2004

CHALLENGES IN ESTIMATING SIZE AND CONSERVATION OF BLACK BEAR IN WEST-CENTRAL FLORIDA

Joshua Hager Brown
University of Kentucky, jhbrow2@uky.edu

ABSTRACT OF THESIS

CHALLENGES IN ESTIMATING SIZE AND CONSERVATION OF BLACK BEAR IN WEST-CENTRAL FLORIDA

The Greater Chassahowitkza Ecosystem black bear (*Ursus americanus floridanus*) population of west-central Florida is likely to be the smallest documented population of the species. It has experienced almost no recruitment since 1997 and exhibits behavior that appears to be a response to human activities. The local diet is dominated by the fruit of saw palmetto and sabal palm, species that exhibit patchy distributions and irregular mast production. These food supplies are often separated by busy highways that have killed 6 bears since 1997, 21% of known individuals. Motion-activated camera surveys suggest that the bear population is declining in this rapidly urbanizing part of Florida; results of the 2002 survey estimated 28 " 18 bears in the GCE, while 2003 estimates recorded 12 " 7 individuals (Lincoln-Petersen). Additionally, blood and hair samples suggest the genetics of this population are extremely depauperate. I recommend a different fire regime in palm-dominated habitats, restoring landscape connectivity to nearby bear populations, and supplementation of the population. Because the threats to this population are manifold and its immediate future is in doubt, a combination of conservation and management tools will be required to prevent extinction of this isolated black bear population.

KEYWORDS: conservation, genetic analysis, Florida black bear, remote photography, population estimation

CHALLENGES IN ESTIMATING SIZE
AND CONSERVATION OF BLACK BEAR
IN WEST-CENTRAL FLORIDA

By

Joshua Hager Brown

David S. Maehr
Director of Thesis

David B. Wagner
Director of Graduate Studies

28 April, 2004

RULES FOR THE USE OF THESES

THESIS

Joshua Hager Brown

The Graduate School

University of Kentucky

2004

CHALLENGES IN ESTIMATING SIZE AND CONSERVATION OF BLACK BEAR IN WEST-CENTRAL FLORIDA

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the College of Agriculture at the University of Kentucky

By

Joshua Hager Brown

Lexington, Kentucky

Director: Dr. David S. Maehr, Professor of Conservation Biology

Lexington, Kentucky

2004

I dedicate this thesis to my parents, Robert and Patricia, who have been wonderful role models and continue to amaze me with their love and support.

ACKNOWLEDGEMENTS

The following thesis was truly a collaborative effort and would not have been possible without the service of many people. I would first like to thank the organizations that provided the economic and logistical support for this project: the University of Kentucky Department of Forestry, the U.S. Fish and Wildlife Service, the Southwest Florida Water Management District, the Florida Fish and Wildlife Conservation Commission, the Florida Division of Forestry, the Florida Department of Environmental Protection, and the Disney Wildlife Conservation Fund. This project was a reality due to the dedication of Mary Barnwell, Kevin Love, Thomas Eason, Stephanie Simek, Gene Kelly, Joyce Kleen, Tom Matthews, Sid Taylor, Wilbur Priest, Greg Batts, Diana Donaghy, and Mark Cunningham. I am indebted to American Aviation for their outstanding telemetry flights and Archbold Biological Station for loaning a field vehicle. I thank the Crystal River State Buffer Preserve for giving me a place to stay during summer research efforts. Dr. Mark Lowe and his family were an invaluable help to me in the field.

Since graduate school, statistical analysis, and writing is often a team effort, I would like to thank my fellow graduate students who have been instrumental in my matriculation. Dr. Jeff Larkin and Dr. John Cox provided endless GIS assistance and continue to help me grow as a professional. I thank Nathan Seward for showing me the value of good field biology and good friendship. Finally, I owe a great deal of thanks to Michael Orlando, who has taught me and continues to teach me what it means to be a wildlife biologist. My success has largely relied on Mike's dedication to this project and his willingness to tutor me.

I would like to thank my major advisor, Dr. David Maehr, for beating the biotech out of me and the "wildlifer" into me. The opportunity to study the magnificent Florida black bear is something that has changed me forever; he gambled on me, and I hope the payoff on that bet has been sufficient. I would also like to thank my committee members, Dr. Mike Lacki and Dr. Keith Schillo, for their willingness to be a part of my research. Their input has been much appreciated.

In addition to the technical and instrumental assistance mentioned above, I would like to thank all my family and friends who were equally instrumental in the completion of my thesis. Ultimately, I thank the bears of the Greater Chassahowitzka Ecosystem for their tenacity, hardiness, and continued effort to survive. I know they will do their part; I only hope we can do ours.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FILES

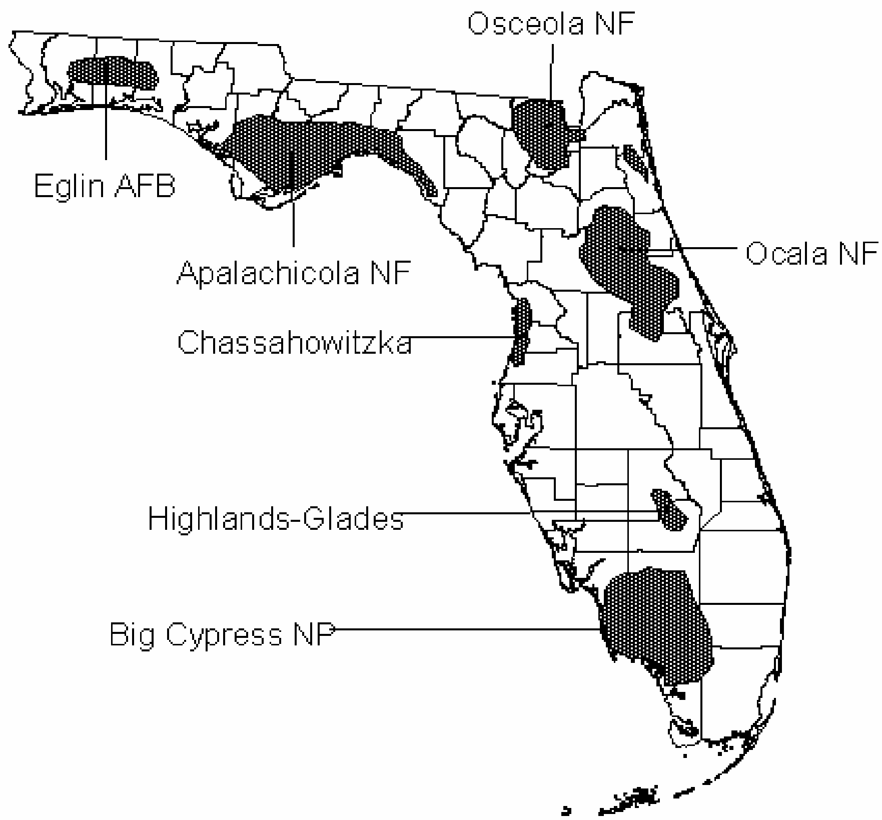
INTRODUCTION

Background

Prior to European settlement, as many as 11,500 black bears (*Ursus americanus floridanus*) inhabited the entire peninsula of Florida (Bentzien 1998, McCown and Eason 2001). Today, perhaps 2500 bears (S. Simek, FWC, personal communication) occupy 50 of the state's 67 counties (Brady and Maehr 1985). Human development, forest fragmentation, and habitat loss are the primary causes of this decline (Hellgren and Maehr 1992). The 4 large populations that remain are all associated with large tracts of public land: Big Cypress National Preserve, Ocala National Forest, Apalachicola National Forest, and Osceola National Forest (Fig. 1) (Maehr et al. 2001). The remaining populations inhabit small, isolated forest systems with little interchange with larger ones (Maehr et al. 1988). The smallest of these populations is located in the Greater Chassahowitzka Ecosystem (GCE) in west-central Florida. With an estimated 20 animals (Cox et al. 1994, Maehr et al. 2001), the GCE black bear population is perhaps the smallest documented in the world (Larkin et al. 2004) and is threatened with imminent extinction.

The distribution and importance of the Florida black bear have varied considerably throughout its history on the peninsula (Dixon 2004). Pre-Columbian Americans such as the Timucua and Seminole both revered and hunted the bear on the Florida peninsula (Belleville 2001). Europeans added to this harvest in the mid-1500s (Dixon 2004). Bartram (1791) described bears on the St. John's River during his explorations of central Florida in the 18th century: "The bears are yet too numerous; they are a strong creature, and prey on the fruits of the country…their flesh is greatly esteemed as food by the natives." The black bear had no formal conservation designation in Florida until 1950 when a hunting season concurrent with the white-tailed deer (*Odocoileus virginianus*) was established (Maehr 1992). The bear hunting season

Figure 1: The current distribution of black bear in Florida (Eason 2001).



was closed in 1971 except in Baker and Columbia counties in north Florida (Scheick 1999). In 1974, the Florida black bear was listed as "threatened" by the Florida Game and Fresh Water Fish Commission, except in Baker and Columbia counties and Apalachicola National Forest, where it could still be hunted during limited fall seasons (Maehr and Wooding 1992). Ultimately, all bear seasons were closed in Florida after the 1993-1994 hunting season (Orlando 2003), when statewide bear numbers may have been 1500 (Scheick 1999) and the distribution of the Florida black bear had been reduced by 83% from its historic range (Wooding 1993, Dixon 2004).

In 1990, the U.S. Fish and Wildlife Service (USFWS) was petitioned to list the Florida black bear as a "threatened" species under the Endangered Species Act of 1973. The ESA defines a "threatened species" as any species likely to become "endangered" within the foreseeable future throughout all or a significant portion of its range. In 1992, the petition was denied by USFWS, claiming that the listing was "warranted but precluded." During this time, numbers were likely increasing in Big Cypress National Preserve, Ocala National Forest, and perhaps elsewhere, but smaller populations such as the GCE and Highlands County were declining (D. Maehr, UK, personal communication).

The Chassahowitzka Black Bear Interagency Committee was formed in 1997 to coordinate management of the black bear in the GCE (M. Barnwell, SWFWMD, personal communication). Its members include the Southwest Florida Water Management District (SWFWMD), the Florida Fish and Wildlife Conservation Commission (FWC), the Florida Division of Forestry (FDOF), the U.S. Fish and Wildlife Service, the Florida Department of Transportation (FDOT), the Florida Department of Environmental Protection (FDEP), Defenders of Wildlife (DOW), Coalition for Anti-Urban Sprawl and the Environment (CAUSE), and the Gulf Coast

Conservancy (GCC). Research was proposed to address the needs of the black bear within the context of agency management directives and began in the fall of 1997, primarily with funding from SWFWMD, FWC, and the University of Kentucky (Smith 2001, Orlando 2003). The first 4 years of research focused on home range analysis, habitat use, food habits, movement patterns, behavioral ecology, survival, and landscape-scale conservation (Smith 2001, Orlando 2003, Larkin et al. 2004).

Objectives

1. Develop a population estimate
2. Refine estimates of home range
3. Examine 3 years of food habits data
4. Recommendations for landscape and population management

Study Area

The GCE encompasses about 68,900 ha in the coastal counties of Pasco, Hernando, and Citrus in west-central Florida (Fig. 2). Public lands in the area include the Starkey-Serenova Wilderness Preserve (SSWP), the Aripeka Coastal Greenway (ACGW), Weeki Wachee Preserve (WWP), the Chassahowitzka Wildlife Management Area (CWMA), Chassahowitzka National Wildlife Refuge (CNWR), the Homosassa Tract of the Withlacoochee State Forest (WSF-HT), Homosassa Springs Wildlife State Park (HSWSP), Crystal River National Wildlife Refuge (CRNWR), Crystal River State Buffer Preserve (CRSBP), St. Martin's Marsh Aquatic Preserve (SMMAP), and the Citrus Tract of the WSF (WSF-CT) (Fig.3).

