in Arizona (83%), and Schwartz and Franzmann (1991) in Alaska (88-100%). In bear populations residing in protected areas in Virginia, hunting (outside protected areas) accounted for 50% and 28.6% of the mortality in the Shenandoah National Park and in the Great Dismal Swamp National Wildlife Refuge, respectively (Carney 1985; Kasbohm 1994; and Hellgren 1988). In those studies, male home ranges extended outside the protection of the Shenandoah National Park and female and male home ranges extended outside the protection of the Great Dismal Swamp National Wildlife Refuge in the fall.

Harvest Rates

Male black bears are more likely than female bears to come in contact with humans because of their large home ranges (Rogers 1976; Beecham 1980; Bunnell and Tait 1980; Lindzey and Meslow 1980; Carney 1985; Beck 1991; Kasworm and Their 1994). However, as hunter movements increase, both sexes become equally vulnerable to harvest and the true sex ratio of the population will be more closely reflected in the sex ratio of the harvest (Bunnell and Tait 1980). Since there is a hunting season in Virginia when bears can be pursued by hounds, one might expect the proportion of females in the harvest to represent the true proportion in the population. However, only 7.8 % of harvested bears were females, and males were harvested at a disproportionately higher rate than females. This likely is related to hunter values and ethics, which leads them to avoid harvesting female bears, although we were unable to confirm this with our data. Hunters also may avoid harvesting radio collared bears. During the dog training season and bear kill season, when bears are pursued by hounds, members of 8 different hunting parties disapproved of the harvest of female bears and many houndsmen avoided killing females (personal observation). In some instances, hunters determined the sex of bears treed by dogs by noting the presence or absence of testicles. When hunters were not sure of the sex, they often expressed a reluctance to shoot (personal observation). There appeared to be an element of self-policing among houndsmen hunting on the study area. Houndsmen ethically opposed to harvesting a female bear exerted pressure on other houndsmen more inclined to harvest females. Because of the reluctance of some Virginia bear hunters to harvest female bears, hunters have petitioned the VDGIF to mark all female bears handled by the agency with orange ear tags. Currently, VDGIF policy is to mark all nuisance females with orange ear tags.

In 1994, the first year of the CABS, female study bears were marked with orange ear tags. We later recognized the bias associated with marking females differently than males and eliminated this marking technique in 1995. After this decision, orange tags were removed from all female study animals subsequently recaptured. Because harvest rates of female bears were low in both 1994 and 1995, it was difficult to determine if the orange tag affected the harvest rate. However, in 1995 only 19 of 55 females were marked with orange tags. There was no difference in harvest rates of female bears in years when females were and were not marked differently than males; thus, it seems unlikely that the tag color contributed to the low harvest. Despite our efforts to correct the bias, houndsmen (Virginia Bear Hunter Association) have actively opposed the removal of orange tags from study animals.

Bunnell and Tait (1980) suggested that vulnerability to harvest is related to a bear's location and behavior. Bears that occupy areas closer to roads are more vulnerable to hunting and other sources of human induced mortality. As vulnerable bears are removed, they may be replaced by young animals that also may be vulnerable (Bunnell and Tait 1980). Waddel (1984) reported that subadult males dominated the harvest in Arizona. In this study, subadult males (1-3 yrs.) dominated the capture ($\underline{n}$=101, $\leq$ 3-years; $\underline{n}$= 28, $\geq$4 years) and harvest ($\underline{n}$=42, $\leq$ 3-years; $\underline{n}$= 5, $\geq$4 years; Figure 1.4). The harvest rate of subadult males (37.2%), although not significantly higher than the harvest rate of adult males (19.1%; χ^2=2.49, $\underline{P}$=0.11) was nearly double the harvest of adult males. The harvest rate for all males increased 1.7-fold between years with subadult male harvest increasing 1.4-fold (51.5%), and adult male harvest rate increasing 57.1-fold (57.1%). In 1994, all males harvested ($\underline{n}$=15) were $\leq$ 3 years old; however, in 1995 4 adult males and 17 subadult males were harvested. The higher harvest rate of subadult males is likely a reflection of their higher vulnerability and may also be reflective of the proportion of young bears in the population.

The proportion of tagged males harvested (tagged males harvested/all males harvested)

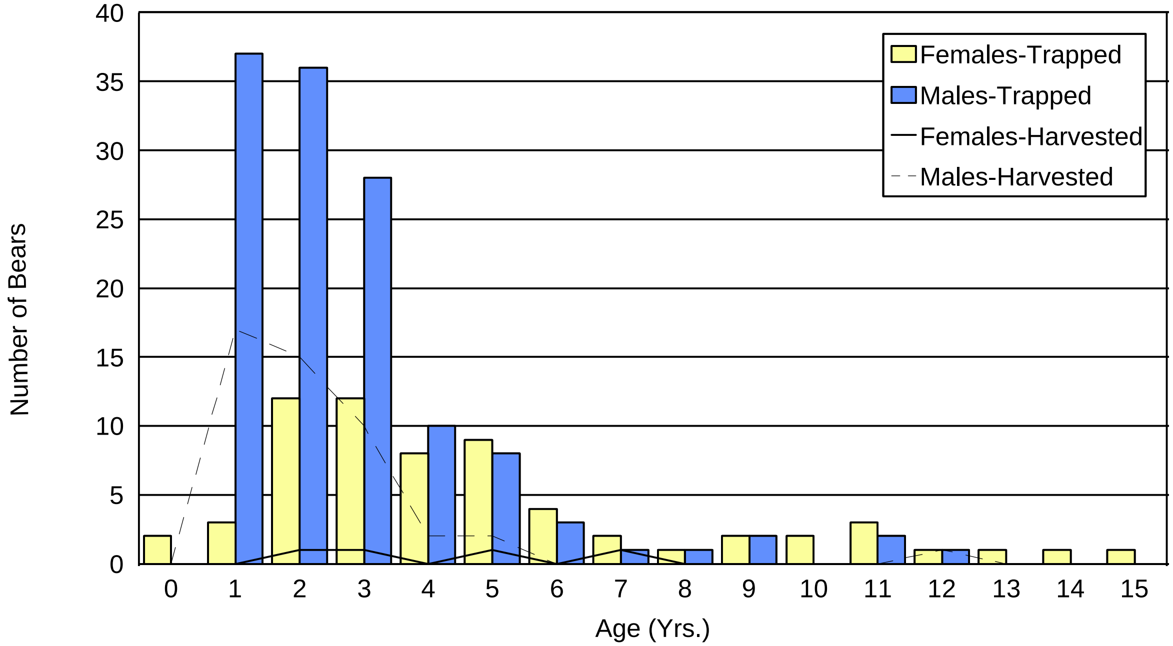

Figure 1.4. Age structure of female and male black bears captured and harvested in 1994 and 1995 on the George Washington-Jefferson National Forests, Virginia.

increased slightly (1.1-fold) between years. By 1995, hunters likely had become more familiar with the study and may have been more comfortable with harvesting a tagged bear, which may have increased tag return rates. In addition, houndsmen expressed to project personnel that they believed there were too many males in the population in 1995 after learning that a radio collared female and her cub were killed by a bear. Harvest rates in the study area accounted for 22.2% (n=115) and 16.9% (n=102) of the state wide harvest in 1994 and 1995, respectively. Therefore, the high harvest of study animals in 1995 was not largely responsible for the 13.8% increase in the 1995 statewide bear harvest. The 1994 and 1995 statewide bear harvest rate followed the cyclic pattern begun in 1989 of low followed by high harvest rates in alternate years (Figure 1.5). In 1994 and 1995, the statewide bear harvest and the bear harvest in our study area by deer hunters (archery and deer rifle seasons) and houndsmen (bear firearm season) was split nearly 50:50 (Martin unpubl. data). However, in 1994 and 1995 the harvest of study animals (i.e. marked bears) by houndsmen (70.6%) was disproportionally higher than by deer hunters (29.4%). This difference may be partially explained by the similarity in our trapping methods and hunting methods used by houndsmen. We trapped bears off roads and trails and to some extent off hunter's bait sites (with their permission). Houndsmen hunt off the same roads and bait sites, and they likely encounter tagged bears more than expected. Kasworm and Their (1994) noted the potential for similar bias in harvest by their trapping methods. The majority of their trapping occurred within 200 m of roads, and they believed their captured bears may have been more prone to harvest.

Population Size

The reliability of the population estimate is influenced by the recapture sample size. Population estimates for male bears were the most reliable due to high recapture (harvest) rates, which resulted in lower variance and tighter confidence intervals. Females exhibited lower recapture rates, which resulted in a large estimated population size associated with a high variance and large confidence interval. Harvest (recapture event) appears to be biased with hunters taking males more frequently than females. Only 2 of 34 females were harvested in 1994 and 1 of 38 in 1995. Less bias associated with the recapture event would improve the population estimate, particularly for females.

Survival

The survival rate for adult females (0.95) in this study was higher than survival rates reported from other exploited bear populations, but similar to survival rates reported for unexploited bear populations. This high survival rate may be related to changing hunter attitudes, hunter selection for large trophy bears, legal protection from harvest of females with cubs, or hunter avoidance of radio collared bears. Adult female survival rates in unexploited populations in Virginia, Colorado, and Mexico ranged from 92-96% (Carney 1985; Beck 1991; Kasbohm 1994; and Doan-Crider and Hellgren 1996). In a lightly exploited population in coastal Virginia, female survival (>1.5 yrs) was 87% (Hellgren and Vaughan 1989). In hunted populations across North America, survival of adult female bears ranged from 79-91% (Waddell 1984; Bunnell and

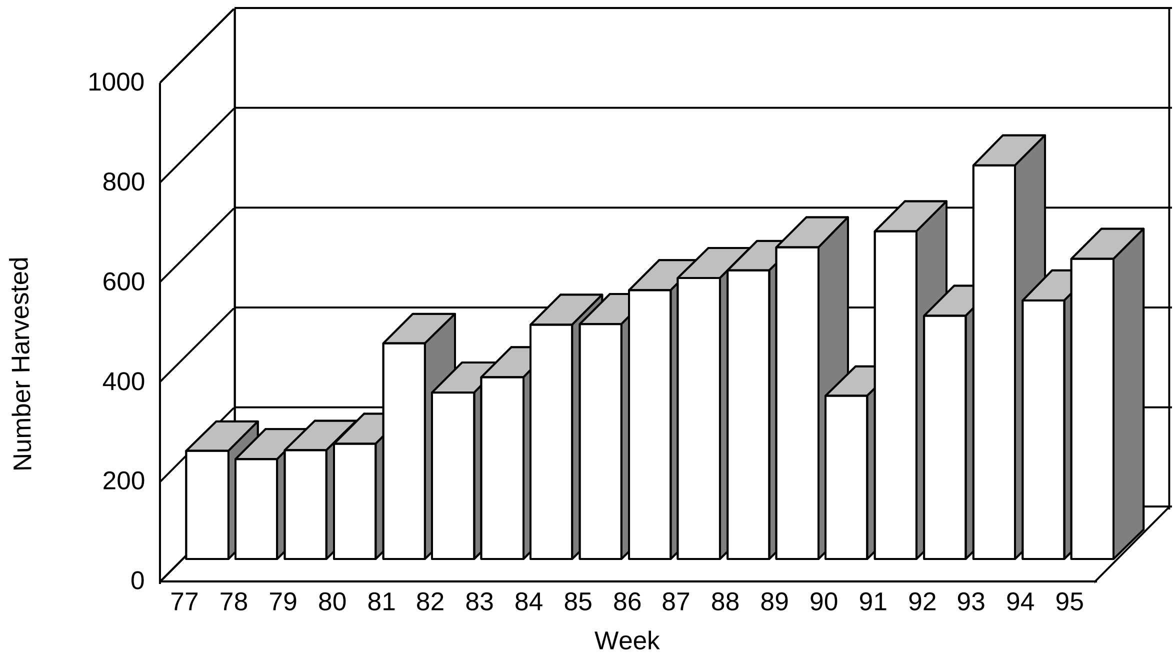

Figure 1.5. Black bear harvest during 1977-1995, in Virginia. (Martin unpub. data)

Tait 1985; and Schwartz and Franzmann 1991; Table 1.5).

Survival rates for subadults are poorly documented because most studies focus their research activities on adult females. In addition, estimating survival of subadult bears is confounded by dispersal (Rogers 1976; Beck 1991). Bunnell and Tait (1985) suggested that subadult mortality may be 15-35 % higher than adult mortality. Subadult females reportedly have a higher probability of survival than subadult males, because subadult females do not disperse and typically occupy their mother's range (Schwartz and Franzmann 1992). Dispersal by subadult males reduces their survival probability and increases the likelihood of human induced mortality (Elowe and Dodge 1989; Schwartz and Franzmann 1992).

Elowe and Dodge (1989) in Massachusetts reported 61% mortality for male bears by 2.5 years of age. Survival of subadult males on 2 study areas with different vegetative composition and prey base in Alaska was 38% and 70% (Schwartz and Franzmann 1991). In 3 unexploited bear populations, subadult male survival ranged from 76-100% (Hellgren 1988-Virginia; Beck 1991-Colorado; and Doan-Crider and Hellgren 1996-Mexico). Illegal harvest reduced subadult male survival (0.76) in Colorado (Beck 1991). Our survival estimate for subadult males fell in the range of survival rates reported in other exploited bear populations despite the small sample size.

Survival of subadult females (90.4%) in this study was significantly higher than survival of subadult males (50%) and was consistent with other studies. Survival rates for subadult females were 93% and 66% in 2 study areas in Alaska and dispersal was not a factor (Schwartz and Franzmann 1991). In an unexploited population in Colorado, 94% of subadult females survived annually (Beck 1991).

Adult males exhibited the highest survival (100%) of any sex and age class, which is not consistent with other studies (59-90%) (Table 1.5). However, this high survival rate is likely a reflection of the small sample size of radio collared adult males ($\underline{n}$=12 for 1994 and $\underline{n}$=12 for 1995) in this study, which focused on adult females. Thus, our survival rates for adult and subadult males were affected by small sample sizes and probably are not reliable estimates. However, survival estimates for adult and subadult females are more likely reliable due to appropriate sample size of collared females.

Detecting bias in harvest rates

We were concerned that our estimates of survival and harvest may be biased. In particular, we suspected that houndsmen would not harvest a collared bear because, either they suspected the collar was on a female bear (houndsmen often avoid killing females), or they did not want to harvest a collared bear because they perceived it as illegal, unethical, or that it could have potential adverse affects on the hunting regulations. Harvest rates for female bears were low, but may be higher than reported due to a bias associated with collaring or marking female bears. We observed no difference in the proportion of female bears harvested by houndsmen and by deer

Table 1.5. Reported survival rates of black bears in North America.

