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HOME RANGE, HABITAT USE, AND FOOD HABITS OF THE BLACK BEAR IN SOUTH-CENTRAL FLORIDA

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ABSTRACT OF THESIS

HOME RANGE, HABITAT USE, AND FOOD HABITS OF THE BLACK BEAR IN SOUTH-CENTRAL FLORIDA

I studied a small, enigmatic, and imperiled black bear population in south-central Florida from 2004 - 2006. Annual home ranges of males (96.0 km^2) were larger than those of females (32.2 km^2). Female home ranges were smaller in winter than in summer or fall. At the landscape scale, bears selected forests, scrub, and citrus, but avoided urban areas. At the home range scale, bears selected bay swamp and hardwood hammock, but avoided urban areas and grassland. Bears selected bay swamp in winter, forests and scrub in summer, and forests, scrub, and marsh in fall. The bear's diverse diet included citrus fruit. Important foods were acorn, saw palmetto fruit, and Florida carpenter ant. The local landscape is dominated by agriculture on private lands, as opposed to large contiguous forests on public land elsewhere in Florida black bear range. Mean patch size of forests was smaller, while edge density, diversity, and evenness were higher in south-central Florida than elsewhere in the state. Diversity of forest habitat may partially account for the persistence of the black bear in this fragmented landscape. Managers should encourage private landowners to adopt practices that promote bear habitat, and focus on habitat diversity, road crossings, and statewide metapopulation structure.

KEYWORDS: *Ursus americanus floridanus*, habitat fragmentation, metapopulation, black bear conservation, habitat diversity

Wade A. Ulrey

25 April 2008

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University of Kentucky

2008

HOME RANGE, HABITAT USE, AND FOOD HABITS OF THE BLACK BEAR IN SOUTH-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

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Lexington, Kentucky

Director: Dr. David S. Maehr

Lexington, Kentucky

2007

To my Dad, who taught me to love the outdoors

ACKNOWLEDGMENTS

The black bear in Highlands County resides almost entirely on private land; this is a great testament to the commitment of local landowners. I thank them all for their efforts, but must single out a few who were critical to my project. Mason Smoak was recently awarded the Disney Conservation Hero Award for his efforts to manage and protect the ecological integrity of the Smoak family's Turkey Track Ranch, and for going above and beyond to support this research project. Not only did Mason serve as my primary contact for the property most important to my research, and a liaison to other local landowners, he also gave of his energy and ability by piloting many crucial telemetry flights in his own airplane, often on short notice. Mason was not alone in this kind of support; the entire Smoak family helped me in countless ways. I owe a great deal to the Smoak family for their kindness, hospitality, and pivotal role in protecting the black bears of Highlands County. They treated me as family and I will not forget them.

The Hendrie family has also been crucial to the success of this project. The beautiful Hendrie ranch, in combination with the adjacent Turkey Track Ranch, supports more bears than any property in the region. John Hendrie is a quiet, respectful man with a deep commitment to the land. The bears could not have a better benefactor.

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I also wish to thank the Florida Fish and Wildlife Conservation Commission for funding and logistical support. Many aspects of bear conservation in the state lie in their hands, and I was glad to have them as partners. Chad Owens, Mike McMillian, Don Buchanon, and Brian Christ were helpful on numerous occasions. Lt. Dale Knapp tirelessly investigated bears that were shot or died in a suspicious manner.

Disney Wildlife Conservation Fund provided funding, Kash 'n' Karry gave the bears and me expired pastries with a smile, Gary Larsen gave a great deal of assistance at the Turkey Track Ranch, Wayne Zahn, Herb Collier, and Arelio assisted me on the properties where each worked, and Romke Sikkema provided hours of safe, productive, and entertaining flights. I wish to recognize a number of friends who volunteered to assist me with fieldwork, and apologize to anyone I have left out. Kelvin Peh, Satya Maliakal-Witt, Tracy Hmielowski, Chris Valligny, Christopher Wood, Erin Maehr, Dani Sattman, Dr. Larry Harris, Luther Quinn, Andrew Tweel, Leonor Alvarez, Marcia Rickey, Nick, Alex, and Hilary Swain, and Jim and Jennifer Nave – thank you.

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CHAPTER ONE
INTRODUCTION

The American black bear (*Ursus americanus*) was the first of the modern bears to inhabit North America, evolving at least 2.5 million years ago from ancestors that crossed the Bering Land Bridge about a million years earlier (Craighead 2000:19). It evolved in the presence of more efficient, and often larger or more aggressive, predators and thus came to fill a generalist niche (Craighead 2000:63). These specialized carnivores included saber-toothed cats (*Smilodon* spp.), scimitar-toothed cats (*Homotherium* spp.), true cats {cougar (*Puma concolor*), American cheetah (*Miracinonyx* spp.), jaguar (*Panthera onca*), American lion (*Panthera atrox*)}, canids {coyotes (*Canis latrans* and *Canis lepophagus*), gray wolf (*Canis lupus*), and dire wolf (*Canis dirus*)}, and the much larger short-faced bears (Subfamily Tremarctinae) (Craighead 2000:63). The cats and short-faced bears captured large prey and the canids captured small and medium prey or cooperatively hunted large prey. Thus, the black bear, like most other bear species, took advantage of the more plentiful plant and insect foods available by adopting omnivory. Following Pleistocene extinctions, the black bear may have been the only North American bear, and the only large omnivore in the contiguous United States for some time before the arrival of the brown bear (*Ursus arctos*) and human (*Homo sapiens*). The more recently evolved brown bear did not migrate to this continent until ~10,000 years ago, about the same time that humans arrived (Craighead 2000:63).

The black bear is the most widespread ursid in North America, and the only bear to inhabit the eastern U.S. in historic times (Whitaker and Hamilton 1998). Since the arrival of Europeans in America, the range of the black bear has retracted in the face of habitat loss and fragmentation (mostly due to expanding agriculture and urbanization), hunting, and persecution by humans. Just as the black bear's former range included all forested parts of North America, the Florida subspecies (*Ursus americanus floridanus*) once inhabited virtually all of Florida (Brady and Maehr 1985, Whitaker and Hamilton 1998). Today, it remains only in disjunct populations (Figure 1.1), and is listed as a threatened species by the Florida Fish and Wildlife Conservation Commission (FFWCC).

My research focused on one of the smallest remnant populations, in Highlands and Glades counties of south-central Florida (Maehr et al. 2004, Figure 1.2).

The modern history of bears in Florida is largely one of conflict with humans, whether directly or indirectly (DeVane 1978). Direct conflicts have included hunting, illegal killing, and vehicular collisions (Maehr et al. 2004). The black bear has been persecuted for damages associated with apiaries, garbage, and livestock (Maehr et al. 2004). Collisions with vehicles are a leading cause of bear mortality in Florida, including the area of this study (Maehr et al. 2004, Simek et al. 2005). Elsewhere, roads severely limit bear movements and occupation of otherwise suitable habitat (Gibeau et al. 2002, Orlando 2003). The intersection of US Highway 27 (US-27) and Florida State Road 70 (FL-70) divided my study area into quadrants (Figure 1.3). They have the potential to act as semipermeable barriers to bear movements, further segregating this small population into subpopulations. Wandering bears, especially males, might mitigate this effect by crossing roads to connect subpopulations, but not without risk of injury or death. Yet, in spite of these direct, and often deadly, conflicts with humans, indirect conflicts are likely a more substantial detriment to bears. Forest conversion to other land uses, fragmentation, and increasing human development have permanently eliminated most of Florida's black bear habitat (Brady and Maehr 1985).

Other bear populations in the state tend to occupy large forests on public lands (Maehr et al. 2001*b*). In contrast, bears in south-central Florida persist in a landscape dominated by agriculture on private lands. These agricultural landscapes may be permeable to bear movements, but insufficient as habitat in and of themselves. The remaining forests here are so small and patchy that Hoctor's (2003) black bear habitat model for Florida identified the south-central Florida region as unsuitable for the species. He noted that "the Highlands population might indicate differences in fragmentation thresholds, patch size, landscape configuration, matrix quality, etc. that may be instructive for future modeling and habitat conservation efforts" (Hoctor 2003:142).

OBJECTIVES

The relatively isolated population of south-central Florida afforded an excellent opportunity to examine the ecology of the black bear in a fragmented landscape at the southern terminus of the Lake Wales Ridge. It is the second smallest bear population in the state, surpassing in size only the Chassahowitzka population (<20) of west-central Florida (Orlando 2003). Genetic variability of bears in south-central Florida is also the second lowest in the state and among the lowest of global bear populations (Dixon 2004). My thesis represents the initial investigation in the ongoing study of the Highlands-Glades black bear population. The purpose of this study was to determine some of the ecological requisites for long-term survival of one of Florida's smallest black bear populations. Because this was the initial field study of this population, I examined basic habitat and dietary needs of the black bear in this fragmented landscape. Specifically, I determined annual and seasonal bear home range sizes, habitat use, and food habits, and compared the quality of available habitat with occupied range elsewhere in Florida.

STUDY AREA

Highlands and Glades counties are located in south-central Florida, midway between the Atlantic Ocean and the Gulf of Mexico (Figure 1.2). The climate is humid sub-tropical, with hot, wet summers and mild, dry winters. From 1932 – 2004, the area received 69 – 195 cm of rainfall annually, with an average of 136 cm (Archbold Biological Station 2007*a*). Minimum and maximum temperatures from 1952 - 2004 were −10.5°C and 39.4°C, respectively (Archbold Biological Station 2007*a*). The average low for January was 8.3°C, whereas the average high for July was 34.1°C (Archbold Biological Station 2007*a*).

Trapping focused on 3 areas of Highlands County that appear to support year-round residents: 1) the privately-owned Turkey Track Ranch and Hendrie Ranch complex east of Venus, 2) the privately-owned Archbold Biological Station (ABS) and XL Ranch southwest of Lake Placid, and 3) the Royce Ranch, Holmes Avenue and Clements tract complex northeast of Lake Placid (Figure 1.4). The latter complex is part of the Lake Wales Ridge Wildlife and Environmental Area managed by FFWCC.

Highlands County includes the southern terminus of the Lake Wales Ridge (Figure 1.4), an ancient Miocene dune system that supports a variety of endemic plants and animals (Archbold Biological Station 2007*b*). This topographic feature is approximately 30 – 65 m above sea level and stretches from Lake and Orange counties in the north to southern Highlands County in the south. The high level of endemism (~ 40 - 60% of species) on the Lake Wales Ridge is due to its former island nature (Myers 1990). It is the oldest terrestrial ecosystem in peninsular Florida.

Glades County is a transitional zone between the Lake Wales Ridge to the north and the Big Cypress physiographic region to the south. It is bounded on the south by the Caloosahatchee River, which may serve as a semipermeable barrier to large carnivore movement (Maehr et al. 2002), although a young male bear from the Big Cypress population successfully crossed the river en route to Highlands County in 1986 (Maehr et al. 1988).

A band of freshwater lakes dots the Lake Wales Ridge landscape. The largest is Lake Istokpoga (11,207 ha) in central Highlands County. Sandy, nutrient-poor soils of the ridge are dominated by xeric upland plant communities, including sand pine scrub, scrubby flatwoods, and sandhills (Myers and Ewel 1990). The margins of the ridge and surrounding lands are a mosaic of mesic and hydric habitats that reflect local drainage patterns. Mesic habitats include pine flatwoods, hardwood hammocks, cutthroat grass (*Panicum abscissum*) seeps, and dry prairies. Hydric habitats include hardwood swamps known locally as baygalls or bayheads, freshwater marshes, wet prairies and cypress swamps.

Sand Pine Scrub

Scrub communities are a distinctive feature of the Lake Wales Ridge. They are dominated by xeric shrubs with or without an overstory of pines, which are usually sparse when present. Scrub communities often have minimal groundcover, with patches of exposed white sand. Scrub communities are found on droughty, infertile, sandy soils.

The communities are maintained by high-intensity infrequent fires, with return intervals of 10 – 100 years (Myers 1990).

The dominant woody species in scrub habitats are sand pine (*Pinus clausa*), Florida rosemary (*Ceratiola ericoides*), scrub hickory (*Carya floridana*), rusty Lyonia (*Lyonia ferruginea*), and several evergreen dwarf oak species, including myrtle oak (*Quercus myrtifolia*), sand live oak (*Q. geminata*), scrub oak (*Q. inopina*), and Chapman oak (*Q. chapmanii*). Other important scrub plants include scrub palmetto (*Sabal etonia*), saw palmetto (*Serenoa repens*), muscadine grape (*Vitis rotundifolia*), hog plum (*Ximenia americana*), greenbriars (*Smilax* spp.), gopher apple (*Licania michauxii*), and prickly pear *(Opuntia compressa*) (Abrahamson et al. 1984).

Southern Ridge Sandhill

Southern ridge sandhill communities (Abrahamson et al. 1984), a specific local version of the more general "high pine" classification described by Myers (1990), normally occur on the upper parts of xeric sand ridges. In contrast to scrub habitat, high pines are maintained by frequent (1 – 10 years) low-intensity surface fires (Myers 1990). Extended periods of change in the fire regime cause a gradual shift from scrub to sandhill or vice versa (Kalisz and Stone 1984, Myers 1985), and both are replaced by mixed hardwoods in the absence of fire (Laessle 1942, Laessle 1958, Monk 1968, Veno 1976, Myers 1985). High pine communities have been reduced by more than 90%, and most of what remains is degraded and fragmented (Myers 1990).

Important trees of southern ridge sandhills are south Florida slash pine (*Pinus elliottii* var. *densa*), turkey oak (*Q. laevis*), sand live oak, myrtle oak, and scrub hickory. Chapman's oak, sand pine, rusty Lyonia, scrub oak, and longleaf pine (*Pinus palustris*) are occasional components. Associated plants include scrub palmetto, saw palmetto, wiregrass (*Aristida stricta*), gopher apple, and shiny blueberry (*Vaccinium myrsinites*).

Scrubby Flatwoods

Scrubby flatwoods appear to be an ecological intergrade between flatwoods and scrub habitat, but are often considered separately because they cover large areas in parts of this region (Abrahamson and Hartnett 1990). Unlike typical flatwoods, scrubby flatwoods occur on well-drained soils without standing water even in the rainy season (Abrahamson et al. 1984).

Here the sand pines of the scrub are largely replaced by the slash pines of the flatwoods. Though somewhat rare in flatwoods or typical scrub habitat, *Q. inopina* is especially important in scrubby flatwoods. *Q. geminata* and *Q. chapmanii* are also prevalent on some sites. Sand pine, south Florida slash pine, myrtle oak, saw palmetto, scrub palmetto, fetterbush (*Lyonia lucida*), staggerbush (*L. fruticosa*), dwarf wax myrtle (*Myrica cerifera* var. *pusilla*), and October flower (*Polygonella polygama*) are fairly common (Abrahamson et al. 1984).

Pine Flatwoods

Pinelands are widespread in the southeastern coastal plain (Schwartz 1994). Flatwoods exist on poorly drained, acidic, nutrient-poor, sandy soils, sometimes underlain by an organic horizon and/or clay hardpan (Abrahamson and Hartnett 1990). Dominance by pines is due, at least in part, to their lower nutrient requirements than hardwoods (Abrahamson and Hartnett 1990). Seasonal fluctuations from flood to drought typify flatwoods (Abrahamson et al. 1984, Abrahamson and Hartnett 1990), and limit the species that live here. "Cutthroat seeps" are unique to south-central Floridian flatwoods where the groundcover is dominated by the endemic cutthroat grass (*Panicum abscissum*), and are found on downslope drainages. The park-like nature of flatwoods, described by early writers as open enough to easily drive wagons through, is maintained by fire (Platt et al. 1988). Frequently burned flatwoods are open and grassy, with few oaks or palms (Harper 1914, Heyward 1939, Edmisten 1963, Moore et al. 1982). Such conditions may be good for maintaining pines and groundcover, but may lower the value of habitat to bears (Maehr and Larkin 2004). Without fire, flatwoods can succeed to cabbage palm (*Sabal palmetto*) hammocks (Edmisten 1963), mesic hardwoods (Monk 1968, Snedaker and Lugo 1972), or bayheads (Monk 1968, Snedaker and Lugo 1972, Peroni and Abrahamson 1986).

In pine flatwoods of south Florida, the overstory is dominated by south Florida slash pine, with scattered live oak *(Q. virginiana*), red bay (*Persea borbonia*) on wet sites, or cabbage palm on less acidic sites with pH 6 – 7.5 due to alkaline marl or shell beds underlying the sand (Abrahamson and Hartnett 1990). Longleaf pine was a historically dominant tree in many upland pine communities in Florida, but has been largely replaced by the faster-growing slash pine over most of the state; however, longleaf pine was probably rare in south-central Florida, even before human intervention. Shrubs common in the understory include saw palmetto, gallberry (*Ilex glabra*), fetterbush, staggerbush, hog plum, tarflower (*Befaria racemosa*), winged sumac (*Rhus coppalina*), and shiny blueberry. Important groundcovers include cutthroat grass, wiregrass, and Atlantic St. Johnswort (*Hypericum reductum*).

Hardwood Hammocks

Hardwood hammocks share many of the plants found in pine forests, including slash pine, but the dominant trees are oaks and cabbage palm. Platt and Schwartz (1990) suggest that live oak – cabbage palm hammocks may be related to flatwoods in the same way that scrub is related to sandhill (Myers 1985). That is, infrequent crown fires may favor hammocks whereas frequent ground fires may favor flatwoods (but see Vince et al. 1989). Mixed species hardwoods occur on soils that contain more organic matter and cations than adjacent sandhills (Harper 1914, Monk 1960).

Live oak and cabbage palm are the dominant trees in hammocks of south-central Florida. Others include laurel oak (*Q. laurifolia*) and red maple (*Acer rubrum*). Understory plants include saw palmetto, ferns, gallberry, (*Lyonia* spp.), and wax myrtle (*Myrica cerifera*). A number of epiphytes are found in hardwood hammocks as well, including spanish moss (*Tillandsia usneoides*), ferns, bromeliads, and orchids.

Dry Prairies

Dry prairies tend to occur on acidic, nutrient-poor sands similar to pine flatwoods, and are often very similar in species composition except for the absence of trees (Abrahamson and Hartnett 1990). The reason for this lack of trees is not clearly understood, but in some areas, dry prairies are known to be an artifact of clearcutting, frequent burning, and grazing (Abrahamson and Hartnett 1990). Most dry prairies in the study area are used as cattle pasture. They provide habitat for species such as crested caracara (*Polyborus plancus*), burrowing owl (*Athene cunicularia*), and Florida sandhill crane (*Grus canadensis patensis*), and are even used by bears in some instances (Layne 1978). Dry prairies include grasses such as wiregrass and broomsedge (*Andropogon virginicus*), as well as low-growing shrubs such as saw palmetto, fetterbush, rusty Lyonia, shiny blueberry, and wax myrtle.

Bayhead

More than half of Florida was historically covered by wetlands (Shaw and Fredine 1956). Due to alternation by humans, less than half of these remain (Ewel 1990). Swamps provide habitat for large carnivores such as bears and Florida panthers (*Puma concolor coryi*) because of their dense cover. Swamps may be more important to these animals than they were in the past due to even more widespread destruction of upland habitats (Ewel 1990). The most prevalent type of swamp in the study area is bayhead. Bayheads are acid stillwater swamps with organic soils and dense canopies of broadleaved evergreen trees. These mixed hardwood communities form where shallow peat-filled depressions expose the water table (Ewel 1990). Bayheads have the lowest fire frequency and longest hydroperiod of any swamp type in Florida, perhaps with shallower water and deeper peat than cypress swamps (Ewel 1990). Mixed hardwoods generate rapidly in strands that are protected from fire, displacing cypress from dominance (Ewel 1990); however, loblolly bay (*Gordonia lasianthus*) sprouts readily after fire and appears to colonize best after severe disturbance (Gresham and Lipscomb 1985). Shallow lakes with fluctuating water levels are often ringed by cypress, grading into mixed hardwoods landward (Ewel 1990). Bayheads are considered to be climax communities developing from cypress domes in the absence of fire (Monk 1966, Clewell 1971).

Predominant trees in bayhead are red bay, loblolly bay, and sweet bay (*Magnolia virginiana*), with a lesser presence of red maple, swamp tupelo (*Nyssa biflora*), and slash pine. Bayhead understory plants include ferns, muscadine grape, dahoon holly (*Ilex cassine*), wax myrtle, and hog plum.

Freshwater Marsh

Freshwater marshes are wetlands dominated by emergent herbaceous vegetation, with less than 1/3 of the cover comprised of trees and shrubs (Kushlan 1990). Water stands at or above the ground surface for much of the year. Topography is the main factor in distribution of marshes over the Florida peninsula (White 1970) because it determines the depth to the water table and the fate of runoff from local rainfall. Although the Lake Wales Ridge lacks expanses of marshland (Kushlan 1990), there are numerous small marshes in intra-ridge valleys. Fires have always been frequent in Florida marshes, with return intervals of 1 - 5 years (Wade et al. 1980). Fire limits invasion of woody vegetation, affects composition of the herbaceous community, and retards or reverses peat accumulation (Alexander 1971, Vogl 1973, Van Arman and Goodrick 1979, Wade et al. 1980). Marshes in Highlands and Glades counties can be classified into three categories: flag marshes or "flag ponds" as they are known locally, wet prairies, and flatwoods marshes or seasonal ponds.

Important marsh species include bladderworts (*Utricularia* spp.), pickerelweed (*Pontederia lanceolata*), arrowhead (*Sagittaria latifolia*), spikerush (*Eleocharis* spp.), maidencane (*Panicum hemitomon*), fire flag (*Thalia geniculata*), Tracy's bulrush (*Rhynchospora tracyi*), saw grass (*Cladium jamaicensis*), muhly (*Muhlenbergia fillipes*), cordgrass (*Spartina bakeri*), white-topped sedge *(Dichromena colorata*), and St. John's-wort (*Hypericum fasciculatum*).

Cypress Swamp

Cypress swamps are less common than bay swamps in the area inhabited by this population, and are primarily located along Fisheating Creek in Glades County. Baldcypress (*Taxodium distichum*) is the dominant tree in cypress swamps, with tree species found in bayheads playing a lesser role. Cypress seeds and seedlings cannot survive prolonged inundation (Ewel 1990), but cypress is the most flood tolerant tree when mature (Harms et al. 1980). Thus, cypress swamps appear to be dependent on regular water level fluctuations. Whereas bayheads seldom burn (Wharton et al. 1977), cypress swamps may burn several times per century, though severe burns after logging or drainage may destroy cypress seeds and roots, favoring replacement by willows and succession to mixed hardwoods (Ewel 1990). In extreme south Florida, *Melaleuca quinquenervia* rapidly invades after cypress is drained and severely burned (Ewel 1990), but this invasive exotic is primarily located south of Lake Okeechobee (Serbesoff-King 2003) and is not commonly seen in Highlands and Glades counties.

Anthropogenic Habitats

Anthropogenic habitats are a major component of the landscape in south-central Florida. The human population of Highlands County was an estimated 97,987 in 2006, and increased 27.7 % from 1990 to 2000, a 4.2% greater increase than the state mean (U.S. Census Bureau 2007). Agriculture dominates the landscape in Highlands and Glades counties. Citrus groves are abundant on the Lake Wales Ridge, and much of the study area supports cattle ranching. Some grasslands are semi-natural dry prairie, and some are improved pastures of mostly Bahia grass (*Paspalum notatum*). Other agricultural uses in the area include caladium fields south of Lake Istokpoga, sugar cane fields in southern Glades County, sod farms of Bahia and St. Augustine grass (*Stenotaphrum secundatum*), tree farms (oak, magnolia, myrtle, pine, etc.), blueberry farms, grape vineyards, winter and summer vegetable farms (lettuce, cucumbers, corn, cabbage, watermelons, etc.), and alligator (*Alligator mississipiensis*) farms. Slash pine and eucalyptus (*E. grandis*) plantations are also prevalent in Glades County. The area's expanding human population has led to development pressure that threatens further loss and fragmentation of natural habitats.

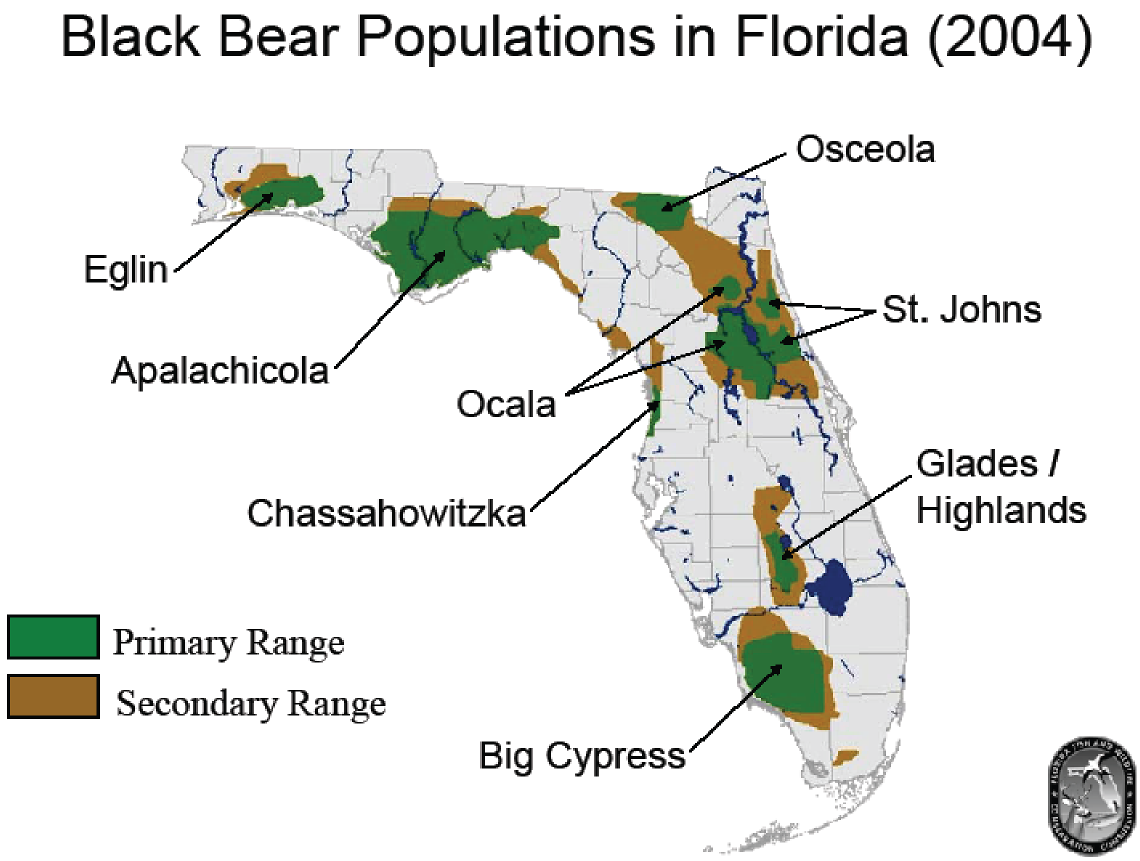

Figure 1.1. Distribution of the black bear in Florida (from Florida Fish and Wildlife Conservation Commission 2007).

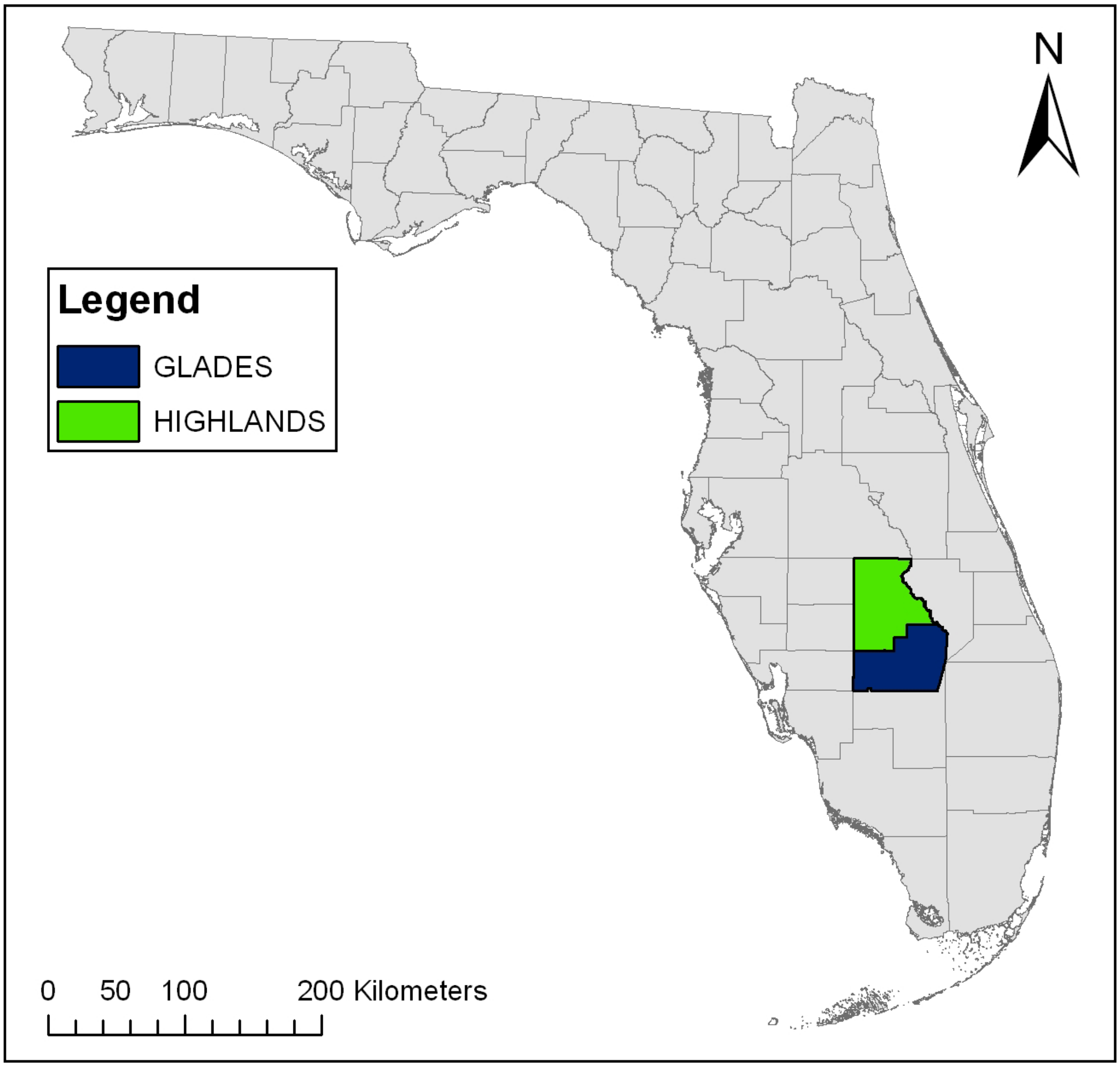

Figure 1.2. Highlands and Glades counties in south-central Florida, USA.