In addition to black bear, other mammal species in the GCE include the white-tailed deer, coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), river otter (*Lutra canadensis*), Sherman's fox squirrel (*Sciurus niger shermani*),

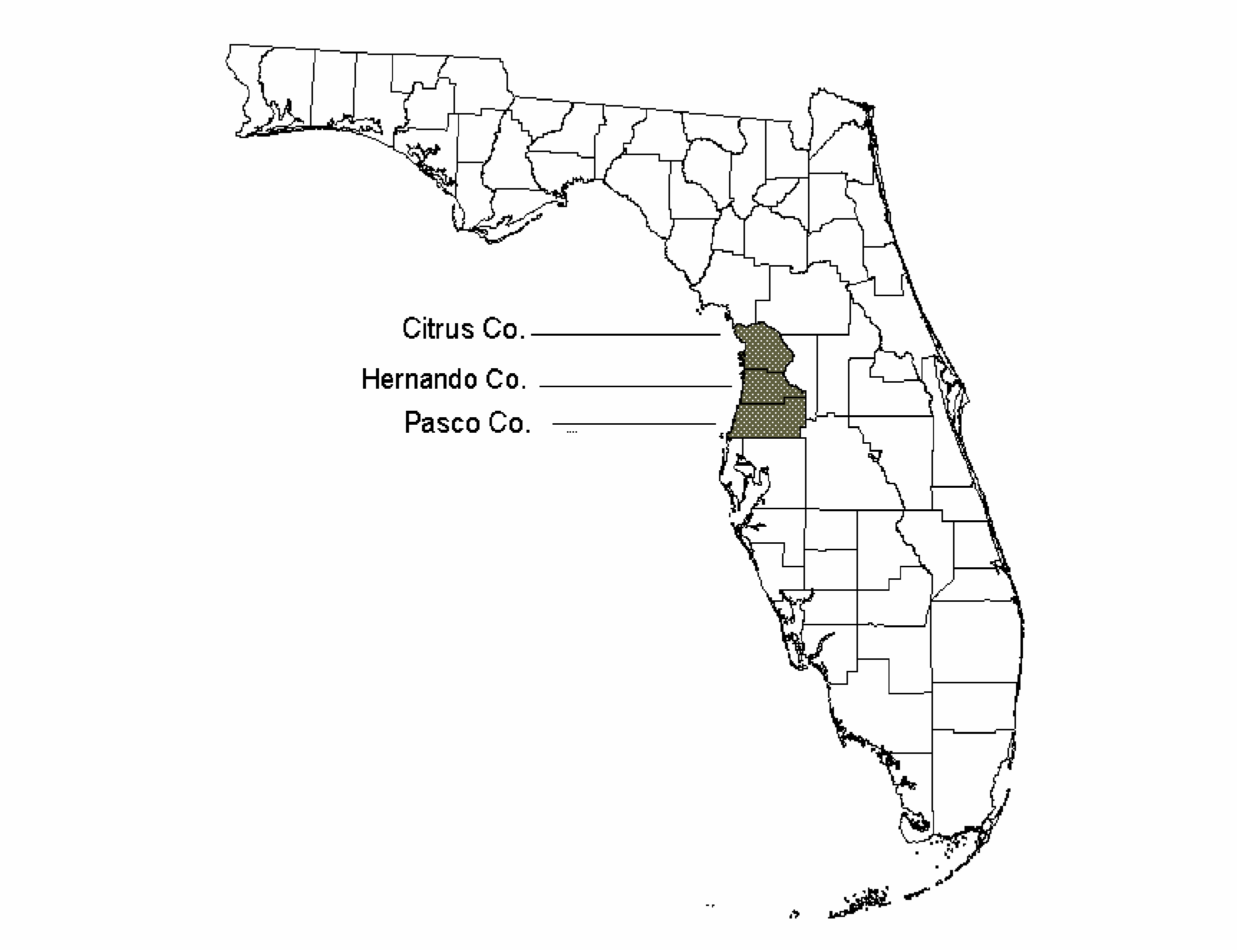


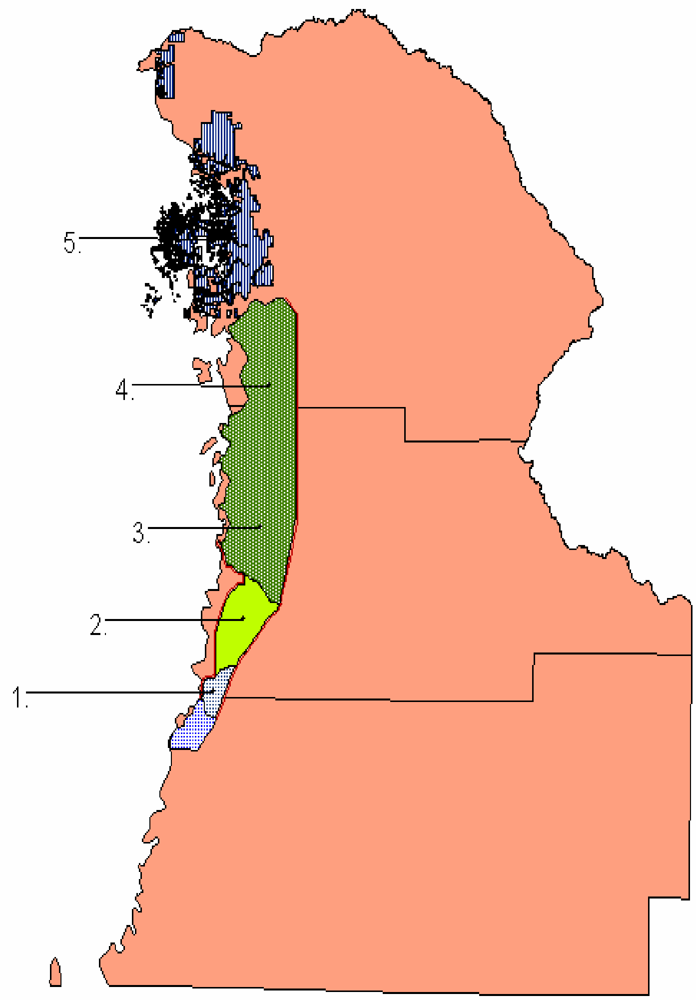
Figure 2: Pasco, Hernando, and Citrus counties contain the Greater Chassahowitzka Ecosystem in west-central Florida.

and West-Indian manatee (*Trichechus manatus*). Exotic vertebrates include feral hog (*Sus scrofa*), nine-banded armadillo (*Dasypus novemcinctus*), and Norway rat (*Rattus norvegicus*). Over 200 bird species inhabit the GCE (Orlando 2003), including the wood stork (*Mycteria americana*), great blue heron (*Ardea herodias*), sandhill crane (*Grus canadensis*), osprey (*Pandion haliaetus*), red-shouldered hawk (*Buteo lineatus*), swallow-tailed kite (*Elanoides forficatus*), and wild turkey (*Meleagris gallopavo*). Reptiles include the American alligator (*Alligator mississippiensis*), gopher tortoise (*Gopherus polyphemus*), eastern indigo snake (*Drymarchon corais couperi*), eastern diamondback rattlesnake (*Crotalus adamanteus*), diamondback terrapin (*Malaclemys terrapin*), and cottonmouth (*Agkistrodon piscivorus*).

Cover types in the GCE include agriculture (1150 ha, 1.7%), rangeland (475 ha, 0.7%), upland forest (8795 ha, 12.8%), lowland forest (21,260 ha, 31.0%), non-forested wetland (17,650 ha, 25.6%), and urban (19,750 ha, 28.4%) (Larkin et al. 2004). Specific habitat types in the GCE include mixed hardwood swamp, pine flatwoods, sandhill, pine plantation, scrub, coastal swamps, freshwater marsh, and saltwater marsh (Myers and Ewel 1990). In forested communities saw palmetto (*Serenoa repens*) and sabal palm (*Sabal palmetto*) are important sources of black bear food and cover (Maehr and Brady 1984, Wooding and Hardisky 1992, Smith 2001). Other important tree species include bald cypress (*Taxodium distichum*), red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), swamp tupelo (*Nyassa aquatica*), black gum (*N. sylvatica*), and laurel oak (*Quercus laurefolia*). Pine flatwoods are dominated by slash pine (*Pinus elliottii*) and, to a lesser extent, longleaf pine (*P. palustris*). Scrub habitats contain sand pine (*P. clausa*) and a variety of oaks (*Quercus* spp.).

Florida’s climate is humid subtropical (Myers 1990). Annual precipitation averages 135 cm and falls mostly between June and September. The remainder of the year is mild and dry.

Figure 3: Primary public lands within the 3-county zone of the GCE: 1. Aripeka Coastal Greenway, 2. Weeki Wachee Preserve, 3. Chassahowitzka Wildlife Management Area & Chassahowitzka National Wildlife Refuge, 4. Homosassa Tract – Withlacoochee State Forest, and 5. Crystal River State Buffer Preserve.



Summer and winter temperatures average 27°C and 19°C, respectively (Winsberg 1996). Sixteen hurricanes have hit the GCE since 1900 (Jarrell et al. 2001), although none occurred during this project. West-central Florida is also the lightning capital of the United States, with more strikes annually than any other state (Ewel and Myers 1990). GCE topography is generally flat, with elevations ranging from 5 to 70 m above mean sea level (Maehr et al. 2003).

The black bear in the GCE exists as an insular population, surrounded on 3 sides by development and on the fourth by the Gulf of Mexico. U.S. Highway 19 and other high volume roads (Sun Coast Toll Road and Interstate 75) form barriers to the east that may limit bear dispersal into or out of the GCE (Larkin et al. 2004). To the south, residential communities in coastal Pasco County are linked to the Tampa-St. Petersburg metropolitan area (human population = 2,242,360) (U.S. Census Bureau 2002). The growing cities of Homosassa Springs and Crystal River, as well as the Cross-Florida Barge Canal, are potential barriers to the north. Within the GCE, County Road (CR) 595 (Osawaw Blvd.) bisects the ACGW and WWP, while Hernando CR 550 separates WWP from the CWMA. Hernando CR 597 (Shoal Line Blvd.) also creates the western border of WWP, dividing it from the saltwater marshes of the Gulf. Bears in the GCE have encountered vehicular collisions on CR 550, CR 595, and U.S. 19 (FWC, unpublished data), and appear to 3976 ha associated with these roads (Orlando 2003).

With nearly 16 million people (U.S. Census Bureau 2002), the Florida human population is expanding into available open space and increasing the number of new roadways. Florida adds a net 750 people daily, a 16% increase from 1990 to 2000 (U.S. Census Bureau 2002). Only 19% of this growth is the result of natural increase (i.e., births). Instead, 50% comes from domestic migration, while nearly a third is due to international migration. Housing developments and golf courses have impacted many of the wetlands that once covered much of the central and southern part of the state. Florida loses about 182 ha of forest and 166 ha of farmland to development every day (Bouvier and Stein 2003). The GCE follows this statewide trend. Pasco, Hernando, and Citrus counties support 590,000 people and grew at 22.6%, 29.4%, and 26.3%, respectively, from 1990 to 2000 (U.S. Census Bureau 2002). With plans to expand the Sun Coast Parkway northward, more lands on the periphery of occupied bear range will soon be developed. This new infrastructure could play a role in the disconnection of the GCE from the statewide metapopulation, limiting future dispersal into and out of the population (Larkin et al. 2004). In fact, 2002 was a record year for bear roadkills in Florida, with at least 132 documented, representing roughly 4% of the state's population (Thomas Eason, FWC, personal communication). Two of these mortalities occurred in the GCE, and that might have been 10% of the GCE subpopulation.

<u>The Tools of Estimating Bear Populations</u>

Wildlife Radio Telemetry

The use of radio telemetry has improved the research abilities of wildlife professionals over the past 40 years. Radio-tracking allows the gathering of information about an animal through the use of radio signals from a device attached to the animal. Basic components include a transmitting subsystem associated with the animal and a receiving subsystem used by the researcher. This technology has allowed studies of movement, behavior, habitat use, survival and productivity of individual animals and entire populations (Samuel and Fuller 1996). The first radio transmitters were used primarily to study physiology (Kenward 2001). These were implanted and used to monitor temperature (Swingland and Frazier 1980), heart rate and other parameters (Ball and Amlaner 1980, Butler 1980, Gessamen 1980). Very high frequency (VHF) radio tracking became the standard when wildlife radio telemetry was first utilized in demographic studies in 1963 (Mech 1967, 1980, 1983, Craighead and Craighead 1970). It was relatively inexpensive and allowed a variety of information to be collected. More recently, satellite tracking has been used to examine more detailed moverments. This technology can link a study animal directly to a researcher's computer (Fancy et al. 1988). Unfortunately, satellite tracking is more expensive can be less accurate than VHF tracking (Larkin et al. 2001). The newest telemetry system is known as GPS tracking (Mech et al. 1990, Merrill et al. 1998). A GPS receiver picks up signals from a set of satellites and stores the animal's locations on a predetermined schedule. Data are collected by recovering the unit in the field or making remote downloads without disturbing the animal.

Originally a device for large animals (Garcelon 1977, Stathearn et al. 1984, Jackson et al. 1985, Adams et al. 1995), radio transmitters have been used on neotropical migrant songbirds and even insects (Nesbitt et al. 1982, Karl and Clout 1987). Cost and battery size are typically the limiting factor when dealing with radio telemetry and it is unusual for an entire population to be instrumented (Pollock 1987). Radio telemetry usually cannot provide direct information for the estimation of animal populations (Fuller and Snow 1988, Cogan and Diefenbach 1998, White and Shenk 2001). However, a sufficient sample of territorial species such as black bear may allow the use of individual home ranges to extrapolate local population size (Mech 1982, Maehr et al. 1991). Mech (1983) further emphasized that there is no other wildlife research technique that rivals the many benefits of radio telemetry.

Remote Photography

Remote-activated cameras have been used since the early 1930s (Gysel and Davis 1956, Young 1946, and Carbone et al. 2001) to document species presence and distribution (Jones and Raphael 1993), identify nest predators (Major 1991, DeGraaf 1995, Hernandez et al. 1997), document behavior (Peterson and Thomas 1998, Bridges et al. 2004), record wildlife underpass use (Foster and Humphrey 1995), and estimate population densities (Mace et al. 1994, Karanth and Nichols 1998). They are effective for monitoring secretive, dangerous, or otherwise difficult to study species (York et al. 2001).