Sex & age class	Survival	Location	Status	Citation
Female	0.95	Virginia	Exploited	This study
adult	0.91	Arizona	Exploited	Waddell 1984
	0.85-0.89	Alaska	Exploited	Schwartz & Franzmann 1991
	0.79	Montana	Exploited	Kasworm & Their 1994
	0.94	Mexico	Unexploited	Doan-Crider & Hellgren 1996
	0.96	Colorado	Unexploited	Beck 1991
	0.92	Virginia	Unexploited	Carney 1985
	0.87	Virginia	Lightly expl.	Hellgren 1988
	0.89-0.94	Virginia	Unexploited	Kasbohm 1994
Female	0.90	Virginia	Exploited	This study
subadult	1.00	Arizona	Exploited	LeCount 1982
	0.93-0.66	Alaska	Exploited	Schwartz & Franzmann 1991
	0.88	Massachusetts	Exploited	Elowe and Dodge 1989
	0.89	Arizona	Exploited	Waddell 1984
	0.94	Colorado	Unexploited	Beck 1991
Male	1.00	Virginia	Exploited	This study
adult	0.59	Virginia	Unexploited	Carney 1985
	0.73	Montana	Exploited	Kasworm & Their 1994
	0.72-0.90	Alaska	Exploited	Schwartz & Franzmann 1991
	0.69	Arizona	Exploited	Waddell 1984
	0.59	Virginia	Unexploited	Hellgren 1988
	0.50	Virginia	Unexploited	Kasbohm 1994
	0.70	Colorado	Unexploited	Beck 1991
Male	0.50	Virginia	Exploited	This study
subadult	0.38-0.70	Alaska	Exploited	Schwartz & Franzmann 1991
	0.77	Arizona	Exploited	LeCount 1982
	0.93	Arizona	Exploited	Waddell 1984
	0.25	Massachusetts	Exploited	Elowe and Dodge 1989
	1.00	Mexico	Unexploited	Doan-Crider & Hellgren 1996
	1.00	Virginia	Unexploited	Hellgren 1988
	0.76	Colorado	Unexploited	Beck 1991
Females	0.83	N.A.		Bunnell & Tait 1985
Males	0.75	N.A.		Bunnell & Tait 1985
Adults	0.79	Oregon	Exploited	Lindzey an Meslow 1980
	0.92	Arizona	Exploited	LeCount 1982
2 year olds	0.78	Oregon	Exploited	Lindzey and Meslow 1980
3 year olds	0.77	Oregon	Exploited	Lindzey and Meslow 1980

hunters or in the number of marked and unmarked bears treed and harvested by houndsmen, which was likely affected by small sample size. Data from the survey appeared to favor harvest of marked bears, but the survey data likely included bears marked with black ear tags on the southwest study area. On the southwest study area black bears were marked with black ear tags to avoid bias associated with visible ear tags. Thus, hunters may not have known the bears they harvested were tagged. The survey results did not provide information on the visibility of ear tags by hunters before they harvested a bear; hunters were only asked if the animal they harvested or treed was tagged.

Fewer females and more males were observed in the harvest sample than in the capture sample. It appears that houndsmen were not just avoiding females because they were radio collared, but houndsmen avoided females because they recognize the important role of females in the maintenance of the bear populations and to the future of bear hunting in Virginia (personal observation).

RECOMMENDATIONS

Recognizing and reducing hunter bias

It was difficult to detect bias in harvest rates. Only a small proportion of captured males were radio collared and a small proportion of captured females were not collared when originally marked in the summer. In addition, the small number of females harvested and the small number of bears treed, as reported in survey responses (Appendix Table A), reduced our confidence in these comparisons. Studies designed to avoid bias, and to estimate true harvest rates and thus survival rates are needed. In the current study design too few males were collared and too few females were left uncollared to detect harvest rate bias and to give accurate estimates of survival of male bears. However, this study was designed primarily to gather information on productivity of the population, requiring us to collar a high number of females. We were unsuccessful in collaring large adult males because their neck and head measurements were similar, and collars slipped off easily. Similarly, we were reluctant to collar juvenile bears because they grow rapidly and were less likely to den, and thus had the potential to outgrow their collars, which could result in severe neck injuries. Other males in this study that were equipped with radio collars often dropped their collars prematurely. We suspect that males tend to attempt to remove their collars more than females, causing increased wear on the cotton spacers at the grommets and premature breakage of the cotton spacer. Intra-abdominal or subcutatneous transmitters may provide the opportunity to gain information on productivity and survival, and allow us the opportunity to assess bias associated with marking bears. In addition, intra-abdominal implants have the potential to provide information on survival, movements, and interactions of subadults and large adult males.

In Minnesota, biologists attempted to determine if a bias existed in harvest rates of collared bears. To prevent bias, hunters who purchased a hunting license for bears were given a packet of information that included a photograph of a collared bear. Hunters were informed that harvesting a collared bear was legal and to treat a collared bear as they would an uncollared bear.

To estimate bias, a survey of hunters who harvested a bear was designed to determine if a harvest was affected by a mark, or if hunters even noticed that the bear was marked (Garshelis pers. comm.).

In one study area in Michigan, hunters were required to keep a log to determine if marking bears resulted in biased harvest estimates. Specifically, the number of bears seen, size, sex, mark, and what influenced harvesting or not harvesting a bear was requested (Visser pers. comm.).

Both Michigan and Minnesota have not analyzed the results of their surveys and logs. Surveys and hunter diaries/logs may help us assess bias associated with marking a bear and may provide additional information about hunting dynamics, ethics, success, and effort. Marking bears with black numbered ear tags (currently being used on the southwest study area of CABS) may reduce the bias in hunters' harvest.

Improving Tag Returns

To increase tag return rates, Maine requires check stations to collect ear tags (MDIFW 1996). In Virginia, check stations are required to collect teeth from all bears harvested. Collecting ear tags when a tooth is collected may improve tag return rates and reduce errors in reporting at check stations.

Sex and age structure

Sex and age structure of captured bears may not be representative of the population, due to differential vulnerability of young males to traps. Intensively trapping a section of the study area until we are confident that all or nearly all bears have been caught in that area would more accurately represent the population sex and age structure.

CONCLUSION

The subadult male segment of the population in this study appears to be heavily exploited. Subadult males composed the largest segment of the harvest, and exhibited low survival (although the reliability of this estimate is affected by small sample sizes). Thirty-seven percent of available subadult males were harvested. The female portion of the population appeared to be lightly exploited based on the older average age ($\bar{x}$ age = 4.9 yrs. and 54.8 % were older females ($\geq$ 4 years)), high survival (95%) and low harvest rate (4.3%). The population under study appears to be heavily exploited based on the young age structure (mean age = 3.4 yrs.) and few older bears ($\geq$ 4 years) in the population (31.4%). The overall survival (84%), however, appears higher than survival rates reported for other exploited populations. Age structures of heavily exploited populations in Maine, Idaho, Pennsylvania and North Carolina exhibited mean ages below 4 years; <55% of each population was adults (>3yrs) (Beecham 1980; Hugie 1982; Lindzey et. al. 1983; and Carlock et. al. 1983; as cited by Hellgren 1988). Carney (1985) believed the high annual adult mortality rate (21.5%) in SNP was indicative of an exploited population. Continued study (with an increased number of subadult and adult males equipped with radio collars) may help improve the reliability of our survival estimates. Based on the large number of males in the capture sample, it appears that the level of harvest is being compensated for by either high productivity, or ingress of subadults, or a combination of the two. Continued research should determine the relationship between different population parameters (survival, reproduction, recruitment, dispersal, movements), and the factors that affect these parameters (habitat quality, effect of hunting and different hunting methods) to determine if current management is acceptable to promote the continued existence of black bears in Virginia. The reliability of survival and harvest estimates should improve with continued study, by removing or recognizing bias and increasing sample size of radio collared males.

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Chapter 2: Cub Survival

Cub survival and the sources of cub mortality are variable among black bear populations (Beck 1991). Habitat quality (Rogers 1976; Wathen 1983 as cited by Hellgren 1988; Elowe 1987; Elowe and Dodge 1989; Beck 1991), nutritional condition of female bears raising cubs, and fall and spring food availability (Roger 1976; Elowe and Dodge 1989; Beck 1991), human disturbance, and age and experience of female bears raising cubs (Elowe and Dodge 1989), and social regulation and predation (LeCount 1987) all have been linked to cub survival. Rogers (1976) and LeCount (1987) hypothesized that the presence of resident adult males would prevent access to areas by young unrelated bears and thus increase cub survival. Kemp (1972) and Young and Ruff (1982), on the other hand, suggested removal of resident adult males may increase survival of cub and subadult bears. However, Ruff (1982) cautioned that the increase in bear numbers attributable to removal of adult male bears in Alberta may not be a factor of increased survival of young bears, but rather a result of immigration of young bears from reservoir areas. In fact, there appears to be little evidence of a compensatory relationship among adult male bear numbers and black bear cub survivorship (Ruff 1982; Rogers 1987; Miller 1990)

Cub production and survival are important to the viability of bear populations. In many studies, cub survival has been estimated by comparing the mean litter size between cubs of the year and yearlings (Rogers 1977; Bunnell and Tait 1985; Carney 1985; Hellgren 1988; Beck 1991; Schwartz and Franzmann 1991; Kasbohm 1994; Doan-Crider and Hellgren 1996). Data from observations of cubs provide minimum survival estimates, and often the cause of mortality and the timing of mortality are unknown. Radio telemetry studies in Massachusetts (Elowe and Dodge 1989) and Arizona (LeCount 1987) provided more accurate estimates of cub survival, provided information on the relative importance of different causes of mortality, and identified the time when cubs were most vulnerable to mortality. Strathearn et. al. (1984) described the uses of an expandable breakaway radio collar for black bear cubs in Ontario, but provided limited information on survival.

Although, productivity in black bear populations is well documented, data on survival of cubs is limited. Knowledge of cub survival rates and the factors that influence these rates are essential to the management of bear populations. The objectives of this study were to (1) estimate cub survival, (2) identify the sources of cub mortality and timing of cub mortality, and (3) evaluate the relative importance of different sources of mortality.

METHODS

Den sites of radio collared female black bears expected to have cubs were visited in March of 1995 and 1996. Adult females were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride in the den with darts fired from CapChur pistols. Cubs were removed from the den to obtain various morphological measurements and to gather data on litter size and sex ratio of cubs, once their mother was immobilized. Cubs were marked with uniquely numbered plastic ear tags (Nasco, Fort Atkinson, Wisconsin) and with a lip tattoo corresponding to the ear tag number (in 1996). In 1995 and 1996, a sample of cubs was equipped with expandable radio collars that we designed, also in 1996 a sample of cubs was equipped with transmitters built to our specifications and implanted subcutaneously (AVM Instruments, Livermore, CA). Transmitters for the expandable radio collar were built by Advanced Telemetry Systems, Isanti, MN (Chapter 3). Cubs were returned to the den site after handling. Adult females were handled to replace missing ear tags, to replace cotton spacers on radio collars, and to adjust the fit of the radio collar. We attempted to monitor adult females and their cubs within 24 hours of handling to ensure that the sow had recovered from immobilization and had not abandoned her cubs.

Radio collared females and cubs were monitored 2 to 4 times a week to determine the timing of den emergence. When bears emerged from their dens, radio collared cubs were monitored daily. If a cub's radio signal was observed on mortality mode, a bearing was taken to the sow and cub signals to determine if they were together. The site of the cub collar was not investigated if the radio signals of the female and cub appeared to be together. However, if they appeared separated, the site of the cub collar was visited to determine the cub's status (prematurely slipped the collar, or mortality). If a mortality had occurred, the mortality site and cub were examined to determine the cause of death. Cub carcasses were collected and necropsied by pathologists at Virginia Tech's College of Veterinary Medicine.

First year survival was estimated from the date cubs were collared (16 March- 14 April) until 4 December. Mean den entrance in this study was 4 December (Godfrey 1996). Heisey-Fuller and Kaplan-Meier staggered entry procedures were used to estimate cub survival (Heisey and Fuller 1985; Pollock et. al. 1989). Intervals for Heisey-Fuller survival estimation were 15 March to 31 May (pre and post den emergence), 1 June to 31 July (breeding season), 1 August to 31 August (period without breeding or hunting), and 1 September to 4 December (chase and hunt season for black bears). Survival rates for male and female cubs were combined because sexual differences in mortality were not observed ($p=0.47$). Mortality dates and dropped collar dates were estimated as the midpoint between the date a collar was last heard on active mode and first observed on mortality mode. The censored date for collars that failed was estimated as the midpoint between the last date collar signals were observed and the first date collar signals were not observed. Radio collared cubs in litters with a fostered cub were excluded from survival analysis due to the influence of introducing an orphaned cub on the survival of the entire litter.

RESULTS

Thirty-one cubs (16M:15F) in 16 litters were equipped with expandable radio collars in March 1995 and 1996. In 1996, 2 uncollared male cubs in 2 of the 16 litters were equipped with transmitters implanted subcutaneously. Two additional cubs (1M:1F) were radio collared following den emergence. Ten radio collared cubs (5M:5F) in 3 litters were excluded from analysis because their survival was influenced by fostering a cub to each litter. Another male cub was excluded from analysis because we believed our handling the cub and attempting to handle his mother may have influenced his survival. The female cub radio collared following den emergence was excluded from survival analysis because she was a previously radio collared cub from a litter with a fostered cub. Twenty-three cubs (13M:10F) in 13 litters were included in survival analysis.

Survival

Six (4M:2F) of 23 radio collared cubs died while still equipped with their radio collars. Six (3M:3F) cubs survived their first year and the fate of 11 cubs (6M:5F) was unknown because they slipped their radio collars prematurely. First year survival estimated with the Kaplan-Meier staggered entry approach (64.3%, n=5-18, SE=0.12) and Heisey-Fuller approach (64.7%, n=2,963 radio days, SE=0.002) were not different.

Survival of radio collared cubs increased with age. Interval survival estimates were 0.71 during 15 March - 31 May (n=1,109 radio days, SE= 0.003), 1.00 during 1 June - 31 July (n=750 radio days, SE=0.003), 0.92 during 1 August - 31 August (n=354 radio days, SE=0.004), and 1.00 during 1 September - 4 December (n=750 radio days, SE=0.00; Table 2.1). Three (2 litters) of 11 radio collared cubs excluded from analysis died,one survived its first year, and the fate of 7 cubs was unknown. At least 4 of 19 cubs that were not radio collared did not appear to survive their first year, based on observational data. One cub was observed dead in its den site after den emergence, one cub was missing during the second den visit in the winter of its birth (mother and sibling were present) and the den site smelled of decay, claws from one cub were observed in a fecal plug collected at the den site of a female that was not observed with cubs, and one cub likely died (his mother produced her second litter the next winter, indicating she had lost her previous litter prior to the end of the breeding season).

Timing and Cause of Mortality

Intraspecific aggression (33.3%), starvation (16.7%), predation (16.7%), research activities (16.7%) and unknown causes (16.7%) accounted for the 6 mortalities of radio collared black bear cubs (Table 2.2). Five of 6 cub mortalities occurred between 2 and 4 months of age.

Two radio collared cubs, excluded from analysis, were abandoned by their mother while or shortly after emerging from the den. One of the 3 uncollared cubs that were known to have died starved and 2 died of unknown causes.

Age and experience of females producing cubs

Five of 8 young mothers (3-5 years old) lost at least one cub in their litter. Two of the 5 young mothers' cubs (1 radio collared, 1 uncollared) died of starvation, and 2 young mothers' cubs (1 radio collared, 1 uncollared) died when they were abandoned by their mother following den visits. The remaining young mother was killed by another bear, and her 2 radio collared cubs died as a result.

Table 2.1. Yearly and interval survival rates for black bear cubs in 1995-96 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989 and Heisey and Fuller 1985).

n	No. of deaths	Survival estimate	95% CI	Survival intervals	Survival estimator
5-18[a]	6	0.64 [c]	0.41-0.87	March-04 Dec. [c]	Kaplan Meier Staggered Entry
2963[b]	6	0.65 [c]	0.46-0.92	March-04 Dec. [c]	Heisey and Fuller
1109[b]	5	0.71 [d]	0.52-0.95	15 March-31 May[d]	Heisey and Fuller
750[b]	0	1.00 [d]	1.00-1.00	01 June-31 July [d]	Heisey and Fuller
354[b]	1	0.92 [d]	0.77-1.00	01 Aug.-31 Aug. [d]	Heisey and Fuller
750[b]	0	1.00 [d]	1.00-1.00	01 Sept.-04 Dec. [d]	Heisey and Fuller

[a] n is a range due to the staggered entry and exit of animals in the model
[b] Total number of radio days that black bear cubs were monitored
[c] Yearly survival estimate for black bear cubs (date marked-den entrance)
[d] Interval survival estimate for black bear cubs

Table 2.2. Cause and timing of mortality for radio collared black bear cubs in 1995-96 on the George Washington-Jefferson National Forests, Virginia.

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
152	227	F	5-17-96	11	Predation
136	234	M	5-28-96	11	Starvation
156	228	M	8-18-96	111	Research activities

Four of 5 young females (discussed above) lost their entire litter; 3 produced a litter of 2 the next winter. Two of the 3 females (4-years old) lost one of 2 cubs in their second litter. One female's cub (not radio collared) was missing during the second den visit. This cub we assumed died of starvation, because at the time of the initial den visit it was substantially smaller (1.2 vs. 1.85 kg) than its sibling. Her remaining cub was last known to be alive on 18 June when it slipped its radio collar. The other female abandoned her cubs when she was disturbed by CABS personnel during a den visit. The sow returned to her den within 24 hours of being disturbed. However, she left her den site shortly after returning to her den, moving only 1 of her 2 cubs. Her cub, abandoned for a second time, did not survive. Her other cub was observed on 7 August with its mother (cub was not radio collared). The third female's radio collared cub survived its first year and the status of her second cub was not known (Table 2.3). Her second cub was equipped with an implanted radio transmitter that was removed in the den by the sow (Chapter 3).

