REPRODUCTIVE ECOLOGY, CUB SURVIVAL AND DENNING ECOLOGY OF THE FLORIDA BLACK BEAR

By

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by

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“In every walk with Nature, one receives far more than he seeks”
Steep Trails, John Muir, 1918

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The Florida black bear (*Ursus americanus floridanus*) currently occurs in several geographically isolated sub-populations. Successful management of the remaining black bear populations in a human-dominated landscape necessitates an understanding of all aspects of black bear ecology, but data on critical demographic variables and denning ecology for the Florida black bear are scarce. Using data from a 4-year (1999-2003) study, I investigated reproductive parameters, cub survival and denning ecology of Florida black bears in Ocala National Forest (ONF) and the adjacent residential area of Lynne, Florida. Thirty-nine litters produced 81 cubs (39M, 42F) for an average litter size of 2.08 ± 0.11. Females produced their first litters at ages 2-6; the mean age of first reproduction was 3.46 ± 0.33 years. Overall, the mean inter-litter interval was 1.83 ± 0.17 years; excluding the females that reproduced in consecutive years due to litter loss, the mean inter-litter interval was 2.11 ± 0.11 years. The mean fecundity rate was 0.49 ± 0.06 and fecundity ranged from 0.27 in 1999 to 0.68 in 2002.

Using specially designed radiocollars, I monitored the fate of 41 bear cubs. Overall, probability of survival of cubs to 9 months of age was 0.46 ± 0.09. The most important causes of cub mortality included cannibalism and direct and indirect mortality from vehicle collisions. My results indicate that reproductive rates of female black bears in the Ocala study area are comparable to those reported for other black bear populations, but that cub survival rates were lower than those reported for most black bear populations.

On average, parturient females denned for a longer period ($\overline{X}$ =113 ± 3.3 days, n = 34) than non-parturient females ($\overline{X}$ =54 ± 6.0 days, n = 17); 6 non-parturient females remained active throughout the winters. Parturient females emerged from dens 50 ± 3.0 days later than non-parturient females, but den entry dates did not differ between the two groups. Most females denned in ground nests (n = 45) and excavated dens (n = 7), but one female denned in a tree den. I found no evidence to suggest that females selected for, or against, specific habitat type for denning in ONF or in Lynne. The lack of selection for particular denning habitat may suggest that most habitats in my study area provided the characteristics female black bears were seeking when selecting a den site, or that the microhabitat characteristics may not be substantially different in the intensively managed and highly fragmented habitats.

CHAPTER 1
INTRODUCTION

Reproduction is a key process by which a species survives, thrives, or, failing this, becomes extinct (Wildt et al. 2003). Dynamics of many wildlife populations are greatly influenced by the reproductive rate, and the rate at which young are recruited into the breeding population (Fuller and Sievert 2001). Thus, knowledge of reproductive ecology and survival of young is critical for wildlife management, because management practices must frequently target these critical population parameters.

In black bear (*Ursus americanus*) populations, reproductive rates are determined by age of first reproduction, inter-litter interval, and litter size (Bunnell and Tait 1981). Reproductive success of black bears also is influenced by cub survival, which may be affected by several factors, including maternal experience and condition, food availability and social factors (Eiler et al. 1989, Elowe 1987, LeCount 1987, Rogers 1976). However, rigorous estimates of cub survival rates, and causes of mortality are limited (Higgins Vashon et al. 2003). Because birth and early maternal care occurs in maternal dens, denning also can influence reproductive success of black bears. Inadequate protection from weather or disturbance can reduce survival of cubs and reproductive success of the female (Alt 1984a, Elowe 1987, Oli et al. 1997). Consequently, data on denning chronology and information on den characteristics are important considerations in formulation or implementation of management plans for black bear conservation.

Reproductive parameters, cub survival rates and denning ecology can vary substantially among black bear populations because different habitats provide different environmental, nutritional and social conditions (Alt 1982, Garshelis 1994, Kasbohm 1996, Kolenosky 1990, McLaughlin et al. 1994). Thus, population-specific data may be necessary for development of sound management and conservation strategies.

For the remaining populations of the Florida black bear (*U. a. floridanus*), management strategies based on population-specific demographic data may be critical. Historically, the Florida subspecies was found throughout Florida and in portions of southern Georgia, Alabama and Mississippi (Brady and Maehr 1985b). In the early 1900's, large-scale logging and unregulated hunting in Florida reduced the statewide bear population to an estimated several hundred. Due to management efforts and maturation of second growth forests, bear populations have since rebounded. However, the current distribution represents an 83% loss from historical levels, and Florida's bear populations occur mainly as geographically isolated sub-populations (Wooding 1993).