Early systems relied on a string tied to bait as a trip line for activation purposes (Gysel and Davis 1956). The earliest remote-activated cameras used solenoids to release the shutter directly (Benter 1934). Young (1946) reported the camera documentation of a Texas red wolf (*Canis lupus*) using this methodology in 1929. Later systems used an electromagnet that released a spring-driven bar when the animal tripped the line (Wing 1948). Pearson (1959) used 16mm motion cameras synchronized to a flash to monitor wildlife use of meadow mouse (*Reithrodontomys* spp.) runways. Dodge and Snyder (1960) suggested that 16 mm systems were too expensive for field use (around $150 each in 1960). Remote photography was continually improved as it became a more practical, but not infallible, tool for wildlife study (Abbott and Coombs 1964, Cowardin and Ashe 1965, Weller and Derksen 1970, Temple 1972, Craig and Craig 1974, and Goetz 1981). Goetz (1981) observed that remote cameras were often negatively affected by changing weather, required much hands-on maintenance, and seldom were equipped to operate during both day and night. The frequency of maintenance was partly addressed with solar-powered batteries (Montalbano et al. 1985, Kristan et al. 1996). The advent of an infrared trigger on remote cameras improved photo capture efficiency (Savidge and Seibert 1988). This advancement ultimately led to the mass production of a variety of systems by commercial companies (e.g., Trailmaster® (Goodson and Associates, Inc., Lenexa, KS); CamTrakker® (CamTrak South, Watkinsville, GA)) (Kucera and Barrett 1993). Such units are now available for about $400. This increased availability also expanded the number of focal species which could be studied with camera systems. Whereas birds and small mammals had dominated early remote photography studies, reptiles (Fridell and Hovingh 1995), large mammals (Mace et al. 1994), and carnivores (Bull et al. 1992) were now capable of being studied with greater ease.

Modern camera systems vary from simple single-shot units using trip lines or pressure pads to more sophisticated infrared-equipped digital models. Low-cost systems often require more maintenance and labor (Zielinski and Kucera 1995), while the most expensive models may be too elaborate or complicated for the desired field application (Brooks 1996). Nonetheless, remote cameras are more effective for monitoring than track counts (Beier and Cunningham 1996, Foresman and Pearson 1998), scat collections (Foran et al. 1997), or other methodologies where individual recognition is difficult. Traditionally, radio telemetry (Mech 1983) has been employed to monitor species (and it was used as a supplement for this study), but it is labor intensive and can be prohibitively expensive. Telemetry requires radio collars, a receiver, antennas, and aerial flights in addition to time and materials needed to trap and instrument animals with the proper radio equipment. Remote photography eliminates most of these costs. After the purchase of cameras, the expenses include film, film development, and periodic site visits. Additionally, CamTrakker® and Forestry Suppliers, Inc. (Jackson, MS) now offer remote systems that utilize a rechargeable battery pack, along with digital cameras. Costing approximately $200 more than the original 35mm units, these digital cameras eliminate film and film development. Large memory cards (i.e., 256 mb of memory) also hold more images than 24 or 36 exposure film rolls that must be checked and replaced frequently.

Another benefit of remote photography is that it is a passive, non-intrusive monitoring approach that does not involve the risks associated with chasing with dogs (Massopust and Anderson 1984), capturing with traps, sedation (Mace et al. 1994), and subsequent telemetry flights. Study animals can be observed when researchers are absent from the field, which greatly reduces economic cost and human effort. Remote photography also does little to alter the behavior of the study animal, and observations may be collected without regard to extremes in weather or time of day (Montalbano et al. 1985).

Hair Snares / Genetic Analysis

The use of genetic testing has had popular application in the wildlife field in recent years. Hair samples collected from snares can be used to identify individual animals, or in our case, bears. Genetic analysis uses mtDNA fingerprinting (Rande et al. 1993). This permits identifying bears that have lost radio collars, ear tags, or are otherwise unrecognizable in a photograph. Although bears have inherently low levels of genetic variation (Paetkau and Strobeck 1994), microsatellite analysis allows examination of variation within very short tandem repeats of DNA, or variable number of tandem repeats (VNTRs, Nakamura et al. 1987). This method allows the level of heterozygosity and the number of alleles to be estimated for each locus, permitting examination of relatedness between individuals, comparisons of multiple populations, or differentiating individual animals. This technique was used to identify all marked bears photographed, as well as to better understand the spatial arrangement of residents by identifying unmarked bears. A better understanding of the genetic profile of these bears should be helpful in designing landscape-scale and population-level management of this small population in the fragmented and urbanizing landscape of west-central Florida.

The use of hair traps to collect hair samples is a relatively new technique, and there is much variation in the establishment of hair traps (Bittner et al., *In press*). Some researchers hang bait in the middle of traps (Mowat and Strobeck 2000), while others saturate the ground with liquid bait (Woods et al. 1999). Others recommend moving bait sites between sampling periods, while some insist on leaving the bait station unchanged (Boulanger 1998). It is important to note that there are still doubts and cautions that are continually voiced about the research promise of non-invasive DNA techniques (Taberlet et al. 1997, Garshelis 2001).

METHODS

Trapping and Handling

Black bears were trapped with Aldrich-type spring-activated foot snares and culvert traps (Erickson 1957, Johnson and Pelton 1980). Traps were set along known travel routes and baited with bakery products or corn (*Zea mays*). Captured animals were immobilized with Telazol (Fort Dodge, Lederle Parentals, Inc. Carolina, Puerto Rico) at a dosage of 7mg/kg (Kreeger 1999) with a pole syringe or dart gun (Telinject USA, Inc. Saugus, CA). Bears were fitted with radio collars (Telonics, Inc., Mesa, Arizona; Telemetry Solutions, Concord, CA) that were equipped with mercury tip switches for activity monitoring. Leather inserts were built into each collar to facilitate detachment within 1 year of deployment (Wooding and Hardisky 1988). Bears were given individually numbered yellow plastic ear tags (Nasco, Inc., Fort Atkinson, WI). Males were tagged in the left ear, while females were tagged in the right ear. These marks, in conjunction with unique physical traits such as ear notches, body size, and pelage characteristics unique to individual bears were used as identification features needed to create a mark-recapture estimate (LeCren 1965). Lip tattoos were applied for field identification during routine recaptures. Whole blood and hair samples were taken from each animal and stored in a –4°C freezer for future genetic analysis. A first premolar was pulled for aging via cementum annuli (Matson's Laboratory, Milltown, MT, USA) (Willey 1974). Measurements including zygomatic width, neck and chest circumference, shoulder height, body length, ear length, and front and rear pad widths and lengths were taken from each bear before release. An overall evaluation of the individual animal's health was assessed as well. Handling methodologies were approved by the University of Kentucky Animal Care and Use Protocol #00156A2000.

Remote Photography and Hair Snare Surveys

I superimposed a 1 km grid on the entire project area (Fig #) following a similar protocol for the Florida panther (*Puma concolor coryi*, D. Shindle, FWC, Naples, FL, personal communication). Inaccessible grids were excluded from the sample grid before camera sites were chosen. This yielded 160 grid cells available for sampling. Because the cost of remote cameras limited the study to only 20 units ($450 per single 35mm unit), I sampled every fourth grid cell (*n*=40) with remote photography and hair snares (Mace et al. 1994). A die was flipped to determine in which cell sampling would begin. Cameras were placed as close to the center of each cell as possible (Mace et al. 1994). Apparent bear trails and places where tracks or other sign had previously been found were targeted. In areas where bears are scarce or seldom reported, I chose locations that seemed likely to facilitate bear travel such as elevated trails through swamps, edges of saw palmetto thickets, or within cabbage palm hammocks. Each camera was placed adjacent to a baited hair snare (within 3 m) consisting of 2 strands of barbed wire (~0.3 m and ~0.6 m above ground) wrapped around 3 to 4 trees to form an enclosed area of approximately $6 m^2$ (Mowat and Strobeck 2000). Ideally, a visitation would produce a hair sample and at least one photograph.

Motion-sensitive CamTrakker® systems consisted of a 35 mm Evoca 70SE cameras, with the shutter release rewired to a motion detector and mounted inside a weatherproof, camouflage plastic casing. During 2003, I also used 2 Camtrakker® digital units with Olympus D-380 cameras. Units were attached to trees with locking cables. Cameras were positioned about 1 m above the ground (approximate shoulder height for a bear) and 3-5 m away from each station. Sensia 100 ASA Fujichrome color slide film (or equivalent) was used for this project. Baits were offered as a paper towel saturated with raspberry or jelly donut extract (Bear Scents, Inc., Lake Mills, WI), 30% honey water, or maple syrup. The towel was placed inside a 1 liter plastic bottle punctured with 4 holes and hung ~3 m above the center of the hair snare. The subject of each picture was identified to species, unknown, or blank. Time, date, and location were recorded for each picture.

Sampling occurred for 2 weeks each in May and July 2002 and 2003. Cameras were run for one week at 20 bait stations, then reestablished at the remaining 20 bait stations during the second week. Multiple photos of an individual taken within a 24-hour period and at the same site were counted as a single capture, whereas individuals recorded at different bait stations within the same 24-hour period were counted as separate sightings (Mace et al. 1994). Twenty CamTrakker® 35 mm cameras were operated from May 9-24 and July 11-29, 2002. The following years, camera surveys were conducted May 9-23 and July 9-23. Two digital CamTrakker® outfits were used in place of 2 malfunctioning 35 mm units.

Food Habits

Bears scats were collected opportunistically during routine fieldwork. Location and date collected were recorded for each scat before being placed in a plastic bag and stored in a freezer at –4°C. These were later thawed and rinsed with water through a kitchen strainer and items were identified to the lowest possible taxon. Percent frequency for each food item was calculated for each season (Maehr 1997): winter (January-April), summer (May-August), and fall (September-December). Species richness (S), species diversity (H'), and species evenness (J') were calculated by year and seasons (Hurlbert 1971, Krebs 1999, and Orlando 2003).

Home Range Analysis

Locations of radio-collared bears were determined at least once each week during summer and fall and biweekly during winter (post den-entrance) from a Cessna 172 at an average elevation of 300 m (Mech 1983). Radio locations were also recorded from the ground opportunistically using triangulation (Mech 1983). Locations were plotted on USGS 7.5 minute quadrangle maps as Universal Transverse Mercator coordinates, along with designations of habitat, activity, date, and time-of-day as described by Mech (1983) and Maehr (1997). Home ranges were analyzed using ArcView 3.2 GIS (ESRI 1999) to generate 100% minimum convex polygons (MCP) and 95% adaptive kernel (AK) home ranges for each individual. The MCP technique was chosen because it is the most frequently used method for studying home ranges, it is conceptually simple, and it does not make any assumptions (Mohr 1947, Hayne 1949). Adaptive kernels may depict a more accurate account of where an individual spends the majority of its time, and thus may have more practical application than MCPs in displaying core habitat areas (Worton 1989). The one caveat about AKs, however, is the problem with dissection of core areas. Corridors may not be represented if few or no radio-locations document them, and home ranges may subsequently be underestimated. Thus, it is important for practical purposes to include the results of both techniques. Annual home ranges are presented along with seasonal home ranges: winter (January-April), summer (May-August) and fall (September-December) as described by Maehr (1997).

Population Estimation using Radio Telemetry

Radio telemetry data have been used in estimates of animal population sizes through mark-recapture/resight techniques (Fuller and Snow 1988, Bowden and Kufeld 1995, White and Shenk 2001, Swann et al. 2002). These studies required an actual resighting of radio-tagged individuals to form estimates, a challenging method for studying elusive species such as black bear. As an alternative, I developed a prediction of the number of black bear the GCE could support based on average female home range size, availability of quality habitat, and percent overlap of home ranges (Mech 1983). This extrapolation should provide a minimum baseline for black bear carrying capacity in the GCE (Maehr et al. 1991).

Population Estimation using Remote Cameras

The Lincoln-Petersen method of mark-recapture estimation (Seber 1982) was used to estimate population size and annual variation. A sample of n_1 bears was captured, marked with ear tags, and released. Subsequent photos and hair samples were considered recaptures (n_2), a proportion of which are marked (m_2). Ideally, the proportion of marked animals in subsequent recaptures should be equivalent to the proportion of marked animals in the total population (N) such that:

$$m_2 / n_2 = n_1 / N$$

A modified version of this estimate containing less bias was developed by Chapman (1951) as

$$N_c = [(n_1 + 1)(n_2 + 1) / (m_2 + 1)] – 1,$$

and holds true as long as $n_1 + n_2 > N$. The variance of N is also described by Seber (1982) such that:

$$\text{var}(N) = \frac{(n_1 + 1)(n_2 + 1)(n_1 – m_2)(n_2 – m_2)}{(m_2 + 1)^2 (m_2 + 2)} .$$

An approximate 95% confidence interval can then be calculated using the methodologies of Lancia et al. (1996), assuming normality for N:

$$N \text{ " } t_{0.95} [\text{var}(N)]^{1/2}.$$

The Lincoln-Petersen model assumes: (1) the population is closed, (2) each animal is equally likely to be captured/recaptured, and (3) marks such as ear tags will not be lost or overlooked (Jones 1996). Given its apparent demographic isolation, the GCE population appears closed to even occasional immigration from neighboring populations. Trapping results since 1997 suggesythat there were no “trap happy” individuals. On the other hand, it is more difficult to document trap shyness. I used odor attractants without a caloric reward to bait camera traps to reduce return visits. Genetic analyses were used to reduce the impact of lost markers such as ear tags and radio collars, and were useful in identifying bears that were not otherwise verified by capture, telemetry, or photography. Thus, the three assumptions seem to be reasonably addressed.