Seven of the 8 females that abandoned their cubs were young and inexperienced (4-5 years old). Four females abandoned their cubs without resulting in a cub mortality. One 4-year old female abandoned her cubs when she was disturbed by CABS personnel during den visits and she returned to her den within 24 hours of being disturbed. Three of 4 females did not return to their dens after abandoning their cubs. These cubs were retrieved from the den site 48 hours after abandonment (see discussion on fostering). The only older female (7 years old) that abandoned her cubs was a nuisance bear that was released into the study area when she was 5 years old. Her cubs, which were only a few days old, died due to exposure within 24 hours of being abandoned. This female was observed in estrus during the summer of her relocation, but was not observed with cubs in the den the following winter. This female's reproductive history is not known; however it appears that she did not produce a litter as a 5 or 6 year old; thus her experience raising cubs was limited despite her older age.

Six of 8 females abandoned their cubs in the den and 2 females abandoned their cubs following den emergence when approached by CABS personnel. Four of 6 females that abandoned their cubs were denned on the ground and 2 were denned in hollow standing trees.

DISCUSSION

Survival

The survival rate for radio collared cubs (0.64) in this study was numerically greater than survival rate for radio collared cubs in Massachusetts (0.59; Elowe 1987 and Elowe and Dodge 1989) and Arizona (0.52; LeCount 1987). Cub survival was numerically higher in Shenandoah National Park (0.73; Kasbohm 1994) and the Great Dismal Swamp National Wildlife Refuge (0.76; Hellgren 1988) where survival of cubs was estimated by comparing changes in mean litter size between cubs of the year and yearlings. Survival rates for black bear cubs, estimated from observational data in other studies, appeared higher than our survival estimated from radio telemetry data (Table 2.4). These differences were likely a result of the different techniques used to estimate survival.

Table 2.3. Female black bears reproductive output and cub survival with respect to age on the George Washington-Jefferson National Forests, Virginia.

1995					1996					
Id	Age	Litter size	Status of litter	Cause of mortality	Id	Age	Litter size	Status of litter	Date cub last known alive	Cause of mortality
63	3	1	mortality[1]	starvation	63	4	2	mortality[2]		starvation
								unknown[1]	6-18-96	
94	3	1	mortality[2]	starvation	94	4	2	mortality[2]		abandoned
								unknown[2]	8-07-96	
110	4	1	mortality[2]	abandoned	110	5	2	survived[1]		
								unknown[1]	4-05-96	
20	3	unknown	survived[2]		73	4	2	survived[1]		
								unknown[1]	4-18-96	
75	3	1	survived[1]		138	5	1	abandon[2]		
65	4	1	mortality[1]	handling	85	5	2	abandon[2]		
								abandon[2]		
4	4	2	unknown[1]		156	6	1	mortality[1]		cannibalism
			unknown[1]							
					187	6	unknown	mortality[2]		unknown

[1] cub radio collared
[2] cub not radio collared

Table 2.3 (cont.). Female black bears reproductive output and cub survival with respect to age on the George Washington-Jefferson National Forests, Virginia.

1995					1996					
Id	Age	Litter size	Status of litter	Cause of mortality	Id	Age	Litter size	Status of litter	Date cub last known alive	Cause of mortality
31	4	1	abandon[2]		51	7	2	mortality[2]		abandoned
								mortality[2]		abandoned
50	5	2	mortality[1]	intraspecific	6	7	3	unknown[2]	7-14-96	
			mortality[1]	aggression				unknown[2]	7-14-96	
								unknown[2]	7-14-96	
					165	12	2	mortality [1]		predation
								unknown[1]	5-02-96	
					154	14	3	survived[1]		
								unknown[1]	10-05-96	
								unknown[1]	10-25-96	
					153	15	3	survived[1]		
								unknown[1]	4-30-96	
								unknown[2]		
					136	16	3	mortality[1]		starvation
								survived[1]		
								unknown[1]	11-15-96	

[1] cub radio collared
[2] cub not radio collared

Table 2.4. Estimated survival rates of black bear cubs in some North American locations.

Survival	n	Major cause of mortality	Timing of Mortality	State	Citation
0.64-0.65	5-18	Intraspecific aggression Starvation Predation	2-4 months	Virginia	This study
0.73	40	Unknown	Unknown	Virginia	Kasbohm 1994
0.76	14	Unknown	Unknown	Virginia	Hellgren 1988
0.59	41	Human disturbance Age & experience of sow Disease	1.5-5 months	Massachusetts	Elowe and Dodge 1989
0.52	23	Cannibalism Predation	2 months after den emergence	Arizona	LeCount 1987
0.46	28	N/A	6-223 days after equipped	Ontario	Strathearn et. al. (1984)
0.80	8	Unknown	Unknown	New York	Simek 1995
0.81	25	Unknown	1-4 months	Mexico	Doan-Crider and Hellgren 1996
0.74 0.91	39 43	Unknown Predation	Unknown	Alaska	Schwartz and Franzmann 1991

Heisey-Fuller vs. Kaplan-Meier

Survival was estimated with both Kaplan-Meier and Heisey-Fuller approaches. Three assumptions of the Kaplan-Meier approach likely were violated: 1) animals of a particular sex or age class were sampled randomly; 2) survival times were independent for different animals; and 3) the censor mechanism was random. Regarding assumption 1, only cubs $\geq$ 2.0 kg were radio collared to reduce the influence of the radio collar on the survival of smaller cubs. Cubs weighing less than 2.0 kg may have a lower survival probability and the survival estimate may have been positively biased (inflated). Regarding assumption 2, survival of cubs was not independent of the survival of their mother and siblings. Pollock et. al. (1989) explained that violating this assumption would not bias survival estimates, but would make survival estimates appear to have smaller variance than they actually have. Regarding assumption 3, Pollock et. al. (1989) explained possible violations of this assumption could result from a predator killing an animal and at the same time destroying the radio transmitter. In this study, 2 cubs were censored shortly after emerging from the den, when predation is likely (radio transmitter may have been destroyed by the predator), and 2 cubs were censored during the deer hunting season (radio collars could have been destroyed by hunters). Upper and lower bounds for the survival curve were generated to reduce the effect of a censoring bias as suggested by Pollock et. al. (1989). An upper bound assumes all censored cubs survived and a lower bound assumes all censored cubs died.

The Heisey-Fuller approach assumed 1) the exact day of death was known, 2) the daily survival and agent-specific mortality rates remained constant within the time period studied, and 3) all individuals within an age or sex class had the same mortality and survival probabilities. By careful selection of intervals, violation of the second assumption can be avoided. The first assumption is not sensitive to errors in the exact number of days that an animal is alive and bias associated with violating this assumption appears negligible (Heisey and Fuller 1985).

Both estimates provided similar survival rates for black bear cubs, which increased our confidence in the survival estimates. Both procedures for estimating survival have weaknesses and strengths. Pollock et. al. (1989) argued that the assumptions of the Heisey-Fuller method were too restrictive. However, the Heisey-Fuller method can estimate interval survival rates and cause-specific mortality rates. Heisey and Fuller (1985) also suggested that by selecting individual days as the interval length, staggered entry of animals into the population is obtained. The Kaplan-Meier staggered entry approach has less restrictive assumptions, allows for staggered entry of animals into the population, and interval survival rates and cause specific mortality rates can be estimated. However, the reliability of the estimate is largely dependent on sample size; Pollock et. al. (1989) suggested that 40-50 animals would need to be radio tagged at all times to obtain good precision. The Heisey-Fuller method uses the number of radio days and not the number of animals as the sample size, thus avoiding problems with small sample size; but, in fact, this may be the biggest criticism of this method.

Timing and Cause of Mortality

In this study, 5 of 6 cub mortalities occurred between 2 and 4 months of age and was consistent with the timing of mortality reported in other studies (Table 2.4). The small size of black bear cubs, which decreases their mobility and ability to escape predators, their inexperience, and high nutritional requirements shortly following den emergence, increase their vulnerability to mortality (LeCount 1987). Rogers, (1977) in Minnesota, reported that mortalities attributed to cubs' nutritional condition occurred until late summer, and cubs that survived until fall survived their first year. Cub deaths in Arizona, attributed to cannibalism and predation, occurred between 1 and 86 days following den emergence (LeCount 1987). Seasonal food availability and quality, which influences nutritional condition of female bears and their cubs, and experience of female bears as mothers, have influenced cub survival more extensively (Rogers 1976; Elowe 1987; Beck 1991; Schwartz and Franzmann 1991). In this study, intraspecific aggression was the major source of mortality for black bear cubs. However, age and experience of female bears and their nutritional condition may have played a larger role than was observed.

Age and experience of female bears producing cubs

In this study, as in Massachusetts (Elowe and Dodge 1989), the inexperience of young females appeared to limit cub survival. Reproductive fitness may have limited some young females' (particularly 3-year old females) ability to produce enough milk to sustain their cubs.

Young female black bears' contribution to the population appears to be minimal. Four of 9 young mothers were known to successfully raise cubs; 3 successfully raised their first litter. Young bears that produce cubs gain experience needed to successfully raise cubs. Thus, over the long term, female bears may likely contribute more to the population as 3 or 4-year old first time mothers than bears in other populations that reach reproductive maturity at a later age.

The contribution of young mothers over a 2-year period was difficult to interpret based on the small sample of bears ($\underline{n}$=3) producing cubs in 2 consecutive years, and the difficulty with cubs remaining radio collared. However, 2 of these 3 females' cubs were last observed alive after June. These cubs had a high probability of surviving their first year based on the cub mortality rates observed in this study. One of 2 cubs of the third female survived its first year and the status of her second cub was not known.

Young females and females of any age that denned on the ground were more likely to abandon their cubs when disturbed. Ground den sites in this study had little structure, which limited protection from disturbance (human, predators, etc.) and inclement weather conditions, and may have attributed to the high degree of abandonment.

Tree dens may provide more security and comfort to bears. Only 2 bears that denned in trees abandoned their cubs, and both were young mothers. Both abandoned their cubs on our second visit to the den site. Tree dens of 3 older females were visited twice without females abandoning their cubs.

Second attempts to visit den sites of young females should be avoided. However, if it is necessary to visit these den sites more than once, handling crews should be prepared for these bears to abandon and take precautions to prevent abandonment and minimize the risk of cub mortality during temporary absence of females. Colder temperatures (<20 degrees Fahrenheit) and snow may make it easier to approach ground den sites without being detected. Commercial disposable hand warmers (Heatmax Inc., Dalton, GA) wrapped in a cloth to prevent burning could be placed in den sites with cubs to provide warmth if temporally unattended.

Fostering

Cubs orphaned during the first winter of the CABS were fostered to female study animals. Cubs abandoned by their mother (n=1) were not handled; rather they were left at the den site for 48 hours to provide the female time to return to her cubs. The location and movements of the mother and the status of the cubs were checked periodically. Cubs whose mother died during handling (n=2) were removed from the den site immediately. All orphaned cubs were fostered to older experienced female bears to improve the chance of survival for the natural cubs and fostered cub. Foster sows were immobilized before introducing the fostered cub. Fostered and natural cubs were marked with uniquely numbered ear tags, some were equipped with expandable radio collars, and all cubs were rubbed with Vicks Vapor Rub to cover human scent and to prevent the sow from distinguishing her natural cubs from the fostered cub.

Fostering cubs to study animals in 1995 likely influenced cub survival and compromised the reliability of our data. Prior to the 1996 den season, a protocol for handling orphaned cubs was established. Orphaned cubs were not fostered to study animals, but were fostered to captive female black bears with cubs at Virginia Tech’s captive bear facility or to female bears outside the study area or hand reared by personnel at Mamont Zoo.

Fostering orphaned cubs to female bears in the wild with a natural litter may be an effective management strategy. However, by fostering orphaned cubs to wild bears, the survival of natural and fostered cubs may be compromised. The additional energetic cost of protecting and feeding a fostered cub(s) can compromise the sow’s health, survival and ability to raise her cubs. In addition, sows have reportedly rejected and killed cubs during a fostering attempt (Gary Alt, biologist Pennsylvania Game Commission, pers. comm.). The timing of fostering appears to be important to the initial survival of the cub. Radio collar failure and premature slipping of radio collars of sows and cubs limited our ability to evaluate the influence of fostering cubs. Future studies aimed at learning more about the influence of fostering cubs is warranted to determine if fostering is a viable management tool in wild bear populations.

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Chapter 3: An expandable radio collar for black bear cubs

Information on survival rates, causes of mortality, relative importance of different mortality factors, and timing of mortality for black bear cubs is limited. In most studies, cub survival is estimated by observing the presence or absence of cubs with their mother throughout their first year and in the den the following winter (Beck 1991; Doan-Crider and Hellgren 1996). These estimates are based on the assumption that if a cub is not present in the den as a 1-year old it has died, thus, these estimates may be inaccurate and provide, at best, minimum survival estimates. Gary Alt (pers. comm.) in Pennsylvania and Carney (1985) in Virginia both reported capturing marked bears later in life that had been documented as dead because they did not den with their mother as yearlings.

Radio telemetry studies provide better estimates of cub survival, identify the time when cubs are most vulnerable to mortality, and identify the cause of mortality. In Massachusetts and Arizona, Elowe (1987) and LeCount (1987) estimated cub survival rates with radio telemetry data. In both studies, cubs remained radio collared only until mid-summer, and information on cub survival beyond July was not available. Difficulty in designing a radio collar that will expand as a cub grows has limited research on cub survival. Our goal was to design a lightweight expandable radio collar that would compensate for one year of growth and would remain on a cub from its first denning period until its second denning period to provide data on first year survival. Two different expandable radio collars and a subcutaneous implantable transmitter were designed for black bear cubs. This chapter describes the collar and implant designs, evaluates the effectiveness of these transmitters in providing data on first year survival, and suggests improvements to the current designs.

METHODS

Cubs ($\geq$2000g) were equipped with expandable radio collars during March and April 1995 and 1996 and with transmitters implanted subcutaneously (Model K7, AVM Instruments, Livermore, CA) during March 1996 (Chapter 2). Cubs still wearing functioning collars on 4 December (mean den entrance date in this study; Godfrey 1996), were considered to have survived their first year. Data collected from black bear cubs and yearlings in Maine and Virginia were used to estimate the neck circumference needed for the collar to fit cubs from 2 to 12 months of age. In Maine the neck circumference for black bear cubs ranged from 140 to 250 mm ($\bar{x}$=173 mm, n=391, SE=0.09) and for yearling bears ranged from 220 to 360 mm ($\bar{x}$=290 mm, n=76, SE=0.37; McLaughlin unpubl. data). In Virginia, neck circumference was 340 to 380 mm ($\bar{x}$=357.2 mm, n=8, SE=5.4) for yearlings and 165 to 490 mm ($\bar{x}$ =406.2 mm, n=39, SE=8.9) for 1.5 year old bears (CABS file data). Thus, cub collars were designed to expand from 250 to 410 mm. Collars of cubs with smaller neck measurements were fitted with foam to ensure proper fit of collars.

The same type of radio transmitter was used on both expandable radio collar designs

(Advance Telemetry Systems (ATS), Isanti, MN). Each transmitter had a 12-month battery and a motion sensitive mortality mode that operated on a 4-hour delay. Transmitters weighed between 62 and 65.3 g and were 55 mm x 25 mm x 15mm. Both radio collar designs employed a sliding mechanism that would allow the radio collar to expand as a cub grew.

