

**Home range dynamics of black bears in the
Alleghany Mountains of western Virginia**

by

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Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree
of
MASTER OF SCIENCE
in
Fisheries and Wildlife Sciences

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August 2005
Blackburg, Virginia

Keywords: Black bear, home range estimators, annual home range, seasonal home range, home range shifts, reproductive status

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ABSTRACT

The Cooperative Alleghany Bear Study (CABS) was initiated in 1994 to address concerns over the lack of biological and ecological data for black bear (*Ursus americanus*) populations in the Alleghany Mountains of western Virginia. I examined home range dynamics of bears during 1994-2002 on 2 study areas that were approximately 160 km apart. I analyzed my data with 3 home range programs (AMA, HRE, and ABODE) and determined the HRE was the least biased and produced the most biologically reasonable home range estimates. I used HRE to generate annual home ranges (fixed-kernel) for 90 bears over 160 bear years; I also generated seasonal home ranges using MCP. Annual and seasonal home ranges of male and female adult bears in the southern study area were larger than that of male and female adult bears in the northern study area, respectively; southern females and northern males had annual home ranges similar in size at the 95% and 75% fixed-kernel contours. In both study areas, most bears did not shift their range when transitioning from spring to summer (North: 63.0%; South: 57.0%) or from summer to fall (North: 67.0%; South: 65.0%), while most bears shifted their seasonal range between spring and fall (North: 67.0%; South: 52.0%). Most female bears in both study areas maintained the same spring and summer home range throughout the duration of the study, while 63% of northern females changed their fall home range and 55% of southern females maintained their fall home range. I found

no differences in annual and seasonal home range size among years or among age classes for adult females, but tests for intra-year seasonal difference indicated that fall range was larger than spring and summer in 1997, when western Virginia experienced a poor mast crop. Females with and without COY had similar annual home ranges in either study area. In the north, seasonal home range size did not differ between females with and without COY, while in the south, breeding females (i.e. without COY) had larger spring ranges and smaller fall ranges than females with COY. In both study areas, females with COY had larger fall home ranges than during spring, while seasonal ranges of breeding females did not vary in size during the year.

ACKNOWLEDGEMENTS

First, and foremost, I would like to acknowledge the Virginia Department of Game and Inland Fisheries (VDGIF), not only for their financial support, but also for their personnel support over the past 10 years. Numerous VDGIF personnel assisted me over the years and I would like to take the opportunity to give a special thanks to Dave Steffan, Al Bourgeois, Dave Kocka, and Joe Watson. Additional thanks goes to: Denny Martin for performing aerial telemetry flights; Larry Crane, who taught me a lot about black bears, climbing trees, immobilizing bears, and appreciating the little things in life; Marv Gautier and Roger Houck, not only for their assistance and advice during trapping and den season, but their constant jokes and cheery demeanor; Betsy Stinson for helping to coordinate VDGIF personnel and her assistance in the field; and Jerry Blank for teaching me how to be a better bear trapper, though I know I will always be a rookie trapper in his book.

I would also like to acknowledge the financial support provided by Virginia Polytechnic Institute and State University, the Virginia Cooperative Fish and Wildlife Research Unit, and the United States Forest Service. Additional support was provided by: Georgia Pacific, National Fish and Wildlife Foundation, National Geographic Society, Northern Shenandoah Audubon Society, Safari Club International, Union Camp Corporation, Virginia Department of Transportation, Virginia Houndsmen and Sporting Dog Association, Virginia Chapter of the Sierra Club, Virginia Wilderness Committee, Wildlife Forever Foundation, and Westvaco. In addition to financial support, the Virginia Bear Hunters Association also provided support in several aspects of fieldwork and data collection. Lastly, I would like to thank Krispy Kreme Corporation and Kroger's for the

day-old pastries, donuts, and cakes they provided to us, as bait for the bears and countless breakfasts and lunches for my crew.

The Cooperative Alleghany Bear Study (CABS) and my master's project would not have been possible without the dedication and hard work of numerous volunteers and technicians throughout the years. Not only did they work countless hours for very little pay, but their personalities and enthusiasm kept my spirits up even on difficult field days. I also made lasting friendships with several of these crew members and I want to give a special thanks to Andrew Trent, Daly Sheldon, Jodi Fox, Dave Edmunds, Brian Balmer, Jen Hebert, John Chelko, Kristin O'Connell, and Jenny McKay for their tireless dedication to my project.

The "cooperative" in CABS not only represented the cooperation that existed between Virginia Tech and other agencies, but it also represented the cooperation that existed between all the graduate students that worked on CABS. A graduate student involved with CABS not only collected data for their own project, but also collected data for all the other students involved with CABS. So, I must thank the ten graduate students that worked on CABS, not only for collecting data for my study, but also for their friendships, support, and advice. These students are: Cale Godfrey, Rachel Gray, Jen Higgins, Kris Higgins, Sybille Klenzendorf, Daniel Lee, Kim Needham-Echols, Deb O'Neill, and Chris Ryan. I would like to give special acknowledgement to Kris Higgins, who put me in contact with Dr. Mike Vaughan, and Rachel Gray, who introduced me to the world of black bears through doughnuts and poopballs.

I would like to acknowledge the my lab mates, Gyasi Quince, Greg Batts, and Catherine Tredick, and the graduate students of the fisheries and wildlife department. Without their advice and support, I might not have made it past the first semester of graduate school. I strongly believe that what makes this department strong and unique is the dedication and cooperation shown among the graduate students, who are so willing to help each other out with classwork, fieldwork, and data analysis. Plus, they are just a fun group to spend time with.

While at Virginia Tech I made several lasting friendships with Gabriela Gonzalez, Mary Tilton, Missy Petty, Tom McNamara, and Sarah Karpanty. Thanks for being there for me in good times and bad, and thanks for your shared love of wine, runs at Pandapas Pond, bike rides around Blacksburg, and Prix Fixes. Your friendships made it difficult for me to leave.

A big thanks to my committee members, Dr. Dean Stauffer and Dr. Jim Frasier, for their guidance throughout the years. In addition, I'm very appreciative to Dean for providing me with teaching opportunities and Jim for providing me with the opportunity to work on the beach with non-furry animals.

I wouldn't be where I am now without the support of my family. My parents encouraged me to get my first wildlife internship and through their shared enthusiasm for my work, and their financial support throughout the years, I was able to stay in this field and have my dreams realized.

Of course, I wouldn't be writing this thesis if it weren't for my advisor, Dr. Mike Vaughan. He has been very supportive since the day I arrived, and has become not only my colleague, but a good friend. While this study could be overwhelming, the fact that he

gave me so much responsibility showed me how much trust he had in my decisions and actions. Mike taught me a lot during my 6 years in Blacksburg, and I owe him for the successes I hope to have in my future career.

Lastly, I owe a huge thanks to all the black bears that were trapped, poked with needles, tattooed, and generally harassed during the course of our research. While they didn't have a choice in volunteering for this study, I was able to learn a lot about wildlife management through their participation. I hope that through this research and my future endeavors in the wildlife field, I can repay them for the sacrifices they made for my project.

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INTRODUCTION

Historically, black bears (*Ursus americanus*) ranged throughout the forested habitats of North America occupying all 49 continental states, all Canadian provinces and territories, and much of northern Mexico (Hall 1981). By the 1980's, black bears in the southeastern United States occupied only about 10% of their former range, due mainly to habitat loss and human-caused mortality (Maehr 1984). In Virginia, the number of black bears harvested annually fluctuated widely throughout the 1980's and into the early 1990's (Martin and Steffen 2000). In 1989, the Virginia Department of Game and Inland Fisheries (VDGIF) decreased the length of the bear hunting season in 9 counties (Bland, Giles, Grayson, Montgomery, Pulaski, Smyth, Tazewell, Washington, and Wythe; VDGIF 2002) and the Virginia Bear Hunter's Association (VBA) adopted a policy that instructed members to avoid harvesting adult female black bears (D. Thorne, VBA, Blacksburg, Virginia, personal communication).

In recent years, black bear populations in many eastern states, including Virginia, appear to be increasing and expanding; Maryland and New Jersey recently opened up hunting seasons on black bears for the first time in decades in response to increasing bear populations. Black bears were extirpated from Ohio for several decades, but in recent years, sightings have increased, including visuals of females with cubs. In Virginia, the number of bears harvested annually continues to increase, possibly indicating an increasing population; in 2003 Virginia experienced a record harvest of 1,500 black bears (Dennis Martin, VDGIF, Verona, Virginia, personal communication).

The Cooperative Alleghany Bear Study (CABS) was initiated in 1994 due to concerns over the lack of biological and ecological data for Virginia's hunted black bear

population. Originally, only one study area was created in CABS; a 860 km² study area in the northwestern region of Virginia. Because conclusions from CABS would be used to make management decisions for the entire bear population in western Virginia, a second study area was created in 1995, in the southwestern region of the state. This provided opportunities to make comparisons between two black bear populations, and would help determine if bear populations throughout western Virginia are similar, or if the populations need to be managed separately.

Cooperators of CABS include the VDGIF, the United States Forest Service (USFS), the Virginia Cooperative Fish and Wildlife Research Unit, and the Virginia Polytechnic Institute and State University (VPI&SU). The study has examined age-specific reproduction and survival, dispersal of subadults, denning ecology, population growth rates, indices of population size, development of population models, and effects of using dogs to hunt bears. One of the original objectives of CABS yet to be summarized is movement patterns and home range attributes of black bears in both study areas.

In this thesis, I will address this objective using radio-telemetry data collected in the 2 study areas of CABS, the northern study area (1994 through 2002) and the southern study area (1995 through 2002) of CABS. Chapter 1 reviews the different ArcGIS extensions available to generate home ranges and discusses how I chose the Home Range Extension (Rodgers and Carr 1998) for generating fixed-kernel and minimum convex polygons. Chapter 2 describes home range attributes of male and female black bears in our 2 study areas. Chapter 3 examines the influence of reproductive status of adult female black bears (i.e. solitary or with cubs of the year) on movement patterns and home range size.

OBJECTIVES AND HYPOTHESIS

The objectives of this research are:

1. To compare home ranges estimated by 3 home range extensions available in ArcGIS.
 - H_0 : There are no differences in the home ranges generated by the 3 home range extensions.
2. To determine home range dynamics of black bears in western Virginia and make comparisons between 2 study areas and with other regions in North America.
 - H_0 : Home range dynamics, such as size and fidelity, of black bears in western Virginia do not differ between study areas.
3. To determine if reproductive status influences home range dynamics of adult female black bears in western Virginia.
 - H_0 : There are no differences in the home ranges dynamics of adult female black bears, irregardless of reproductive status.

GENERAL METHODS

Description of study area

The Cooperative Alleghany Bear Study had 2 study sites in western Virginia, a northern and a southern site (Figure 1). The 1,544 km² southern study area of CABS occupied the Blacksburg Ranger District and a portion of the New Castle Ranger District of the George Washington and Jefferson National Forests (GWJNF) in Giles, Craig, and Montgomery counties (United States Department of Agriculture 1965). This portion of the GWJNF is heavily fragmented by private land. National forest lands are located primarily on ridges, while the valleys consist of private agricultural lands. Elevation ranged from 1,378 m, at Mountain Lake, to 492 m along Craig Creek drainage. At Mountain Lake, temperatures ranged from an average high of 24°C in July to an average

low of -9°C in January with total precipitation averaging 125cm, including 134 cm of snow (<http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMAIN.pl?va5828> in Bridges 2005).

The dominant tree species were white oak (*Quercus alba*), scarlet oak (*Q. coccinea*), chestnut oak (*Q. prinus*), black oak (*Q. velutina*), and northern red oak (*Q. rubra*). Other overstory species include pignut hickory (*Carya glabra*), bittersweet hickory (*C. cordiformis*), red maple (*Acer rubrum*), pitch pine (*Pinus rigida*), eastern white pine (*P. strobus*), and table mountain pine (*P. pungens*). Intermediate and codominate trees included black tupelo (*Nyssa sylvatica*), sourwood (*Oxydendrum arboreum*), and black locust (*Robinia pseudoacacia*). Important understory trees include sassafras (*Sassafras albidum*), mountain laurel (*Kalmia latifolia*), flowering dogwood (*Cornus florida*), downy serviceberry (*Amerlanchier arborea*), witch hazel (*Hamamelis virginia*), Alleghany chinkapin (*C. pumila*), great rhododendron (*Rhododendron maximum*), and eastern hemlock (*Tsuga canadensis*; K. Higgins 1997).

The 860-km² northern study area was in the Dry River and Deerfield Ranger Districts of GWJNF in Augusta and Rockingham counties. This area is not fragmented by private land, and was characterized by the mountainous terrain of the Appalachian Mountains. The highest elevation was Elliott Knob (1,360m), while the lowest elevation was at the base of Little North Mountain (488m; Kozak 1970 in J. Higgins 1997). Temperature and precipitation measurements were recorded at Dale Enterprises in the adjacent Shenandoah Valley. At Dale Enterprises, temperatures ranged from an average high of 30°C in July to an average low of -5°C in January with total precipitation averaging 90 cm, including 63 cm of snow (<http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMAIN.pl?va5828> in Bridges 2005). The mountainous regions of the study

area usually receive more precipitation and average 2.8-5.6°C cooler than in the Shenandoah Valley (Rawinski et al. 1994 in Godfrey 1996).

The dominant tree species were eastern hemlock, sugar maple (*A. saccharum*), American beech (*Fagus gradifolia*), yellow birch (*Betula allegheniensis*), chestnut oak, pitch pine, white oak, black oak, northern red oak, yellow poplar (*Liriodendron tulipifera*), and eastern white pine. Common understory trees and shrubs were scrub oak (*Q. ilicifolia*) and mountain laurel (*Kalmia latifolia*; Godfrey 1996 and J. Higgins 1997).

Trapping and handling

Trapping, handling, and monitoring procedures for CABS were established at its inception in 1994 and have been modified only slightly since. From 1994 – 2002 bears were trapped from early June to late August using spring-activated Aldrich foot snares and culvert traps. From January to late March, dens of hibernating bears were entered to measure reproductive performance. Bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride (concentration of 300mg/ml) at a dosage of 1cc/45.4 kg (100 lbs.), using dart pistol, jabstick, or blowgun. After handling, yohimbine (concentration of 5 mg/ml) was administered at a dosage of 5cc/45.4 kg (100 lbs.) as an antagonist to the xylazine. While immobilized, the bear's temperature, morphological measurements, weight, body condition, reproductive condition, estimated age, and sex were recorded. Each bear was marked with a numbered eartag and tattooed inside the upper lip with the same number; select bears received a radio collar, cub collar, or eartag transmitter. The upper first premolar was extracted for cementum annuli analysis (Willey 1974). Blood samples and hair samples were taken for genetic and nutritional analyses.

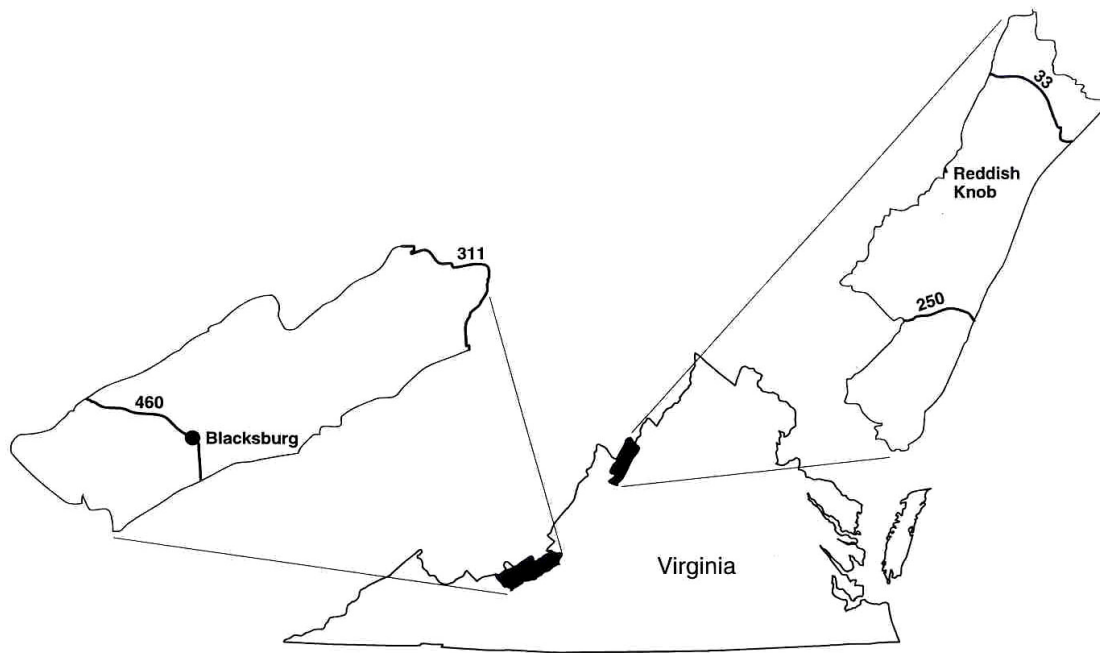


Figure 1. The northern and southern study areas in the George Washington and Jefferson National Forests, Virginia.

The following morphological measurements were taken to the nearest mm: total body length, zoological length, width of head at zygomatic arches, chest girth, neck girth, ear length, shoulder height, tail length, testical length and width, canine width and breadth, front paw width and length, and hind paw width and length.

Telemetry

Radio collared bears were monitored by ground surveys and aerial surveys to determine location, activity status (radio signal on active or on mortality mode), and estimate timing of den entrance and emergence. Aerial surveys were conducted 1-2 times a month, while ground surveys were done daily. For ground surveys, locations were triangulated from a minimum of 3 bearings taken from known telemetry stations within a 30-minute time interval. Global Positioning System (GPS) was used to determine the location of the telemetry stations. Telemetry error was estimated by placing transmitters in locations unknown to observers, and bearings were collected using the techniques described earlier; average telemetry error was 9°. Each bearing was rated on a scale of 1 to 5, based on signal strength and confidence in the signal direction. Bearings with a rating of 5 in either signal strength or confidence were discarded. We attempted to monitor bears ≥ 1 per week to obtain data on habitat use and home range size. We assumed that bears are able to traverse their home range within 24 hours. Thus, to assure independence between observations, locations for each bear were taken >24 hours apart. Azimuths were collected between dawn and dusk, so locations reflect diurnal movements and habitat use. Bears were classified as alive, censored, or dead (mortality signal). Bears were censored when their transmitter had not been heard for 3 months; by 3 months all attempts to locate the bear by ground and aerial surveys were exhausted. Censoring can

be due to radio loss, radio failure, or emigration from the study area. When a collar was still for ≥ 30 minutes, a mortality signal of was emitted. Bears with mortality signals were located so that cause of death could be assessed and the dropped collar recovered.

Bear locations used to estimate home range and habitat use were collected from aerial surveys, ground telemetry, dropped transmitters, den sites, site of mortality, and visuals from both observers and camera surveys. Bear locations and error ellipses estimated from azimuths collected from ground telemetry were calculated using a modified SAS program (White and Garrott 1990). Location estimates were considered unreliable and removed from analysis if the 95% error ellipse exceeded 200 ha. The average error ellipse for each location was 30 hectares (n=8,252) and 19 hectares (n=1,246) for females and males, respectively. Seventy-seven percent of female locations and 78% of male locations had error ellipses below the average. Approximately 4% of both female and male locations had error ellipses between 100 and 200 ha (Figure 2).

Range size estimators and statistics

Annual home range estimates were calculated with the fixed-kernel method while seasonal home range estimates were calculated using minimum convex polygon, due to the low number of locations. Minimum convex polygon is conceptually simple, easy to draw, and not constrained by assuming that animal movements and home range must fit an underlying statistical distribution. A method to improve MCP is to eliminate the problem of extreme data points by creating MCP's that include only 95% of the locations. Excluding extremes in the data points can be justified statistically because extremes are not reliable and tend not to be repeatable as patterns in the centers of

distribution (Powell et al. 1997). Also, by eliminating locations that occur well outside the normal range of activity of an animal, we can identify regions with the highest density of animal locations (Lawson and Rodgers 1997).

The fixed-kernel method is preferred over minimum convex polygon because the MCP method does not provide information about concentrated areas of use, and assumes that home range is used evenly by an animal, ignoring the distribution of animal locations within the outer boundary (Lawson and Rodgers 1997). MCP also incorporates areas that are not used, and is sensitive to extreme data points and sample size. Home ranges calculated with differing numbers of data points might not be comparable (Samuel and Fuller 1996). These problems can lead to inaccuracies in determining habitat use by giving a distorted picture of what the animal is using.

The kernel density method is a better estimator than MCP in calculating home range (Worton 1989, Harris et al. 1990, Powell et al. 1997). It considers the distribution of locations within the home range and determines 1 or more core-activity areas (Worton 1989). Unlike other home range estimators, it is not influenced by grid size or placement (Powell et al. 1997). The kernel method estimates home range by taking each location and covering it with a 3-dimensional hill, the kernel, whose volume is 1 and whose shape, the band width, is chosen by the researcher. The band width is often referred to as the smoothing parameter and is used to control the amount of variation in the estimate. It can be held constant for a data set (fixed-kernel) or it can vary (adaptive-kernel). The latter results in data points that are covered with kernels of different widths ranging from low, broad kernels for widely spaced points, to sharply peaked, narrow kernels for tightly packed points. Narrow kernels reveal small-scale details in the data, while wide kernels

smooth out sampling error, but hide local detail. Because each kernel is a density, the resulting estimate is a true probability density function itself (Worton 1989). If a distribution is not normal, the process of least squares cross-validation can be used to determine band width and to select the band widths with the minimum estimated error. One potential problem with the adaptive-kernel method is that a minor change in the smoothing parameter value has a large effect on overall range size, especially for small sample sizes (Harris et al. 1990). Powell et al. (1997) found that the fixed-kernel estimator, using cross-validation to select band width, produced the more accurate home range estimates and had smaller variance than home ranges calculated using the adaptive-kernel estimator.

Besides determining activity centers, another advantage of using a kernel estimator is its ability to generate dependable estimates with few locations. In North Carolina, Noel (1993) investigated the number of locations needed for the fixed- and adaptive-kernel estimators to generate consistent estimates of the 95% home range area. He found that with as few as 20 locations, both fixed- and adaptive-kernel estimators generated dependable estimates. I used a minimum of 20 locations to estimate fixed-kernel home ranges and minimum convex polygon.

Indices of habitat quality

I reasoned that differences in habitat quality between study areas might explain differences in home range dynamics, thus I examined some parameters I thought could serve as indices of habitat quality. These parameters included annual hard mast production, amount of food provided by bear hunters, population densities, bear weights,

and macrohabitat features, such as forested and non-forested land, road densities, and land ownership (i.e. public versus private) and were obtained as follows:

Hard mast.-VDGIF biologists conduct annual surveys to quantify hard mast production from late August to early September (Sharp 1958, Coggin and Peery 1973). They examined the same trees every year and determined the mean number of acorns / 10 limbs/ tree (Fearer et al. 2002). I used mast survey data, provided by VDGIF, from the 3 mast survey regions constituting our study areas (D. Martin, VDGIF, Verona, Virginia, personal communication).

Supplemental food.-Until 1999, bear hunters were allowed to provide food to bears on both public and private lands in Virginia; in 1999 bear hunters were restricted to having artificial feed sites only on private lands (Gray 2001). To estimate the amount and distribution of food provided to black bears by hunters, Gray (2001) surveyed members of the Virginia Bear Hunter's Association (VBHA). I used her data to estimate the amount of supplemental food provided on both study areas.

Bear densities.-Bridges (2005) determined bear densities on the northern and southern study areas using photography-based capture-recapture data. I used these data for my analysis.

Bear weights.-We recorded the weights of male and female adult bears captured during the summer and winter June 1994 through April 2003. I tested these weights for regional differences with the test for repeated measures, fixed-effects, since some bears were measured more than one time (proc mixed; SAS Institute, Inc. 1990).

Macrohabitat features.-To determine study area boundaries for this analysis I constructed a conglomerate home range (95% MCP) using all locations collected during CABS

(Figure 3). Based on the polygon generated around the locations, the northern study area was 184,898 hectares, while the southern study area was 160,961 hectares (Appendix B). The boundaries of both study areas contained land in Virginia and West Virginia.

I obtained data on the composition of forested and non-forested land from the 1992 National Land Cover Data (NLCD). The NLCD was created from Landsat Thematic Mapper satellite data collected from the early to mid-1990's. It is a 21-class land cover classification scheme and provides data on a state-by-state basis. Land was classified into 4 categories: forested, agriculture, developed, and other.

I obtained road densities from Census 2000 TIGER/Line data (Census 2000 Redistricting Data 2001), which was created from the Topologically Integrated Geographic Encoding and Referencing (TIGER) database of the United States Census Bureau. Data on roads were available on a county-by-county basis for each state. For this study, I classified roads as highways, high traffic paved roads, low traffic paved roads, or low traffic unpaved roads, including gated Forest Service roads.

I obtained data on ownership of land in Virginia through the Department of Conservation and Recreation (DCR). The DCR compiled data from federal and state agencies, planning district commissions, non-profit organizations, and localities to create the Conservation Lands database. Data on the ownership of land in West Virginia was obtained through the West Virginia Gap Analysis Project, which was a collaboration between several state and federal agencies and West Virginia University's Natural Resource Analysis Center. Land stewardship data for both states included federal lands (National Wildlife Refuges, National Forests, National Forest Recreation Areas, National Forest Scenic Areas, National Forest Wilderness Areas, Department of Defense Sites,

National Park Service, National Historic Parks, National Recreation Areas, National Rivers, and Wild and Scenic Riverways); state lands (State Parks and Recreation Areas, State School Lands, WVDNR Wildlife Management Areas, VDGIF Wildlife Management Areas), local government lands (parks), and non-governmental organization lands. Because these databases contained information on all public land within each state, land that was not classified in these GIS (Geographical Information Systems) databases were assumed to be privately owned.

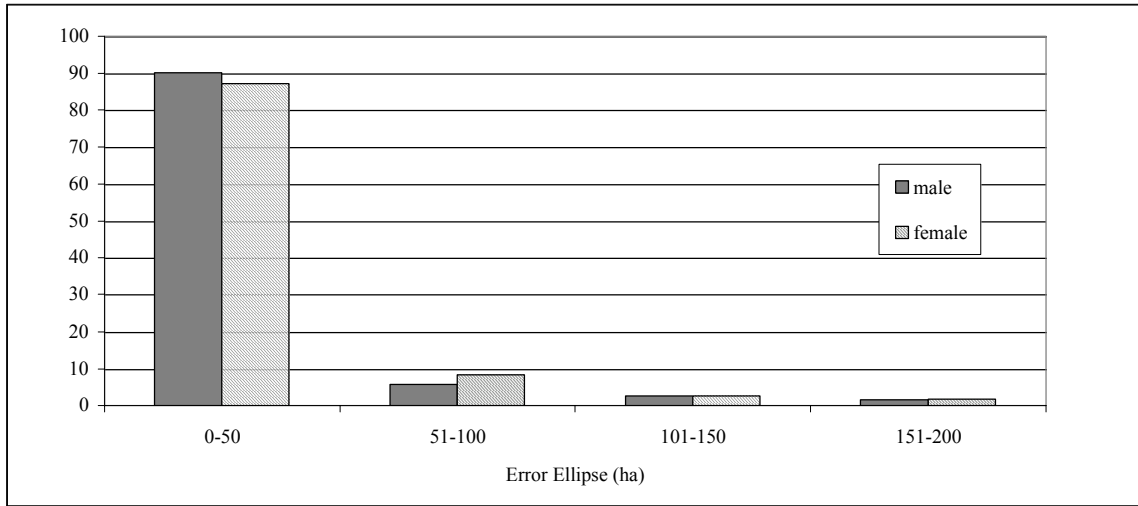


Figure 2. Percentage of locations with error ellipses (hectares) of male and female bears in the Cooperative Alleghany Bear Study, George Washington and Jefferson National Forest, Virginia, June 1994 through December 2002.

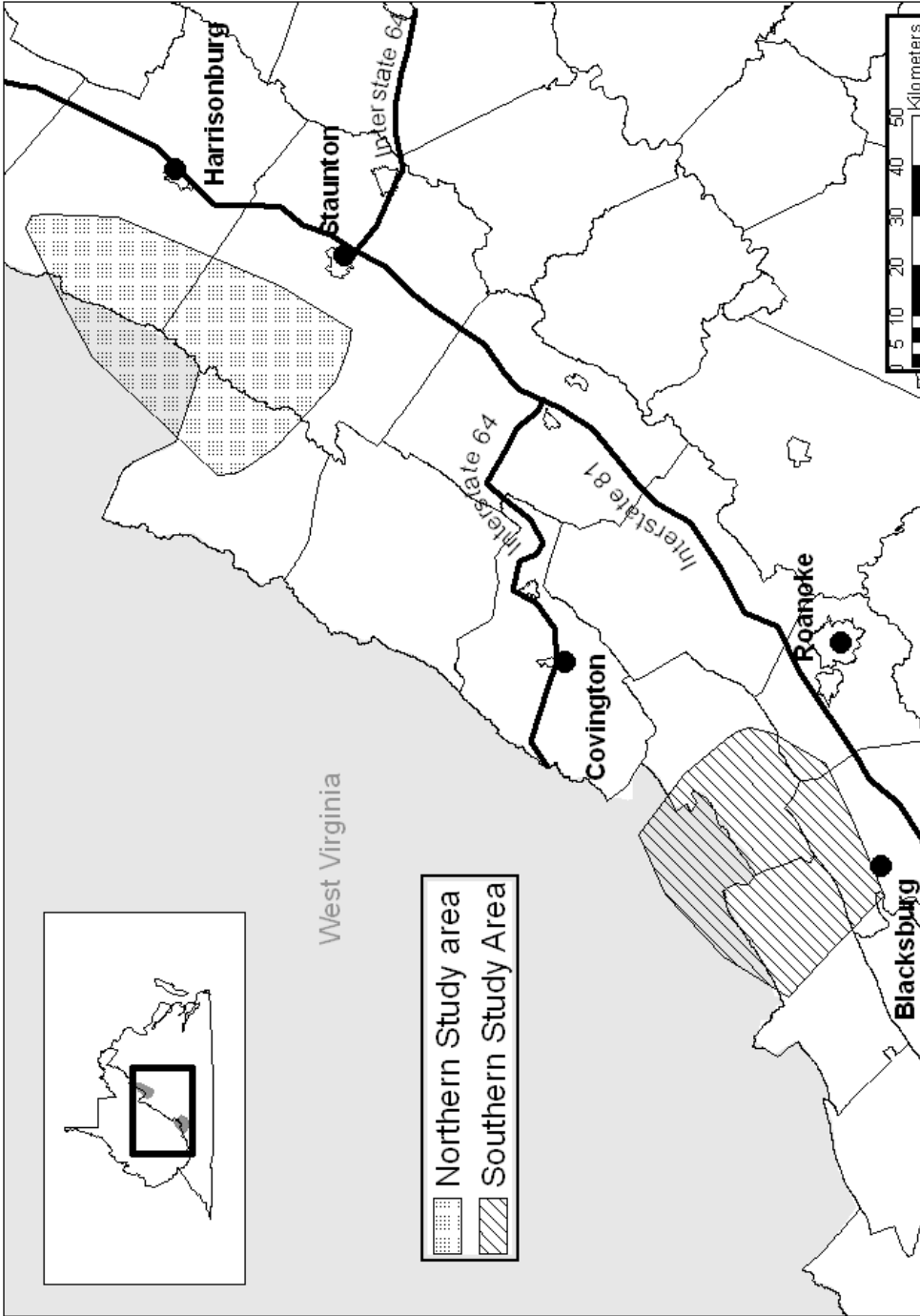


Figure 3. Boundaries of the northern and southern study areas (conglomerate home ranges; 95% MCP) in the Cooperative Alleghany Bear Study, George Washington and Jefferson National Forest, Virginia, June 1994 through December 2002.

Chapter 1. Comparisons of home range estimates generated by the Animal Movements, Home Range, and ABODE extensions.

INTRODUCTION

Background

A variety of techniques and software programs are available to evaluate home-range size and determine patterns of use within the home range (Harris et al. 1990, White and Garrot 1990). Larkin and Halkin (1994) summarized the functionality, user interfaces, and other characteristics of 11 software programs that were available at the time. Other researchers have evaluated differing home range estimators, such as minimum convex polygon, harmonic mean, and kernel (Garton et al. 1985, Boulanger and White 1990, Harris et al. 1990, White and Garrot 1990, Worton 1995). However, few studies have addressed the potential for differences in home range estimates based on the software package the user selects to generate home ranges (Larson and Rodgers 1997). Because of the availability of numerous home range estimators and home range analysis software programs, some users of these programs suspect they are unlikely to produce similar and comparable results, even if the values of the parameters in user-defined algorithms are held constant (Lawson and Rodgers 1997).

Larkin and Halkin (1994) did not test for differences, but reported that different home range values were calculated by the software packages they reviewed. They recommended that computational algorithms and their control parameters should be standardized, though they recognized that some algorithms, such as those that compute the positions of contour lines, are inherently resistant to standardization.

More recently, Lawson and Rodgers (1997) addressed the differences in home range size computed by 5 software programs. They found large differences in the reported home ranges using several home range estimators computed by the differing software programs, and concluded that comparisons of home range size and habitat use of a particular species among research studies could be misleading.

These prior studies evaluated only software programs in which the user-interface was either DOS- or Windows-based. No studies have yet addressed more recent software programs that are designed to work in either Arcview 3.2 or ArcGIS 8x or higher. These programs, offered as downloadable extensions, take advantage of the increasing preference among researchers for programs which permit the user to easily export home range polygons into GIS for habitat analysis (Rodgers and Carr 1998). Currently, the 3 extensions designed for estimating home range size within the ArcGIS environment are Animal Movement Analysis Extension (AMA), developed by Hooge et al. (1999), Home Range Extension (HRE), developed by Rodgers and Carr (1998), and ABODE, developed by Laver (2005).

AMA was designed for use in Arcview 3.2 and allows the user to calculate home range size by a variety of home range estimators, such as kernel, harmonic mean, minimum convex polygon, and Jennrich-Turner bivariate normal. Because the fixed-kernel estimator was selected to estimate home ranges for this study, I will discuss only its use in this extension program. AMA calculates fixed-kernel home ranges using either an ad hoc calculation of a smoothing parameter (H), least square cross validation (LSCV; Silverman 1986), or a user-defined smoothing parameter. The authors' suggested using the ad hoc calculations, because the results are "very close to the LSCV, especially with

large sample sizes,” and using the LSCV takes “significant processing time.” (Hooge et al. 1999).