As Florida's human population continues to increase, further loss and fragmentation of bear habitat likely continues. Thus, long-term persistence of Florida black bears depends on formulation and implementation of science-based management plans, which require data on all aspects of bear ecology. Although black bear reproductive ecology, cub survival, and denning ecology have been investigated elsewhere, rigorous estimates of black bear reproductive parameters and denning ecology of Florida black bear are limited (Harlow 1961, Harlow 1962, Seibert 1995, Wooding and Bukata 1996, Wooding and Hardisky 1992). In addition, information on cub survival rates, causes and timing of cub mortality are not available for Florida black bears. The objective of this research was to provide data on reproductive parameters, cub survival, including causes and timing of mortality, and denning ecology of Florida black bears in north central Florida.

In Chapter 2, I investigate reproductive ecology of Florida black bears. Based on a 4-year study, I provide estimates of age of first reproduction, litter size, and inter-litter interval, and overall and age-specific fecundity rates. I examine factors influencing reproductive parameters. In addition, I investigate cub survival rates, the causes and timing of cub mortality, and the factors influencing cub survival. In Chapter 3, I investigate female black bear denning ecology. I determine the denning chronology, den type and habitat characteristics of den sites.

Taken together, data presented in this thesis will provide information beneficial to the management and conservation of the Florida black bear. Cub survival and reproductive data presented herein also may be used for population modeling and population viability analysis. Data on den characteristics will help wildlife managers to implement management activities to enhance the quality of the denning habitat. Denning chronology data will also allow managers to take necessary actions such that disturbance to denning bears is minimized.

CHAPTER 2
BLACK BEAR REPRODUCTIVE ECOLOGY AND CUB SURVIVAL IN NORTH CENTRAL FLORIDA

Introduction

Recruitment, in the broadest sense, is the addition of new individuals to a population. The process is clearly important for understanding a range of ecological phenomena, including dynamics of wildlife populations (Caley et al. 1996). Recruitment rate is influenced by the proportion of productive females, litter size and offspring survival (Fuller and Sievert 2001). These reproductive parameters in mammals are thought to be influenced by maternal condition and food availability (Brand and Keith 1979, Fuller and Sievert 2001, Landa et al. 1997, Lindstrom 1989, Sadleir 1969). Human-caused disturbance, habitat loss and mortality also may significantly affect important life cycle components, including recruitment. Large carnivores may be particularly sensitive to anthropogenic presence, due to their large home ranges, low reproductive rates, and potential for conflict with humans (Gittleman et al. 2001, Noss et al. 1996).

Reproductive parameters of the American black bear (*Ursus americanus*) vary considerably among populations. These differences are largely attributed to local differences in the quality, quantity and availability of nutritional resources (Alt 1982, Beecham 1980, Eiler et al. 1989, Jonkel and Cowan 1971, Kasbohm 1996, Kolenosky 1990, McLaughlin et al. 1994). Therefore, information on reproductive parameters from one black bear population to another may not be applicable.

Survival rates of young also vary considerably among populations; however, factors affecting this parameter are not well understood (Bunnell and Tait 1981). Estimates of survival rates of black bear cubs are usually obtained by comparing numbers of cubs present in natal dens to the number of yearlings that survive to den the next winter (Alt 1982, Eiler et al. 1989, Kasbohm 1996, Miller 1994). This method, however, may underestimate survival rate (Higgins Vashon et al. 2003), and does not provide information pertaining to specific causes of cub mortality. Causes of mortality can be determined by monitoring radio-collared animals, but, standard radio-collars are inappropriate for rapidly growing bear cubs (LeCount 1987). Few studies have utilized radiocollars designed to accommodate cub growth (Elowe 1987, Higgins Vashon et al. 2003, LeCount 1987) to provide important insights into the causes and timing of cub mortality. Causes of cub mortality probably vary considerably among populations, and population-specific data may be critical for developing sound management strategies.

For the threatened Florida black bear (*U. a. floridanus*), management strategies for the conservation of the remaining populations necessitates population-specific data on all aspects of bear ecology. Black bears once ranged throughout Florida, but currently occur in 6 core and 2 remnant geographically isolated sub-populations (Eason 2000). Although aspects of Florida black bear life history have been studied (Brady and Maehr 1985a, Maehr and Brady 1984, Maehr et al. 2001, Wooding and Hardisky 1994), rigorous estimates of reproductive parameters are scarce. Available data are based on field observations (Harlow 1961) and examination of reproductive tracts (Wooding and Bukata 1996) and no systematic study has been conducted to investigate reproductive parameters and the factors affecting these parameters. Furthermore, data on cub survival and factors affecting cub survival currently are not available. These data are critical in aiding management decisions for the Florida black bear, especially with the continued threat to the state's bear population from human-induced mortality and habitat loss.