Expandable Cub Collar A Design (1995)

The collar was constructed of 1/8" neoprene rubber (Skyline Tank and Rubber, Roanoke, VA). The collar was 37 mm wide and 410 mm long with the transmitter affixed to the center of the collar with 2 collar fasteners (ATS, Isanti, MN.; Figure 7). The antenna was 240 mm long and 3/32 inches in diameter. The sliding mechanism consisted of a brass plate (150 mm x 30 mm) with a slit in the middle (143 mm x 4 mm) fitted on the collar material with 4 stainless steel machine bolts. The collar material was cut along the slit of the brass plate. A 2-prong collar fastener (ATS, Isanti, MN) was fitted on the opposite end of the collar (Figure 3.1). To attach the collar, the collar fastener was fitted into the slit of the brass plate and collar material. The bolts on the collar fastener were tightened to produce the appropriate amount of friction on the sliding mechanism (subjectively). The pressure on the collar allowed the collar fastener to slide along the brass plate and expand as the cub grew. The collar was designed to expand and then break away. The breakaway mechanism consisted of extending the slit in the collar material to the edge of the collar. The collar fastener then could slide along the brass plate to the end of the collar and drop off. Foam (1/4") was glued to the collar of cubs with neck circumference smaller than 250 mm. The completed radio collar weighed 171-172 g.

Expandable Cub Collar B Design (1996)

The collar was constructed of 1-ply butyl belting that was attached to the transmitter by ATS during manufacturing. The collar was 25 mm wide and 460 mm long with the transmitter affixed to the center of the collar (Figure 3.2). The antenna was 240 mm long and 3/16 inches in diameter. A 100 mm piece of tire inner tube (30.3 mm in diameter) was fitted around the transmitter and the antenna to protect the antenna from breaking (inset Figure 3.2). The sliding mechanism consisted of tapering the collar material to 15 mm on one side of the transmitter and attaching a 2-prong collar fastener to the other end of the collar (Figure 3.2). The tapered end was fitted between the 2 prongs of the collar fastener. The bolts of the collar fastener were tightened to produce the appropriate amount of friction between the collar material and the collar fastener. The tightness of the collar fasteners was subjective. The pressure on the collar allowed the collar fastener to slide along the tapered end of the collar material and expand as the cub grew. This collar was designed also to expand and break away. The t-shaped end of the collar material was designed to allow the collar to breakaway, but also to prevent premature slipping of the collar. The completed radio collar weighed 93-101 g.

Implant transmitter design

Each transmitter implant was equipped with a 10-month battery and a motion sensitive

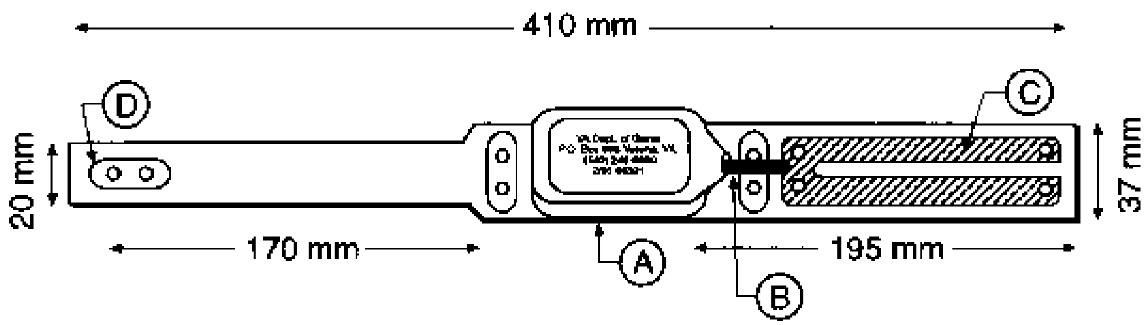

Figure 3.1. Expandable collar design for black bear cubs in the winter of 1995 on the George Washington-Jefferson National Forests, Virginia. (A=transmitter (55 mm x 25 mm), B=antenna (240 mm), C=brassplate-sliding mechanism (150 mm x 30 mm), D=collar fasteners).

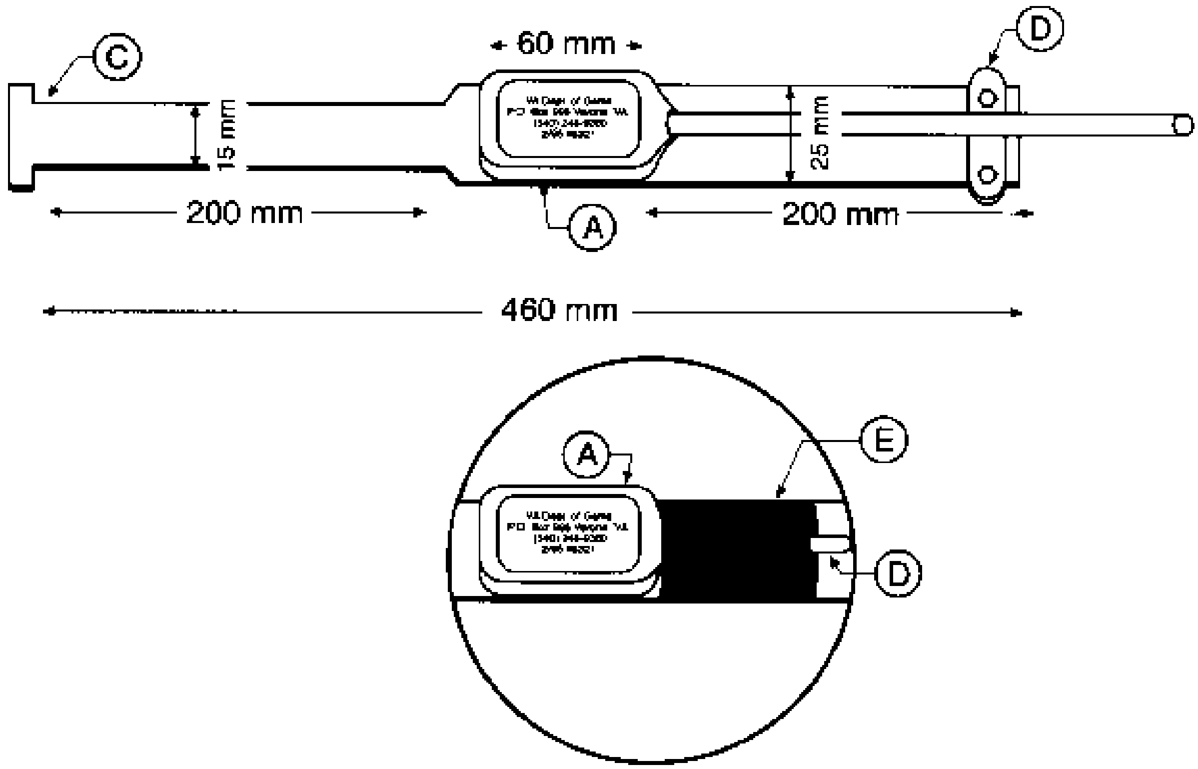

Figure 3.2. Expandable collar design for black bear cubs in the winter of 1996 on the George Washington-Jefferson National Forests, Virginia. (A=transmitter (55 mm x 25 mm), B=antenna (240 mm), C=sliding mechanism, D=collar fastener, E=inner tube (100 mm)).

mortality mode with a 4-hour delay. The current drain was 0.1 milliamps and had a corresponding power output of -10 to -12 dBm. The power output was reduced by extending the battery life to 10 months. The transmitter and mortality sensor was 22 mm x 19 mm x 6 mm and weighed 3.1 g. The battery package was 25 mm x 16 mm x 6 mm and weighed 6.8 g. The completed transmitter was 52 mm x 23 mm x 7.5 mm and weighed 18-22 g. The antenna was 180 mm long with an epoxy bead on the tip of the antenna to prevent the antenna from migrating through the skin (Figure 3.3).

Equipping cubs with a subcutaneous implant involved a simple surgical procedure. The surgery was perform by a licensed DVM. The procedures for the surgery were prepared by the Colorado Division of Wildlife (Beck and Miller unpubl. report). The surgical procedures were approved by the Animal Care Committee at Virginia Polytechnic Institute and State University.

Cubs were immobilized with 4:1 mixture of ketamine hydrochloride and xylazine hydrochloride and were given a local anesthetic (Lidocaine). Cubs were given oxygen during the surgery and were placed on a hot water bottle to maintain their core body temperature. Respiration and heart rate were monitored throughout the surgery. A surgical drape was placed over the cub. Two dorsal midline incision sites were identified; the cranial site on the lower third of the neck and the caudal site in the lubosacral region. These sites were spaced so that the entire length of the transmitter and antenna would lie between the caudal point of the cranial site and the cranial margin of the caudal site. The incision sites were prepared by shaving the hair and scrubbing the site with betadine. A 20-30 mm longitudinal incision was made at the cranial site. The skin and subcutaneous tissues were incised and a 30 x 50 mm pocket caudal to the incision between muscle fascia and the overlying subcutis was made with a blunt dissection. A longitudinal stab incision was made at the caudal site. Alligator forceps (450 mm) were used to tunnel subcutaneously from the caudal site to the subcutaneous pocket. At the subcutaneous pocket the antenna was grasped by the alligator forceps. As the antenna was pulled caudad, the transmitter body was pushed through the cranial site into the subcutaneous pocket. The transmitter was sutured to the underlying muscle fascia. Both incisions were closed with subcuticular sutures. The overlying epidermis at each site was sealed with cyanoacrylate ester (VetBond, Superglue)(Beck and Miller unpubl. report). Cubs were given antagonil to reverse the drug and antibiotics (LA 200) to fight any infection following the surgery. All surgeries were conducted in the field and all surgical equipment was sterilized. The radio transmitters were sterilized with a cold gas sterilization procedure and kept in a sterile bag (Augusta Medical Center, Fishersville, VA.).

RESULTS

In 1995, 17 cubs in 8 litters (9M:8F) were equipped with an expandable cub collar A; none remained collared the entire year. Six cubs in 4 litters retained the collars until their death, 4 cubs in 3 litters slipped their collars in the den, 6 cubs in 4 litters slipped their collars following den emergence, and one transmitter failed. Collars that slipped or failed following den emergence were worn for 20-172 days ($\underline{n}$=7). Cubs that died wore their collars for 11-40 days ($\underline{n}$=6; Table

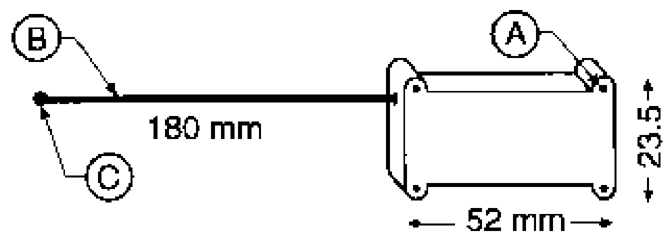

Figure 3.3. Subcutaneous implant transmitter for black bear cubs on the George Washington-Jefferson National Forests, Virginia. (A=suture holes, B=antenna, C=epoxy bead).

3.1). One collar was slipped in April, 2 were slipped in July, 2 were slipped in August and 1 was slipped in September. One cub that dropped her collar in the den was caught in a snare in July and was recollared. This cub wore her second collar for 48 days. None of the mortalities appeared to be related to the collar or its design.

In March 1996, we equipped 14 cubs in 8 litters (7M:7F) with an expandable cub collar B. Five cubs were still equipped with functioning radio collars on 4 December; cubs wore their collars for 243-263 days. In addition, a male cub, captured in a snare in August 1996, was equipped with a radio collar. This cub was collared until 4 December (118 days). Three cubs in 3 litters were equipped with collars until their death, 2 cubs in 2 litters slipped their collars in the den, 2 cubs slipped their collars following den emergence (June and November), and 2 transmitters failed (October). Collars that slipped or failed following den emergence were worn for 69-224 days (n=4). Cubs that died wore their collars for 53-148 days (n=3; Table 3.2). None of the mortalities appeared to be related to the collar or its design.

In 1996, 2 cubs (2M:0F) in 2 different litters were equipped with transmitters implanted subcutaneously. One cub's transmitter switched to mortality 8 days after the surgery was performed. The transmitter was recovered at the den site and may have been removed from the cub by the sow. There was no evidence of mortality at the den site. The remaining transmitter was censored 24 days following surgery. The reception of the implanted transmitter was considerably reduced, which may have been a factor in losing the signal.

DISCUSSION

The cub collar design used in 1995 slipped off all cubs prematurely and provided data on cub survival only until late summer. Apparently, the cub's growth exerted pressure on the collar causing the slit in the sliding mechanism to spread apart, thus allowing the collar fastener to slide more easily along the brass plate. In addition, the external antennas broke at the base of the transmitters, which reduced the range of the signal.

The collar used in 1996 was designed to avoid problems associated with the 1995 cub collar design. To reduce the likelihood of collars slipping prematurely, the sliding mechanism on the 1996 collar design was simplified and the slit and brass plate was eliminated. To reduce antenna breakage, a larger diameter antenna was used on the 1996 collar design; this antenna appeared obtrusive. A 1/8" diameter antenna larger than the 3/32" diameter antenna used in 1995, but smaller than the 3/16" used in 1996, may appear less obtrusive and should still be large enough to prevent the antenna from breaking. The piece of inner tube effectively held the antenna against the collar material, which protected the antenna from catching on brush and breaking. The collar fastener (30 mm) overlapped the collar material (25mm) on the 1996 collar design (see Figure 3.2, D). We observed one instance where this overlap may have caused injury. A collar retrieved from a mortality site had irritated the neck of a cub; a small amount of pus was found around one edge of the collar fastener. Increasing the width of the collar material from 25 to 32 mm would eliminate the overlap of the collar fastener and perhaps prevent or reduce the

Table 3.1. Length of time radio collars were worn by black bear cubs in the winter of 1995 on the George Washington-Jefferson National Forests, Virginia.

Id #	Date Collared	Date Recovered	Status	Time collared (days)
112	3-21-95	4-29-95	Slipped in den	39
118	3-12-95	4-29-95	Slipped in den	48
113	3-08-95	4-17-95	Mortality	40
114	3-08-95	4-17-95	Mortality	40
115	3-08-95	3-26-95	Slipped in den	18
115a	7-16-95	9-02-95	Slipped post den	48
124	3-22-95	7-05-95	Slipped post den	105
116	4-14-95	8-31-95	Slipped post den	139
122	3-16-95	3-27-95	Mortality	11
123	3-16-95	3-27-95	Mortality	11
125	3-27-95	8-05-95	Slipped post den	131
128	3-27-95	4-29-95	Slipped in den	33
129	3-27-95	4-16-95	Slipped post den	20
130	3-27-95	4-16-95	Failed	20
126	3-26-95	7-31-95	Slipped post den	127
127	3-26-95	9-14-95	Slipped post den	172
131	3-28-95	4-15-95	Mortality	18
132	4-11-95	4-24-95	Mortality	13

Table 3.2. Length of time radio collars were worn by black bear cubs in the winter of 1996 on the George Washington-Jefferson National Forests, Virginia.

Id #	Date Collared	Date Recovered	Status	Time collared (days)
234	4-05-96	5-28-96	Mortality	53
235	4-05-96	12-04-96[a]	Survived	243
236	4-05-96	11-15-96	Slipped post den	224
224	3-20-96	12-04-96[a]	Survived	259
225	3-20-96	4-18-96	Slipped in den	29
229[b]	3-24-96	4-30-96	Failed	37
231	3-24-96	12-04-96[a]	Survived	255
221	3-16-96	12-04-96[a]	Survived	263
222	3-16-96	10-25-96	Failed	223
223	3-16-96	10-05-96	Failed	203
219	4-10-96	6-18-96	Slipped post den	69
232[b]	3-28-96	4-05-96	Slipped in den	8
233	3-28-96	12-04-96[a]	Survived	251
228	3-23-96	8-18-96	Mortality	148
226	3-22-96	5-02-96	Slipped in den	41
227	3-22-96	5-17-96	Mortality	56
333	8-08-96	12-04-96[a]	Survived	118

[a] Collars were still operating on 12-04-96, the mean date of den entrance for female black bears in this study (Godfrey 1996)

[b] Implanted transmitter

probability of injury. Another potential problem with this design is the exposure of the collar material to the elements, which could damage the collar material and hinder the expansion of the collar. A protective sleeve around the entire collar that is sealed to prevent debris and other material from damaging the collar, but would not hinder the expansion of the collar may be needed. Careful inspection of the collars on yearlings handled in the den the winter following initial attachment may help direct future improvements to this collar design.