The Home Range Extension (HRE) is also designed for Arcview 3.2 and allows the user to select the minimum convex polygon, adaptive-kernel, and fixed-kernel estimator to calculate home ranges. To generate a home range using fixed-kernel, the user can specify the smoothing parameter (H) 4 different ways. The first method is subjective because the user defines the smoothing parameter. The second method is to use an automated method, in which H is the optimum value with reference to a known standard distribution (i.e. href; Silverman 1986; Worton 1989, 1995). While the href method is effective when describing a concentrated group of locations, it can potentially oversmooth the utilization distribution since animals tend to have multiple centers of activity in their home range (Rodgers and Carr 1998).

The LSCV method is a third way to select the H value and overcomes the potential problem of oversmoothing a home range that is not unimodal (i.e. multiple centers of activity; Worton 1989). However, it can actually have the reverse affect of href by undersmoothing the utilization distribution (Rodgers and Carr 1998, Sain et al. 1994). A compromise between the href and LSCV methods is a forth option available in HRE, the biased cross-validation (BCV; Rodgers and Carr 1998). Simulation studies have shown that the BCV method performed well and with “reasonable variability” when compared to the LSCV and href method (Sain et al. 1994); however, this method has not been tested in the context of estimating home ranges (Rodgers and Carr 1998).

The third extension, ABODE, is available for ArcGIS version 8x or higher and was designed by Peter Laver, a graduate student at Virginia Polytechnic Institute and

State University. As well as allowing the user to calculate home ranges using MCP and fixed-kernel, ABODE can also generate core home ranges and analyze data for asymptotic relationships. ABODE offers flexibility in selecting parameters to determine the smoothing factor for fixed-kernel home ranges. The user can specify if their data is discretized (i.e. many locations in a dataset overlap), temporal (i.e. collected at a regular time interval), or neither, and define 4 different smoothing functions: User defined, HRef, LSCV, or displacement. The displacement option is a feature not available in the prior 2 extensions; it allows the user to base their smoothing factor on the sampling interval that was used to collect data, whether it was regular or irregular. The smoothing factor is then estimated by calculating the distance between all pairs of consecutive points that fall into the defined time interval. An arithmetic mean is generated, which is the mean displacement in distance units per mean sampling interval (e.g. daily, weekly, monthly); this is used as the smoothing factor.

Justification

Effective management of black bears depends on understanding and predicting home range and habitat needs (Clark et. al. 1993). Home range attributes are helpful in assessing differences between populations and can serve as a general indicator of underlying differences in habitat quality. By understanding the relationship between black bears and their habitat, limiting factors can be identified and effective decisions can be made regarding hunting regulations and forest management. Estimates of home ranges also can aid researchers in gaining insights into an animal's behavior and ecology, such as mating patterns and reproduction, social organization and interactions, foraging and food choices, and limiting resources (Powell 2000). Because many inferences are made

from home range estimates, it is imperative we use methods that are biologically appropriate and most accurately quantify an animal's use of space.

It was not clear to me which method would best quantify movement patterns of black bears that I monitored from 1995-2002 on the Cooperative Alleghany Bear Study (CABS). Thus, I designed a study to evaluate which software program, AMA, HRE, or ABODE, serves as a better method to estimate black bear home ranges.

METHODS

Estimating Home Range Size

For analyses, I used adult black bears from the northern and southern study areas of CABS monitored from January 1995 through December 2002, and only bears that had a minimum of 20 locations. In all 3 extensions, I used fixed-kernel to generate home ranges at the 50%, 75%, and 95% contour; these 3 contour levels are commonly used in home range analyses (personnel observation), therefore results are more applicable.

I selected both the ad hoc LSCV and LSCV as the smoothing parameter when using AMA, the BCV as the smoothing factor when using HRE, and LSCV as the smoothing parameter when using ABODE; these smoothing methods were selected based on the recommendations of the authors of each program. I also generated minimum convex polygons because of their widespread use in studies on animal movements, thus providing measures of comparisons between these results and results reported by other studies on black bears. In addition, because MCP's tend to be sensitive to extreme data points and sample size (Samuel and Fuller 1996) I wanted to compare how the home ranges estimated using AMA, HRE, and ABODE would compare to an estimator known for its tendency to exaggerate home range area. Proc GLM blocked by bear (SAS

Institute, Inc., Cary, NC), with $\alpha=0.05$, was used to test for differences in home range size among the estimators. Post-hoc testing of home range sizes was conducted if $\alpha<0.10$ from the prior test.

RESULTS

One hundred thirty-eight bears with 8,335 locations were used in the analysis (Table 1.1). The number of locations per bear ranged from 20 to 245, with an average of 60.4 locations per bear. Females in both study areas, on average, had more locations per bear than male black bears.

Northern Study Area

Home ranges generated using the 5 estimators differed for adult male black bears at all 3 contours ($P<0.05$; Table 1.2). AMA-generated home ranges were 1.7 to 1.8-fold larger than HRE- and MCP-generated home ranges, respectively. At the 95% contour, ABODE-generated home ranges were similar to home ranges generated using HRE and MCP, while at the 50% contour, ABODE estimates were similar to AMA estimates (Table 1.2). Examples of home range polygons created by the 5 home ranges estimators can be seen in Figures 1.2.

Adult female black bear home ranges also differed at all 3 contours ($P<0.05$; Table 1.2). Excluding the 95% ABODE estimate, both the AMA- and ABODE estimates were considerably larger than the HRE- and MCP estimates; the latter 2 were similar (Table 1.2). At the 50% and 75% contour, AMA estimates were similar to ABODE estimates (Table 1.2). Examples of home range polygons created by the 5 home ranges estimators can be seen in Figure 1.1.

Table 1.1. Summary statistics for radio-collared adult black bears in the George Washington Jefferson National Forests, Virginia, January 1995 – December 2002.

Parameter	Northern study area		Southern study area		Total
	Female	Male	Female	Male	
Number of bears	76	16	41	5	138
Number of locations	5,463	556	2,161	155	8,335
Range of locations	20-245	20-69	20-145	20-53	20-245
\bar{x} location/bear	71.9	34.8	52.7	31.0	60.4

^a Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

Table 1.2. Comparisons of overall home range size (km²; S.E.) of adult black bears using 5 home range estimators. George Washington Jefferson National Forests, Virginia, January 1995 – December 2004.

Region	Program	Estimator	N	Male			Female		
				95%	75%	50%	95%	75%	50%
North	AMA ^a	Ad hoc	16	105.9 A (18.7)	40.6 A (9.3)	18.9 A (4.7)	33.5 A (4.8)	11.8 A (1.5)	4.9 A (0.6)
		LSCV	16	109.6 A (19.3)	42.5 A (9.7)	19.8 A (4.9)	34.3 A (5.1)	12.3 A (1.6)	5.2 A (0.7)
	HRE ^b	BCV	16	61.8 B (11.5)	27.7 BC (5.4)	12.2 B (2.5)	16.8 C (1.4)	7.3 B (0.6)	3.2 B (0.3)
	ABODE	LSCV	16	75.2 B (11.5)	36.6 AB (5.7)	17.4 A (2.8)	24.6 B (2.5)	10.9 A (1.0)	5.2 A (0.5)
	MCP ^c		16	62.6 B (9.9)	20.8 C (3.9)	--	18.4 BC (2.3)	6.9 B (0.6)	--
				F _{4,14} =9.31 P<0.0001	F _{4,15} =4.89 P=0.002	F _{3,15} =3.56 P=0.02	F _{4,75} =10.99 P<0.0001	F _{4,74} =10.25 P<0.0001	F _{3,75} =7.71 P<0.0001
South	AMA	Ad hoc	5	399.9 AB (109.6)	144.8 (44.4)	44.3 AB (11.1)	63.0 A (8.4)	26.5 A (3.4)	11.7 A (1.7)
		LSCV	5	416.4 A (115.1)	151.6 (46.6)	46.2 AB (11.0)	64.0 A (8.8)	27.3 A (3.6)	12.1 A (1.8)
	HRE	BCV	5	174.6 C (74.7)	80.7 (37.1)	18.5 B (3.4)	47.7 B (4.9)	21.2 B (2.0)	9.2 B (0.9)
	ABODE	LSCV	5	316.3 BC (113.5)	158.0 (50.4)	61.5 A (22.3)	45.6 B (4.1)	25.5 AB (3.0)	12.2 A (1.4)
	MCP		5	244.7 BC (94.6)	143.5 (57.1)	--	37.8 B (3.9)	16.8 C (2.4)	--
				F _{4,4} =3.40 P=0.03	F _{4,4} =0.96 P=0.46	F _{3,3} =2.91 P=0.09	F _{4,38} =7.28 P<0.0001	F _{4,40} =8.02 P<0.0001	F _{3,40} =2.67 P=0.05

^aAMA: Animal Movements Extension

^bHRE: Home Range Extension

^cMCP: Minimum Convex Polygon

Southern Study Area

Home range estimates for adult males on the southern study area differed only at the 95% contour ($F_{4,4}=3.40$ $P=0.03$; Table 1.2); HRE estimates were 2.3- to 2.4-fold smaller than AMA estimates. However, at the 50% contour the p-value approached significance ($F_{3,3}=2.91$, $P=0.09$; Table 1.2); ABODE estimates at the 50% contour were 3.3-fold larger than HRE estimates (61.5 km² versus 18.5 km²; Table 1.2). Examples of home range polygons created by the 5 home ranges estimators can be seen in Figure 1.4.

Home range estimates for adult females on the southern study area differed among the 5 estimators at all contour levels ($P<0.01$; Table 1.2). MCP estimates were the smallest, while AMA estimates were the largest; the difference between the 2 was 1.6- to 1.7-fold (Table 1.2). HRE estimates were 1.3-fold smaller than AMA estimates at all 3 contours (Table 1.2). Examples of home range polygons created by the 5 home range estimators can be seen in Figure 1.3.

DISCUSSION

I found significant differences in the home ranges estimated by the 3 software programs offered as extensions in Arcview 3.2 and ArcGIS (Table 1.2). Overall, AMA estimates differed from HRE- and MCP estimates, within each subset of data (i.e. northern males, northern females, southern males, southern females; Table 1.2). In one case (southern males; Table 1.2), the difference in mean home range between AMA and HRE was 2.4-fold, or 241.8 km². AMA-estimates also were larger than MCP estimates. Because MCP's tend to be sensitive to extreme data points (Samuel and Fuller 1996) and include areas of non-use, they tend to overestimate the area used by an animal. But, it

appears that the AMA extension might be more sensitive to outlier locations, thus exaggerating the area used by an animal.

While it is biologically important to recognize brief excursions outside the home range that outlier locations represent, it also is important to identify core home range use; one needs to be able to differentiate between areas of core use and areas in which excursions occurred. An area used more heavily represents a core in the home range that is more important than other areas (Powell 2000). By including outlier locations, the core home range is not only exaggerated, but the occurrence of an excursion might not be obvious. In addition, an area that received little use by an animal might be given more importance than it should receive. While these potential biases caused by outlier locations were observed in several home ranges generated by AMA and ABODE, they were not observed in the home ranges generated by HRE and MCP using the same data (Figure 1.1: Bear ID 204, Bear ID 305; Figure 1.3: Bear ID 10011; Figure 1.4: Bear ID 10140, Bear ID 10177). Laver (2005) found that the AMA extension was unable to distinguish areas of low probability within a distribution, thus it included areas of non-use; depending on the animal, some of these areas, such as a body of water, were not likely part of the animal's home range.

While examples of AMA estimates that were larger than HRE and MCP estimates were observed in all 4 subsets of data (Figure 1.1: Bear ID 72, Bear ID 165, Bear ID 204; Figure 1.2: Bear ID 76; Figure 1.3: Bear ID 10139, Bear ID 10253; Figure 1.4: Bear ID 10140, Bear ID 10317), individual bears' mean home ranges showed exceptions to this pattern. In some cases HRE- and/or MCP-generated home ranges were larger than AMA-generated home ranges at varying resolutions (HRE > AMA: Figure 1.1, Bear ID 73;

Figure 1.3, Bear ID 10044, Bear ID 10185, Bear ID 10264; MCP > AMA: Figure 1.1, Bear ID 15, Bear ID 73; Figure 1.2; Bear ID 177; Figure 1.3, Bear ID 10254; Figure 1.4, Bear ID 10177).

Differences in home range size among the home range extensions varied in statistical significance among the subsets of data. At the 50%, 75%, and 95% contours, home range size differed ($P < 0.05$) for male and female black bears in the northern study area and females black bears in the south. In contrast, I observed statistical significance only at the 95% contour for males in the southern study area. Sample size differed among subsets, possibly explaining the difference in statistical results observed; sample size varied from a low of 5 male bears in the southern study area to a high of 76 females in the northern study area. Increasing sample size normally increases the power of statistical results (Cohen 1988), thus the results we observed with northern females might best reflect the actual differences that occur among the differing home range extensions.

Concern about the number of locations necessary to generate accurate home ranges is prevalent among researchers, and several studies have attempted to address this issue (Leban et al. 2001). One concern is that home ranges generated with too few locations will not accurately reflect the true movements of the animal. Seaman et al. (1999) found that small sample sizes (i.e. locations per animal) overestimated home range area; however, Hansteen et al. (1997) found that small sample sizes generally underestimated home range size. While differences in the results of these 2 studies might be explained by the use of different programs to generate home ranges, and differing methods used to determine the smoothing factor and to define home range area, these contradicting conclusions make it difficult to determine how the number of locations

affect home range results. While I did not test the effect of the number of locations on the size and configuration of home ranges generated through each extension, I did include a representation of individual bears with varying degrees of locations (20-245 locations; Figures 1.1 through 1.4). At one extreme, Bear ID 305 (Figure 1.1) had 20 locations; the AMA, HRE, and ABODE extensions included an outlier location at the 95% resolution, while the MCP-generated home range did not include this outlier. Additionally, the AMA and ABODE-generated home range configurations were circular and included large areas that had no locations. This phenomenon also was observed for bear ID 204 (Figure 1.1), who had 77 locations; AMA- and ABODE-generated home ranges were circular and included areas with no locations. Though bear ID 204 had 3.9 times more locations than bear ID 305, AMA and ABODE still placed weight on the outlier locations, causing exaggerations in home range size and configuration.

Besides exaggerated home ranges, I also observed the AMA extension had difficulty with overlapping locations when using the ad hoc LSCV as the smoothing parameter. When location datasets contained overlapping locations, the AMA extension could not generate a home range because it would select $h = 0$ as a smoothing factor. This problem was recognized by Silverman (1986), who observed that when discretization is severe and overlap between points is extensive, LSCV will choose a smoothing parameter that tends to zero. However, this problem often happened with only 2 overlapping locations in the dataset. To remedy this problem I removed the location, if I could identify it, and reran the dataset through the extension. While I was then able to generate a home range with the altered dataset, this introduced bias and potential error, since a data point was removed. Using the same dataset prior to alterations, I was able to

generate home ranges in the HRE and ABODE extensions without any need to alter the data. But discretization might have been a factor in my home range results from the HRE extension; several bears' home ranges were depicted as contours around single locations or small clusters, resulting in small islands throughout the distribution (Figure 1.1: Bear ID 31; Figure 1.2: Bear ID 177; Figure 1.4: Bear ID 10140, Bear ID 10177). This visualization is often a clue that discretization is occurring in the data (Laver 2005).

Because the AMA extension was developed earlier than the HRE and ABODE extensions, it is better known among researchers and has become increasingly popular for home range analyses. At the 18th Eastern Black Bear Workshop (2005, Tallahassee, Florida), all home ranges that were discussed in presentations were generated using AMA (personal observation). Besides its easy integration with Arcview 3.2, another attraction of the AMA extension is that it allows the batch processing of data files, a tool not available in the HRE extension. However, this option is available in ABODE.

Due to the results of this study, I chose to use the HRE extension for all my analyses of black bear home ranges. Not only does it offer greater flexibility in selecting a smoothing factor, but I have concerns over the difference in size between AMA-, HRE- and MCP-generated home ranges. HRE-generated home ranges, and to some extent MCP-generated home ranges, are biologically more sound when compared to the results of other studies across North America, in particular a study performed by J. Higgins (1997) in the first 2 years of CABS (Appendix A). While I recognize that direct comparisons are limited, due to variation in home range size from a variety of factors such as regional differences, sampling regimen and size, analysis method, and software program used, these studies do provide a framework for identifying patterns of home

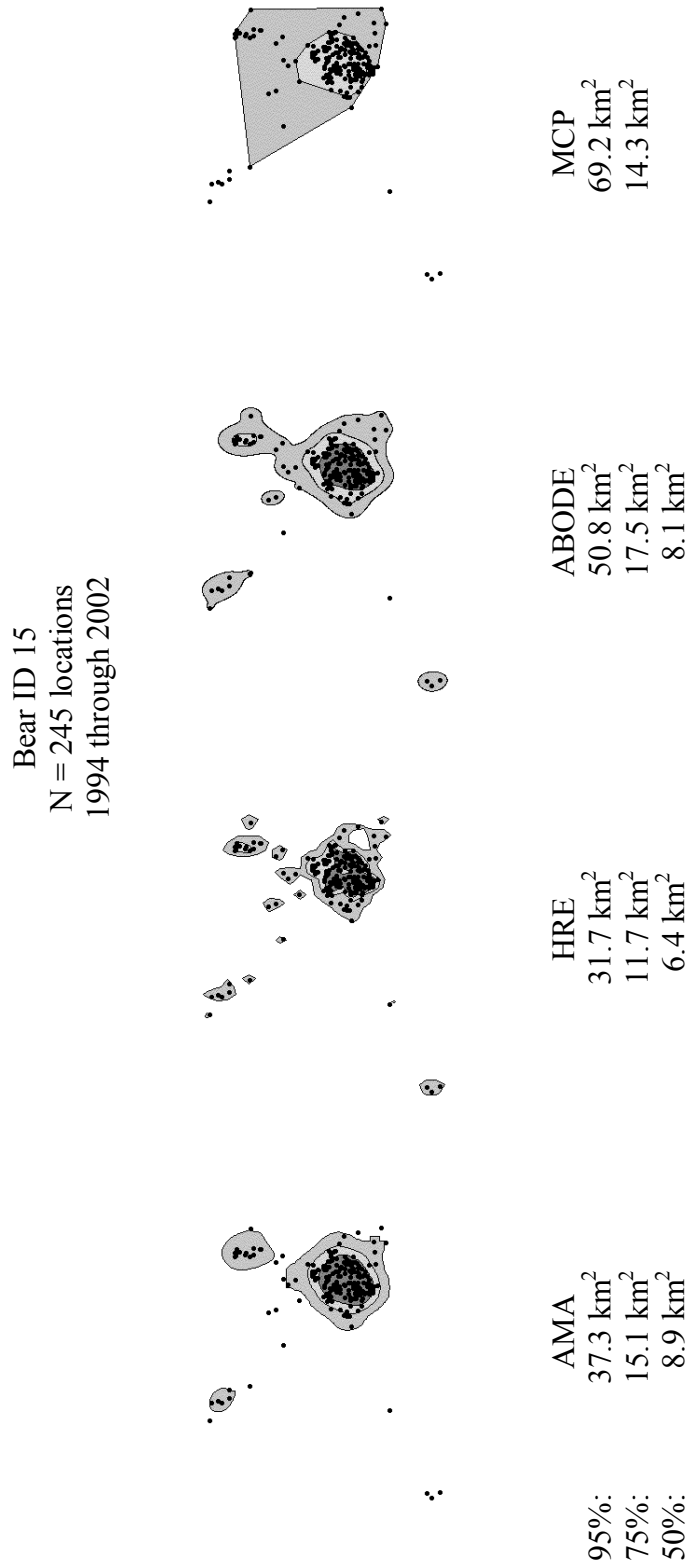
range characteristics among studies. Anecdotal evidence from my field observations while monitoring these bears also support the home range estimates generated from HRE. The amount of area that the AMA extension estimated was biologically improbable based on my familiarity with the study area and the bears monitored, and my personal observations while collecting telemetry locations from the ground and air.

I recognize that some of the home ranges generated by HRE also seem unreasonable (i.e. Bear ID 177); this shows that every program has difficulty generating home ranges and the user must be aware of these faults. For many years, researchers have tried to move beyond minimum convex polygons and create methods that better described an animal's home range. Perhaps minimum convex polygons should be reconsidered due to the simplicity of their design; they are easily understood and less likely to be biased by the choices a researcher makes, such as type of home range (fixed-kernel, adaptive kernel, harmonic), home range estimator software program, and smoothing factor, to list just a few.

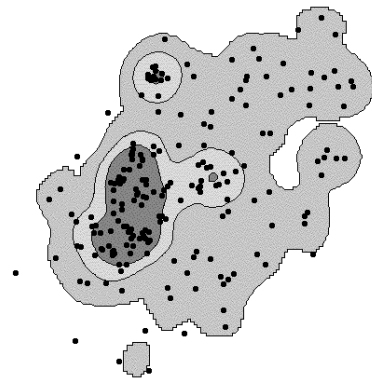
Besides wanting to select the home range software I felt best represented bear movements on our study area, I also was concerned that with the increasing convenience these software programs offer, many researchers use them without questioning their resulting home range estimates. With the heavy reliance placed on home ranges to help draw conclusions on animal movement patterns and habitat use, newer programs should be tested for biological soundness and reliability. Inaccurate estimates of home ranges could lead to faulty inferences regarding an animal's use of space. Forethought should be used in deciding what type of software program one should use to generate ranges; one cannot assume that different software packages will yield similar results. This assumption

leads to the inability to make valid comparisons among studies and the continuation of non-standardization in handling animal location data (Lawson and Rodgers 1997). Until there is a standard comprehensive analysis program, researchers should assess how the available software programs best meet their specific objectives and particular species and, if possible, be aware of the programming and algorithms used in the home range software packages. Researchers often run a pilot study to test the feasibility of addressing a research question and to identify any potential weaknesses in the initial experimental design. This vigilance in maintaining proper scientific methodology and statistical design must also be carried over into the post-experiment phase of the study; once the data are collected, there continues to be a need to perform tests to determine the best method of data analysis.

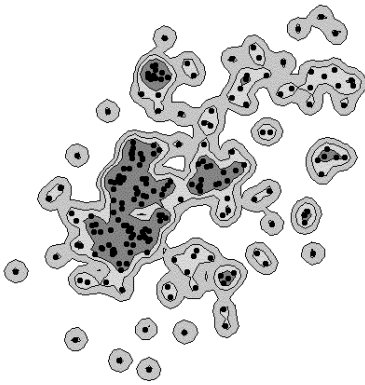
Figure 1.1. 95%, 75%, and 50% fixed-kernel home ranges generated with Animal Movements Analysis (AMA), Home Range Extension (HRE), and ABODE, and 95% and 75% minimum convex polygon (MCP) home ranges of adult female black bears (arranged chronologically by Bear ID number) in the northern study area of the Cooperative Alleghany Bear Study (CABS), George Washington and Jefferson National Forest, Virginia. June 1994 through December 2002. AMA-generated fixed-kernel home ranges using LSCV are not pictured due to the similarity with the ad hoc home ranges.



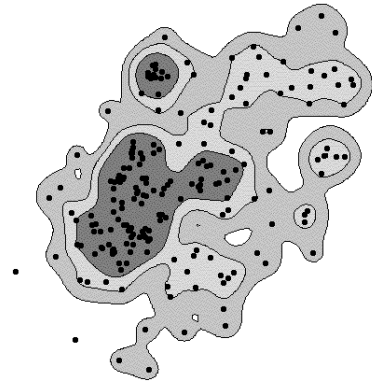
Bear ID 31
 N = 226 locations
 1994 through 2000



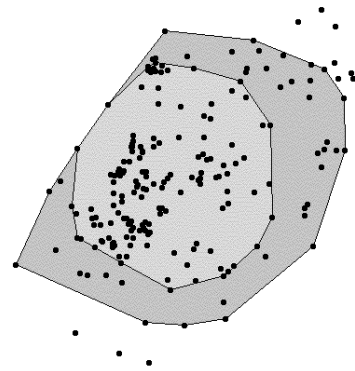
AMA
 95%: 11.7 km²
 75%: 2.8 km²
 50%: 1.1 km²



HRE
 95%: 7.9 km²
 75%: 3.6 km²
 50%: 1.5 km²

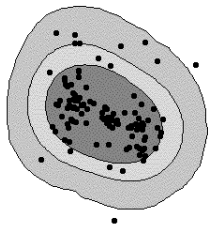


ABODE
 95%: 11.8 km²
 75%: 5.8 km²
 50%: 2.4 km²

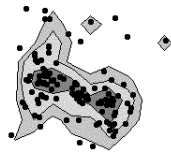


MCP
 95%: 11.2 km²
 75%: 5.9 km²

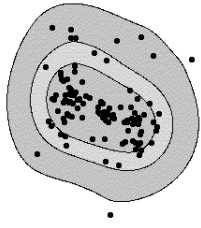
Bear ID 72
 N = 122 locations
 1997 through 1998



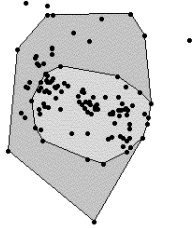
AMA
 95%: 33.7 km²
 75%: 17.2 km²
 50%: 9.3 km²



HRE
 10.6 km²
 5.9 km²
 1.8 km²

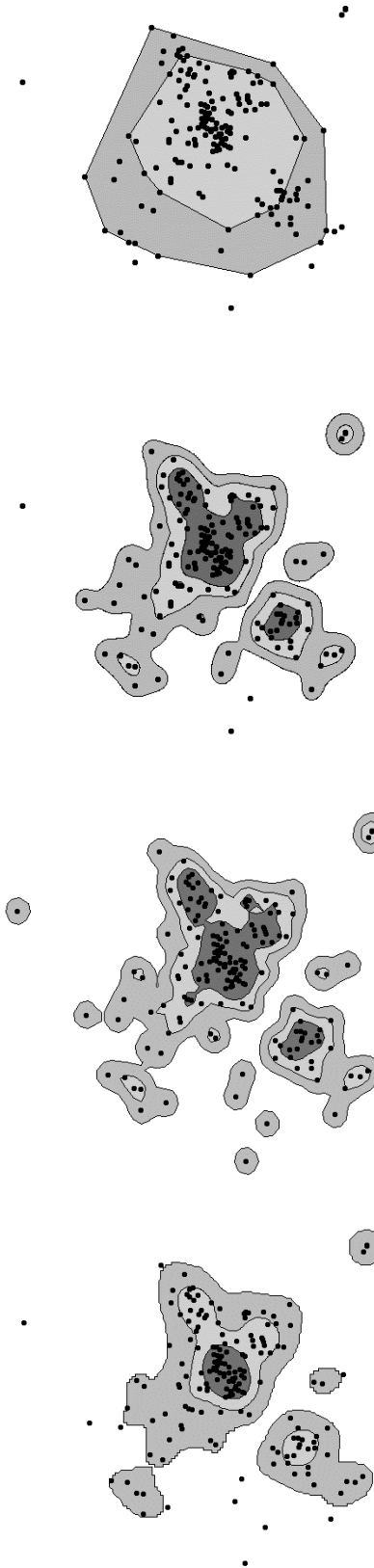


ABODE
 31.6 km²
 14.4 km²
 7.3 km²



MCP
 17.3 km²
 6.6 km²

Bear ID 73
 N = 173
 1994 through 1999



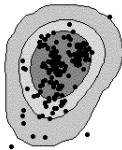
AMA
 95%: 13.9 km²
 75%: 3.5 km²
 50%: 0.9 km²

HRE
 17.1 km²
 7.4 km²
 3.2 km²

ABODE
 18.4 km²
 8.2 km²
 3.5 km²

MCP
 21.2 km²
 10.0 km²

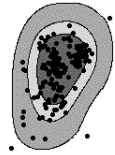
Bear ID 165
 N = 203 locations
 1995 through 2002



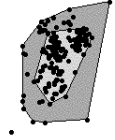
95%: AMA
 31.2 km²
 75%: 15.4 km²
 50%: 7.8 km²



95%: HRE
 11.6 km²
 75%: 5.6 km²
 50%: 1.2 km²

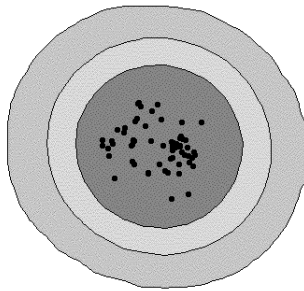


95%: ABODE
 8.3 km²
 75%: 3.9 km²
 50%: 1.6 km²

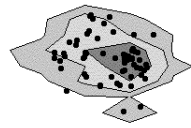


95%: MCP
 18.8 km²
 75%: 6.4 km²

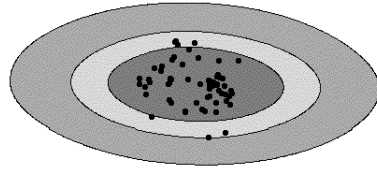
Bear ID 204
 N = 77 locations
 1995 through 2000



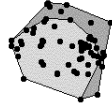
95%: AMA
 140.9 km²
 75%: 79.7 km²
 50%: N/A



HRE
 23.8 km²
 11.6 km²
 3.0 km²

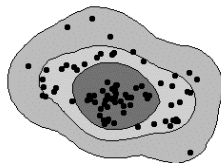


ABODE
 21.5 km²
 11.2 km²
 5.3 km²



MCP
 14.0 km²
 10.1 km²

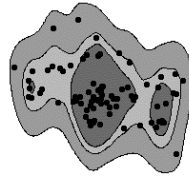
Bear ID 300
 N = 92 locations
 1996 through 2000



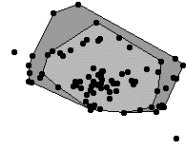
95%: 31.3 km²
 75%: 13.8 km²
 50%: 5.6 km²



HRE
 18.6 km²
 8.8 km²
 3.2 km²



ABODE
 4.4 km²
 2.3 km²



MCP
 14.4 km²
 9.4 km²

Bear ID 305
 N = 20 locations
 1999 through 2000

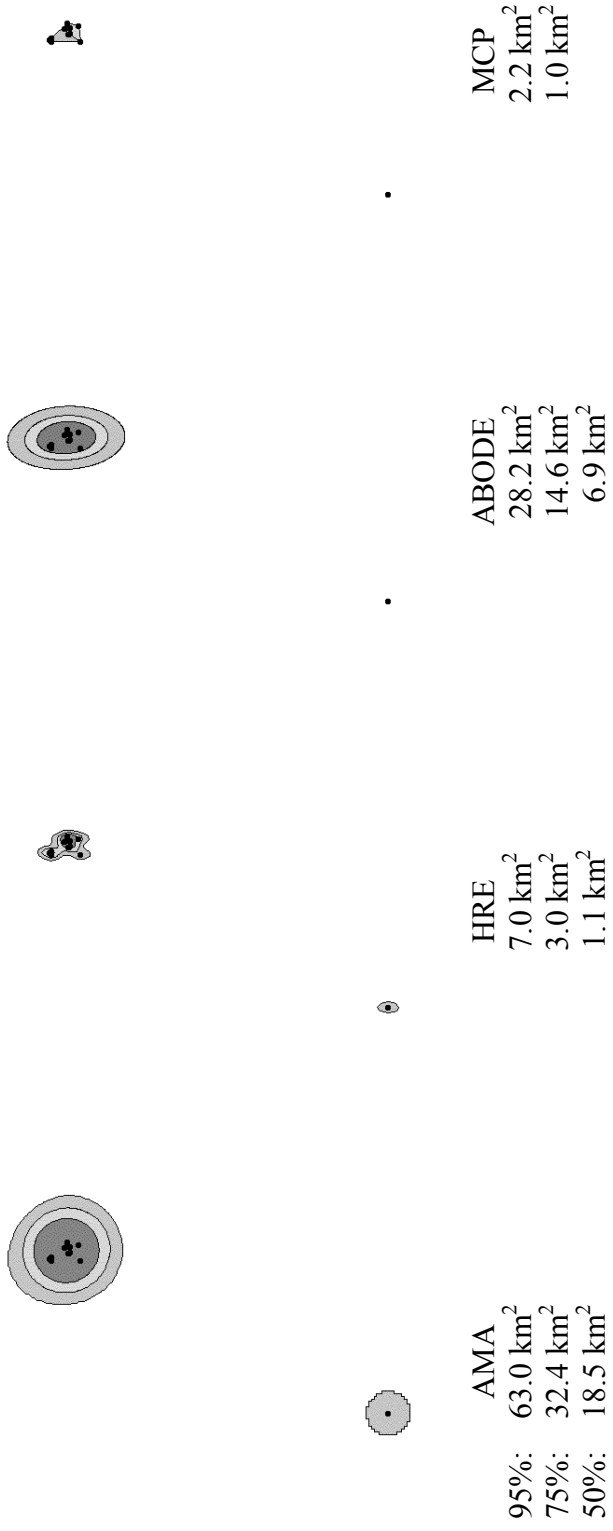
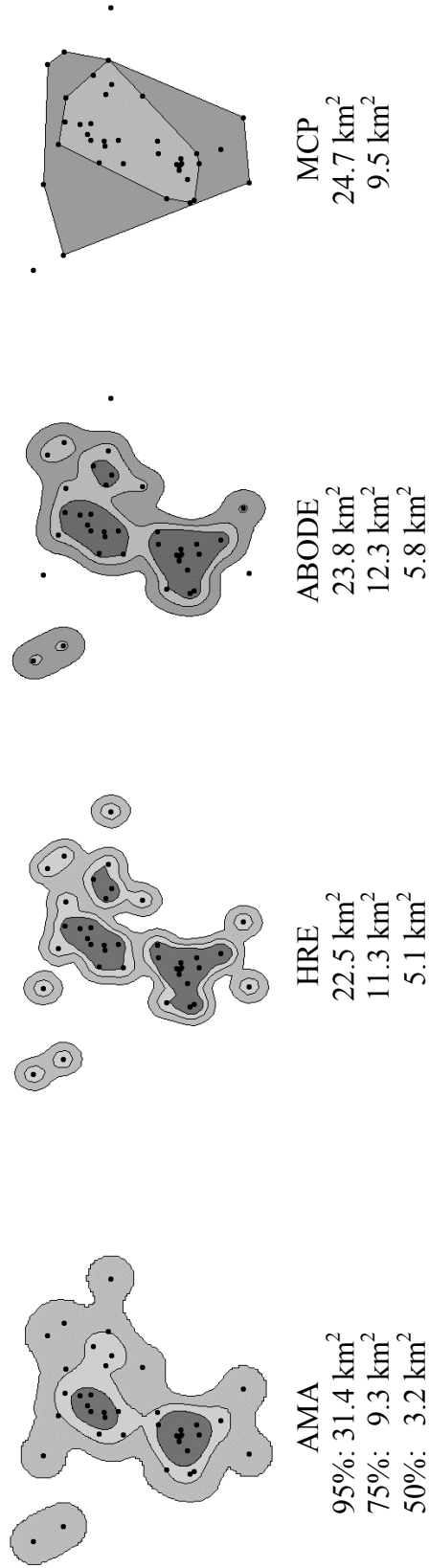
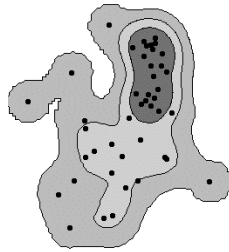


Figure 1.2. 95%, 75%, and 50% fixed-kernel home ranges generated with Animal Movements Analysis (AMA), Home Range Extension (HRE), and ABODE, and 95% and 75% minimum convex polygon (MCP) home ranges of adult male black bears (arranged chronologically by Bear ID number) in the northern study area of the Cooperative Alleghany Bear Study (CABS), George Washington and Jefferson National Forest, Virginia. June 1994 through December 2002. AMA-generated fixed-kernel home ranges using LSCV are not pictured due to the similarity with the ad hoc home ranges.