I also used a derivation of the Lincoln-Petersen estimator known as a score interval (Agresti 1990). This creates confidence intervals for binomial parameters and works particularly well for small populations. The score interval is shown below:

$$m_2\left(\frac{n_2}{n_2+Z_{\alpha/2}^2}\right) + \frac{(1)(Z_{\alpha/2})^2}{(2)(n_2+Z^2)} +/- (Z_{\alpha/2})\left(\frac{1}{n_2+Z_{\alpha/2}^2}\right)^{1/2}\left[m_2(1-m_2)\left(\frac{n_2}{n_2+Z_{\alpha/2}^2}\right) + \frac{(1/4)(Z_{\alpha/2})^2}{n_2+Z_{\alpha/2}^2}\right].$$

It makes the same assumptions as Lincoln-Petersen.

Pollock et al. (1990) noted that most popular computer programs designed to distill data (i.e., CAPTURE [White et al. 1978]; MARK; and JOLLYAGE [Pollock 1981]), do not perform well when capture probabilities are low and population sizes are small. Because this characterizes the GCE population, I disregarded the use of computer programs to model the population trends of the GCE.

Population Estimating using Genetic Analysis

Hair snares were run in combination with remote cameras in May and July 2002 and 2003 to collect hair for population estimates (Mace et al. 1994, Paetkau et al. 1998, Mowat and Strobeck 2000, Boulanger and McLellan 2001). Twenty-one different hair samples were collected in the GCE in 2002, while no hair was found during the 2003 sampling periods. Hair samples collected were shipped to Wildlife Genetics International, Inc. (Nelson, British Columbia, Canada) in January 2004, and those were analyzed at 12 microsatellite loci (*G1A*, *G10B*, *G10C, G1D*, *G10H*, *G10J*, *G10L*, *G10P*, *G10X*, *MU59*, *MU50*, and *G10M*) and compared to the original 28 samples previously submitted (blood and hair samples of 28 marked GCE bears had been analyzed at WGI, representing bear captures from 1997-2001). This cross-reference with the known samples should provide a better understanding of which unknown hair samples represent recaptures, as opposed to those that represent previously unmarked individuals. Mark-recapture statistics were to be applied to these results to obtain a third population estimate.

RESULTS

Trapping

Physical capture identified 28 different bears in the GCE from summer 1997 through summer 2001 (Table 1). This includes bears captured through trapping efforts (86%) and those encountered solely due to vehicular collision (14%). Nine (32%) of these bears were neonatal cubs, only one of which was verified as surviving to sub-adulthood status (bbCh114) after being recaptured 1.5 years after her birth in Aripeka. Another 9 (32%) are known to be dead, 6 of which were due to roadkill and 2 due to poaching. The cause of the other death remains unknown.

Home Range Analysis

Eight black bear were individually radio tracked in the GCE from August 2001-August 2002. Their movement data were added to the radio locations from the previous 4 years to generate 100% minimum convex polygons (MCP) and 95% adaptive kernels (AK) for a 5-year home range analysis of GCE bears using 11 radio-collared bears and over 3500 radio locations (Tables 2 and 3). Annual female home range size was about 77.8 km^2 (SD=56.8 km^2) based on 100% MCPs (Fig. 4) and only 24.1 km^2 (19.1 km^2) using AKs (Fig. 5). Female MCP estimates were significantly larger than AK estimates at the "=0.05 level (t=2.00, df=8) (Table 5). Two radio-collared female bears were excluded from the female home range average because their movements may not mimic those of an adult bear. The first, bbCh114, was a 1.5 year-old sub-adult nearing dispersal age when she was fitted with a radio collar. The second, bbCh125, was a spring 2002 cub of bbCh104 who was outfitted with a radio collar and then tracked from April through June 2002. Annual male home range size was approximately 158.3 km^2 (SD=30.9 km^2) based on 100% MCPs (Fig. 6) and approximately 166.5 km^2 (SD=67.6 km^2) based on 95% AKs

Table 1: Summary of bears captured in the GCE from 1997-2003.

Bear	Age (yr)	Sex	Weight (kg)	Most Recent Status
101	N/A	F	86	12/1/98-Dead-possible poaching WSF
102	13	F	103	ACGW
103	15.5	F	84	possible poaching -CWMA- 10/1/99
104	9.5	F	85	roadkill 9/30/02-ACGW-US 19
105	9.5	M	159	poached Fall 2002, Serenova/Pasco Co.
106	9	M	136	dropped collar 10/16/01-CWMA
107	10.5	M	151	roadkill 7/30/03-ACGW-CR 595
108	14	F	116	CWMA-8/02
109	7.5	M	114	released in Libery Co (Nuisance Bear)
110	15	F	64	CWMA-8/02
111	8	M	159	dropped Collar 5/22/02-WWP
112	N/A	M	11	released 1/12/99-CWMA-Ryle Creek
113	3.5	F	1	N/A
114	4	F	43	signal failed - 5/14/02 – ACGW
115	3.5	M	1	N/A
116	3.5	F	1	N/A
117	3.5	F	1	N/A
118	3.5	M	1	N/A
119	3.5	M	1	N/A
120	N/A	M	N/A	roadkill-US 19-Sugar Mill Woods
121	14	M	136	dropped collar 7/20/00
122	6	M	159	dropped collar 7/13/01
123	0.1	F		dead Spring 2001
124	1	F	2	ACGW-4/02
125	1	F	2	ACGW-6/02
126	17	F	83	roadkill 9/20/02-ACGW-US 19
127	0.5	M	12	roadkill 9/21/01-ACGW-CR 595
128	0.5	M	11	roadkill 9/21/01-ACGW-CR 595

(Fig. 7). Unlike females, there was no significant difference between male MCP and AK estimates at the "=0.05 level (t=0.22, df=6) (Table 5). However, male home ranges were significantly larger (" = 0.05) than female home ranges using both MCP and AK methods (Table 4). Overall, male black bears experienced a 93% overlap in their home ranges, while females only exhibited a 38% overlap.

Radio Telemetry Population Estimates

Using 5 years of GCE radio telemetry data and over 3500 radio locations, I developed a predictive model that estimated the number of black bear the GCE could support. The GCE contains about 68,900 ha of non-contiguous habitat suitable for bear use. Females have an average home range of 2,408 ha using the 95% adaptive kernel, which shows the necessary core bear areas. Dividing the total available land by the average female home range size suggests the GCE could support 28 female bears (68,900 / 2,408 = 28). This assumes no home range overlap. The 100% MCP may also be used, as female MCPs were significantly larger than adaptive kernels. Average female MCP home ranges were 7,779 ha, which infers the GCE could only support 9 females (68,900 / 7,779 = 9). If a 50:50 sex ratio is assumed, the adaptive kernel method estimates that the GCE could support 56 adult bears, whereas the MCP method would yield an estimate of only 18 adult individuals. These estimates are not an accurate depiction of the exact number of bears in the GCE, but they do offer a glimpse at the carrying capacity of the ecosystem.

Remote Photography Surveys

There were 585 pictures taken during the 2002 camera sessions, with 73 of these photos identifying bear presence. Eight bears were known as marked (n_1) during this sampling period. Twelve different bears (n_2) were captured on film. Three (m_2) were previously marked. Using

Table 2: Seasonal home ranges for female black bear in the GCE from 1997-2002.

SUMMER		
Female	MCP (ha)	Kernel (ha)
102	509	509
103	1573	403
104	2396	936
108	6544	8490
110	4255	1882
114	N/A	N/A
Average	3055	2444
SD	2383	3429
FALL		
Female	MCP (ha)	Kernel (ha)
102	1797	1174
103	2060	1637
104	9230	1946
108	5853	5433
110	14701	11029
114	232	280
Average	6728	4243
SD	5401	4151
WINTER		
Female	MCP(ha)	Kernel (ha)
102	720	495
103	334	255
104	342	101
108	4158	2121
110	1127	121
114	345	331
Average	1336	618
SD	1610	854

Table 3: Seasonal home ranges of male black bear in the GCE from 1997-2002.

SUMMER		
Male	MCP (ha)	Kernel (ha)
105	7602	8716
106	9310	11723
111	11918	18156
122	9400	7831
Average	9557	11606
SD	1777	4673
FALL		
Male	MCP(ha)	Kernel (ha)
105	16107	9937
106	7313	12503
111	14231	32845
122	3391	3391
Average	10260	14669
SD	5939	12710
WINTER		
Male	MCP(ha)	Kernel (ha)
105	12247	21235
106	5816	2356
111	11667	18447
122	7674	7674
Average	9351	12428
SD	3112	8903

Figure 4: 100% minimum convex polygon home ranges of 6 female black bear radio-tracked in the GCE from August 1997-August 2002. Red lines represent highway boundaries.

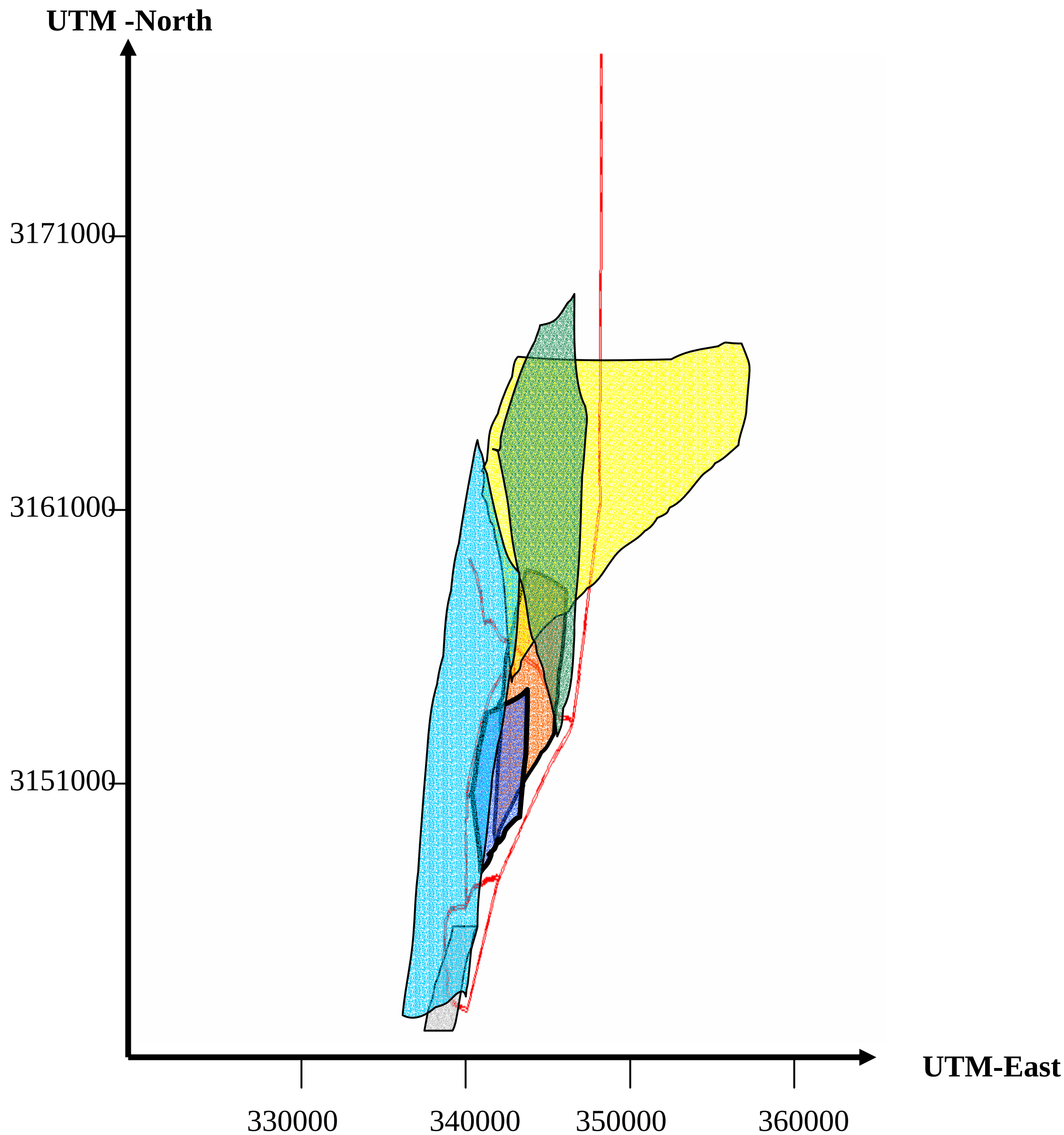


Figure 5: 95% adaptive kernel home ranges of 5 female black bears radio-tracked in the GCE from August 1997-August 2002. Red lines represent highway boundaries.