The tightness of the collar fasteners on both designs was subjective. A more systematic method for tightening the collar fasteners is needed to ensure the appropriate amount of pressure on the sliding mechanism. Without a standardized amount of pressure a collar may not expand or may expand to easily and drop off prematurely. A torque wrench to measure tension may standardize the pressure on the collar fasteners. The collars of the 7 yearlings in the den during winter 1996-97 will be inspected to determine if the collar expanded appropriately. The tightness of the collar fasteners should be checked with a torque wrench to help assess the appropriate amount of pressure that is needed to allow the collar to expand.

Our goal was to design a collar that weighed $\leq$4% of a cub's body weight. The 1995 cub collar design weighed 8.5% of a cub's body weight (2000 g). However, we believed that this would not be a problem because the weight of the collar would be close to 4% of a cub's body weight by den emergence. In 1996, we were able to reduce the weight of the new collar design to 5.0 % of the body weight of cubs handled in March (2000 g.).

The opportunity to equip cubs with subcutaneous implants was limited by the low weights of cubs in March 1996 ($\bar{x}$=1.7 kg, n=24) and the availability of veterinarians to perform the surgery. The limited information obtained suggests some improvements to the design are needed. It may be more efficient to sacrifice battery life for more power output. The reception range of the transmitter was 1.7 miles over flat land (prior to implanting the transmitter), which made it difficult to monitor cubs in the mountainous terrain of the study area. Also, the size of cubs limited our opportunity to equip cubs with implants, thus a larger transmitter to improve power output may not be the solution. Effective size and range of implant prototypes can be tested in cubs in captivity at Virginia Tech's bear research facility and in carcasses of cubs that died soon after den emergence.

Data on first year survival was provided by the 1996 collar design. Fewer cubs slipped their collars in 1996 and 5 of 14 cubs were still equipped with collars on 4 December. Future improvements to the cub collar and implant designs should improve our understanding of cub survival.

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Chapter 4: Home range and spatial relationships

Food availability and distribution (Jonkel and Cowan 1971; Amstrup and Beecham 1976; Rogers 1977; Young and Ruff 1982; Powell 1987; Hellgren 1988; Smith and Pelton 1990), sex, age (Reynolds and Beecham 1980; Garshelis and Pelton 1981; Hellgren 1988) kinship (Jonkel and Cowan 1971; Lindzey and Meslow 1977; Garshelis and Pelton 1981), social behavior (Jonkel and Cowan 1971; Lindzey and Meslow 1977), and reproductive status (Hellgren 1988) influence home range size, movements, and territorial behavior in black bears. Smith and Pelton (1990) suggested home range size and the degree of territoriality are an indicator of habitat quality. Further, Amstrup and Beecham (1976) suggested the regional variation in home range size may be explained by the quantity, quality and distribution of food as influenced by climate and topography. In northern boreal forests, productivity is low and overlap of home ranges of female bears is minimal (Jonkel and Cowan 1971; Rogers 1976; Young and Ruff 1982; Powell 1987). In contrast, in Southern Appalachian hardwoods, productivity is higher and female bears exhibit extensive home range overlap (Garshelis and Pelton 1981; Garner 1986; Powell 1987; Hellgren 1988; Smith and Pelton 1990). Jonkel and Cowan (1971) and Smith and Pelton (1990) observed relatively smaller home ranges for bears in Montana and Arkansas, respectively and attributed the small size to productive and diverse habitats.

The degree of home range overlap is quite variable among and between sexes of black bears in North America. Many studies reported extensive home range overlap among male bears and between male and female bears, but the degree of home range overlap among female bears is variable, ranging from nonexistent to extensive. Reynolds and Beecham (1980) attributed home range overlap in Idaho to patchy and unpredictable distribution of food.

Male black bears typically occupy larger home ranges than female bears (Amstrup and Beecham 1976; Reynolds and Beecham 1980; Alt et. al. 1980; Garshelis and Pelton 1981; Hugie 1982; Carr 1983; Smith and Pelton 1990). Amstrup and Beecham (1976) argued that adult males can increase their reproductive potential by using areas that encompass the home ranges of several breeding adult females, which leads to the use of large areas that can not be defended as territories. They further argued that a female bear’s home range may represent the minimum area required by a black bear for self-maintenance in a given habitat.

Spatial use and home range size of black bears subject to hunting, in Virginia is unknown. The objectives of this segment of the study of Virginia’s hunted bear population were to estimate home range size of male and female bears, and to assess the degree of home range overlap between and within sex classes.

METHODS

Black bears were captured and equipped with radio transmitters in the summers of 1994 through 1996 as described in Chapter 1. Telemetry locations were obtained from September

1994 to September 1996. Radio collared bears were located from the ground with hand-held receivers and H-antennas and from fixed-wing aircraft mounted with directional H-antennas. An attempt was made to locate each radio collared bear 1 to 3 times a week from the ground. Ground telemetry locations were supplemented with aerial locations approximately every 10 days. Ground telemetry locations were estimated by triangulation from 2 to 3 fixed points (telemetry receiving stations) along roads and trails in the study area. Telemetry receiving stations were assigned Universal Transverse Mercator (UTM) coordinates with a self-correcting Global Positioning System (GPS) unit (Rockwell International Corp., Cedar Rapids, Iowa), which was accurate within 5 to 25 m. Aerial locations of collared bears were assigned UTM coordinates with Loran-C and GPS units.

Ground and aerial telemetry location error was calculated from radio telemetry locations of transmitters placed at known points in the study area and from locations of known den site locations of radio collared bears. The location of test collars and den sites was unknown by the telemetry operator at the time of the location. The average error for ground telemetry and aerial telemetry locations was $\pm$11 degrees and 475m respectively. Due to the high aerial telemetry error, aerial locations were not included in home range analyses.

For ground telemetry, the coordinates of an animal's location were estimated with Andrew's maximum likelihood estimator for 3 or more bearings (Lenth 1981; Garrott and White 1990). To define acceptable locations for home range analysis, estimated mean home range size of female (15 km^2) and male (169 km^2) black bears in the southern United States was used (Smith and Pelton 1990; Garner 1986; Hellgren 1988; Kasbohm 1994; Schrage 1994). Acceptable locations had error ellipses $\leq$ 5% of a female ($\leq$ 75 ha) and male ($\leq$ 377 ha) bear's home range size. In addition, telemetry locations were not included in analyses if the first and last compass bearing taken to locate an animal was > 30 minutes apart and if the intersecting angle(s) of 2 bearings was < 30 degrees.

Home range analyses were conducted with the computer software RangesV (Institute of Terrestrial Ecology, Dorset, England). No bears were monitored for 12 consecutive months; thus annual home range size was not estimated for black bears in this study. However, total home range size was estimated for each sex and age class (subadult, transitional age, and adult) and seasonal home range size was estimated for female bears of different reproductive classes (solitary females, females with cubs, and females with yearlings) with the 95% minimum convex polygon (MCP) method (Hayne 1949) and the 95% normal kernel method (Worton 1989). The incremental area analysis feature of the RangesV program was used to determine if an adequate number of locations were obtained to identify a bear's total or seasonal home range. Incremental area analysis plots the percentage of an individual animal's home range that is identified with each successive telemetry location obtained. Total home range size was estimated for males, subadult females ($\leq$ 3 years old), adult females($\geq$ 4 years old), and transitional age females. Transitional age females included bears that were subadults at the start of the telemetry year (September), but had entered the adult age class during the second half of the telemetry year (February). Seasonal home ranges were estimated for females with cubs, females with yearlings, and solitary females.

Seasons were based on changes in plant phenology as described by Garner (1986): spring (den emergence to 15 June), summer (16 June to 15 September), fall (16 September to den entry or 15 January).

The MCP method is a simple procedure that is used widely and, thus, can be used to compare our estimates with other studies. However, MCP is largely affected by outliers and small sample size (Jennrich and Turner 1969; Garrot and White 1990). Nonparametric approaches are less affected by outliers, and have no assumptions about the underlying shape of the home range. Harmonic mean is sensitive to grid size and grid origin. The kernel method is an extension of the harmonic mean method and is a robust estimator that avoids several of the pitfalls associated with harmonic mean procedure (Kenward and Hodder 1990). Thus the kernel method, a nonparametric approach, was used.

Home range areas were tested for differences between age and sex classes using nonparametric one-way layout tests (Kruskal-Wallis) with a protected ($\underline{P}$=0.05) LSD procedure to make median comparisons. Telemetry data for each age and sex class were pooled between years because of small sample size, and because differences in home range areas were not observed between years ($\underline{P}$>0.05).

Stability of range areas for female bears monitored in both years was estimated with multiple rate permutation procedures (MRPP) using the program BLOSSOM (Midcontinent Ecological Science Center, National Biological Survey) and by comparing the degree of overlap between an animals home range in different years. MRPP tests whether 2 sets of locations come from a common probability density distribution. The MRPP statistic is based on the within group average of pairwise distance measures between locations compared to the average distance between locations when groups are ignored (Garrot and White 1990). The null hypothesis for MRPP analysis is two or more utilization distributions are the same (e.g. bear id 6 home range in 1994 is the same as id 6 home range in 1995).

The degree of overlap of home ranges between and among different sex classes was estimated to observe the presence or absence of territoriality among black bears in Virginia. Home range overlap was estimated by calculating the percent of each bear’s polygon or ellipsoid that overlapped with another bear polygon or ellipsoid.

RESULTS

Home range size

Total home range size was not different among different sex and age classes ($\underline{P}$>0.05) with either home range estimator; differences between the smallest and largest home ranges were only 1.3 fold (MCP) and 1.6 fold (Kernel; Table 4.1). However, with one exception, males had the largest home ranges. When using MCP, transitional age female bears used home ranges identical in size to home ranges of male bears. Transitional age female bears had the largest home ranges of female bears, regardless of the estimator used (Table 4.1).

Table 4.1. Estimated home range size for black bears on the George Washington-Jefferson National Forests, Virginia, 1994-1996.

	Home range (km^2) 95% MCP				Home range (km^2) 95% Kernel			
	N	Number of locations[1]	Mean	Range	N	Number of locations[1]	Mean	Range
Adult females	16	7-35 (22)	5.5	1.5-11.6	27	6-35 (18)	6.8	1.5-18.4
Subadult females	4	7-28 (17)	5.6	1.3-14.2	4	7-28 (21)	9.0	2.5-21.6
Transitional age females	11	7-36 (21)	7.2	2.4-20.1	10	7-36 (21)	10.0	3.9-16.6
Males	7	8-19 (13)	7.2	0.8-16.1	5	8-19 (13)	11.2	0.8-27.9

[1]Number of locations are presented as a range because the number of locations varied for each bear (incremental area analysis-Appendix Figure I and Appendix Figure J) included in home range analyses. The number in parentheses ( ) is the average number of locations.

The 95% normal kernel estimator consistently estimated larger total home ranges than the 95% MCP estimator ($\bar{x}$=2.9 km^2; Table 4.1). Incremental area analysis using 95% normal kernel retained more adult female ranges than MCP. However, fewer male ranges were identified with the 95% normal kernel. Comparisons of home range size with different home range estimators was not appropriate since different estimators often identified a different group of animals in their analyses (Table 4.2).

Seasonal home range

Data were sufficient to estimate fall, spring and summer range sizes for females with cubs and solitary females, but only spring ranges for females with yearlings. Summer ranges as well as fall ranges of females with cubs and solitary females were not different for MCP estimates (P=0.10 and 0.37) or kernel (P=0.57 and 0.80) estimates (Table 4.3). Similarly, spring ranges of solitary females and females with yearlings did not differ with MCP (P=0.71) or kernel (P=0.18) analysis. However, with MCP (P=0.005), but not kernel (P=0.90) spring ranges of solitary females were larger than spring ranges of females with cubs. In addition, females with yearlings had larger spring ranges than females with cubs when estimated with kernel (P=0.03), but not MCP (P=0.22; Table 4.3).

Home range sizes of solitary females did not differ by season (P >0.05) with MCP estimates, but fall ranges were larger than summer ranges (P=0.03) with kernel estimates (Table 4.3).

Spring and summer ranges of females with cubs did not differ with either estimator (MCP-P=0.50; kernel-P=0.66). However, fall ranges of females with cubs were larger than spring and summer ranges of females with cubs when estimated with MCP (P=0.003 and 0.006 respectively) and kernel (P=0.008 and 0.013, respectively).

Home range stability

Eight of 13 female black bears monitored in both 1994 and 1995 had enough locations to identify their home range in both years. Only one male bear was monitored in both years; thus stability of home range was not estimated for males. Home ranges of 4 of 8 female bears did not differ from year to year (P>0.05) based on MRPP analyses (Table 4.4). Five of 8 females' home ranges in different years overlapped considerably (>89%), thus, suggesting site fidelity (Table 4.4).

Home range overlap

The degree of home range overlap among female bears in 1994 ranged from 0.1-94.2 % ($\bar{x}$=19.7%) and 3.6-100 % ($\bar{x}$=31.2%) estimated with MCP (Figure 4.1) and kernel methods,

Table 4.2. Incremental area analysis selection of bears to include in total and seasonal home range analysis using MCP and kernel analyses on the George Washington-Jefferson National Forests, Virginia, 1994-96.

Home range	Sex/Reproductive status	N	MCP	Kernel
			Number included in analysis[a]	Number included in analysis[a]
Total	Female	62	31	41
Total	Male	11	7	5
Fall	Female w/ cub	11	10	9
Fall	Solitary female	36	24	25
Spring	Female w/ cub	23	12	13
Spring	Solitary female	11	5	1
Spring	Female w/yearlings	8	4	3
Summer	Female w/ cub	19	9	10
Summer	Solitary female	23	6	9

[a] Number of animals included in home range analysis based on incremental analysis (plots number of locations and size of home range) plots using Ranges V computer program.

Table 4.3. Seasonal home range size (km^2) of solitary female black bears, female black bears with cubs, and female black bears with yearlings on the George Washington-Jefferson National Forests, Virginia, 1994-96.

	95% MCP						95% Normal Kernel					
	N	Median	Mean	SE	Range	Locations per bear[1]	N	Median	Mean	SE	Range	Locations per bear[1]
Fall												
Females with cubs	10	4.6	5.8	1.6	0.5-18.3	6-16	9	5.6	6.9	1.7	0.7-17.3	6-16
Solitary females	24	2.5	4.7	1.1	0.1-25.0	7-18	25	4.4	7.2	1.2	1.0-20.7	6-18
Spring												
Females with cubs	12	1.1	1.1	0.2	0.3 - 3.5	5-10	13	1.6	2.1	0.4	0.5 - 5.0	5-10
Solitary females	5	2.3	3.9	1.5	1.5 - 9.6	9-22	1	1.5	1.5		1.5 - 1.5	9
Females with yearlings	4	2.4	2.6	1.1	0.2 - 5.2	5-10	3	4.8	5.8	1.5	3.9 - 8.8	7-10
Summer												
Females with cubs	9	1.2	1.4	0.3	0.4 - 2.8	6-14	10	2.3	2.3	0.4	0.6-4.1	5-14
Solitary females	6	2.3	2.2	0.5	0.6 - 4.2	6- 8	9	2.2	2.5	0.5	0.8-4.9	5- 8

[1]Number of locations are presented as a range because the number of locations varied for each bear (incremental area analysis) included in home range analyses.

Table 4.4. Home range stability of female black bears in 1994 and 1995 on the George Washington-Jefferson National Forests, Virginia as measured by degree of home range overlap and MRPP.