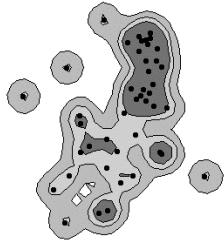
Bear ID 12
 N = 41 locations
 1994 through 1995



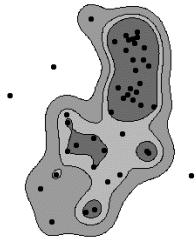
Bear ID 76
 N = 54 locations
 1995 through 1998



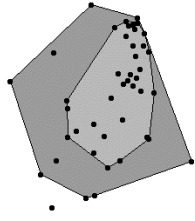
AMA
 95%: 56.0 km²
 75%: 21.1 km²
 50%: 6.3 km²



HRE
 40.7 km²
 19.7 km²
 8.6 km²

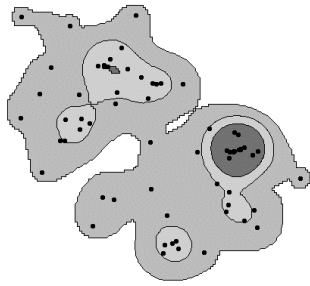


ABODE
 38.5 km²
 21.5 km²
 10.5 km²

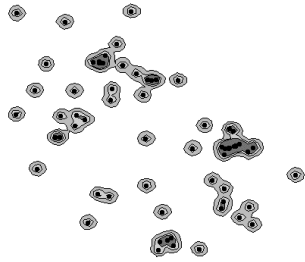


MCP
 39.1 km²
 15.1 km²

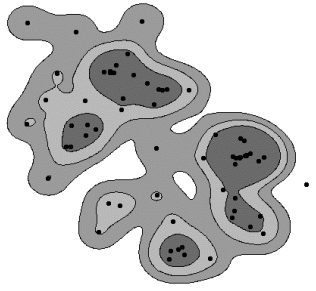
Bear ID 177
 N = 69 locations
 1995 through 2002



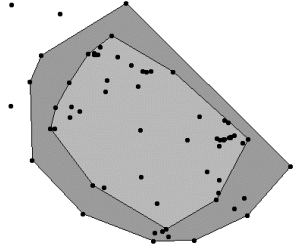
AMA
 95%: 135.0 km²
 75%: 32.0 km²
 50%: 6.5 km²



HRE
 27.5 km²
 10.8 km²
 3.5 km²

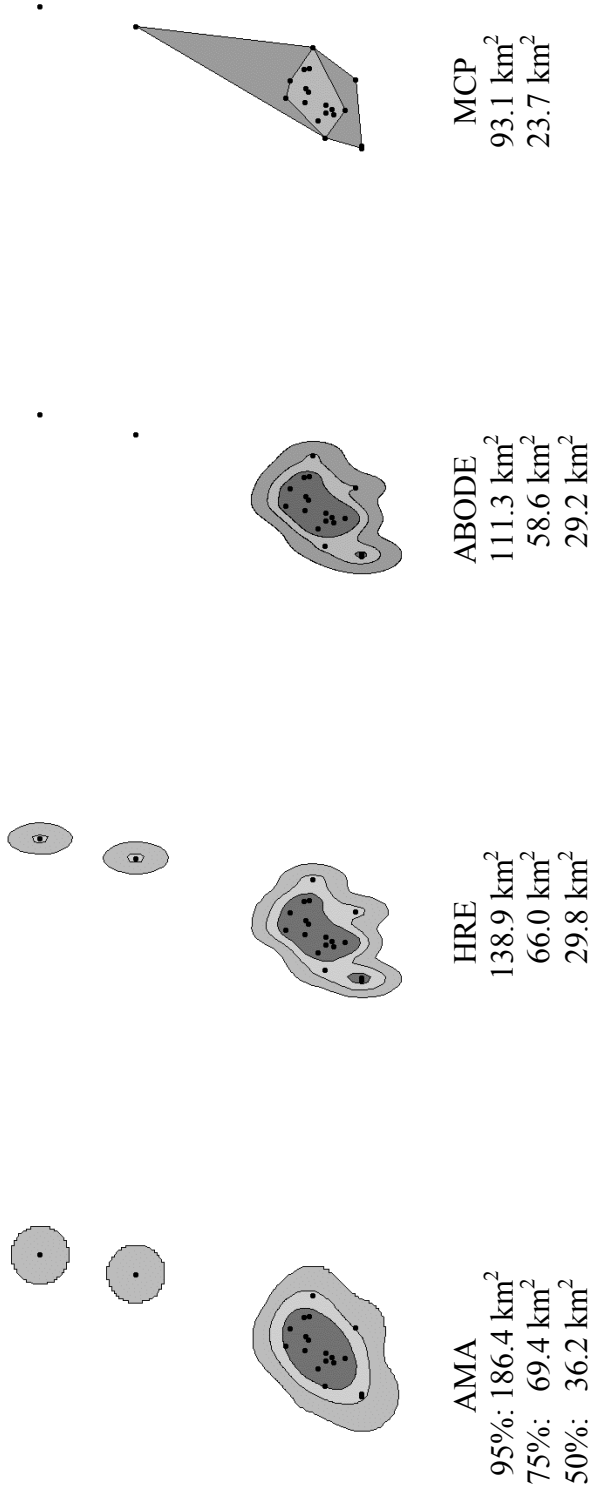


ABODE
 137.7 km²
 67.5 km²
 29.7 km²



MCP
 112.4 km²
 65.1 km²

Bear ID 193
 N = 20 locations
 1997



Bear ID 462
 N = 30 locations
 1998 through 1999

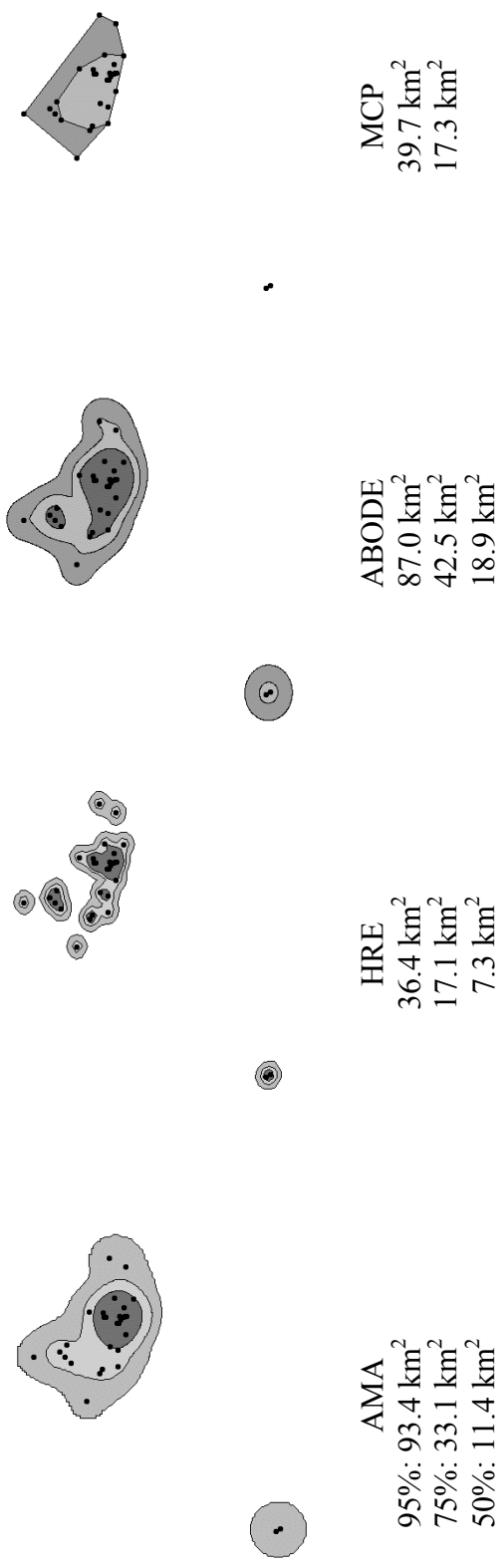
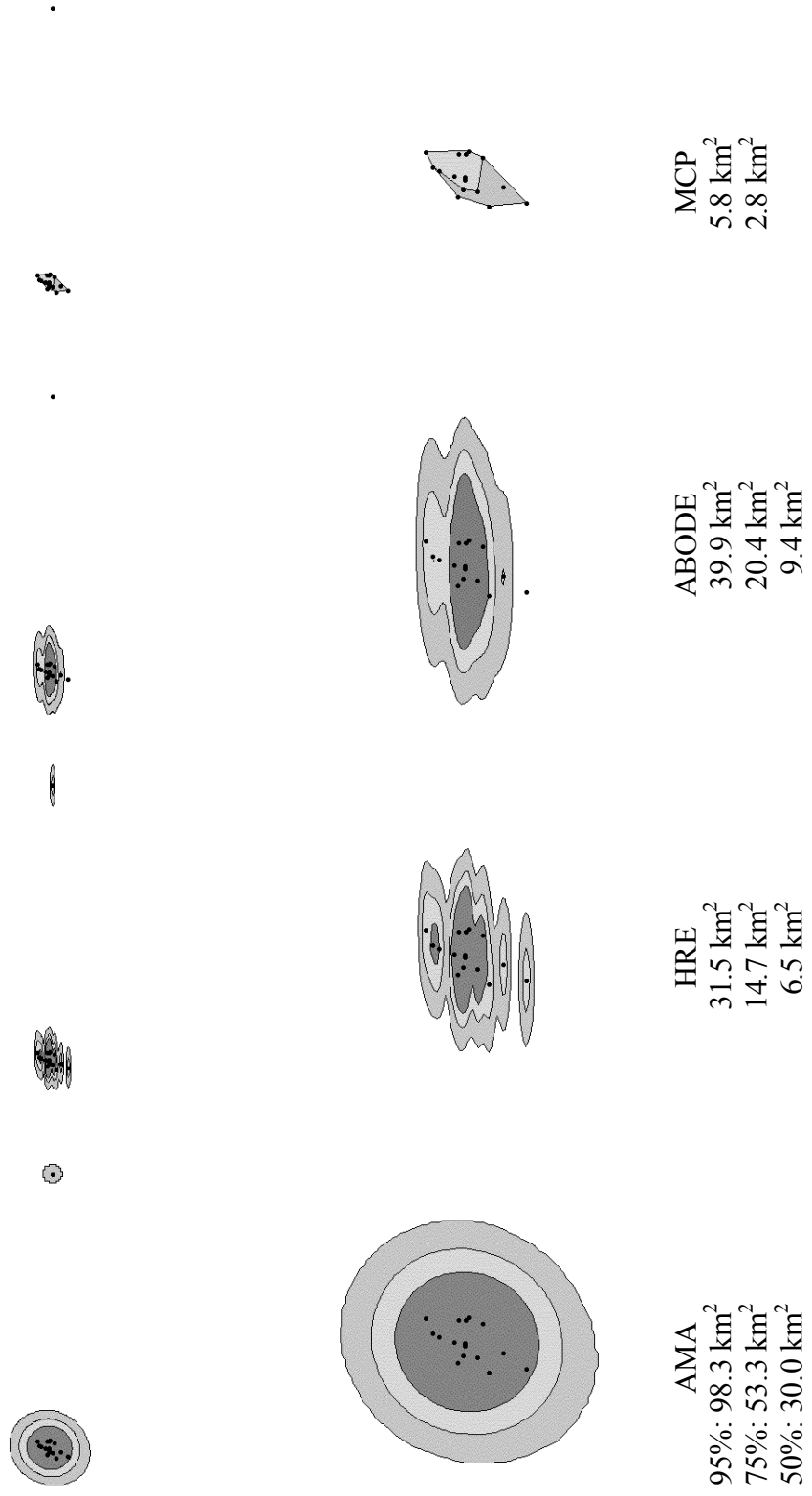


Figure 1.3. 95%, 75%, and 50% fixed-kernel home ranges generated with Animal Movements Analysis (AMA), Home Range Extension (HRE), and ABODE, and 95% and 75% minimum convex polygon (MCP) home ranges of adult female black bears (arranged chronologically by Bear ID number) in the southern study area of the Cooperative Alleghany Bear Study (CABS), George Washington and Jefferson National Forest, Virginia. June 1994 through December 2002. AMA-generated fixed-kernel home ranges using LSCV are not pictured due to the similarity with the ad hoc home ranges.

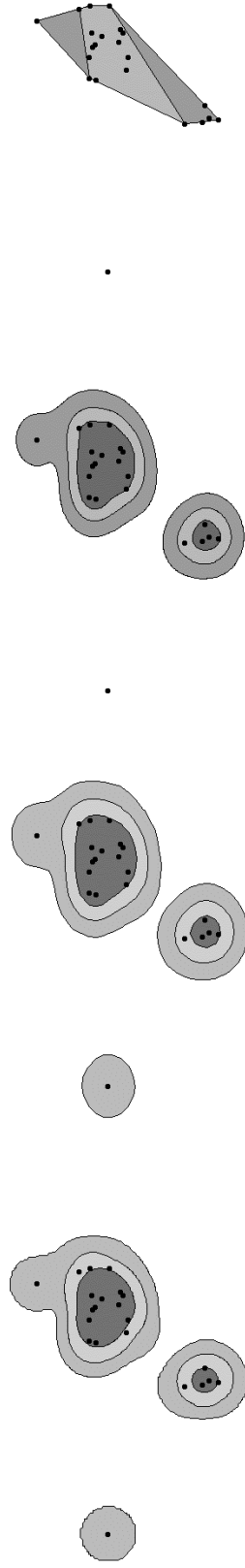
Bear ID 10011

N = 22 locations

1995 through 1996, 1998



Bear ID 10044
 N = 25 locations
 1995 through 1998



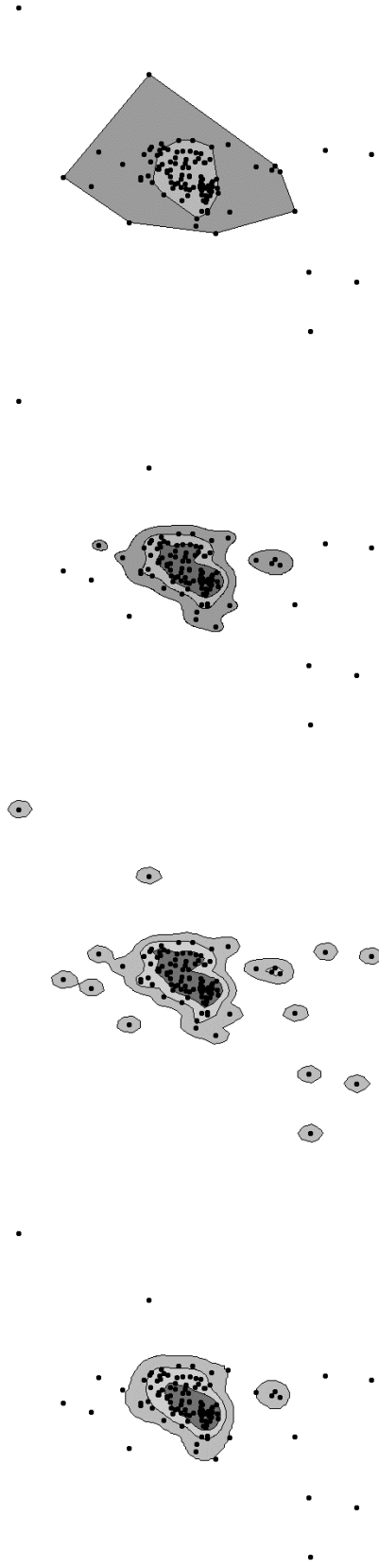
AMA
 95%: 33.3 km²
 75%: 14.0 km²
 50%: 6.0 km²

HRE
 38.0 km²
 16.5 km²
 7.6 km²

ABODE
 28.8 km²
 13.9 km²
 6.9 km²

MCP
 13.2 km²
 7.6 km²

Bear ID 10047
 N = 135 locations
 1995 through 2002



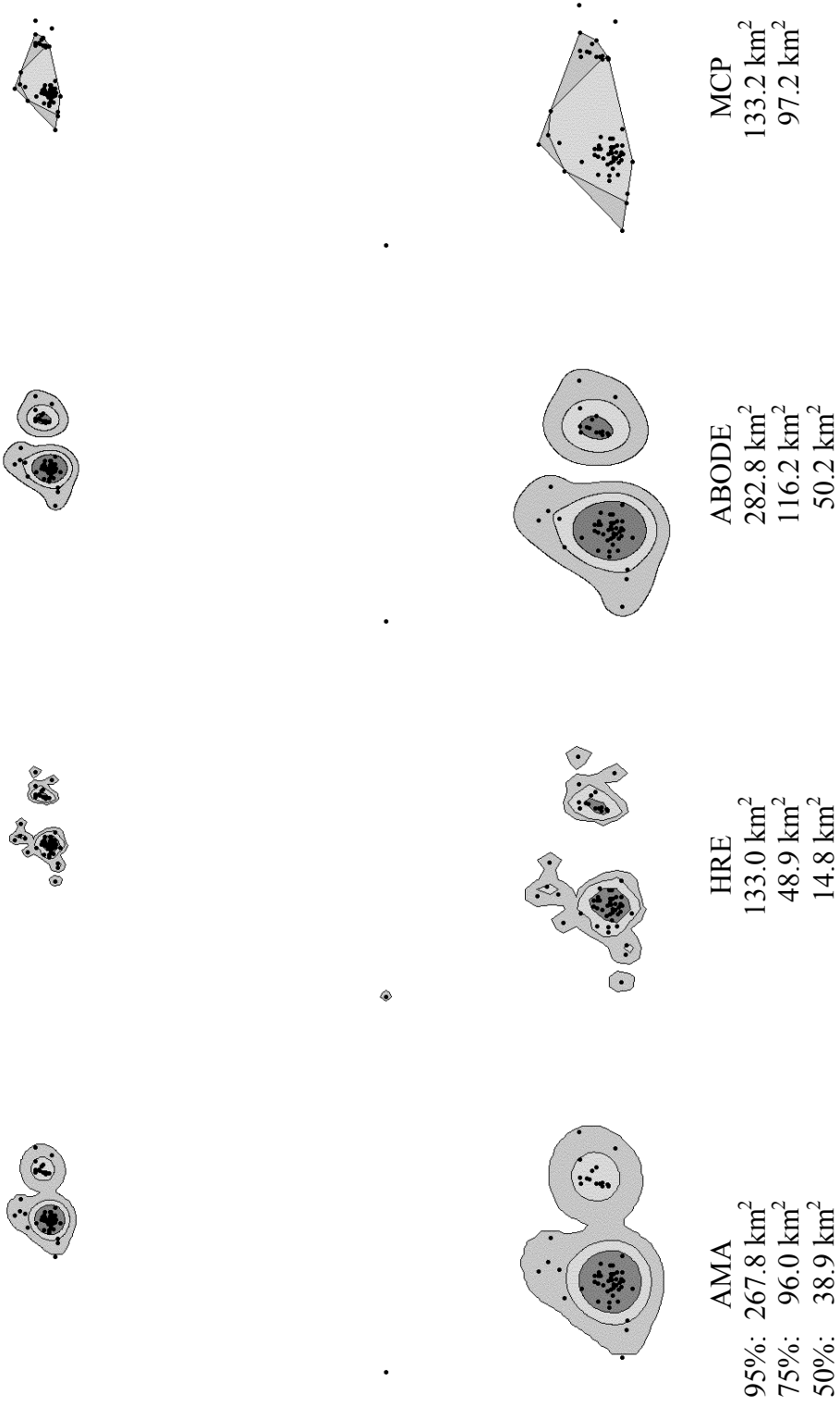
AMA
 95%: 35.5 km²
 75%: 33.1 km²
 50%: 11.4 km²

HRE
 36.4 km²
 17.1 km²
 7.3 km²

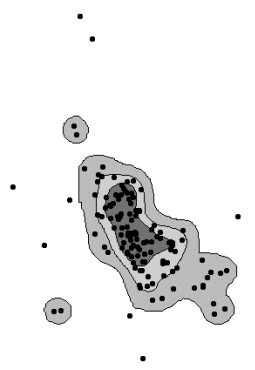
ABODE
 87.0 km²
 42.5 km²
 18.9 km²

MCP
 39.7 km²
 17.3 km²

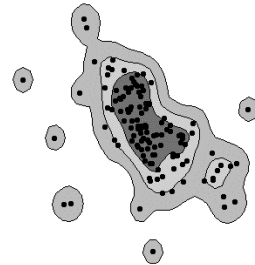
Bear ID 10112
 N = 64 locations
 1996 through 2002



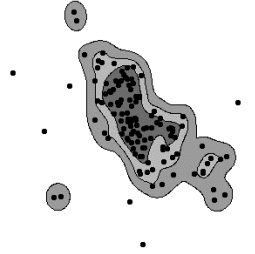
Bear ID 10139
 N = 145 locations
 1998 through 2002



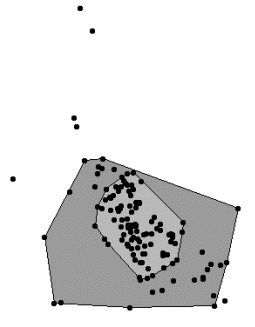
AMA
 95%: 52.5 km²
 75%: 33.1 km²
 50%: 11.4 km²



HRE
 36.4 km²
 17.1 km²
 7.3 km²

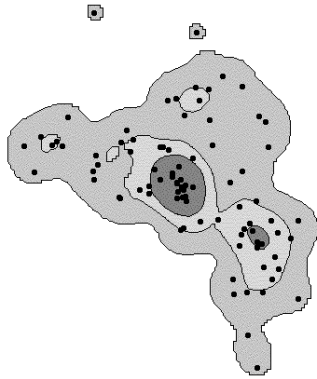


ABODE
 87.0 km²
 42.5 km²
 18.9 km²

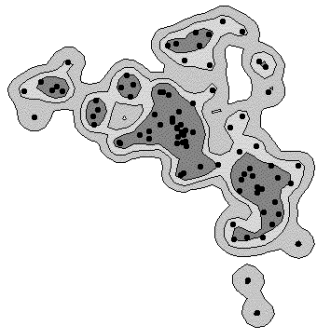


MCP
 39.7 km²
 17.3 km²

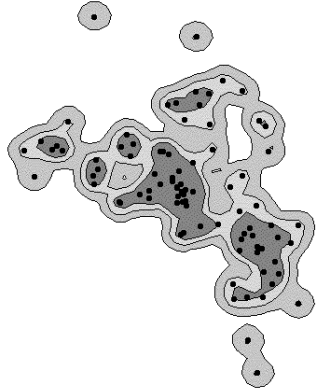
Bear ID 10185
 N = 96 locations
 1999 through 2002



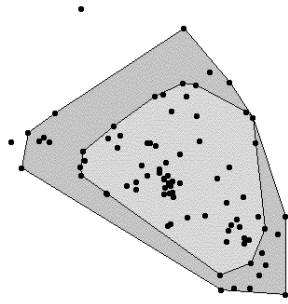
AMA
 95%: 47.3 km²
 75%: 12.0 km²
 50%: 3.0 km²



HRE
 40.4 km²
 20.3 km²
 9.4 km²



ABODE
 87.0 km²
 42.5 km²
 18.9 km²



MCP
 39.7 km²
 17.3 km²

Bear ID 10227
 N = 84 locations
 2000 through 2002



AMA
 95%: 54.7 km²
 75%: 33.1 km²
 50%: 11.4 km²



HRE
 36.4 km²
 17.1 km²
 7.3 km²

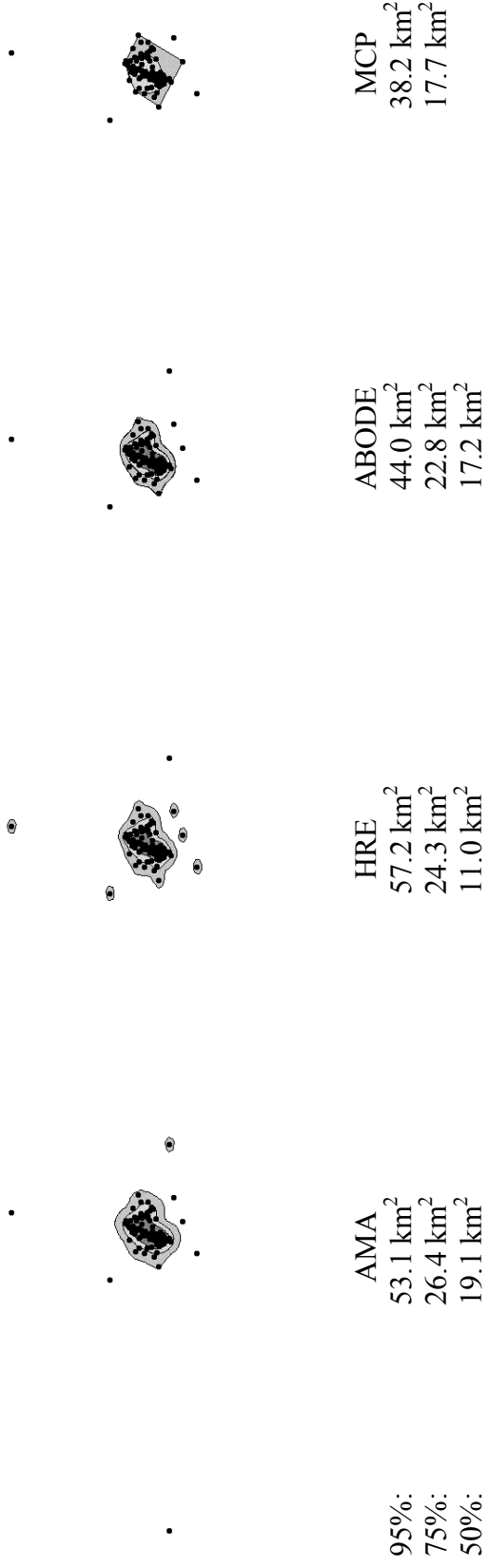


ABODE
 87.0 km²
 42.5 km²
 18.9 km²

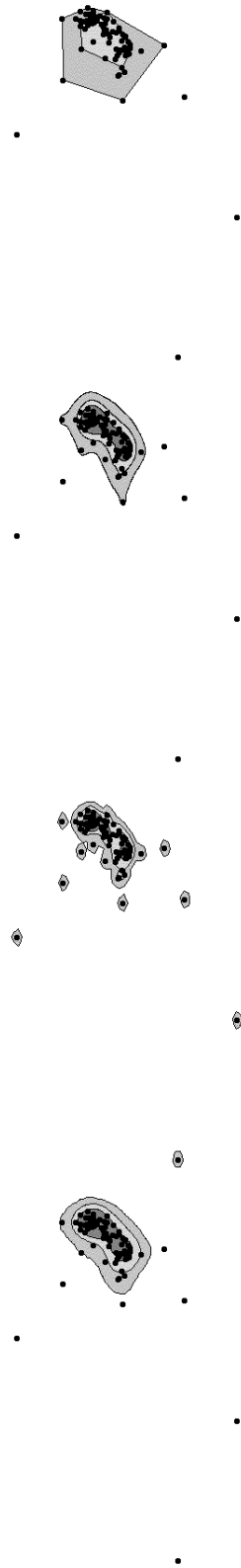


MCP
 39.7 km²
 17.3 km²

Bear ID 10253
 N = 105 locations
 2000 through 2002



Bear ID 10254
 N = 98 locations
 2000 through 2002



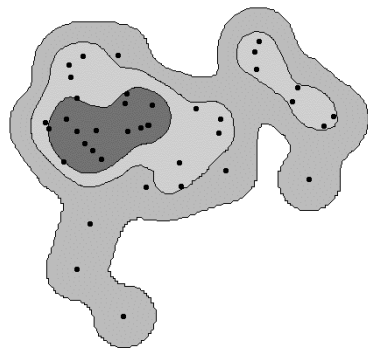
95%: AMA
 74.6 km²
 75%: 37.9 km²
 50%: 19.1 km²

HRE
 62.1 km²
 25.8 km²
 11.0 km²

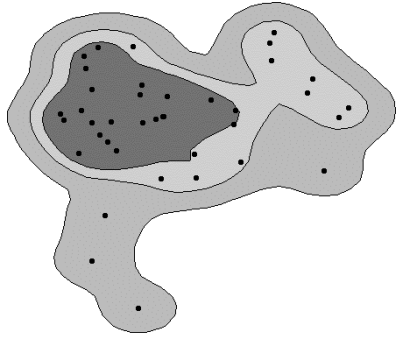
ABODE
 68.5 km²
 32.6 km²
 17.2 km²

MCP
 91.5 km²
 26.2 km²

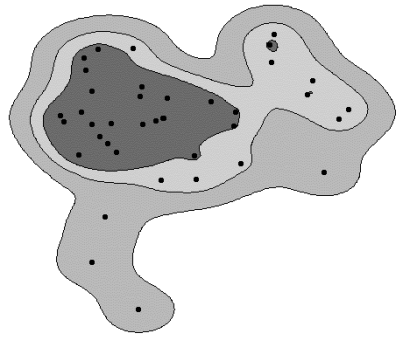
Bear ID 10264
 N = 52 locations
 2000 through 2002



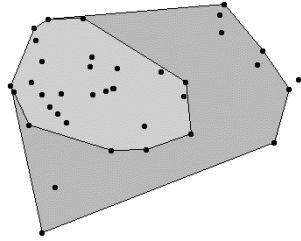
AMA
 95%: 39.8 km²
 75%: 15.4 km²
 50%: 4.6 km²



HRE
 95%: 45.4 km²
 75%: 22.3 km²
 50%: 10.5 km²



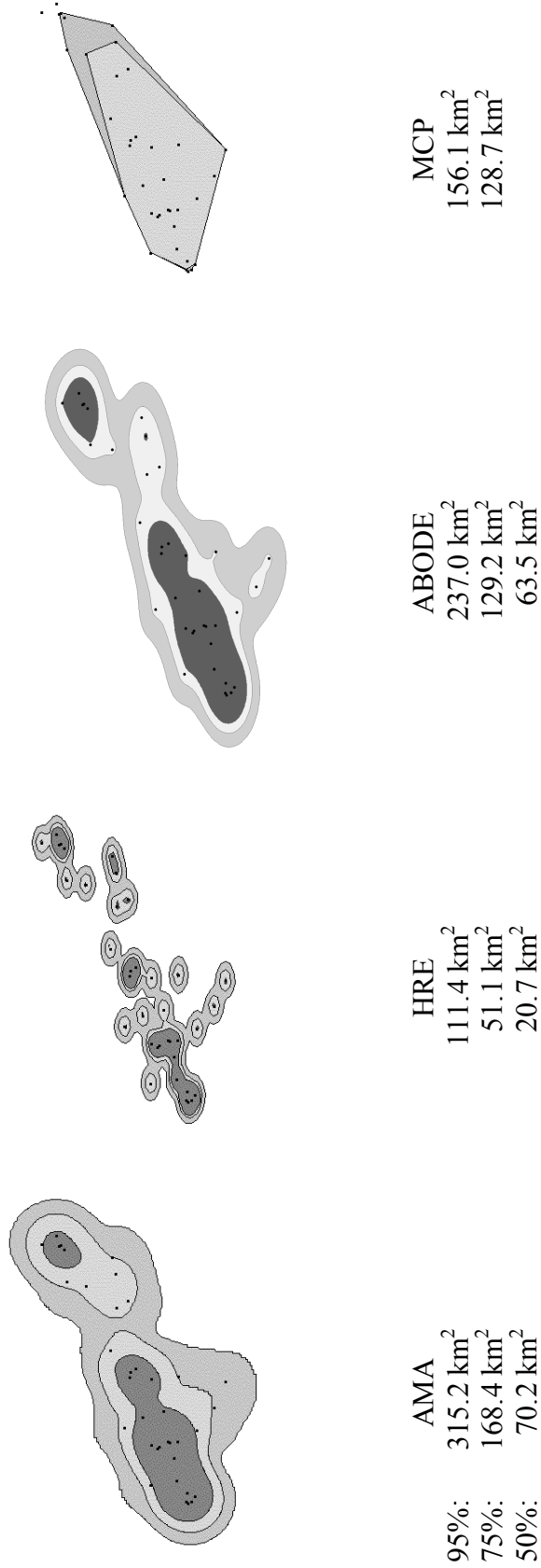
ABODE
 95%: 44.5 km²
 75%: 22.4 km²
 50%: 10.5 km²



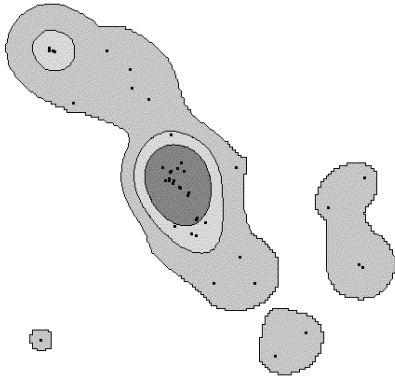
MCP
 95%: 28.4 km²
 50%: 10.9 km²

Figure 1.4. 95%, 75%, and 50% fixed-kernel home ranges generated with Animal Movements Analysis (AMA), Home Range Extension (HRE), and ABODE, and 95% and 75% minimum convex polygon (MCP) home ranges of adult male black bears (arranged chronologically by Bear ID number) in the southern study area of the Cooperative Alleghany Bear Study (CABS), George Washington and Jefferson National Forest, Virginia. June 1994 through December 2002. AMA-generated fixed-kernel home ranges using LSCV are not pictured due to the similarity with the ad hoc home ranges.