Objectives of this study were to: (1) investigate reproductive biology of the Florida black bear, and (2) provide rigorous estimates of Florida black bear cub survival rates. I estimated age of first reproduction, litter size, inter-litter interval and fecundity rate, and investigated factors influencing these parameters. I also investigated the causes and timing of cub mortality, and evaluated the factors influencing survival of cubs.

Study Area

The study was conducted within Ocala National Forest (ONF) and in the adjacent residential community of Lynne in north-central Florida. The Ocala bear population is 1 of 8 populations in Florida. ONF has the highest density of bears in the state (estimated at 0.28 bears/km^2), and the population is believed to be stable or slightly increasing (McCown et al. 2004). ONF provides one of the largest and most important bear habitats remaining in Florida. Field work was centered along State Road 40 (SR 40) and extended approximately 6 km north and south of SR 40 between the Oklawaha River and State Road 19 (Fig. 1). This area encompassed approximately 400 km^2 and covered the central portion of ONF and Lynne.

The major vegetation types are: 1) swamps and marshes along the Oklawaha and St. Johns Rivers; 2) pine flatwoods between the rivers and central ridge; 3) mixed hardwood swamps; and 4) dune-like interior ridges of sand pine and scrub oaks interspersed with numerous lakes and ponds (Ayedelott et al. 1975). Other plant communities within the study area include wetland hardwoods and prairies.

The sand pine/scrub oak community is managed as a commercial crop within ONF with several timber harvesting compartments. Stand age ranges from recently harvested clear cuts (0-2 years) to mature stands (≥ 25 years). In addition to timber, ONF is managed for recreation and wildlife resources. With the exception of four designated wilderness areas, the ONF contains an extensive grid of U.S. Forest Service maintained roads, off-road vehicle roads, and forest trails.

The community of Lynne is located on the western boundary of ONF. It contains highly fragmented habitat of residential and commercial development interspersed with parcels of forest service lands. Approximately 80% of adult female black bears in Lynne have been diagnosed with demodicosis (mange) (Mark Cunningham, unpublished data). The mites live in the hair follicles, and severe infestations result in hair loss. In domestic dogs, demodicosis is often the result of immunosuppression and can be fatal if left untreated (Scott et al. 1995). The underlying cause of demodicosis occurring in bears in this region and its effect on adult or cub survival are unknown.

Methods

Reproductive Parameters

Adult females were captured using Aldrich spring-activated foot snares, and immobilized with 1:1 mixture of Tiletamine hydrochloride and Zolezepam hydrochloride (Telazol ®) administered at 3.0 - 4.5mg/kg of estimated body weight via remote injection gun. Females were fitted with a motion-sensitive radio collar (150-151 Mhz; Telonics, Mesa, Arizona). Collars had a leather “break-away” connector that allowed them to fall off after approximately 2 years. Bears were marked with lip-tattoos and ear tags for identification. Bears were measured, weighed, and evaluated for body condition and reproductive status. Body condition was quantified on a scale 1 to 5 (1 = excellent, thick subcutaneous fat over entire body; 2 = good, moderate subcutaneous fat; 3 = fair, minimal subcutaneous fat but well muscled; 4 = poor, no appreciable subcutaneous fat; and 5 = emaciated). Hair and blood samples were collected for genetic analysis, and first pre-molars were extracted for age determination (Willey 1974). Females were examined for vulval swelling as an indicator of estrus (Jonkel and Cowan 1971). Nipples were examined for lactation, length and color. These indicators of reproductive status, and subsequent documentation of cub production, were used to estimate age of first reproduction, inter-litter interval and fecundity.

I located instrumented bears 1-3 times a week on the ground using standard triangulation methods, and aerially with a single-engine Cessna 172 aircraft equipped with wing-mounted antennas. Information on denning status and location of dens were obtained from radio-telemetry.

I investigated evidence of cub production from late January to the end of February by listening for cub vocalizations in the vicinity of dens of radio-collared females. To minimize disturbance to denning females, I quietly clipped through the vegetation and established a small trail within 10-20 m of the den site. This method allowed for a quiet approach and permitted me to listen for cub vocalization without disturbing the bears.