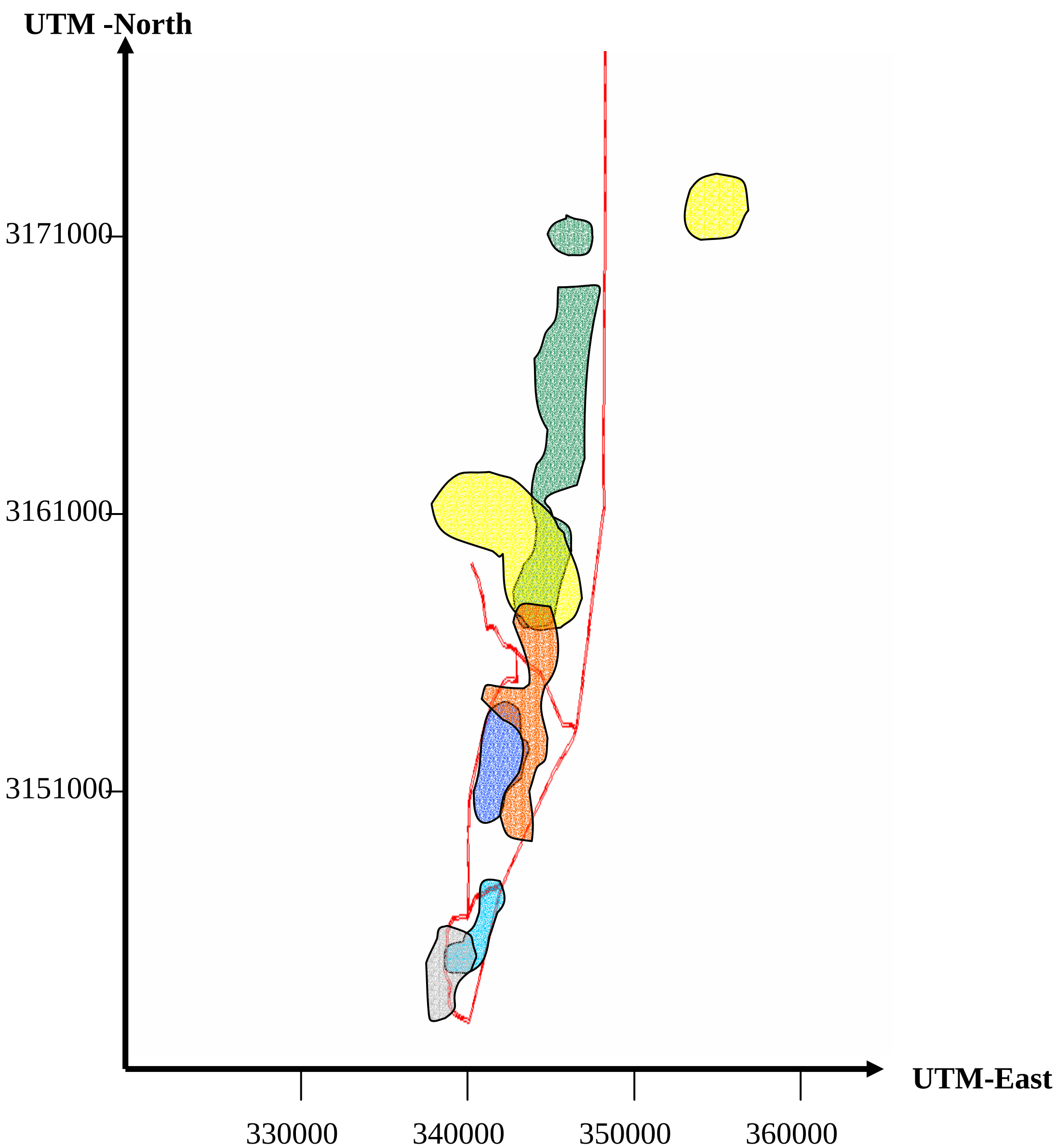


Figure 6: 100% minimum convex polygon home ranges of 4 male black bears radio-tracked in the GCE from August 1997-August 2002. Red lines represent highway boundaries.

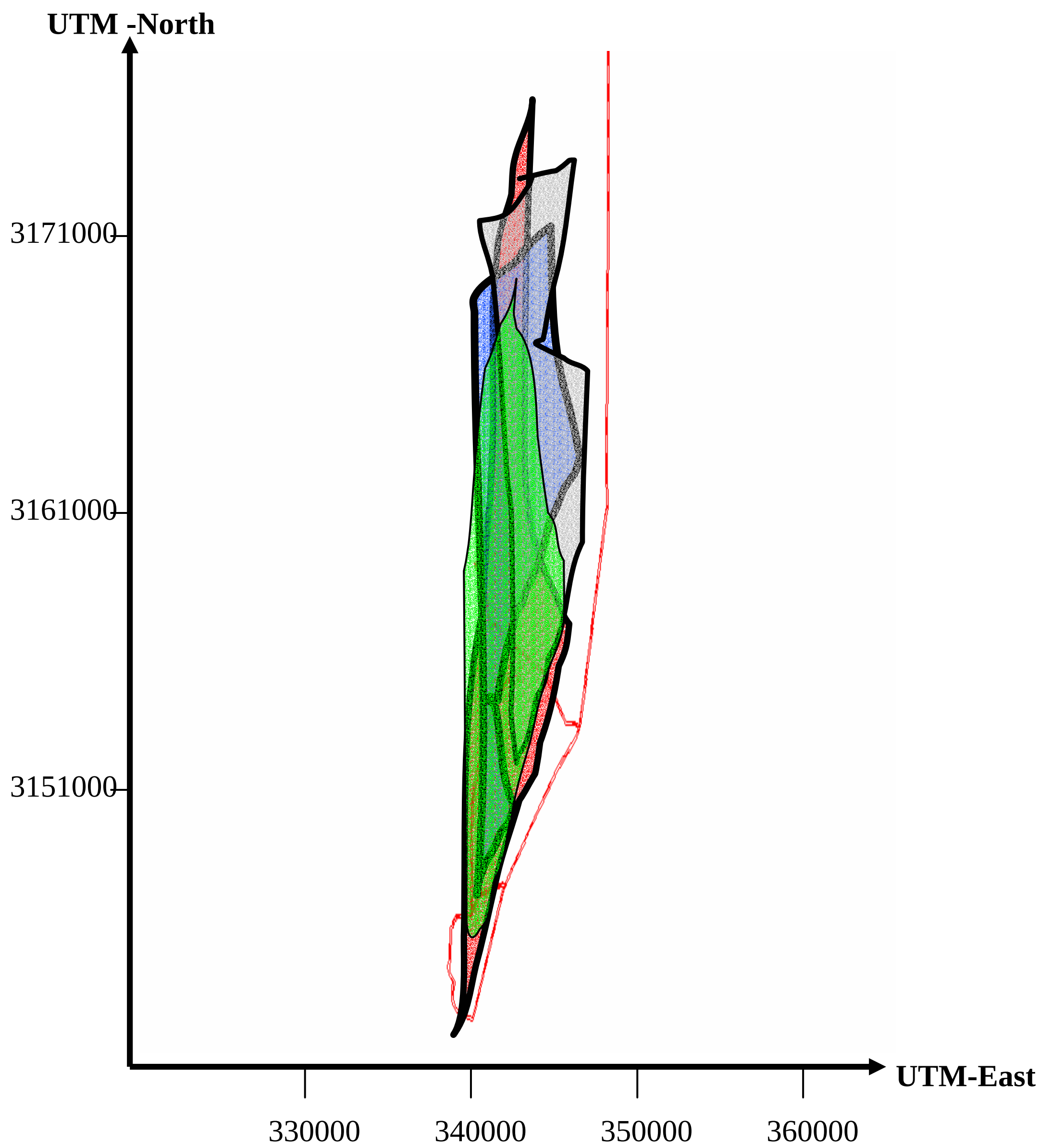


Figure 7: 95% adaptive kernel home ranges of 4 male black bears radio-tracked in the GCE from August 1997-August 2002. Red lines represent highway boundaries.

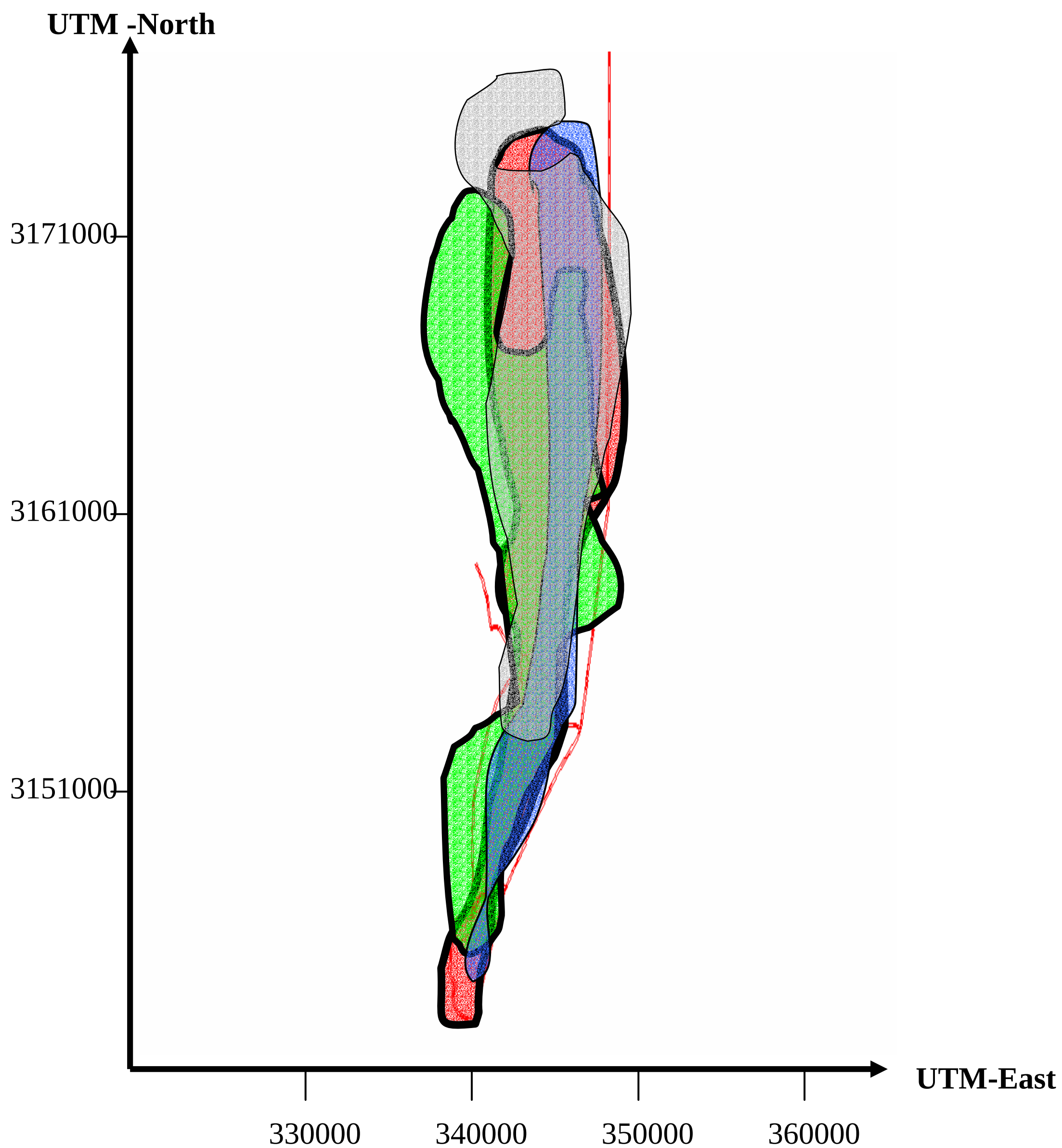


Table 4: Male home ranges versus female home ranges in the GCE from August 1997-August 2 2002 using both the 100% minimum convex polygon (MCP) and 95% adaptive kernel (AK) methods.

Season	Method	Standard Error	T-value	Degrees of Freedom	Significant
Annual	MCP	29.74	2.71	7	Yes
	AK	34.72	4.10	7	Yes
Summer	MCP	13.88	4.68	7	Yes
	AK	27.95	2.93	7	Yes
Fall	MCP	38.27	0.93	7	No
	AK	66.21	1.57	7	No
Winter	MCP	17.15	4.67	7	Yes
	AK	44.68	2.59	7	Yes

Table 5: The 100% minimum convex polygon (MCP) method versus the 95% adaptive kernel (AK) method for estimating home range size of both male and female black bear in the GCE from August 1997-August 2002. Annually, female MCP estimates were significantly larger than AK estimates, while there was no significant difference between male MCP and AK estimates.

Season	Sex	Standard Error	T-value	Degrees of Freedom	Significant
Annual	Female	26.80	2.00	8	Yes
	Male	37.17	0.22	6	No
Summer	Female	18.67	0.33	8	No
	Male	25.00	0.82	6	No
Fall	Female	30.46	0.82	8	No
	Male	70.15	0.63	6	No
Winter	Female	8.15	0.89	8	No
	Male	47.16	0.65	6	No

the Lincoln-Petersen estimator with these data yielded a population estimate ("=0.05) of 28 " 18 bears in the GCE (28 " [2.306 x $65.81^{1/2}$]). A score interval produced a 95% confidence interval of 19-37 bears.

During 2003 sampling, there were n_1=6 bears marked in the GCE. Only 2 bears (n_2) were captured on 87 total photographs, 7 of which identified bear presence. One (m_2) of these individuals was marked, while the other was an unknown bear. Lincoln-Petersen produced an estimate ("=0.05) of 12 " 7 bears in the GCE using these data. The score interval estimates 8-20 bears with 95% confidence. These estimates indicate a substantial decline from those of the previous year.