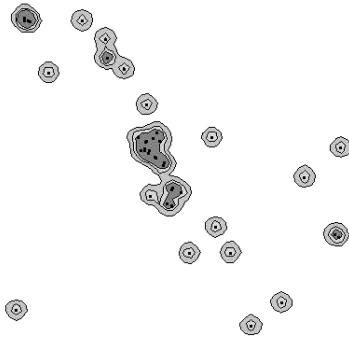
Bear ID 10140
 N = 50 locations
 1997 through 2002



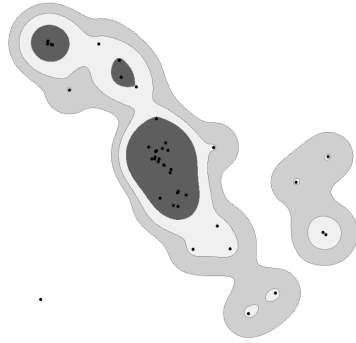
Bear ID 10177
 N = 53 locations
 1998 through 2001



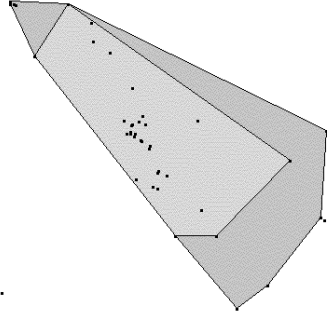
AMA
 95%: 618.1 km²
 75%: 127.9 km²
 50%: 55.5 km²



HRE
 124.2 km²
 49.1 km²
 20.2 km²

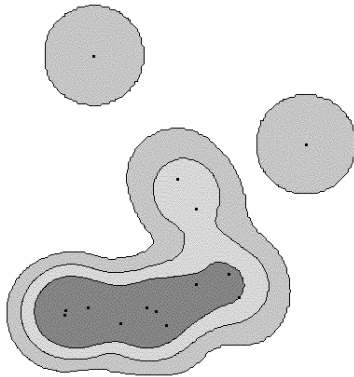


ABODE
 722.9 km²
 325.1 km²
 122.7 km²

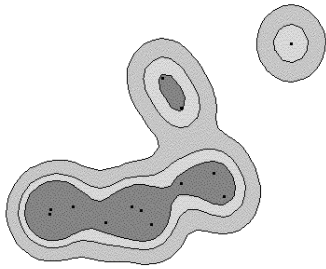


MCP
 598.7 km²
 348.7 km²

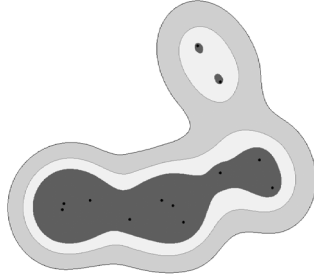
Bear ID 10249
 N = 23 locations
 2000 through 2001



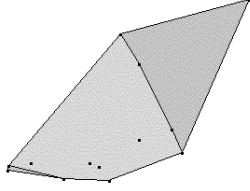
AMA
 95%: 696.6 km²
 75%: 302.0 km²
 50%: N/A



HRE
 467.8 km²
 227.4 km²
 N/A

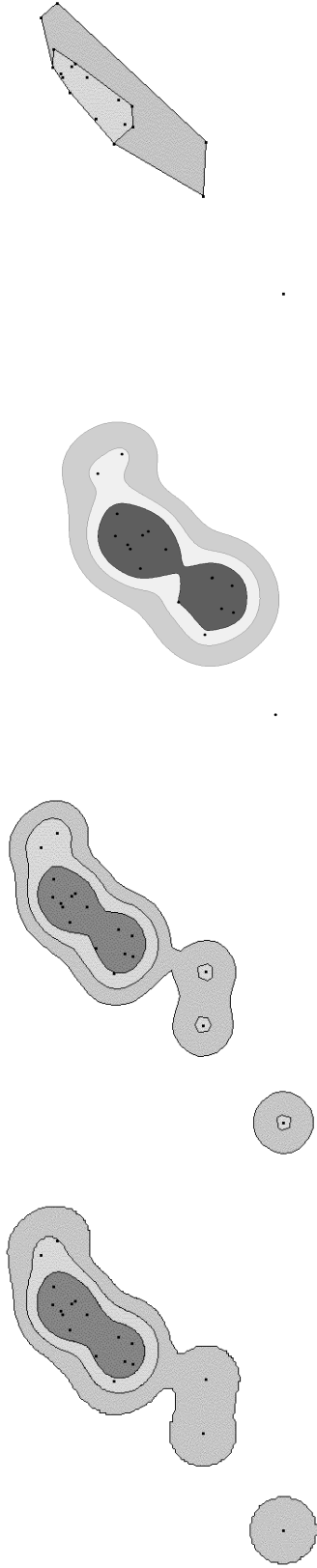


ABODE
 379.8 km²
 209.9 km²
 N/A



MCP
 262.3 km²
 158.4 km²

Bear ID 10317
 N = 22 locations
 2001



AMA
 95%: 134.7 km²
 75%: 48.3 km²
 50%: 25.2 km²

HRE
 122.3 km²
 53.6 km²
 24.5 km²

ABODE
 69.1 km²
 37.0 km²
 19.1 km²

MCP
 50.2 km²
 12.9 km²

Chapter 2. Home range and movement patterns of black bears in the Alleghany Mountains of western Virginia.

INTRODUCTION

Background

Burt (1943) provided one of the first descriptions of home range, which is still widely cited by researchers; home range is “that area traversed by the individual in its normal activities of food gathering, mating, and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered as in part of the home range.” The concept of home range has been debated and redefined (Mohr 1947, Jewell 1966, Baker 1978, Hansteen et al. 1997) since Burt’s attempt, with researchers questioning the term “normal,” and specifying a need to include a temporal component (White and Garrott 1990), as well as recognizing centers of activity (i.e. intensity of use in various parts of the home range; Hayne 1949). In an attempt to define home range using past and present suggestions, Kernohan et al. (2001) described an animal’s home range as “the extent of area with a defined probability of occurrence of an animal during a specified time period.” Despite the various ideas regarding how to define an animal’s use of space, most researchers agree that home ranges reveal to us the ecological requirements of the animal, and movements within home ranges are the behavioral manifestations of basic biological requirements (Seaman and Powell 1990), since an animal’s movements reflect its search for resources, such as food, shelter, and mates. Several characteristics can affect the size and shape of a bear’s home range. These include sex, age (Reynolds and Beecham 1980, Garshelis and Pelton 1981), kinship (Jonkel and Cowan 1971, Garshelis and Pelton 1981), social behavior (Jonkel and Cowan

1971, Lindzey and Meslow 1977), reproductive status (Hellgren and Vaughan 1989), and food availability and distribution (Jonkel and Cowan 1971, Young and Ruff 1982, Smith and Pelton 1989).

Gese et al. (1988) found that coyotes in Colorado that occupied habitats with higher prey densities had smaller home ranges than coyotes that occupied habitats with lower prey densities. In Maine, Litvaitis et al. (1986) observed a negative correlation between bobcat (*Felis rufus*) home range size and estimated snowshoe hare density (*Lepus americanus*). Male bobcats occupied larger home ranges when low hare densities (<0.5/ha) were reported. Thus, in some cases, annual changes in home range size provide a relative index of food abundance between years and regions. Regional variability in areas occupied by black bears may reflect variability in abundance and distribution of preferred foods (Pelchat and Ruff 1986). Individuals foraging in habitats containing large amounts of food likely have an advantage over those foraging in habitats containing smaller amounts of food because they can reduce the amount of energy they expend in searching for food. Smith and Pelton (1989) stated that home ranges could be indicative of habitat quality and that comparative analyses of the sizes of black bear home ranges in different populations would be useful in evaluating habitats.

Seasonal changes in habitat use patterns also appear to be due primarily to food availability and nutrition (Beeman 1975, Amstrup and Beecham 1976, Beeman and Pelton 1980, Young and Beecham 1983, Unsworth et al 1989, Powell et al. 1997). Concentrations of hard mast, soft mast, and/or artificial food resources appear to stimulate seasonal change in home range movements. Responses to hard mast failures have resulted in black bears exhibiting increased fall movements and home range

expansions (Beeman 1975, Amstrup and Beechum 1976, Garshelis and Pelton 1981, Garris 1983, Pelchat and Ruff 1986, Rogers 1987).

Powell et al. (1997) found that both male and female black bears responded to yearly variations in productivity of hard mast in fall. In years when hard mast abundance was great, male and female annual home range size, summer home range size, and fall home range size were smaller than in years when hard mast abundance was low. Core areas remained unaffected by variation in mast abundance. Food abundance did not affect spring home ranges for bears, thus they reasoned that bears cannot anticipate food production or adjust their spring home ranges appropriately.

In Shenandoah National Park (SNP) mast failure affected the movements of black bears during fall (Kasbohm et al. 1998). In 1987, gypsy moths (*Lymantria dispar*) began to defoliate the oak-hickory dominated forest, and by 1991 about two-thirds of SNP had been defoliated to some degree. Both convex and concave polygon home ranges of bears in defoliated areas were larger than for bears prior to infestation (38 km² versus 23 km², P=0.054 and 0.057, respectively). And while spring and summer home range did not differ between defoliation periods, fall home range was twice as large for bears in defoliated areas as for bears prior to defoliation (26 km² versus 14 km², P=0.025 and 0.001 for convex and concave areas, respectively; Kasbohm et al. 1998). Food availability also seemed to affect the magnitude of home range shifts. Significant shifts in summer to early fall range centers for bears living in defoliated areas were 2x greater than that observed before defoliation. Beeman (1975) found that in years with fair to poor mast, fall home ranges were disjunct from the bear's spring–summer home range.

In years with high mast abundance, fall home ranges overlapped with spring-summer home range.

Garshelis and Pelton (1981) noted that black bears in the Great Smoky Mountain National Park exhibited distinct home range shifts with a change in season. The most distinct shift occurred between summer and fall, with 23 of 29 bears exhibiting a shift in activity center and home range boundaries. They also observed that bears living in the same sections of the study area responded to the same habitat changes and exhibited similar seasonal movements.

In an earlier CABS study, J. Higgins (1997) reported that northern study area bears exhibited seasonal home ranges, and that home range sizes in the study were small compared to other studies done in Virginia and the United States. She suggested that small home range size could be reflective of good habitat quality. But, it may also be indicative of the influence of artificial feeding sites for bears. Until 1999, bear hunters in Virginia were allowed to create feeding stations on public lands, which may have allowed bears to occupy smaller areas to meet their energy requirements.

Black bears must fulfill their nutritional needs for the entire year in 5-8 months for normal body maintenance, storage of body fat for the winter, and production and maintenance of cubs by females (Beeman and Pelton 1980). Researchers have observed that bears in areas that experience mast crop failures suffer from lower reproductive rates (Rogers 1987), decreased yearling survival, and disperse outside their home range (Jonkel and Cowan 1971, Reynolds and Beecham 1980, Garshelis and Pelton 1981, Rogers 1987, Smith and Pelton 1989). Therefore, feeding is one of the most important

activities bears participate in and is reflected in the areas they use (Pelchat and Ruff 1986).

The changing food cycle permits bears to condense nutrient demands into their shortened time period, and their diet is typified by herbaceous vegetation in spring, berry-producing shrubs in the summer, and hard mast in the fall (Eagle 1979, Graber and White 1983, Noyce and Coy 1989, Costello 1992). Because bears are opportunistic omnivores and can take advantage of changes in food availability, they exploit many foods by following phenology, distribution, and abundance of various vegetation (Rogers and Allen 1987, Smith and Pelton 1989). Thus, one would expect bears to use certain areas within their home range in response to changing levels of resource productivity and distribution (Lindzey and Meslow 1977, Landers et al. 1979, Unsworth et al. 1989, Hellgren et al. 1991).

Justification

Knowledge of an animal's spatial movements allows researchers and managers to assess how much space and what habitat(s) are necessary (Poelker and Hartwell 1973) to provide for a bears' needs. Knowledge of space use patterns can also help us learn the effect of various factors (i.e. fluctuations in food supply, population densities, habitat alternations) on spacing behavior and movements (Simon 1975, Carpenter and MacMillan 1976, Gass et al. 1976). With seasonal changes in resource distribution and abundance (i.e. soft mast, hard mast), encroachment of urban development, changes in black bear population densities, resource demands on forested lands, and the popularity of the black bear as a game animal, land managers need to consider the movement and home range needs of the black bear population in western Virginia to assure its

perpetuation. Studies investigating animal movement patterns help biologists and managers have a better understanding of population densities, habitat quality, dispersals, and responses to environmental factors.

METHODS

Home range analysis

I used the Home Range extension (HRE; Rodgers and Carr 1998), in the software program ArcView 3.2, to estimate home range size. Both HRE's features and the reasons I opted to use it are detailed in chapter 1 of this thesis. Locations for each bear were recorded as Universal Transverse Mercator (UTM) coordinates and were used to generate both minimum convex polygons and fixed-kernel home ranges at the 95%, 75%, and 50% contours. I analyzed data collected during 1994-2002 in the northern and southern study areas. Home range sizes were estimated on a seasonal (all locations within a season) and annual (all locations within a year) basis. To estimate annual home ranges, I used only bears with ≥ 20 locations that were representative of the entire year. For seasonal home range analyses I included some bears that were discarded in the prior analyses, because these bears had enough locations during a season(s). For individual bears that were monitored for ≥ 1 year, the mean of all the ranges for that individual were used when I tested for differences in home range size by age category and season, in order to avoid pseudoreplication.

Factors used in analysis

Year effect.-To test for among year differences in home range size, I used one-way ANOVA (proc GLM; SAS Institute, Inc. 1990) with a protected LSD procedure to make mean comparisons. For adult female black bears monitored ≥ 1 year in the northern study

area, I made direct year-to-year comparisons of home range size using the paired-t test (Snedecor and Cochran 1980).

Age effect.-To test for the potential effect of bear age on home range size, I defined adult female black bears as bears ≥ 3 years old, then I placed females in 4 age categories (1=3 years old, 2=4-5 years old, 3=6-10 years old, and 4= ≥ 11 years old). These categories were based on age of first reproduction and litter size differences for the different age groups (Bridges 2005). Due to low sample sizes for each age category ($n \leq 2$), I did not test for age effect on male black bears in either study area. I compared annual home ranges of the 4 age categories with a one-way ANOVA with a protected LSD procedure to make mean comparisons. For individual bears monitored in ≥ 1 age category, I used a paired t-test to compare home range size of females when they transitioned into an older age category.

Regional and sex effects.- Population demographics and habitat quality may alter a bear's movement patterns, thus I compared annual home ranges of male and female black bears for between-study area and between-sex differences. I pooled (over years) and averaged annual home ranges of bears and then tested for differences in size with a two-way ANOVA.

Seasonal effect.-To test if among year differences existed within seasonal home ranges of adult female black bears, I used a one-way ANOVA with protected LSD procedure to make mean comparisons. Comparisons in home range size among seasons and between study areas were made with a fixed-effects, repeated measures ANOVA (proc GLM), since some bears were monitored for multiple years.

I used 95% MCP's because of the low number of locations available for several bears within a given season; the low number of locations was often below the threshold at which fixed-kernel ranges could be generated. But, by using MCP's, comparisons could be made with other studies that examined seasonal home range movements in black bears. For seasonal analyses, I classified locations into 3 periods, based on changes in plant phenology (Garner 1986), bear behavior, and hunting activities (spring: den emergence-15 June; summer: 16 June-31 August; fall: 1 September – den entry or 31 December).

Home range stability.-I used multiple response permutation procedure (MRPP) in the software program BLOSSOM (Midcontinent Ecological Science Center, National Biological Survey) on seasonal ranges to test the stability of home ranges within and among years. MRPP tests whether 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 (White and Garrot 1990). The null hypothesis for MRPP analysis is 2 or more utilization distributions are the same.

I used chi-square analysis to test for differences in the proportion of adult female black bears that exhibited intra-year seasonal shifts in their home range. The effects of year, region, and age on intra-year home range fidelity also was tested using chi-square analysis. I used chi-square analysis to determine if bears exhibited inter-year shifts within their seasonal home range (i.e. does fall home range in year 1 differ from fall home range in year 2), I used chi-square analysis to determine if age and time (comparisons of consecutive and non-consecutive years) had an effect on inter-year seasonal shifts.

Unless otherwise stated, $\alpha=0.05$ was selected for statistical significance for all tests.

Post-hoc testing was conducted if $\alpha<0.10$.

RESULTS

I monitored 90 adult black bears (14M:76F) from fall 1994 through December 2002 over 160 bear years and 381 bear seasons in the northern and southern study area of CABS.

Year Effects.- Only adult female black bears had a sample size large enough to test for among year differences in home range size. I used data collected from 1995-2000 in the northern study area and from 2000-2002 in the southern study area to construct annual home ranges. Annual home range size did not differ among years on either study area at the 95% fixed-kernel contour (North: $F_{5,66}=1.01$, $P=0.42$; South: $F_{2,29}=0.82$, $P=0.45$; Table 2.1) or the 50% fixed-kernel contour (North: $F_{5,67}=0.91$, $P=0.48$; South: $F_{2,29}=1.12$, $P=0.34$; Table 2.1). Average annual home range size ranged from 10.1 km² to 30.4 km² in the north and 46.3 km² to 66.7 km² in the south (Table 2.1).

To reduce potential error caused by individual variation of bears, female bears monitored for more than one year were analyzed using a paired t-test to look for differences in home range size between years. In all year-to-year comparisons, no differences were observed in home range sizes between years in either study area at the 50% or 95% fixed-kernel contour ($P>0.05$; Table 2.2). However, annual home ranges of southern study area bears monitored in 2000 and 2002 approached significance ($P=0.07$; Table 2.2); female bears' home ranges were 1.6-fold larger in 2000 than 2002 (Table 2.2).

Table 2.1. Annual home range size (km²; S.E.) of adult female black bears in the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, January 1995 through December 2002.

Region ^a	Year	N	95% fixed-kernel	N	50% fixed-kernel
North	1995	14	16.9 (2.6)	14	3.8 (0.6)
	1996	3	12.0 (2.3)	3	3.0 (0.7)
	1997	25	15.6 (2.4)	26	2.9 (0.4)
	1998	10	16.8 (3.7)	10	3.1 (0.6)
	1999	12	30.4 (14.6)	12	5.2 (1.8)
	2000	8	10.1 (2.3)	8	2.2 (0.6)
			<i>P</i> =0.42		<i>P</i> =0.48
South	2000	4	66.7 (7.1)	4	14.4 (1.8)
	2001	15	59.1 (10.2)	15	12.0 (1.9)
	2002	13	46.3 (7.5)	13	9.5 (1.5)
			<i>P</i> =0.45		<i>P</i> =0.34

^a Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

Table 2.2. Year (Year₁, Y₁) to year (Year₂, Y₂) comparisons of annual home range size (km²; S.E.) of adult female black bears monitored for ≥1 year in the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, January 1995 through December 2002.

Region	Year ₁	Year ₂	N	95% fixed-kernel			50% fixed-kernel		
				Y ₁	Y ₂	<i>P</i> -value	Y ₁	Y ₂	<i>P</i> -value
North	1995	vs. 1996	12	11.0 (1.8)	10.6 (2.2)	0.88	2.4 (0.4)	2.5 (0.5)	0.94
		vs. 1997	11	12.2 (2.2)	16.0 (3.3)	0.26	2.5 (0.4)	3.4 (0.5)	0.50
		vs. 1998	8	11.1 (2.9)	17.4 (4.7)	0.19	2.0 (0.5)	3.6 (0.8)	0.11
		vs. 1999	4	9.9 (5.3)	22.6 (11.6)	0.15	2.3 (1.4)	5.3 (2.9)	0.15
	1996	vs. 1997	9	11.4 (2.8)	14.3 (4.0)	0.49	2.4 (0.6)	2.7 (0.6)	0.53
		vs. 1998	4	13.8 (5.9)	19.2 (6.7)	0.11	2.9 (1.2)	4.1 (1.0)	0.15
		vs. 1999	2	18.1 (13.1)	15.7 (6.3)	0.79	3.7 (2.8)	3.2 (0.6)	0.85
	1997	vs. 1998	9	14.2 (2.7)	17.1 (4.1)	0.45	3.3 (0.8)	3.7 (0.8)	0.63
		vs. 1999	10	12.9 (2.7)	35.4 (17.2)	0.24	3.2 (0.9)	6.5 (2.3)	0.22
	1998	vs. 1999	7	18.2 (5.3)	18.1 (6.8)	0.98	3.9 (1.1)	4.3 (1.8)	0.74
South	2000	vs. 2001	4	66.7 (7.1)	99.6 (25.1)	0.26	14.4 (1.8)	20.0 (4.2)	0.36
		vs. 2002	3	68.7 (9.6)	42.5 (2.2)	0.07	11.7 (3.8)	10.5 (1.2)	0.15
	2001	vs. 2002	11	61.6 (11.5)	43.1 (7.1)	0.21	12.6 (2.2)	9.3 (1.6)	0.25

Because no differences were detected in annual home ranges among years, data were pooled over years for further analysis of mean annual home ranges by age, region, and sex in both study areas. Home range data for adult male black bears also were pooled because of small sample sizes.

Age Effects.- Home range size of adult female bears did not differ by age class in either study area (North: $F_{3, 62}=0.57$, $P=0.64$; South: $F_{2, 18}=3.06$, $P=0.07$; Table 2.3) at the 95% fixed-kernel contour. The p -value for southern bears did approach significance, thus Fisher's LSD was performed; no differences were found among the age classes. Home ranges were similar in size at the 50% fixed-kernel contour in both study areas (North: $F_{3, 62}=0.79$, $P=0.50$; South: $F_{2, 20}=1.76$, $P=0.20$; Table 2.3).

Home range size of individual bears in the northern study area monitored in more than 1 age class did not differ at either the 95% and 50% fixed-kernel contour ($P>0.05$; Table 2.4). Low sample size in the southern study area precluded testing for changes in home ranges size when bears transitioned into an older age class.

Annual Home Range

Regional effects.- Home ranges of adult female bears on the southern study area were 2.9- to 4.2-fold larger than female home ranges on the northern study areas ($P<0.001$; Table 2.5). Likewise, adult male home ranges on the southern study area were 2.4- to 5.8-fold larger than northern male home ranges ($P<0.001$; Table 2.5).

Sex effects.- In both study areas, female black bears had smaller home ranges than male black bears ($P < 0.0001$; Table 2.5; Figure 2.1). In the northern study area, male home ranges were 2.3- to 4.2-fold larger than female home ranges and in the southern study area, male home ranges were 2.2- to 5.8-fold larger than female home ranges (Table 2.6).

Regional/Sex interaction.-There was a significant interaction between sex and region at all contours ($P < 0.05$; Table 2.5). However, home ranges of southern females and northern males appeared to be similar (40.5 km^2 versus 45.7 km^2 ; Table 2.6), so I performed a Wilcoxon Rank sum test to determine if they were different. At the 50% fixed-kernel contour, southern female ranges were larger (1.3-fold) than northern male ranges ($Z = -2.0719$, $P = 0.04$; Table 2.6). But there were no differences in home range size at the other 3 contours (95% MCP: $Z = 0.1492$, $P = 0.88$; 95% fixed-kernel: $Z = -1.5733$, $P = 0.12$; 75% fixed-kernel: $Z = -1.7404$, $P = 0.08$; Table 2.6).

Seasonal home range

Among year effects.-In the northern study area, adult female home range size in summer and fall did not differ among years (summer: $F_{5, 49} = 0.75$, $P = 0.59$; fall: $F_{5, 95} = 0.04$, $P = 1.0$; Table 2.7), but spring ranges did differ among years ($F_{5, 85} = 2.28$, $P = 0.05$; Table 2.7). Fisher's protected LSD indicated that spring ranges in 1995 were larger (1.8- and 2.1-fold) than spring ranges in 1996 and 1997, respectively (Table 2.7).

No differences were detected in seasonal home range size among years in the southern study area ($P > 0.05$; Table 2.7). Spring ranges varied from 5.1 km^2 to 11.9 km^2 , summer ranges varied from 8.8 km^2 to 15.4 km^2 , and fall ranges varied from 10.0 km^2 to 20.0 km^2 (Table 2.7).

Table 2.3. Effects of age (ANOVA) on annual home range size (km²; S.E.) for adult female black bears in the George Washington Jefferson National Forests, Virginia, USA, June 1994 – December 2002.

Region ^a	Age class ^b	N	95% fixed-kernel	50% fixed-kernel
North	1	9	11.9 (2.8)	2.9 (0.7)
	2	24	13.4 (1.8)	2.9 (0.4)
	3	23	15.9 (2.5)	3.6 (0.6)
	4	10	11.9 (2.4)	2.5 (0.5)
			<i>P</i> =0.64	<i>P</i> =0.50
South	1	3	56.0 (17.7) A ^c	12.0 (2.7)
	2	12	31.6 (4.0) A	8.2 (1.2)
	3	8	57.3 (10.8) A	11.7 (1.9)
			<i>P</i> =0.07	<i>P</i> =0.20

^a Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^b Age class: 1=3 year olds, 2=4-5 year olds, 3=6-10 year olds, 4= \geq 11 year olds

^c Among age classes, means followed by the same letter within a region are not different. (*P*>0.05)

Table 2.4. Comparison^a of annual home range size (km²; S.E.) of adult female black bears monitored in more than 1 age class^b in the northern study area of the George Washington Jefferson National Forests, Virginia, USA, June 1994 – December 2002.

Comparison of age classes	N ^c	95% kernel (km ²)	<i>P</i> value	50% kernel (km ²)	<i>P</i> value
1 vs. 2	9	11.9 vs. 10.6 (2.8) (1.7)	0.60	2.6 vs. 2.2 (0.7) (0.4)	0.41
1 vs. 3	6	10.5 vs. 13.7 (3.2) (6.5)	0.41	2.4 vs. 3.3 (0.9) (1.6)	0.36
2 vs. 3	12	13.3 vs. 14.6 (2.1) (3.4)	0.67	2.9 vs. 3.4 (0.5) (0.9)	0.55

^a Paired t-test

^b Age class: 1=3 year olds, 2=4-5 year olds, 3=6-10 year olds

^c N: Same bears monitored in \geq 1 age class

Table 2.5. Effects of region and sex (ANOVA) on home range size of adult black bears at the 95%, 75%, and 50% fixed-kernel and 95% minimum convex polygon (MCP) in the George Washington Jefferson National Forests, Virginia, USA, January 1995-December 2002.

Resolution	Factor	d.f.	SS	MS	F-ratio	P-value
95% fixed-kernel	Sex ^a	1	11470.0	11470.0	25.58	<0.0001
	Region ^b	1	24459.0	24459.0	54.55	<0.0001
	Interaction	1	1801.8	1801.8	4.02	0.05
	Error	85	38113.4	448.4		
95% MCP	Sex	1	70836.9	70836.9	18.00	<0.0001
	Region	1	44381.6	44381.6	11.28	0.0012
	Interaction	1	71580.2	71580.2	18.19	<0.0001
	Error	86	338431.6	3935.3		
75% fixed-kernel	Sex	1	2197.9	2197.9	25.40	<0.0001
	Region	1	4885.5	4885.5	56.45	<0.0001
	Interaction	1	451.7	451.7	5.22	0.03
	Error	86	7442.5	86.5		
50% fixed-kernel	Sex	1	384.8	384.8	20.77	<0.0001
	Region	1	1028.6	1028.6	55.53	<0.0001
	Interaction	1	111.8	111.8	6.03	0.02
	Error	86	1593.0	18.5		

^a Sex: Male, female

^b Region: North: counties include Augusta, Rockingham
South: counties include Craig, Giles, and Montgomery

Table 2.6. Mean annual home range size (km²; S.E.) by region and sex of adult black bears in the George Washington Jefferson National Forests, Virginia, USA, January 1995 – December 2002.

Sex	Region ^a	N ^b	95% fixed-kernel	95% MCP	75% fixed-kernel	50% fixed-kernel
Male	North	10	40.5 (13.1)	40.0 (10.8)	17.9 (6.1)	7.6 (2.7)
	South	4	98.6 (10.4)	233.4 (157.1)	45.0 (4.3)	20.5 (2.5)
Female	North	48	14.7 (1.5)	9.5 (1.2)	7.0 (0.7)	3.3 (0.4)
	South	28	45.7 (4.8)	40.0 (6.2)	20.5 (1.9)	9.5 (0.9)

^a Region: North: counties include Augusta, Rockingham
South: counties include Craig, Giles, and Montgomery

^b N: Sample size includes individual bears whose annual home ranges were averaged

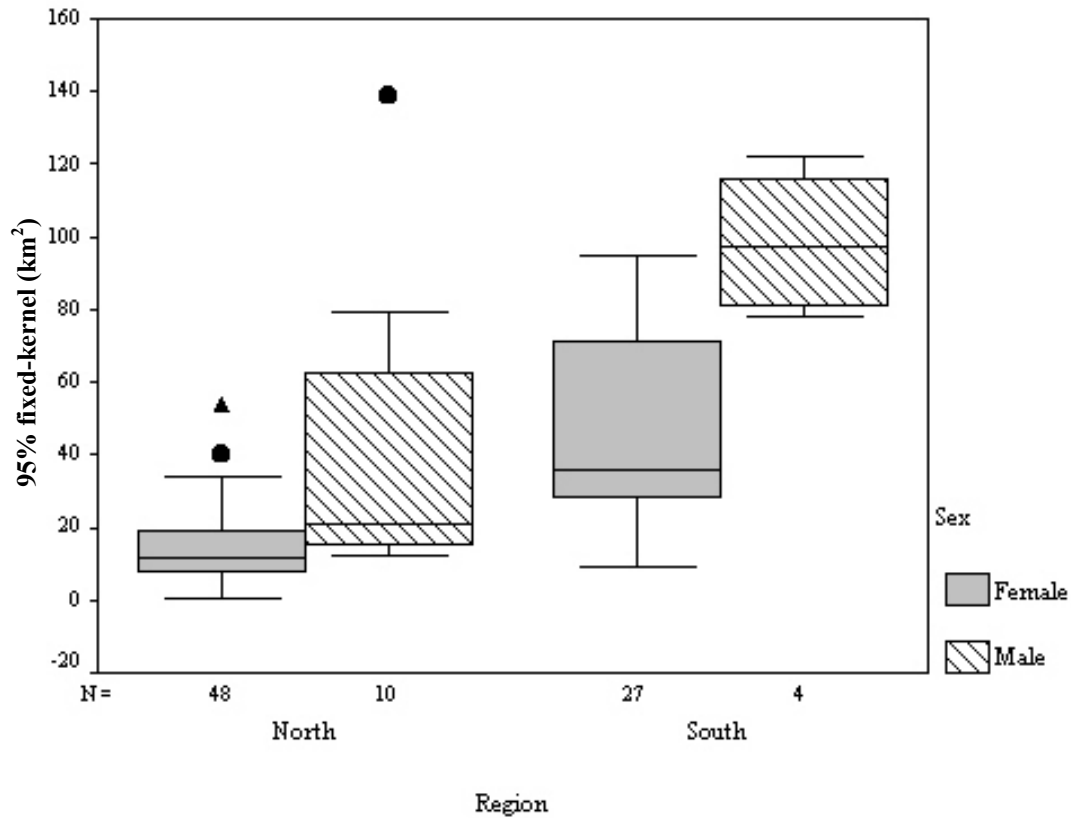


Figure 2.1. Annual 95% fixed-kernel home range of adult black bears in the northern and southern study area of the Cooperative Alleghany Bear Study in George Washington Jefferson National Forests, Virginia, USA, January 1995 – December 2002. Boxes represent the interquartile range containing 50% of the values. The error bars are the 5th and 95th percentiles and ● are outliers beyond the 5th and 95th percentiles. Extremes (▲) are cases with values more than 3 times larger than the interquartile range.

Regional effects.- Adult female seasonal home ranges in the south (years pooled) were consistently larger than in the north ($F_{1, 88}=96.13$, $P<0.0001$; Table 2.8; Figure 2.2). Southern home ranges were 2.9-, 5.0-, and 2.4-fold larger than northern home ranges during spring, summer, and fall, respectively (Table 2.9).

Though I pooled years to make regional comparisons of within seasonal home ranges, in some season/year combinations, data were sufficient to examine these without pooling (i.e. spring 2000, summer 1996 and 2000, fall 1995 and 2000; Table 2.10). With the exception of fall 2000, southern females' seasonal home ranges were larger (2.3- to 4.3-fold) than northern females ($P<0.05$; Table 2.10). During fall 2000, home ranges did not differ by region ($Z=-1.3761$; $P=0.17$; Table 2.10), though southern female home range were 2.0-fold larger than northern females (4.9 km² versus 10.0 km²).

Within year effects.- In the northern study area, home range sizes among seasons did not differ in 5 of 6 years ($P>0.05$; Table 2.11) though in each case, fall ranges were numerically larger (1.2- to 2.5-fold) than spring and summer ranges (Table 2.11). The exception was in 1997; fall range was 2.1- and 2.4-fold larger than summer and spring ranges, respectively ($F_{2, 68}=4.11$; $P=0.02$; Table 2.11). In the southern study area, no differences were detected among seasonal home ranges during the 4 years examined ($P>0.05$; Table 2.11).

In the northern study area (years pooled), home range size differed among seasons ($F_{2, 123}=11.01$, $P<0.0001$; Table 2.8); fall ranges were 1.8- and 2.1-fold larger than spring and summer ranges, respectively (Table 2.9); spring and summer ranges were similar in size ($F_{1, 123}=0.36$, $P=0.55$; Table 2.8; Table 2.9). In the southern study area, no

Table 2.7. Comparisons of among year, within season home range size (km²; S.E.) of adult female black bears in the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, September 1994 through December 2002.