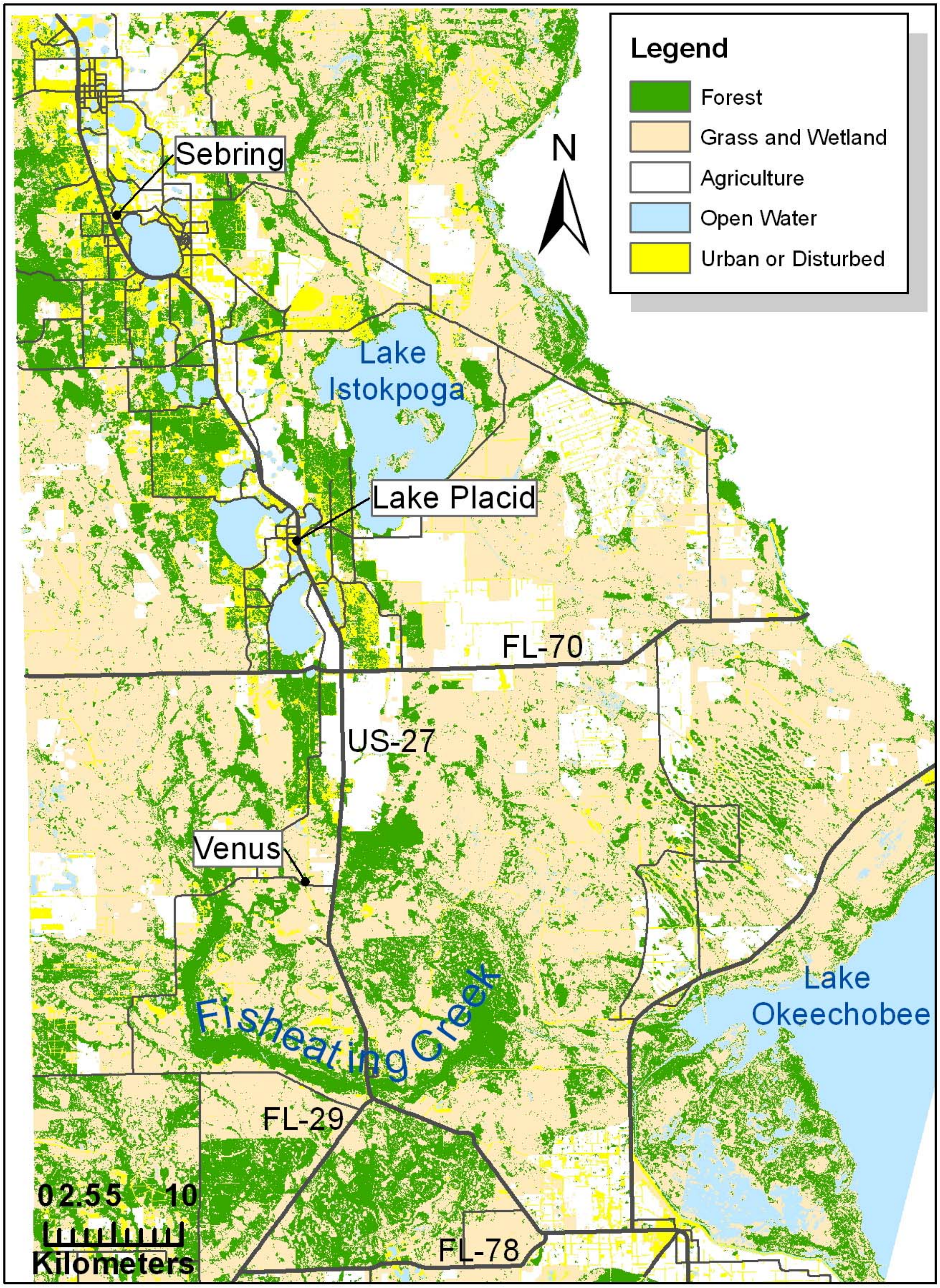

Figure 1.3. Towns, highways, and bodies of water in south-central Florida, USA.

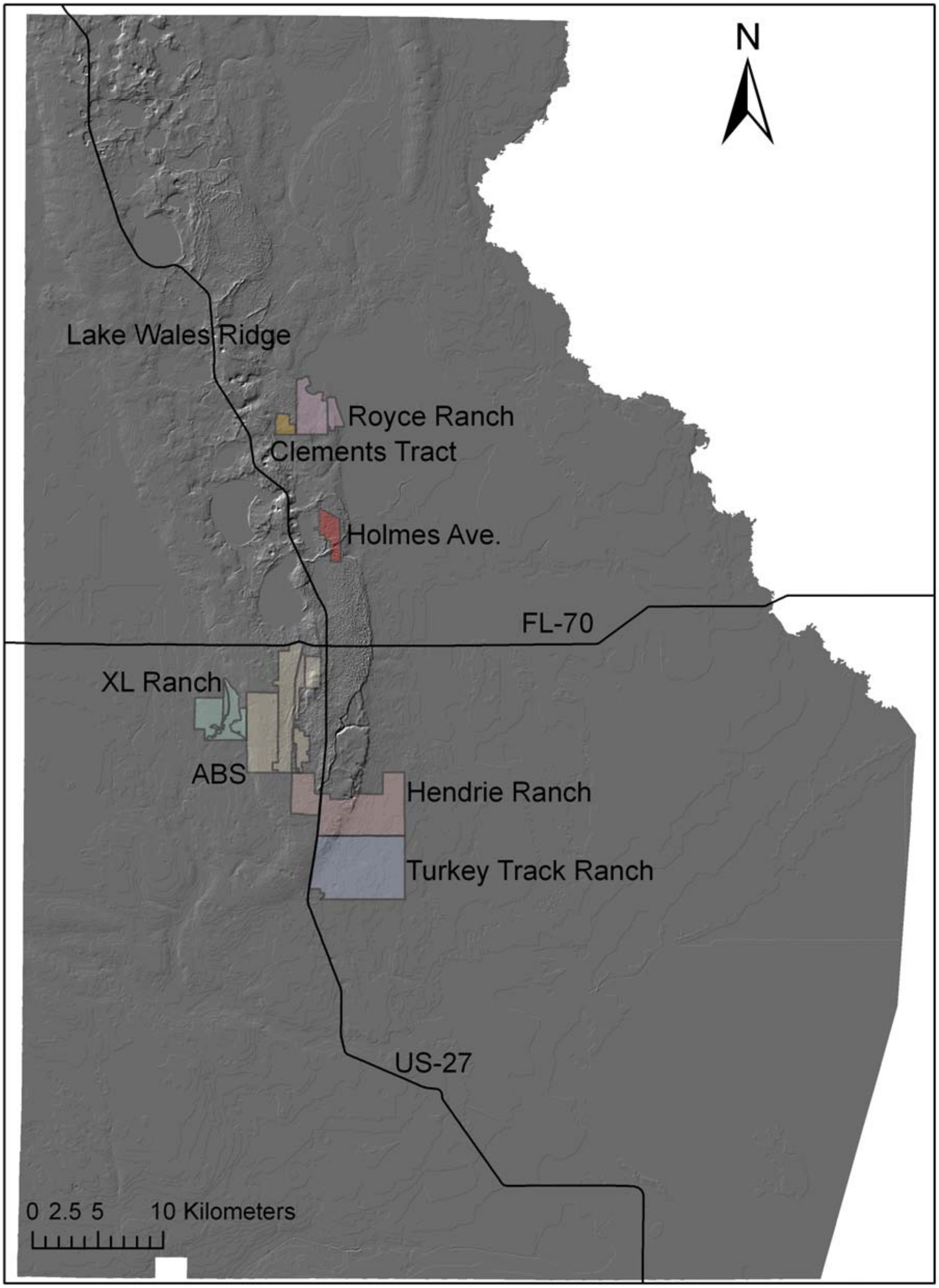

Figure 1.4. Lake Wales Ridge topography and important bear research areas in south-central Florida, USA.

CHAPTER TWO
HOME RANGE SELECTION

The concept of home range has been used in ecology and natural history studies since Burt (1943:351) defined it as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young." While it denotes a theoretical concept of home range, this definition is hard to apply in actual practice because it lacks a temporal component. To more accurately portray multi-dimensional space use over time, the home range definition I use here is "the extent of area with a defined probability of occurrence of an animal during a specified time period" (Kernohan et al. 2001). Many techniques have been developed for quantifying home range. The most commonly used home range estimator is the minimum convex polygon (Mohr 1947), which simply connects the outermost animal locations to form a polygon. Newer techniques often attempt to estimate a utilization distribution, based on probability of the animal occurring at any specific point (Marzluff et al. 2001).

Black bear home range size varies with habitat quality, population density, season, gender, and age (Whitaker and Hamilton 1998). Home range size estimates may guide management decisions, or indicate movement differences between or within species (Kenward et al. 2001). Telemetry studies and home range analysis had previously been conducted for all Florida black bear populations except the Highlands-Glades population (Dusi et al. 1987, Seibert 1993, Wooding and Hardisky 1994, Maehr 1997, Stratman 1998, Maehr et al. 2003, Dobey et al. 2005). I performed home range analysis to: 1) examine spatial requirements in this small, imperiled black bear population, 2) identify seasonal patterns related to food availability and other influences, 3) make comparisons with other black bear populations, and 4) provide information vital to regional and statewide conservation planning. I hypothesized that black bear home ranges would be larger in this population than in other Florida black bear populations, reasoning that the fragmented landscape should force bears to access distant patches of habitat in order to meet their life requisites. I also hypothesized that highways divide the bear population into segments by restricting bear movements, and that males are the primary mechanism for connecting population segments.

METHODS

Capture and Handling

My analyses are based on data collected from May 2004 to December 2006. Most bears were trapped using Aldrich spring-activated snares (Johnson and Pelton 1980) and anesthetized using Telazol® administered at 4 - 7 mg/kg of body mass (Kreeger 1996) with a pole syringe (Pond and O'Gara 1994). I also captured bears with tranquilizer dart rifles (Pneudart, Inc., Williamsport, PA, USA) or a culvert trap (Erickson 1957). These methods were particularly useful for recapturing bears that had become wary of snares. All traps were baited with pastries. Traps were checked at least twice per day to minimize the amount of time a bear spent in the trap. Trap checks were conducted in the morning and evening, when bears in the area appeared to be most active.

Measurements taken of captured animals included mass, total length, chest girth, neck girth, and foot dimensions. Each bear received an ear tag with a unique number/color combination, a uniquely-numbered tattoo on the inside of the upper lip, and in the latter part of the study, a uniquely coded Passive Integrated Transponder (PIT) tag (Biomark, Inc, Boise, ID). Biological samples included feces, ectoparasites, whole blood, serum, hair, and a first premolar for aging by cementum annuli (Willey 1974).

Each bear was fitted with either a VHF (very high frequency) radio-collar or with a collar containing a GPS (global positioning system) unit as well as a VHF beacon (Telonics, Inc., Mesa, AZ, USA; Lotek Wireless, Inc., Newmarket, Ontario, Canada). VHF collars had an integral motion-activated tip switch that instantaneously changed the VHF pulse period when the bear moved its head. Both types of collars initiated a "mortality" signal if the collar did not move for 4 hours. Each collar incorporated a leather spacer, programmable electronic breakaway, or both to ensure that the collar fell off within 2 years or less. This project was conducted under FFWCC permit # WX03549. All animal handling procedures were approved by University of Kentucky IACUC Protocol #00626A2003.

Radio-telemetry

All collared animals were located once each week by fixed-wing aircraft. For each location, I recorded habitat type, time, and whether the collar's tip switch indicated activity. From the plane, I electronically plotted each location on an aerial photograph in ArcView 3.2 (ESRI 1999) or ArcGIS 9.1 (ESRI 2006). After each flight, locations were transferred to an electronic database as Universal Transverse Mercator (UTM) coordinates. Any collar that was in "mortality" mode was investigated on foot to determine if the bear was dead or if the collar had detached. I also collected locations on foot to locate dens, increase location sample size, collect scats and hair samples, and record food sources, rest sites, and mark trees. For ground locations, I found bears by homing to the VHF beacon, then either visually identified the animal or triangulated from 2-3 locations within 5 minutes. For each triangulation location, I obtained my location with a handheld GPS (Rino 110, Garmin, Olathe, KS), recorded azimuth to the bear, and recorded the time of day.

GPS collars were programmed to attempt 4 – 24 fixes per day. Along with geographic position, data for each fix attempt included date, time, fix status (whether a 2-dimensional, 3-dimensional, or failure), collar function status, altitude, measures of activity, dilution of precision measures related to satellite geometry, temperature, and number of satellites used. These data were stored internally by the collar, downloaded remotely via spread spectrum technology, or downloaded when the collar was retrieved.

Telemetry Error

Errors of 100 to 200 m are typical of studies tracking animals from aircraft, with accuracy affected by the landscape, pilot, and researcher (Moen et al. 1996). To assess the accuracy of aerial telemetry locations, I compared location estimates obtained by aerial telemetry with reference locations for those same animals, taken within 20 minutes. Accuracy of reference locations was dependent on the performance of a hand-held Garmin GPS unit or a GPS collar. Garmin (2007) GPS receivers are accurate to within 15 m 95% of the time, and "Generally…within 5 to 10 meters…under normal conditions." To assess GPS collar accuracy, I compared location estimates obtained by GPS collars to hand-held GPS reference locations of 3 dropped collars and 3 bears visually identified within 5 minutes. To assess ground telemetry error, I compared 4 ground telemetry locations to reference GPS collar locations taken within 20 minutes.

Survival

I calculated annual survival using the Mayfield method (Mayfield 1961, Trent and Rongstad 1974, Mayfield 1975). The Kaplan-Meier method (Kaplan and Meier 1958) is more popular than Mayfield in recent literature, but a minimum simultaneously monitored sample size of 25 animals per treatment, and preferably 50, is recommended (Winterstein et al. 2001). Although Kaplan-Meier has been modified to accommodate staggered entry of additional animals after the beginning of the study (Pollock et al. 1989), analysis still should not start until the minimum sample size is met (Winterstein et al. 2001). All data gathered before that point would be censored and thereby lost from the analysis.

I analyzed survival of males and females separately. I calculated a daily survival rate and an annual survival rate for each, using the following equations (Mayfield 1975):

$$\text{Daily Survival} = 1 - (\text{Number of Deaths} / \text{Exposure Days})$$

$$\text{Annual Survival} = (\text{Daily Survival})^{365}$$

Exposure days were the sum of the number of days that each animal was monitored. When bears dropped their collars, they were assumed to be alive at the time of collar drop, and censored from analysis after the last known contact with each animal. Missing animals were treated differently because of uncertainty related to their disappearance. Loss of radio contact with a bear could be caused by collar failure, emigration, or human-related death and subsequent deactivation of the collar. Because the probability of each of these scenarios was unknown, I calculated 2 extreme survival rates. A minimum survival rate was calculated by assuming that all missing animals were dead after last radio contact with them. To calculate a maximum survival rate, I assumed that missing animals were alive, and censored the data after last contact with the animal, essentially treating missing animals the same as those which dropped their collars.

Home Range Analysis

Kernohan et al. (2001) evaluated 12 home range estimators, based on the following criteria: sensitivity to sample size, sensitivity to autocorrelation, whether calculations were based on the complete utilization distribution, whether the estimator was nonparametric, if it could calculate multiple centers of activity, sensitivity to outliers, and comparability to other estimators when using the same dataset. Fixed and adaptive kernels scored highest in this evaluation, receiving good marks in all categories except comparability. Fixed kernels (FK) generally give more accurate and precise estimates of home range than adaptive kernels (Worton 1995, Seaman and Powell 1996, Seaman et al. 1999). Although the minimum convex polygon (MCP) method is sensitive to both sample size and outlier locations, it is prevalent in historical and contemporary publications (Kernohan et al. 2001), so comparability with other studies is a benefit of the MCP method (Harris et al. 1990, Kernohan et al. 2001). Due to complementary strengths and weaknesses of MCP and FK home range estimators, I utilized both techniques (Harris et al. 1990, Kenward et al. 2001). For kernel home ranges, I calculated 95% contours to represent home ranges and 50% contours to represent core areas (Hodder et al. 1998).

The ability of an estimator to accurately portray home range generally increases with the number of locations obtained for each animal (Kernohan et al. 2001), although MCPs tend to expand with sample size (Kenward et al. 2001). A minimum sample size of 30 locations has been suggested for FKs (Seaman et al. 1999) and MCPs (Kernohan et al. 2001). At smaller sample sizes, FK methods often overestimate home range (Seaman et al. 1999) and MCP methods tend to underestimate home range (Bekoff and Mech 1984, Laundre and Keller 1984, Harris et al. 1990). Thus, I chose a minimum sample size of 30 locations for both the MCP and FK methods.

For seasonal analyses, I divided the year into 3 equal seasons (Maehr 1997, Maehr et al. 2003): winter was January through April, summer was May through August, and fall was September through December. These 3 seasons represent denning, breeding, and hyperphagia periods, respectively. Annual home ranges were estimated for bears with either VHF or GPS data, but seasonal analyses required the more frequent locations collected by GPS collars. For annual analyses, animals with ≥1 month of data in each of the 3 seasons and ≥30 locations were included. For seasonal analyses, I included animals with ≥1 month of data and ≥30 locations for a particular season. When I had sufficient data from a particular bear for home ranges in multiple years (annual or seasonal), I generated a separate home range for each year or season and reported the average. In other black bear studies, home ranges are sometimes calculated for all bears, and sometimes for adults only. To ensure comparability, I included bears of all age classes in statistical analyses, but also calculated a mean home range size and SE for adults only.

I generated 95% and 50% FK, and 100 % MCP home ranges and calculated the size of each using the HawthsTools extension (Beyer 2004) in ArcGIS 9.2 (ESRI 2006). All statistical analyses were conducted in SAS (SAS Institute 2003) with a rejection level of $\alpha = 0.05$. For annual home ranges, I used a Wilcoxon two-sample test for differences in home range size between sexes. I used a Kruskal-Wallis test to determine if seasonal home range size differed among seasons for each sex. When a seasonal effect was detected, I performed a series of nonparametric post-hoc tests using the KWPOST macro in SAS to determine which seasons differed.

RESULTS

Capture and Radio-telemetry

From May 2004 through December 2006, I collected 21,129 locations (19,482 GPS collar fixes, 1,486 aerial telemetry points, and 161 ground telemetry points) of 41 bears (Table 2.1, Table 2.2) from all age classes (1-21 years of age; Figure 2.1) and both genders (20 female, 21 male). Thirty-one bears wore GPS collars (17 females, 14 males), but only 19 of these were used in home range analyses. A combination of factors (e.g., GPS failures, spread spectrum failures, and collars with stored data still deployed on bears at end of study) resulted in a reduced accumulation of GPS data (compare Figures 2.1 and 2.2)

Telemetry Error

Mean aerial telemetry error (± SE) relative to 13 dropped collars, 2 dead bears, and 1 visual sighting within 2 minutes of the aerial location was 106 ± 22 m. Mean error relative to 37 GPS collar locations within 20 minutes of the aerial location was 187 ± 25 m. Mean error relative to all 53 reference locations was 162 ± 19 m. Mean error distance for 4 ground telemetry locations was 281 ± 244 m, but I don't feel that this is representative of my usual error for the technique. Three of the ground locations had relatively small errors of 3, 24, and 86 m. I suspect a transcription error for the fourth location, with an error of 1010 m. Mean GPS collar error distance was 48 ± 31 m. See Chapter 3 (p. 47) for a discussion of precision based on GPS collar testing, and subsequent data censoring to improve location accuracy.

Survival

I calculated survival based on telemetry data for 20 female and 20 male bears from May 2004 – December 2006. Females accumulated 9,479 exposure days. At the end of 2006, 10 collared females were known to be alive, 1 was dead, 7 had dropped their collars, and 2 were missing or left the study under suspicious circumstances. Minimum annual survival rate for females was 0.89, and maximum annual survival was 0.96. Males were monitored for 5,410 exposure days, with 6 alive, 4 dead, 6 having dropped their collars, and 4 missing at the end of 2006. Minimum and maximum annual survival rates were 0.62 and 0.76 for males.

Causes of Mortality

All deaths documented during this study were due to humans or unknown causes. Among collared bears, roadkills accounted for 4 deaths (F14, M3, M14, and M16) and at least one bear was illegally shot (M8). Cause of death was undetermined for one bear (M4), an apparently healthy adult male prior to his death. The reasons for 5 bears' (F2, F5, M1, M6, and M12) disappearances were unknown. Among these, only F5's collar was found. The others could have been due to collar failures, dispersals outside the study area, or being killed by humans and the collars subsequently deactivated or destroyed.

Road Effects

Deaths caused by vehicle collisions varied seasonally and among years. No bear roadkills from Highlands and Glades counties were documented in 2004, but 6 (including

2 collared animals) were reported in 2005, and another (M16) in 2006. Of these 7 deaths, 4 occurred between 17 May and 17 June of 2005. All 4 were males.

Home Range Analysis

I created annual home ranges for 18 bears (12 female, 6 male) using each of the 3 home range estimators (Appendices 1 and 2). I also generated 34 seasonal home ranges (9 winter, 11 summer, 14 fall) for 18 bears (12 female, 6 male) using each of the 3 estimators (Appendices 3 and 4).

100% Minimum Convex Polygon

Male annual home ranges (162.8 ± 35.6 km^2) were larger than female annual home ranges (69.0 ± 27.5 km^2, $W = 81$, $P = 0.021$; Table 2.3). There was a seasonal effect on female home range size ($P = 0.003$, Table 2.4). Female home ranges were smaller in winter (5.5 ± 3.0 km^2) than in fall (31.1 ± 5.8 km^2, $P = 0.002$) or summer (68.7 ± 44.7 km^2, $P = 0.004$). Fall and summer home ranges did not differ among females ($P = 0.936$). Male home ranges did not differ among seasons ($P = 0.326$, Table 2.4).

95% Fixed Kernel

Male annual home ranges (96.0 ± 18.3 km^2) were larger than female annual home ranges (32.2 ± 9.0 km^2, $W = 85$, $P = 0.010$; Table 2.3). I found a seasonal effect on female home range size ($P = 0.021$, Table 2.4). Female home ranges were smaller in winter (8.6 ± 4.0 km^2) than in fall (19.2 ± 2.2 km^2, $P = 0.010$) or summer (30.4 ± 14.3 km^2, $P = 0.022$). Fall and summer home ranges did not differ among females ($P = 0.953$). Male home ranges did not differ among seasons ($P = 0.165$, Table 2.4).

50% Fixed Kernel

Male annual core home ranges (19.7 ± 4.3 km^2) were larger than female annual core home ranges (6.0 ± 1.7 km^2, $W = 85$, $P = 0.010$; Table 2.3). Female core home range size was affected by season ($P = 0.020$, Table 2.4). Female core home ranges were smaller in winter (2.3 ± 1.3 km^2) than in fall (3.9 ± 0.4 km^2, $P = 0.015$) or summer (6.0 ±

2.4 km^2, $P = 0.012$). Male core home ranges did not differ among seasons ($P = 0.202$, Table 2.4).

DISCUSSION

South-central Florida supports a small black bear population that does not exhibit obvious effects of isolation as does the population in west-central Florida (Brown 2004). My capture data exhibited an even sex ratio and a fairly even age distribution with both sexes represented in all age classes. Average age for females (4.2) was higher than for males (3.0), presumably due to higher mortality among males.

Bear population growth rates are most influenced by female survival and reproductive rates (Taylor et al. 1987, Eberhardt 1990). Annual survival in south-central Florida (0.89 – 0.96 for females, and 0.62 – 0.76 for males) was similar to estimates from other Florida black bear populations (0.89 – 1.0 for females, and 0.66 – 0.76 for males) (Seibert 1993, Land 1994, Dobey et al. 2005).

Suspicious evidence surrounded the death or disappearance of several study animals. For example, M16 was found along US-27, but missing his collar. The collar's signal could be heard from the roadway, but it was at least 1 km away. No necropsy was performed on the bear, and the collar quit transmitting before field personnel could recover it, suggesting that someone may have tampered with the collar.

Investigation of M4's carcass showed no broken bones or other evidence of automobile collision and the death site was >2 km from the nearest highway. However, the carcass was found <100 m from a wildlife feeder and tree stand, similar to the area where M8 was shot. Shooting is suspected in this case, but cannot be confirmed. The area was searched with a metal detector, but no bullet was found.

Bear M1 was last located in late May of 2005. A local resident bragged of shooting a bear wearing a collar matching the description of our equipment 2 – 3 weeks later. Around this same time, I was unable to locate M1 on a routine telemetry flight and he was never heard again. The alleged shooting took place ~8 km outside M1's normal range. The alleged shooter said that he left the bear lay where it fell and did not mention taking or destroying the collar, but all other animals collared at the time were known to be alive in the following weeks. Thus, if the shooting actually took place, M1 was the only plausible target.

The collar from bear F5 was found in an open pasture, a habitat infrequently used by bears, and outside her normal home range. The collar attachment hardware was missing, suggesting that humans, and not the bear, removed the collar. Human-caused mortality is suspected in this case as well, but cause of death could not be confirmed.

Bears are remarkably adaptable and intelligent (Craighead 2000, Maehr et al. 2001*b*, Pelton 2003). Perhaps more than any other carnivore, bears learn how to survive from their mothers (Schoen 1990, Craighead 2000:29). These traits suggest that bears make choices rather than acting solely on instinct, a phenomenon leading to a high degree of behavioral variation among individuals. Such individual variability makes it harder to draw inferences or generalizations for a population, especially with small sample sizes. Because this is a small population, my sample size was limited. Small sample size coupled with high variability led to large standard errors (Appendices 1, 2, 3, and 4) and reduced statistical power to detect differences among the independent variables (sex and season). I caution that some biological patterns may have been missed due to the limitations of my statistical analysis. On the other hand, 40 captures may represent a relatively large proportion of the entire population compared to other bear studies.

Mean home range size varied among methods, as would be expected (Kernohan et al. 2001, Belant and Follmann 2002), but the overall patterns were consistent regardless of home range estimator used. Annual home ranges were larger for males than females, as is normal for the species. The wide-ranging habits of males expose them to greater risk of highway impact and human-related mortality. Interspecific aggression is also potentially higher among males, but I did not observe injuries that were obviously attributable to fighting.

Female home range size was comparable to other studies of the Florida black bear (Table 2.5); however, mean home range size (especially with the MCP method) was strongly influenced by 2 subadult females (F9 and F10) with unusual movement patterns. Female F9 was captured on the Turkey Track Ranch in November 2004. She remained on that property and the neighboring Hendrie Ranch until crossing US-27 in mid-April 2005. Afterwards, her movements became erratic. She made wide-roaming movements interspersed with periods of localized residency, including a stay of 4 – 6 weeks in a citrus grove and several visits to a patch of scrub. Both of these habitats were adjacent to US-27, just east of the Turkey Track/Hendrie Ranch area.

Female F10 was captured in the Turkey Track/Hendrie Ranch area in December 2004. She stayed in this section of southern Highlands County until May 2005 when she moved a straight-line distance of ~19 km to an area dominated by pine plantations in Glades County. She remained in this area until October, and then returned to her area of capture in Highlands County. The following May (2006), she again moved to Glades County, where she remained until August. Due to logistical issues, the bear was not tracked again until the following winter. By this time, she had once again returned to the Turkey Track/Hendrie area in Highlands County.

These 2 bears may have been demonstrating exploratory movements, as is often seen in young bears (Maehr et al. 1988). Although subadult males more commonly disperse (Garshelis and Pelton 1981, Schwartz and Franzmann 1992, Lee and Vaughan 2003), subadult females sometimes roam far from their mothers' ranges as well, even approximating the home range size of adult males (Lindzey and Meslow 1977, Clevenger and Pelton 1990, Hellgren et al. 2005). One of the longest female black bear dispersals on record (~60 km) occurred nearby in the Big Cypress Swamp (Maehr 1997). Excluding subadults from my sample of females decreased mean MCP home range size from 69.0 ± 27.5 km^2 to 45.1 ± 15.0 km^2, and decreased mean 95% FK home range size from 32.2 ± 9.0 km^2 to 20.2 ± 4.5 km^2 (Tables 2.5 and 2.6). MCP and 95% FK home range sizes for adult females were comparable to adult female home ranges in other studies (Table 2.6).

Annual FK home range size of male bears in south-central Florida was small relative to males in Okefenokee Swamp and Eglin Air Force Base. However, male home ranges in Okefenokee were the largest reported in Florida, and Eglin researchers used a different home range estimator (adaptive kernel). Moreover, MCPs for all age class males, and MCPs for adult males, were well within the range of other studies (Tables 2.5 and 2.6).

The finding that male and female home ranges were similar to other populations contradicts my hypothesis that they would be larger in the Highlands-Glades population.

My initial reasoning was that bears would travel over areas of less desirable habitats to reach disjunct patches of quality habitat. But perhaps the opposite is true; that is, home range size could be constrained by agriculture and highways, forcing bears to maintain smaller home ranges to avoid these undesirable habitats. However, while females rarely crossed highways or open areas, males frequently crossed both, so this may not be the explanation. Instead, I postulate that the available forest, though in small and sometimes disjunct patches, is very productive bear habitat. That is, the diversity of habitats and their high degree of interspersion provide more plentiful resources per unit area than any single type of forest could, and is greater than is found elsewhere in Florida (See "Habitat Diversity Analysis" in Chapter 3).