Home range overlap[1]		MRPP				
Id-year	Overlap (%)	Id-year	Number of locations	Test Statistic	Average within group distance[2]	p-value
6-94 and 6-95	96.9	6-94	35	-1.4	1.8	0.09
6-95 and 6-94	49.0	6-95	29		1.2	
15-94 and 15-95	39.9	15-94	29	-8.9	1.2	0.00003
15-95 and 15-94	44.5	15-95	20		1.7	
31-94 and 31-95	100.0	31-94	35	-0.6	1.7	0.22
31-95 and 31-94	44.2	31-95	30		1.4	
62-94 and 62-95	36.8	62-94	16	-2.3	1.2	0.04
62-95 and 62-94	92.6	62-95	20		1.7	
63-94 and 63-95	60.8	63-94	19	-0.6	1.3	0.21
63-95 and 63-94	89.3	63-95	23		1.7	
73-94 and 73-95	50.7	73-94	28	-2.6	1.6	0.03
73-95 and 73-94	47.7	73-95	27		1.4	
85-94 and 85-95	74.9	85-94	14	0.2	1.6	0.47
85-95 and 85-94	91.7	85-95	22		1.6	
94-94 and 94-95	16.6	94-94	11	-3.5	0.9	0.01
94-95 and 94-94	57.5	94-95	10		1.5	

[1] Estimate of site fidelity (home range stability) based on the percent of home range overlap of an individual bears home range in different years.

[2] Within group average pairwise distance measures between telemetry locations (km).

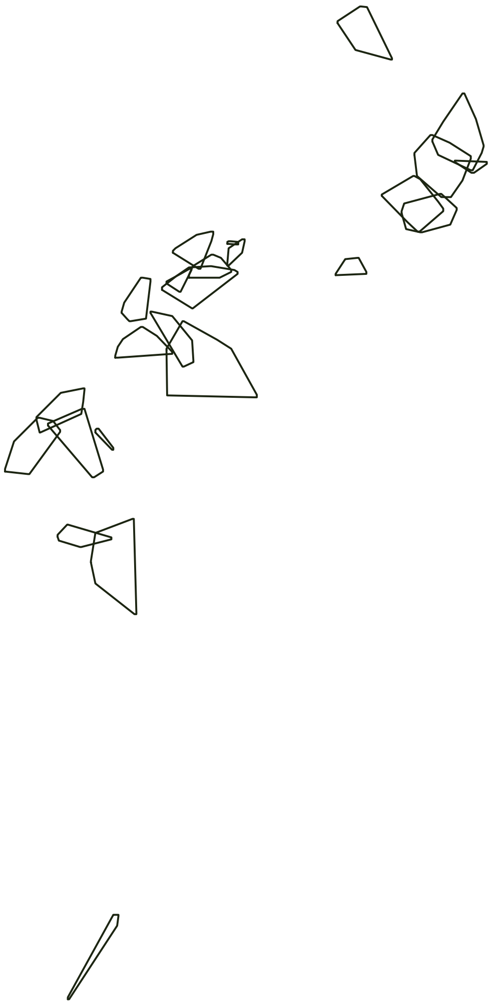

Figure 4.1. Home range overlap of female black bears in 1994 estimated with minimum convex polygon method on the George Washington-Jefferson National Forests, Virginia.

respectively. In 1995, the degree of home range overlap among female bears ranged from 0.1-95.9 % ($\bar{x}$=23.0%) and 3.6-100% ($\bar{x}$=28.2%) estimated with MCP (Figure 4.2) and kernel, respectively. Among male bears, the degree of home range overlap in 1994 ranged from 5-50.7 % ($\bar{x}$=19.6%) and 14.3-100% ($\bar{x}$=77.4%) estimated with MCP (Figures 4.3) and kernel, respectively. Ranges of male bears (n=6) did not overlap in 1995 with either home range estimators. In 1994, the ranges of males and female bears overlapped between 3.7 and 45.4% ($\bar{x}$=23.0) and 6.7-100% ($\bar{x}$=38.0%) estimated with MCP (Figure 4.4) and kernel , respectively. In 1995, the degree of overlap of female and male area ranged from 0.1-98.1% ($\bar{x}$=27.8%) and 3.6-85.7% ($\bar{x}$=37.1%) estimated with MCP (Figure 4.5) and kernel, respectively.

DISCUSSION

Home range size

Ranges of males were not larger than ranges of females, which does not fit the general pattern observed in other black bear populations (Amstrup and Beecham 1976; Reynolds and Beecham 1980; Alt et. al. 1980; Garshelis and Pelton 1981; Hugie 1982; Carr 1983; Hellgren 1988; Smith and Pelton 1990). Size of home range in other studies, appears to be related to food availability (Amstrup and Beecham 1976; Eubanks 1976; Lindzey and Meslow 1977; Alt et. al. 1980; Garshelis and Pelton 1981; Hugie 1982); large home ranges for males may be influenced by their metabolic requirements (Harsted and Bunnell 1979 as cited by Carr 1983) and their breeding strategy (Amstrup and Beecham 1976). Male home range size in this study was smaller than reported in other studies, but small sample size may have influenced the accuracy of our estimates. Only a small sample of male bears ($\leq$ 12) was radio collared each year and few remained radio collared for the entire year. Premature breakage of cotton spacers caused collars to drop. In addition, male bears were more difficult to locate from the ground because of their extensive movements and use of inaccessible areas, and most aerial telemetry locations were unusable because they were not accurate. Thus, some bears (particularly males) may have occupied larger areas than we detected. Ground telemetry error also was high, and inflated the size of error ellipses associated with each location, thus reducing the number of useable locations. The mountainous terrain of the study area undoubtedly influenced the high error associated with both ground and aerial telemetry locations.

The large home range of transitional age females observed may reflect dispersal behavior. Female offspring typically occupy a portion of their mothers range (Rogers 1977) and do not disperse great distances. Information on dispersal patterns and movements are needed to evaluate the home range dynamics of dispersing age females.

Estimated home range sizes for all bears in this study were small compared to most studies in Virginia (Garner 1986; Hellgren 1988; Kasbohm 1994; Schrage 1994), and throughout North America (Eubanks 1976; Alt et. al. 1980; Garshelis and Pelton 1981; Smith and Pelton 1990;

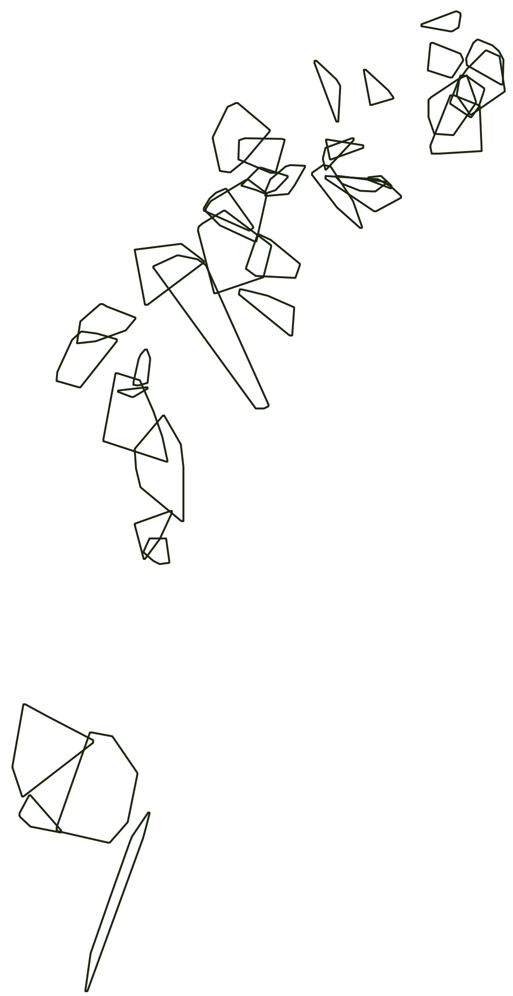

Figure 4.2 . Home range overlap of female black bears in 1995 estimated with minimum convex polygon method on the George Washington-Jefferson National Forests, Virgina.

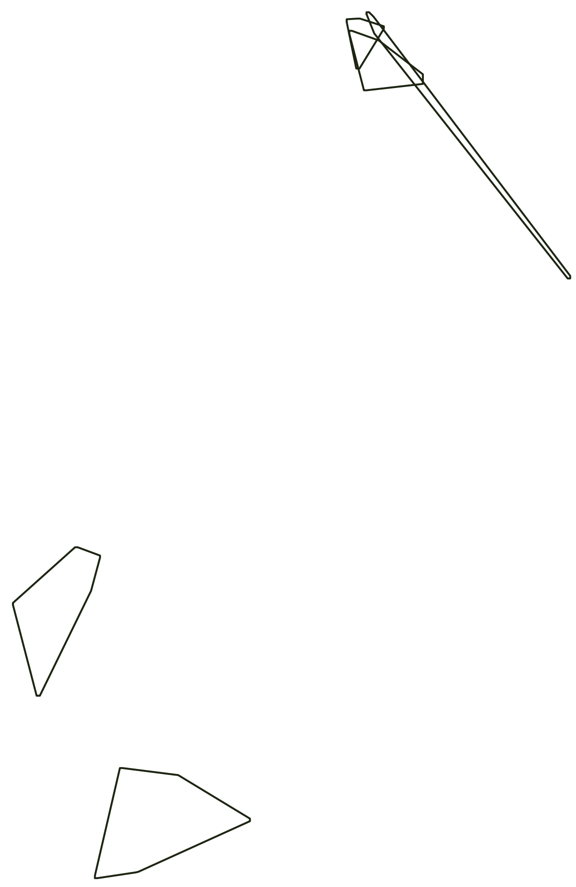

Figure 4.3. Home range overlap of male black bears in 1994 estimated with minimum convex polygon method on the George Washington-Jefferson National Forests, Virgina.

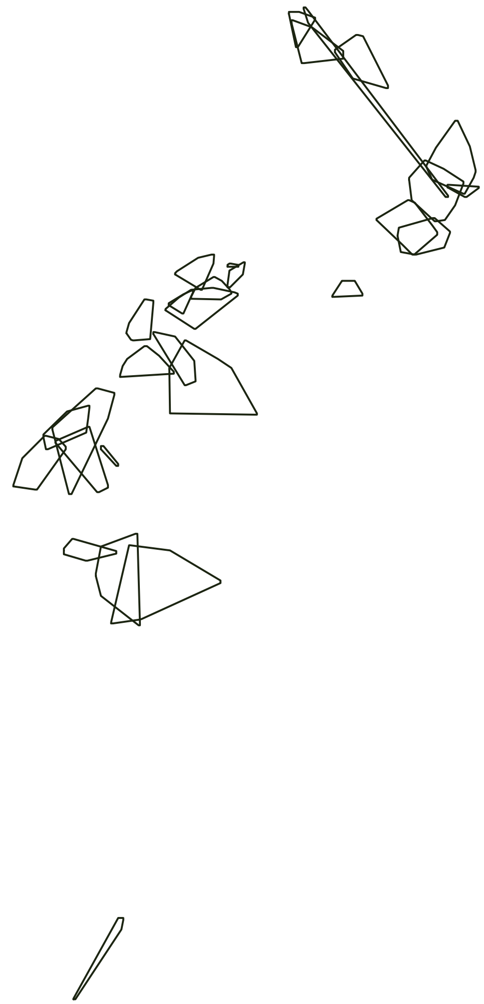

Figure 4.4. Home range overlap of female and male black bears in 1994 estimated with minimum convex polygon method on the George Washington-Jefferson National Forests, Virgina.

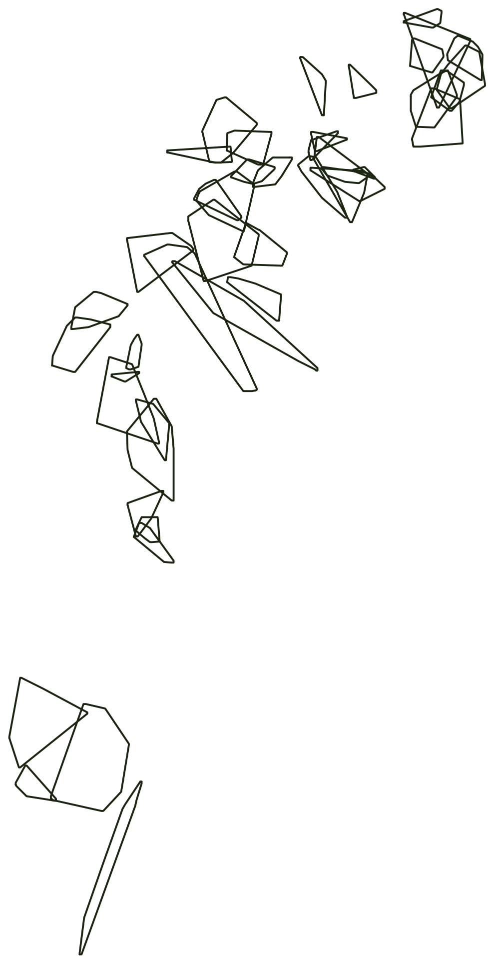

Figure 4.5. Home range overlap of female and male black bears in 1995 estimated with minimum convex polygon method on the George Washington-Jefferson National Forests, Virgina.

Table 4.5). Carr (1983) in Tennessee and Schrage (1994) in Virginia reported small home ranges for female bears during one year of their 2-year studies (Table 4.5). Jonkel and Cowan (1971) and Smith and Pelton (1990) suggested small home range size reflected improved habitat quality. The small home range size exhibited by black bears within the George Washington-Jefferson National Forests may reflect good habitat quality on the study area, but just as likely may highlight the influence of artificial feeding sites for bears, maintained by houndsmen throughout the year. These sites may provide supplemental foods to bears, and their importance following den emergence, when weights of bears are low and when natural foods are scarce, is unknown. Artificial feeding sites in combination with natural food may allow bears to occupy smaller areas and still meet their daily energy requirements. Habitat quality, food availability, and the effect of baiting must be assessed to obtain a better understanding of range dynamics of black bears on the George Washington-Jefferson National Forests.

Seasonal home range

Comparisons of MCP seasonal home range estimates and kernel seasonal home range estimates for female bears of the same reproductive status were inappropriate, because different animals were included in MCP home range estimation than were included in kernel home range estimation.

Different methodologies make size comparison of home ranges with other studies difficult (Young and Ruff 1982; Hellgren 1988). We failed to detect a significant difference in seasonal home range use of female bears of different reproductive status with the exception of some spring ranges (females with cubs and solitary females-MCP and females with cubs and females with yearlings-kernel). However, numerically our data support the general pattern in seasonal home range size reported throughout North America with the exception of summer range size. Spring ranges of females with cubs were smaller than spring ranges of solitary females (disregards sample of 1 for solitary females with kernel analysis). Spring ranges of females with yearlings estimated with MCP, although not statistically different, was 2.2-fold larger than females with cubs. Lindzey and Meslow (1977), Rogers (1977), Alt et. al. (1980), Carr (1983), and Smith and Pelton (1990) suggested spring ranges of females with cubs were smaller than solitary females and females with yearlings due to the limited mobility of their cubs. Carr (1983) in Tennessee and Clark (1991) in Arkansas reported that breeding females occupied larger summer ranges than females with cubs, and they suggested the reproductive success of the breeding population would be enhanced by occupying larger areas during the breeding season. Numerically, depending on the analysis used, solitary females had summer ranges 1.1-1.9 times the size of females with cubs. By fall, this trend had reversed and females with cubs had ranges 1.3-1.8 fold larger than solitary females. Alt et. al. (1980) and Smith and Pelton (1990) suggested the greater nutritional requirements of the family unit and increased mobility of cubs may explain larger fall ranges of females with cubs.

Table 4.5. Home range size and degree of overlap of bear home ranges in some North American locations.

Overlap	Male home range (km^2)	Female home range (km^2)	State	Citation
Extensive (M)	119	20	Alberta	Young & Ruff 1982
Extensive (F&M)				
	1440-Spec.pond	41-Spec.Pond area	Maine	Hugie 1982
	492-Staceyville	22-Staceyville area		
N/A	328	26- SHSA area	Massachusetts	Fuller 1993
		23 CWSA area		
Extensive (M)(F)	318-adult	28-adult	Massachusetts	Elowe 1984
	37- subadult	31-subadult		
	11-yearling	13-yearling		
Exclusive (F)	112	50	Idaho	Amstrup & Beecham 1976
Extensive (M)				
Exclusive (M)(F)(M&F)	60-adult	12	Idaho	Reynolds & Beecham 1980
	16-subadult			
N/A	173	41	Pennsylvania	Alt et. al. 1980
		25	Pennsylvania	McLaughlin 1981
	116	22	Virginia-SNP	Garner 1986
		12-1990	Virginia-SNP	Schrage 1994
		7-1991		
		15 solitary 1982-84	Virginia-SNP	Kasbohm 1994
		30 solitary 1987-89		
		11 w/cubs 1982-84		
		20-w/cubs 1987-89		

Table 4.5 (cont.). Home range size and degree of overlap of bear home ranges in some North American locations.