Region	Year	N ^a	Spring	N	Summer	N	Fall	
North ^b	1994	·	·	·	·	10	5.4 (0.8)	
	1995	16	5.0 (0.8) A ^c	11	3.0 (0.6)	29	5.8 (1.4)	
	1996	19	2.4 (0.4) B	13	2.3 (0.4)	·	·	
	1997	27	2.8 (0.5) B	18	2.4 (0.4)	27	6.0 (1.4)	
	1998	12	3.6 (0.8) AB	2	3.6 (1.5)	14	5.6 (1.7)	
	1999	11	4.0 (0.9) AB	5	3.5 (1.5)	14	5.4 (1.4)	
	2000	6	3.0 (1.0) AB	6	3.9 (1.0)	7	4.9 (1.5)	
			F _{5,85} =2.28 P=0.05		F _{5,49} =0.75 P=0.59		F _{5,95} =0.04 P=1.0	
	South	1995	·	·	·	·	11	20.0 (7.4)
		1996	2	5.1 (1.5)	5	9.8 (5.0)	4	10.6 (2.6)
2000		5	7.9 (2.6)	4	8.8 (2.2)	9	10.0 (2.8)	
2001		18	11.9 (1.6)	13	14.6 (2.3)	20	12.3 (1.9)	
2002		11	8.0 (1.2)	14	15.4 (3.1)	18	14.9 (3.4)	
			F _{3,32} =1.85 P=0.16		F _{3,32} =0.76 P=0.52		F _{4,57} =0.81 P=0.52	

^a The sample size includes individual bears that were monitored for \geq than 1 specific season; the mean of their seasonal home range was recorded

^b Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^c Within a region, means followed by the same letter within a season are not different. ($P>0.05$)

Table 2.8. Effects of region and season (ANOVA) on seasonal home range size (95% MCP) of adult female black bears in the northern and southern study area of the Cooperative Alleghany Bear Study in George Washington Jefferson National Forests, Virginia, USA, September 1994 through December 2002.

Factor	Test of Fixed Effects	
	F	P value
Region ^a	F _{1,88} =96.13	<0.0001
Season ^b	F _{2,116} =5.87	0.004
Region*season	F _{2,116} =2.49	0.09
Season within north	F _{2,123} =11.01	<0.0001
Season within south	F _{2,81} =2.07	0.14

	North		South	
	F	P value	F value	P value
Spring vs. Summer	F _{1,123} =0.36	0.55	F _{1,81} =2.98	0.09
Spring vs. Fall	F _{1,123} =15.11	0.0002	F _{1,81} =3.49	0.09
Summer vs. Fall	F _{1,123} =16.79	<0.0001	F _{1,81} =0.00	0.98

^a Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery
^b Seasons: spring, summer, fall

Table 2.9. Seasonal home range size (95% MCP; S.E.; km²) of adult female black bears in the northern and southern study area of the Cooperative Alleghany Bear Study in George Washington Jefferson National Forests, Virginia, USA, September 1994 through December 2002.

Season	N ^a	North ^b	N	South
Spring	47	3.3 (0.5)	23	9.7 (1.8)
Summer	32	2.8 (0.5)	25	13.9 (1.7)
Fall	47	5.8 (0.5)	38	13.9 (1.4)

^a N: number of individual bears used in test
^b Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

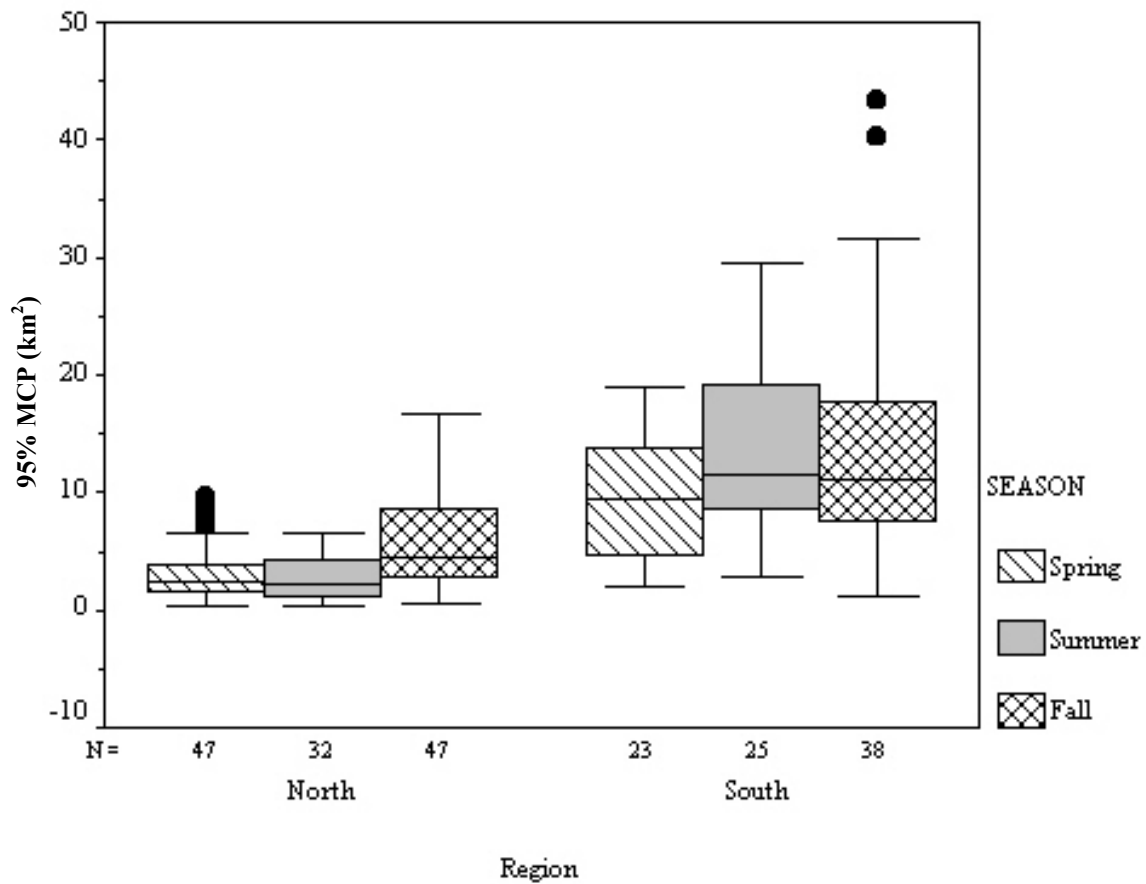


Figure 2.2. Seasonal 95% MCP of adult female black bears in the northern and southern study area of the Cooperative Alleghany Bear Study in George Washington Jefferson National Forests, Virginia, USA, September 1994 – December 2002. Boxes represent the interquartile range containing 50% of the values. The error bars are the 5th and 95th percentiles and ● are outliers beyond the 5th and 95th percentiles. Extremes (▲) are cases with values more than 3 times larger than the interquartile range.

Table 2.10. Comparisons of seasonal home range size between regions of adult female black bears (95% MCP; S.E.; km²) on the northern and southern study area of adult female bears in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA.

Season	Year	N	North ^a	N	South	Significance	
						Z	P value
Spring	2000	6	3.0 (1.0)	5	7.9 (2.6)	1.9170	0.06
Summer	1996	13	2.3 (0.4)	5	9.8 (5.0)	2.2683	0.02
	2000	6	3.9 (1.0)	4	8.8 (2.2)	2.2386	0.03
Fall	1995	29	5.8 (1.4)	11	20.0 (7.4)	2.4689	0.01
	2000	7	4.9 (1.5)	9	10.0 (2.8)	-1.3761	0.17

^a Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

Table 2.11. Within year differences in seasonal home range size (km²; S.E.) of adult female black bears in the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, January 1995 through December 2002.

Region ^a	Year	Season	N	95% MCP	
North	1995	Spring	16	5.0 (0.8)	
		Summer	11	3.0 (0.6)	
		Fall	29	5.8 (1.4)	
					$F_{2,54}=1.02; P=0.37$
	1996	Spring	19	2.4 (0.4)	
		Summer	13	2.3 (0.4)	
		Fall	--	--	
					$F_{1,30}=0.03; P=0.87$
	1997	Spring	27	2.8 (0.5) B ^b	
		Summer	18	2.4 (0.4) B	
		Fall	27	6.0 (1.4) A	
					$F_{2,70}=4.11; P=0.02$
	1998	Spring	12	3.6 (0.8)	
		Summer	2	3.6 (1.5)	
		Fall	14	5.6 (1.7)	
					$F_{2,25}=0.59; P=0.56$
	1999	Spring	11	4.0 (0.9)	
		Summer	5	3.5 (1.5)	
		Fall	14	5.4 (1.4)	
					$F_{2,27}=0.59; P=0.56$
	2000	Spring	6	3.0 (1.0)	
Summer		6	3.9 (1.0)		
Fall		8	4.9 (1.0)		
				$F_{2,21}=1.65; P=0.22$	
South	1996	Spring	2	5.1 (1.5)	
		Summer	5	9.8 (5.0)	
		Fall	4	10.6 (2.6)	
					$F_{2,8}=0.29; P=0.76$
	2000	Spring	5	7.9 (2.6)	
		Summer	4	8.8 (2.2)	
		Fall	9	10.0 (2.8)	
					$F_{2,15}=0.16; P=0.86$
	2001	Spring	18	11.9 (1.6)	
		Summer	13	14.6 (2.3)	
		Fall	20	12.3 (1.9)	
					$F_{2,48}=0.49; P=0.61$
	2002	Spring	11	8.0 (1.2)	
		Summer	14	15.4 (3.1)	
		Fall	18	14.9 (3.4)	
				$F_{2,40}=1.59; P=0.27$	

^a Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^b Within a region, means followed by the same letter within a year are not different. ($P>0.05$)

differences were detected among seasonal home ranges ($F_{2, 81}=2.07$, $P=0.14$; Table 2.8; Figure 2.2).

Seasonal home range fidelity

Intra-year seasonal shifts

Year effects.- The proportion of adult female bears that did and did not shift ranges seasonally during 1995, 1997, 1999 and 2000 was not different among these years ($P>0.05$; Table 2.12). I was unable to include the years 1996 and 1998 due to low sample sizes. Overall, most bears did not shift their seasonal home range when transitioning from spring to summer and summer to fall, while most bears shifted their seasonal range from spring to fall. The exception was in 1999, when 6 of 8 female bears shifted their range between spring and summer (Table 2.12); however, the overall chi-square was not statistically significant.

In the southern study area, the proportion of adult female bears that did and did not shift ranges seasonally during 2001 and 2002 was not different ($P>0.05$; Table 2.12). Because no differences were detected in the frequency of seasonal shifts among years, seasonal data were pooled among years for each study area.

Regional effects.- Adult female bears on the north and south study areas shifted ranges among seasons in the same proportion ($P>0.05$; years pooled; Table 2.13). In both study areas, most bears did not shift their range when transitioning from spring to summer (North: 63.0%; South: 57.0%; Table 2.13) or from summer to fall (North: 67.0%; South: 65.0%; Table 2.13), while most bears shifted their seasonal range between spring and fall (North: 67.0%; South: 52.0%; Table 2.13).

Age effects.- The proportion of adult females that did and did not shift home ranges between seasons (years and regions pooled) did not differ by age class ($P>0.05$; Table 2.14). Most bears in all age classes did not shift their seasonal range when transitioning from spring to summer and from summer to fall. However, a majority of bears in all age classes shifted their range between spring and fall (Table 2.14).

Seasonal transitions.- In the northern study area, proportionally more adult females shifted home ranges between spring and fall (67%) than between spring and summer (37%), or between summer and fall (33%; $\chi^2=13.3181$, $P=0.001$, $df=2$; Table 2.15). In the southern study area, the proportion of adult females that did and did not shift home ranges seasonally was not different for any seasonal transition comparisons ($\chi^2=1.4154$, $P=0.49$, $df=2$; Table 2.15). Fifty-seven percent and 65% of bears did not shift their home range when transitioning from spring to summer, and summer to fall, respectively (Table 2.15) A slight majority of bears (52%; Table 2.15) shifted their home range between spring and fall.

Inter-year seasonal shifts

Year effects.- There was no difference in the proportion of adult female bears that shifted ranges within season, between consecutive years over the duration of the study (1994-2002); this was true for all seasons on both study areas ($P>0.05$; Table 2.16). Nor were there differences when comparisons were made between non-consecutive years (e.g. 1-5 years apart; $P>0.05$; Table 2.17). Therefore, I pooled data across years for each study area, to increase statistical power.

In the northern study area, proportionally more females (years and ages pooled) shifted their fall range (63%) than in spring (45%) or summer (37%; $\chi^2=14.95384$, $P=0.0006$, $df=2$; Table 2.18). In the southern study area, most females (Spring: 75%; Summer: 78%; Fall: 55%; Table 2.18) did not shift their seasonal home range ($\chi^2=3.894419$, $P=0.14$, $df=2$; Table 2.18).

Age effect.- The effect of age (years pooled) on inter-year seasonal shifts was examined using only female black bears in the northern study area; low sample size in the southern study area precluded testing. Some bears that I monitored multiple years transitioned from one age class to another age class and some did not. Among those that did not, 74% of ≥ 11 year-old females shifted their spring home range, while most 4-10 year-old females (55% and 65%) did not ($\chi^2=9.1969$, $P=0.01$; Table 2.19). Though there was an overall significance among the 3 age classes, most bears ≥ 4 years old did not shift their summer home range ($\chi^2=6.8101$, $P=0.03$; Table 2.19). Most bears (>50%) in all age classes shifted their fall range among years ($\chi^2=3.8676$, $P=0.15$, $df=2$; Table 2.19).

Among bears that transitioned from one age class to another, most (>50%; years pooled) 2 year olds that became adults shifted their range every season. Most adult females that transitioned into an older age class did not shift their spring or summer home range, but shifted their fall home range ($P>0.05$; Table 2.19). Overall, there were no differences in within season shifts among bears that transitioned into an older age class ($P>0.05$; Table 2.19).

Table 2.12. Seasonal home range fidelity among years^a for adult female black bears in the northern and southern study area in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA. January 1995-December 2002.

Region	Years	Spring to Summer				Summer to Fall				Spring to Fall			
		No		Yes		No		Yes		No		Yes	
		N	%	N	%	N	%	N	%	N	%	N	%
North ^b	1995	8	67.0	4	33.0	7	58.0	5	42.0	3	25.0	9	75.0
	1997	14	74.0	5	26.0	14	74.0	5	26.0	8	42.0	11	58.0
	1999	2	25.0	6	75.0	5	63.0	3	37.0	2	25.0	6	75.0
	2000	3	60.0	2	40.0	3	60.0	2	40.0	2	40.0	3	60.0
		$\chi^2=5.8246, P=0.12, df=3$				$\chi^2=0.9368, P=0.82, df=3$				$\chi^2=1.3565, P=0.72, df=3$			
South	2001	7	58.0	5	42.0	7	58.0	5	42.0	7	58.0	5	42.0
	2002	5	56.0	4	44.0	6	67.0	3	33.0	3	33.0	6	67.0
		$\chi^2=0.0162, P=0.90, df=1$				$\chi^2=0.1514, P=0.70, df=1$				$\chi^2=1.2886, P=0.26, df=1$			

^a χ^2 tests were conducted on the proportion of female bears that did and did not shift home ranges (MRPP) between seasons

^b Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

Table 2.13. Seasonal home range fidelity^a between regions for adult female black bears in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA. June 1994-December 2002.

Shift occurrence	Region	Spring to summer		Summer to fall		Spring to fall	
		n	%	N	%	n	%
No	North ^b	29	63.0	31	67.0	15	37.0
	South	13	57.0	15	65.0	11	48.0
Yes	North	17	37.0	15	33.0	31	67.0
	South	10	43.0	8	35.0	12	52.0
Regional effects ^c		$\chi^2=0.2738, P=0.60, df=3$		$\chi^2=0.0326, P=0.86, df=3$		$\chi^2=1.5121, P=0.22, df=3$	

^a Data pooled across years for both study areas

^b Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^c χ^2 tests were conducted on the proportion of female bears between regions that did and did not shift home ranges (MRPP) between seasons

Table 2.14. Seasonal home range fidelity^a among age classes for adult female black bears in the northern and southern study area in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, January 1995-December 2002.

Shift Occurrence	Age class ^b	Spring to Summer		Summer to Fall		Spring to Fall	
		N	%	N	%	N	%
No	1	6	67.0	8	73.0	3	37.5
	2	25	62.5	27	67.5	15	54.0
	3	31	76.0	29	78.0	15	37.5
	4	7	44.0	6	50.0	3	25.0
Yes	1	3	33.0	3	27.0	5	62.5
	2	15	37.5	13	32.5	13	46.0
	3	10	24.0	8	22.0	25	62.5
	4	9	56.0	6	50.0	9	75.0
		$\chi^2=5.3316, P=0.15, df=3^c$		$\chi^2=3.6805, P=0.30, df=3$		$\chi^2=3.3443, P=0.34, df=3$	

^a Data pooled across years for both study areas

^b Age class: 1=3 year olds, 2=4-5 year olds, 3=6-10 year olds, 4= \geq 11 year olds

^c χ^2 tests were conducted on the proportion of female bears in each age class that did and did not shift home ranges (MRPP) between seasons

Table 2.15. Between season home range shifts for adult female black bears in the northern and southern study area in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, June 1994-December 2002.

Region	Seasonal transition	No ^a		Yes	
		N	%	N	%
North ^b	Spring to Summer	29	63.0	17	37.0
	Summer to Fall	31	67.0	15	33.0
	Spring to Fall	15	33.0	31	67.0
$\chi^2=13.3181, P=0.001, df=2^c$					
South	Spring to Summer	13	56.0	10	44.0
	Summer to Fall	15	65.0	8	35.0
	Spring to Fall	11	48.0	12	52.0
$\chi^2=1.4154, P=0.49, df=2$					

^a No: No shift occurred between seasons; Yes: A shift occurred between seasons

^b Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

^c χ^2 tests were conducted on the proportion of female bears within each region that did and did not shift home ranges (MRPP) between seasons

Table 2.16. Inter-year seasonal home range fidelity between consecutive years for adult female bears in the northern and southern study area in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA. June 1994-December 2002.

Region	Year	Spring						Summer						Fall					
		No ^a		Yes		No		Yes		No		Yes		No		Yes			
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%		
North ^b	1994 to 1995	--	--	--	--	--	--	--	--	--	--	--	2	20.0	8	80.0			
	1995 to 1996	4	50.0	4	50.0	8	89.0	1	11.0	--	--	--	--	--	--	--			
	1996 to 1997	12	63.0	7	37.0	6	67.0	3	33.0	--	--	--	--	--	--	--			
	1997 to 1998	7	44.0	9	56.0	--	--	--	--	4	27.0	11	73.0	--	--	--	--		
	1998 to 1999	4	40.0	6	60.0	--	--	--	--	5	42.0	7	58.0	--	--	--	--		
	1999 to 2000	3	75.0	1	25.0	2	50.0	2	50.0	5	50.0	5	50.0	5	50.0	5	50.0		
	2000 to 2001	--	--	--	--	--	--	--	--	1	25.0	3	75.0	$\chi^2=2.85$, $P=0.58$, $df=4$					
South	1995 to 1996	--	--	--	--	--	--	--	--	4	100.0	0	0.0						
	2000 to 2001	3	60.0	2	40.0	2	67.0	1	33.0	5	50.0	5	50.0						
	2001 to 2002	7	87.5	1	12.5	9	90.0	1	10.0	10	71.0	4	29.0						
		$\chi^2=1.3108$, $P=0.25$, $df=1$					$\chi^2=0.9652$, $P=0.33$, $df=1$			$\chi^2=3.4386$, $P=0.18$, $df=2$									

^a No: No shift occurred between years; Yes: A shift occurred between seasons

^b Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^c χ^2 tests were conducted on the proportion of female bears that did and did not shift home ranges (MRPP) within seasons, between consecutive years

Table 2.17. Inter-year seasonal home range fidelity between non-consecutive years for adult female black bears in the northern and southern study area in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA. June 1994-December 2002.

Region	No. of years elapsed	Spring				Summer				Fall			
		No ^a		Yes		No		Yes		No		Yes	
		N ^b	%	N	%	N	%	N	%	N	%	N	%
North ^c	1	30	52.0	28	48.8	19	66.0	10	34.0	19	36.0	34	64.0
	2	22	56.0	17	44.0	7	54.0	6	46.0	14	37.0	24	63.0
	3	16	70.0	7	30.0	5	71.0	2	29.0	11	38.0	18	62.0
	4	2	22.0	7	78.0	2	67.0	1	33.0	9	43.0	12	57.0
	5	1	50.0	1	50.0	-	-	-	-	1	11.0	8	89.0
		$\chi^2=5.4572, P=0.14, df=4^d$											
		$\chi^2=0.1695, P=0.92, df=3$											
		$\chi^2=2.6835, P=0.44, df=4$											
South	1	10	77.0	3	23.0	11	85.0	2	15.0	19	68.0	3	32.0
	2	2	67.0	1	33.0	2	67.0	1	33.0	9	33.0	9	67.0
		$\chi^2=0.1368, P=0.71, df=1$											
		$\chi^2=4.3516, P=0.23, df=1$											
		$\chi^2=7.2563, P=0.06, df=1$											

^a No: No shift occurred between years; Yes: A shift occurred between seasons

^b Data pooled across years for both study areas

^c Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^d χ^2 tests were conducted on the proportion of female bears that did and did not shift home ranges (MRPP) within seasons between non-consecutive years

Table 2.18. Seasonal home range fidelity within regions (age and years pooled) for adult female black bears in the northern and southern study area in the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA. June 1994-December 2002.

Region	Shift	Spring				Summer				Fall	
		N	%	N	%	N	%	N	%	N	%
North ^a	No	73	55.0	33	63.0	57	37.0				
	Yes	60	45.0	19	37.0	97	63.0				
$\chi^2=14.95384, P=0.0006, df=2^b$											
South	No	12	75.0	14	78.0	23	55.0				
	Yes	4	25.0	4	22.0	19	45.0				
$\chi^2=3.894419, P=0.14, df=2$											

^a Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^b χ^2 tests were conducted on the proportion of female bears that did and did not shift home ranges (MRPP) within seasons

Table 2.19. Seasonal home range fidelity (years pooled) among age class^a for adult female black bears in the northern study area of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, June 1994 – December 2002.

Transition occurred ^c	Initial age class	Spring						Summer						Fall					
		No ^b		Yes		No		Yes		No		Yes		No		Yes			
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%		
No	2	5	55.5	4	45.5	4	100.0	0	0.0	3	50.0	3	50.0	3	50.0	3	50.0		
	3	28	65.0	15	35.0	11	58.0	8	32.0	12	41.0	17	59.0	17	59.0	17	59.0		
	4	6	26.0	17	74.0	8	100.0	0	0.0	4	18.0	18	82.0	18	82.0	18	82.0		
																		$\chi^2=3.8676, P=0.15, df=2$	
Yes	Yearling	--	--	--	--	--	--	--	--	2	40.0	3	60.0	3	60.0	3	60.0		
	Subadult	5	38.5	8	61.5	0	0.0	3	100.0	6	40.0	9	60.0	9	60.0	9	60.0		
	1	9	53.0	8	47.0	4	57.0	3	33.0	10	32.0	21	68.0	21	68.0	21	68.0		
	2	18	60.0	12	40.0	4	57.0	3	33.0	17	48.5	18	51.5	18	51.5	18	51.5		
	3	7	87.5	1	22.5	2	40.0	3	60.0	3	33.3	6	66.7	6	66.7	6	66.7		
																		$\chi^2=2.8489, P=0.42, df=3$	
																		$\chi^2=3.3314, P=0.34, df=3$	
																		$\chi^2=2.0123, P=0.73, df=4$	

^a Age class: yearling=1 year olds, subadult=2 year olds, 1=3 year olds, 2=4-5 year olds, 3=6-10 year olds, 4= \geq 11 year olds

^b No: No shift occurred between years; Yes: A shift occurred between seasons

^c Transition occurred=No: Bear did not move into older age class; Yes: Bear did move into older age class

^d χ^2 tests were conducted on the proportion of female bears that did and did not shift home ranges (MRPP) within seasons

DISCUSSION

Regional variability within North America

Black bear space use patterns have been studied extensively in North America (e.g. Appendix A) and regionally in Virginia, specifically the Great Dismal Swamp (GDS; Hellgren and Vaughan 1990), Shenandoah National Park (SNP; Garner 1986, Kasbohm 1998), and in southwestern Virginia (CABS; J. Higgins 1997, K. Higgins 1997). While direct comparisons with other home range studies are complicated by differences in sampling protocol, sample size, and analytical techniques, these studies do provide a framework for identifying patterns of black bear home range characteristics.

Annual home ranges of adult male and female black bears in this study (Table 2.6) were within the general patterns observed in other regions. Mean annual home range of adult female black bears in other regions ranged from 2.4 km² in southwestern Washington (n=6; island population; Lindzey and Meslow 1977) to 68.9 km² in lower Michigan (n=16, Hirsch et al. 1999) while mean annual home range size of adult males varied from 5.1 km² in southwestern Washington (n=5, Lindzey and Meslow 1977) to 328 .0 km² in Massachusetts (n=29, Fuller 1993). Other studies' reported home ranges falling within these 2 extremes, and sample sizes ranged from 2 to 41 bears (Appendix A). Home ranges of black bears in Virginia also have shown variability; in SNP, mean annual home range of adult female black bears reported by Garner (1986) and Kasbohm (non-defoliated area; 1998) were 22.0 km² and 23.2 km², respectively. In GDS, Hellgren and Vaughan (1990) reported adult female and male mean annual home ranges of 27.0 km² and 111.7 km², respectively.

Several factors thought to affect the size and shape of a bear's home range, which might also explain the regional variability observed in home range sizes between this and other studies, include sex, age (Reynolds and Beecham 1980, Garshelis and Pelton 1981), kinship (Jonkel and Cowan 1971, Garshelis and Pelton 1981), social behavior (Jonkel and Cowan 1971, Lindzey and Meslow 1977), reproductive status (Hellgren and Vaughan 1989), population densities (Young and Ruff 1982), and food availability and distribution (Jonkel and Cowan 1971, Young and Ruff 1982, Smith and Pelton 1989).

However, methodological differences also might explain regional home range differences in North America and within Virginia (see Appendix A). A variety of factors can affect the final home range that is generated, such as the number of animals monitored, the number of locations per animal collected (Garton et al. 2001; Leban et al. 2001), location error, the home range estimator chosen (i.e. minimum convex polygon, harmonic mean, kernel; Boulanger and White 1990, Harris et al. 1990, White and Garrot 1990, Worton 1995) and the software program used to generate the home range (Larkin and Halkin 1994, This thesis, chapter 1).

The number of bears used in the reported studies varied widely (Appendix A), as did the number of locations per bear, which not only complicates regional comparisons, but also puts into question the accuracy of the reported home ranges. How many animals and locations/animal are required to describe mean annual home range size? While most studies listed in Appendix A did not report the number of locations/bear, most reported number of bears, which averaged 13.3 females (range: 2 to 41) and 7.8 males (range: 1 to 29). For analyzing annual home ranges, I used 76 adult females and 14 adult males (Table 2.6) and discarded data from 151 females and 55 males because these bears either

had too few locations in the year (≤ 20) or did not have representative locations for the entire year. Statistical tests are more powerful as sample size (i.e. number of animals) increases, and several studies have shown that when >20 animals are used, differences detected are less likely to be biased by extremes in data (Alldredge and Ratti 1986, Samuel and Fuller 1994). Since increasing sample size normally increases the power of statistical results (Cohen 1988), I believe my results accurately describe bear movements in western Virginia, particularly for adult females.

Besides the factors mentioned above, other factors may affect the size of home ranges reported in other regions. Prior studies have shown that bear home ranges can reflect seasonal and yearly changes in population demographics and habitat features (Beeman 1975, Amstrup and Beechum 1976, Garshelis and Pelton 1981, Garris 1983, Pelchat and Ruff 1986, Powell et al. 1997). Thus, the duration of the study (i.e. number of months and years) and the time of year locations are collected might ultimately affect home range size estimates. Kernohan et al. (2001) recommended that a systematic sampling scheme be designed that most accurately estimates an animal's spatial movements. Animal locations should be sampled during the entire duration of the study and during the sampling period in which inferences will be drawn. Due to their extensive movements and use of inaccessible areas, bears can be difficult to monitor. Thus, researchers are often limited in their ability to follow a specified sampling interval, which can affect sample sizes and the number of locations collected per bear.

While this study's annual home ranges were based on location data collected throughout the year, many studies listed in Appendix A did not state the sampling protocol used to generate their home ranges. If sampling was more intense during a

particular year or particular season, then the resulting home ranges could be biased; the reported annual home range would be more reflective of the bear's movement during that time period rather than reflective of its movements during the entire year. Sampling should be temporally and spatially unbiased during the observation period for home range estimates to be comparable (Garshelis et al. 1983) not only among regions, but within a study.

Variability during CABS

In an earlier CABS study, conducted in the northern study area, J. Higgins (1997) reported annual home ranges of 5.5 km² to 6.8 km² for adult females and 7.2 km² to 11.2 km² for adult males, at the 95% MCP and fixed-kernel contour, respectively (Appendix A). J. Higgin's (1997) female and male home ranges were 2.2- to 5.6-fold smaller, respectively, than the annual home ranges for northern bears reported in this study (Table 2.6). In the northern study area, the annual male home range size reported by J. Higgins (1997) was 1.3-fold smaller than annual female home range size in this study (11.2 km² versus 14.7 km²). The general pattern in other black bear populations has been that males have significantly larger ranges than females (Appendix A).

Estimated size of home ranges in the 2 studies may have differed, in part, because we used different programs to generate home ranges (Ranges V versus Home Range Extension) and we had different sample sizes (Higgins: n=34, Olfenbuttel: n=90). My results were based on 8 years of data, whereas J. Higgin's (1997) results were based on 2 years of data. While I used Higgin's telemetry data, I included only bears that had location data throughout the year. This was to avoid biasing my results by including home ranges that were more representative of a specific time of year; a period in which

data were collected more intensively. On the CABS study, fieldwork was most demanding during summer (June through August) and winter (January through March) months. Thus, telemetry data were less emphasized during those times of year. To avoid producing home ranges that were more reflective of late spring and fall movements, I included only bears that had locations that were equally representative of the entire year. J. Higgins (1997) included all bears, regardless of when the location data were collected.

Regional variability in western Virginia

Estimates of regional home range size varied significantly; mean annual home range size for male and female bears in the southern study area was 2.4- to 3.1-fold larger than male and female home ranges in the northern study area, respectively. In most years, there were not enough locations to generate seasonal home ranges in the south (1997-1999) and north (2001-2002), so data were pooled. Not surprisingly, seasonal ranges (years pooled) for adult females also followed this pattern; southern spring, summer, and fall ranges were 2.9-, 5.0-, and 2.4-fold larger, respectively, than northern seasonal ranges. Direct comparisons (years not pooled) of the northern and southern seasonal ranges were possible only in 1995, 1996, and 2000. Overall, results from individual years mirrored that of the pooled seasonal data; seasonal home ranges were 2.3- to 4.3-fold larger in the southern study area. The exception was fall home range in 2000; while it was 2.0-fold larger in the south than the north, the difference was not statistically significant.

Regional variability in the size of home ranges for black bears may be attributed to the varying influences of human-related activities, climate, topography, and

differences in quantity, quality, availability, and distribution of food sources (Garris 1983, Pelchat and Ruff 1986). Smith and Pelton (1989) noted that home range size could be indicative of habitat quality and that comparative analyses of the sizes of black bear home ranges in different populations would be useful in evaluating habitats. Researchers have found changes in home range size reflect responses by male and female black bears to variations in food productivity. When mast abundance was low, bears in Tennessee, Idaho, Alberta, and North Carolina increased their movements and expanded their home ranges (Beeman 1975, Amstrup and Beechum 1976, Garshelis and Pelton 1981, Garris 1983, Pelchat and Ruff 1986, Powell et al. 1997). Thus, bears apparently optimize their movements to efficiently exploit their habitat (Brody and Pelton 1989).

Young and Ruff (1982) suggested that home range size, if estimated by the same methods, provides a means of comparing habitat quality between areas. Thus, the differences in home range size between the 2 CABS study areas may reflect regional differences in features that contribute to habitat quality. While habitat features, such as escape cover and den site availability, are important ecological components in a bear's life history, access, distribution, and abundance of food resources is a primary contributing factor in determining habitat quality. To address some of the possible explanations for why home range size differed between the 2 study areas, I examined several parameters that might be indicative of habitat quality (Appendix B).

With the exception of summer ($t=-3.16$; $P=0.02$; Appendix C), when southern adult females were 8.4 kg heavier than northern females, weights did not differ between study areas, even when examined by year, season (i.e. winter den weights), reproductive status, and age class ($P>0.05$; Appendix C). Adult males in the south were heavier ($t=-$

2.13; $P=0.04$; Appendix D) than northern males, particularly those 6-10 year olds ($t=4.51$; $P<0.01$; Appendix D). The low sample size in the southern study area precluded testing for seasonal and yearly differences in male weights between the regions.

Other studies have found that bear weight reflected food abundance, specifically hard mast crops. In Massachusetts, Elowe and Dodge (1989) discovered that following a poor mast year, bears were emaciated and weights were typically 25-40% lower than weights of the same bears following an abundant mast year. K. Higgins (1997) reported that adult females in Maine exposed to poor fall mast crops had a lower physical condition ratio than those exposed to high fall mast crops. She also noted that den weights of adult females following good fall mast crops were higher than den weights of adult females following poor fall mast crops (K. Higgins 1997). However, she cautioned against using external morphological measurements, such as body weight and length, to estimate physical condition because it may be sensitive only when bears appear to be near starvation. Instead, K. Higgins (1997) suggested that body weight might be useful in comparing the physical condition of 2 or more populations or the same population under differing conditions. Thus, body weight could be a useful index to gauge habitat quality between different regions. Though weights differed regionally between adult males in this study, this could be an artifact of the difference in sample sizes between the regions (North: $n=241$; South: $n=43$), and biased sampling in both regions. My data on male weights might be biased towards younger and/or lighter bears because all captured males were not treated the same; during trapping events, field personnel were limited in recording the weights of larger bears (i.e. ≥ 250 lbs.) due to lack of proper equipment and/or our inability to physically weigh the bear. The weights of 55% of southern adult

males and 29% of northern adult males went unrecorded, partially based on the field personnel present at the time of capture, thus differences in male weights may be Type I error. I'm hesitant to draw any conclusions regarding the relationship between male weight and regional habitat quality.

With the exception of summer, adult female weights did not differ between study areas, suggesting that both populations were on a similar nutritional plane. However, since southern bears' home ranges were larger than their northern counterparts, these bears likely had to travel farther to find adequate food sources.