Although scale varies between methods, the proportional differences between seasons and between sexes are similar. Regardless of which home range estimator was used, mean home range size was consistently smallest in winter, largest in summer, and intermediate in fall for each sex. However, only the smallest home ranges (females in winter) were statistically different from other seasons. Mean female home range for summer was larger than for fall, but F10 was not represented in fall. Her summer home range was 5 – 9 times larger than the next largest summer home range, thereby inflating the mean (Appendix 3). By using a nonparametric test, F10's unusually large summer home range was simply ranked as relatively largest and did not affect the statistical results as drastically as it affected the mean home range size. There was no seasonal effect on male home range, although mean fall home range was 1.6 – 4.9 times larger than winter, and mean summer home range was 1.3 – 2.3 times larger than fall. This may be attributable to small sample size of males ($n = 2$ for winter, 4 for summer, and 3 for fall; Appendix 4). Differences in home range size between the seasons can be understood based on the seasonal biology of the species and available food resources (see Chapter 4).

Winter is the denning and parturition season for bears, and female home ranges were smallest at this time. Mean home range size for males was also smallest in winter, but statistical tests failed to detect a seasonal difference. Hibernation allows bears to conserve energy in winter when costs of foraging exceed potential caloric intake (Graber 1990). This negative energy balance can result through lower temperatures and reduced availability of natural foods. For females, parturition is also linked to hibernation

(Whitaker and Hamilton 1998). Female black bears generally prefer to den in secure structures such as hollow trees and logs (Pelton et al. 1980, Wathen 1983, Smith 1986, Wathen et al. 1986), or excavated holes in the ground under tree roots, boulders or rock outcroppings (Eubanks 1976, Beecham et al. 1983, Manville 1987, Mack 1990, Beck 1991). One adult female and her yearling cub denned in a hollow bay tree, but due to the lack of old-growth forest with large hollow trees and the relatively flat topography of the study area, the rest were ground nests in dense vegetation, as seen elsewhere in Florida (Wooding and Hardisky 1988, Seibert 1993, Seibert 1995, Maehr 1997, Orlando 2003). All dens were in saw palmetto thickets or bay swamps. Adult males were sometimes inactive for a few days to a few weeks, but all moved occasionally throughout the winter. Subadult bears of both sexes tended to remain active throughout the winter, though their home ranges were smaller than in other seasons. Except for nursing females, warm temperatures and continued availability of some foods might make hibernation less necessary in Florida than elsewhere. If available food is sufficient to meet or exceed the increased metabolic demands of foraging (versus denning), then bears can benefit from activity through accelerated growth (Maehr et al. 2001*a*) and improved body condition over the winter (Maehr 1997).

Summer is the breeding season for the black bear, and the search for mates has been suggested as the reason that males tend to have expansive home ranges at this time, while female summer home ranges tend to be smaller or similar to fall home ranges (Wooding and Hardisky 1988, Seibert 1993). In south-central Florida, mean home range size of male black bears was largest in summer, but a seasonal difference was not detected. This was probably due to small sample size. Female home range sizes in my study fit the trend ordinarily seen for the species (i.e., home ranges were larger in summer than in winter, but were not different in summer than in fall).

Bears become hyperphagic in the fall to prepare for winter, and may travel widely to access food sources (Maehr 1997). Previous studies found that female black bear home ranges are often largest in fall (Jones and Pelton 2003), while fall home ranges of male black bears tend to be larger than winter home ranges, but smaller than breeding season home ranges (Lindzey and Meslow 1977, Alt et al. 1980). In south-central Florida, mean home range sizes for males suggest this same trend, and I suspect that fall home range size for males truly was intermediate between summer and winter home range size, but statistics did not detect a seasonal effect, probably due to small sample size. Female home ranges in fall were larger than in winter, but were not different than in summer.

The south-central Florida bear population has a history of increasing road mortality over the past 20 years (Maehr et al. 2004). In addition to causing mortality, roads may restrict bear movements. In the Chassahowitzka population of west-central Florida, bear home ranges were elongated on a north-south axis that paralleled major highways (Maehr et al. 2003). Otherwise suitable habitat there was avoided because of proximity to roads and associated noise (Orlando 2003). In south-central Florida, home ranges were primarily located in forested areas, whereas roads, urban areas (notably the town of Lake Placid), and agricultural areas formed boundaries to occupied forest. As my hypothesis predicted, roads divided the Highland-Glades population into sub-centers where adult female home ranges were clustered. These sub-centers coincided with 3 of the quadrants delineated by the intersection of US-27 and FL-70 (Figure 2.3). The remaining quadrant (i.e., north of SR-70 and west of US-27), was also used by bears, but no reproduction was documented there during the course of my study.

The largest population sub-center was east of Venus in the southeast quadrant, encompassing the eastern edge and terminus of the Lake Wales Ridge and adjacent habitats to the east. A second band of home ranges occured on the eastern side of the ridge, in the northeast quadrant from north of FL-70 to the outskirts of the town of Lake Placid. The third major cluster of female home ranges was in the southwest quadrant, centered on ABS, the XL Ranch, and other neighboring ranches north of Venus. Secondary areas that were used less regularly by study animals included: Southwest Florida Water Management District's Jack Creek property and surrounding areas in the northwest quadrant; a roughly triangular patch of habitat dominated by slash pine plantations north of the Caloosahatchee River and bordered by US-27, FL-29, and FL-78; and swamps associated with Fisheating Creek in northern Glades County.

Males and subadult females were not as clearly categorized into 1 of the 3 subpopulations as adult females. Instead, they tended to inhabit large areas encompassing multiple population centers, or one of the population centers and a variable amount of surrounding territory (Figures 2.4 and 2.5). Wide-ranging movements have been noted among subadult bears elsewhere, as they explore, disperse, or attempt to establish territories in the matrix of existing adult home ranges (Clevenger and Pelton 1990, Whitaker and Hamilton 1998, Hellgren et al. 2005). As predicted, male home ranges overlapped several female home ranges, and effectively connected the population centers, thereby mitigating the local reproductive isolation that could be caused by profound habitat fragmentation. For example, M4, after his capture northeast of Lake Placid, moved to the XL Ranch in the southeast quadrant, continued on to the Turkey Track/Hendrie Ranch complex, and finally moved further south, where he died in Glades County. These movements occurred over just 6 months, and M4 was excluded from home range analyses because I had not yet collected enough telemetry locations at the time of his death. His movements illustrate how such individuals can connect the population sub-centers (this bear visited all 3 quadrants), but they do so at a greater risk of mortality.

Table 2.1. Female black bears captured in south-central Florida, USA, 2004 - 2006.

ID	Age[a]	Number of Locations			Status
		VHF	GPS	Total	
F1	19	116	1591	1707	Active
F2	1[b]	39	12	51	Unknown
F3	4	101	741	842	Active
F4	5	82	1699	1781	Collar detached
F5	7	56	976	1032	Unknown, found collar detached and missing hardware
F6	5	69	1612	1681	Active
F7	Old Adult[b]	49	630	679	Collar detached
F8	7	90	1709	1799	Active
F9	1[b]	91		91	Detached
F10	1[b]	57	528	585	Active
F11	1[b]	82	817	899	Active
F12	1[b]	28		28	Active
F13	1[b]	68		68	Active
F14	Subadult[b]	15	321	336	Dead, roadkilled
F15	1[b]	47	886	933	Active
F16	<1[b]	30		30	Collar detached
F17	6	13		13	Collar detached
F18	1[b]	16		16	Active
F19	Adult[b]	10	626	636	Active
F20	Subadult[b]	3		3	Collar detached
Average	4.2				

[a] Age at first capture, from cementum annuli data.

[b] Age estimated visually.

Table 2.2. Male black bears captured in south-central Florida, USA, 2004 - 2006.

		Number of Locations			
ID	Age[a]	VHF	GPS	Total	Status
M1	Adult[b]	34	292	326	Unknown
M2	Old Adult[b]	8		8	Collar detached
M3	3	39		39	Dead, roadkilled
M4	4	20		20	Dead, cause unknown
M5	Adult[b]	87	361	448	Collar detached
M6	2	28		28	Unknown
M7	3	34		34	Collar detached
M8	3	10	1962	1972	Dead, illegally shot
M9	1[b]	18		18	Collar detached
M10	3	92	3098	3190	Active
M11	2	86		86	Active
M12	Adult[b]	17		17	Unknown
M13	1[b]	19	18	37	Collar detached
M14	1[b]	25	815	840	Dead, roadkilled
M15	1[b]	20		20	Active
M16	3	14	770	784	Dead, roadkilled
M17	5	4	18	22	Collar detached
M18	1	12		12	Active
M19	Subadult[b]	11		11	Active
M20	<1[b]				Not collared
M21	Adult[b]	7		7	Active
Average	3.0				

[a] Age at first capture, from cementum annuli data.

[b] Age estimated visually.

Table 2.3. Annual home range size (km^2) of Florida black bears in south-central Florida, USA, 2004 – 2006.

		Home range size (mean ± SE)	
Home Range Estimator	*W*; *P*[a]	Females	Males
100% MCP	81; 0.021	69.0 ± 27.5	162.8 ± 35.6
95% FK	85; 0.010	32.2 ± 9.0	96.0 ± 18.3
50% FK	85; 0.010	6.0 ± 1.7	19.7 ± 4.3

[a] *W* = Wilcoxon statistic, *P* = *P*-value (one-sided) associated with Wilcoxon two-sample test

Table 2.4. Seasonal home range size (km^2) of Florida black bears in south-central Florida, USA, 2004 – 2006.

		Home range size (mean ± SE)		
HR Estimator	Gender	Winter	Summer	Fall
100 % MCP	Females (*P* = 0.003)	5.5 ± 3.0 [a]	68.7 ± 44.7 [b]	31.1 ± 5.8 [b]
100 % MCP	Males (*P* = 0.326)	30.6 ± 24.0	197.8 ± 101.4	149.8 ± 53.2
95% FK	Females (*P* = 0.021)	8.6 ± 4.0 [a]	30.4 ± 14.3 [b]	19.2 ± 2.2 [b]
95% FK	Males (*P* = 0.165)	22.8 ± 10.1	118.9 ± 39.1	55.8 ± 4.5
50% FK	Females (*P* = 0.020)	2.3 ± 1.3 [a]	6.0 ± 2.4 [b]	3.9 ± 0.4 [b]
50% FK	Males (*P* = 0.202)	5.4 ± 2.2	19.8 ± 5.9	8.5 ± 0.8

[a, b] Means without common letters were different ($P < 0.05$).

Table 2.5. Mean annual home range sizes (km^2) of Florida black bears of all age classes in south-central Florida compared to those elsewhere in the range of the subspecies.

	Home range size						
	100% MCP		95% FK		50% FK		
Location	F	M	F	M	F	M	Reference
Highlands-Glades	69.0	162.8	32.2	96.0	6.0	19.7	This study
Big Cypress	57.1[a]	303.2[a]					Land 1994
Osceola N. F.			30.3				Dobey et al. 2005
Osceola N. F.	66.4	171.1					Mykytka & Pelton 1988
Apalachicola N. F.	65	176					Seibert 1993
Eglin Air Force Base			87.5[b]	350.7[b]	8.6[b]	42.3[b]	Stratman 1998
Okefenokee Swamp, GA			55.9	342.8			Dobey et al. 2005
Southwest Alabama	9.9[c]	20.7[c]					Dusi et al. 1987
Mean of other studies	65.7	173.6	43.1				
SE of other studies	0.7	2.4	12.8				

[a] Estimation method not specified, not included in mean.

[b] Adaptive kernel method, not included in mean.

[c] Polygon method (not MCP), not included in mean.

Table 2.6. Mean annual home range sizes (km^2) of adult Florida black bears in south-central Florida compared to those elsewhere in the range of the subspecies.

	Home range size						
	100% MCP		95% FK		50% FK		
Location	F	M	F	M	F	M	Reference
Highlands-Glades	45.1	161.8	20.2	133.2	3.5	26.6	This study
Big Cypress	54.2	283.7					Maehr 1997
Chassahowitzka	29.0	105.3					Maehr et al. 2003
Ocala N. F.	25	135					Wooding & Hardisky 1994
Osceola N. F.	52	215					Wooding & Hardisky 1994
Mean of other studies	40.1	184.8					
SE of other studies	7.6	40.3					

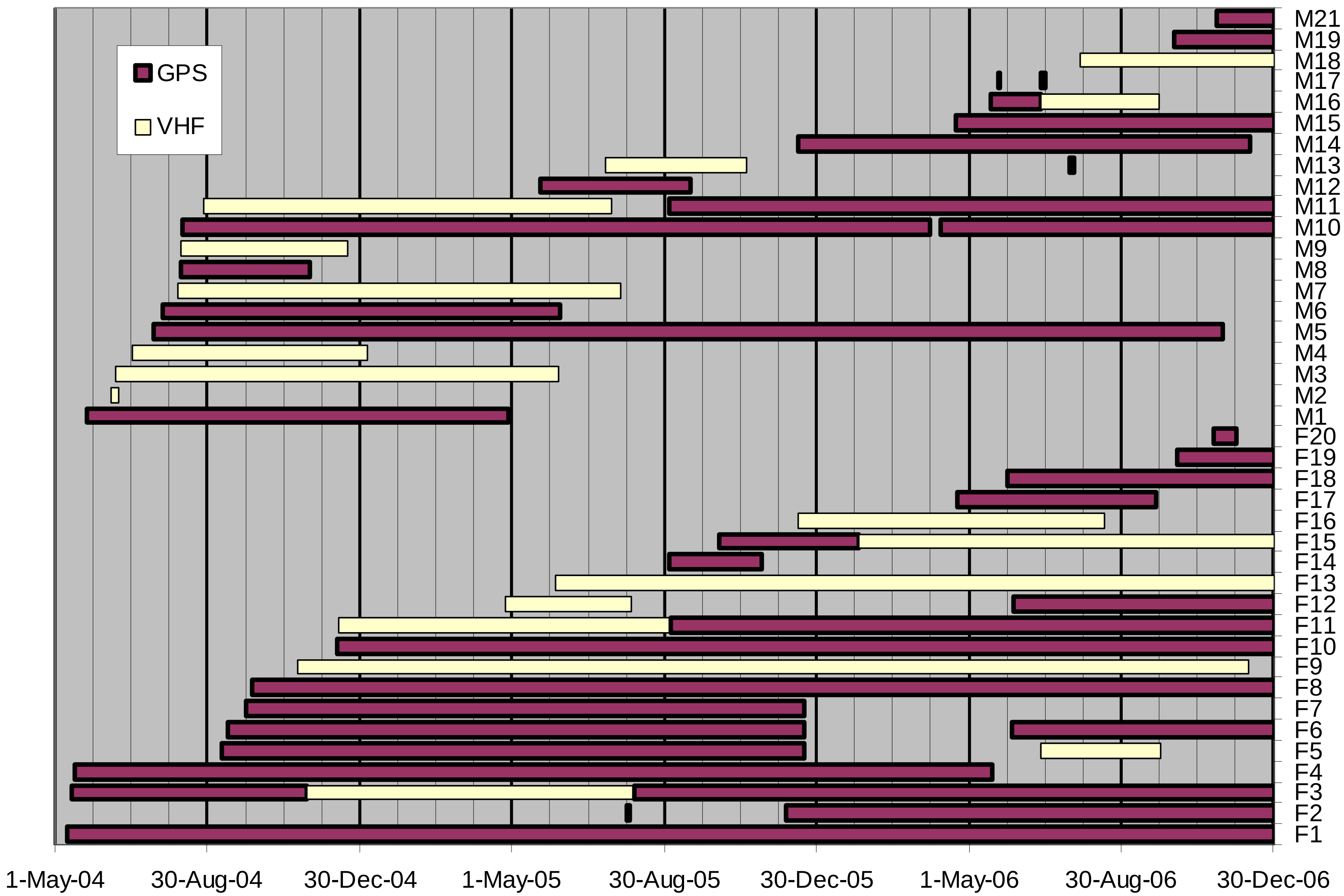

Figure 2.1. Date ranges of collar deployment on black bears in south-central Florida 2004-2006.

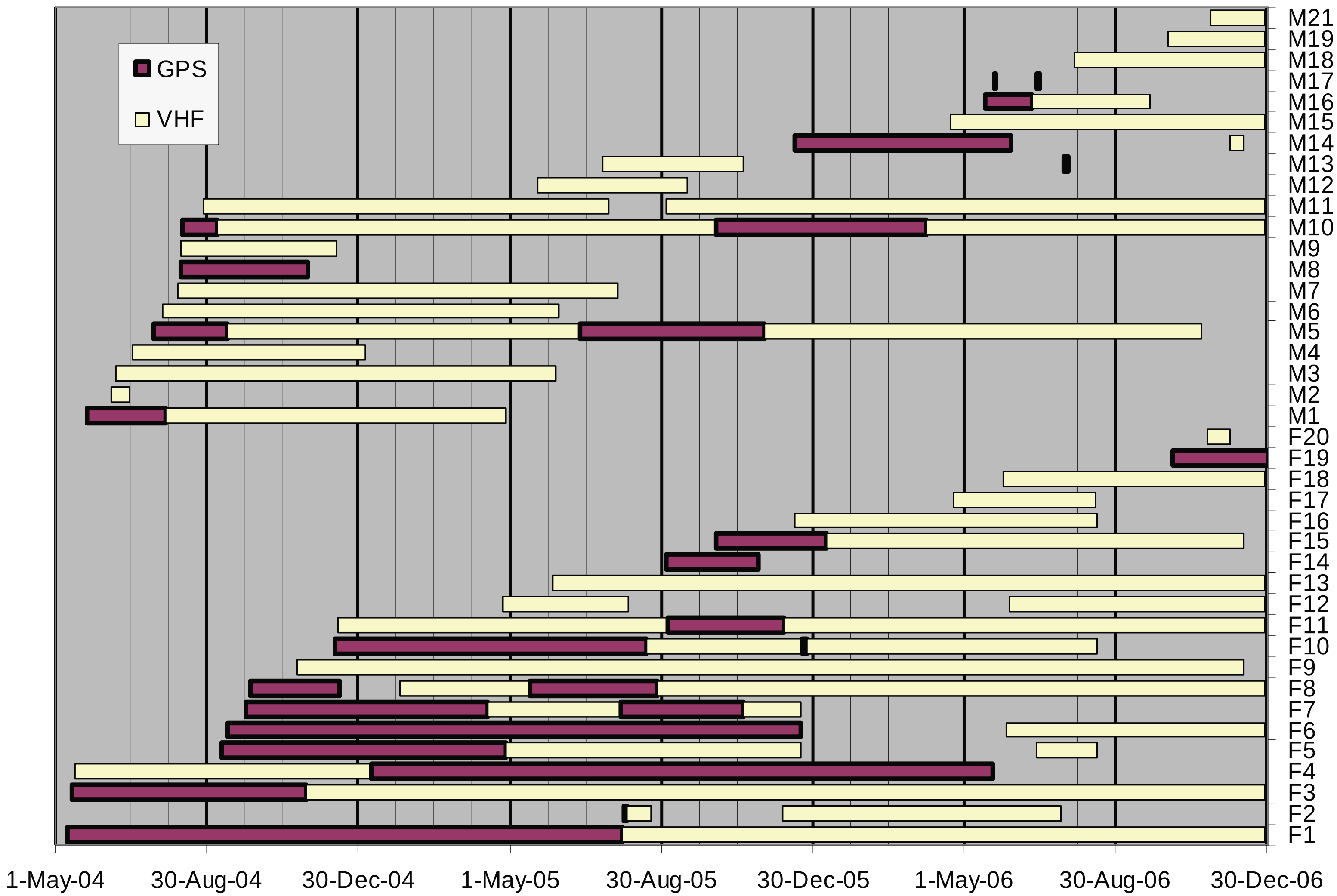

Figure 2.2. Date ranges of location data obtained from black bears in south-central Florida 2004-2006.

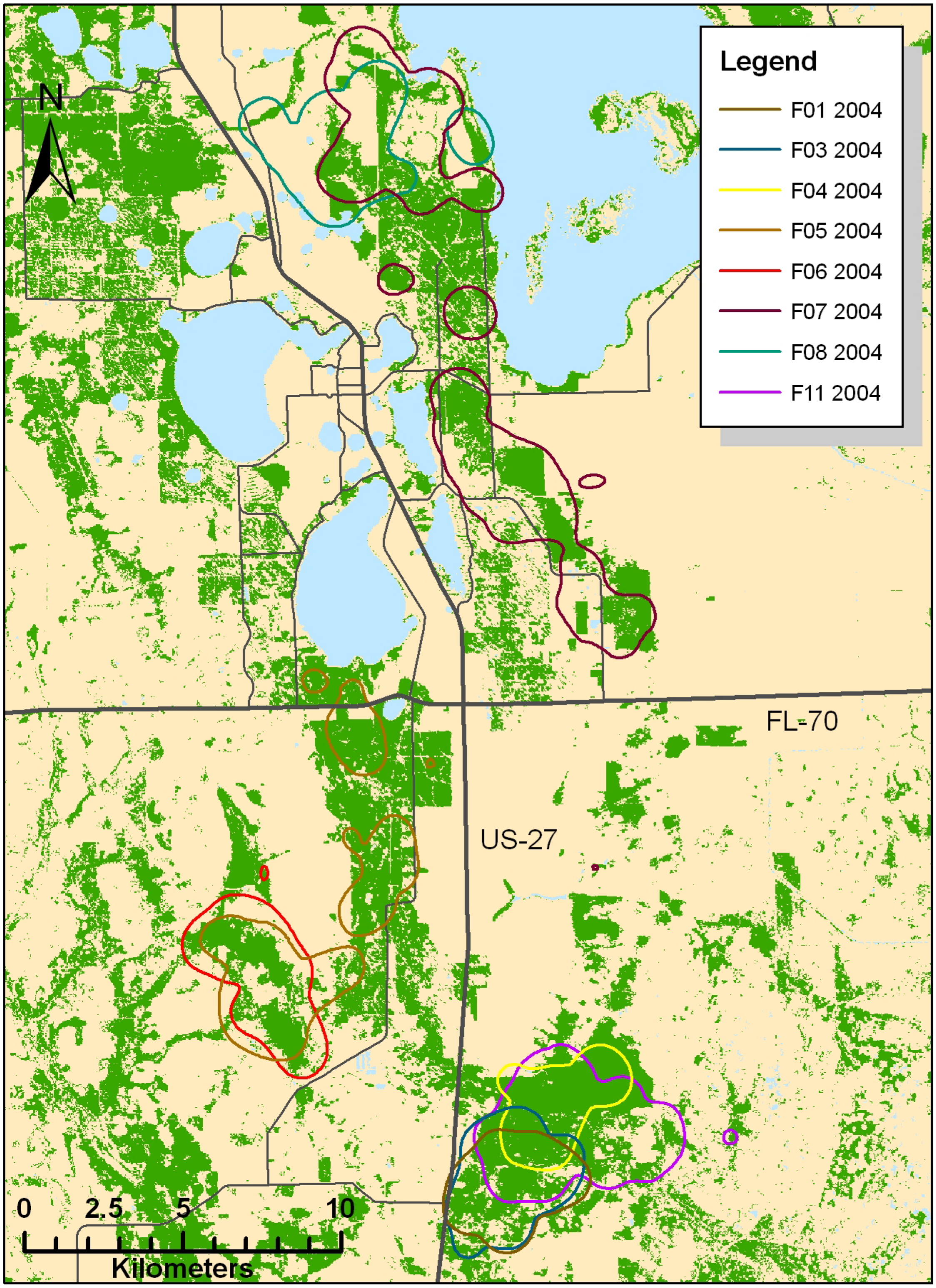

Figure 2.3. 95% FK annual home ranges of female black bears in south-central Florida 2004 – 2005. Forest is symbolized by green, water by blue, and all other habitats by tan.

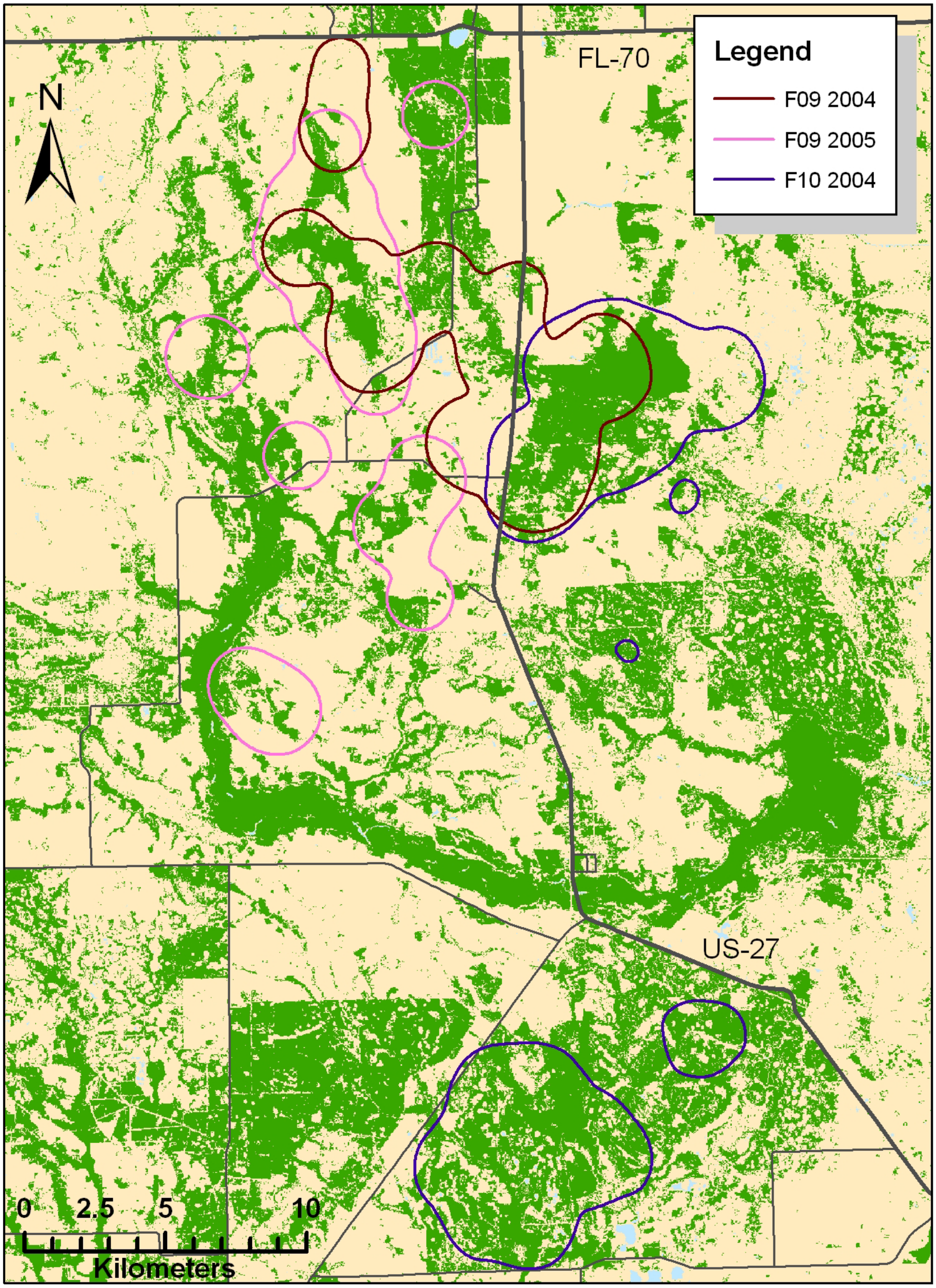

Figure 2.4. 95% FK annual home ranges of 2 female black bears (F9 and F10) in south-central Florida 2004 – 2006. Forest is symbolized by green, water by blue, and all other habitats by tan.

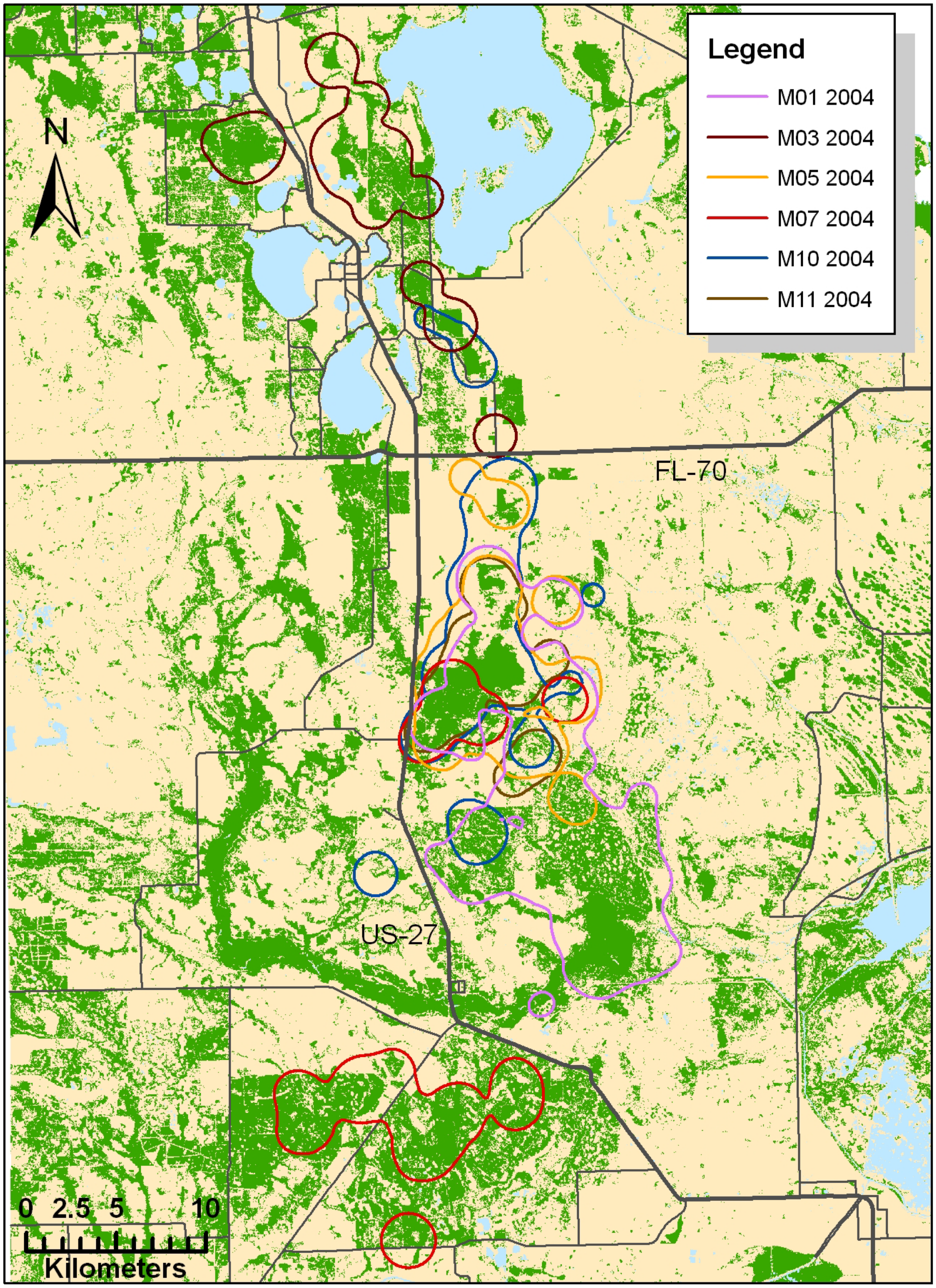

Figure 2.5. 95% FK annual home ranges of male black bears in south-central Florida 2004 – 2005. Forest is symbolized by green, water by blue, and all other habitats by tan.