I visited natal dens from March to April. I did not immobilize females; they typically left the den shortly after I approached dens within viewing distance. The cubs were brought to a nearby area (25-50 m from den). For each cub, sex, mass, morphometric measurements, teeth eruption, health and body condition were noted. Body condition for the cubs was evaluated using the same scale as adults (1 = excellent to 5 = emaciated), but was based more on size and muscle mass than amount of fat. For identification, I lip-tattooed cubs from 2000 and 2001 cohorts, I used a transponder chip inserted subcutaneously between the shoulder blades for cubs from 2002 and 2003 cohorts. I estimated age of cubs based on body size, mass, tooth eruption, whether eyes were open or closed, and minimum known age (based on the date cubs were first heard in that den). In 2003, I also measured cub hair and ear lengths and used a method described in Bridges et al. (2002) to estimate age. Cubs were returned to the maternal den within 45 minutes, and the female was monitored with radio-telemetry until she returned to the den site. The family group was monitored again the following morning to verify that the mother and the cubs remained together.

I performed statistical analyses of the reproductive data using SAS (SAS institute, Inc. Cary, N.C). I used the Kruskal-Wallis test to test the null hypothesis that litter size did not differ among cohorts, and to test null hypothesis that body mass of cubs born in litters of different sizes were equal. I used the Spearman rank-correlation to test if litter size was correlated with maternal age, body mass, and size (length, chest and neck). I used the Wilcoxon rank-sum test to compare litter size and litter mass of cubs between ONF and Lynne, and between primiparous and multiparous females. I also used the Wilcoxon rank-sum to test the null hypothesis that mass of male and female cubs, and mass of cubs born to primiparous and multiparous females, were equal. I estimated age-specific fecundity rates by dividing the estimated number of female cubs by the number of radio-collared females in the appropriate age class. Thus, some females were included in more than 1 age class if they produced more than 1 litter during the study. I obtained the number of cubs from den visits and/or observations made during capture or tracking of the adult female. For unknown litter sizes, I assigned a litter size of 2 (the most frequent litter size). Females that were captured in summer with no indications of having produced cubs that year (no lactation, or evidence of cubs with her, and produced litter the following winter) were assumed not to have reproduced that year.

Cub Survival and Causes of Mortality

During den visits in 2002 and 2003, cubs weighing more than 1.5 kg were fitted with lightweight radiocollars. Cubs that did not meet my minimum body weight criterion for radio-collaring were revisited and collared at a later date. The collars employed a sliding mechanism designed to expand with cub growth (Higgins Vashon et al. 2003). In 2002, I used a 55-65 gram transmitter with a 12-hour mortality switch (American Wildlife Enterprises, Tallahassee, FL). However, due to numerous transmitter failures in 2002, I switched to a model with a 2-hour mortality switch that weighed 64 grams (Telonics, Mesa, Arizona) in 2003. None of the transmitters used in 2003 failed. As an added safety measure, I used a 20 mm elastic piece of cotton as a break-away device on all collars. The collar weight was ≤ 4% of cub body-mass.

After den emergence, I located radio-collared females and cubs 4 to 7 times per week for the first 3 months (April-June), and at least twice a week thereafter. This schedule provided intensive monitoring during the period with highest expected mortality (LeCount 1987, Elowe 1987). I approached cubs immediately if a collar transmitted a mortality signal, or if a cub was located away from the mother, regardless of the activity mode of the transmitter. Upon finding a dead cub, I recorded field sign near the collar/cub site, such as tracks, scat, blood, and hair. I placed cub remains on ice and transported them to the FWC Wildlife Research Laboratory for necropsy.

I used the Kaplan-Meier method with staggered entry design to estimate survival of cubs from the date of collaring to date of documented death or until the collar was dropped (Pollock et al. 1989). If the exact date of a cub's death was unknown, I used the midpoint of the interval between the date the cub was last known to be alive and the date the mortality signal was first detected. Log-rank tests were used to test the null hypotheses that survival curves would not differ between cohorts, study sites (ONF, Lynne), male and female cubs, cubs born to primiparous and multiparous females, and lightweight (< 2 kg) and heavyweight (≥ 2 kg) cubs. The Kaplan-Meier method assumed that survival times were independent among animals (Pollock et al. 1989). Survival times of cubs within the same litter may violate this assumption. Violation of this assumption does not cause bias in estimates of survival, however, it does result in underestimation of the variances (K.H. Pollock, pers. comm.). I used SAS (SAS institute, Inc. Cary, N.C) for all statistical analysis except for the Kaplan-Meier, which was performed in S-plus (MathSoft, Inc. Seattle, WA). For all statistical analyses, significance was assessed at $\alpha = 0.05$.