Artificial feed sites were a feature that may have contributed to overall habitat quality in western Virginia. Bear hunters set up year-round supplemental feed sites that provided supplemental food to bears, on both public and private property. While supplemental feeding occurred in both study areas, more food was provided to bears in the northern study areas (Gray 2001). Gray (2001) found that twice as much food was provided to bears in counties making up the northern study area versus the southern study area (Appendix B). Concentrated areas of reliable food sources might affect home ranges by reducing their size, since bears would not have to travel as far to get the food they need. However, in western Washington, Fersterer et al. (2001) did not find differences in the home range size of bears that were in feeding versus non-feeding areas. However, his sample size of bears in non-feeding areas was small in comparison to his sample size in feeding areas (non-feeding: $n=8$; feeding: $n=17$), which might have affected his results. He did note that the feeding stations concentrated bears at specific locations, but he did not go into further details about this observation.

As explained earlier, hard mast abundance has been shown to be a critically important component of a bear's diet. Researchers have observed that bears in areas that experience mast crop failures experience lower reproductive rates (Rogers 1987), decreased yearling survival, and disperse outside their home range (Jonkel and Cowan 1971, Reynolds and Beecham 1980, Garshelis and Pelton 1981, Rogers 1987, Smith and Pelton 1989). Therefore, feeding is one of the most important activities bears participate in and is reflected in the areas they use (Pelchat and Ruff 1986). One would expect that if mast production differed between regions, home range dynamics also would differ. However, I found no difference in the amount of hard mast (VDGIF hard mast index) between the 2 study areas ($t=0.35$, $P=0.73$; Appendix E). The sampling techniques used by VDGIF to measure hard mast production are not adequate for conducting meaningful tests specifically on hard mast distribution throughout the 2 study areas. Hard mast distribution and/or some other component could be affecting the difference in home range size of bears in each study area, however I am unable to determine this due to the lack of data currently available on mast distribution.

Roads have been implicated frequently as having an important role in modifying black bear behavior and habitat use. Brody and Pelton (1989) suggested that the behavior of bears in response to roads is learned, and is linked to the costs and benefits experienced or perceived by the bear. Because home range size differed between regions, I examined road densities within the study areas. However, road densities (mile/km^2) appear to be similar in both study areas (Appendix B).

In both regions, low traffic paved roads were the dominant road type (Appendix B). The amount of traffic on a road can determine if a road acts as a barrier (Carr and

Pelton 1984, Brody and Pelton 1989, Beringer et al 1989). Major highways impede black bear movements (Miller 1975, Brody 1984, Brody and Pelton 1989) and can cause mortality from impact with vehicles. In the southern Appalachians, bears crossed lightly traveled roads (<100 vehicles/day), but avoided crossing roads that were more heavily traveled (>10,000 vehicles/day; Wooding and Maddrey 1994). Roads can also be beneficial for bears; in the GDS, Hellgren and Vaughan (1989) documented bears frequently using margins of unpaved roads to feed on important food plants, such as wild black cherry, black berry, and pokeberry (*Phytolacca americana*). Carr and Pelton (1984) found that bears in Great Smoky Mountains National Park (GSMNP) often crossed roads and used habitat along the roadsides. In Michigan, black bears used oil pipeline rights-of-way, oil well service roads, and logging roads as travel routes (Manville 1983). Within the CABS study areas, roads increased hunters' ability to create artificial feed sites within areas used by bears, providing supplemental food to bear diets, but possibly resulting in nuisance activity (personal observation). While more in-depth analysis should be performed to relate bear movements to roads, it does not appear that roads explain regional differences in home ranges in this study.

The expanding human populations has severely reduced and fragmented black bear habitat in the eastern United States (Rossell and Litvaitis 1994). Few studies have documented how human densities affect black bear habitat use patterns, but studies have shown that with increasing human populations, black bear habitat is impacted by development, expansion of agricultural lands, and increased human activity. Forested areas are important to bears because they offer essential life history requirements, such as food, den sites, and security cover from humans and other bears (Lindzey and Meslow

1977). But, forested areas are also a valued resource to timber interests, developers, and recreationists, which might come in conflict with bear habitat requirements. The extent of human activities in each study area in this study may be reflected by 1) the amount of forested and non-forested land, and 2) the proportion of land in private versus public ownership.

While the percent of forested and non-forested land in both study areas were similar, land ownership was different between the 2 regions (Appendix B). Fifteen percent of land in the southern study area was comprised of public land, versus 61% in the northern study area (Appendix B). Not only might land management practices differ, based on ownership (Donnelly 2003), but the high percentage of private land in the southern study area may be an indication of a more fragmented, heterogeneous habitat.

While the percentage of forested lands between regions was similar (South: 80%; North 86%; Appendix B), forest age and stand type may vary based on management of forested lands (both public and private) within each study area. Pinder et al. (1999) concluded that a threat to southeastern forests was the conversion of older forests to short-rotation plantations on private lands. In the Upper Coastal Plain of South Carolina and Georgia, conversions to short-rotation homogenous pine plantations is occurring at rates faster than urbanization (Pinder et al. 1999). The large proportion of land in private ownership in the southern study area may present problems for public agencies in managing and maintaining forest resources desirable for black bears; land management goals of most private landowners is largely unknown and might conflict with bear habitat needs. Though abundance of food resources may be similar between study areas, as indicated by similarities in bear weights, hard mast production, and forested lands,

distribution of these foods likely differs between regions. Southern bears may have to travel more extensively to find patches of food if their landscape is more fragmented due to the extent of private landownership.

Bear population densities could be a factor for differences in home range sizes between study areas. Trapping success, bait station surveys, and harvest rates suggested that black bear population densities were higher in the north than the south. In 2002, a direct comparison, using photography-based capture-recapture data, was performed and indicated there were 1.32 bears/km² on the northern study area, but only 0.78 bears/km² on the southern study area (Appendix B; Bridges 2005). Beringer (1986) theorized that differences in home range sizes among black bear populations in Tennessee (Cherokee National Forest and Great Smoky Mountains National Park) was likely a reflection of differences in population densities, since habitat quality appeared to be the same between these regions. Young and Ruff (1982) found that females were sensitive to crowding and, as a result, may decrease their home range size in response to an increase in population densities. Higher population densities may also be indicative of a higher rate of home range overlap and fewer unoccupied areas for bears to establish home ranges. Because I could compare densities in only 1 year, I was unable to determine if population densities were significantly different between the 2 study areas. However, population densities were numerically higher in the north, perhaps causing an inverse relationship in home range size.

Home range size can serve as an indicator of habitat quality (Young and Ruff 1982, Smith and Pelton 1989), and the differences in home range size between the study areas in this study suggests there also exists differences in habitat quality between the study

areas. Among the parameters I examined that may be indicative of habitat quality, I believe the differences in the composition of land ownership within each study area serves as the best explanation for why there are regional differences in home range size. With the high proportion of private land in the southern study area, I expect a variety of differing land management goals exists, which creates a more fragmented, heterogeneous landscape. Thus, food distribution is likely to be more scattered, causing bears to travel further to find these food patches, resulting in larger home ranges. Additionally, though bear densities, through crowding, may affect home range size, I believe that bear densities serve more as a reflection of habitat quality; the higher density of bears in the northern study area versus the southern study area may indicate that the north's available habitat can support more bears.

Variability between the sexes

In both study areas, annual home ranges of males were larger than ranges of females, which fits the general pattern observed in other black bear populations over the past 30 years (Beeman 1975, Amstrup and Beecham 1976, Lindzey and Meslow 1977, Reynolds and Beecham 1980, Alt et al. 1980, Grashelis and Pelton 1981, Hugie 1982, Young and Ruff 1982, Carr 1983, Hellgren 1988, Smith and Pelton 1990, Fuller 1993, VanManen 1994, Maehr et al. 2003, Onorato et al. 2003; Appendix A). While habitat richness can determine home range size (Koehler and Pierce 2003), male home range size may also be function of larger male body size (Harestad and Bunnell 1979, Quigley 1982), breeding behavior (Rogers 1977, Herrero and Hamer 1977), and site fidelity exhibited by females (i.e. females stay in one area, thus males must travel to encounter them; Clark 1991). Male bears likely travel more extensively in search of food to meet

the metabolic needs necessary to maintain their larger body size. Other factors affecting range size of male and female bears may be differences in their strategy for maximizing individual fitness. The reproductive success of males likely depends on their ability to breed with several females (Orians 1969, Rogers 1987, Powell et al. 1997). Hence, it is advantageous for promiscuous males to be mobile, less attached to specific areas, and occupy large areas that overlap with ranges of many females. The reproductive success of females is not as likely to improve by breeding with many males, so females could maximize fitness through detailed knowledge of resource abundance, phenology, and location within their home range (White 1996). Thus, they are less mobile, occupying areas only extensive enough to ensure adequate food for self-maintenance and the development of young (Amstrup and Beecham 1976).

As stated earlier, adult male home ranges were larger than adult female home ranges within each study area. However, home range size of southern adult females were similar to that of northern adult males. This reemphasizes the fact that regional differences exist between the study areas, possibly related to habitat quality. While home ranges of northern males reflect their extensive travels in search of both females and adequate food for their larger size, southern females, who are smaller in size, apparently have to travel just as extensively in order to find adequate food for self-maintenance and cub development.

Inter-year variability

Annual home range.- Adult females (ages pooled) in both study areas exhibited no inter-year differences (1995-2002) in home range size. Even when making year-to-year comparisons of annual home ranges using the same bears (i.e. bears radio-tracked for

multiple years), there were no differences in female range size. In North Carolina, Jones (1994) reported no difference among annual home range sizes of female bears and thought that the dynamics of spatial use change might occur over a time scale longer than a few years. However, in the northern study area, I used data of individual bears spanning 6 years (1995-2000; Table 2.1) and found no differences in home range size.

In western North Carolina and in GSMNP, Tennessee, home range size of adult male and female bears did not vary among years (Warburton and Powell 1986, Garshelis and Pelton 1981, Quigley 1982). However, these studies were conducted during normal mast years and diet has been shown to have a significant influence on home range size (Gittleman and Harvey 1982). Powell et al. (1997) found that in years when hard mast was abundant, male and female annual home ranges were smaller than in years when hard mast was scarce. However, core areas remained unaffected by variations in mast abundance. In this study, annual home ranges at the 50% contour did not differ among years. Core areas represent the most important portion of a bear's home range (Burt 1943, Kaufmann 1962, Samuel and Green 1988) because it is more heavily used than other parts. Powell et al. (1997) theorized that peripheral portions, rather than core areas, of home ranges were sensitive to variation in food supplies and should receive more attention since they constitute the majority of a bear's home range.

Researchers have found evidence of an inverse relationship between home range size of black bears and habitat quality (Amstrup and Beecham 1976, Lindzey and Meslow 1977, Carr 1983, Kasbohm 1998), thus the lack of difference in range size among years suggests that habitat quality has been relatively stable in both study areas during the duration of CABS. However, hard mast production, a key component of a

bear's diet, has varied from poor to good during the CABS study (Denny Martin, VDGIF, personnel communication; Appendix E). Despite fluctuations in hard mast abundance among years, bears maintained the size of their annual home range. We may see a response in black bears home range dynamics and population demographics only in years of extremely poor mast abundance; in years when abundance is fair to good, mast abundance may meet the minimum threshold of nutritional needs. Noel (1983) found that even though annual food productivity varied in North Carolina, there was no correlation with annual home range size.

Seasonal home range.- Evidence indicated that black bears are most likely to make seasonal movements during fall, when hard mast is available. Garshelis and Pelton (1981), in Tennessee, and Rogers (1977), in Minnesota, reported that bears traveled long distances during fall food shortages, expanding their fall ranges. However, despite fluctuations in hard mast abundance, no inter-year differences were detected in fall range size for either study area. Powell et al. (1997) found fall and summer home range sizes were smaller in years when hard mast abundance was high. As with fall range size, summer range size did not differ among years. The only difference detected in seasonal range size among years was during spring in the northern study area; spring range during 1995 was 2.1- and 1.8-fold larger than in 1996 and 1997. No differences in spring range size were detected among the other years. This result differed from Powell et al. (1997) who found that food abundance did not affect spring home ranges for bears. They reasoned that bears cannot anticipate food production or adjust their spring home ranges appropriately.

In Tennessee, Garris (1983) found that while annual and summer home range size for black bears did not differ between years, fall range size was significantly larger in 1980 than in 1981. He attributed this not only to more abundant acorn production in 1981, but to acorns being more evenly distributed in 1981. Van Manen (1994) concluded that fall ranges tended to vary more from year-to-year than spring or summer ranges because hard mast production in the southern Appalachians is unpredictable and variable.

The lack of inter-year difference in fall range size might be due to the availability of alternative food sources to bears during years when hard mast abundance was poor. During a complete hard mast failure in SNP, Kasbohm et al. (1998) observed that females successfully fed on soft mast as alternative fall foods. Garshelis and Pelton (1981) made similar observations in GSMNP; bears fed on abundant black cherry until its depletion rather than search for acorns. In western Virginia, black bears may have relied on various soft mast species available during fall, including wild grape (*Vitis* sp.), dogwood (*Cornus florida*), black gum (*Nyssa sylvatica*), black cherry (*Prunus serotina*), and autumn olive (*Eleagnus umbellata*).

In both study areas, bears may have relied on food provided by hunters in years when natural foods were scarce (Gray 2001). Until July 1999, bear hunters had established year-round artificial feed sites on both public and private lands; after July 1999 hunters were restricted to providing food only on private lands. Food provided by hunters consisted mainly of shelled, crack, and sweet feed corn, pastries, lard, apples, bread, ham, and livestock feed (Gray 2001). Many of these food items are higher in fat content than natural foods (Gray 2001) and may have buffered the effect of low hard mast abundance on home range movements.

Lastly, the lack of inter-year differences in fall home range size in both regions might be a reflection of female bears adapting to poor hard mast abundance by entering hibernation earlier, rather than traveling extensively to find food patches. Thus, their fall ranges would not expand. Several researchers have suggested that food abundance in fall affects the timing of denning for bears (Alt 1980, Johnson and Pelton 1980, Tietje and Ruff 1980, Beecham et al. 1983, O'Pezio et al. 1983). Clark (2004) suggested that during years of low mast abundance, bears will enter dens earlier in the fall to minimize further energy expenditures. In Maine, Schooley et al. (1994) documented that when beechnuts were scarce, bears denned in October rather than in November. Early hibernation during times of poor mast also was documented in Ontario, Canada (Kolenosky and Strathearn 1987) and in the southern Appalachians (Johnson and Pelton 1980, Carney 1985). However, exceptions exist; Vaughan (2002) found that in SNP, bears with home ranges in areas defoliated by gypsy moths (no acorns) denned later than bears with home ranges in areas not defoliated by gypsy moths. Because CABS data on den entry were lacking, I was unable to test for relationships between den entry dates and hard mast abundance in this study.

Inter-year stability.- While bears may not change their home range size in response to environmental and/or demographic variation, they may respond by shifting their geographic location. Adult female bears on both study areas were as likely as not to shift seasonal ranges between years (Table 2.16) or over longer time intervals (Table 2.17). Therefore, I pooled the data for further analysis and to increase statistical power. In the northern study area, most females maintained the same spring (55%) and summer (63%) home range throughout the duration of the study (Table 2.18). However, 63% of northern

females did change their fall home range between years, possibly in reaction to changes in hard mast abundance and distribution. Similarly, most females in the southern study area maintained their spring (75%) and summer (78%) home range throughout the years. However, unlike the northern females, a majority of southern females also maintained their fall home range through the years (55%; Table 2.18).

These results differed from J. Higgin's (1997) prior examination of home range stability in western Virginia. She found that half of the females monitored during 2 years exhibited stable home ranges. However, her sample size was low ($n=8$), and 2 bears within the sample had ≤ 20 telemetry locations annually. Also, stability was tested only between 2 years, and she tested home range stability on an annual, rather than a seasonal basis. Home range fidelity might not always be detectable on an annual basis; in this study, 2 out of 3 seasonal home ranges (spring and summer) remained stable throughout the years.

While several studies have not detected shifts in home range on an annual basis (Reynolds and Beechum 1980, Brody 1984, Warburton 1984, Clark 1992), other studies have detected inter-year seasonal shifts. In GSMNP, Van Manen (1994) reported differences in range fidelity from year-to-year during the fall, and attributed this to the unpredictability of hard mast production. In SNP, Vaughan et al. (1988) found that while spring and summer home ranges of females were similar between years, during the fall bears used different areas from year-to-year. They concluded that the lack of fidelity exhibited during fall was a reflection of yearly variation in hard mast distribution. A later study in SNP also showed greater frequency in inter-year summer to early fall home range center shifts during a period (1987-1989) in which the park experienced a gypsy

moth invasion, resulting in wide-spread overstory canopy defoliation and a complete acorn crop failure in defoliated areas (Kasbohm et al. 1998). However, all these studies tested for home range fidelity using different techniques. Most tested inter-year seasonal shifts by measuring distances between seasonal activity centers between years. In the initial study in SNP, Vaughan et al. (1988) compared core areas of use within convex polygons to describe home range stability among years. These methods for estimating a geographic change in home range differed from MRPP, which I used. As with attempts to make regional comparisons of home range size, the variety of methods used to determine home range fidelity makes comparisons with other studies difficult.

As mentioned earlier, mast abundance and distribution may play a role in determining whether bears shift the location of their annual or seasonal home range. While they were a minority in this study, females that exhibited inter-year shifts in their seasonal home range might have done so in response to inadequate food within their own home range. These bears may also be responding to the harvesting of male and female bears in the area, which would open up previously occupied areas. During CABS, harvest rates for tagged bears (1994-2002; 870M:621F) was 0.32 for males and 0.09 for females (Bridges 2005). Harvest rates for radio-collared females and males were 0.0 to 0.06 and 0.02 to 0.25, respectively (1994-1999; Klenzendorf 2002). With the removal of bears each fall due to hunting, the social structure of the population likely changes and bears may alter their home ranges in response.

Most older females (≥ 11 years old) shifted their spring range among years, while younger females (4-10 years old) did not. All bears that were 4-5 years old and ≥ 11 years shifted their summer home range, versus 32% of bears 6-10 years old. However, results

for inter-year summer shifts might have been affected by low sample size; while I was able to examine 19 bears aged 6-10 years old, I had only 4 bears aged 4-5 years old and 8 bears aged ≥ 11 years old. Females in all age classes shifted their fall range among years, which is a pattern previously observed in year-to-year comparisons of inter-year seasonal fidelity. It's probable that all adult females who shifted their fall range did so for the reasons discussed earlier; changes in mast abundance and distribution.

It is difficult to interpret these results since no clear pattern emerged. In addition, results might be confounded by transitions in age and reproductive status, changes in factors that determine habitat quality, and changes in population demographics and social structure. At present, I found no other bear studies that examined inter-year shift based on adult age classes.

Examining inter-year seasonal fidelity among age classes can be confounded by transition of bears to older age classes, thus I tested among age class differences with this in consideration. Bears transitioning into older age classes, especially from subadults to adults, likely would have more instability associated with their home range during the transition. After family breakup, yearlings disperse from their mothers and travel until they establish a home range (Rogers 1987, Schwartz and Franzmann 1992). Purported advantages to dispersing include reduction of feeding competition with female kin, reduced mate competition with male kin, and inbreeding avoidance (Rogers 1987). However, these advantages are more applicable to male bears. It appears that female yearlings and subadults do not travel as extensively as males after family breakup, and in fact, often they don't disperse (Elowe and Dodge 1989, White et al. 2000). Rather they establish their home range adjacent to or within their mother's home range (Alt 1978,

Rogers 1987, Schwartz and Franzmann 1992). In an earlier CABS study, Lee (2003) found that none of 20 subadult females dispersed, and contributed this to low levels of female harvest and high population densities, which may create fewer open home range spaces. If there are few unoccupied areas for females to move into then this may explain why there were no differences among age classes in the proportion of inter-year seasonal shifts, when the occurrence of an age transition was considered (Table 2.19). Though overall chi-square testing did not show a statistical difference, a majority of subadults shifted their spring and summer range among years (61.5% and 100%; Table 2.19), while a majority of adults did not. Knowledge of foraging areas may be passed from mother to offspring, or through range expansion movements (Rogers 1977, Garshelis and Pelton 1981). While subadult females may not disperse after family breakup, they may travel more extensively in the process of familiarizing themselves with the resources within an area.

Intra-year variability

Black bears generally forage on seasonally abundant food and exhibit distinct seasonal cycles in food consumption (Rogers 1976, Lindzey and Meslow 1977, Beeman and Pelton 1980, Smith 1983, Eagle and Pelton 1983, Garshelis et. al. 1983, Grenfell and Brody 1986, Schooley et. al. 1994). The seasonal movements exhibited by black bears appear to be governed by temporal availability, distribution, phenology, and abundance of preferred foods (Amstrup and Beecham 1976, Garshelis and Pelton 1981, Pelchat and Ruff 1986, Rogers 1987). Patterns in seasonal movements also have been related to reproductive behavior (i.e. solitary females versus females with COY; Smith and Pelton 1989; see chapter 3).

Seasonal home range.- When I tested for within-year differences in seasonal ranges, fall range was 2.1- and 2.4-fold larger than spring and summer, respectively, only in 1997 in the northern study area. There were no other years in which seasonal ranges differed in size in either regions (Table 2.11). In 1997, western Virginia experienced a poor mast year and, subsequently, a reproductive failure (Bridges 2005); range size might have expanded during fall 1997 due to increased movements by bears to find food. Fall ranges were larger than spring and summer for every year in the northern study area; while the differences were not significant and may or may not be biologically meaningful, it follows a pattern seen in other studies (Villarrubia 1982, Carr 1983, Garris 1983, Brody 1984, Beringer 1986, Clevenger 1986, Van Manen 1994). With seasonal data pooled across years, I found that fall home range sizes of adult females on the northern study area were 1.8-fold and 2.1-fold larger than spring and summer, respectively; spring and summer range sizes were similar (Table 2.8). Other studies of bear populations in the southern Appalachians also have documented significant increases in adult female home range size between summer and fall (Villarrubia 1982, Carr 1983, Garris 1983, Brody 1984, Beringer 1986, Clevenger 1986, Van Manen 1994). During late summer and fall, black bears exhibit hyperphagic behavior (Rogers and Allen 1987), in which they forage more intensely for high energy foods that will maximize fat reserves before denning. The constant search for fall foods may necessitate increases in travel, depending on mast abundance and distribution. Villarrubia (1982) surmised that in certain areas of Cherokee National Forest, Tennessee, summer foods were locally abundant and clumped whereas fall foods were more dispersed, thus bears had to travel farther in the fall to find food.

Another factor that may alter fall home range size in western Virginia is “chase season.” Chasing bears with dogs is legal during the bear firearm season in December, and during a bear-dog training season from the 1st Saturday in September to the 1st Saturday in October. Clevenger (1986) suggested that hunting pressure, especially from the use of dogs, plays a role in the increased fall home ranges of bears. Massapout and Anderson (1984) in Wisconsin, and Allen (1984) in Maine, reported that most bears stayed within their home range when pursued by dogs. Earlier, K. Higgin’s (1997) found that 2 of 3 female bears on the southern study area stayed within their annual home range when chased by hounds. However, K. Higgins (1997) reported that pursued bears traveled at a faster rate and covered a greater distance than their normal daily movements. These increased movements may have contributed to larger fall ranges in the northern study area.

While I found that northern fall home ranges were larger than both spring and summer home ranges, Clark (1992) found the opposite trend in Arkansas; home ranges of female bears were larger in summer than fall, and he attributed this to poorer overall habitat quality in summer compared to fall, when acorns were abundant. During summer, patchy resources might force bears to travel greater distances compared to fall (Reynolds and Beecham 1976). Also, females may expand summer ranges to increase breeding opportunities (Smith and Pelton 1989).

In the southern study areas seasonal home ranges of adult females did not differ in size; summer and fall ranges were, statistically and numerically, the same size. In Pisgah National Forest, North Carolina, Beringer (1986) and Siebert (1989) also reported no differences in range size of females between summer and fall. In the Tensas River Basin

of Louisiana, spring, summer, fall, and winter ranges of males and females did not change, though summer and fall ranges were numerically larger (Weaver 1999). Despite these conflicting results, it appears that the common theme researchers attribute to driving seasonal home range size is the distribution and abundance of food; if these 2 factors are high, then bears can minimize their travel efforts while still meeting their energy requirements.

Intra-year stability.- Intra-year home range fidelity of adult female bears in this study did not vary by year, age, or study area. Similarly, Klenner (1987) in western Manitoba reported no differences in seasonal range shifts between subadult and adult females. During this study, some females shifted their seasonal home range when transitioning from spring to summer and summer to fall, but a majority did not. However, when I looked at seasonal shifts over a longer period of time, I observed that a majority of females did exhibit a shift in their home range between spring and fall. VanManen (1994) observed that female shifts between spring-summer and summer-fall were relatively small. Perhaps intra-year shifts in seasonal home ranges are better detected over the long term (i.e. spring to fall) versus the short term (i.e. spring to summer), because these shifts are gradual over time. The gradual shift in seasonal use within a bear's annual home range might reflect the availability of a mosaic of habitat types within their range, thus providing a diversity of foods during all seasons.

Other studies that have examined intra-year shifts in seasonal home range measured distances between seasonal activity centers to determine whether geographic changes were significant. In North Carolina (Brody 1986, Seibert 1989) and Arkansas (Clark 1992), distances between summer and fall activity centers of adult females was not

significant. However, bears in the southern Appalachians (Garshelis and Pelton 1981, Carr 1983, Garris 1983, Clevenger 1986), in Virginia (Hellgren and Vaughan 1990, Kasbohm et al. 1998), and in Idaho (Reynolds and Beecham 1980) exhibited significant seasonal changes in activity centers, possibly in response to phenological development of the surrounding habitat (Amstrup and Beecham 1976, Reynolds and Beecham 1980) and patchy distribution of late summer and fall food sources, particularly acorns (Clark 1992). In western Virginia, the landscape is dominated by oak types, so the distribution of oaks is not patchy, though acorn production may be. This might explain the lack of shifts I observed between summer and fall home ranges. Brody (1984) noted that while there was a significant increase in range size between summer and fall, there was not a geographic shift in activity centers.

Age effect

Annual home range size of adult females did not differ by age class (i.e. 1, 2, 3) in either study area. While other studies have made comparisons between subadult (i.e. bears ≤ 3 years old) and adult home range sizes (Rogers 1977, Reynolds and Beecham 1980, Rogers 1987, Clevenger and Pelton 1990, Hellgren and Vaughan 1990, Schwartz and Franzmann 1992, Wooding and Hardisky 1994, Onorato et al. 2003), none compared among adult age classes. The lack of difference in annual home range size among adult females may reflect the relative stability in population demography and the strong site fidelity adult females exhibit once they have established their home range.

Though bears ≥ 3 years old are considered adults, differences still likely exist between “young adults” and “older adults.” In western Virginia and throughout North America, younger females (3- and 4-year old) had smaller litter sizes than older females

(≥ 5 years old; Elowe and Dodge 1989, Kordek and Lindzay 1980, Kolenosky 1990, Noyce and Garshelis 1994, Costello et al. 2003, Bridges 2005). In western Virginia, Bridges (2005) found age of first reproduction did not always occur at 3 years (61%), and that 3-year-olds gave birth 12 days later than older females. Though these reproductive parameters may differ among adult ages, it does not appear age is important in determining home range size. Reproductive status, adult age, and home range dynamics are further examined in chapter 3.

Conclusion

Long-term, multi-region research projects, such as this one, are uncommon in black bear literature (Pelton and VanManen 1996) therefore, this study provided a unique opportunity to examine home range dynamics of 2 black bear populations in western Virginia. One advantage was our ability to monitor individual bears over multiple years; variation among individual bears can obscure the relationship between home range dynamics and influencing factors (Villarrubia 1982). However, if individual bears are located not only throughout the chosen observation period, but also monitored equally during this time, this strengthens comparability in home range size and site fidelity within a study. In this study, individual bears monitored ≥ 1 year ($n=39$) did not change home range size on an annual basis (North: 1995-2000; South: 2000-2002) or as they aged. Nor did these bears shift their spring and summer home ranges among years. The stability of both range size and geographic location in 2 of 3 seasons indicate that the factors that influence home range dynamics have also remained relatively stable during CABS. The fidelity bears showed during spring and summer might reflect the importance

of familiarity with one's home range; having prior knowledge of dependable food resources in an area might increase a bear's fitness, by maximizing food intake while minimizing energy expenditures (Rogers 1977, Garshelis and Pelton 1981).

The lack of difference in range size also allowed me to pool data and increase statistical power when testing how other factors, such as region, might have affected home range size. Differences detected in home range size and geographic range shifts are less likely to be biased by extremes in data when ≥ 20 animals are used (Alldredge and Ratti 1986, Samuel and Fuller 1994). The length of the CABS study and the number of bears monitored increases the robustness of my statistical results.

Direct comparisons of home ranges from different black bear populations are confusing and often meaningless due to discrepancies in sampling techniques and methods of calculation. We kept our sampling methods consistent, which allowed us to make regional comparisons within western Virginia. I detected that home ranges of northern bears were smaller than that of southern bears, though the centers of the 2 study areas were approximately 160 km apart. Other regional differences were as follows: fall ranges were larger than spring and summer ranges in the north, while no differences existed among seasonal ranges in the south; most northern females shifted their fall range among years, while most southern females did not; intra-year seasonal shifts differed for northern females, whereas intra-year seasonal shifts were similar for southern females. The ability of an area to provide for the annual needs of bears (i.e. food, shelter, mates; Hamilton 1978), as well as the population demographics within that area (i.e. age and sex structure, density; Pelton 1982), partially determines home range size and fidelity. The

differences I observed in the home range dynamics of the 2 study areas likely reflects regional differences in some or all of these factors.

The opportunity to monitor bears over multiple years allowed us to examine how variability affects home range dynamics in western Virginia and gain some insight into the quality of habitat in this region. Knowledge of a bear's home range provides insight into several behavioral and ecological processes, such as social organization of a population, foraging patterns, location of important habitat components, and if resources are limiting. It also, simply, identifies where an animal is occurring, which is critically important for managing a species. However, attempting to understand home range dynamics of bears is complicated by the many influencing factors that function in determining how a bear chooses to move around its environment. While I attempted to examine some explanatory factors (i.e. mast abundance, population densities, macrohabitat features), it is difficult, not only to measure, but to account for all the factors that affect bear movements. There are still many unknowns that might further explain the movement patterns of bears observed in this study.

Chapter 3. The influence of reproductive status on home range dynamics of adult female black bears.

INTRODUCTION

Use of space by black bears (*Ursus americanus*) is a function of the distribution and abundance of food resources (Garshelis and Pelton 1981, Jonkel and Cowan 1971, Kolenosky and Strathearn 1987, Lindzey and Meslow 1977, Lindzey et al. 1986, Powell et al. 1987, Rudis and Tansey 1995, Schoen 1990), reproductive and social status of individual animals, population density, and presence of potential competitors, including humans (Garshelis 2000, Mace and Wallace 1997, Powell et al. 1997). While habitat quality may serve as a strong influence in determining movement patterns and home range size and social organization, reproductive status also may influence home range size in females (Koehler and Pierce 2003).

Adult female black bears have a biennial reproductive cycle. Females give birth to cubs in their winter dens during January or February, then remain with their offspring for approximately 18 months. Females without cubs of the year (COY) breed during June or July, either as first time breeders or experienced mothers recently separated from their yearlings, then remain solitary for about 6 months until their cubs are born (Alt et al. 1977). From den exit (March/April) to June, females are either solitary, or traveling with cubs or yearlings. Females unsuccessful at breeding and females that lose their cubs after breeding season are assumed to repeat the solitary cycle. Therefore, each year female black bears in a population are either solitary from June through December or traveling with their cubs (Alt et al. 1977).

How the reproductive status of an adult female black bear affects her movements throughout the year is not well understood. Short-term studies with low sample sizes may be data-poor and often little confidence can be placed in interpretation of the data. Thus, conclusions drawn about the effect of reproductive status on a female's movements have been contradictory from studies that have examined this question.

While several studies concluded that the presence of cubs limits a female bear's movements following den emergence (Alt et al. 1977, Lindzey and Meslow 1977, Reynolds and Beecham 1980, Kolenosky and Starthearn 1986), others have shown that females with cubs exhibit high activity levels in the spring (Amstrup and Beecham 1976, Garshelis and Pelton 1980), perhaps an avoidance response to conspecifics (Powell et al. 1997), and/or a response to nutritional demands placed on the family unit during a time of limited food availability (Rogers 1976, Seaman 1993). However, most studies agreed that as the year progressed, females with cubs appear to increase their home range size, reaching a peak in the fall (Alt et al. 1977, Smith and Pelton 1990, J. Higgins 1997, Dahle and Swenson 2003).

Solitary female black bears in Pennsylvania and brown bears in Sweden used larger areas throughout the year than females with cubs; home range size for solitary females peaked during the breeding season (Alt et al. 1977, Dahle and Swenson 2003). By increasing their movements during breeding season, solitary females purportedly benefit through mate selection (Andersson 1994). This is theoretically mediated through male-male competition for female choice, leading to fertilization insurance (Gray 1997), sperm competition (Parker 1970, Stockley and Purvis 1993), and selection of the most genetically compatible sperm (Wilson et al. 1997). In addition, females mating with

competing males might reduce the risk of infanticide because males cannot identify their offspring (Ebensperger 1998). While direct observation of female reproductive strategies seldom has been documented, Schenk and Kovac (1995) found evidence of multiple paternity within litters of female black bears in Ontario, indicating that multiple mating occurs in both sexes.

The Cooperative Alleghany Bear Study (CABS) was initiated in 1994 to address concerns over the lack of biological and ecological data from Virginia's hunted black bear (*Ursus americanus*) population. As part of CABS, we collected data in 2 study areas from January 1995 through December 2002, specifically to determine if reproductive status of female black bears had an effect on their seasonal movement patterns and home range size. The objectives of this chapter were to compare annual and seasonal home ranges of adult females with and without COY, determine the degree of annual home range stability, and examine movement patterns of adult females in the 2 study areas to determine if differences exist.

METHODS

Based on results from chapter 1, I used the Home Range Extension (Rodgers and Carr 1998), designed for use in the software program ArcView 3.2 to estimate home range size. This extension allows the user to estimate home range size using both the MCP and kernel methods. Locations for each bear were recorded as Universal Transverse Mercator (UTM) coordinates and were plotted in ArcView 3.2 so that home range estimates could be calculated.

I defined adult female black bears as bears ≥ 3 years old; subsequently, all adult females were classified as breeding females or females with cubs of the year (COY).