CHAPTER THREE
HABITAT USE

The concept of habitat, and selection of certain types of habitat by a species, is a cornerstone of wildlife ecology and management (Schoen 1990). Black bears across North America are forest-dwelling generalists (Hillman and Yow 1986). Uplands, lowlands, hardwoods, and conifers have all been deemed important to the black bear (Wooding and Hardisky 1994, Orlando 2003, Dobey et al. 2005, Benson and Chamberlain 2007). While many different habitats can be beneficial to the black bear, roads and urban areas are quite detrimental. "Because human tolerance for bears is generally low, inaccessible, forested habitat appears to be a prerequisite for their continued existence near or adjacent to human populations…" (Schoen 1990:146).

Measurements of black bear habitat can include more than just the types of habitat where bears are found, but also the diversity and arrangement of those habitats. Diversity and richness of habitats has been credited for allowing bears to maintain smaller home ranges than neighboring populations (Lindzey and Meslow 1977). High edge ratios might be important to bears because they can indicate habitat with a diversity of food sources available throughout the year (Stratman 1998). As patch size decreases, animals have an opportunity to sample more habitat types with less travel time (Debinski et al. 2001). Assessing the scale and diversity of habitats available to a species complements and adds to a study of habitat selection.

Habitat use has been described for all major bear populations in Florida (Mykytka and Pelton 1989, Seibert 1993, Land 1994, Wooding and Hardisky 1994, Maehr 1997, 2001, Maehr et al. 2003, Orlando 2003, Dobey et al. 2005) except in Highlands and Glades counties. These studies used a variety of methods (e.g., compositional analysis, Neu et al. (1974), electivity index), but all sought to answer the same basic question: what habitats do bears select in a particular landscape? South-central Florida's unique landscape makes this same question especially important.

Hoctor (2003) accurately predicted bear occurrence statewide, but the Highlands-Glades area was an exception. His model showed very little potential bear habitat in my study area, although least cost paths generated between the Big Cypress National

Preserve and Ocala National Forest passed through the area. This led to the suggestion that research should be conducted to determine how bears use this fragmented landscape and why bears to persist in Highlands and Glades counties. I chose to study habitat selection by this population of bears to provide a fundamental piece of knowledge about the ecology of this population, guide management decisions, assess seasonal patterns of habitat use, compare my study area to other populations in the state, and relate habitat use to food habits, space requirements, and seasonal movements. Because my study area contained less forest, and the distribution of that forest appeared more patchy than other primary bear range in the state, I hypothesized that bears in south-central Florida would utilize more non-forested habitats than bears elsewhere in Florida and the southeastern U.S.

METHODS

Habitat Classification

I used Euclidean distance analysis (Conner and Plowman 2001) to estimate seasonal and annual patterns of black bear habitat use. Classification of habitat type was derived from a GIS (geographic information system) landcover map (Florida Fish and Wildlife Conservation Commission 2004), created from 2003 Landsat Enhanced Thematic Mapper satellite imagery. This classification partitioned plant communities and land uses into 43 categories, 33 of which were present in my study area. Based on knowledge of the study area, I reclassified the data into the following 11 categories: agriculture, not including pasture or citrus groves (AGR), bay swamp (BAY), citrus grove (CIT), freshwater marsh (FWM), grassland (GRA), hardwood hammock (HWH), pine forest (PIN), scrub (SCR), urban (URB), open water, and other (Table 3.1). The original “Bare soil” classification was problematic because it included scrub, citrus, and disturbed habitats. Therefore, I first reclassified “Bare soil” into “Other”, and then manually redigitized citrus groves and scrub habitats within the study area by comparing the landcover map with an ortho-rectified aerial photograph of the study area (U.S. Department of Agriculture 2006). “Other”, excluding “Bare soil” accounted for <0.1% of the study area, and was excluded from the analysis. Open water was not considered to be potential bear habitat and was excluded as well.

Collar Testing

Because topography and vegetation can interfere with GPS reception of satellite signals, GPS units perform best in areas of low relief with little to no canopy cover (Moen et al. 1996, Sigrist et al. 1999). Vegetation type, percentage canopy cover, tree density, tree height, tree basal area, and terrain conditions affect GPS performance (Rempel et al. 1995, Frair et al. 2004). In wildlife studies, this introduces a bias if either location accuracy or fix-rate differs among habitat types (Rodgers 2001, Frair et al. 2004). Fix-rate is the proportion of fix attempts that are successful. Because data points are missing (not just inaccurate), fix-rate has the potential to be the larger source of bias in GPS collar data. To assess the degree of fix-rate bias in my study, I placed test collars in representative habitat types within the study area, elevated ~1 m above the ground. Collars were programmed the same as actual collars used on bears and allowed to run for ≥1 day in each location. Each collar/test site combination was considered 1 test, regardless of length of deployment time or number of location attempts. I classified each test site into 1 of 5 categories based on vegetative structure: bay swamp, pine forest, hardwood hammock, shrubland (e.g., scrub, saw palmetto thicket, and wetland thicket – all of which have dense understory growth, but no dominant tree canopy), and open (e.g., prairie, pasture, and marsh characterized by low-growing herbaceous vegetation). I calculated fix-rate bias as the number of failed attempts divided by the total number of attempts, and converted the results to percentages.

Because GPS collars attempted multiple fixes in the same location, I was also able to measure precision of location estimates. I calculated the average of all fix locations in a test. I considered this average to be the “true” location of the collar, and calculated the distance, or “error” of each fix from the true location. I averaged all location errors to obtain the overall mean precision.

For each location, collars recorded an elevation estimate and positional dilution of precision (PDOP), a product of satellite geometry. Using data from fix-rate bias testing, I utilized these 2 parameters to identify points that were likely to have large location errors.

Screening locations with high PDOP or horizontal dilution of precision (HDOP) can be used to increase locational precision (Rempel et al. 1995, Moen et al. 1996, D'Eon et al. 2002, D'Eon and Delparte 2005). Similarly, locations with a high degree of altitude (vertical) error can also have relatively large location (horizontal) error (Moen et al. 1997). All location estimates were plotted in a GIS and overlaid on a digital elevation model (U.S. Geological Survey 1999). The elevation value from the GIS layer was assumed to be the "true" elevation for each point. I then calculated the absolute value of the difference between the collar estimate of elevation and this true elevation to provide an elevation "error" for each point. For each of these parameters (i.e., PDOP and elevation error), I deleted all observations that were extreme outliers. I considered extreme outliers to be any value that was more than 3 times the interquartile range above the upper quartile. There is a potential for data screening to systematically cause bias by preferentially removing locations only from certain habitats (D'Eon and Delparte 2005). To quantify this bias, I divided the number of locations censored from each habitat type by the total number of locations in that habitat, and converted the results to percentages.

Censoring test collar data on the basis of PDOP and elevation error improved precision. Therefore, I censored actual GPS data from collared bears in a similar manner.

Euclidean Distance Analysis

Techniques for assessing habitat use should: "1) use the animal as the sampling unit; 2) permit hypothesis testing among meaningful groups; 3) work at multiple spatial scales; 4) allow for the nonindependence of habitat proportions (i.e., the unit-sum constraint);" 5) "be robust to telemetry error"; and 6) "provide summary statistics for evaluation of effect size if a statistical difference is detected" (Conner and Plowman 2001, p. 276). Euclidean distance analysis (EDA) meets all of these criteria (Conner and Plowman 2001).

EDA has several advantages over classification-based methods such as compositional analysis. It is more accurate, more robust to telemetry error, and has the potential to indicate use or avoidance of habitat edges (Conner et al. 2003). Habitat selection is a hierarchical process (Johnson 1980) with selection at any one level based on selection at more general level(s), which means that animals make habitat selection choices based partially on habitats surrounding the area in question (Conner et al. 2003). For example, establishment of a home range is based partially on habitats surrounding that home range. Because EDA calculates distance to the nearest occurrence of a feature whether it lies within the home range boundary or not, characteristics of surrounding habitats are considered in EDA. Further, EDA can assess use of linear or point features, while classification-based techniques are most appropriate for areal features.

I used a Euclidean distance-based approach to assess annual and seasonal habitat selection of bears. I assessed habitat use at Johnson's (1980) second and third order levels: selection of a home range location on the landscape, and selection of habitats within the home range, respectively. I generated 95% fixed kernel annual and seasonal home ranges for each bear (see Chapter 2), and designated the study area as an MCP encompassing all home ranges (Figure 3.1). I generated 10,000 random points in the study area, and 1000 random points in each home range. Because third order analysis utilized GPS data which I knew to be biased for certain habitats, I adjusted my random points accordingly. Bias for a habitat type was defined as the proportion of points excluded by the combination of fix-rate bias and censoring of GPS test collar data. For each bear I multiplied the bias for each habitat by the proportion of total bear locations (VHF and GPS) that were GPS data. I generated a 20 % excess of random points for each home range (although any excess larger than the largest bias would do), and removed a proportion of random points in each habitat equal to the bias of actual data for that habitat. After correcting for these biases, I randomly removed excess points, leaving 1000 in each home range. I used the Nearest Feature Extension (Jenness Enterprises 2007) to calculate the distance of each random point and bear location to the nearest occurrence of each habitat type. I assigned a distance of zero to points falling within the target habitat type.

For second order, or landscape scale selection, I created 9 distance ratios (1 for each habitat type) by dividing average distances from random points in each home range by average distances from random points throughout the entire study area (Conner and Plowman 2001). For third order, or home range scale selection, I created distance ratios by dividing average distances from estimated bear locations in each home range by average distances from random points in the home range (Conner and Plowman 2001). I used a MANOVA to test if season affected habitat selection. When a seasonal effect was detected, I used Tukey-Kramer post-hoc tests to determine which seasons differed. When a model was significant, I used univariate *t*-tests to determine which habitats were selected or avoided. Selection was indicated if the distance ratio was significantly <1 for a particular habitat type. Avoidance was indicated if the ratio was significantly >1. Because I felt that the consequences of a Type I error (e.g., concluding that a habitat was selected when, in fact, it was not) were less damaging to management decisions than the consequences of a Type II error (e.g., failing to detect habitats that were actually selected), I chose a relatively liberal α-level of 0.10 for all habitat analyses.

Statewide Habitat Diversity Analysis

I compared diversity of habitat in my study area MCP (Figure 3.1) to diversity in other occupied bear range within the state. For the other major bear populations in the state, I analyzed habitats within the areas designated "primary bear range" by FFWCC (2007; Figure 1.1). Classification of habitat types were derived from a GIS landcover map (Florida Fish and Wildlife Conservation Commission 2004) similar to the one I used for EDA. This map incorporated the areas of citrus grove and scrub habitats that I manually redigitized prior to EDA. The map partitioned plant communities and land uses into 43 categories. I reclassified the data into the following 5 categories: agriculture, disturbed, forest, open, and water. I used the Patch Analyst 4 extension (Rempel 2008) in ArcGIS 9.2 (ESRI 2006) to calculate the mean patch size and total area for each habitat type in each study area. For each study area, I calculated percent composition of each habitat type as the total area of that habitat type divided by total landscape area. To assess the diversity of preferred habitats available to bears (Mykytka and Pelton 1989, Seibert 1993, Wooding and Hardisky 1994, Maehr 1997, Stratman et al. 2001, Orlando 2003, Dobey et al. 2005), I separated the "forest" category into hardwood hammock, pine forest, scrub, and swamp. I then used Patch Analyst to calculate mean patch size, edge density, Shannon's Diversity Index, and Shannon's Evenness Index for forested habitats in each area of bear occupation. When the dataset for an area was too large for the extension to handle, I split the area into 2 sections and ran each separately (e.g., Apalachicola East and Apalachicola West).

RESULTS

Collar Testing

Estimated precision of 644 locations taken by test collars was 14.71 ± 0.81 m (Figure 3.2). I found a bias due to failed fix attempts for bay swamp and shrubland at the rates of 2.92% and 0.76%, respectively (Table 3.2). I detected no fix-rate bias for the remaining habitats. Locations in the forested cover types of hardwood hammock, bay swamp, and pine forest showed higher mean location errors (19.5 ± 2.2 m, 18.6 ± 1.6 m, and 17.5 ± 2.4 m, respectively) than those in non-forested shrubland (5.5 ± 0.4 m) and open (11.7 ± 1.9 m) cover types (Table 3.2).

Points with PDOP ≥11.3, and points with elevation error ≥80.4 m were determined to be outliers (Figures 3.3 and 3.4). Therefore, these points were removed from the dataset. Data removed accounted for 9.87% in bay swamp, 8.16% in hardwood hammock, and 5.88% in pine forest. No points met the criteria for exclusion in shrubland or open areas, indicating that outliers were more likely in forest. Censoring 35 locations (5.44% of data) improved mean precision to 12.65 ± 0.71 m, a 14.8% improvement; but more importantly, it preferentially removed points from higher error classes. I eliminated only 3.4% of points with <60 m error, but 48.3% of points with ≥60 m error (Figure 3.5). Because censoring improved precision of test collar data, I censored actual GPS data from collared bears in the same way (i.e., locations with PDOP ≥11.3 or elevation error ≥80.4 m were eliminated from further analyses). Censored locations accounted for 5.12% of GPS data.

Second Order Selection

I analyzed landscape scale habitat selection based on 34 seasonal home ranges (25 for females, 9 for males; Table 2.4, Appendices 2 and 4), and found that bears selected habitats differently than random ($F = 64.56$, $P < 0.001$), but there was no seasonal effect ($F = 1.08$, $P = 0.396$). For annual analyses, I found no effect of sex on habitat selection ($F = 1.89$, $P = 0.192$), so bears of both genders (12 females, 6 males; Table 2.3, Appendices 1 and 3) were pooled. Bears selected habitats when choosing an annual home range ($F = 22.20$, $P < 0.001$). Bay swamp, scrub, pine forest, hardwood hammock, and citrus were selected, whereas urban was avoided (Table 3.3, Appendices 5 and 6). Agriculture, freshwater marsh, and grassland were not used differently than random.

Third Order Selection

Home range scale analysis of annual home ranges for 18 bears revealed no sex effect ($F = 1.67$, $P = 0.241$), but indicated habitat selection ($F = 25.84$, $P < 0.001$). Bears selected bay swamp and hardwood hammock, but avoided urban and grassland habitats within their home ranges (Table 3.3, Appendices 5 and 7). Distance to all other habitats did not differ from random.

I analyzed home range scale habitat selection based on 34 seasonal home ranges and found that bears selected habitats within their home range ($F = 39.75$, $P < 0.001$), and that there was a seasonal effect ($F = 2.35$, $P = 0.010$). Post-hoc tests detected a seasonal effect for 3 habitats. Bay swamp was selected more in winter than in summer ($P = 0.001$) or fall ($P < 0.001$), grassland was avoided in winter but not in summer ($P = 0.028$) or fall ($P = 0.002$), and pine forest was selected in summer ($P = 0.042$) and fall ($P = 0.013$) but not in winter. In winter, 9 bears (Table 3.3, Appendices 5 and 8) selected bay swamp, but avoided grassland and freshwater marsh. In summer, 11 bears (Table 3.3, Appendices 5 and 9) selected bay swamp, pine forest, hardwood hammock, and scrub. In fall, 14 bears (Table 3.3, Appendices 5 and 10) selected pine forest, bay swamp, hardwood hammock, scrub and freshwater marsh.

Habitat Diversity

Habitat composition in south-central Florida was different than elsewhere in Florida's occupied bear range. Agriculture and open areas made up a larger portion of the study area (10.1% and 50.2%, respectively) than elsewhere in the state (0 - 6.7% and 4.1 - 28.4%, respectively; Table 3.4). Mean patch size of agriculture and open areas (51.2 ha and 7.2 ha, respectively) was also larger than elsewhere in the state (0.4 - 13.0 ha and 0.7 - 2.0 ha, respectively; Table 3.4). Conversely, the percent composition and mean patch size of forest in south-central Florida (30.0% and 5.2 ha) were smaller than elsewhere in the state (56.5 – 82.9% and 13.0 – 95.3 ha; Table 3.4). However, within the forested areas of south-central Florida, all measures of diversity I calculated were higher than in forested areas of other occupied bear range in the state. Mean patch size of specific forest types in south-central Florida (1.42 ha) was smaller than in the rest of the state (1.63 – 5.27 ha; Table 3.5). Edge density in south-central Florida (291 m/ha) was higher than elsewhere in the state (128 – 241 m/ha; Table 3.5). Shannon's Diversity Index, H', and Shannon's Evenness Index, J', were both higher in south-central Florida ($H' = 1.32$ and $J' = 0.95$) than in the rest of the state ($H' = 0.72 – 1.23$ and $J' = 0.58 –$ 0.89; Table 3.5).

DISCUSSION

Elsewhere in Florida black bear range, swamps (except for cypress swamp in Big Cypress, Maehr 1997), upland hammocks, and pinelands (except for longleaf pine in north Florida; Wooding and Hardisky 1994, Mykytka and Pelton 1989) were used similarly or more relative to availability (Table 3.6). Shrub/scrub was ambiguous, being used more, less, or equal to availability in different studies (Table 3.6). Wetlands, disturbed/agricultural (except in Big Cypress, Maehr 1997), open/grassland, and other habitats were used similarly or less relative to availability (Table 3.6).

Another way of looking at habitat selection in other studies is the ranking of habitat types relative to each other. Of those habitats ranking in the top third of each study, 14 were swamp, 5 were pinelands, 1 was disturbed/agricultural, and 1 was riparian forest (Table 3.7). Of those habitats ranking in the middle third of each study, 6 were swamp, 6 were upland hammocks, 5 were pinelands, 2 were wetlands, 2 were disturbed/agricultural, and 1 was shrub/scrub (Table 3.7). Of those habitats ranking in the lowest third of each study, 3 were pine, 3 were shrub/scrub, 3 were wetlands, 3 were disturbed/agricultural, 2 were swamp, 2 were upland hammock, 2 were open areas, 2 were mangrove, and 1 was sabal palm hammock/coastal marsh (Table 3.7).

Results from my study show similar trends to other studies. All forests were selected, and ranked highest, especially swamps. Wetlands, disturbed and agricultural areas (with the exception of citrus), and open habitats were avoided, and tended to rank low as well. Scrub was selected and ranked second at the landscape scale in my study, whereas shrub and scrub communities had varying results in other studies, but this category included a variety of different habitats that I lumped together in an attempt to simplify interpretation. These habitats are similar in being dominated by shrubs or small trees, but their attractiveness to bears may differ greatly, as reflected in the varying results from other studies. My hypothesis that bears in south-central Florida would use forested habitats less than bears in other parts of the state was not valid. Highlands and Glades counties have a larger proportion of grassland, citrus, and agriculture than other areas inhabited by bears, but the diverse forest types in this fragmented landscape are apparently productive, and were selected by bears.

Second Order Selection

At the landscape scale, bears chose all forest types, scrub, and citrus for establishment of annual home ranges. That trees were the predominant cover in all selected habitats supports the concept that the black bear is a forest obligate (Maehr et al. 2001*b*). Although forests make up a minority of Highlands and Glades counties (15.5%, Table 3.1), they are clearly important components of bear home ranges.

Citrus was the only anthropogenic habitat selected. Citrus fruit is sometimes eaten by bears (see Chapter 4), but it is not a major food item. Therefore, it does not seem likely that citrus would truly be selected. This is supported by the fact that citrus was not selected annually or seasonally at the home range scale. Perhaps citrus showed up as a selected habitat because it is often next to bay swamp and scrub, the 2 most selected habitats. Most citrus groves in Highlands County are on the Lake Wales Ridge in former scrub habitat, and many still border scrub. Also, because bay swamps are prevalent along the ridge, many of these are in close proximity to citrus groves. Selection for citrus groves may only have been an artifact of actual selection for bay swamp and scrub.

Grassland, wetland, and agricultural habitats provide little food or cover for bears and were not selected at the landscape scale. Urban areas were avoided, as would be expected, but growing housing developments will likely bring more people to the limits of bear habitat. A diverse landscape with a variety of forest types relatively far from urban areas appeared to be the best bear habitat. This is in keeping with Whitaker and

Hamilton's (1998:424) characterization of optimum bear habitat as "relatively inaccessible terrain with thick understory and goodly supplies of mast."

Third Order Selection

At the annual home range scale, bears selected bay swamp and hardwood hammock. Bay swamp was the most selected habitat at almost every scale and season. As such, bears established home ranges with higher proportions of bay swamp than would be expected in the study area (second order selection), and then utilized the bay swamp in their home ranges more intensely than would be expected (third order selection). Hardwood hammocks tended to be less common and occurred in smaller patches than other forest types (i.e., bay swamp and pine forest), so it may have been important due to its scarcity.

I did not detect a seasonal shift in bear home range composition (second order selection), but rather a seasonal shift in habitat usage within the home range (third order selection). Apparently, bears maintained home ranges with a variety of forested habitats, and then selectively used certain habitats seasonally.

Bay swamp was selected in winter, whereas grassland and freshwater marsh were avoided. Winter is the denning season, so secure cover is the most important habitat characteristic at this time. Bay swamps, more than any other habitat type in the area, were characterized by dense vegetation, especially in the understory. In addition to structural cover, swamp habitats may provide bears with security due to their remoteness and general avoidance by humans. Grassland and freshwater marsh were the most open habitat types in the study area, with little concealing cover, few trees, and few, if any, important foods (see Chapter 4). As such, they had no value to bears as denning cover and were avoided in winter.

In summer, bears selected all forest types (i.e., bay swamp, pine forest, and hardwood hammock) and scrub. The black bear is a forest obligate and dietary generalist. Thus, a variety of forest types might benefit this space-limited population. In other areas, bears have been known to travel long distances in late summer and early fall to mast-rich areas outside their normal home ranges (Maehr 1997, Orlando 2003). Bears have most often been observed at ABS, a property dominated by scrub vegetation, from

July – November (Maehr et al. 2004). Sightings were more frequent in years of higher acorn production on ABS, suggesting that mast was an important attractant in scrub (Maehr et al. 2004). Most bears had access to each of the selected habitats within their home range, so they adjusted their habitat use patterns (third order selection) rather than engaging in short-term migrations to and from food supplies.

Fall is the season of hyperphagy for bears, so their primary activity is foraging. All forest types, scrub, and freshwater marsh were selected in fall. As the season progressed, scrub was used less as live oak and laurel oak acorns became available in hardwood hammocks. Freshwater marsh may have been important because of an ant (*Crematogaster* spp.) that bears seek out at this time of year (Maehr 1997), but in my analysis of food habits, I did not find this genus in scats collected during fall. Fall was the only season in which bay swamp was replaced by pine forest as the most selected habitat. The understories of pine flatwoods are often dominated by saw palmetto. The olive-size fruit of this species is a staple of bear diets throughout the state (Maehr and Brady 1984, Stratman 1998, Maehr et al. 2001*b*, Orlando 2003). As the fruit ripened, bears spent more time in flatwoods than at any other time of year. Black bears in south-central Florida employed a strategy consistent with optimal foraging theory; in each season, they used habitats that contained the most abundant source of nutrition, and utilized habitat patches within their regular home ranges to expend the least amount of energy (Emlen 1966, MacArthur and Pianka 1966).

Habitat Diversity

The black bear in south-central Florida selected forest in every season, but was faced with living in a landscape with more, and larger, areas of agriculture and open habitats than is found in other bear habitat in the state. Forest patches are smaller and less common than in other areas of bear habitation, yet the bear persists. Diversity of habitats valuable to the species may be the key to its survival. In Arkansas and north Florida, bears selected areas of high habitat diversity and high edge ratios (Clark et al. 1993, Stratman et al. 2001). Similarly, the heterogeneous nature of the landscape in south-central Florida, with several habitats available to an animal within a relatively small area, may be an important reason that this population persists when models suggest it should not (Hoctor 2003). The fact that among forested areas of bear habitat in the state, south-central Florida had the smallest patch size, highest edge density, highest diversity, and greatest evenness of habitats is evidence that the remaining forest here is unexpectedly productive bear habitat.

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Table 3.1. Reclassification scheme of landcover map used to analyze Florida black bear habitat selection in south-central Florida, USA, 2004 - 2006.

Reclassified category	Area (km^2)	%[a]	Original landcover categories (%[a] of each category in parentheses)
Agriculture	343	6.5	Row/field crops (3.8), Sugar cane (2.1), Other agriculture (0.4)
Bay swamp	226	4.3	Hardwood swamp (1.6), Cypress swamp [b] (1.2), Mixed wetland forest (1.1), Bay swamp (0.3)
Citrus[c]	365	6.9	Citrus (6.4)
Freshwater marsh	824	15.5	Freshwater marsh and wet prairie (9.3), Shrub swamp [b] (4.6), Cattail marsh (1.4), Sawgrass marsh (<0.1), Melaleuca[b] (<0.1)
Grassland	2071	39.1	Improved pasture (21.7), Dry prairie (12.8), Shrub and brushland [b] (1.8), Unimproved pasture (1.2), Grassland (0.5), Australian pine [b] (<0.1)
Hardwood hammock	208	3.9	Hardwood hammocks and forest (2.6), Mixed pine-hardwood forest (0.9), cabbage palm-live oak hammock (0.4), cypress/pine/cabbage palm [b] (<0.1)
Pinelands	389	7.3	Pinelands (7.2)
Scrub[c]	116	2.2	Xeric oak scrub (1.6), sand pine scrub (0.3), sandhill (<0.1)
Urban	274	5.2	High impact urban (3.6), Low impact urban (1.4), Extractive (<0.1)
Water	486	9.2	Open Water (9.0)
Other			Bare soil/clearcut[c] (2.7), Exotic plants (<0.1)

[a] Percentage of Highlands and Glades counties composed of reclassified category

[b] Original category reclassified based on comparison to aerial photos and knowledge of the study area, rather than name (e.g., many areas originally classified as Cypress swamp were in bay swamp habitat with no cypress trees)

[c] Bare/soil clearcut category was manually redigitized into citrus and scrub categories

Table 3.2. GPS collar testing in south-central Florida.

Site[a]	Tests[b]	Fix attempts	Successful	Failed	Censored	Mean error[c] (m)	Fix-rate bias (%)	Censor bias (%)	Total bias (%)
Bay	9	240	210	7	23	15.1	2.92	9.87	12.79
Hwh	7	98	90		8	15.9		8.16	8.16
Pin	9	68	64		4	16.7		5.88	5.88
Shr	13	131	130	1		5.5	0.76		0.76
Ope	10	115	115			11.7			
Total	48	652	609	8	35	14.8	n/a	n/a	n/a

[a] Bay = Bay swamp, Hwh = Hardwood hammock, Pin = Pine forest, Shr = Shrubland, Ope = Open

[b] Number of tests (a test is a unique collar/location combination)

[c] Mean error of data remaining after censoring.

Table 3.3. Habitat selection by black bears in south-central Florida, USA, 2004-2006.

Scale[a]	Season	Habitat Ranking[b]																
2	Annual	**Bay**[c]	>[d]	**Scr**	>	**Pin**	>	**Hwh**	>	**Cit**	>>	Agr	>	Fwm	>	Gra	>>	**Urb**
		0.54		0.57		0.60		0.62		0.67		0.86		1.05		1.09		1.64
3	Annual	**Bay**	>>	**Hwh**	>	Pin	>	Scr	>	Cit	>	Agr	>	Fwm	>	**Urb**	>>	**Gra**
		0.48		0.83		0.89		0.91		0.99		1.01		1.10		1.14		1.62
3	Winter	**Bay**	>>	Scr	>	Agr	>	Cit	>	Urb	>	Hwh	>	Pin	>	**Fwm**	>>	**Gra**
		0.22		0.92		0.95		0.96		0.98		1.04		1.10		1.33		1.90
3	Summer	**Bay**	>	**Pin**	>	**Hwh**	>	**Scr**	>>	Cit	>	Fwm	>	Agr	>	Urb	>	Gra
		0.63		0.71		0.73		0.78		0.96		0.96		1.04		1.07		1.23
3	Fall	**Pin**	>	**Bay**	>	**Hwh**	>	**Scr**	>	**Fwm**	>	Urb	>	Agr	>	Cit	>	Gra
		0.66		0.73		0.78		0.79		0.92		0.99		1.00		1.03		1.04

[a] 2 = 2nd Order (landscape scale selection), 3 = 3rd Order (home range scale selection)

[b] Agr = agriculture, Bay = bay swamp, Cit = citrus grove, Fwm = freshwater marsh, Gra = grassland, Hwh = hardwood hammock, Pin = pine forest, Scr = scrub, Urb = urban area

[c] Habitat types in bold had a distance ratio (below) that differed significantly ($P \leq 0.10$) from 1.00.