Genetic Analysis / Hair Snares

Normally, a marker system with a mean heterozygosity (*H*) in the range of 0.7 to 0.8 is used in genetic analysis. However, the 12-loci data from the GCE from the original 29 known samples displayed mean *H* of 0.31, well outside the range of marker variability covered by past experience. Additionally, 2 loci, *MU50* (*H*=0) and *G10M* (*H*=0.03), were disregarded because their variability was so low. This created a 10-loci marker system with a mean *H* of 0.34. The important question to then ask was: what is the match probability for a 10-loci marker system with *H*=0.34 (D. Paetkau, WGI, personal communication)? Typically, 1 in 1000 pairs of unrelated animals have identical genotypes, but the GCE probably does not have unrelated individuals. Thus, the 29 known genotypes can be used to create an empirical power test (29*28/2 =406) (D. Paetkau, WGI, personal communication). This estimates that the GCE has a match probability of about 1 in 406 individuals.

After establishing the match probability, 6 of the 21 unknown samples were classified as insufficiently complete. The remaining 15 samples were genotyped using the 10-loci system, and it was determined they were tied to 3 individuals, all of which were previously known or marked. Using these data with the Lincoln-Petersen estimator, there are only $N = 8$ bears (var(N) = 0) in the GCE, as we recaptured 0 unmarked bear and had 8 marked (m_1) in the population at the time of sampling. A score interval provides a confidence interval of 0-3 bears in the GCE; this is intuitively unreliable because there were 8 known marked bears during the 2002 sample. There are no estimates for 2003 because hair collection was unsuccessful.

Winter Denning

Three female winter dens were investigated in spring 2002. Two dens were located in saw palmetto thickets, while the other was in a *Smilax* thicket in a dry cypress swamp. BbCh104 switched den sites from a mixed hardwood swamp to a relatively open saw palmetto thicket between 22-24 January 2002. Average time spent in the den was 81 days (n = 3, standard deviation = 39). Female bbCh104) had 2 female cubs (bbCh124 and 125). The cubs were examined on 14 March 2002 for approximately 30 minutes and then returned to the den site. Physical measurements and blood and hair samples were collected, and lip tattoos were administered. Females bbCh104 and 125 are known to have left the den on 12 April 2002, the latest of all radio-collared individuals.

Food Habits

From August 1999 to August 2002, 307 scats were collected in the GCE. These contained 17 natural food items (Table 6). Annual diet was dominated by saw palmetto (33.2%) and other plant fiber (36.8%). Winter scats (n=56) contained plant fiber (59.8%), saw palmetto (16.2%), animal matter (10.8%), bess beetle (*Odontotaenius disjunctus* , 2.7%), sabal palm (2.7%), acorns (*Quercus* spp., 4.1%), and the fruit of swamp tupelo (*Nyssa biflora*, 1.4%). Winter diet had a diversity and evenness of 1.33 and 0.64, respectively. Summer scats (*n*=95) were dominated by plant debris (36.5%), grape (*Vitis* spp., 22.4%), animal matter (9.6%), bess beetle (5.8%), the fruits of bitter gallberry (*Ilex glabra*, 4.5%), and the apical meristems of saw palmetto (7.8%) and cabbage palm (3.8%). Additional summer food items included blackberry (*Rubus* spp., 3.2%), ants (Formicidae, 2.6%), and the larvae of 2 different insects from the Passiladiae family (0.6% each). Summer diversity (*H'*) equaled 1.93, while evenness was 0.75. Fall food items (*n*=156) were heavily dominated by the fruits of saw palmetto (33.8%) and sabal palm (33.6%). Other occurrences in the fall diet were persimmon (*Diospyros virginianus*, 11.7%), acorns (5.2%), swamp tupelo (3.5%), bess beetle (3.5%), swamp tupelo (3.5%), plant fiber (3.0%), animal matter (3.5%), ants (2.0%), and chick pea (0.4%). Species diversity and evenness were 1.70 and 0.71, respectively, for fall food items (Table 7).

These data suggest that saw palmetto and sabal palm are very important food sources for bear in the GCE. Similarly, nearby bear populations in Ocala and Osceola National Forests depend on the fruits and meristems of saw palmetto for a large percentage of their diet (Maehr and Brady 1984a, Maehr and Brady 1984b). While Maehr and Brady (1984b) report that items such as black gum, odorless bayberry (*Myrica inodora*), and yellow jackets (*Vespula* spp.) are more important in bear diets in Apalachicola National Forest (ANF), Stratman and Pelton (1999) suggest that saw palmetto is equally important in ANF as in other parts of Florida. Due to saw palmetto's cycling nature of producing boom and bust mast crops in successive years, food habit studies must take into consideration multiple years of data collection. Interestingly, 1999 and 2001 were both large mast production years for saw palmetto. In those 2 fall seasons, 99% of GCE bear scats contained saw palmetto seeds, accounting for a 63% overall occurrence. Diversity values decreased to 1.29, and the evenness equaled 0.62. Using 100% MCPs, male (t =

Table 6: Frequency of occurrence and percent frequency of food items in GCE black bear scats (*N*=307) from Aug 1999-Aug 2002.

Food Item	Frequency of Occurrence	Percent Frequency
Plant matter		
Serenoa repens	102	33.2
Sabal palmetto	86	28.0
Pinus spp.	1	0.3
Vitis spp.	35	11.4
Diospyros virginianus	30	9.8
Cicer arietnum	1	0.3
Vaccinium spp.	5	1.6
Quercus spp.	15	4.9
Nyssa sylvatica	9	2.9
Ilex glabra	7	2.3
Animal matter		
Odontotaenius disjunctus	19	6.2
Ants (Formicidae)	6	2.0
Bees (Hymenoptera)	2	0.7
Beetle larvae (Passalidae)	2	0.6

Table 7: Diet diversity of GCE black bear from August 1999-August 2002.

	Total Scats (*n*)	Richness	Diversity (*H′*)	Evenness (*J′*)
Annual	307	17	2.56	0.74
Fall	156	11	1.70	0.71
Winter	56	8	1.33	0.64
Summer	95	13	1.93	0.75

3.54, df = 3) and female (t = 7.89, df = 5) home ranges were significantly larger during fall seasons when saw palmetto was abundant as opposed to fall seasons when saw palmetto was not. Bumper crop fall seasons for saw palmetto (1999 and 2001) had average female home ranges of 17.70 km^2 (n = 5, SD = 16.60) and average male home ranges of 47.27 km^2 (n = 2, SD = 5.49). In between these periods, there was little saw palmetto production in the GCE, and collected bear scats reflected this deficiency. Fall 2000 bears scats contained no saw palmetto. In its absence, sabal palm was an important food source, accounting for a 62.9% food occurrence. Overall diversity and evenness values were similar to the other falls (H'=1.35 and J'=0.61). Average home range size using 100% MCPs also increased as bears movements did, perhaps in search of additional food sources. Female home ranges averaged 87.11 km^2 (n = 2, SD = 6.67) in 1999, while males averaged 71.89 km^2 (n = 3, SD = 10.01).

Mortality

Six bears died of human causes in the GCE from August 2001 to May 2004. The primary cause of death was due to vehicular collision (n=5), while the other was attributed to poaching (Table 8). No natural mortality was documented during this time.

Cost Analysis

The approximate costs of each sample technique of population estimation varied considerably (Table 9). These estimates do not include human work hours and are based on the cost for 1 field season. It is clear that hair snares are indeed the cheapest method of research (~$1650). However, my data suggests that hair snares are not the most reliable method of estimating population size due to low capture success and limited genetic diversity. Remote photography, although not inexpensive (~$9,500), is both reliable and moderately affordable. Once purchased, cameras may be reused over multiple field seasons and may be utilized to perform other wildlife

Table 8: Documented GCE black bear mortality during research years Aug 2001-May 2004.

ID#	Sex	Age (yrs)	Date of Death	Location	Cause
127	M	0.5	9/21/01	CR 595	Roadkill
128	M	0.5	9/21/01	CR 595	Roadkill
126	F	9.5	9/20/02	US 19	Roadkill
104	F	17	9/30/02	US 19	Roadkill
105	M	10	Fall 2002	SSWP	Poaching
107	M	10.5	7/30/03	CR 595	Roadkill

surveys (e.g., wild turkey or gopher tortoise). Additionally, bait prices may vary (i.e., using honey is cheaper than buying commercial scent), and film and battery costs can be reduced by using rechargeable batteries and digital cameras. Radio telemetry (~$13,000) is the most expensive means of monitoring the GCE bear population. Additionally, it is the most time intensive. Whereas it may take an entire field season to outfit 15 bears with radio collars, a remote photography or hair snare study may be set up and run to completion within a matter of weeks. Conversely, radio telemetry can provide researchers will fine scale movement patterns that the other 2 techniques cannot.

Table 9: Cost analysis of population estimation techniques**.**

Radio Telemetry			
radio collar	$250	15	$3,750
receiver	$2,000	1	$2,000
antennae	$100	3	$300
snares	$33/snare	30	$990
Telazol	$25/5mL	30	$750
flights	$100/hour	52	$5,200
		Total	$12,990
Remote Photography			
camera	$450	20	$9,000
film	$46/10 pack	4	$184
batteries	$6/4 pack	20	$120
film development	$0.40/photo	336	$134.40
bait	$54/gallon	2	$108
		Total	$9,546
Hair Snares			
barbed wire	$18/roll	2	$36
coin envelopes	$10/box	1	$10
bait	$54/gallon	2	$108
hammer	$10	1	$10
nails	$5/box	1	$5
hair analysis	***	21	$1,481.13
		Total	$1,650.13

DISCUSSION

Population Estimation Methods

The goals of managing animal populations are often stated in terms of a target population size (Lancia et al. 1996). Local managers of the GCE require a plan for black bear monitoring that falls within the context of their own specific management directives. My research utilized 3 sampling methods that yielded markedly distinct results (Table 10). Radio telemetry proved useful for predicting potential density and portraying the spatial arrangement of bears in the GCE. For population estimations, though, radio telemetry is imprecise (Fuller and Snow 1988) and is the most costly of the 3 techniques employed. Remote photography was the most effective in providing a population estimate for the GCE. This estimate reinforced our earlier figure of 20 bears in the GCE (Cox et al. 1994), but the 2-year trend suggested in this study is temporally limited. Nonetheless, fewer photographs were taken of fewer bears in the GCE during 2003. This is likely the result of mortality of 3 bears that were regularly observed The apparent decline could be real if other bears were not recruited into the population. Another factor that may have contributed to fewer photos was the record rainfall during 2003. Baits presented as odor attractants were frequently flushed with rain, leaving them odorless and ineffective. In addition, 7 remote cameras malfunctioned due to moisture during these rainy months, thereby eliminating capture opportunities.

Although hair snares were cost effective, they represented 2 problems. First, capture success was highly variable: I collected 21 samples in 2002 and 0 in 2003. This is perhaps due to the use of odor attractants as bait. Attractants may lure a bear to a bait station and activate a remote camera, but there may be insufficient incentive to enter the snare. Second, the reduced genetic

Table 10: Results of using the 3 methods of radio telemetry, remote photography, and hair snares to estimate population size of Florida black bear in the Greater Chassahowitzka Ecosystem of west-central Florida.

Method	Population Estimate
Radio Telemetry	
100% MCPs	18
95% AKs	56
Remote Photography	
2002 Lincoln-Petersen	28 " 18
2002 Score Interval	19 - 37
2003 Lincoln-Petersen	12 " 7
2003 Score Interval	8 - 20
Hair Snares / Genetic Analysis	
2002 Lincoln-Petersen	8 " 0
2002 Score Interval	0 - 3
2003 Lincoln-Petersen	N/A
2003 Score Interval	N/A

structure of this GCE population makes individual identification difficult even with a 12-loci marker system (D. Paetkau, WGI, personal communication).

Unless additional spatial data are needed, the GCE bear population could be monitored with relatively inexpensive camera surveys and hair snares. Additional bait sites should be added to the 40 stations already in place, especially in the northern GCE, where a young, unmarked bear was photographed in May 2002. Additional surveys would be warranted in the Croom Tract of the WSF, Crystal River State Buffer Preserve, and Goethe State Forest. Both Lincoln-Petersen and score intervals can be used to create population estimates. Hair snares may not provide accurate estimates, but they are a cost effective and non-invasive method of genotyping unmarked individuals that are known only from photographs.

Physical capture of individual bears and outfitting them with radio collars should be done on a limited basis. First, there is a significant risk involved to both the bear and the researcher when physical capture is employed. Second, capture methods and telemetry requirements are costly. Captures in traps allow the "marking" of individuals with radio collars and ear tags. Because captures have not taken place in the GCE since fall 2001, marks such as these will eventually be lost. Fortunately, an individual bear may sometimes be recognized in a photo due to pelage characteristics, ear notches, chest blazes, or other physical attributes, although these "marks" may be overlooked as well. Thus, a new method of marking individuals must be conceived for mark-recapture analysis, or the occasional trapping of black bear in the GCE will have to occur on a limited basis.

Additional methods such as deer hunter surveys and the GCE bear telephone hotline should be continued. Hunter surveys placed at the white-tailed deer check station allow the hunters of the CWMA and HT-WSF to report bears and bear sign. Further, this maintains interest among local hunters. Similarly, the bear hotline allows citizens of the GCE to participate in the conservation of the Florida black bear.