Breeding females included adult female black bears that were either solitary or with yearlings. Females with COY were females whose cubs survived until their second denning period (i.e., to 1 year of age). Because of an inadequate number of telemetry locations in some years (i.e. ≤ 20 locations/bear), I included only bears monitored during 1995-1999 from the northern study area and bears monitored during 2000-2002 from the southern study area in the analyses. For individual bears monitored for more than 1 year, I used the mean of all the ranges for that individual to avoid pseudoreplication when I tested for differences in home range size by reproductive category, age category, and season.

To determine if home range size differed with age, I placed females in 4 age categories (3 years old, 4-5 years old, 6-10 years old, and ≥ 11 years old), which were based on age of first reproduction and litter size (Bridges 2005). To test among age class differences by reproductive status, annual home ranges were compared with a two-way ANOVA (proc GLM; SAS Institute, Inc. 1990) with a protected LSD procedure to make mean comparisons. To determine if home range size differed by year, I used two-way ANOVA (proc GLM; SAS Institute, Inc. 1990) with a protected LSD procedure to make mean comparisons to test for among year differences by reproductive status.

I used the Wilcoxin Rank Sum test to test for differences in the 95% MCP home ranges between reproductive classes within each season. MCP's were used because of the low number of locations (i.e. <10 locations) available for several bears within a given season; the low number of locations often was below the threshold at which fixed-kernel ranges could be generated. But by using MCP's, comparisons can be made with other studies that examined seasonal home range movements in black bears. Seasons were

based on changes in plant phenology (Garner 1986), bear behavior, and hunting activities (spring: den emergence-15 June; summer:16 June-31 August; fall:1 September – den entry or 31 December). I pooled telemetry data over years for each reproductive class due to small sample size, and because there was no difference in home range area among years (see chapter 2).

To test for intra-year home range fidelity for females of both reproductive classes, I tested seasonal ranges (i.e. spring, summer, fall) within a year for differences using multiple response permutation procedure (MRPP) in the software program BLOSSOM (Midcontinent Ecological Science Center, National Biological Survey). MRPP tests whether 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 (White and Garrot 1990). The null hypothesis for MRPP analysis is 2 or more utilization distributions are the same. I used a chi-square test to test for differences in the proportion of females with and without COY (i.e. breeding females) that exhibited a significant shift within their annual home range; data from all years were combined due to small sample sizes.

MRPP also was used to test for inter-year seasonal home range fidelity of females that were monitored consecutively during both reproductive cycles. I used chi-square analysis to test for differences in the proportion of females that exhibited a significant shift within their seasonal range, when their reproductive status changed.

Unless otherwise stated, $\alpha=0.05$ was selected for statistical significance for all tests; program SAS (1990) was used for all statistical analyses.

RESULTS

During 1995-2002, I monitored 56 individual adult female black bears for 105 bear years in the northern and southern study area of the Cooperative Alleghany Bear Study.

Home range size

Age Effects.- Annual home range size of adult female black bears in the northern study area did not differ by reproductive status, age class, or their interaction at the 95% and 50% fixed-kernel contour ($P>0.05$, Table 3.1, Table 3.2) On the southern study area, annual home range size differed overall at the 95% fixed-kernel contour ($F_{6,22}=2.72$, $P=0.04$; Table 3.1, Table 3.2), but further testing failed to detect differences in home range size by reproductive status ($F_{1,22}=3.37$, $P=0.08$; Table 3.2), by age class ($F_{3,22}=2.31$, $P=0.11$; Table 3.2), or their interaction ($F_{2,22}=0.52$, $P=0.48$; Table 3.2). Therefore, data were pooled across age classes in both study areas for future analyses.

Year effects.- During 1995-1999, annual home range size of adult female black bears in the northern study area did not differ by reproductive status, year, or their interaction in the northern study area ($P>0.05$; Table 3.3, Table 3.4) at the 95% fixed-kernel contour. Thus, yearly home ranges were pooled in further analyses. An extreme outlier was removed from analysis for females with COY in 1999; the home range represented by this outlier was 6.8-fold greater in size than the next lowest value in the sample set. The mean home range size for females with COY was 33.29 km² (S.D.=21.7), including the outlier, but only 11.8 km² (S.D.=3.6; Table 3.3) when the outlier was excluded. However, including the outlier still did not result in an among year difference

Table 3.1. Age-specific annual home range size (SE; km²) for adult female black bears with and without COY^a in the George Washington and Jefferson National Forests, Virginia, January 1995 – December 2002.

Region ^b	Age class	95% kernel			50% kernel			w/o COY	
		N	with COY	N	w/o COY	N	with COY		N
North	3 years old	2	15.3 (10.4)	3	7.2 (2.1)	2	3.7 (2.8)	3	1.5 (0.4)
	4-5 years old	7	15.1 (5.2)	10	14.1 (2.1)	7	3.5 (1.3)	10	3.1 (0.5)
	6-10 years old	13	14.7 (2.4)	14	17.5 (4.5)	13	3.4 (0.6)	15	3.9 (1.1)
	≥ 11 years old	5	21.5 (6.1)	5	9.6 (2.8)	5	4.2 (1.0)	5	2.2 (0.7)
South	3 years old	1	44.8	1	90.7	1	11.2	1	17.0
	4-5 years old	6	43.9 (11.1)	8	33.3 (6.0)	6	8.8 (1.8)	8	7.1 (1.5)
	6-10 years old	3	100.5 (31.5)	8	48.2 (9.5)	3	19.4 (5.8)	8	9.8 (2.0)
	≥ 11 years old	--	--	2	26.4 (17.2)	--	--	2	5.7 (4.2)

^a COY=cubs of the year; w/o COY: includes breeding and solitary females

^b Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

Table 3.2. Effects (ANOVA) of reproductive status and age on annual home range sizes of adult females black bear at the 95% and 50% fixed-kernel contour in the George Washington Jefferson National Forests, Virginia, January 1995-December 2002.

Region ^a	Level	Factor	d.f.	SS	MS	F-ratio	<i>P</i> -value
North	95%	Model	7	642.1	91.7	0.64	0.72
		Reproductive Status ^b	1	51.6	51.6	0.36	0.55
		Age class ^c	3	138.0	46.0	0.32	0.81
		Interaction	3	452.5	150.8	1.06	0.38
		Error	51	7268.0	142.5		
	50%	Model	7	26.3	3.8	0.43	0.88
		Reproductive status	1	2.9	2.9	0.33	0.57
		Age class	3	8.1	2.7	0.31	0.82
		Interaction	3	15.3	5.1	0.59	0.63
		Error	52	452.3	8.7		
South	95%	Model	6	12853.4	2142.2	2.72	0.04
		Reproductive status	1	2656.3	2656.3	3.37	0.08
		Age class	3	5460.4	1820.1	2.31	0.11
		Interaction	2	330.1	330.1	0.52	0.48
		Error	22	17352.4	788.7		
	50%	Model	6	428.4	71.4	2.27	0.07
		Reproductive status	1	85.3	85.3	2.71	0.11
		Age class	3	209.1	69.7	2.22	0.12
		Interaction	2	134.0	67.0	2.13	0.14
		Error	22	692.3	31.5		

^a Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^b Reproductive status defined as females with cubs of the year (COY) and breeding females

^c Age class defined into 4 categories: 3 years old, 4-5 years old, 6-10 years old, ≥ 11 years old

Table 3.3. Annual home range size (SE; km²) of adult females with and without COY^a in the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, January 1995 through December 2002.

Region ^b	Year	95% kernel			
		N	with COY	N	w/o COY
North	1995	6	21.1 (4.7)	8	13.7 (2.6)
	1996	2	7.7 (0.5)	2	13.9 (2.3)
	1997	11	16.2 (3.4)	12	15.0 (4.1)
	1998	4	25.5 (7.0)	6	11.0 (2.2)
	1999	7	11.8 (3.6)	4	23.1 (11.3)
South	2001	7	37.6 (4.6)	7	68.9 (13.8)
	2002	3	80.5 (17.5)	10	35.0 (4.9)

^a COY=cub of the year; w/o COY: includes breeding and solitary females

^b Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

Table 3.4. Effects (ANOVA) of reproductive status and year on home range sizes of adult females black bear at the 95% fixed-kernel contour in the George Washington and Jefferson National Forests, Virginia, January 1995-December 2002.

Region ^a	Factor	d.f.	SS	MS	F-ratio	<i>P</i> -value
North ^b	Reproductive Status ^c	1	58.1	58.1	0.41	0.52
	Year	4	137.5	34.4	0.24	0.91
	Interaction	4	1001.4	250.4	1.77	0.15
	Error	52	7359.4	141.5		
South	Reproductive status	1	817.3	817.3	0.79	0.38
	Year	1	968.3	968.3	0.93	0.34
	Interaction	1	5505.7	5505.7	5.31	0.03
	Error	24	24880.5	1036.7		

^a Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^b Northern study area: 1995, 1996, 1997, 1998, 1999

Southern study area: 2001, 2002

^c Reproductive status defined as females with cubs of the year (COY) and breeding females

in home range size ($F_{4,26}=0.42$, $P=0.80$).

While home range size did not differ by reproductive status or year in the southern study area, there was a significant interaction between the 2 factors ($F_{1,24}=5.13$, $P=0.03$; Table 3.3, Table 3.4). Despite statistical significance, I pooled home range data across years in the southern study area because I believed it probable that differences in yearly home range size were due to small sample size, rather than true differences (Type I error). Certain bears with a predilection for large movements, irregardless of their reproductive status, were heavily represented in both 2001 and 2002. Mean home range size (95% fixed-kernel) for southern study area females with COY was 2.1-fold larger in 2002 than in 2001 (Table 3.3), but 2.0-fold larger in 2001 than in 2002 for breeding females (Table 3.3). Sample size was small for females with COY in 2002 ($n=3$; Table 3.3), possibly causing extremes in home range size to bias the results.

Reproductive Status. - Annual home ranges of northern study area female bears with and without COY were not different at the 95% ($Z=0.89$, $P=0.38$; Table 3.5, Figure 3.1) or 50% fixed-kernel contours ($Z=0.98$, $P=0.33$; Table 3.5). Removing an extreme outlier in both reproductive classes reduced the standard error for females with COY, but home range size still did not differ ($Z=0.44$, $P=0.66$; Table 3.5) at the 95% fixed-kernel level. Females with COY had home ranges 1.1-fold larger than breeding females with extreme outliers removed.

On the southern study area, female bears of differing reproductive classes had statistically similar home ranges at the 95% ($Z=1.3$, $P=0.20$; Table 3.5, Figure 3.1) and 50% fixed-kernel contours ($Z=1.35$, $P=0.19$; Table 3.5). When an outlier was removed

from females with COY, home range size between reproductive classes at the 95% fixed-kernel contour still did not differ ($Z=0.9878$, $P=0.33$; Table 3.5).

To reduce error from individual variation of bears, female bears that were monitored through different reproductive cycles were analyzed separately. In the northern study area, annual home ranges of individual female bears monitored in year(s) when they did and did not have COY were 1.9- to 2.4-fold larger when they had COY, but the differences were not significant at the 95% ($t=-1.53$, $P=0.15$; Table 3.5) or 50% fixed-kernel contour ($t=1.39$, $P=0.19$; Table 3.5). One bear was removed from analysis because her home range sizes were extreme outliers. Removing this female with an extremely large home range from the analysis did not change the statistical significance ($t=0.86$, $P=0.43$; Table 3.5), but reduced the standard error from 12.2 to 2.6.

Southern study area females monitored through both reproductive cycles had statistically similar home ranges (95% fixed-kernel: $t=1.67$, $P=0.19$; 50% fixed-kernel: $t=1.70$, $P=0.19$; Table 3.5).

Seasonal home range size

Seasonal home range size (95% MCP) during spring, summer, and fall for adult female bears with and without COY in both the northern and southern study area did not differ among years ($P>0.05$; Table 3.6), thus I pooled data within season across years.

Northern Study area

Home range size (95% MCP) for adult female black bears on the northern study area during spring ($Z=0.4158$, $P=0.68$), summer ($Z=0.1553$, $P=0.88$) and fall ($Z=0.32$, $P=0.75$) did not differ by reproductive status (Table 3.7). Fall ranges of females with

Table 3.5. Annual home range size (SE; km²) of adult female bears with and without COY^a in the northern and southern study areas of the Cooperative Alleghany Bear Study in the George Washington and Jefferson National Forests, Virginia, January 1995-December 2002.

Region ^b	Bears included in analysis	95% kernel			95% kernel outlier removed ^d			50% kernel			P value			
		N	With COY	N	w/o COY	N	With COY	N	With COY	N		w/o COY	P value	
North	All bears	23	23.7 (7.6)	28	14.2 (2.1)	22	16.4 (2.3)	27	14.8 (2.2)	23	4.4 (0.90)	28	3.1 (0.52)	<i>P</i> =0.33
	Same bears ^c	14	29.0 (12.2)	14	12.1 (2.6)	13	16.6 (3.1)	13	13.1 (2.7)	14	4.9 (1.4)	14	2.6 (0.62)	<i>P</i> =0.19
South	All bears	12	60.0 (11.2)	17	43.0 (7.5)	11	51.4 (7.8)	17	43.0 (7.5)	12	12.0 (2.0)	17	8.7 (1.6)	<i>P</i> =0.19
	Same bears	9	61.9 (13.6)	9	47.5 (12.0)	-	-	-	-	9	12.7 (2.5)	9	9.5 (2.5)	<i>P</i> =0.19

^a COY=cubs of the year, w/o COY: includes breeding and solitary females

^b Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^c Same bears=Female bears monitored through both reproductive cycles

^d Outliers removed represented bears whose home range size were beyond the 95th percentile

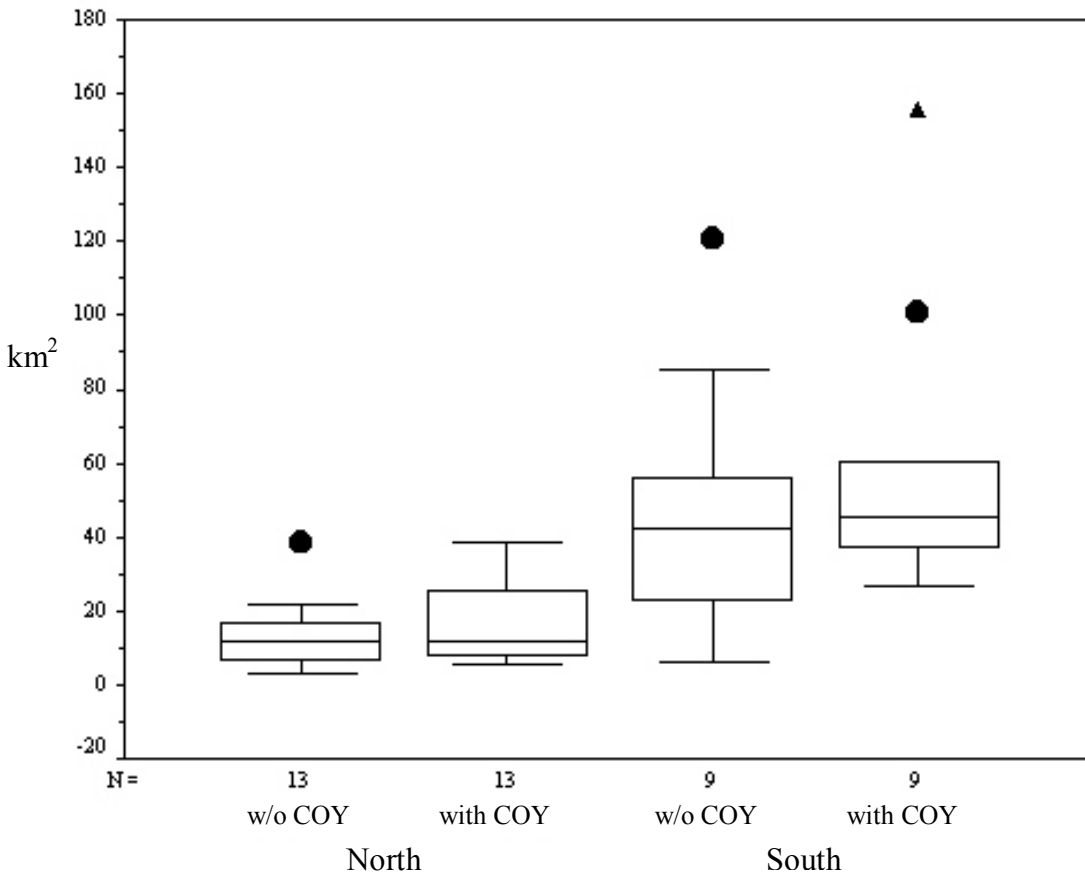


Figure 3.1. Annual 95% fixed-kernel home ranges of adult female bears monitored when they were with and without COY^a in the northern and southern study areas of the Cooperative Alleghany Bear Study in the George Washington and Jefferson National Forests, Virginia, January 1995-December 2002. Boxes represent the interquartile range containing 50% of the values. The error bars are the 5th and 95th percentiles and ● are outliers beyond the 5th and 95th percentiles. Extremes (▲) are cases with values more than 3 times larger than the interquartile range. Two extreme outliers, representing one bear monitored in through both reproductive statuses, are not displayed in the north (with COY=184.0 km² and without COY=4.1 km²).

^a COY=cubs of the year; without COY includes solitary and breeding females

Table 3.6. Seasonal home range size (S.E.; km²) by year of adult female black bears with and without COY^a in the northern and southern study areas of the Cooperative Alleghany Bear Study in George Washington and Jefferson National Forests, Virginia, January 1995 through December 2002.

Region ^b	Season	Year	With COY		Without COY		
			N	95% MCP	N	95% MCP	
North	Spring	1995	6	5.0 (1.6)	5	5.2 (1.5)	
		1996	2	1.9 (0.9)	2	4.3 (0.4)	
		1997	11	2.5 (0.7)	10	2.2 (0.6)	
		1998	4	5.3 (1.4)	5	3.0 (1.4)	
		1999	7	2.8 (0.7)	4	6.1 (1.7)	
		2000	-	-	5	2.7 (1.1)	
					<i>P</i> =0.20		<i>P</i> =0.14
	Summer	1995	5	3.1 (1.1)	6	2.8 (0.9)	
		1996	2	2.2 (0.1)	2	3.6 (1.1)	
		1997	9	2.4 (0.6)	8	2.3 (0.7)	
		1998	1	6.1 (-)	1	1.1 (-)	
		1999	4	3.8 (1.9)	-	-	
		2000	-	-	5	3.8 (1.2)	
					<i>P</i> =0.56		<i>P</i> =0.67
	Fall	1995	5	11.0 (7.5)	8	5.2 (1.4)	
		1996	-	-	-	-	
		1997	11	4.7 (0.9)	12	4.2 (0.8)	
		1998	4	10.7 (5.0)	6	2.6 (0.6)	
1999		7	3.9 (1.5)	3	9.3 (4.2)		
2000		-	-	5	5.8 (2.0)		
				<i>P</i> =0.33		<i>P</i> =0.15	
South	Spring	2000	1	2.3 (-)	3	11.7 (2.0)	
		2001	8	7.3 (1.7)	6	14.8 (2.9)	
		2002	3	5.6 (1.5)	7	9.4 (1.4)	
					<i>P</i> =0.55		<i>P</i> =0.23
	Summer	2000	1	19.1 (-)	1	28.0 (-)	
		2001	6	19.4 (6.7)	7	11.9 (2.8)	
		2002	3	16.7 (4.8)	8	12.5 (2.0)	
					<i>P</i> =0.97		<i>P</i> =0.11
	Fall	2000	1	10.3 (-)	3	9.9 (7.3)	
2001		8	21.0 (7.1)	7	13.5 (3.6)		
2002		3	19.1 (5.4)	8	8.8 (1.6)		
				<i>P</i> =0.86		<i>P</i> =0.55	

^a COY=cubs of the year; w/o COY: includes breeding and solitary females

^b Counties in north: Augusta, Rockingham; counties in south: Craig, Giles, Montgomery

COY were 2.2-fold larger than summer ranges ($F_{2, 54}=3.12$, $P=0.05$; Table 3.7); spring range did not differ from summer or fall ranges. Home range size of breeding females (i.e. without COY) did not differ seasonally ($F_{2, 63}=2.29$, $P=0.11$; Table 3.7).

Seasonal home ranges of female bears monitored during both reproductive cycles did not change in size when their reproductive status changed (Spring: $t=1.23$, $P=0.24$; Summer: $t=0.01$, $P=0.99$; Fall: $t=1.13$, $P=0.29$; Table 3.7, Figure 3.2).

Southern study area

Summer ranges of southern study area females with and without COY did not differ ($Z=1.0832$, $P=0.29$; Table 3.7). However in spring, breeding females occupied ranges 1.7-fold larger than females with COY ($Z=-2.3664$, $P=0.03$; Table 3.7), while in fall breeding females used ranges 1.9-fold smaller than females with COY ($Z=2.0241$, $P=0.05$; Table 3.7).

Home range size for females with COY differed among seasons ($F_{2, 30}=4.58$; $P=0.02$; Table 3.7); summer and fall ranges were similar ($P>0.05$), but spring ranges were 2.9-fold and 3.2-fold smaller than summer and fall ranges, respectively ($P<0.05$; Table 3.7). Home ranges of breeding females did not differ among seasons ($F_{2, 40}=0.16$, $P=0.86$; Table 3.7).

Female bears in the southern study area monitored during both reproductive cycles had smaller spring ranges (7.0 versus 9.7 km²) when they had COY than when they did not (Spring: $t=2.59$, $P=0.03$; Table 3.7). Neither summer nor fall range size differed by reproductive class for this subset of bears (Summer: $t=-0.37$, $P=0.72$; Fall: $t=-1.04$, $P=0.33$; Table 3.7).

Table 3.7. Seasonal home range size (S.E., km²) of adult females black bears with and without COY^a in the northern and southern study area of the Cooperative Alleghany Bear Study in George Washington Jefferson National Forest, Virginia, January 1995 through December 2002.

Region ^b	Bears in analysis	Season	95% MCP				<i>P</i> value ^c
			N	With COY	N	W/O COY	
North	All ^c	Spring	22	3.5 AB ^d (0.6)	25	3.6 (0.6)	<i>P</i> =0.68
	All	Summer	16	2.9 B (0.5)	18	3.0 (0.5)	<i>P</i> =0.88
	All	Fall	19	6.3 A (1.6) <i>P</i> =0.05	23	4.9 (0.8) <i>P</i> =0.11	<i>P</i> =0.75
	Same	Spring	12	3.4 (0.7)	12	4.1 (0.9)	<i>P</i> =0.24
	Same	Summer	6	3.2 (0.7)	6	3.2 (0.8)	<i>P</i> =0.99
	Same	Fall	10	6.1 (2.2)	10	4.0 (1.1)	<i>P</i> =0.29
	South	All	Spring	12	6.5 B (1.2)	14	11.1 (1.2)
All		Summer	10	18.6 A (4.1)	14	12.4 (1.8)	<i>P</i> =0.29
All		Fall	11	21.0 A (5.1) <i>P</i> =0.02	15	11.0 (2.0) <i>P</i> =0.86	<i>P</i> =0.05
Same		Spring	9	7.0 B (1.6)	9	9.7 (1.1)	<i>P</i> =0.03
Same		Summer	7	15.6 A (2.9)	7	14.2 (2.2)	<i>P</i> =0.72
Same		Fall	9	17.5 A (3.5)	9	12.3 (3.1)	<i>P</i> =0.33

^a COY=cubs of the year; w/o COY: includes breeding and solitary females

^b Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

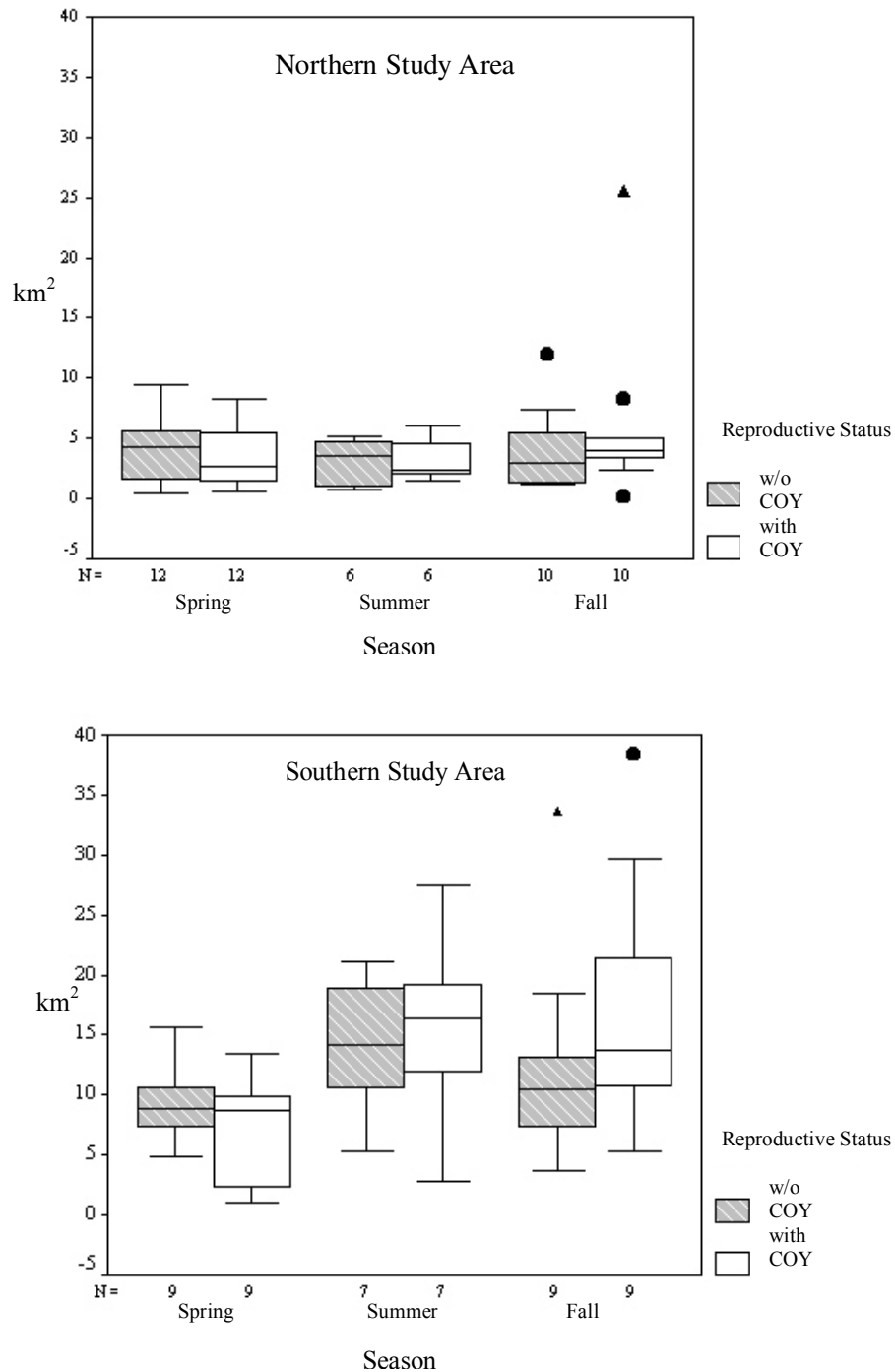
^c All=all bears monitored during CABS; Same=individual bears monitored during both reproductive cycles

^d Among seasons, means followed by the same letter within a region are not different (*P*>0.05).

^e *P* value=tested for differences between females with and without COY within each season using paired t-test.

Figure 3.2. Seasonal 95% MCP home ranges of individual adult female bears monitored when they were with and without COY^a in the northern and southern study area of the Cooperative Allegheny Bear Study in the George Washington Jefferson National Forests, Virginia, January 1995-December 2002. Boxes represent the interquartile range containing 50% of the values. The error bars are the 5th and 95th percentiles and ● are outliers beyond the 5th and 95th percentiles. Extremes (▲) are cases with values more than 3 times larger then the interquartile range.

^a COY=cubs of the year; without COY includes solitary and breeding females



Intra- and inter-year home range fidelity

Northern study area

During 1995-1999, on 22 of 32 occasions and 17 of 31 occasions, females with COY and breeding females (i.e. without COY), respectively, exhibited shifts within their annual home range; females with and without COY did not exhibit shifts more than expected ($\chi^2=1.29$, $P=0.26$, $df=1$; Table 3.8). Additionally, the proportion of females that did and did not exhibit a shift within their annual home range did not differ by reproductive status ($\chi^2=2.61$, $P=0.11$, $df=1$; Table 3.8); 69% of females with COY exhibited a seasonal shift in their home range versus 55% of breeding females.

On 12 of 28 occasions individual females exhibited a shift in their annual home range when their reproductive status changed; these females did not exhibit a shift in their annual home range more than expected ($\chi^2=3.09$, $P=0.38$, $df=3$; Table 3.9). However, when comparing the 2 types of transitions that occurred, females with cubs that transitioned to being solitary shifted home ranges in a higher proportion (60%) than breeding females that transitioned to having cubs (25%; $\chi^2=12.16$, $P=0.007$, $df=3$; Table 3.9).

Southern study area

During 2000-2002, on 7 of 13 occasions and 7 of 20 occasions, females with COY and breeding females, respectively, exhibited shifts within their annual home range; females with and without COY did not exhibit shifts more than expected ($\chi^2=1.66$, $P=0.20$, $df=1$; Table 3.8). Females with COY exhibited a greater degree of shifts within their annual home range than breeding females ($\chi^2=4.92$, $P=0.03$, $df=1$; Table 3.8); 58%

Table 3.8. Intra-year home range fidelity^a for adult female black bears from 1995-2002 on the George Washington and Jefferson National Forest, Virginia as measured by MRPP^b.

ID	Region ^c	Year	Reproductive status	Number of locations	<i>P</i> -value
6	North	1995	Breeding ^d	50	0.01
6	North	1997	Breeding	30	0.38
13	North	1995	Breeding	33	<0.01
13	North	1997	with COY	25	<0.01
13	North	1998	Breeding	23	0.40
13	North	1999	with COY	22	0.04
15	North	1995	with COY	55	<0.01
15	North	1997	Breeding	31	0.17
15	North	1998	with COY	30	<0.01
15	North	1999	Breeding	38	<0.01
31	North	1995	with COY	56	0.05
31	North	1997	Breeding	34	<0.01
31	North	1998	with COY	30	0.20
31	North	1999	Breeding	34	<0.01
62	North	1995	with COY	51	<0.01
62	North	1996	Breeding	25	0.45
62	North	1997	with COY	27	<0.01
63	North	1995	Breeding	43	0.51
63	North	1997	with COY	30	0.60
63	North	1998	Breeding	23	0.58
72	North	1995	with COY	31	0.01
72	North	1996	Breeding	23	0.19
72	North	1997	with COY	26	0.67
73	North	1995	Breeding	49	0.03
73	North	1997	Breeding	35	0.02
73	North	1998	Breeding	26	0.12
75	North	1995	with COY	52	<0.01
75	North	1997	with COY	24	0.23
75	North	1998	Breeding	18	<0.01
85	North	1995	Breeding	47	0.25
88	North	1995	with COY	25	0.03
90	North	1995	with COY	22	<0.01
94	North	1995	with COY	35	<0.01
94	North	1997	Breeding	38	0.36
94	North	1998	with COY	28	<0.01
94	North	1999	Breeding	22	<0.01
110	North	1995	Breeding	35	<0.01
110	North	1996	with COY	24	<0.01
110	North	1997	Breeding	30	<0.01
138	North	1997	with COY	42	0.03
152	North	1997	with COY	29	0.81
153	North	1996	with COY	26	0.22
161	North	1997	with COY	39	<0.01
165	North	1997	with COY	33	0.10
165	North	1998	Breeding	24	0.04
165	North	1999	with COY	38	<0.01
169	North	1997	Breeding	30	<0.01
169	North	1999	with COY	22	<0.01
172	North	1997	with COY	41	<0.01

172	North	1999	with COY	20	<0.01
176	North	1997	Breeding	30	0.86
178	North	1997	Breeding	35	0.04
181	North	1997	Breeding	23	0.29
187	North	1999	with COY	27	0.18
198	North	1997	Breeding	20	<0.01
285	North	1998	Breeding	21	<0.01
285	North	1999	Breeding	20	<0.01
293	North	1997	with COY	42	0.02
300	North	1997	Breeding	33	0.39
300	North	1998	with COY	32	0.10
304	North	1997	Breeding	18	0.78
304	North	1999	with COY	28	<0.01
402	North	1999	with COY	23	0.53
10047	South	2000	Breeding	21	0.82
10047	South	2001	with COY	25	<0.01
10047	South	2002	Breeding	28	<0.01
10084	South	2001	Breeding	28	0.11
10084	South	2002	with COY	28	<0.01
10112	South	2001	Breeding	22	0.96
10139	South	2000	Breeding	33	0.10
10139	South	2001	Breeding	44	<0.01
10139	South	2002	with COY	43	<0.01
10180	South	2002	Breeding	31	0.43
10185	South	2000	Breeding	20	0.02
10185	South	2001	with COY	38	0.09
10185	South	2002	Breeding	29	0.50
10190	South	2000	with COY	24	0.72
10190	South	2001	Breeding	35	<0.01
10227	South	2000	Breeding	17	0.76
10227	South	2002	Breeding	39	0.01
10251	South	2001	with COY	34	0.13
10251	South	2002	Breeding	45	0.01
10253	South	2001	Breeding	34	0.80
10253	South	2002	Breeding	40	0.28
10254	South	2001	Breeding	32	0.22
10254	South	2002	Breeding	39	0.06
10259	South	2002	with COY	36	0.47
10265	South	2001	with COY	29	<0.01
10265	South	2002	Breeding	31	<0.01
10266	South	2001	with COY	27	0.09
10266	South	2002	Breeding	34	0.51
10268	South	2001	with COY	39	0.07
10268	South	2002	Breeding	51	<0.01
10271	South	2001	with COY	29	<0.01
10273	South	2001	with COY	36	<0.01
10276	South	2001	Breeding	27	0.40

^a Spring, summer, and fall locations in one year tested against each other for differences in distribution

^b Multi-response permutation procedures

^c Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^d Breeding: includes solitary and females without COY

Table 3.9. Inter-year seasonal home range fidelity^a between reproductive classes for adult female black bears, as measured by MRPP^b, George Washington and Jefferson National Forest, Virginia. January 1995 through December 2002.