Overlap	Male home range (km^2)	Female home range (km^2)	State	Citation
		15 solitary	Virginia-GDS	Hellgren 1988
		14 with cubs		
Extensive (M)(F)(M&F)	7	6	Virginia-GWJNF	This study
Extensive (F)			North Carolina	Powell 1987
	119-1980	13-1980	Tennessee	Carr 1983
	36-1981	6-1981		
Seasonal (M)(F)	116-adult	12 -adult	Arkansas	Smith & Pelton 1990
	148-subadult	9-subadult		
	90	35	Arkansas	Clark 1991

Smith and Pelton (1990) suggested patterns of seasonal use were related to food distribution and abundance and to reproductive behavior. In this study, females with cubs occupied larger areas in the fall than in the spring or summer, as their cubs matured and became more mobile. Similar findings were reported in Pennsylvania and Arkansas where home range size of females with cubs increased in the fall (Alt et. al. 1980; Smith and Pelton 1990). However, Hellgren (1988) reported unexplainably small fall home ranges of females with cubs in southeastern Virginia. In this study, home ranges of solitary females did not change seasonally when estimated with MCP; however, solitary females had larger fall ranges than summer ranges estimated with the kernel method. Again, this was likely a factor of sample size and the estimator used. Improved data collection should improve sample size and interpretation of the data.

Home range stability

Garrot and White's (1990) review of MRPP suggested that small changes in home range use by an animal may indicate an absence of site fidelity, when in fact the change in home range use is minor. Therefore, we used the degree of home range overlap of an animals home range in different years as a check on MRPP, a strategy which confirmed the interpretation of MRPP analysis. MRPP and home range overlap analyses provided complimentary results on the degree of home range stability of 8 females monitored in both years of the study. Half of the females monitored during 2 years exhibited stable home ranges and half did not.

Two of 4 of the females that didn't exhibit stable home ranges had $\leq$ 20 telemetry locations annually. All females that exhibited stable home ranges had > 20 locations. Perhaps, not enough locations were obtained to identify these 2 animals home range.

Home range overlap

The degree of home range overlap observed is a minimum estimate; less than 50% of the bears captured were equipped with radio collars, and we did not capture all the bears that occupied our study area. In addition, all bears that were radio collared were included in overlap analysis regardless if enough locations had been obtained to identify an animals range, therefore some ranges probably were underestimated and the degree of overlap may be higher than reported. The degree of home range overlap in areas of the study area where >5 radio collared bears occurred was extensive, indicating a high degree of tolerance among bears on the study area. In areas where <5 radio collared bears occurred home range overlap data were limited. Tolerance among black bears may be influenced by family relationships (Jonkel and Cowan 1971; Lindzey and Meslow 1977; Garshelis and Pelton 1981), age and sex of bears, reproductive status and habitat productivity. Family relationship of bears on the study area have not been identified; however, I suspect that several bears with overlapping ranges are related. As this study continues, offspring of radio collared adult females will be equipped with radio transmitters, which should shed light on the factors influencing the tolerance observed among black bears in Virginia. In addition, this study population is young (31.4% of population is > 4 years), which may explain the high degree of tolerance.

Extensive home range overlap among and between sexes of black bears has been observed nationwide (Lindzey and Meslow 1977; Amstrup and Beecham 1976; Reynolds and Beecham 1980; Garshelis and Pelton 1981; Elowe 1984; Garner 1986; Powell 1987; Hellgren 1988; Smith and Pelton 1990; Clark 1991) although, in some populations, bears temporally avoided each other in areas of overlap (Young and Ruff 1982; Garshelis and Pelton 1981; Clark 1991). Minimal home range overlap was observed in Montana, Minnesota, and Maine (Jonkel and Cowan 1971; Rogers 1977; Hugie 1982). Powell (1987) suggested the lower productivity of northern habitats influenced territorial behavior, although Young and Ruff (1982) suggested the exclusive use of home ranges among adult female bears in Alberta may not have been related to food supply, but to guarantee the use of some resource necessary to successful cub production. Small home range size and the high degree of tolerance exhibited by black bears in Virginia suggests that habitat productivity is high. However, our confidence in our home range estimates was influenced by small sample size (number of locations per bear and number of bears included in analyses). Future study, designed to improve telemetry data collection, as well as, assessing habitat quality, food availability, the effect of baiting bears, and dispersal dynamics will improve our knowledge of the health of Virginia's hunted bear population.

Study design

Telemetry data collection was not a primary objective of the CABS. Capturing and marking bears, obtaining data on reproduction and survival, and assessing the effect of pursuing bears with hounds were the primary objectives in the preliminary phase of this research. Early spring and mid fall were the only months of the year that telemetry data collection was emphasized. To improve the quality and quantity of telemetry data, the emphasis of the study and the study design would have to be modified. Under the current study design for ground telemetry locations, 3 bearings with intersecting angles $\geq$ 30 degrees obtained within 30 minutes of the first bearing are used to estimate an animals location under ideal conditions. Two bearings were accepted in areas were road systems made it difficult to obtain more than 2 bearings. With the advent of the maximum likelihood estimators, locations obtained with 3 or more bearings can be used to estimate an animal's location. Obtaining more than 3 bearings to estimate an animals location would improve the accuracy of telemetry locations and would help to distinguish true readings from signal bounce. During field data collection, striving to obtain locations with 3 bearings with intersecting angles closer to 45 degrees will also reduce the error. Quality rather than quantity of locations needs to be emphasized with both ground and aerial telemetry data collection. The availability of field personnel and priorities of the research have limited telemetry data collection. Ideally, a graduate student and technician(s) solely responsible for telemetry data collection would improve the quantity and quality of telemetry locations especially in winter and summer months, where telemetry locations have been poorly represented. Considerable thought needs to be put into evaluating and improving telemetry data collection.

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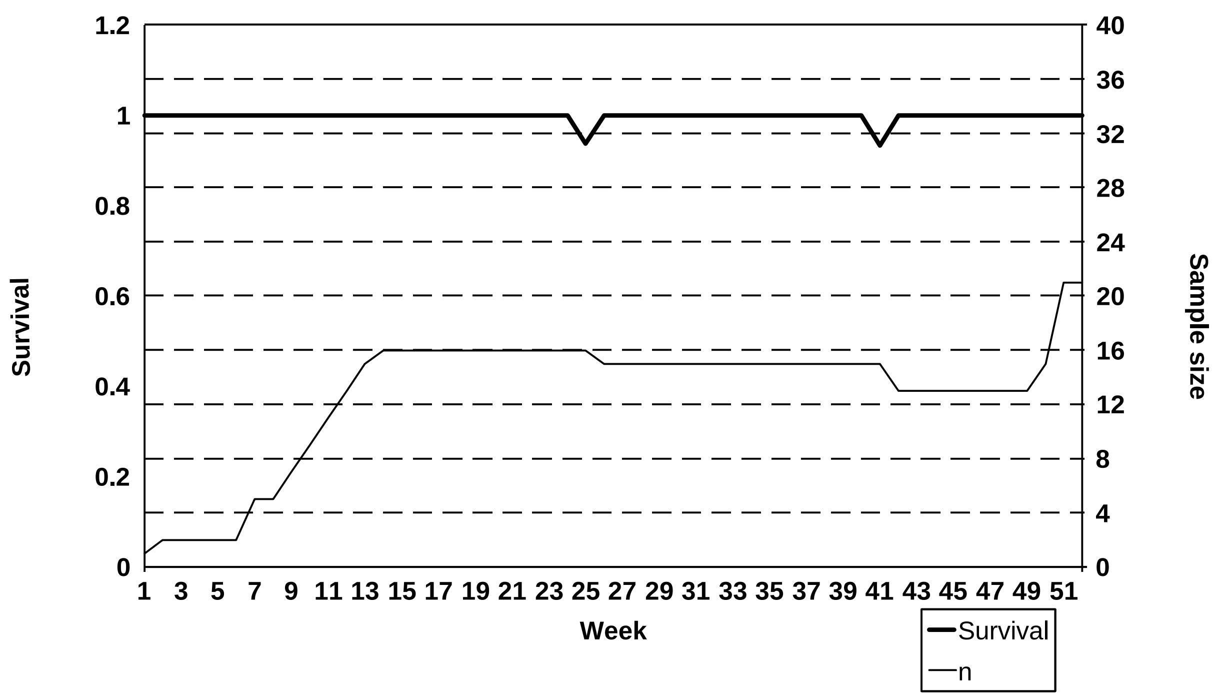
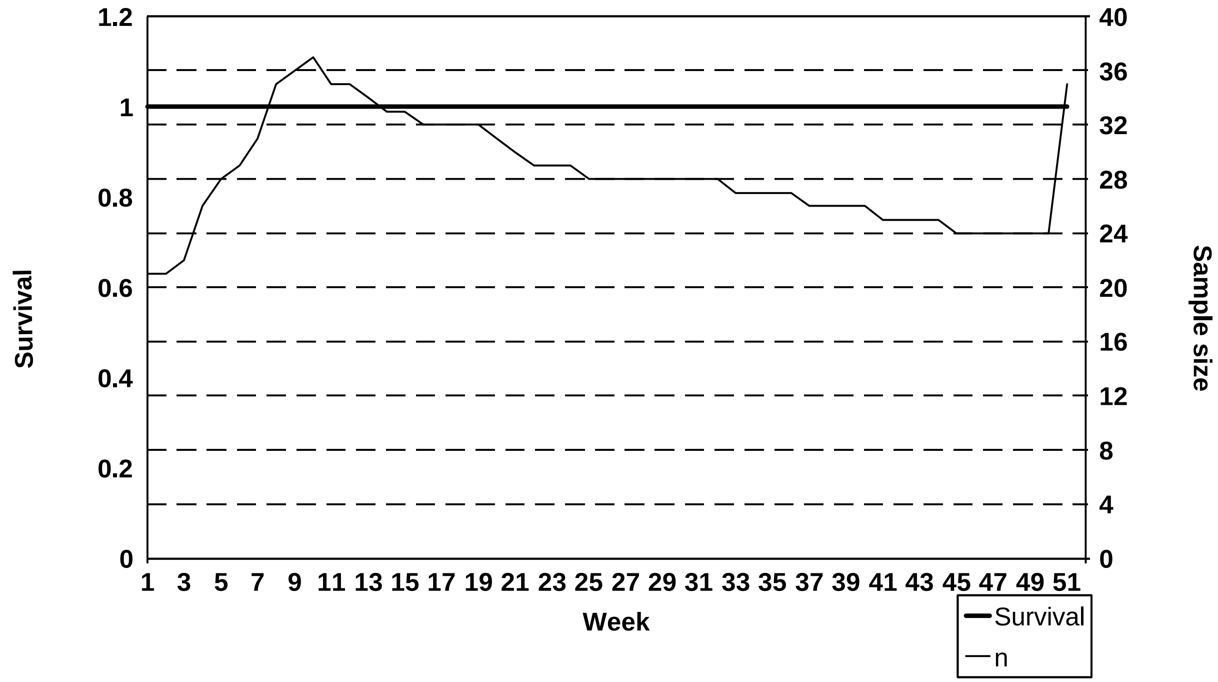
Appendix Table A. 1995 Virginia bear hunter survey data (K. Higgins unpub. data).

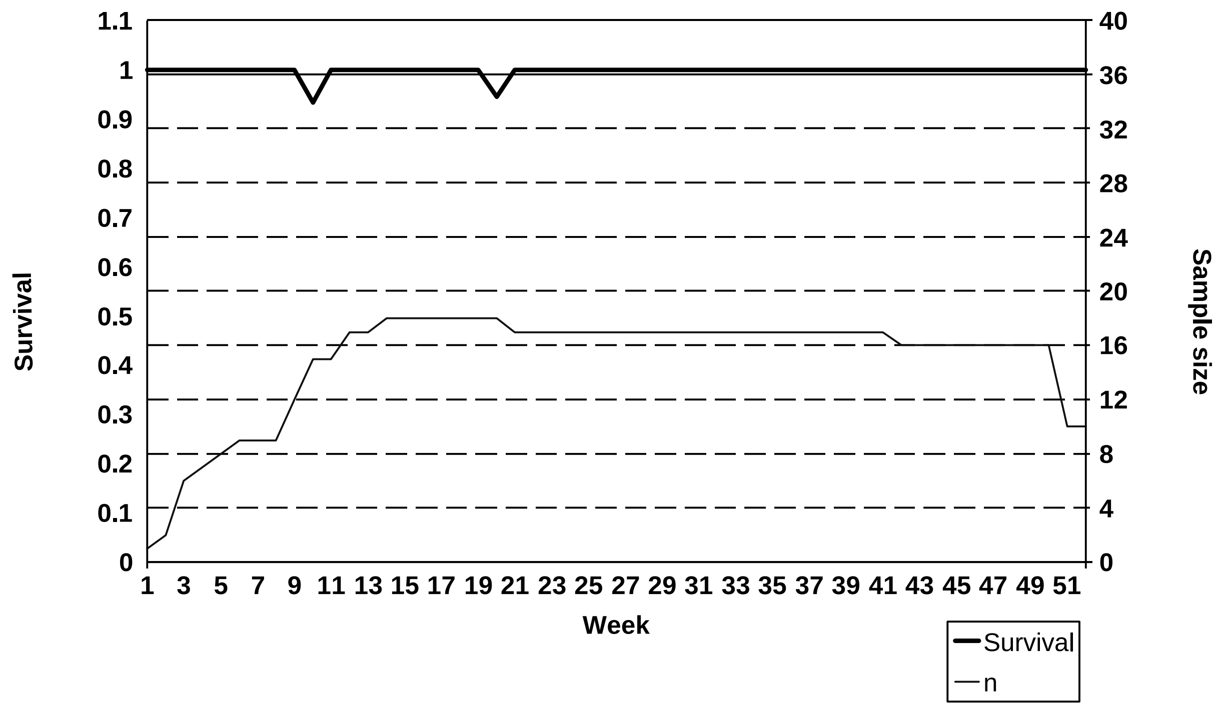
	Total bears	Marked Bears	Unmarked bears
Number of bears treed	28	13	15
Number of bears harvested	8	6	2
Harvest rate (%)		46.2	13.3



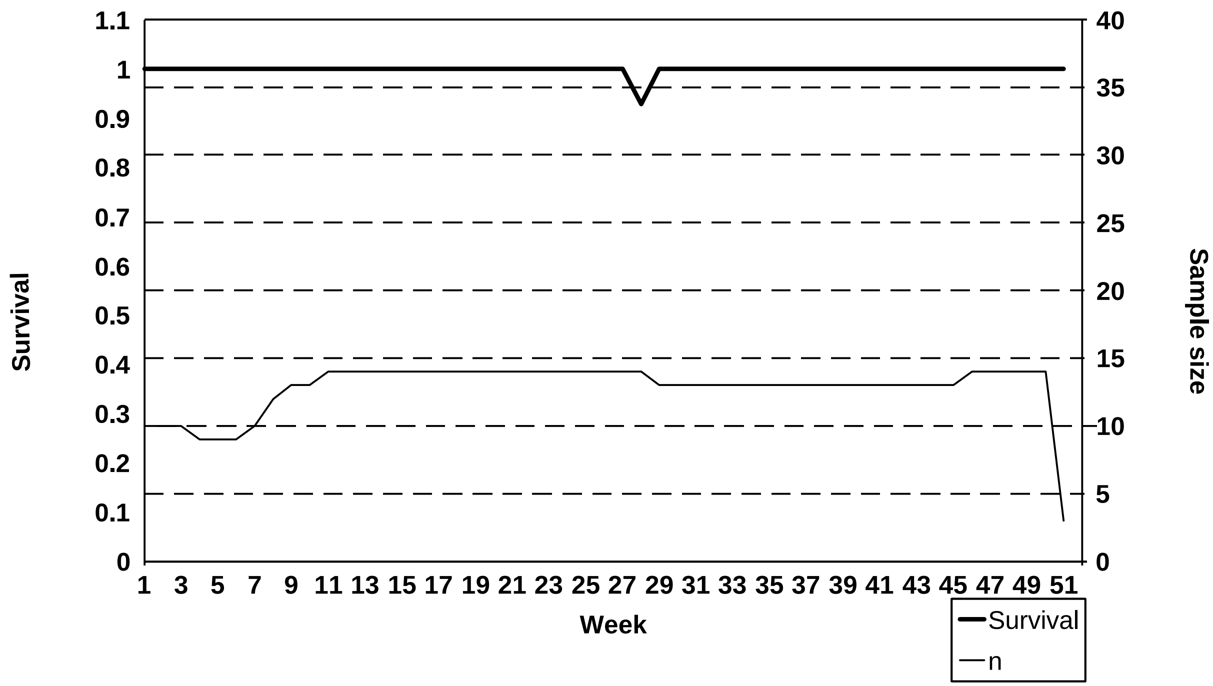
Appendix Figure A. Adult female survival curve and weekly sample size in 1994 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