Management Implications

Land management will likely determine the fate of the black bear in the GCE. Because it is largely a forested species (Wooding et al. 1994, Maehr et al. 2001), the preservation and management of suitable habitat is key to the survival of black bear in the GCE. This includes the maintenance and management of adequate annual nutrition. Thus, saw palmetto should be a concern of land managers in the GCE. Palmetto is not a regular mast producer (Orlando 2003), and its productivity may be linked to fire (Hilmon 1969). Hilmon suggested that saw palmetto flowers and refoliates following a fire, but it does not reach maximum fruit production until 6-9 years post-burn. This suggests that the 2-4 year prescribed fire rotation (M. Barnwell, SWFWMD, personal communication) may be too frequent for optimal saw palmetto fruit production. Over sufficient time and space, this burn cycle could reduce the production of a critical food source in the GCE (Maehr et al. 2001). Land managers should consider burning on longer cycles, and avoid winter burns due to the chance of incinerating natal dens (Maehr et al. 2001).

Mortality continues to be one of the limiting factors of the GCE black bear population. The 37 roadkills in the study area from 1976-2004 (Orlando 2003, this study) represent a substantial loss to such a small and isolated population. Franklin (1980) suggested a population should contain at least 50 individuals for short-term genetic stability, but >500 would greatly enable a population to withstand the stochastic changes in natural ecosystems (e.g., drought, flood, hurricane). If the GCE estimate of 20 individuals is accurate and the population has experienced an average of 3 mortalities in the past 2 years, the future of the GCE black bear is in doubt.

Isolation of the GCE is another management. Few other carnivore species display a level of isolation similar to GCE bears. Populations of brown bear (*Ursus arctos*) in Europe (Linnell et al. 2002), channel island fox (*Urocyon littoralis*) in California (Gray 2003), and Asiatic cheetah (*Acinonyx jubatus*) in Iran (Driscoll et al. 2002) may be similar to the GCE black bear in terms of genetics and demographics, but these populations are separated from larger populations of their species by great distances. The GCE, however, is within 70 km of Ocala National Forest, a stable population of black bears. Creating connections with this population will not be easy, though (Larkin et al. 2004). Since the early 1990s, more than 151,000 ha of bear habitat have been purchased in Florida by the state and federal governments within the 4 core bear areas (Ocala NF, Apalachicola NF, Osceola NF, and Big Cypress NP). Public lands that support bears have grown to more than 1.2 million ha in the past 20 years. Connecting nearby core populations to the GCE should now be a priority (Hoctor 2003). These corridors must then be made feasible for the facilitation of black bear travel within them. This may include wildlife underpasses, the creation of green-ways, reforestation, and reducing speed limits in high bear use areas.

<u>Genetic Consequences</u>

GCE bears have the lowest levels of observed heterozygosity ($H_0 = 0.287$) and the fewest number of alleles per locus (A = 2.25) of all 8 Florida subpopulations (Florida average $H_O = 0.65$ and A = 5.5) (Dixon 2004). Thus, all individuals are closely related in this population. The GCE also exhibits the highest average F_{ST} values ($F_{ST} = 0.4170$), a population subdivision estimator that shows the disconnect and limited gene flow between the GCE and the rest of the Florida metapopulation (Florida average $F_{ST} = 0.2110$).

Frankham (1995) confirmed that inbreeding increases the risk of extinction in naturally outbreeding species such as the black bear. While inbreeding may not be the ultimate cause of extinction, it may weaken the population by decreasing reproductive rates and increasing susceptibility to environmental change (Soulé 1980, Frankham 1995). Inbreeding likely contributes to population decline especially for large carnivores (Mills and Smouse 1994). For the GCE bear population to survive it must reestablish connections with other populations. Such reconnections could occur through landscape restoration or translocation from other populations. Sub-adult females from nearby populations could be released into northern areas of the GCE, where males are found but where females are absent. Similar translocation strategies have been successful in the Kenai Peninsula of Alaska and the Big South Fork region of Kentucky and Tennessee (Schwartz and Franzman 1992, Eastridge 2000). Supplementation would diversify the gene pool of the population, but it may also facilitate the movement of bears out of the GCE and into the Big Bend area. This area is most likely to be reached by dispersing GCE bears because of the relatively few landscape obstacles compared to other potential dispersal routes (Larkin et al. 2004). Female bears in the GCE have typically resided in the southern portion of the study area (Smith 2001, Orlando 2003). Consequently, males inhabit these areas during the mating season. Southward dispersal out of the GCE is unlikely because of extensive urbanization and many movement barriers. The last 4 bears that left the GCE in this direction were killed in the urban-wildland interface. Occasional sightings are reported in the 600,000 ha Big Bend, an area with extensive forest cover and few roads (Cox et al. 1994, Maehr et al. 2001). The creation of a landscape linkage between the GCE and the Big Bend area could rescue this small population from likely extinction.

Conclusions

The GCE black bear population is the smallest in Florida and perhaps North America. At approximately 20 individuals, it depends upon the mast production of only a handful of species, avoids areas of human activity, experiences little or no recruitment, and is isolated from other populations. As land in west-central Florida continues to urbanize and become fragmented, the urgency of management intervention increases. A logical succession of actions could begin with population supplementation followed by land-savings actions and habitat restoration that promote the natural connections between populations. The conservation of the small GCE population will maintain a flagship species and the ecological services that cannot be provided by smaller, more numerous omnivores (Maehr et al., *in press*). These actions must begin soon, however, before stochastic events preclude the need.

References

Abbott, H.G., and A.W. Coombs. 1964. A photoelectric 35-mm camera device for recording animal behavior. Journal of Mammalogy 45:327-330.

Agresti, A. 1990. Categorical Data Analysis. John Wiley & Sons Press. New York, NY. 558pp.

Ball, N.J., and C.J. Amlaner. 1980. Changing heart rates of herring gulls when approached by humans. Pages 589-594 in C.J. Amlaner, Jr. and D.W. Macdonald, editors. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford, England.

Bartram, W. 1791. Travels of William Bartram. Dover Publications, New York, NY. 414 pp.

Belleville, B. 2001. River of Lakes: A Journey on Florida's St. Johns River. University of Georgia Press, Athens, GA. 220pp.

Benter, W.P. 1934. Apparatus for wildlife photography. Nature 23:154.

Bentzien, M.M. 1998. New 12-month finding for a petition to list the Florida black bear. Federal Register 63(235):67613-67618.

Bittner, S.L., T.L. King, and W.F. Harvey. *In press*. Estimating Maryland's black bear population using hair snaring and DNA analysis. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies.

Brady, J.R., and D.S. Maehr. 1985. Distribution of black bears in Florida. Florida Field Naturalist 13:1-7.

Boulanger, J. 1998. DNA mark-recapture methods for inventory of grizzly bear populations in British Columbia: Elk Valley case study. Report prepared for Ministry of Environment, Lands, and Parks. Wildlife Research Branch, Victoria. 22pp.

Boulanger, J., and B. McLellan. 2001. Closure violation in DNA-based mark-recapture estimation of grizzly bear populations. Canadian Journal of Zoology 79:642-651.

Bouvier, L., and S.M. Stein. 2003. Focus on Florida: population, resources, and quality of life. Negative Population Growth Special Report. 9pp.

Bowden, D.C., and R.C. Kufeld. 1995. Generalized mark-sight population size estimation applied to Colorado moose. Journal of Wildlife Management 59:840-851.

Bridges, A.S., J.A. Fox, C. Olfenbuttel, and M.R. Vaughan. 2004. American black bear denning Behavior: observations and applications using remote photography. Wildlife Society Bulletin 32:188-193.

Brooks, R.T. 1996. Assessment of two camera-base systems for monitoring arboreal wildlife Wildlife Society Bulletin 24:298-300.

Bull, E.L., R.S. Holthausen, and L.R. Bright. 1992. Comparison of 3 techniques to monitor marten. Wildlife Society Bulletin 20:406-410.

Butler, P.J. 1980. The use of radio telemetry in the studies of diving and flying of birds. Pages 569-577 *in* C.J. Amlaner, Jr. and D.W. Macdonald, editors. A handbook on biotelemetry radio tracking. Pergamon Press, Oxford, England.

Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J.R. Ginsberg, M. Griffiths, J. Holden, K. Kawanishi, M. Kinnaird, R. Laidlaw, D.W. Macdonald, D. Martyr, C. McDougal, L. Nath, T. O'Brien, J. Seidensticker, D.J.L. Smith, M. Sunquist, R. Tilson and W.N. Shahruddin. 2001. The use of photographic rates to estimate densities of tigers and other cryptic mammals. Animal Conservation 4:75-79.

Caro, T.M., and M.K. Laurenson. 1994. Ecological and genetic factors in conservation: a cautionary tale. Science 263:485-486.

Chapman, D.G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Published Statistics 1:131-160.

Cogan, R.D., and D.R. Diefenbach. 1998. Effect of undercounting and model selection on a sightability-adjustment estimator for elk. Journal of Wildlife Management 62:269-279.

Cowardin, L.M., and J.E. Ashe. 1965. An automatic camera device for measuring waterfowl use. Journal of Wildlife Management 29:636-640.

Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the gaps in Florida's wildlife habitat conservation system. Florida Game and Fresh Water Fish Commission, Tallahassee, FL. 231pp.

Craig, G.H., and J.L. Craig. 1974. An automatic nest recorder. Ibis 116:557-561.

Craighead, F.C., Jr., and J.J. Craighead. 1970. Grizzly bear prehibernation and denning activities as determined by radio-tracking. Wildlife Monograph 31:1-35.

Cutler, T.L. and D.E. Swann. 1999. Using remote photography in wildlife ecology: a review Wildlife Society Bulletin 27:571-581.

Danielson, W.R., R.M. DeGraaf, and T.K. Fuller. 1996. An inexpensive and compact automatic camera system for wildlife research. Journal of Field Ornithology 67:414-421.

DeGraaf, R.M. 1995. Nest predation rates in managed and reserved extensive northern hardwood forests. Forest Ecology and Management 79:227-234.

Driscoll, C.A., M. Menotti-Raymond, G. Nelson, D. Goldstein, and S.J. O'Brien. 2002. Genomic microsatellites as evolutionary chronometers: a test in wild cats. Genome Research 12:414-423.

Dunbar, M.R., M.W. Cunningham, J.B. Wooding, and R.P. Roth. 1996. Cryptorchidism and delayed testicular descent in Florida black bears. Journal of Wildlife Diseases 32:661-664.

Eastridge, R. 2000. Experimental repatriation of black bears to the Big South Fork area of Kentucky and Tennessee. M.S. Thesis, University of Tennessee, Knoxville, TN.

Erickson, A.W. 1957. Techniques for live-trapping and handling black bears. Trans. North American Wildlife Conference. 22:520-543.

ESRI. 1999. ArcView 3.2. ESRI Press, Redlands, CA.

Fancy, S.G., L.E. Pank, D.C. Douglas, C.H. Curby, G.W. Garner, S.C. Amstrup, and W.L. Regelin. 1988. Satellite telemetry: a new tool for wildlife research and management. Resource Publication 172. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Foresman, K.R., and D.E. Pearson. 1998. Comparison of proposed survey procedures for detection of forest carnivores. Journal of Wildlife Management 62:1217-1226.

Foster, M.L., and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23:95-100.

Frankham, R. 1995. Inbreeding and extinction: a threshold effect. Conservation Biology 9:792-799.

Fridell, R.A., and P. Hovingh. 1995. Experimental use of remotely-triggered cameras to monitor occurrence of timber rattlesnakes (*Crotalus horridus*). Herpetological Review 26:189-190.

Fuller, T.K., and W.J. Snow. 1988. Estimating winter wolf densities using radio telemetry data. Wildlife Society Bulletin 16:367-370.

Garcelon, D.K. 1977. An expandable drop-off transmitter collar for young mountain lions. California Fish and Game 63:185-189.

Gessaman, J.A. 1980. An evaluation of heart rate as an indirect measure of daily energy metabolism of the American kestrel. Comparative Biochemistry and Physiology 65:273-289.

Goetz, R.C. 1981. A photographic system for multiple automatic exposures under field conditions. Journal of Wildlife Management 45:273-276.

Gysel, L.W. and E.M. Davis, Jr. 1956. A simple automatic photographic unit for wildlife research. Journal of Wildlife Management 20:451-453.

Hayne, D.W. 1949. Calculation of size home range. Journal of Mammalogy 30:1-18.

Hellgren, E.C. and D.S. Maehr. 1992. Habitat fragmentation and black bears in the eastern United States. Proceedings of the Eastern Black Bear Workshop on Management and Research 11:154-165.

Hernandez, F., D. Rollins and R. Cantu. 1997. Evaluating evidence to identify ground-nest predators in west-Texas. Wildlife Society Bulletin 25:826-831.

Hilmon, J.B. 1969. Autecology of saw palmetto (*Serenoa repens*). Dissertation, Duke University, Durham, NC.

Hoctor, T.S. 2003. Regional landscape analysis and reserve design to conserve Florida's biodiversity. Ph.D. dissertation. University of Florida, Gainesville, FL.

Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:577-585.

Jackson, D.H., L.S. Jackson, and W.K. Seitz. 1985. An expandable drop-off transmitter harness for young bobcats. Journal of Wildlife Management 49:46-49.