ID	Region ^c	Reproductive status 1 ^d	Reproductive status 2 ^e	Spring		Summer		Fall	
				# of locations	P-value	# of locations	P-value	# of locations	P-value
6	North	Breeding	with COY	34	0.17	15	0.04	-	-
6	North	with COY	Breeding	23	0.12	15	0.12	-	-
13	North	with COY	Breeding	-	-	-	-	24	0.09
13	North	Breeding	with COY	20	0.14	-	-	20	0.79
15	North	with COY	Breeding	40	<0.01	16	0.02	-	-
15	North	Breeding	with COY	31	0.04	-	-	19	<0.01
15	North	with COY	Breeding	35	<0.01	-	-	22	<0.01
31	North	with COY	Breeding	25	0.07	16	0.36	-	-
31	North	Breeding	with COY	31	<0.01	-	-	28	<0.01
31	North	with COY	Breeding	34	0.07	-	-	28	<0.01
62	North	with COY	Breeding	-	-	25	0.08	35	0.46
62	North	Breeding	with COY	26	0.01	-	-	-	-
63	North	with COY	Breeding	25	0.05	-	-	21	0.39
72	North	with COY	Breeding	-	-	15	0.80	31	0.10
72	North	Breeding	with COY	29	0.01	15	0.87	-	-
73	North	Breeding	with COY	31	0.10	24	0.20	-	-
73	North	with COY	Breeding	26	0.48	-	-	-	-
75	North	with COY	Breeding	-	-	-	-	18	0.32
94	North	Breeding	with COY	-	-	-	-	45	<0.01
94	North	with COY	Breeding	17	<0.01	-	-	32	<0.01
110	North	with COY	Breeding	29	0.44	-	-	-	-
154	North	Breeding	with COY	-	-	21	0.36	-	-
161	North	Breeding	with COY	24	<0.01	-	-	-	-
165	North	with COY	Breeding	19	0.33	-	-	28	<0.01
165	North	Breeding	with COY	24	0.01	-	-	25	0.14
165	North	with COY	Breeding	37	0.18	26	0.04	-	-
187	North	with COY	Breeding	-	-	28	0.52	26	0.70
300	North	Breeding	with COY	30	0.03	-	-	22	0.21
10025	South	Breeding	with COY	-	-	-	-	23	0.16
10047	South	Breeding	with COY	22	0.66	-	-	15	0.50
10047	South	with COY	Breeding	-	-	18	0.002	22	0.04

10139	South	Breeding	with COY	36	0.55	22	0.28	17	0.04
10185	South	Breeding	with COY	19	<0.01	-	-	21	0.01
10185	South	with COY	Breeding	23	0.07	22	0.50	18	0.53
10190	South	with COY	Breeding	17	0.43	17	0.02	25	<0.01
10251	South	with COY	Breeding	27	0.12	15	0.88	36	0.10
10265	South	with COY	Breeding	14	0.47	21	0.47	19	0.10
10266	South	with COY	Breeding	21	<0.01	15	0.84	23	0.08
10268	South	with COY	Breeding	29	0.39	28	0.54	36	0.07

^a Season (i.e. spring, summer, and fall) during reproductive status 1 tested against same season during reproductive status 2 for each individual transition

^b Multi-response permutation procedures

^c Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^d Reproductive Status 1 - The reproductive status during the first year of analysis

^e Reproductive Status 2 - The reproductive status the following year after reproductive status 1

of females with COY exhibited a shift in their annual home range versus 38% of breeding females.

On 5 of 11 occasions, females exhibited a shift in their annual home range when their reproductive status changed; these females did not exhibit a shift in their annual home range more than expected ($\chi^2=1.52$, $P=0.68$, $df=3$; Table 3.9). When comparing the 2 types of transitions that occurred, females that transitioned from being solitary to having cubs (50%) shifted their annual home range more frequently ($\chi^2=10.13$, $P=0.02$, $df=3$; Table 3.9) than females that transitioned from having cubs to being solitary (43%).

DISCUSSION

Home range size

Annual home ranges of female bears with and without COY differed little among age classes and years. While home range size of 6-10 year old adult females on the southern study area were 2.2-fold larger than bears ≥ 11 years old, the high standard error associated with each home range estimate partially explains why home range size associated with each age class did not differ (Table 3.3). In addition, though testing showed southern study area breeding females had significantly larger home ranges in 2001 than in 2002 (68.9 versus 35.0 km²) and females with COY had significantly smaller home ranges in 2001 than in 2002 (37.6 versus 80.5 km²), it is unlikely this is reflective of a change in the extent of movements between years exhibited by female bears. Rather, it likely reflects the tendency of individual bears to maintain the same home range size despite their reproductive status; 9 of 10 bears represented in 2001 also were represented in 2002 in a different reproductive status (2002: $n=14$; Table 3.3).

The lack of difference in annual home range size between bears with and without COY suggests that cubs do not inhibit the movements of their mothers throughout the year. Even bears that transitioned from one reproductive class into another did not appear to change their overall movements in response to the presence or absence of cubs. Researchers have hypothesized that if cubs restrict a female's movement, they do so only immediately after den emergence (Alt et al. 1977), though this time period was not defined. Reynolds and Beecham (1980) found that the home ranges of 3 of 4 females monitored over 3 years, through different reproductive cycles, were similar. Heyden and Meslow (1999) also found no differences in annual home range size related to the presence of cubs. The apparent lack of restricted movements observed in females with cubs versus their solitary counterpart, may be because mothers' do not leave the denning area until their cubs are mobile enough to travel. In a study conducted in the northern study area of the Cooperative Alleghany Bear Study, cameras were placed at den sites to document den emergence activity. All 8 female bears with COY exhibited activity bouts in which they temporarily departed from and subsequently returned to their den prior to final family-group emergence (Bridges et al. 2004). The high level of extra den activity towards the end of the hibernation period could reflect the female testing to see if her cubs will follow. In addition, bears may remain in the general vicinity of their den for 10-12 days after emergence (Hellgren and Vaughan 1989), allowing their cubs time to develop until they are physically able to stay with their mother when she leaves the denning area. Once leaving the denning area, mothers may rely on defensive mechanisms to protect their cubs, such as sending the cubs up a tree when threatened, which would preclude the need for the cubs to keep up with their mother at signs of danger.

While the differences in annual home range size I observed were not statistically significant, females with COY consistently had numerically larger annual home ranges, likely reflecting greater movement, either during the entire year or during certain times of year. Alt et al. (1977) also found that females with offspring maintained larger annual home ranges than breeding females.

Seasonal home range

Northern Study Area.- Seasonal home range size for females with and without COY were not different. These results differ slightly from findings of an earlier study conducted on black bear movements in the northern study area from September 1994 through December 1996. J. Higgins (1997) found that spring ranges of females with COY were significantly smaller than both solitary females and females with yearlings. The difference in conclusions likely is due to the long-term nature of this study (9 years) versus Higgins (2 years).

As in this study, J. Higgins (1997) found no difference in summer and fall ranges of females with and without COY, though females with COY had slightly larger home ranges than breeding females during the fall. This is further evidence that cubs do not restrict their mother's movements as they move through their range in search of food. Range size of females with and without COY decreased from spring to summer, then peaked during the fall.

Females with COY had significantly larger fall home ranges than during the summer, while spring and summer ranges were similar in size. This increase in home range size as the year progressed may reflect the increased mobility of cubs and/or the greater nutritional requirements of the family unit (Alt et al. 1977, Smith and Pelton

1990). Increasing seasonal ranges throughout the year could also be the manifestation of avoidance behavior in mothers. Dahle and Swenson (2003) in Sweden found that female brown bears (*Ursus arctos*) with cubs had smaller ranges during the mating season than during the post-mating season. They hypothesized that during the mating season females with cubs might be employing movements that reduced their risk of intra-specific infanticide. Similarly, Seaman (1993) concluded that the smaller breeding and summer ranges of black bears in North Carolina were the result of pressure on females to reduce their movements in response to male activities. Avoiding males during mating season could be a counter strategy used by females with dependent offspring to increase the survival of their offspring (Ebensperger 1998). This strategy to avoid other bears, specifically adult males, to reduce infanticide also has been reported in studies conducted in Wyoming's Yellowstone National Park, Alaska, and North Carolina (Barnes and Bray 1967, Erickson 1965, Seaman 1993).

Breeding females exhibited no differences in range size among the 3 seasons. While female black bears have been observed increasing their daily movements and using larger areas when in estrus (Alt et al., Rogers 1987, Dahle and Swenson 2003), the extent of these movements could also be influenced by the ratio of males to females in the area. Fewer males could result in the need of females to roam over larger areas to encounter adult males (Swenson and Dahle 2003). Conversely, if the ratio of males to females in an area is high, breeding females either have to roam over a smaller area or not roam at all in order to encounter adult males. In the northern study area, the ratio of adult bears during 1994-2003 was 0.43M:0.57F (Bridges 2005), thus during the breeding season (June-July)

females might not have to wander far to find a suitable mate, causing range size to be small.

Southern study area.- Unlike the northern study area, females without COY on the southern study area had larger spring ranges than females with COY, which agrees with J. Higgin's (1997) earlier findings from the northern study area. When all bears were included in the analysis, the opposite occurred during fall; females with COY had larger fall ranges than solitary females. As discussed earlier, cubs may initially restrict their mother's movements after den emergence (Alt et al. 1977). However, smaller spring ranges in females with COY may be due to the timing of den emergence. Studies have shown that while environmental factors play a role (i.e. photoperiod, snow melt, temperature), den emergence may also be associated with the presence of cubs and their development condition (Lindzey and Meslow 1976, O'Pezio et al. 1983, Rogers 1987). In Arkansas, Oli et al. (1997) found that pregnant females denned up to 33.6 days longer than non-pregnant females, while in southeastern Virginia, Hellgren and Vaughan (1989) found that pregnant females, on average, emerged 41 days later than non-pregnant females. Therefore, larger spring ranges exhibited by females without COY may be due to earlier emergence from their den, giving them more opportunity to travel, and, consequently, allowing researchers to collect more location data. During fall, females with COY may have larger fall ranges than their solitary counterparts because they have to travel more in order to meet the greater nutritional needs required of their family. However, when analysis was restricted to just females monitored during both reproductive cycles, there was no difference in fall range sizes between females with and without COY.

While breeding females in the southern study area exhibited no differences in their seasonal range size, females with COY increased their range size throughout the year, reaching a peak during fall. Summer and fall ranges of females with COY were significantly larger than spring range. This also follows patterns observed in other studies (Alt et al. 1977, Kolenosky and Strathearn 1986, Smith and Pelton 1990, J. Higgins 1997, Dahle and Swenson 2003) and may reflect the increased mobility of cubs over time. It also suggests that as cubs develop, nutritional demands placed on the family unit increase (Smith and Pelton 1990), which may result in larger home ranges. If food availability is limited, bears may have to travel further to find patches of abundant food to meet their nutritional requirements (Rogers 1977, Garshelis and Pelton 1981). During the CABS study (1995 through 2002), we experienced a poor fall mast crop in 1997; this was the only year in which female black bears had significantly larger fall home ranges than their spring and summer home ranges (see chapter 2; Table 2.11). As to whether the community structure of the population would permit or restrict a bear's movements is unclear; there is no clear understanding of the social structure of black bears and the extent of their intraspecific tolerance during food shortages.

Regional differences

In the northern study area, there was no difference in seasonal range size between females with and without COY. In the southern study area, females with COY had smaller spring ranges and larger fall ranges (using all bears) than females without COY. The differences between the 2 study areas could be due to differences in habitat quality; annual and seasonal home ranges were smaller in the north, possibly indicating higher

quality habitat. The notion that home range size is linked to habitat quality is supported by McLoughlin et al. (2000) who felt their results, based on a study of female brown bear populations in North America, supported the space-use model, which predicts that average home range size will show an inverse relationship with habitat quality. Habitat quality in their study was determined by abundance and predictability of food, and if these 2 factors are high, then individuals could maximize energy intake over less area. If habitat quality differs between the southern and northern study areas, then we may see a behavioral response manifested through differences in home range sizes. Females with COY may be most sensitive to changes in resources because of the greater nutritional demand of their cubs. Thus, southern females with COY may be responding to changes in habitat quality by expanding their fall range size.

While we have no data that would permit us to compare food availability between study areas, we do know the northern study area had a higher abundance of feed sites maintained by bear hunters (Gray 2001). In a survey designed to gauge the amount of food provided by Virginia's bear hunters, Gray (2001) found that 51.7% of survey respondents (n=121) fed bears in the northern study area versus 33.1% in the southern study area. In addition, of the 2,942,394 kg of food provided to bears by hunters during one year, 45.7% was distributed in the northern study area, versus 21.2% in the southern study area. Gray (2001) also found that 76% of bear hunters had feed sites on public land. Sixty-two percent of the northern study area was comprised of public lands (i.e. national forest, state forests), versus 15% in the southern study area (Appendix B). Greater access to public lands in the northern study area could provide greater supplemental feeding opportunities. Also, differences in the composition of land ownership might reflect

differences in land management practices, thus potentially affecting habitat quality.

Further studies into possible differences in habitat features should be conducted to verify this potential difference between the 2 study areas.

Stability of home range movements

The extent of seasonal stability within annual home ranges did not differ between females with and without cubs in either study area. Neither reproductive class appeared to differ in the degree of seasonal shift that occurred in their home range, thus changes in seasonal use of a female's home range appear to be affected by cues other than the presence of cubs. However, while a majority of breeding females in the north exhibited seasonal shifts in their home range, a majority of breeding females in the south did not exhibit seasonal shifts in their home range. Klenner (1987) found that only a low proportion of black bears in western Manitoba exhibited a seasonal shift in their home range and suggested that this reflected the sufficiency of the habitat within the annual home range to support the bear's seasonal nutritional needs. While his suggestion may explain why some bears did or did not shift within their annual home range, there are several other factors that may have played a role in home range fidelity, such as changes in the social structure of the population as a result of mortalities, dispersals into and out of the population, and birth rates.

The stability of a female's home range differed depending on the type of reproductive transition that occurred. In the northern study area, a majority of breeding females that had cubs the following year exhibited no shift in their annual home range, while a majority of females that entered the breeding stage did exhibit a shift in their annual home range. While researchers have reported that solitary females make

excursions during the breeding season (Barber and Lindzey 1983), this doesn't wholly explain why we observed a difference in the occurrence of shifts based on the type of reproductive transition. The observation of home range shifts based on reproductive status has not been addressed in the literature. One possibility is that breeding females that have cubs the following year restrict their movements to areas they are most familiar with in order to minimize their energy expenditures when searching for food, and also decrease the potential for encountering unfamiliar threats. Or, perhaps females entering the breeding stage shift their range to allow their offspring (i.e. the yearlings from which they just separated) to establish home ranges.

Study design and further studies

Because the Cooperative Alleghany Bear Study (1994-2002) had many objectives, telemetry data collection was not the only priority; capturing and marking bears, obtaining data on reproduction and survival, estimating population parameters based on bait, remote camera, and hair snag surveys, monitoring yearling survival and dispersal, and assessing the effect of pursuing bears with hounds were among the other objectives of the study, requiring our research priorities to be diversified. Telemetry data collection was most emphasized in the spring and fall, since the other objectives of CABS were addressed during winter and summer. But while this might have affected the quality and quantity of the telemetry data, the duration of this study and the number of bears involved helps reduce the potential error inherently involved with studies based on telemetry data. Tests are more powerful as the number of animals increase, and several studies have shown that when >20 animals are used, differences detected are less likely to be biased by extremes in data (Alldredge and Ratti 1986, Samuel and Fuller 1994).

Also, estimates of home range size may be influenced by experimental design (Koehler and Pierce 2003). Home range estimates could be influenced by the number of telemetry locations, duration and season of monitoring effort, and the estimator chosen to calculate home range size (White and Garrot 1990, Powell 2000). However, despite concerns with accuracy of home range estimates, they can still serve as comparable indices for different categories (Dahle and Swenson 2003), as long as caution is placed in making conclusive inferences.

Because there were differences in home range movements observed between reproductive classes, there are several questions to be addressed. Do females with COY select different habitats than breeding females? Are differences in home range movements between breeding females and females with COY due to preference for specific escape cover, or due to differences in nutritional requirements, as hypothesized by Seaman (1993), who concluded that females with cubs have unique spring nutritional requirements because they catabolized greater amounts of protein in order to support lactation (Ramsey and Dunbrack 1986).

Also, home range movements of adult female black bears differed between the 2 study areas, leading us to question if the reason(s) are due to differences in habitat quality, in population densities, and/or in male to female ratios? These questions should be addressed in the future.

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Appendix A. Estimates of mean annual home range sizes (km²) of black bears in North America.

Location	Source	Year	Method	Program ^a	N ^a	Male	N	Female
Arkansas	Smith and Pelton	1989	95% MCP ^b	TELEM ^c	6	116.0	6	12.0
Arkansas	Clark	1991	100% MCP	HOME RANGE	2	89.7	27	34.7
Arkansas	Oli et al.	2002	95% Harmonic MCP	CALHOME	--	91.9	16	48.1 4.9
California	Novick and Stewart	1982	100% MCP	--	--	22.4	--	17.1
Canada Alberta	Young and Ruff	1982	95% Minimum area ^d	--	--	119.0	--	19.6
Canada western Manitoba	Klenner	1987	95% Jennrich and Turner index ^e	--	1	2921.9 (1980)	5	29.1 (1980)
Florida ANF ^g	Seibert	1993	100% MCP	TELEM	10	209.0	4	65.0
Florida OONF	Wooding and Hardisky	1994	100% MCP	TELEM	12	170.0	8	28.0
Florida	Maehr et al.	2003	100% MCP	AMA	3	105.3	3	19.3 (1998)
Idaho	Amstrup and Beechum	1976	100% MCP	--	2	112.1	7	48.9
Idaho	Reynolds and Beecham	1980	100% MCP	--	4	60.0	5	12.0
Louisiana	Taylor	1971	100% MCP	--	2	111.1	2	19.7
Louisiana Deltic	Marchington	1995	95% Adaptive kernel	CALHOME	4	52.3	6	12.6

Louisiana Deltic	Anderson	1997	95% MCP	CALHOME	2	46.1	11	8.8
			95% MCP			41.6		13.2
Louisiana	Beausoleil	1999	Adaptive kernel 95% MCP	CALHOME	5	37.7	12	8.9
			95% Adaptive kernel			12.6		7.1
Louisiana Deltic and Tensas	Weaver	1999	95% MCP	CALHOME	3	8.1	6	4.8
			95% Adaptive kernel			112.2		6.8
			95% MCP			59.7		4.3
Maine	Hugie	1982	100% MCP	--	5	17.0	9	43.0
Maryland	Webster	1994	100% MCP	HOME RANGE	--	--	3	39.8
			95% MCP	MIPS ^c				40.5
Massachusetts	Elowe	1984	100% MCP	--	3	318.0	8	28.0
Massachusetts SHSA and CWSA	Fuller	1993	95% harmonic mean	MCPAAL ^d	29	328.0	35	26.0
Michigan lower peninsula	Manville	1983	100% MCP	--	11	150.4	5	68.9
Michigan Drummond Island	Hirsch et al.	1999	100% MCP	MCPAAL	3	75.6	16	40.7
			95% harmonic mean		3	64.6	16	32.8
Mississippi WRNWR and BGMT	White	1996	95% MCP	CALHOME	3	81.3	11	10.9
North Carolina (coastal)	Hardy	1974	100% Minimum area	--	--	175	--	11
North Carolina (coastal)	Hamilton	1978	100% MCP	--	3	91.0	3	8.0

North Carolina (mountains)	Wharburton	1984	100% MCP	--	2	79.0	2	18.0
North Carolina	Beringer	1986	100% MCP	TELEM	--	--	7	14.8
North Carolina	Seibert	1989	100% MCP	MCPAAL	4	39.0	9	12.0
North Carolina	Reagan	1991	100% MCP	MCPAAL	--	--	11	9.1
North Carolina MCBL	Lombardo	1993	100% MCP	MCPAAL	2	60.5	7	20.4
North Carolina NPP	Jones	1996	95% MCP	CALHOME	--	--	10	8.6
North Carolina BP GS	Jones and Pelton	2003	95% harmonic mean	CALHOME	--	--	8	11.6 6.6
Oregon central Cascades	Heyden and Meslow	1999	95% MCP	CALHOME	--	--	12	11.0 5.3 39.1
			95% adaptive kernel	HOME RANGE			14	30.0
Pennsylvania	Alt et al.	1980	95% Jennrich and Turner Index	--	5	173.0	12	41.0
Tennessee GSMNP	Beeman	1975	100% MCP	--	1	21.0	7	7.2
Tennessee GSMNP	Garshelis and Pelton	1980	100% MCP	--	10	21.2	14	8.4
Tennessee GSMNP	Garshelis and Pelton	1981	95% bivariate distribution ^f	--	8	41	12	15
Tennessee GSMNP	Quigley	1982	95% bivariate distribution ^f	--	5	32.1	6	5.2
Tennessee CNF	Villarrubia	1982	100% MCP	--	9	30.1	12	11.6
Tennessee GSMNP	Carr	1983	100% MCP	--	4	119.0	3	13.0
						poor mast		poor mast year

							36.0		6.0
							good mast		good mast year
Tennessee GSMNP	Garris	1983	100% MCP	--	5	192.4	8	22.7	
Tennessee GSMNP	VanManen	1994	95% MCP	HOME RANGE	11	250.3	12	11.2	
			95% adaptive kernel	CALHOME	11	299.0	12	16.6	
Texas BIBE	Onorato et al.	2003	95% MCP	AMA	7	97.7	7	32.1	
Virginia SNP	Garner	1986	95% MCP	TELEM	--	116.0	--	22.0	
Virginia GDS	Hellgren and Vaughan	1989	100% MCP	TELEM	10	111.7	11	27.0	
Virginia southwest	Higgins	1997	95% MCP	Ranges V	7	7.2	16	5.5	
			95% fixed kernel		5	11.2	27	6.8	
Virginia SNP	Kasbohm	1998	95% MCP	TELEM	--	--	17	26.7 solitary (1982-84) 40.7 solitary (1987-89) 14.6 w/cubs (1982-84) 34.2 w/cubs (1987-89) 5.3	
Washington	Poelker and Hartwell	1973	100% MCP	--	--	51.6	--	2.4	
Washington	Lindzey and Meslow	1977	100% MCP	--	5	5.1	6	37.1	
Washington NE Cascades	Lyons et al.	2002	95% adaptive kernel	CALHOME	--	289.7	--	28.3	
Washington Olympic Snoqualmie	Koehler and Pierce	2003	95% fixed kernel	KERNELHR	2	125.5	4	18.0	
Okanogan					29	17	15	25.9	

West Virginia	Brown	1980	Bivariate normal	--	13	204.0	8	49.0
West Virginia	Kraus	1990	Mean convex polygon	MCPAAL	--	--	15	26.3
Wisconsin	Kohn	1982	100% MCP	--	13	71.2	7	13.7

^aIf sample size or program was not clearly specified, it was not included in the table.

^b MCP-Minimum Convex Polygon

^c TELEM-Koeln 1980

CALHOME-Kie et al. 1996

AMA-Animal Movement Analysis, Hooge et al. 1999

HOME RANGE-Ackerman, et al. 1990

Ranges V-Kenward and Hodder 1996

KERNELHR-Seaman et al. 1998

^d Mohr 1947

^e Jennrich and Turner 1969

^f Koepl et al. 1975

^g ANF-Apalachicola National Forest

OONF-Osceola and Ocala National Forests

SHSA-Savoy/Hawley

CWSA-Conway/Williamsburg

WRNWR-White River National Wildlife Refuge

BGMT-Big and Montgomery Islands

NPP-Neuse/Pamlico Peninsula

BP-Big Pocosin

GS-Gum Swamp

GSMNP-Great Smoky Mountains National Park

CNF-Cherokee National Forest

BIBE-Big Bend National Park

SNP-Shenandoah National Park

GDS-Great Dismal Swamp

^c MIPS-Map and Imaging Processing System, Skrdla 1992

^d MCPAAL-Microcomputer Program for the Analysis of Animal Locations, Stuwe and Blohowiak

Appendix B. Study area size, population density, and habitat indices of the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington and Jefferson National Forest, Virginia, USA. June 1994-March 2003.

Feature	South ^a	North
Study area (ha)	160,961	184,898
Population density ^b (bears/km ²)	0.78 (95% C.I. = 0.62-1.00)	1.32 (95% C.I. = 1.08-1.62)
Weight (kg; SE)		
Female	64.9 (2.2)	67.0 (1.4)
Male	119.3 (4.8)	107.1 (3.0)
Food provided by bear hunters (kg/year)	623,788	1,344,674
Land ownership (%)		
Public	15.0	61.0
Private	85.0	39.0
Forested vs. non-forested (%)		
Forested land	80.0	86.0
Agriculture	18.0	13.2
Developed	1.0	0.3
Other	1.0	0.5
Roads (mile/km ²)		
Highways	0.02	0.03
High traffic (paved)	0.03	0.02
Low traffic (paved)	0.58	0.51
Low traffic (dirt)	0.13	0.15

^a Counties in north: Augusta, Rockingham; Counties in south: Craig, Giles, Montgomery

^b Bridges (2005)

Appendix C. Results from test of repeated measures on adult female black bear weight (kg., S.E.) in the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, June 1994 – March 2003.

Effect	South	North	Degrees of freedom	t value	<i>P</i>
Region ^a	64.9 (2.2)	67.0 (1.4)	199	-1.12	0.26
Region (winter)	63.9 (2.7)	66.5 (2.3)	27	0.72	0.88
Region (summer)	65.8 (2.4)	57.4 (1.0)	27	-3.16	0.02
Region (solitary)	66.0 (2.8)	64.2 (1.7)	53	-0.55	0.50
Region (with COY ^b)	63.7 (2.5)	59.7 (1.5)	53	-1.40	0.95
Region (age class 1 ^c)	57.1 (5.6)	51.3 (3.2)	56	-0.90	0.99
Region (age class 2)	63.1 (2.4)	58.8 (1.4)	56	-1.57	0.77
Region (age class 3)	67.5 (2.7)	66.4 (1.5)	56	-0.39	1.00
Region (age class 4)	71.6 (4.9)	71.4 (1.9)	56	-0.05	1.00
Region (1995)	61.8 (4.0)	67.5 (2.2)	133	1.26	0.21
Region (1996)	63.6 (3.3)	59.0 (2.0)	133	-1.19	0.24
Region (1997)	67.7 (3.4)	61.7 (1.9)	133	-1.53	0.13
Region (1998)	68.1 (4.9)	59.8 (2.0)	133	-1.56	0.12
Region (1999)	70.0 (4.9)	66.7 (2.1)	133	-0.62	0.53
Region (2000)	60.1 (4.2)	59.4 (2.1)	133	-0.15	0.88
Region (2001)	65.4 (4.3)	59.0 (2.0)	133	-1.35	0.18
Region (2002)	64.6 (4.0)	59.6 (1.9)	133	-1.14	0.26

^a Region= Counties in north: Augusta, Rockingham
 Counties in south: Craig, Giles, Montgomery

^b COY=cubs of the year

^c Age class: 1=3 year olds, 2=4-5 year olds, 3=6-10 year olds, 4= ≥11 year olds

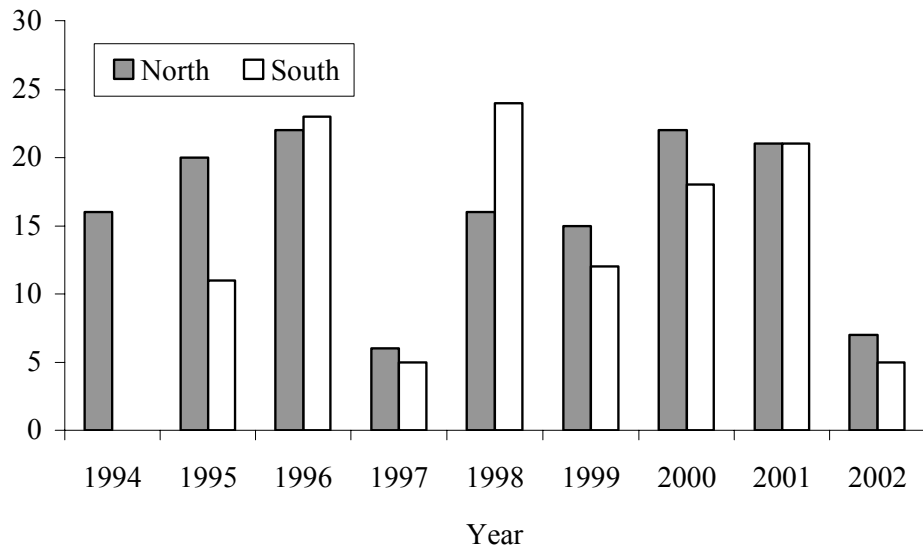
Appendix D. Results from test of repeated measures of adult male black bear weight (kg., S.E.) in the northern and southern study areas of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA, June 1994 – March 2003.

Effect	South	North	Degrees of freedom	t value	<i>P</i>
Region ^a	119.2 (4.8)	107.2 (3.0)	189	-2.13	0.04
Region (age class 1 ^b)	79.3 (4.2)	76.6 (2.0)	38	-0.58	0.57
Region (age class 2)	103.8 (5.6)	101.4 (2.3)	38	-0.40	0.69
Region (age class 3)	174.6 (11.4)	119.8 (4.1)	38	-4.51	<0.01
Region (age class 4)	--	131.0 (5.6)	38	--	--

^a Region= Counties in north: Augusta, Rockingham

Counties in south: Craig, Giles, Montgomery

^b Age class: 1=3 year olds, 2=4-5 year olds, 3=6-10 year olds, 4= ≥11 year olds



Appendix E. Mean number of acorns / 10 limbs / tree sampled in the northern and southern study area of the Cooperative Alleghany Bear Study, George Washington Jefferson National Forests, Virginia, USA. Note that research did not start in the south until June 1995.

VITA

COLLEEN OLFENBUTTEL

EDUCATION

OHIO UNIVERSITY Athens, OH
Bachelor of Science, Wildlife Biology, 3/97, GPA 3.49/4.00 Cum Laude

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY Blacksburg, VA
Master's in Science, 12/05 GPA 3.85/4.00

RELEVANT EXPERIENCE

09/99-present

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY Blacksburg, VA
Graduate Associate, Advisor: Dr. Michael Vaughan
60+hours/week

Project title: Black bear (*Ursus americanus*) home range and habitat use in western Virginia

01/99-09/99

INSTITUTE FOR WILDLIFE STUDIES San Diego, CA
Wildlife Biologist, Supervisors: Doug Cooper, Suellen Lynn, Dave Garcelon 60+hours/week
Assisted on the San Clemente Island Loggerhead Shrike Recovery Project and Island Fox Monitoring Program

04/98-11/98
05/97-11/97

U.S. FISH & WILDLIFE SERVICE, ECOLOGICAL SERVICES Helena, MT
Wildlife Biologist, GS-5; Supervisors: Ed Bangs, Joe Fontaine
60+hours/week
Assisted on Northern Rocky Mountain Wolf Recovery Project

01/98 – 03/98

MICHIGAN DEPARTMENT OF NATURAL RESOURCES Crystal Falls, MI
Wildlife technician; Supervisor: Jim Hammill 50+hrs./week
Assisted on the state of Michigan's annual wolf count survey

02/97 - 05/97

U.S. GEOLOGICAL SERVICE, BIOLOGICAL RESOURCES DIVISION Ely, MN
Wildlife Technician-volunteer; Supervisors: Dr. L. David Mech, Dr. Mike Nelson 60+hours/week
Live-trapped, immobilized, examined, ear-tagged, radio-collared, and translocated white-tailed deer using clover traps and rocket nets

06/96 - 09/96 **HIAWATHA NATIONAL FOREST** Munising, MI
SCA Resource Assistant-Crew Leader; Supervisors: Dr. William Bowerman, Stacy Christiansen 60 hours/week
Performed raptor survey transects and vegetation analysis transects in Hiawatha Nat'l. Forest and Pictured Rocks Nat'l. Lakeshore

06/95 - 09/95 **NATIONAL BIOLOGICAL SERVICE** Kodiak, AK
SCA Resource Assistant-Biological Technician; Supervisor: Dr. Tom Smith 60+hours/week
Collected vegetation inventory data for Katmai Brown Bear Mapping Project
Collected brown bear-human interaction data for Kulik River Brown Bear Project

TEACHING EXPERIENCE

01/05-05/05 **VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY** Blacksburg, VA
Teaching Assistant for Principles of Biology Lab
Supervisor: Mary Schaeffer 30 hours/week
Instructing three 2-hour introductory biology lab classes

09/99 - present **VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY** Blacksburg, VA
Research Associate, Advisor: Dr. Mike Vaughan 20 hours/week
Aid undergraduates on their independent research projects:
Lead classroom groups to bear dens for lessons on black bear denning ecology
Instruct undergraduates on research techniques (telemetry, animal immobilization and handling, trapping, measurements of morphology) used at the Center for Ursid Research and on the Cooperative Allegheny Bear Study
Lead and instruct school groups (ages 4-18) on research being conducted at the Center for Ursid Research

01/01 - 05/01 **VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY** Blacksburg, VA
Teaching Assistant for Wildlife Habitat Ecology and Mgmt.
Professor: Dr. Dean Stauffer 20 hours/week
Assisted in lectures and laboratory section of class.
Gave guest lectures, administered exams, led field trips, and provided office hours for students

09/96 - 12/96

OHIO UNIVERSITY BIOLOGY DEPARTMENT Athens, OH
Lab Assistant for freshman biology lab; Supervisor: Dr. Mary Nossek

Helped teaching assistant prepare lab and supervised students during lab class

PROFESSIONAL SOCIETIES

- The Wildlife Society-National chapter
- The International Bear Association

GRANTS

Title: Use of ultrasonography as a non-invasive tool to detect and monitor black bear fetal development
Graduate Research Development Project, April 2002
Amount: \$300.00

PUBLICATIONS

- Bridges, Andrew S., J. Fox, C. Olfenbittel, and M. Vaughan. 2004. American black bear denning behavior: observations and applications using remote photography. *Wildlife Society Bulletin. In press*
- Lee, Daniel J., C. Olfenbittel, A. Bridges, and M. Vaughan. 2003. Effectiveness and efficacy of ear tag transmitters used on black bears in western Virginia. *Wildlife Society Bulletin. In review.*
- Bridges, Andrew S., C. Olfenbittel, and M. Vaughan. 2002. A mixed regression model to estimate neonatal black bear cub age. *Wildlife Society Bulletin* 30(4):1253-1258.