[d] > = a rank order difference with $P > 0.10$, >> = a rank order difference with $P \leq 0.10$.

Table 3.4. Habitat composition of primary bear range in Florida, USA.[a]

	Agriculture		Disturbed		Forest		Open		Water	
Study area	MPS	PC	MPS	PC	MPS	PC	MPS	PC	MPS	PC
Highlands-Glades	51.2	10.1	1.9	5.9	5.2	30.0	7.2	50.2	8.1	3.9
Big Cypress	13.0	6.7	2.7	7.3	13.0	56.5	2.0	28.4	0.7	1.2
Chassahowitzka	0.4	0.0	3.7	12.0	15.8	65.5	1.7	16.6	2.3	5.9
Ocala-St. Johns	1.5	3.0	1.4	8.4	13.5	66.1	1.3	17.7	2.2	4.8
Osceola	10.8	0.3	1.3	5.0	39.0	82.9	1.4	10.5	1.9	1.3
Apalachicola East	6.1	0.5	2.1	11.2	26.8	73.2	0.9	13.3	1.3	1.8
Apalachicola West	8.0	1.0	1.7	7.2	49.9	81.6	1.0	8.3	2.2	1.9
Eglin	5.7	0.5	6.7	13.4	95.3	81.6	0.7	4.1	1.1	0.5

[a] MPS = mean patch size (ha), PC = percent composition (percentage of total landscape composed of a particular habitat type).

Table 3.5. Forested habitat diversity of primary bear range in Florida, USA.

	MPS[a]		ED[b]		SDI[c]		SEI[d]	
Study area	Rank	Value	Rank	Value	Rank	Value	Rank	Value
Highlands-Glades	9	1.42	1	291	1	1.32	1	0.95
Big Cypress	8	1.63	2	241	9	0.72	6	0.65
Chassahowitzka	4	2.99	9	128	6	0.84	7	0.60
Ocala	6	2.70	5	158	2	1.23	2	0.89
St. Johns	7	2.09	3	231	5	0.95	5	0.69
Osceola	2	4.21	8	129	7	0.80	8	0.58
Apalachicola East	3	3.14	4	184	4	1.00	4	0.72
Apalachicola West	1	5.27	7	138	8	0.76	9	0.55
Eglin	5	2.82	6	156	3	1.20	3	0.87

[a] Mean patch size (ha)

[b] Edge density (m/ha)

[c] Shannon's Diversity Index

[d] Shannon's Evenness Index

Table 3.6. Habitat selection (use vs. availability)[a] by Florida black bears in south-central Florida compared to selection elsewhere in the range of the subspecies.

Study area	Habitat types[b]									Reference
	HS	SW	UH	PI	SH	WE	DI	OP	OT	
Highlands-Glades[c]	>		>	>	>	=	>=<[d]	=		This study
Highlands-Glades[e]	>		>	=	=	=	=<[f]	<		This study
Big Cypress	>	<	≥	>	≥	<	>	<	≤[g]	Maehr 1997
Chassahowitzka	≥		=	=		=	=			Maehr et al. 2003
Chassahowitzka	>	>	>	>	=				<[h]	Orlando 2003
Ocala	=			><[i]	≤					Wooding & Hardisky 1994
Osceola	>	>	=	=<[j]	<					Mykytka & Pelton 1989
Apalachicola	=	=	=	=	<	=	=			Seibert 1993

[a] (>), (≥), (=), (≤), and (<) indicate habitat types used more, marginally more, equal, marginally less, or less in proportion to availability, respectively.

[b] HS = hardwood swamp, SW = other swamp, UH = upland hammocks, PI = pine forest or plantation, SH = shrub/scrub, WE = wetlands, DI = disturbed/agricultural, OP = open/grassland, OT = other.

[c] 2nd Order Selection.

[d] Citrus used more than available, agriculture used equal to available, and urban used less than available.

[e] 3rd Order Selection.

[f] Citrus and agriculture used equal to available, urban used less than available

[g] Mangrove.

[h] Sabal palm hammock/coastal marsh.

[i] Slash pine used more than available, longleaf pine used less than available.

[j] Slash pine used equal to available, longleaf pine used less than available.

Table 3.7. Habitat rankings based on selection by Florida black bears in south-central Florida compared to rankings elsewhere in the range of the subspecies.

	Habitat rankings[a, b]									
Study area	1	2	3	4	5	6	7	8	9	Reference
Highlands-Glades[c]	HS	SH	PI	UH	DI[d]	DI	WE	OP	DI	This study
Highlands-Glades[e]	HS	UH	PI	SH	DI[f]	DI	WE	DI	OP	This study
Big Cypress	PI	DI	HS	SW[g]	UH	WE	OT[h]	SW	OP	Maehr 1997
Big Cypress	PI	HS	SW[i]	UH	DI	OT[h]	SW	WE		Land 1994
Chassahowitzka	HS	PI	DI	UH	WE					Maehr et al. 2003
Chassahowitzka	HS	SW	PI	UH	SH	OT[j]				Orlando 2003
Ocala	PI[k]	HS	SH	PI						Wooding & Hardisky 1994
Osceola[c]	HS[l]	PI	SW	HS	UH	DI	WE			Dobey et al. 2005
Osceola[e]	HS[m]	SW	HS	WE	PI	UH	DI			Dobey et al. 2005
Osceola	HS	SW	PI[n]	UH	SH	PI				Mykytka & Pelton 1989
Apalachicola	SW[o]	SW	PI	UH	HS	DI	SH			Seibert 1993
Eglin Air Force Base	OT[p]	SW	PI[q]	PI	OP					Stratman et al. 2001

[a] Rank of habitat types in order of selection with 1 most selected and 9 least selected (rankings do not necessarily imply statistical differences between levels).

[b] HS = hardwood swamp, SW = other swamp, UH = upland hammocks, PI = pine forest or plantation, SH = shrub/scrub, WE = wetlands, DI = disturbed/agricultural, OP = open/grassland, OT = other.

[c] 2nd Order Selection.

[d] Citrus, other agriculture, and urban ranked 5, 6, and 9, respectively.

[e] 3rd Order Selection.

Table 3.7 (continued)

[f] Citrus, other agriculture, and urban ranked 5, 6, and 8, respectively.

[g] Thicket swamp ranked 4 and cypress swamp ranked 8.

[h] Mangrove.

[i] Cypress swamp ranked 3 and thicket swamp ranked 7.

j Sabal palm hammock/coastal marsh.

[k] Slash pine flatwoods ranked 1 and longleaf pine ranked 4.

[l] Blackgum-bay-cypress ranked 1 and loblolly bay ranked 4.

[m] Blackgum-bay-cypress ranked 1 and loblolly bay ranked 3.

[n] Slash pine ranked 3 and longleaf pine ranked 6.

[o] Shrub swamp ranked 1 and cypress ranked 2.

[p] Riparian.

[q] Pine production areas ranked 3 and sandhills ranked 4.

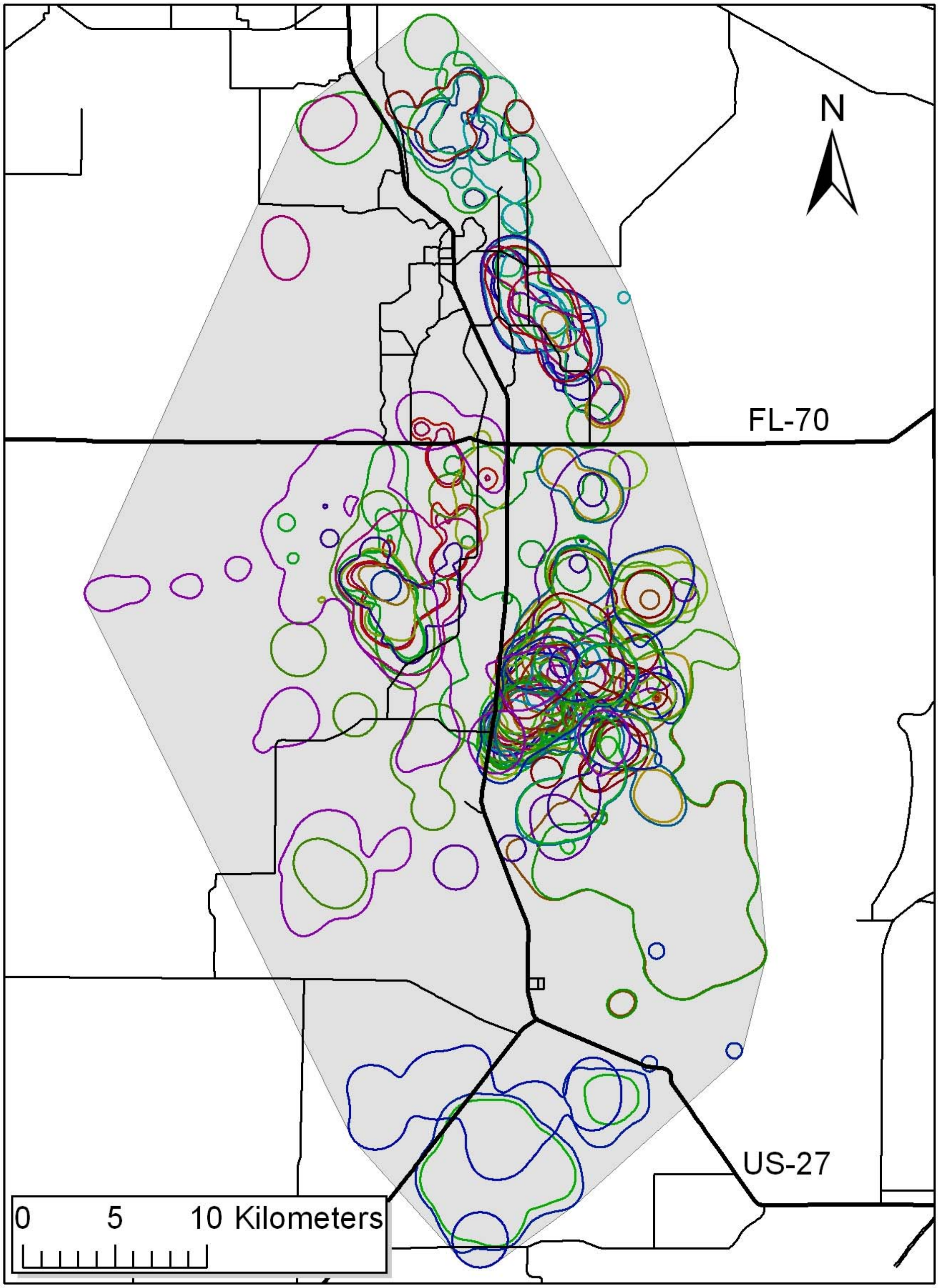

Figure 3.1. Study area MCP (gray) and 95% FK home ranges used in Euclidean distance analysis of black bear habitat selection in south-central Florida, 2004 - 2006.

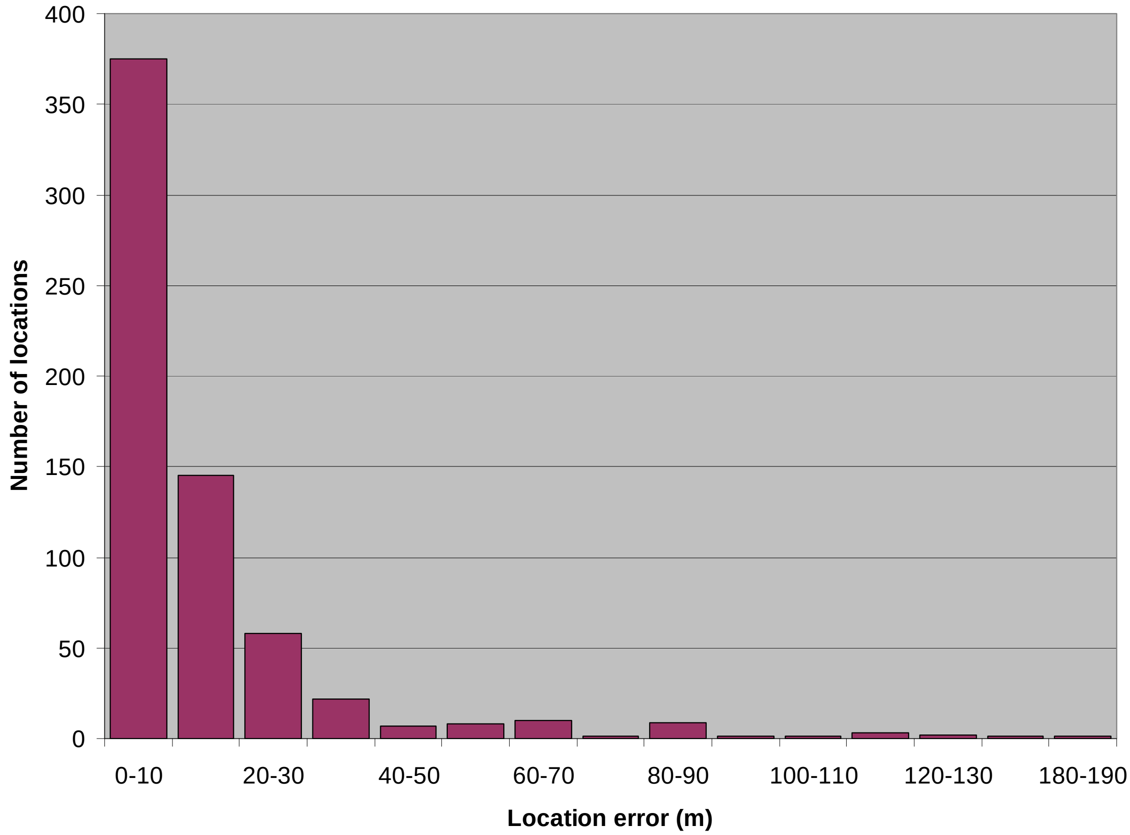

Figure 3.2. Location error from GPS collar testing in south-central Florida, USA, 2004 - 2006.

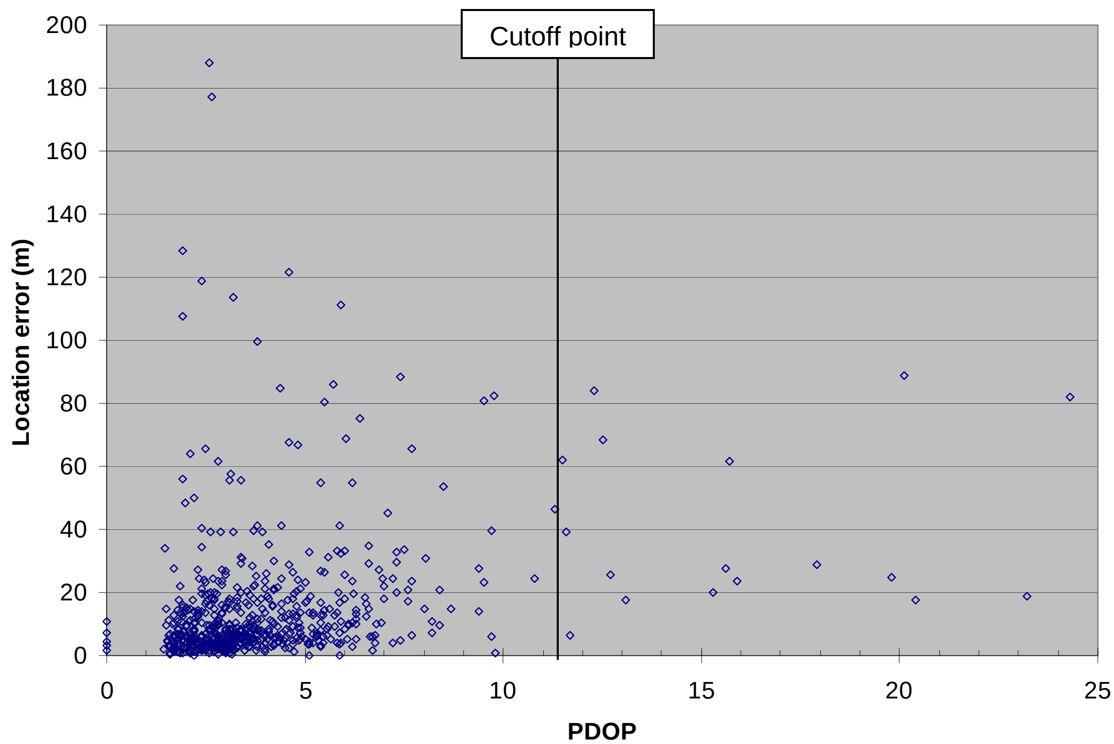

Figure 3.3. Distribution of PDOP and location error from GPS collar testing in south-central Florida, USA, 2004 - 2006.

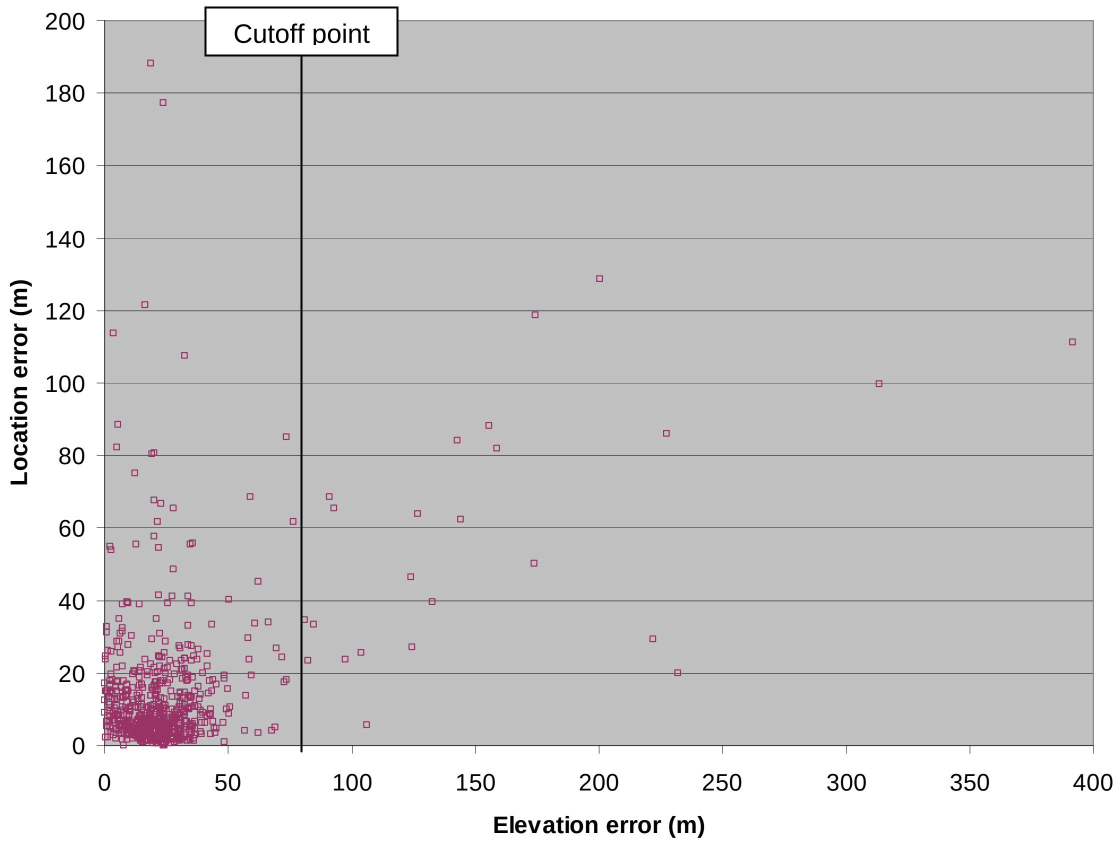

Figure 3.4. Distribution of elevation error and location error from GPS collar testing in south-central Florida, USA, 2004-2006.

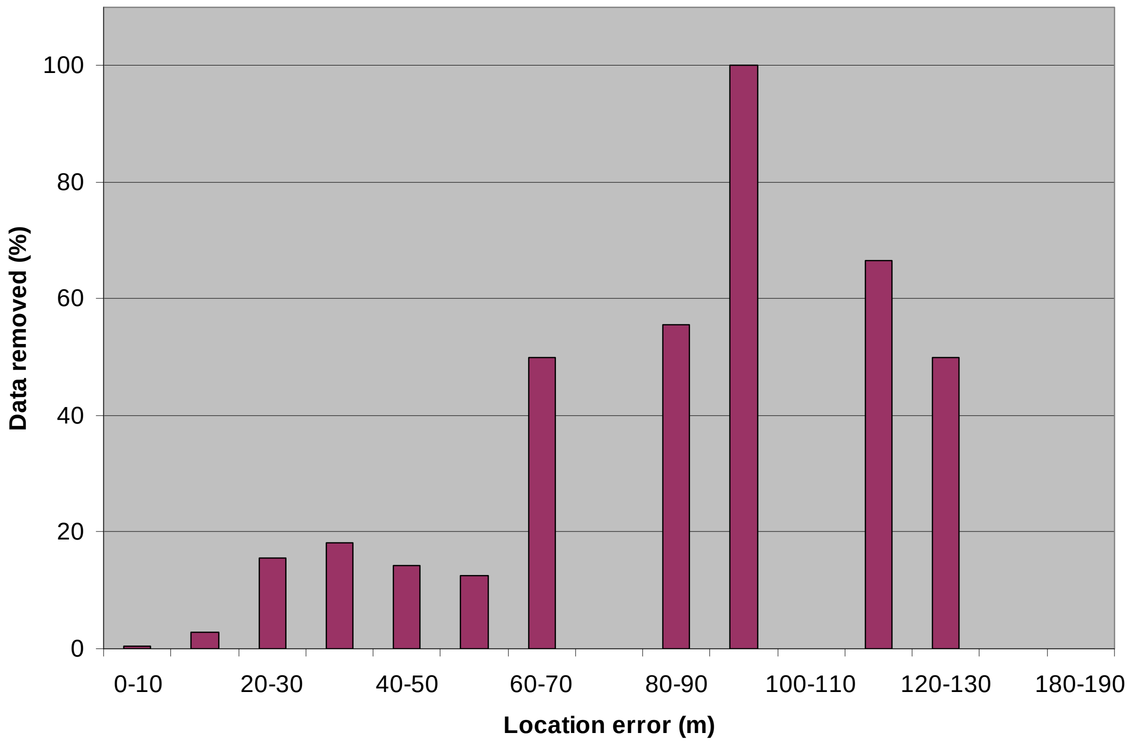

Figure 3.5. Percentage of locations removed by PDOP and elevation error filtering of GPS collar testing data in south-central Florida, USA, 2004 - 2006.

CHAPTER FOUR
FOOD HABITS

Bears select a wider variety of foods than most species in the order Carnivora, and diet varies seasonally (Whitaker and Hamilton 1998). In spring they feed primarily on grasses and forbs, whereas energy-rich fruits and mast are more important in summer and fall. The diet of the black bear influences a variety of behaviors and demographic characteristics. Food resources can affect home range size, habitat use, human-bear interactions, size and growth rates of populations, reproduction, and individual mass growth (Beeman and Pelton 1980, Maehr et al. 2001*a*, Benson and Chamberlain 2006). Seasonal shifts in home range size and habitat use are often the result of shifting food resources at local and landscape scales.

Habitat selection and food habits studies are complementary investigations, with each potentially contributing to interpretation of the other. When one aspect of a study (e.g., radio-telemetry or scat analysis) misses some important component in the natural history of a population, the other may reveal the oversight, thereby affording a more complete and accurate assessment of habitat use and food habits (Benson and Chamberlain 2007).

In my study area, the distribution of habitats is unique among Florida bear populations. The south-central Florida landscape is more fragmented than other parts of the state that harbor bears, and agriculture is nowhere more widespread in Florida bear range than in Highlands and Glades counties (Hoctor 2003, Maehr et al. 2004). I studied food habits of the south-central Florida black bear to learn how this unusual arrangement of habitats influences nutrition, movements, and conservation of this small population.

METHODS

I collected scats at trapsites, and opportunistically during other fieldwork. Each scat was placed in a plastic bag, labeled with date and UTM coordinates, and frozen. I later thawed and dissected scats by rinsing each one through a standard kitchen strainer (1.5 mm mesh). Food items were identified to the lowest possible taxon using a variety of field guides and identification manuals (Martin and Barkley 1961, Borror and White 1970, U.S. Forest Service 1974, Borror et al. 1989, Milne and Milne 1998, Elzinga 2004, Marshall 2006). I ranked all items in each scat from most to least prevalent based on visual estimates of relative volume.

I calculated annual and seasonal percent composition (percentage of total items that a particular item comprised) and percent frequency (percentage of scats that contained a particular item) of each food item at the lowest identifiable taxon (Whitaker 1988, 1994). For analysis of ranks based on relative volume, I reclassified foods by combining taxonomically related items to reduce the number of categories. Unidentified and trace or incidental items were also eliminated from further analysis to simplify results and increase power of statistical tests. I calculated a mean ranking for each food and ranked each relative to other items in each season. Due to unequal sample sizes among seasons, I did not annually rank foods by volume. I used a Kruskal-Wallis test to determine if rankings differed among food items within each season. When selection was detected, I performed a series of nonparametric post-hoc tests using the KSPOST macro in SAS to determine which foods differed. As in my other analyses, seasons were defined as: winter (January – April), summer (May – August), and fall (September – December). All statistical analyses were conducted in SAS (SAS Institute 2003) with a rejection level of $\alpha = 0.05$.

RESULTS

Diversity

I recorded 531 occurrences of 55 different items from a sample of 166 scats (Table 4.1). Of these scats, 32 were collected in winter, 34 were collected in summer, and 95 were collected in fall. Collection date was missing from 5 samples, so these scats were included in annual, but not seasonal, results. Winter scats contained 91 occurrences of 26 different items (Appendix 11), summer scats contained 147 occurrences of 39 different items (Appendix 12), and fall scats contained 277 occurrences of 46 different items (Appendix 13).

Percent Composition

Overall, arthropods (mainly insects) were the most prevalent group by percent composition, followed by soft mast, hard mast, anthropogenic foods, vegetation, and vertebrates (Figure 4.1). The most common groups in winter were anthropogenic food, arthropods, hard mast, and vegetation (Appendix 11, Figure 4.1). Common groups in summer were arthropods and soft mast (Appendix 12, Figure 4.1). Arthropods, soft mast, and hard mast were most prevalent in fall (Appendix 13, Figure 4.1).

Percent Frequency

The most frequently eaten foods overall were acorns, saw palmetto fruit, Florida carpenter ants, vegetation, corn, beetles (adults or larvae), and grapes (Table 4.1). The most frequent food items in winter were acorns, corn, leafy green vegetation, "deer chow" pellets (commercial feed intended for deer at wildlife feeding stations), and weevil larvae (Appendix 11). Frequent summer foods were ants (especially Florida carpenter ants), grapes, vegetation (including grass), corn, bumble bees, termites, citrus fruit, saw palmetto fruit, and feral hog (Appendix 12). Frequent food items in fall were saw palmetto fruit, acorns, Florida carpenter ants, corn, hickory nuts, and weevil larvae (Appendix 13).

Relative Volume

The most important foods in winter (by relative volume) were acorn, vegetation, corn, and deer chow (Table 4.2). Important summer foods were ant, vegetation, grape, and other fruit (Table 4.2). Top-ranked fall foods were saw palmetto fruit and acorn (Table 4.2).

DISCUSSION

The south-central Florida black bear appears to have an unusually diverse diet, with 55 total items identified. However, most of these items are rare (29 items account for <1% each), and some are likely incidental rather than intentionally consumed. Still, breadth of diet may be important for survival. For instance, saw palmetto is susceptible to periodic mast failures (Maehr and Brady 1982), while swamp tupelo is more consistent (Maehr and Brady 1984). Local acorn crops also exhibit annual productivity fluctuations (Abrahamson and Layne 2003) that are associated with annual variation in black bear observations on the oak-rich ABS (Maehr et al. 2004). A variety of mast species, including less preferred foods such as swamp tupelo, may be important in years when some mast crops fail (Maehr and Brady 1984, Maehr and DeFazio 1985).

The most numerous food items overall were acorns, saw palmetto fruit, Florida carpenter ants, and corn. The first 3 are naturally prevalent in the study area, whereas the last is available to bears only where supplied by humans. The 3 natural foods are common throughout much of Florida and are major items in the diet of other bear populations (Maehr and Brady 1984, Maehr and DeFazio 1985). This finding supports the concept of the black bear as a generalist omnivore. Such opportunism makes the bear adaptable, and may explain in part its continued existence in the highly fragmented landscape of south-central Florida.

Of the most frequently consumed foods, corn and ants were both fairly common throughout the year, while acorns were rarely eaten in summer, and saw palmetto was common only in fall. Sample size was much higher in fall (95 scats) than in winter (32 scats) or summer (34 scats), but bears also consume much greater quantities of food in fall, so scats are more easily found then, and overall totals may reflect total annual diet. Still, the best way to understand which foods are biologically significant to the species is to consider diet seasonally.

Fewer and lower quality natural foods were available to the black bear in winter than in other seasons. During this time, bears in south-central Florida utilize a dwindling crop of acorns, and then turn to other resources, including anthropogenic foods. Winter is the only season when leafy green vegetation was one of the top food items. Corn and deer feed pellets were available at wildlife feeders on many private properties throughout the study area. Feeders were generally intended to supplement the diets of white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Melleagris gallopavo*), but were frequented by many other species of wildlife, including mourning dove (*Zenaida macroura*), northern bobwhite (*Colinus virginianus*), sandhill crane (*Grus canadensis*), squirrels (*Sciurus spp.*), feral hog (*Sus scrofa*), and black bear. While the species' distributional limitations and decreased population can be attributed to human causes (e.g., habitat destruction and fragmentation, and anthropogenic causes of mortality), this is one instance where bears may benefit from human activity. Feeders may be especially important to bears in times of food scarcity, such as winter. Much as the introduced exotic Brazilian pepper (*Schinus terebinthifolius*) provides an energy-rich winter food in south Florida (Maehr 1997), corn and deer feed supplement winter diets in Highlands and Glades counties. This artificial abundance may promote higher activity than would have occurred before European settlement.