Jones, L.L.C., and M.G. Raphael. 1993. Inexpensive camera systems for detecting martens, fishers, and other animals: guidelines for use and standardization. United States Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-306.

Karanth, K.U., and J.D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79:2852-2862.

Karl, B.J., and M.N. Clout. 1987. An improved radio transmitter harness with a weak link to prevent snagging. Journal of Field Ornithology 58:73-77.

Kenward, R.E. 2001. Historical and practical perspectives. Pages 3-12 *in* J.J. Millsbaugh and J.M. Marzluff. Radio tracking and animal populations. Academic Press, San Diego, CA.

Krebs, C.J. 1999. Ecological Methodology. Addison-Wesley Educational Publishers, Inc. Menlo Park, CA. 620pp.

Kreeger,T.J. 1999. Handbook of Wildlife Chemical Immobilization. Wildlife Pharmaceuticals, Inc., Fort Collins, CO. 342pp.

Kristan, D.M., R.T. Golightly, Jr., and S.M. Tomkiewicz, Jr. 1996. A solar powered transmitting video cameras for monitoring raptor nests. Wildlife Society Bulletin 24:284-290.

Kucera, T.E., and R.H. Barrett. 1993. The Trailmaster® camera system for detecting wildlife. Wildlife Society Bulletin 21:505-508.

Lancia, R.A. J.D. Nichols, and K.H. Pollock. 1996. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T.A. Bookhout, editor. Research and Management Techniques for Wildlife and Habitats. Allen Press, Inc. Lawrence, KS.

Larkin, J.L., R.A. Grimes, L. Cornicelli, J.J. Cox, and D.S. Maehr. 2001. Returning elk to Appalachia: foiling Murphy's Law. Pages 101-118 *in* D.S. Maehr, R.F. Noss, and J.L. Larkin. 2001. Large Mammal Restoration. Island Press, Washington, D.C.

Larkin, J.L., D.S. Maehr, T.S. Hoctor, M.A. Orlando, and K. Whitney. 2004. Landscape linkages and conservation planning for the black bear in west-central Florida. Animal Conservation 7:1-12.

Linnell, J.D.C., D. Steuer, J. Odden, P. Kaczensky, and J.E. Swenson. 2002. European brown bear compendium. Safari Club International Foundation, Wildlife Conservation Issues - Technical Series Number 004A. 125pp.

Mace, R.D., S.C. Minta, T.L. Manley, and K.E. Aune. 1994. Estimating grizzly bear population size using camera sightings. Wildlife Society Bulletin 22:74-83.

Maehr, D.S. 1992. Florida black bear. Pages 265-275. *in* S.R. Humphrey, editor. Rare and Endangered Biota of Florida. Volume I. Mammals. University Press of Florida, Gainesville, FL.

Maehr, D.S. 1997. The comparative ecology of bobcat, black bear, and Florida panther in south Florida. Bulletin of the Florida Museum of Natural History 40:1-176.

Maehr, D.S., and J.R. Brady. 1984a. Food habits of Florida black bears. Journal of Wildlife Management 48:230-235.

Maehr, D.S., and J.R. Brady. 1984b. Comparison of food habits in two north Florida black bear populations. Florida Scientist 47:171-175.

Maehr, D.S., T.S. Hoctor, L.J. Quinn, and J.S. Smith. 2001. Black bear habitat management practices for Florida. Technical Report No.17. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL. 83 pp.

Maehr, D.S., E.D. Land, and J.C. Roof. 1991. Social ecology of Florida panthers. National Geographic Research and Exploration 7:414-431.

Maehr, D.S., J.L. Layne, E.D. Land, J.W. McCown, and J. Roof. 1988. Long distance movements of a Florida black bear. Florida Field Naturalist 16:1-6.

Maehr, D.S., J.S. Smith, M.W. Cunningham, M.E. Barnwell, J.L. Larkin, and M.A. Orlando. 2003. Spatial characteristics of an isolated Florida black bear population. Southeastern Naturalist 2:433-446.

Maehr, D.S., M.A. Orlando, and J.J. Cox. *in press*. Large carnivores, herbivores, and omnivores in South Florida: An evolutionary approach to conserving landscapes and biodiversity. *In* J. Ray, J. Berger, and K. Redford, editors, Large Carnivores and Biodiversity: Does saving one conserve the other? Island Press, Washington, D.C.

Massopust, J.L. and R.K. Anderson. 1984. The response of black bears to being chased by hunting dogs. Eastern Workshop for Black Bear Research and Management 7:59-65.

McCown, J. W., and T. H. Eason. 2001. Black bear movements and habitat use relative to roads in Ocala national forest: preliminary findings. Pages 397-404 *in* G.L. Evink, L. Coryell, L. Terwilliger, C. McCraken, K. Yondora, A. Peppers, and D. Zeigler, editors. A Time For Action, Proceedings of the International Conference on Ecology and International Conference on Ecology University, Keystone, Colorado, USA.

Mech, L.D. 1967. Telemetry as a technique in the study of predation. Journal of Wildlife Management 31:422-429.

Mech, L.D. 1982. Wolves (radio telemetry). Pages 227-228 *in* D.E. David, editor. Handbook of census methods for terrestrial vertebrates. CRC Press, Boca Raton, FL.

Mech, L.D. 1983. Handbook of radio-tracking. University of Minnesota Press, Minneapolis, MN. 108pp.

Mech, L.D., K.E. Kunkel, R.C. Chapman, and T.J. Kreeger. 1990. Field testing of commercially manufactured capture collars on white-tailed deer. Journal of Wildlife Management 54:297-299.

Merrill, S.B., L.G. Adams, M.E. Nelson, and L.D. Mech. 1998. Testing releasable GPS radiocollars on wolves and white-tailed deer. Wildlife Society Bulletin 26:830-835.

Mills, L.S., and P.E. Smouse. 1994. Demographic consequences of inbreeding in small remnant populations. American Naturalist 144:412-431.

Minta, S. and M. Mangel. 1989. A simple population estimate based on simulation for capture-recapture and capture-resight data. Ecology 70:1738-1751.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223-249.

Montalbano III, F., P.W. Glanz, M.W. Olinde, and L.S. Perrin. 1985. A solar-powered time-lapse camera to record wildlife activity. Wildlife Society Bulletin 13:178-182.

Moruzzi, T.L., T.K. Fuller, R.M. DeGraaf, R.T. Brooks, and W. Li. 2002. Assessing remotely triggered cameras for surveying carnivore distribution. Wildlife Society Bulletin 30: 380-386.

Mowat, G. and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. Journal of Wildlife Management 64:183-193.

Myers, R.L., and JJ. Ewel, editors. 1990. Ecosystems of Florida. University of Central Florida Press, Orlando, FL. 765 pp.

Nakamura, Y., M. Leppert, and P. O'Connell. 1987. Variable number of tandem repeat (VNTR) markers for human gene mapping. Science 227:1616-1622.

Nesbitt, S.A., B.A. Harris, R.W. Repenning, and C.B. Brownsmith. 1982. Notes on red-cockaded woodpecker study techniques. Wildlife Society Bulletin 10:160-163.

Orlando, M.A. 2003. The ecology and behavior of an isolated black bear population in west central Florida. M.S. Thesis, University of Kentucky, Lexington, KY. 88pps.

Paetkau, D. and C. Strobeck. 1994. Microsatellite analysis of genetic variation in black bear populations. Molecular Ecology 3:489-495.

Paetkau, D., L.P. Waits, P.L. Clarkson, L. Craighead, E. Vyse, R. Ward, and C. Strobeck. 1998. Variation in genetic diversity across the range of North American brown bear. Conservation Biology 12:418-429.

Pearson, O.P. 1959. A traffic survey of *Microtus-Reithrodontomys* runways. Journal of Mammalogy 40:169-180.

Pollock, K.H. 1981. Capture-recapture models allowing for age-dependent survival and capture rates. Biometrics 37:521-529.

Pollock, K.H. 1987. Experimental design of telemetry projects. Journal of Raptor Research 21:129-131.

Pollock, K.H., J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs No. 107.

Samuel, M.D. and M.R. Fuller. 1996. Wildlife radiotelemetry. Pages 370-418 *in* Bookhout, T.A., editor. 1996. Research and Management Techniques for Wildlife and Habitats. Allen Press, Inc., Lawrence, KS. 740pp.

Savidge, J.A., and T.F. Seibert. 1988. An infrared trigger and camera to identify predators at artificial nests. Journal of Wildlife Management 52:291-294.

Scheik, B.K. 1999. Black bear diet, movements, and habitat selection in North Florida and

South Georgia. M.S. Thesis, University of Florida, Gainesville, FL. 112pp.

Schwartz, C.C., and A.W. Franzman. 1992. Dispersal and mortality rates of subadult black bears from the Kenai Peninsula, Alaska. Journal of Wildlife Management 56:426-431.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Oxford University Press, New York, NY.

Sekerak, C.M., T.H. Eason, and C.R. Small. 2002. Using partnerships to address human-black bear conflicts in central Florida. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 56:136-147.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-134.

Smith, J.S. 2001. Home range and habitat characteristics of a west central Florida black bear population. M.S. Thesis, University of Kentucky, Lexington, KY. 163pp.

Snedecor, G.W. and W.G. Cochran. 1989. Statistical Methods, Eighth Edition. Iowa State University Press, Ames, Iowa.

Soulé, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-159 *in* M.E. Soulé and B.A. Wilcox, editors. Conservation Biology: an evolutionary-ecological perspective. Sinauer, Sunderland, MA.

Strathearn, S.M., J.S. Lotimer, G.B. Kolenosky, and W.M. Lintack. 1984. An expanding break-away radio collar for black bear. Journal of Wildlife Management 48:939-942.

Stratman, M.R. and M.R. Pelton. 1999. Feeding ecology of black bears in Northwest Florida. Florida Field Naturalist 27:95-102.

Swann, D.E., R.C. Averill-Murray, and C.R. Schwalbe. 2002. Distance sampling for Sonoran desert tortoises. Journal of Wildlife Management 66:969-975.

Swingland, I.R., and J.G. Frazier. 1980. The conflict between feeding and overheating in the Aldabran giant tortoise. Pages 611-615 *in* C.J. Amlaner, Jr. and D.W. Macdonald, editors. A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford, England.

Taberlet, P., J.J. Camarro, S. Griffin, E. Uhres, O. Hanotte, L.P. Waits, C. Dubois-Paganon, T. Burke, and J. Bouvet. 1997. Noninvasive genetic tracking of an endangered Pyrenean brown bear population. Molecular Ecology 6:689-876.

Temple, S.A. 1972. A portable time-lapse camera for recording wildlife activity. Journal of Wildlife Management 36:944-947.

U.S. Census Bureau. 2002. Table CO-EST2002-01-12: Florida county population estimates: April 1, 2000 to July 1, 2002. U.S. Census Bureau, Population Division. Washington, D.C.

Weller, M.W., and D.V. Derksen. 1972. Use of time lapse photography to study nesting activities of birds. Auk 89:196-200.

White, G.C., K.P. Burnham, D.L. Otis, and D.R. Anderson. 1978. User's manual for program CAPTURE. Utah State University Press, Logan, UT. 40pp.

White, G.C., and T.M. Shenk. 2001. Population estimation with radio-marked animals. Pages 329-350 *in* Millspaugh, J.J., and J.M. Marzluff. Radio tracking and animal populations. Academic Press, San Diego, CA.

Willey, C.H. 1974. Aging black bears from first premolar tooth sections. Journal of Wildlife Management 38:97-100.

Wing, A. 1948. Electric remote control for self-cocking shutters. American Photography 42:387.

Wooding, J.B. 1993. Management of the black bear in Florida, a staff report to the commissioners. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.

Wooding, J.B., J.A. Cox, and M.R. Pelton. 1994. Distribution of black bears in the southeastern coastal plain. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 48:270-275.

Wooding, J.B. and T.S. Hardisky. 1988. Black bear habitat study. Final performance report, W-42-35. Florida Game and Fresh Water Fish Commission, Tallahassee, FL. 69pp.

Woods, J.G., D. Paetkau, D. Lewis, B.N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616-627.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

York, E.C., T.L. Moruzzi, T.K. Fuller, J.F. Organ, R.M. Sauvajot, and R.M. DeGraaf. 2001. Description and evaluation of a remote camera and triggering system to monitor carnivores. Wildlife Society Bulletin 29:1228-1237.

Young, S.P. 1946. The Wolf in North American History. The Caxton Printers, Ltd., Caldwell, ID. 149pp.

Zielinski, W.J., and T.E. Kucera. 1995. American marten, fisher, lynx and wolverine: survey methods for their detection. Pacific Northwest Research Station, USDA Forest Service General Technical Report PSW-GTR-157.

VITA

Joshua Hager Brown

Born: June19, 1979, Morehead, KY

Education

B.S., 2001, Agricultural Biotechnology, University of Kentucky, Lexington, KY
Minor in Biology
Commonwealth Diploma, 1997, Rowan County Senior High School, Morehead, KY

Professional Positions

Research Assistant: 8/02-5/04
University of Kentucky Department of Forestry, Lexington, KY
Wildlife Technician: 8/01-8/02
Chassahowitzka Black Bear Project, Weeki Wachee, Florida
University of Kentucky Department of Forestry, Lexington, KY

Awards

Best student paper, Kentucky Chapter of The Wildlife Society, 3/28/04