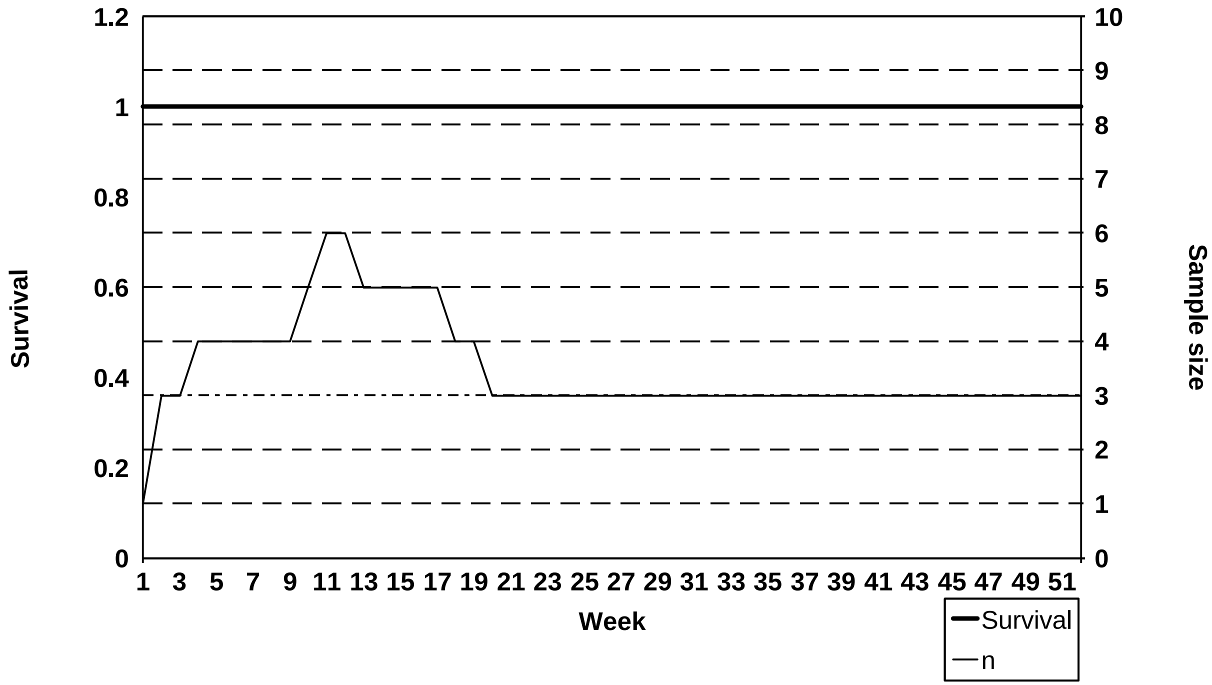
Appendix Figure B. Adult femal survival curve and weekly sample size in 1995 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



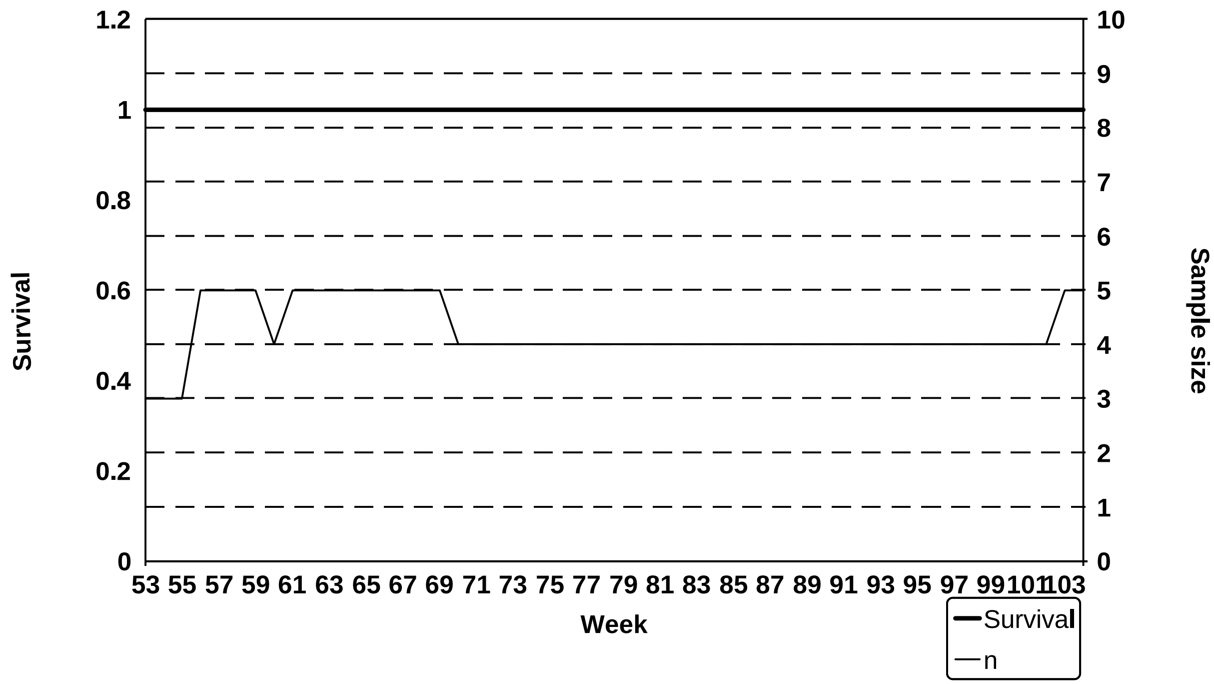
Appendix Figure C. Subadult female survival curve and weekly sample size in 1994 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



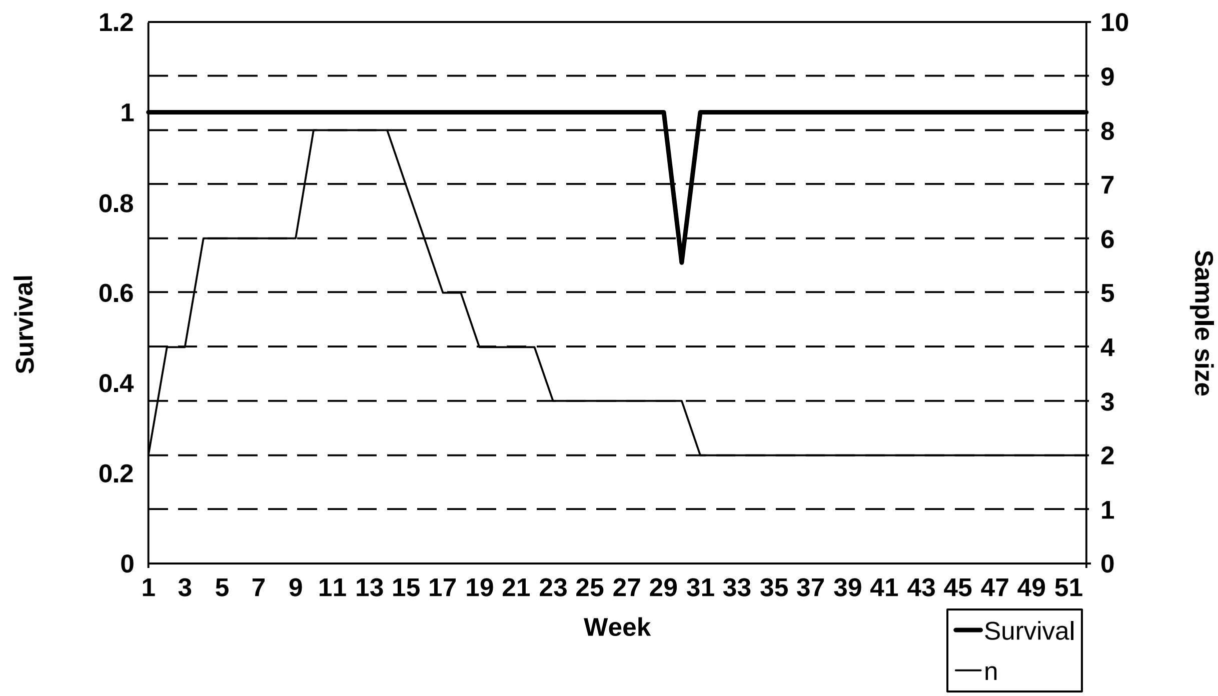
Appendix Figure D. Subault female survival curve and weekly sample size in 1995 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



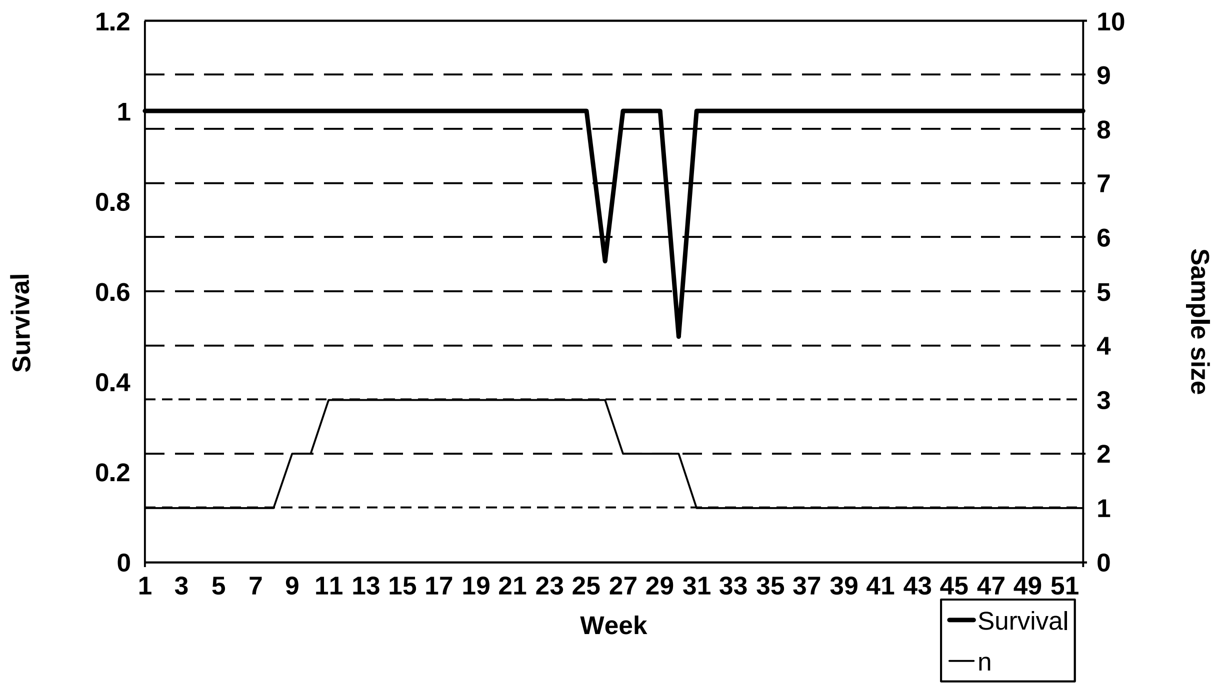
Appendix Figure E. Adult male survival curve and weekly sample size in 1994 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



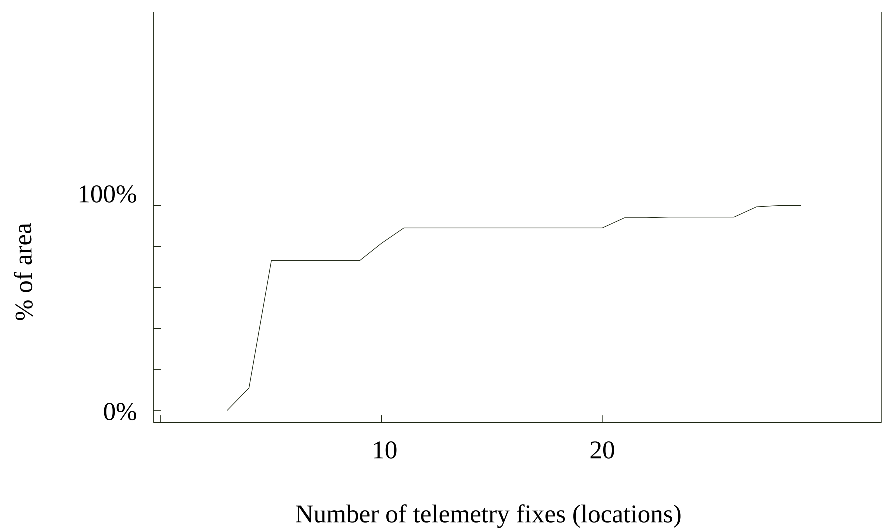
Appendix Figure F. Adult male survival curve and weekly sample size in 1995 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



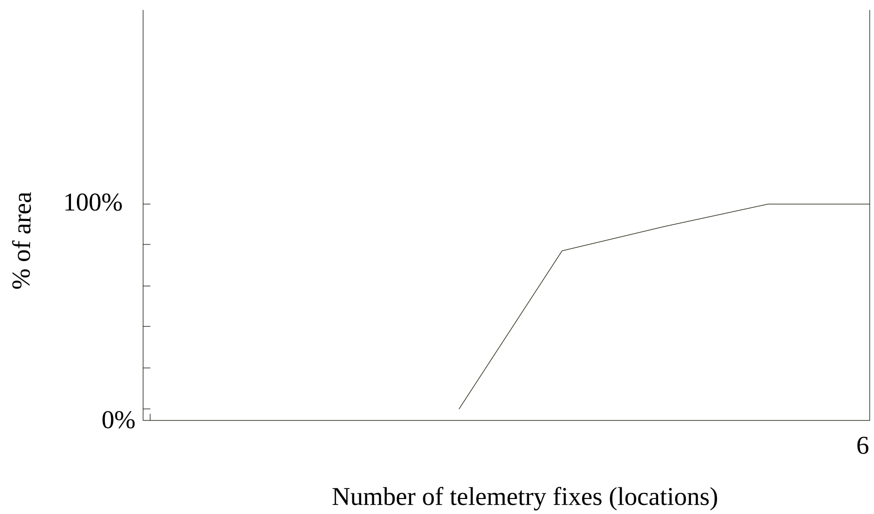
Appendix Figure G. Subadult male survival curve and weekly sample size in 1994 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



Appendix Figure H. Subadult male survival curve and weekly sample size in 1995 on the George Washington-Jefferson National Forests, Virginia (Pollock et. al. 1989).



Appendix Figure I. Incremental area plot for an adult female (id 15) with 30 telemetry locations estimated with MCP method.



Appendix Figure J. Incremental area plot for an adult female (id 143) with 6 telemetry locations estimated with MCP method.

Vita

Jennifer Carol Higgins was born in Boston, Massachusetts on December 24, 1970 to Theresa and Richard Higgins. Her family settled in Maine in 1978, where she graduated from Camden-Rockport High School in 1989. She attended the University of Maine and received her Bachelors of Science degree in Wildlife Management in 1993. Following graduation she worked for the Maine Department of Inland Fisheries and Wildlife's black bear study trapping bears. In the fall of 1993, she worked for the Pennsylvania Game Commission trapping black bears. She began work on her Masters of Science degree at Virginia Polytechnic and State University in January of 1994.