Hymenopterans were an especially important source of food in the summer. The black bear throughout its range eats mostly plants, however, colonial insects such as ants and bees provide a concentrated source of highly nutritious food (Maehr 1997). Soft mast, such as grapes, saw palmetto fruits, blackberries, and blueberries, was also readily eaten in summer. Bears are "...inordinately fond of fruits, consuming great quantities..." (Whitaker and Hamilton 1998:425). Maehr et al. (2001*b*) suggested that citrus is among the foods not eaten by the black bear, and indeed the fruits had not been identified in the studies they summarized. An important finding of my study is that bears in this population regularly consumed citrus fruit (percent frequency = 11.76 in summer, 6.32 in fall, and 7.23 annually). While citrus is not a major component of the diet, at least some individuals occasionally ate it. Bear F9 frequented, and may have lived entirely within, a citrus grove for up to 6 weeks. It seems probable that citrus fruit was her main sustenance during this period. There is a certain type of cattle food that contains orange pulp (Cary Lightsey, XL Ranch Operator, pers. comm.), so it is possible that some portion of the citrus seeds and pulp found in scats came from this source. However, several people in the area have reported watching bears eat oranges. Grove owners contacted FFWCC and researchers on this project on 2 separate occasions, complaining of bears eating oranges and damaging young citrus trees. With this revelation, it seems plausible that "The diet of the black bear in Florida is so variable that it might be easier to list species that it does not consume" (Maehr et al. 2001*b*:6).

During fall bears become hyperphagic in preparation for winter. They have been documented to increase weight by as much as 100% in fall (Hellgren et al. 1990). In my study area, foods that facilitated this weight gain were saw palmetto fruits (4.9% protein, 9.4% fat) and acorns (5.9% protein, 4.3% fat) (Maehr 1997). These mast crops were often more abundant than any other food source and were clustered. Bears focused on these items in the fall, but still utilized other resources when available. Florida carpenter ants, corn, hickory nuts, and weevil larvae were each found in >10% of fall scats (Appendix 13). The coleopterans I refer to as "weevil larvae" were only found in scats which also contained acorns. I believe these to be larvae of acorn weevils (*Curculio* spp.) ingested via infested acorns. Fall diet of the black bear in south-central Florida reflects general preferences of the species. Saw palmetto is the single most universal item in the diet of the black bear throughout Florida (Maehr et al. 2001*b*). Similarly, acorns are often prevalent in the diet of the black bear throughout North America (Cottam et al. 1939, Bennett et al. 1943, Harlow 1961, Landers et al. 1979, Beeman and Pelton 1980).

A general trend has often been noted for the black bear, whereby preferred diet shifts from vegetation in winter and early spring to soft mast in summer, and then to hard mast in fall (Maehr and Brady 1984, Whitaker and Hamilton 1998). Insects can also be important (Maehr and Brady 1984, Whitaker and Hamilton 1998). This basic trend was observed in south-central Florida, with some notable exceptions. While grapes and other soft mast were important foods in summer, saw palmetto fruit did not ripen until fall. Thus, soft mast was prevalent in both summer and fall in south-central Florida. In addition, enough acorns persisted beyond fall to make hard mast an important dietary component in winter as well as fall. Insects were most abundant in summer, but because of warm climate, they were fairly common in scats from all seasons.

Table 4.1. Annual food habits of the black bear in south-central Florida, 2004 - 2006.

Food item	*n*	% Composition	% Frequency
Arthropods	162	30.5	53.6
Insects	157	29.6	53.0
Hymenoptera	79	14.9	34.3
Formicidae	67	12.6	31.9
Florida carpenter ant (*Camponotus floridanus*)	49	9.2	29.5
Acrobat ant (*Crematogaster* spp.)	7	1.3	4.2
Unknown ant	11	2.1	6.6
Apidae	10	1.9	6.0
Bumble bee (*Bombus* spp.)	5	0.9	3.0
Unknown bee	5	0.9	3.0
Vespidae	2	0.4	1.2
Guinea wasp (*Polistes exclamans*)	1	0.2	0.6
Yellowjacket (*Vespula* spp.)	1	0.2	0.6
Coleoptera	43	8.1	22.9
Weevil larva (*Curculio* spp.)	15	2.8	9.0
Bess bug (*Odontotaenius disjunctus*)	9	1.7	5.4
Scarab beetle (Family Scarabaeidae)	2	0.4	1.2
Unknown beetle larva	9	1.7	5.4
Unknown beetle	8	1.5	4.8
Isoptera	13	2.5	7.8
Subterranean termite (Family Rhinotermitidae)	8	1.5	4.8
Unknown termite	5	0.9	3.0
Diptera			
Fly larva	1	0.2	0.6
Odonata			
Dragonfly nymph	1	0.2	0.6
Unknown insect adult	13	2.5	7.8
Unknown insect larva or pupa	7	1.3	4.2
Arachnids			
Acarina			
Tick (Family Ixodidae)	5	0.9	3.0

Table 4.1 (continued)

Soft Mast	130	24.5	61.4
Fruit	101	19.0	54.8
Saw palmetto (*Serenoa repens*)	61	11.5	36.8
Grape (*Vitis* spp.)	17	3.2	10.2
Gallberry (*Ilex glabra*)	7	1.3	4.2
Blueberry (*Vaccinium* spp.)	5	0.9	3.0
Blackberry (*Rubus* spp.)	4	0.8	2.4
Swamp tupelo (*Nyssa biflora*)	3	0.6	1.8
Palmetto (*Sabal* spp.)	2	0.4	1.2
Dahoon holly (*Ilex cassine*)	1	0.2	0.6
Brazilian pepper (*Schinus terebinthifolius*)	1	0.2	0.6
Other Seeds	4	0.8	2.4
Ragweed (*Ambrosia* spp.)	2	0.4	1.2
Smartweed (*Polygonum* spp.)	1	0.2	0.6
Unknown grass seed	1	0.2	0.6
Unknown fruit or seed	25	4.7	15.1
Hard Mast	79	14.9	42.8
Acorn (*Quercus* spp.)	63	11.9	38.0
Hickory nut (*Carya* spp.)	16	3.0	9.6
Anthropogenic	75	14.1	30.1
Corn (*Zea mays*)	41	7.7	24.7
“Deer Chow” pellets	13	2.5	7.8
Citrus fruit (*Citrus* spp.)	12	2.3	7.2
Unknown grain	7	1.3	4.2
Paper	1	0.2	0.6
Plastic	1	0.2	0.6
Vegetation	47	8.9	27.7
Vegetation (general)	12	2.3	7.2
Leafy green vegetation	11	2.1	6.6
Plant fiber	10	1.9	6.0
Grass	10	1.9	6.0
Palm heart	3	0.6	1.8
Lichen	1	0.2	0.6

Table 4.1 (continued)

Vertebrates	30	5.7	16.3
Mammals	20	4.0	12.7
Raccoon (*Procyon lotor*)	6	1.1	1.8
Feral hog (*Sus scrofa*)	4	0.8	2.4
Nine-banded armadillo (*Dasypus novemcinctus*)	4	0.8	2.4
White-tailed deer (*Odocoileus virginianus*)	3	0.6	2.4
Unknown hair	4	0.8	3.6
Reptiles			
Gopher tortoise (*Gopherus polyphemus*)	4	0.8	2.4
Birds			
Feathers	1	0.2	0.6
Unknown bones/cartilage	4	0.8	2.4
Unknown	8	1.5	4.2
Total	531	100.0	319.9

Table 4.2. Seasonal rankings[a] (relative volume) of food items of the black bear in south-central Florida, USA, 2004 – 2006.

Food item	Winter	Summer	Fall
Acorn	1 a	14 fg	2 ab
Vegetation	2 ab	2 ab	7 def
Corn	3 abc	5 bcd	6 cdef
Deer Chow	4 abcd	13 efg	13 g
Coleoptera	5 bcde	10 defg	4 cd
Other fruit or seed	6 cde	4 abc	5 cde
Other insect or arthropod	7 de	8 cdef	10 efg
Ant	8 de	1 a	3 bc
Vertebrate	9 de	7 cde	8 def
Isoptera	10 e	9 defg	11 fg
Bee or wasp	11 e	6 cde	15 g
Saw palmetto fruit	12 e	12 efg	1 a
Grape	14 [b] e	3 abc	14 g
Citrus fruit	14 [b] e	11 efg	12 fg
Hickory nut	14 [b] e	15 g	9 def

[a] Rankings without a common letter are different ($P < 0.05$).

[b] This food item was not found in this season. Rankings of all items not found in a season were averaged.

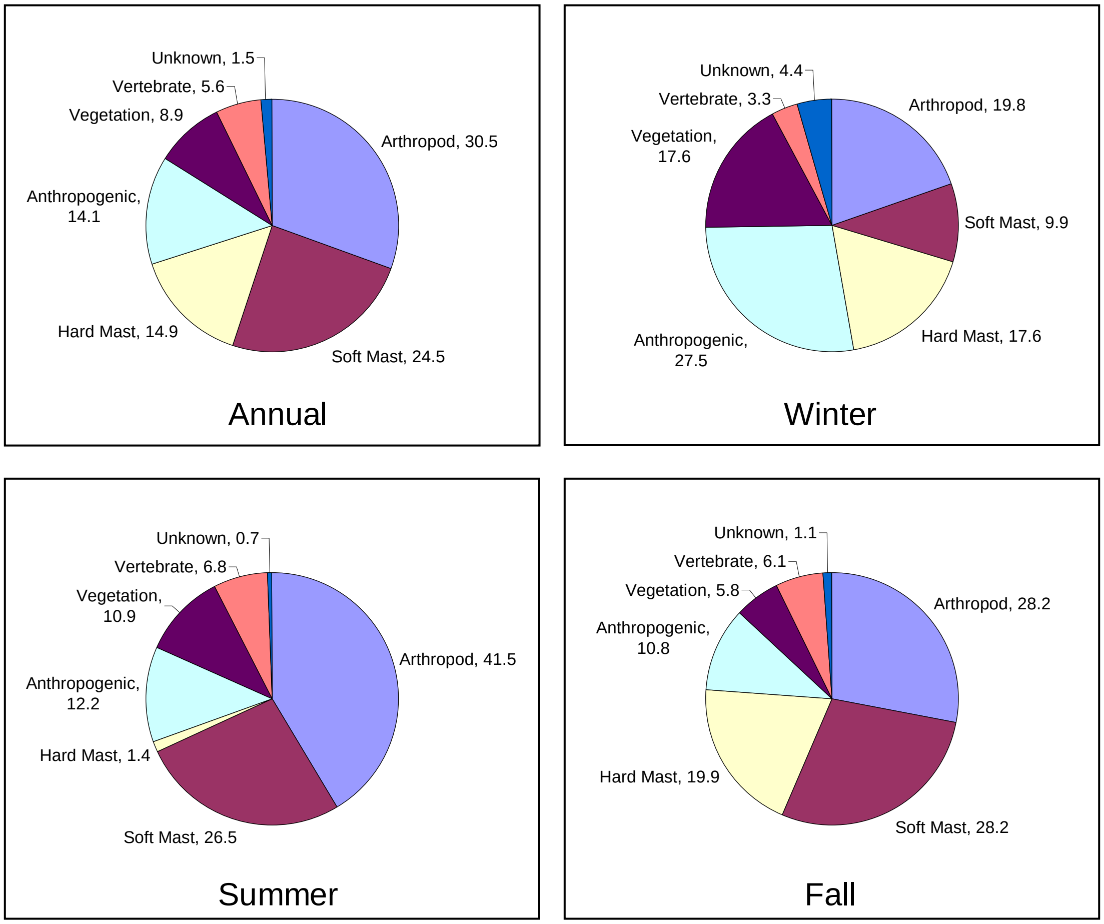

Figure 4.1. Relative abundance (percent composition) of food items of the black bear in south-central Florida, 2004 - 2006.

CHAPTER FIVE
CONCLUSION

As human populations expand and demand more space and natural resources, global biodiversity suffers (Ehrlich 1988). Twenty years ago, almost 40% of potential net primary productivity on Earth was consumed or eliminated (via reduced productivity) by our species (Ehrlich 1988). The anthropogenic impact is so great that an area's species richness and human population density can predict the density of threatened species (McKee et al. 2004). One way of depicting the damage is the current rate of extinctions, 100 – 1000 times faster than the normal (i.e., not human-caused) background extinction rate (Society for Conservation Biology 2007). Wilson (1984:121) singled out loss of biodiversity as the biggest current environmental problem: "The one process now going on that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendants are least likely to forgive us."

The biggest threats to global biodiversity are habitat loss and fragmentation, habitat degradation, introduced species, and overharvest (Society for Conservation Biology 2007). The same factors threaten the black bear in south-central Florida. The most prevalent of these threats in Highlands and Glades counties are the loss and fragmentation of bear habitat. Examples of habitat degradation include timber harvest that eliminates potential den sites in large hollow trees, conversion of natural forests to plantations, altered water flow that reduces the availability of wetland forests to bear occupation, and disturbances caused by ATVs. Florida seems to be especially susceptible to invasions of exotic species because it lacks the cold winters that control or eliminate many invaders in more northern climes. For example, Old World climbing fern (*Lygodium microphyllum*) invades Florida's wetland habitats (including bay swamps), climbing into tree tops and shading out native plants. It is also a fire hazard, facilitating the spread of fires into the forest canopy and over wet areas that would normally serve as fire breaks (Langeland and Burks 1998). Overharvest is a particular threat in small populations. Although the bear is now protected from hunting in Highlands and Glades counties, substantial harvests were recorded in the past (Maehr et al. 2004), and poaching continues today. Couple illegal shootings with the incidence of roadkills in the area, and human-caused bear mortalities account for most local bear deaths. The combination of these factors threatens the population's continued existence.

Noss (1990:360-361) defined five categories of species that may be conservation priorities: "(1) ecological indicators: species that signal the effects of perturbations on a number of other species with similar habitat requirements; (2) keystones: pivotal species upon which the diversity of a large part of a community depends; (3) umbrellas: species with large area requirements, which if given sufficient protected habitat area, will bring many other species under protection; (4) flagships: popular, charismatic species that serve as symbols and rallying points for major conservation initiatives; and (5) vulnerables: species that are rare, genetically impoverished, of low fecundity, dependent on patchy or unpredictable resources, extremely variable in population density, persecuted, or otherwise prone to extinction in human-dominated landscapes." The black bear in south-central Florida may fit into all of these categories. Bears are sensitive to land use changes, and therefore, good indicators of ecosystem health (Dobey et al. 2005). Distribution of the bear in Florida could be an indicator of landscapes that retain some critical proportion of the original forested habitats, and an indicator of the quality of those habitats. The bear may act as a keystone species by virtue of its role as a seed disperser (Maehr 1984, 1997, Maehr et al. 2001*b*) and its relations with the giant palm weevil and native palms (Maehr et al. 2005). Of special importance is the bear's long-distance and voluminous seed dispersal of saw palmetto, another keystone species (Maehr and Layne 1996, Maehr et al. 2001*b*). The Florida black bear may be an even better umbrella species than the Florida panther, with more threatened species sharing lands proposed for conservation (Cox et al. 1994, Simberloff 1998, Maehr et al. 2001*b*). As a popular and charismatic species, the black bear would also be an excellent flagship for biodiversity conservation in Florida (Maehr et al. 2001*b*). With a more extensive distribution than the Florida panther, the black bear, Florida's largest terrestrial carnivore, could draw support from people in areas where the former does not reside (i.e., most of the state). Last, in accord with Noss' (1990) definition of a vulnerable species, the black bear in south-central Florida is rare (U.S. Fish and Wildlife Service 1998), genetically impoverished (Dixon 2004), of low fecundity (this is true of bears in general, Whitaker and Hamilton

1998), dependent on patchy or unpredictable resources (Cox et al. 1994, Hoctor 2003, Maehr et al. 2004), persecuted (Maehr et al. 2004; see pages 21-24, this study), and prone to extinction in a human-dominated landscape (Maehr et al. 2004). By any of these criteria, the south-central Florida black bear warrants priority conservation status.

To effectively conserve biodiversity, including the genetic variability of a species, units below the species level must be preserved, though defining these units can be challenging (Moritz 2002, Green 2005). The black bear in south-central Florida should be a conservation priority whether managers are concerned with protecting biodiversity at the species level (i.e., the black bear species could persist without the Florida metapopulation, but genetic diversity would be sacrificed through loss of the southernmost part of the species' range in the east), the subspecies level (i.e., the Highlands-Glades population has the potential to connect the Big Cypress population to north Florida, Georgia, and Alabama populations of the Florida subspecies *U. a. floridanus*), the statewide level (i.e., maintaining this population's function as a stepping stone in a statewide metapopulation), or the local level (i.e., persistence of the relatively isolated population in Highlands and Glades counties).

The black bear was an enigma in south-central Florida. The fact that Hoctor's (2003) habitat model predicted bear occupancy for the rest of the state, but not in Highlands and Glades counties begged the question "How can it persist here at all?" Certainly the diversity of food and habitat, as well as the spatial context within which bears find these resources are factors in its persistence. In south-central Florida, as elsewhere within its range, home range selection, habitat use, and food habits are intertwined. Understanding any one of these aspects of bear ecology is heightened by understanding the dynamic interactions of all three.

The important foods (i.e., acorns, saw palmetto fruit, Florida carpenter ants, beetles, grapes) in the annual diet of the south-central Florida black bear derived from the forested habitats selected for home ranges (bay swamp, hardwood hammocks, and pine forest), and influenced how they were used. Corn would appear to be an exception, because it is not a natural item in forests, but wildlife feeders were usually placed in forest, so even this anthropogenic food fit the pattern. Among females, the smallest home ranges (e.g., F1, F4, F8) tended to be in areas with an interspersion of different habitats. These 3 bears were all adults that raised cubs. According to optimal foraging theory, they bears were maximizing feeding efficiency relative to energy output (Emlen 1966, MacArthur and Pianka 1966), a strategy that may promote fast growth, as well as high cub production and survival (Erlinge 1981, Sih 1982). By including multiple habitat types in a small area, they had access to a variety of food sources in close proximity. This arrangement of habitats may preclude the need for dramatic seasonal home range shifts that can put bears at risk of highway mortality.

Reproductive performance is of particular importance in small populations. To protect vulnerable young cubs, female black bears generally prefer natal dens in sheltered locations such as excavations under boulders, rock ledges, or tree roots, in caves, or in hollow trees, sometimes as high as 20m (Whitaker and Hamilton 1998). As with other studies in Florida (Dobey et al. 2005, Garrison et al. 2007), dens were generally ground nests built in dense cover. One notable exception was a hollow bay tree stump that was further excavated (109 × 64 cm) for use by an adult female and her yearling cub (F8 and F12) during winter of 2005. Maehr (1997) found a similar den in south Florida, a hollow cypress stump repeatedly used as a natal den by the same animal. At 4 of 6 female dens visited in winter 2005, I found a series of 2 – 5 nests within 20 m of each other. Windfalls were used for cover at 2 of these dens, as well as the den of an adult male (M1). An unusually active hurricane season in 2004 provided shelter in the form of wind-thrown bay trees, cover that may remain useful for many years.

In winter, south-central Florida bears selected bay swamps. I suspect that the closed canopy and thick understory in bay swamps provide some of the best security cover in the area. This probably contributes to year round selection of swamps, but may be especially important in winter when bears seek dense cover for denning. Although some bears remained active and fed throughout the winter, home ranges tended to be smaller than in other seasons. Leafy green vegetation was common only in winter scats. Other Florida food habits studies listed wetland plants such as alligator flag (*Thalia geniculata)* and pickerel weed (*Pontederia cordata*) as important food items during winter and spring, when other foods are scarce (Maehr and Brady 1984, Maehr 1997). Bears may have obtained this food within the bay swamps preferred for denning, but acorns were the most common winter food, and most oaks in the area are mesic or xeric species that do not grow in wetlands. Here, the juxtaposition of bay swamps to hardwood hammocks (with live oak and laurel oak), or to scrub habitats (with many oak species) may be an energetic benefit to bears.

All forest types and scrub were selected in summer, and diet was also varied. Grapes and Florida carpenter ants were especially prevalent, but corn, vegetation, bees, citrus fruit, and feral hogs were also eaten with some regularity. Summer home ranges were large relative to other seasons, which may have been due, in part, to the diversity of habitats and food resources used at this time of year. More importantly, summer incorporates the breeding season, when males move widely in search of estrous females.

Fall was the only season when bay swamp was not the most selected habitat. Pine flatwoods often have a saw palmetto understory, and were the habitat most selected by bears in fall – clearly a function of food distribution. Fall diets were diverse, but dominated by few species; saw palmetto fruit and acorns were often the only items identified in scats. Bay swamp, hardwood hammock, scrub, and freshwater marsh were also selected in fall. Forests were consistently the most important habitat types for all bears during all seasons.

MANAGEMENT IMPLICATIONS

Metapopulation Insights

It has been suggested that the Florida black bear should be managed as a metapopulation (Hoctor et al. 2000, Maehr et al. 2001*b*, Maehr et al. 2003, Dixon et al. 2006). The fragmented landscape and isolated nature of the Highlands-Glades population provide insight into how such a metapopulation structure could evolve. One observation that can be gleaned from telemetry data in Highlands and Glades counties is that agricultural habitats were permeable to bear movements. This distinguishes agricultural lands from other types of development which were barriers to bear movement. While open and human-altered areas such as cattle pasture and citrus groves may not independently support resident bears, they can serve as linkages between areas of higher quality habitat. The eastern side of the Lake Wales Ridge in southern Highlands County is an excellent example of this idea. The Turkey Track Ranch and Hendrie Ranch complex in southern Highlands County is the stronghold of bears in the area, as more adult females were documented here than anywhere else in the study area. Northeast of Lake Placid are 4 conservation properties (Clements tract, Royce Ranch, Highland Park Estates, and Holmes Avenue) that also support resident bears (Figure 5.1). Between these two subpopulation centers is an archipelago of forested islands in a sea of pasture and citrus groves. Collared bears traversed this matrix numerous times, remaining in forest as much as possible. Because I rarely found collared bears in the open, it is likely that they crossed pastures quickly, using the tree islands as stepping stones. While these small forest patches may not be areas that provide resources other than cover, they could be some of the most important pieces of habitat for local bear conservation because of their apparent linkage function. Similarly, the Highlands-Glades black bear population is a strategic part of a statewide metapopulation (Figure 5.2). The long-distance movement of a male black bear from the Big Cypress population in south Florida to Highlands County has been documented (Maehr et al. 1988). This movement was long enough to connect any 2 populations in the state, proving that bears have the dispersal capability to maintain a metapopulation structure in the state, if adequate travel corridors are present. Dixon (2004) showed that bears in the Highlands-Glades population are more closely related to those in the Big Cypress population than to other bear populations in the state, which indicates that other bears have not only traveled between these 2 populations, but also reproduced, even if infrequently. Although south-central Florida supports one of the state's smallest bear populations, it appears to be the only practical linkage for movement between the Big Cypress population and bear habitat to the north.

Conservation Properties

Highlands and Glades counties do not contain a single conservation property ≥10,000 ha, the minimum black bear sanctuary size proposed by Hellgren and Maehr (1992). However, there are 20 separate conservation properties in Highlands County (including ABS) that, when combined, total 14,094 ha. I documented bears using 12 of these properties (Figure 5.1). When combined with 3 important private ranches that promote biodiversity conservation, total protected land covers 21,914 ha.

Foremost among these private properties is the Turkey Track Ranch, owned by the Smoak family, on the southern border of Highlands County. This ranch has a conservation easement in place to protect the land and natural resources in perpetuity. It is a working cattle ranch, but managed in a sustainable and environmentally responsible way. The neighboring Hendrie Ranch does not have a conservation easement in place, but the owners maintain extensive natural areas that are inaccessible to most people. The Hendrie bay swamp may be the single most important piece of bear habitat in the area. These two properties combine to form a block of contiguous forest that breaks the pattern of fragmentation so prevalent in the rest of the study area. West of the Lake Wales Ridge, the XL Ranch is another example of a working cattle ranch that promotes conservation and provides valuable habitat for the black bear. The owners, the Lightsey family, work closely on conservation issues with the neighboring Archbold Biological Station. ABS is a privately funded non-profit research station. Known for long term ecological research on scrub communities, Lake Wales Ridge endemic species, and the scrub jay (*Aphelocoma coerulescens*), ABS is virtually at the center of the study area and was used by 12 bears during this study.

While these private properties have been essential to the persistence of the black bear in south-central Florida, further habitat improvement and conservation on private lands in the region will be necessary. FFWCC, ABS, non-profit organizations such as The Nature Conservancy, and the University of Kentucky should partner with local landowners to promote bear conservation on private lands whenever possible. Extension and outreach services could help conservation-minded landowners protect or improve bear habitat on their properties. Education efforts (e.g., meetings of local farmers and ranchers, school groups, community interest groups, and ABS summer camps) focused on bears could spark interest in bear conservation. Lastly, conservation easements have already proven effective at conserving important pieces of bear habitat in the area; securing easements on more private lands would be extremely beneficial by protecting habitat on such lands in perpetuity and including local citizens as part of the solution.

Although Highlands and Glades counties have less public land than other bear-inhabited portions of the state, FFWCC owns 14 properties in the area that form a network of refugia for wildlife. We have seen little sign of use by bears at 4 of these properties (<76 ha each), but the others are frequented by bears and appear to be important. These include the Holmes Avenue, Royce Ranch, and Clements tract properties northeast of Lake Placid, as well as the Lake Placid Scrub Preserve and McJunkin properties adjacent to ABS. Private lands are the most important properties for bear conservation in south-central Florida, but public lands such as FFWCC properties may be more likely to support additional bears in the future because habitat restoration and management can improve conditions for bears, and public agencies have the opportunity to protect important pieces of the landscape through land acquisition. New acquisitions and management of existing properties should incorporate a diversity of forest habitats, as suggested for bear management in Ocala National Forest (Moyer et al 2008) and statewide (Maehr et al 2001). Currently, FFWCC lands in south-central Florida are dominated by xeric scrub communities. They are important because they protect many of the rare and endemic species found on the Lake Wales Ridge, as well as providing bear habitat. Yet, important local ecosystems such as bay swamp, oak and cabbage palm hammocks, and pine flatwoods are underrepresented on FFWCC property. By diversifying the types of communities found on public lands, management agencies could create biotic reserves that conserve a more complete and representative sample of the area's historic natural communities, and which contain the high levels of habitat diversity that are so important to the black bear in south-central Florida.

Bear locations from this study were found on properties that would be good candidates for protection. On the east side of the ridge, connectivity among the Hendrie Ranch, Holmes Avenue, and Royce Ranch should be protected and enhanced. Properties immediately adjoining ABS and the XL Ranch to the south were frequently used by study animals and would also be excellent candidates for protection. A series of small forested patches tenuously connects ABS and the Lake Placid Scrub Preserve to Jack Creek and across US-27 to the Clements tract. The Fisheating Creek corridor and Lykes Brothers properties in Glades County have also been used by bears and should be incorporated into regional landscape planning.

Roads and rivers have the potential to act as semipermeable barriers to bear movement (White et al. 2000). How permeable these obstructions are depends on the width of the barrier, the surrounding landscape, and traffic volume on roads. I did not document bears crossing the Caloosahatchee River (the north boundary of the Big Cypress population); however, Maehr et al. (1988) documented a bear from Big Cypress crossing the Caloosahatchee River en route to Highlands County, ABS, and the Lake Placid area. Maintaining connection between these 2 populations is essential to statewide metapopulation function, but habitat loss from both the east and west along the river likely restrict bear movements. Maintaining a corridor for bear dispersal across the Caloosahatchee River should be a priority for bear conservation in the state.

While the Caloosahatchee River and habitat loss restrict long distance movements between the Highlands-Glades and Big Cypress populations, highways in this study restricted movements at a local scale. Although some bears did not cross highways, several traditional crossing zones were apparent in corridors outlined by bear locations. I recommend that 4 of these areas be investigated as potential wildlife crossing locations (Figure 5.3). The proposed southern crossing on US-27 is an area where the Hendrie family owns property on both sides of the highway. This could be advantageous, because the Hendries, as outlined above, are proponents of bear conservation. Similarly, FFWCC manages properties on both sides of the highway at the western proposed crossing on FL-70. North of the proposed crossing is the Lake Placid Scrub Preserve, and south of the proposed crossing is the McJunkin property. If determined to be suitable wildlife crossing locations, these 2 areas (especially the western FL-70 location), might be developed as wildlife crossings without requiring the purchase of land.

FUTURE RESEARCH

This was the initial telemetry study of the black bear in south-central Florida. The basic spatial characteristics of the core population have now been described, but several areas of potential bear habitat deserve further attention. Remote camera surveys, and trapping, if evidence of bear use is found, should be expanded to these areas: northern Highlands County properties such as Highlands Hammock State Park, Avon Park Bombing Range, and Arbuckle Wildlife Management Area; Jack Creek and surrounding properties northwest of Lake Placid; Bluehead Ranch in western Highlands County; and Fisheating Creek and other forested lands in Glades County. Other topics to address for this population could include a population viability analysis, estimating population size, and genetic analysis.

Future studies should examine the potential to connect disjunct black bear populations, and identify corridors that would support dispersal. Because of the fragmented landscape and segregation of females into population sub-centers, the future of this population may be more dependent on male movements to maintain genetic diversity than in other Florida bear populations. GPS collar data could allow for fine scale analysis of movements, especially those of males, through the fragmented but diverse landscape of south-central Florida. For example, how do bears travel between habitat near Lake Istokpoga and the primary core east of Venus? What are the primary travel routes for bears that move north and south along the west side of the ridge from ABS to Jack Creek? An in-depth look at how roads affect the population and the feasibility of mitigating this challenge via structural improvements at traditional bear crossing locations could improve safety for bears and people alike. Maintaining or creating connections between the Highlands-Glades population and other bear populations in the state should be a management priority and a focus of future research to guide those management efforts.

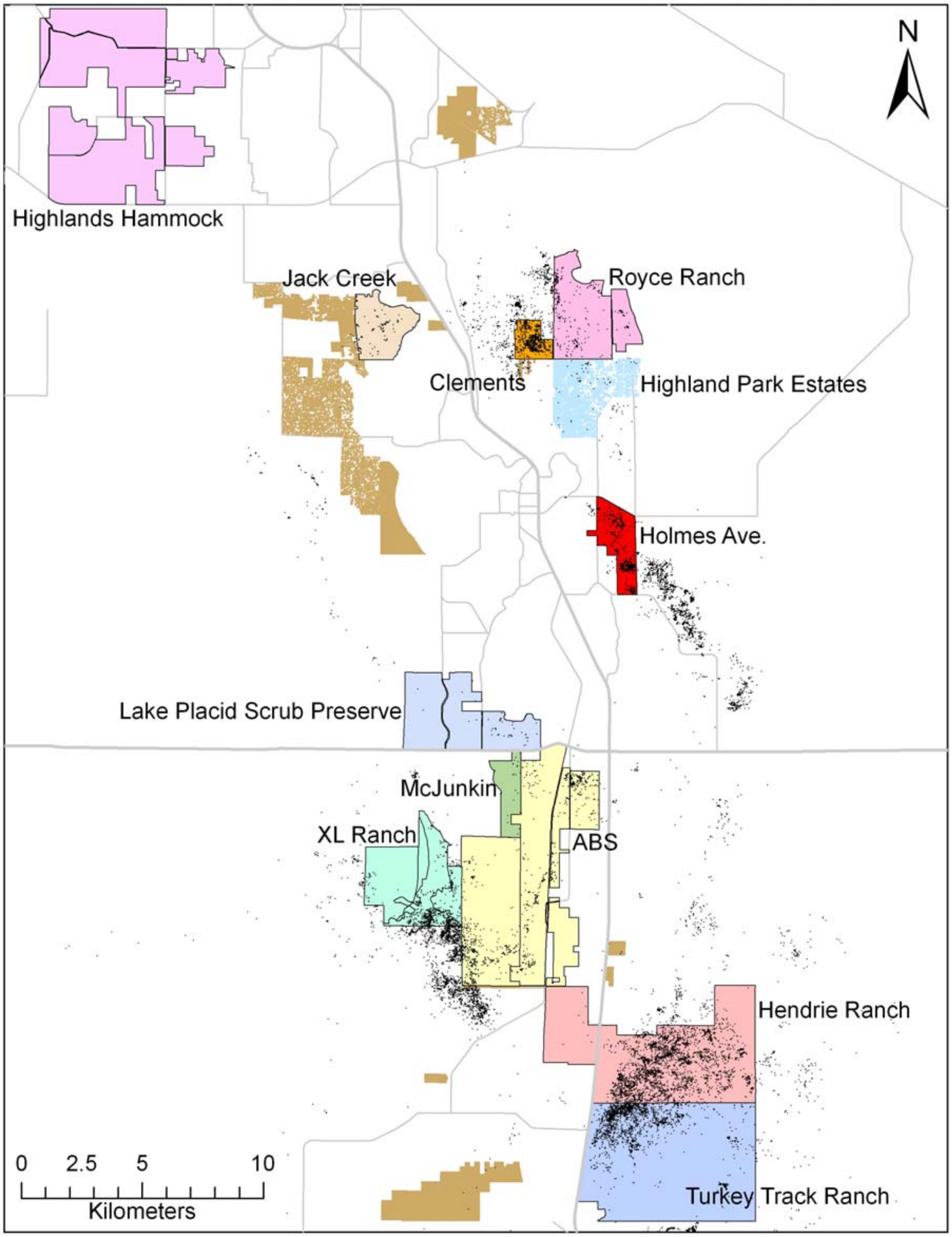

Figure 5.1. Important lands for black bear conservation in Highlands County, Florida, USA. Labeled properties are those mentioned in the text. Black dots are bear locations.

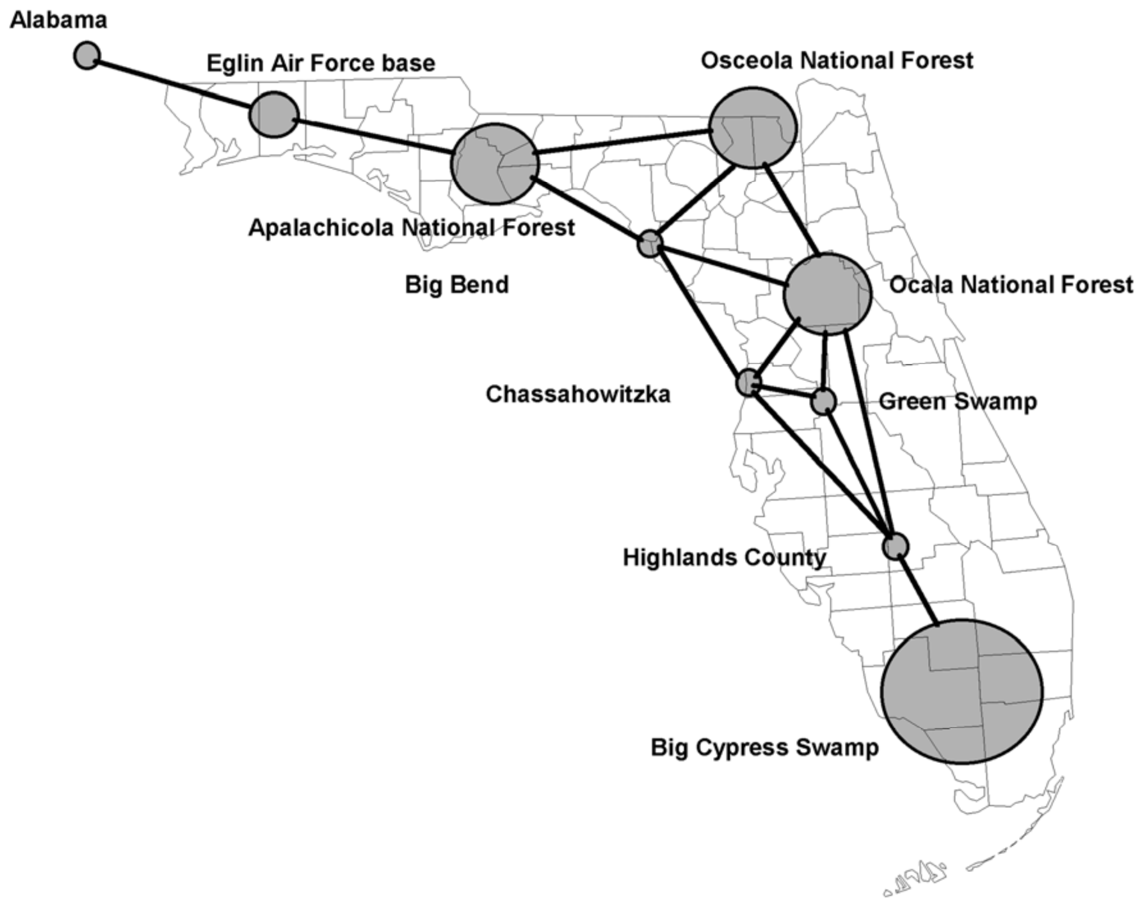

Figure 5.2. Hypothetical metapopulation connections between black bear populations in Florida, USA (from Maehr et al. 2001*b*:40).

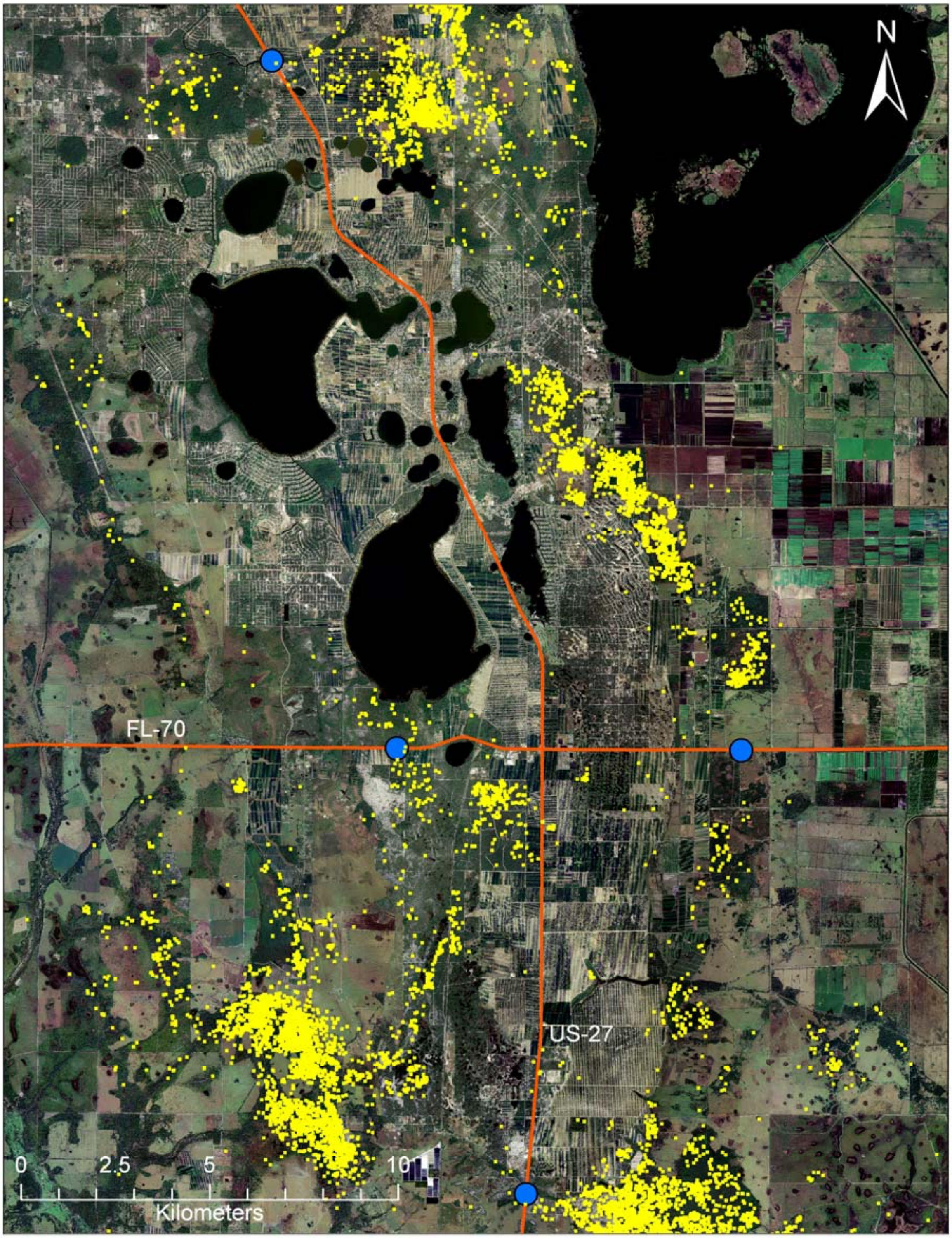

Figure 5.3. Bear locations (yellow points) and proposed wildlife crossings (blue circles) on US-27 and FL-70 in Highlands County, Florida, USA.

Appendix 1. Annual home range size (km^2) of female black bears in south-central Florida, USA, 2004 - 2006.

			Home range size		
ID	Age class[a]	*n*[b]	100% MCP	95% FK	50% FK
F1[c]	Adult	1664	17.6	11.7	2.4
F3[c]	Adult	807	16.2	15.2	3.5
F4[c]	Adult	1728	22.3	13.6	3.4
F5	Adult	974	74.2	25.8	2.0
F6	Adult	1421	37.1	15.4	2.9
F7	Adult	605	122.6	44.9	7.8
F8[c]	Adult	1617	25.7	14.9	2.5
F9[c]	Subadult	89	102.8	82.5	18.0
F10	Subadult	551	348.6	108.4	18.1
F11[c]	Subadult	788	20.7	18.5	4.5
F13	Subadult	48	23.6	18.1	3.6
F15	Subadult	809	16.6	17.5	3.7
Mean			69.0	32.2	6.0
SE			27.5	9.0	1.7

[a] Age at first capture

[b] Number of locations used to calculate home range

[c] Multiple annual home ranges were calculated for this animal. *n* is the total number of locations for both years. Home range sizes are the average of the two years.

Appendix 2. Annual home range size (km^2) of male black bears in south-central Florida, USA, 2004 - 2006.

			Home range size		
ID	Age class[a]	*n*[b]	100% MCP	95% FK	50% FK
M1	Adult	324	224.9	184.7	39.1
M3	Subadult	39	103.4	70.3	11.0
M5	Adult	435 [c]	98.6	81.6	14.0
M7	Subadult	34	273.6	92.9	24.5
M10	Subadult	3124 [c]	218.8	85.2	14.9
M11	Subadult	75 [c]	57.2	61.6	14.5
Mean			162.8	96.0	19.7
SE			35.6	18.3	4.3

[a] Age at first capture

[b] Number of locations used to calculate home range

[c] Multiple annual home ranges were calculated for this animal. *n* is the total number of locations for both years. Home range sizes are the average of the two years.

Appendix 3. Seasonal[a] home range size (km^2) of female black bears in south-central Florida, USA, 2004 - 2006.

					Home range size								
		n[b]			100% MCP			95% FK			50% FK		
ID	Age[c]	W	S	F	W	S	F	W	S	F	W	S	F
F1	A	379	773[d]	480	2.9	15.0	16.7	5.1	11.1	13.3	1.2	2.6	3.1
F3	A		400	345		18.1	14.7		13.4	12.4		3.2	3.1
F4	A	562[d]	554	579	3.7	30.0	14.7	5.3	18.0	13.3	1.4	4.1	3.6
F5	A	445		515	0.2		53.0	2.0		32.1	0.6		5.5
F6	A	456	456	707[d]	2.1	34.3	30.9	4.3	18.8	19.6	1.0	4.3	4.5
F7	A	30	74	549[d]	0.6	11.8	73.8	3.1	16.2	32.2	0.8	3.2	5.7
F8	A		250	1309		36.2	24.9		19.1	16.8		4.1	2.8
F10	S	283	185		23.0	335.7		32.5	116.2		9.8	20.3	
F11	S			721			24.3			21.1			5.6
F14	S			336			49.3			20.7			2.0
F15	S	69		726	5.7		15.5	7.7		17.0	1.4		3.6
F19	A			407			24.6			12.1			2.9
Mean					5.5	68.7	31.1	8.6	30.4	19.2	2.3	6.0	3.9
SE					3.0	44.7	5.8	4.0	14.3	2.2	1.3	2.4	0.4

[a] W = winter, S = summer, F = fall

[b] Number of locations used to calculate home range

[c] Age at first capture, S = subadult, A = adult

[d] Multiple seasonal home ranges were calculated for this animal and season (in different years). *n* is the total number of locations for both years. Home range sizes are the average of the two years.

Appendix 4. Seasonal[a] home range size (km^2) of male black bears in south-central Florida, USA, 2004 - 2006.

					Home range size								
		n[b]			100% MCP			95% FK			50% FK		
ID	Age[c]	W	S	F	W	S	F	W	S	F	W	S	F
M1	A		302			211.5			174.2			34.8	
M5	A		267[d]	134[d]		93.7	43.5		85.8	52.0		15.0	8.5
M8	S			1354			199.2			64.8			9.9
M10	S	1437		1545	54.5		206.8	32.9		50.5	7.6		7.0
M14	S	581	166		6.6	10.3		12.7	24.4		3.2	7.0	
M16	S		718			475.6			191.3			22.5	
Mean					30.6	197.8	149.8	22.8	118.9	55.8	5.4	19.8	8.5
SE					24.0	101.4	53.2	10.1	39.1	4.5	2.2	5.9	0.8

[a] W = winter, S = summer, F = fall

[b] Number of locations used to calculate home range

[c] Age at first capture, S = subadult, A = adult

[d] Multiple seasonal home ranges were calculated for this animal and season (in different years). *n* is the total number of locations for both years. Home range sizes are the average of the two years.

Appendix 5. Habitat selection by black bears in south-central Florida, USA, 2004 - 2006.[a]

	Annual second order			Annual third order			Winter third order			Summer third order			Fall third order		
Rank[b]	Hab[c]	Ratio	*P*[d]	Hab	Ratio	*P*	Hab	Ratio	*P*	Hab	Ratio	*P*	Hab	Ratio	*P*
1	**Bay**	**0.54**	**<0.001**	**Bay**	**0.48**	**<0.001**	**Bay**	**0.22**	**<0.001**	**Bay**	**0.63**	**<0.001**	**Pin**	**0.66**	**<0.001**
2	**Scr**	**0.57**	**0.001**	**Hwh**	**0.83**	**0.016**	Scr	0.92	0.169	**Pin**	**0.71**	**<0.001**	**Bay**	**0.73**	**0.001**
3	**Pin**	**0.60**	**<0.001**	Pin	0.89	0.201	Agr	0.95	0.181	**Hwh**	**0.73**	**0.002**	**Hwh**	**0.78**	**0.001**
4	**Hwh**	**0.62**	**<0.001**	Scr	0.91	0.201	Cit	0.96	0.103	**Scr**	**0.78**	**0.012**	**Scr**	**0.79**	**0.078**
5	**Cit**	**0.67**	**0.003**	Cit	0.99	0.779	Urb	0.98	0.510	Cit	0.96	0.472	**Fwm**	**0.92**	**0.069**
6	Agr	0.86	0.187	Agr	1.01	0.812	Hwh	1.04	0.872	Fwm	0.96	0.588	Urb	0.99	0.881
7	Fwm	1.05	0.409	Fwm	1.10	0.192	Pin	1.10	0.638	Agr	1.04	0.464	Agr	1.00	0.956
8	Gra	1.09	0.421	**Urb**	**1.14**	**0.028**	**Fwm**	**1.33**	**0.055**	Urb	1.07	0.211	Cit	1.03	0.591
9	**Urb**	**1.64**	**0.006**	**Gra**	**1.62**	**0.002**	**Gra**	**1.90**	**0.005**	Gra	1.23	0.156	Gra	1.04	0.768

[a] Second order ratio = mean distance from random locations in home ranges divided by mean distance from random locations in study area. Third order ratio = mean distance from bear locations divided by mean distance from random locations in home ranges.

[b] Rank of habitat types (rankings do not necessarily imply statistical differences between selection levels).

[c] Habitat type: Agr = agriculture, Bay = bay swamp, Cit = citrus, Fwm = freshwater marsh, Gra = grassland, Hwh = hardwood hammock, Pin = pinelands, Scr = scrub, Urb = urban. Bold type indicates habitats that were selected or avoided.

[d] *P*-values associated with univariate *t*-tests comparing distance ratios to 1.

Appendix 6. Ranking matrix of annual landscape-scale habitat selection by black bears in south-central Florida, USA, 2004 - 2006.

	Scr [a]	Pin	Hwh	Cit	Agr	Fwm	Gra	Urb
Bay	0.794 [b]	0.449	**0.069**	0.319	**0.027**	**<0.001**	**0.003**	**<0.001**
Scr		0.814	0.681	0.217	**0.001**	**0.004**	**0.001**	**<0.001**
Pin			0.609	0.616	**0.080**	**<0.001**	**<0.001**	**<0.001**
Hwh				0.701	**0.076**	**<0.001**	**0.001**	**<0.001**
Cit					**<0.001**	**0.016**	**0.008**	**<0.001**
Agr						0.226	0.123	**<0.001**
Fwm							0.662	**0.013**
Gra								**0.004**

[a] Habitat: Agr = agriculture, Bay = bay swamp, Cit = citrus, Fwm = freshwater marsh, Gra = grassland, Hwh = hardwood hammock, Pin = pinelands, Scr = scrub, Urb = urban.

[b] *P*-value from pairwise univariate *t*-test comparing rank order. Bold type indicates a significant rank order difference.

Appendix 7. Ranking matrix of annual home range-scale habitat selection by black bears in south-central Florida, USA, 2004 - 2006.

	Hwh[a]	Pin	Scr	Cit	Agr	Fwm	Urb	Gra
Bay	**0.002**[b]	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Hwh		0.182	0.350	**0.051**	**0.019**	**<0.001**	**0.001**	**<0.001**
Pin			0.853	0.324	0.192	**0.006**	**0.014**	**<0.001**
Scr				0.131	**0.037**	**0.098**	**0.003**	**<0.001**
Cit					0.366	0.268	**0.003**	**0.001**
Agr						0.326	**0.026**	**0.001**
Fwm							0.657	**0.007**
Urb								**0.005**

[a] Habitat: Agr = agriculture, Bay = bay swamp, Cit = citrus, Fwm = freshwater marsh, Gra = grassland, Hwh = hardwood hammock, Pin = pinelands, Scr = scrub, Urb = urban.

[b] *P*-value from pairwise univariate *t*-test comparing rank order. Bold type indicates a significant rank order difference.

Appendix 8. Ranking matrix of winter home range-scale habitat selection by black bears in south-central Florida, USA, 2004 - 2006.

	Scr[a]	Agr	Cit	Urb	Hwh	Pin	Fwm	Gra
Bay	**<0.001**[b]	**<0.001**	**<0.001**	**<0.001**	**0.032**	**0.014**	**0.001**	**0.001**
Scr		0.528	0.456	0.303	0.631	0.392	**0.018**	**0.001**
Agr			0.897	**0.075**	0.713	0.457	**0.020**	**0.003**
Cit				0.525	0.722	0.469	**0.022**	**0.003**
Urb					0.781	0.525	**0.025**	**0.003**
Hwh						0.627	0.175	**0.001**
Pin							0.113	**<0.001**
Fwm								**0.016**

[a] Habitat: Agr = agriculture, Bay = bay swamp, Cit = citrus, Fwm = freshwater marsh, Gra = grassland, Hwh = hardwood hammock, Pin = pinelands, Scr = scrub, Urb = urban.

[b] *P*-value from pairwise univariate *t*-test comparing rank order. Bold type indicates a significant rank order difference.

Appendix 9. Ranking matrix of summer home range-scale habitat selection by black bears in south-central Florida, USA, 2004 - 2006.

	Pin[a]	Hwh	Scr	Cit	Fwm	Agr	Urb	Gra
Bay	0.388[b]	0.317	0.207	**0.008**	**0.005**	**0.001**	**0.001**	**0.017**
Pin		0.820	0.455	**0.005**	**0.001**	**0.001**	**<0.001**	**0.005**
Hwh			0.632	**0.008**	**0.006**	**0.001**	**0.002**	**0.008**
Scr				**0.072**	0.158	**0.019**	**0.010**	**0.017**
Cit					0.978	**0.065**	0.220	**0.065**
Fwm						0.462	0.255	0.111
Agr							0.625	0.224
Urb								0.370

[a] Habitat: Agr = agriculture, Bay = bay swamp, Cit = citrus, Fwm = freshwater marsh, Gra = grassland, Hwh = hardwood hammock, Pin = pinelands, Scr = scrub, Urb = urban.

[b] *P*-value from pairwise univariate *t*-test comparing rank order. Bold type indicates a significant rank order difference.

Appendix 10. Ranking matrix of fall home range-scale habitat selection by black bears in south-central Florida, USA, 2004 - 2006.

	Bay[a]	Hwh	Scr	Fwm	Urb	Agr	Cit	Gra
Pin	0.409[b]	**0.049**	0.275	**<0.001**	**0.003**	**<0.001**	**0.001**	**0.006**
Bay		0.451	0.711	**0.013**	**0.071**	**0.010**	**0.004**	**0.084**
Hwh			0.936	**0.038**	**0.097**	**0.015**	**0.012**	**0.092**
Scr				0.307	**0.010**	**0.038**	**0.044**	**0.004**
Fwm					0.480	0.280	0.217	0.381
Urb						0.877	0.563	0.628
Agr							0.361	0.706
Cit								0.972

[a] Habitat: Agr = agriculture, Bay = bay swamp, Cit = citrus, Fwm = freshwater marsh, Gra = grassland, Hwh = hardwood hammock, Pin = pinelands, Scr = scrub, Urb = urban.

[b] *P*-value from pairwise univariate *t*-test comparing rank order. Bold type indicates a significant rank order difference.

Appendix 11. Winter food habits of the black bear in south-central Florida, 2004 - 2006.

Food item	*n*	% Composition	% Frequency
Arthropods			
Insects	18	19.8	40.6
Hymenoptera	5	5.6	12.5
Formicidae	4	4.4	9.4
Florida carpenter ant (*Camponotus floridanus*)	3	3.3	9.4
Acrobat ant (*Crematogaster* spp.)	1	1.1	3.1
Apidae			
Unknown bee	1	1.1	3.1
Coleoptera	9	9.9	25.0
Weevil larva (*Curculio* spp.)	5	5.5	15.6
Bess bug (*Odontotaenius disjunctus*)	2	2.2	6.3
Unknown beetle	2	2.2	6.3
Isoptera			
Subterranean termite (Family Rhinotermitidae)	1	1.1	3.1
Odonata			
Dragonfly nymph	1	1.1	3.1
Unknown insect adult	2	2.2	6.3
Soft Mast	9	9.9	18.8
Fruit	4	4.4	9.4
Saw palmetto (*Serenoa repens*)	1	1.1	3.1
Gallberry (*Ilex glabra*)	1	1.1	3.1
Blueberry (*Vaccinium* spp.)	1	1.1	3.1
Dahoon holly (*Ilex cassine*)	1	1.1	3.1
Other Seeds			
Smartweed (*Polygonum* spp.)	1	1.1	3.1
Unknown fruit or seed	4	4.4	12.5
Hard Mast			
Acorn (*Quercus* spp.)	16	17.6	50.0
Anthropogenic	25	27.5	40.6
Corn (*Zea mays*)	12	13.2	37.5
"Deer Chow" pellets	9	9.9	28.1
Unknown grain	4	4.4	12.5

Appendix 11 (continued)

Vegetation	16	17.6	46.9
Leafy green vegetation	10	11.0	31.3
Palm heart	2	2.2	6.3
Plant fiber	2	2.2	6.3
Vegetation (general)	2	2.2	6.3
Vertebrates	3	3.3	9.4
Mammals	2	2.2	6.3
Raccoon (*Procyon lotor*)	1	1.1	3.1
Unknown hair	1	1.1	3.1
Unknown bones/cartilage	1	1.1	3.1
Unknown	4	4.4	9.4
Total	91	100.0	284.4

Appendix 12. Summer food habits of the black bear in south-central Florida, 2004 - 2006.

Food item	*n*	% Composition	% Frequency
Arthropods	61	41.5	76.5
Insects	60	40.8	76.5
Hymenoptera	42	28.6	70.6
Formicidae	32	21.8	61.8
Florida carpenter ant (*Camponotus floridanus*)	19	12.9	55.9
Acrobat ant (*Crematogaster* spp.)	6	4.1	17.7
Unknown ant	7	4.8	20.5
Apidae	8	5.4	23.5
Bumble bee (*Bombus* spp.)	5	3.4	14.7
Unknown bee	3	2.0	8.8
Vespidae	2	1.4	5.9
Guinea wasp (*Polistes exclamans*)	1	0.7	2.9
Yellowjacket (*Vespula* spp.)	1	0.7	2.9
Coleoptera	5	3.4	14.7
Bess bug (*Odontotaenius disjunctus*)	2	1.4	5.9
Scarab beetle (Family Scarabaeidae)	1	0.7	2.9
Unknown beetle	1	0.7	2.9
Unknown beetle larva	1	0.7	2.9
Isoptera	5	3.4	14.7
Subterranean termite (Family Rhinotermitidae)	2	1.4	5.9
Termite	3	2.0	8.8
Unknown insect adult	5	3.4	14.7
Unknown insect larva or pupa	3	2.0	8.8
Arachnids			
Acarina			
Tick (Family Ixodidae)	1	0.7	2.9

Appendix 12 (continued)

Soft Mast	39	26.5	82.4
Fruit	27	18.4	70.6
Grape (*Vitis* spp.)	16	10.9	47.1
Saw palmetto (*Serenoa repens*)	4	2.7	11.8
Blackberry (*Rubus* spp.)	3	2.0	8.8
Blueberry (*Vaccinium* spp.)	3	2.0	8.8
Gallberry (*Ilex glabra*)	1	0.7	2.9
Unknown fruit or seed	12	8.2	35.3
Hard Mast	2	1.4	5.9
Acorn (*Quercus* spp.)	1	0.7	2.9
Hickory nut (*Carya* spp.)	1	0.7	2.9
Anthropogenic	18	12.2	41.2
Corn (*Zea mays*)	11	7.5	32.4
Citrus fruit (*Citrus* spp.)	4	2.7	11.8
"Deer Chow" pellets	3	2.0	8.8
Vegetation	16	10.9	47.1
Vegetation (general)	6	4.1	17.7
Grass	5	3.4	14.7
Plant fiber	3	2.0	8.8
Palm heart	1	0.7	2.9
Leafy green vegetation	1	0.7	2.9
Vertebrates	10	6.8	26.5
Mammals	8	5.4	23.5
Feral hog (*Sus scrofa*)	4	2.7	11.8
White-tailed deer (*Odocoileus virginianus*)	3	2.0	8.8
Nine-banded armadillo (*Dasypus novemcinctus*)	1	0.7	2.9
Reptiles			
Gopher tortoise (*Gopherus polyphemus*)	1	0.7	2.9
Unknown bones/cartilage	1	0.7	2.9
Unknown	1	0.7	2.9
Total	147	100.0	432.4

Appendix 13. Fall food habits of the black bear in south-central Florida, 2004 - 2006.

Food item	*n*	% Composition	% Frequency
Arthropods	78	28.2	48.4
Insects	75	27.1	47.4
Hymenoptera	30	10.8	28.4
Formicidae	29	10.5	28.4
Florida carpenter ant (*Camponotus floridanus*)	25	9.0	26.3
Unknown ant	4	1.4	4.2
Apidae			
Unknown bee	1	0.4	1.1
Coleoptera	28	10.1	25.3
Weevil larva (*Curculio* spp.)	10	3.6	10.5
Bess bug (*Odontotaenius disjunctus*)	5	1.8	5.3
Scarab beetle (Family Scarabaeidae)	1	0.4	1.1
Unknown beetle larva	8	2.9	8.4
Unknown beetle	4	1.4	4.2
Isoptera	7	2.5	7.4
Subterranean termite (Family Rhinotermitidae)	5	1.8	5.3
Unknown termite	2	0.7	2.1
Diptera			
Fly larva	1	0.4	1.1
Unknown insect adult	6	2.2	6.3
Unknown insect larva or pupa	3	1.1	3.2
Arachnids			
Acarina			
Tick (Family Ixodidae)	3	1.1	3.2
Soft Mast	78	28.2	67.4
Fruit	66	23.8	63.2
Saw palmetto (*Serenoa repens*)	52	18.8	54.7
Gallberry (*Ilex glabra*)	5	1.8	5.3
Swamp tupelo (*Nyssa biflora*)	3	1.1	3.2
Palmetto (*Sabal* spp.)	2	0.7	2.1
Grape (*Vitis* spp.)	1	0.4	1.1
Blackberry (*Rubus* spp.)	1	0.4	1.1
Blueberry (*Vaccinium* spp.)	1	0.4	1.1
Brazilian pepper (*Schinus terebinthifolius*)	1	0.4	1.1

Appendix 13 (continued)

Other Seeds	3	1.1	3.2
Ragweed (*Ambrosia* spp.)	2	0.7	2.1
Unknown grass seed	1	0.4	1.1
Unknown fruit or seed	9	3.3	9.5
Hard Mast	55	19.9	51.6
Acorn (*Quercus* spp.)	44	15.9	46.3
Hickory nut (*Carya* spp.)	11	4.0	11.6
Anthropogenic	30	10.8	23.2
Corn (*Zea mays*)	18	6.5	19.0
Citrus fruit (*Citrus* spp.)	6	2.2	6.3
Unknown grain	3	1.1	3.2
"Deer Chow" pellets	1	0.4	1.1
Paper	1	0.4	1.1
Plastic	1	0.4	1.1
Vegetation	16	5.8	15.8
Plant fiber	5	1.8	5.3
Grass	5	1.8	5.3
Vegetation (general)	5	1.8	5.3
Lichen	1	0.4	1.1
Vertebrates	17	6.1	15.8
Mammals	11	4.0	11.6
Nine-banded armadillo (*Dasypus novemcinctus*)	3	1.1	3.2
Raccoon (*Procyon lotor*)	2	0.7	2.1
White-tailed deer (*Odocoileus virginianus*)	1	0.4	1.1
Unknown hair	5	1.8	5.3
Reptiles			
Gopher tortoise (*Gopherus polyphemus*)	3	1.1	3.2
Birds			
Feathers	1	0.4	1.1
Unknown bones/cartilage	2	0.7	2.1
Unknown	3	1.1	3.2
Total	277	100.0	291.6

LITERATURE CITED

Abrahamson, W. G., and D. C. Hartnett. 1990. Pine flatwoods and dry prairies. Pages 103-149 *in* R. L. Myers, and J. J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida, USA.

Abrahamson, W. G., A. F. Johnson, J. N. Layne, and P. A. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: an example of the southern Lake Wales Ridge. Florida Scientist 47:209-250.

Abrahamson, W. G., and J. N. Layne. 2003. Long-term patterns of acorn production for five oak species in xeric Florida uplands. Ecology 84:2476-2492.

Alexander, T. R. 1971. Sawgrass biology related to the future of the Everglades ecosystem. Soil Crop Science Society of Florida Proceedings 31:72-74.

Alt, G. L., G. J. Matula, F. W. Alt, and J. S. Lindzey. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. International Conference on Bear Research and Management 4:131-136.

Archbold Biological Station. 2007*a*. <http://www.archbold-station.org/abs/archbold/mprofact.htm.>. Accessed 18 January 2007.

Archbold Biological Station. 2007*b*. <http://www.archbold-station.org/fai/ridge.html.>. Accessed 10 January 2007.

Beck, T. D. I. 1991. Black bears of west-central Colorado. Technical Publication No. 39. Colorado Division of Wildlife, Fort Collins, Colorado, USA.

Beecham, J. J., D. G. Reynolds, and M. G. Hornocker. 1983. Black bear denning activities and den characteristics in west-central Idaho. International Conference on Bear Research and Management 5:79-86.

Beeman, L. E., and M. R. Pelton. 1980. Seasonal foods and feeding ecology of black bears in the Smoky Mountains. International Conference on Bear Research and Management 4:141-147.

Bekoff, M., and L. D. Mech. 1984. Simulation analyses of space use: home range estimates, variability, and sample size. Behavior Research Methods, Instruments, and Computers 16:32-37.

Belant, J. L., and E. H. Follmann. 2002. Sampling considerations for American black and brown bear home range and habitat use. Ursus 13:299-315.

Bennett, L. J., P. F. English, and R. L. Watts. 1943. The food habits of the black bear in Pennsylvania. Journal of Mammalogy 24:25-31.

Benson, J. F., and M. J. Chamberlain. 2006. Food habits of Louisiana black bears (*Ursus americanus luteolus*) in two subpopulations of the Tensas River Basin. American Midland Naturalist 156:118-127.

Benson, J. F., and M. J. Chamberlain. 2007. Space use and habitat selection by female Louisiana black bears in the Tensas River Basin of Louisiana. Journal of Wildlife Management 71:117-126.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com/htools.

Borror, D. J., C. A. Triplehorn, and N. F. Johnson. 1989. An introduction to the study of insects. Harcourt Brace, Orlando, Florida, USA.

Borror, D. J., and R. E. White. 1970. A field guide to insects: America north of Mexico. Houghton Mifflin, New York, New York, USA.
Brady, J. R., and D. S. Maehr. 1985. Distribution of black bears in Florida. Florida Field Naturalist 13:1-7.
Brown, J. H. 2004. Challenges in estimating size and conservation of black bear in west-central Florida. Thesis, University of Kentucky, Lexington, Kentucky, USA.
Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24:346-352.
Clark, J. D., J. E. Dunn, and K. G. Smith. 1993. A multivariate model of female black bear habitat use for a geographic information system. Journal of Wildlife Management 57:519-526.
Clevenger, A. P., and M. R. Pelton. 1990. Pre and post breakup movements and space use of black bear family groups in Cherokee National Forest, Tennessee. International Conference on Bear Research and Management 8:289-295.
Clewell, A. F. 1971. The vegetation of the Apalachicola National Forest: an ecological perspective. Final Report. U.S. Forest Service, Atlanta, Georgia, USA.
Conner, L. M., and B. W. Plowman. 2001. Using Euclidean distance to assess nonrandom habitat use. Pages 275-290 *in* J. J. Millspaugh, and J. M. Marzluff, editors. Radio tracking and animal populations. Academic Press, San Diego, California, USA.
Conner, L. M., M. D. Smith, and L. W. Burger. 2003. A comparison of distance-based and classification-based analyses of habitat use. Ecology 84:526-531.
Cottam, C., A. L. Nelson, and T. E. Clarke. 1939. Notes on early winter food habits of the black bear in George Washington National Forest. Journal of Mammalogy 20:310-314.
Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the gaps in Florida's Wildlife Habitat Conservation System. Florida Game and Freshwater Fish Commission, Tallahassee, Florida, USA.
Craighead, L. 2000. Bears of the world. Voyageur Press, Stillwater, Minnesota, USA.
D'Eon, R. G., and D. Delparte. 2005. Effects of radio-collar position and orientation on GPS radio-collar performance, and the implications of PDOP in data screening. Journal of Applied Ecology 42:383-388.
D'Eon, R. G., R. Serrouya, G. Smith, and C. O. Kochanny. 2002. GPS radiotelemetry error and bias in mountainous terrain. Wildlife Society Bulletin 30:430-439.
Debinski, D. M., C. Ray, and E. H. Saveraid. 2001. Species diversity and the scale of the landscape mosaic: do scales of movement and patch size affect diversity? Biological Conservation 98:179-190.
DeVane, A. 1978. DeVane's early Florida history. Sebring Historical Society, Sebring, FL.
Dixon, J. D. 2004. Conservation genetics of the Florida black bear. Thesis, University of Florida, Gainesville, Florida, USA.
Dixon, J. D., M. K. Oli, M. C. Wooten, T. H. Eason, J. W. McCown, and D. Paetkau. 2006. Effectiveness of a regional corridor in connecting two Florida black bear populations. Conservation Biology 20:155-162.
Dobey, S., D. V. Masters, B. K. Scheick, J. D. Clark, M. R. Pelton, and M. E. Sunquist. 2005. Ecology of Florida black bears in the Okefenokee-Osceola ecosystem. Wildlife Monographs 158:1-41.

Dusi, J. L., D. T. King, and L. K. Malo. 1987. Ecology of the black bear in southwest Alabama. Alabama Department of Conservation and Natural Resources, Alabama Agricultural Experiment Station, and U.S. Department of Interior, Washington, D.C., USA.

Eberhardt, L. L. 1990. Survival rates required to sustain bear populations. Journal of Wildlife Management 54:587-590.

Edmisten, J. E. 1963. The ecology of the Florida pine flatwoods. Dissertation, University of Florida, Gainesville, Florida, USA.

Ehrlich, P. R. 1988. The loss of diversity: causes and consequences. Pages 21-27 *in* E. O. Wilson, editor. Biodiversity. National Academy Press, Washington, D.C., USA.

Elzinga, R. J. 2004. Fundamentals of entomology. Pearson Education, Upper Saddle River, New Jersey, USA.

Emlen, J. M. 1966. The role of time and energy in food preference. American Naturalist 100:611-617.

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

Erlinge, S. 1981. Food preference, optimal diet and reproductive output in stoats Mustela erminea in Sweden. Oikos 36:303-315.

ESRI. 1999. ArcView. Version 3.2. Redlands, California, USA.

ESRI. 2006. ArcGIS. Version 9.2. Redlands, California, USA.

Eubanks, A. L. 1976. Movements and activities of the black bear (*Ursus americanus*) in the Great Smoky Mountains National Park. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Ewel, K. C. 1990. Swamps. Pages 281-323 *in* R. L. Myers, and J. J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida, USA.

Florida Fish and Wildlife Conservation Commission. 2004. GHCHAB_03. Available at www.fgdl.org. Tallahassee, Florida, USA.

Florida Fish and Wildlife Conservation Commission. 2007. <http://www.myfwc.com/bear/distribmap.htm>. Accessed 31 August 2007.

Frair, J. L., S. E. Nielsen, E. H. Merrill, S. R. Lele, M. S. Boyce, R. H. M. Munro, G. B. Stenhouse, and H. L. Beyer. 2004. Removing GPS collar bias in habitat selection studies. Journal of Applied Ecology 41:201-212.

Garmin. 2007. Garmin home page. <http://www8.garmin.com/support/faqs/search.jsp>. Accessed 12 May 2007.

Garrison, E. P., J. W. McCown, and M. K. Oli. 2007. Reproductive ecology and cub survival of Florida black bears. Journal of Wildlife Management 71:720-727.

Garshelis, D. L., and M. R. Pelton. 1981. Movements of black bears in the Great Smoky Mountains National Park. Journal of Wildlife Management 45:912-925.

Gibeau, M. L., A. P. Clevenger, S. Herrero, and J. Wierzchowski. 2002. Grizzly bear response to human development and activities in the Bow River Watershed, Alberta, Canada. Biological Conservation 103:227-236.

Graber, D. M. 1990. Winter behavior of black bears in the Sierra Nevada, California. International Conference on Bear Research and Management 8:269-272.

Green, D. M. 2005. Designatable units for status assessment of endangered species. Conservation Biology 19:1813-1820.

Gresham, C. A., and D. J. Lipscomb. 1985. Selected ecological characteristics of *Gordonia lasianthus* in coastal South Carolina. Bulletin of the Torrey Botanical Club 112:53-58.

Harlow, R. F. 1961. Characteristics and status of Florida black bear. Transactions of the North American Wildlife Conference 26:481-495.

Harms, W. R., H. T. Schreuder, D. D. Hook, C. L. Brown, and F. W. Shropshire. 1980. The effects of flooding on the swamp forest in Lake Ocklawaha, Florida. Ecology 61:1412-1421.

Harper, R. M. 1914. Geography and vegetation of northern Florida. Florida Geological Survey, Annual Report 6:163-451.

Harris, S., W. J. Cresswell, P. G. Forde, W. J. Trewhella, T. Woollard, and S. Wray. 1990. Home-range analysis using radio-tracking data - a review of problems and techniques particularly as applied to the study of mammals. Mammal Review 20:97-123.

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.

Hellgren, E. C., D. P. Onorato, and J. R. Skiles. 2005. Dynamics of a black bear population within a desert metapopulation. Biological Conservation 122:131-140.

Hellgren, E. C., M. R. Vaughan, R. L. Kirkpatrick, and P. F. Scanlon. 1990. Serial changes in metabolic correlates of hibernation in female black bears. Journal of Mammalogy 71:291-300.

Heyward, F. 1939. Some moisture relationships of soils from burned and unburned longleaf-pine forests. Soil Science 47:313-325.

Hillman, L. L., and D. L. Yow. 1986. Timber management for black bear. Eastern Workshop on Black Bear Management and Research 8:125-134.

Hoctor, T. S. 2003. Regional landscape analysis and reserve design to conserve Florida's biodiversity. Dissertation, University of Florida, Gainesville, Florida, USA.

Hoctor, T. S., M. H. Carr, and P. D. Zwick. 2000. Identifying a linked reserve system using a regional landscape approach: the Florida ecological network. Conservation Biology 14:984-1000.

Hodder, K. H., R. E. Kenward, S. S. Walls, and R. T. Clarke. 1998. Estimating core ranges: a comparison of techniques using the common buzzard (*Buteo buteo*). Journal of Raptor Research 32:82-89.

Jenness Enterprises. 2007. Nearest Features extension to ArcView. Version 3.8b. Flagstaff, Arizona, USA.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Johnson, K. G., and M. R. Pelton. 1980. Prebaiting and snaring techniques for black bears. Wildlife Society Bulletin 8:46-54.

Jones, M. D., and M. R. Pelton. 2003. Female American black bear use of managed forest and agricultural lands in coastal North Carolina. Ursus 14:188-197.

Kalisz, P. J., and E. L. Stone. 1984. The longleaf pine islands of the Ocala National Forest, Florida: a soil study. Ecology 65:1743-1754.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53:457-481.

Kenward, R. E., R. T. Clarke, K. H. Hodder, and S. S. Walls. 2001. Density and linkage estimators of home range: nearest-neighbor clustering defines multinuclear cores. Ecology 82:1905-1920.

Kernohan, B. J., R. A. Gitzen, and J. J. Millspaugh. 2001. Analysis of animal space use and movements. Pages 125-166 *in* J. J. Millspaugh, and J. M. Marzluff, editors. Radio tracking and animal populations. Academic Press, San Diego, California, USA.

Kreeger, T. J. 1996. Handbook of wildlife chemical immobilization. Wildlife Pharmaceuticals, Inc., Fort Collins, Colorado, USA.

Kushlan, J. A. 1990. Freshwater Marshes. Pages 324-363 *in* R. L. Myers, and J. J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida, USA.

Laessle, A. M. 1942. The plant communities of the Welaka area with special reference to correlation between soils and vegetational succession. University of Florida Publications in Biological Science Services, Gainesville, Florida, USA.

Laessle, A. M. 1958. The origin and successional relationships of sandhill vegetation and sand-pine scrub. Ecological Monographs 28:361-387.

Land, E. D. 1994. Southwest Florida black bear habitat use, distribution, movements, and conservation strategy. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida, USA.

Landers, J. L., R. J. Hamilton, A. S. Johnson, and R. L. Marchinton. 1979. Foods and habitat of black bears in southeastern North Carolina. Journal of Wildlife Management 43:143-153.

Langeland, K. A., and K. C. Burks. 1998. Identification and biology of non-native plants in Florida's natural areas. University of Florida, Gainesville, Florida, USA.

Laundre, J. W., and B. L. Keller. 1984. Home-range size of coyotes: a critical review. Journal of Wildlife Management 48:127-139.

Layne, J. N., editor. 1978. Rare and endangered biota of Florida. Volume 1: Mammals. University Presses of Florida, Gainesville, Florida, USA.

Lee, D. J., and M. R. Vaughan. 2003. Dispersal movements by subadult American black bears in Virginia. Ursus 14:162-170.

Lindzey, F. G., and E. C. Meslow. 1977. Home range and habitat use by black bears in southwestern Washington. Journal of Wildlife Management 41:413-425.

MacArthur, R. H., and E. C. Pianka. 1966. On optimal use of a patchy environment. American Naturalist 100:603-609.

Mack, J. A. 1990. Black bear dens in the Beartooth Face, south-central Montana. International Conference on Bear Research and Management 8:273-277.

Maehr, D. S. 1984. The black bear as a seed disperser in Florida. Florida Field Naturalist 12:40-42.

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. 1982. Fall food habits of black bears in Baker and Columbia counties, Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36:565-570.

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

Maehr, D. S., and J. T. DeFazio. 1985. Foods of black bears in Florida. ADD JR TO DEFAZIO. Florida Field Naturalist 13:8-12.

Maehr, D. S., E. C. Hellgren, R. L. Bingham, and D. L. Doan-Crider. 2001*a*. Body mass of black bears from Florida and Mexico. Southwestern Naturalist 46:129-133.

Maehr, D. S., T. S. Hoctor, L. J. Quinn, and J. S. Smith. 2001*b*. Black bear habitat management guidelines for Florida. Technical Report No. 17. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida, USA.

Maehr, D. S., E. D. Land, D. B. Shindle, O. L. Bass, and T. S. Hoctor. 2002. Florida panther dispersal and conservation. Biological Conservation 106:187-197.

Maehr, D. S., and J. L. Larkin. 2004. Do prescribed fires in south Florida reduce habitat quality for large carnivores? Natural Areas Journal 24:188-197.

Maehr, D. S., and J. N. Layne. 1996. The saw palmetto: Florida's all-purpose plant. The Palmetto 16:6-10, 15, 21.

Maehr, D. S., J. N. Layne, T. S. Hoctor, and M. A. Orlando. 2004. Status of the black bear in south-central Florida. Florida Field Naturalist 32:85-101.

Maehr, D. S., J. N. Layne, E. D. Land, J. W. McCown, and J. Roof. 1988. Long distance movements of a Florida black bear. Florida Field Naturalist 16:1-24.

Maehr, D. S., M. A. Orlando, and J. J. Cox. 2005. Large carnivores, herbivores, and omnivores in south Florida: an evolutionary approach to conserving landscapes and biodiversity. Pages 293-314 *in* J. C. Ray, K. H. Redford, R. S. Steneck, and J. Berger, editors. Large carnivores and the conservation of biodiversity. Island Press, Washington, D.C., USA.

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

Manville, A. M. 1987. Den selection and use by black bears in Michigan's northern lower peninsula. International Conference on Bear Research and Management 7:317-322.

Marshall, S. A. 2006. Insects - their natural history and diversity: with a photographic guide to insects of eastern North America. Firefly Books, Buffalo, New York, USA.

Martin, A. C., and W. D. Barkley. 1961. Seed identification manual. University of California Press, Berkeley, California, USA.

Marzluff, J. M., S. T. Knick, and J. J. Millspaugh. 2001. High-tech behavioral ecology: modeling the distribution of animal activities to better understand wildlife space use and resource selection. Pages 309-326 *in* J. J. Millspaugh, and J. M. Marzluff, editors. Radio Tracking and Animal Populations. Academic Press, San Diego, California, USA.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mayfield, H. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

McKee, J. K., P. W. Sciulli, C. D. Fooce, and T. A. Waite. 2004. Forecasting global biodiversity threats associated with human population growth. Biological Conservation 115:161-164.

Milne, L., and M. Milne. 1998. National Audubon Society field guide to North American insects and spiders. Chanticleer Press, New York, New York, USA.

Moen, R., J. Pastor, and Y. Cohen. 1997. Accuracy of GPS telemetry collar locations with differential correction. Journal of Wildlife Management 61:530-539.

Moen, R., J. Pastor, Y. Cohen, and C. C. Schwartz. 1996. Effects of moose movement and habitat use on GPS collar performance. Journal of Wildlife Management 60:659-668.

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

Monk, C. D. 1960. A preliminary study on the relationships between the vegetation of a mesic hammock community and a sandhill community. Quarterly Journal of the Florida Academy of Science 23:1-12.

Monk, C. D. 1966. An ecological study of hardwood swamps in north-central Florida. Ecology 47:649-654.

Monk, C. D. 1968. Successional and environmental relationships of the forest vegetation of north-central Florida. American Midland Naturalist 79:441-457.

Moore, W. H., B. F. Swindel, and W. S. Terry. 1982. Vegetation responses to prescribed fire in a north Florida flatwoods forest. Journal of Range Management 35:386-389.

Moritz, C. 2002. Strategies to protect biological diversity and the evolutionary processes that sustain it. Systematic Biology 51:238-254.

Moyer, M. A., J. W. McCown, and M. K. Oli. 2008. Scale-dependent habitat selection by female Florida black bears in Ocala National Forest, Florida. Southeastern Naturalist 7:111-124.

Myers, R. L. 1985. Fire and the dynamic relationship between Florida sandhill and sand pine scrub vegetation. Bulletin of the Torrey Botanical Club 112:241-252.

Myers, R. L. 1990. Scrub and high pine. Pages 150-193 *in* R. L. Myers, and J. J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida, USA.

Myers, R. L., and J. J. Ewel. 1990. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida, USA.

Mykytka, J. M., and M. R. Pelton. 1989. Management stategies for Florida black bears based on home range habitat composition. International Conference on Bear Research and Management 8:161-167.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

Noss, R. F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

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

Pelton, M. R. 2003. Black bear. Pages 547-555 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America. John Hopkins University Press, Baltimore, Maryland, USA.

Pelton, M. R., L. E. Beeman, and D. C. Eagar. 1980. Den selection by black bears in Great Smoky Mountains National Park. International Conference on Bear Research and Management 4:149-151.

Peroni, P. A., and W. G. Abrahamson. 1986. Succession in Florida sandridge vegetation: a retrospective study. Florida Scientist 49:176-191.

Platt, W. J., G. W. Evans, and S. L. Rathbun. 1988. The population dynamics of a long-lived conifer (*Pinus palustris*). The American Naturalist 131:491-525.

Platt, W. J., and M. W. Schwartz. 1990. Temperate hardwood forests. Pages 194-229 *in* R. L. Myers, and J. J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida, USA.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7-15.

Pond, D. B., and B. W. O'Gara. 1994. Chemical immobilization of large mammals. Pages 125-139 *in* T. K. Bookhout, editor. Research and Management Techniques for Wildlife and Habitats. The Wildlife Society, Bethesda, Maryland, USA.

Rempel, R. 2008. Patch Analyst 4. Available at http://flash.lakeheadu.ca/~rrempel/patch/.

Rempel, R. S., A. R. Rodgers, and K. F. Abraham. 1995. Performance of a GPS animal location system under boreal forest canopy. Journal of Wildlife Management 59:543-551.

Rodgers, A. R. 2001. Recent telemetry technology. Pages 79-121 *in* J. J. Millspaugh, and J. M. Marzluff, editors. Radio tracking and animal populations. Academic Press, San Diego, California, USA.

SAS Institute. 2003. SAS. Version 9.1. Cary, North Carolina, USA.

Schoen, J. W. 1990. Bear habitat management: a review and future perspective. International Conference on Bear Research and Management 8:143-154.

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

Schwartz, M. W. 1994. Natural distribution and abundance of forest species and communities in northern Florida. Ecology 75:687-705.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77:2075-2085.

Seibert, S. G. 1993. Status and management of black bears in Apalachicola National Forest. Florida Game and Fresh Water Fish Commission, Tallahasee, Florida, USA.

Seibert, S. G. 1995. Winter movements and denning of black bears in northwest Florida. Proceedings of the Annual Conference of Southeastern Fish and W ildlife Agencies 49:283-291.

Serbesoff-King, K. 2003. Melaleuca in Florida: a literature review on the taxonomy, distribution, biology, ecology, economic importance and control measures. Journal of Aquatic Plant Management 41:98-112.

Shaw, S. P., and C. G. Fredine. 1956. Wetlands of the United States, their extent and their value for waterfowl and other wildlife. Circular No. 39. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Sigrist, P., P. Coppin, and M. Hermy. 1999. Impact of forest canopy on quality and accuracy of GPS measurements. International Journal of Remote Sensing 20:3595-3610.

Sih, A. 1982. Optimal patch use: variation in selective pressure for efficient foraging. The American Naturalist 120:666-685.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: Is single-species management passe in the landscape era? Biological Conservation 83:247-257.

Simek, S. L., S. A. Jonker, B. K. Scheick, M. J. Endries, and T. H. Eason. 2005. Statewide assessment of road impacts on bears in six study areas in Florida from May 2001 - September 2003. Final Report Contract BC-972. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida, USA.

Smith, T. R. 1986. Activity and behavior of denned black bears in the lower Mississippi River valley. International Conference on Bear Research and Management 6:137-143.

Snedaker, S. C., and A. E. Lugo. 1972. Ecology of the Ocala National Forest. U.S. Forest Service, Southeast Region, Atlanta, Georgia, USA.

Society for Conservation Biology [SCB]. 2007. SCB home page. <http://www.conbio.org/Resources/Education/faq.cfm>. Accessed 10 December 2007.

Stratman, M. R. 1998. Habitat use and effects of prescribed fire on black bears in northwestern Florida. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Stratman, M. R., C. D. Alden, M. R. Pelton, and M. E. Sunquist. 2001. Habitat use by American black bears in the sandhills of Florida. Ursus 12:109-114.

Taylor, M. K., D. P. DeMaster, F. L. Bunnell, and R. E. Schweinsburg. 1987. Modeling the sustainable harvest of female polar bears. Journal of Wildlife Management 51:811-820.

T. H. White, Jr., J. L. Bowman, B. D. Leopold, H. A. Jacobson, W. P. Smith, and F. J. Vilella. 2000. Influence of Mississippi alluvial valley rivers on black bear movements and dispersal: implications for Louisiana black bear recovery. Biological Conservation 95:323-331.

Trent, T. T., and O. J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. Journal of Wildlife Management 38:459-472.

U.S. Census Bureau. 2007. <http://factfinder.census.gov/home/saff/main.html>. Accessed 7 September 2007.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2006. Orthophoto mosaic for Highlands County, FL. Available at http://datagateway.nrcs.usda.gov/.

U.S. Fish and Wildlife Service. 1998. Endangered and threatened wildlife and plants; new 12-month finding for a petition to list the Florida black bear. Federal Register 63(235):1-10.

U. S. Forest Service. 1974. Seeds of woody plants in the United States, Agriculture Handbook 450. U.S. Department of Agriculture, Forest Service, Washington, D.C., USA.

U.S. Geological Survey. 1999. U.S. Geological Survey national elevation dataset. Available online at http://gisdata.usgs.net/ned/. Reston, Virginia, USA.

Van Arman, J., and R. Goodrick. 1979. Effects of fire on a Kissimmee River marsh. Florida Scientist 42:183-195.

Veno, P. A. 1976. Successional relationships of five Florida plant communities. Ecology 57:498-508.
Vince, S. W., S. R. Humphrey, and R. W. Simons. 1989. The ecology of hydric hammocks: a community profile. Biological Report No. 85. U.S. Fish and Wildlife Service, Washington, D.C., USA.
Vogl, R. J. 1973. Effects of fire on the plants and animals of a Florida wetland. American Midland Naturalist 89:334-347.
Wade, D. D., J. J. Ewel, and R. Hofstetter. 1980. Fire in south Florida ecosystems. US Department of Agriculture, Forest Service General Technical Report No. SE-17. Southeast Forest Experimental Station, Asheville, North Carolina, USA.
Wathen, W. G. 1983. Reproduction and denning of black bears in the Great Smoky Mountains. Thesis, University of Tennessee, Knoxville, Tennessee, USA.
Wathen, W. G., K. G. Johnson, and M. R. Pelton. 1986. Characteristics of black bear dens in the southern Appalachian region. International Conference on Bear Research and Management 6:119-127.
Wharton, C. H., H. T. Odum, K. C. Ewel, M. Duever, A. Lugo, R. Boyt, J. Bartholomew, E. DeBellevue, S. Brown, M. Brown, and L. Duever. 1977. Forested wetlands of Florida - their management and use. Division of State Planning, Tallahassee, Florida, USA.
Whitaker, J. O., Jr. 1988. Food habits analysis of insectivorous bats. Pages 171-189 *in* T. H. Kunz, editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, DC, USA.
Whitaker, J. O., Jr. 1994. Food availability and opportunistic versus selective feeding in insectivorous bats. Bat Research News 35:75-77.
Whitaker, J. O., Jr., and W. J. Hamilton, Jr. 1998. Mammals of the Eastern United States. Third edition. Cornell University, Ithaca, New York, USA.
White, W. A. 1970. The geomorphology of the Florida peninsula. Geological Bulletin No. 51. Florida Department of Natural Resources, Tallahassee, Florida, USA.
Willey, C. H. 1974. Aging black bears from first premolar tooth sections. Journal of Wildlife Management 38:97-100.
Wilson, E. O. 1984. Biophilia. Harvard University Press, Cambridge, Massachusetts, USA.
Winterstein, S. R., K. H. Pollock, and C. M. Bunck. 2001. Analysis of survival data from radiotelemetry studies. Pages 351-380 *in* J. J. Millspaugh, and J. M. Marzluff, editors. Radio tracking and animal populations. Academic Press, San Diego, California, USA.
Wooding, J. B., and T. S. Hardisky. 1988. Black bear habitat study. Final Performance Report, Statewide Wildlife Research. Florida Game and Freshwater Fish Commission, Tallahassee, Florida, USA.
Wooding, J. B., and T. S. Hardisky. 1994. Home range, habitat use, and mortality of black bears in north-central Florida. International Conference on Bear Research and Management 9:349-356.
Worton, B. J. 1995. Using Monte-Carlo Simulation to Evaluate Kernel-Based Home-Range Estimators. Journal of Wildlife Management 59:794-800.

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Whitaker, J.O., Jr., C.L. Gummer, A. Howard, W.A. Ulrey, and V. Brack, Jr. 2005. Bats of Camp Atterbury in south-central Indiana. Proceedings of the Indiana Academy of Science 114(2):216-223

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