Results

Reproductive Parameters

Estrus and age of first reproduction

From May 1999 to July 2003, 52 females were captured a total of 67 times. I observed estrus (swelling of the external genitalia) on 29 occasions (43%) in 24 individuals. Estrus was documented from 11 May to 26 August, although most females (86%) were observed in estrus from 10 June to 10 August. I determined age of first reproduction for 13 females. Of these, 3 produced first litters as 2-year olds, 4 as 3-year-olds, 4 as 4-year-olds, 1 as a 5-year-old and 1 as a 6-year old. The mean age of primiparity was 3.46 ± 0.33 years.

Inter-litter interval and birth date

Twelve inter-litter intervals were obtained from 11 individual females. Three (25%) litters were produced at a 1-year interval, 8 (67%) at a 2-year interval, and 1 (8%) at a 3-year interval. Only those females that experienced a complete loss of litter prior to breeding season produced litters in 2 consecutive years. Overall, the mean inter-litter interval was 1.83 ± 0.17 years; excluding the females that reproduced in consecutive years, the mean inter-litter interval was 2.11 ± 0.11 years.

The estimated median birth date was 28 January, and ranged from 15 January to 13 March. Most litters (92%, n = 36) were born between 15 January and 8 February. The mean estimated age of cubs examined in dens was 7.3 weeks, and ranged from 3 to 10 weeks.

Litter size and fecundity rates

The mean litter size observed in 39 natal dens was 2.08 ± 0.11, and modal litter size was 2 (Fig. 2). There was no significant difference in litter size among cohorts (χ^2= 2.58, df = 3, P = 0.46), between ONF and Lynne litters (Z = 0.78, P = 0.43) or between litters born to primiparous and multiparous females (Z = -1.86, P = 0.06; Table 1). However, excluding 1 female (R086) with atypical reproductive history from the analysis resulted in first time litters being significantly smaller than subsequent litters ($\overline{X}_{\text{primiparous}}$ = 1.43; $\overline{X}_{\text{multiparous}}$= 2.15; Z = -2.52, P = 0.01). R086 was first captured at age 3. She was in estrus, weighed 51 kg and was observed with males during the following breeding seasons, but she did not produce cubs until 6 years of age. At age 6, she had a litter of 3 cubs.

Overall, litter size was correlated with litter order ($r_s = 0.356$, $P = 0.026$), maternal age ($r_s = 0.334$, $P = 0.040$), body mass ($r_s = 0.411$, $P = 0.027$), and chest circumference ($r_s = 0.499$, $P = 0.007$). However, when first and subsequent litters were considered separately, only correlation between litter size and chest circumference of multiparous females was significant ($r_s = 0.483$, $P = 0.042$). Age-specific fecundity rate ranged from 0.23 for 3-year-olds to 0.94 for 8-year-olds and averaged 0.49 (Table 2). Yearly fecundity rates ranged from 0.23 in 1999 to 0.68 in 2002 (Table 3).

Cub and litter mass

The mean mass of 81 cubs in natal dens was 2.02 ± 0.06 kg and ranged from 0.53 to 2.92 kg. Male cubs were slightly heavier (2.06 ± 0.08 kg) than female cubs (1.98 ± 0.09), however, the difference was not significant ($Z = 0.40$, $P = 0.69$). Mass of cubs born to primiparous females did not differ from those born to multiparous females ($Z = -1.83$, $P = 0.07$). Litter size did not influence body mass of cubs, except that cubs from a litter of 4 were substantially lighter than other cubs (Table 4). Overall, the mean litter mass was 4.19 ± 0.25 kg.

Sex ratio

Sex of 81 cubs (39 M, 42 F) did not deviate from parity ($\chi^2 = 0.111$, $df = 1$, $P = 0.739$). Sex composition of individual litters was: 4 single litters were all male (M), and 3 single litters were all female (F); twins consisted of 4 all male litters, 6 all female litters, and 13 MF litters; triplets consisted of 1 all male litter, 3 MMF litters, and 4 MFF litters; and 1 quadruple MFFF litter.

Health and physical condition of cubs

Fifty-two of 81 cubs (64%) evaluated during den visits were judged to be in excellent or good condition, and 29 (36%) were in fair or poor condition. The majority of cubs (93%) had their eyes open. Teeth eruption varied from none (20%), to partial (63%) to complete (17%) depending on the age at the time of examination. Dermatitis characterized by multifocal discrete areas of scabbing, scaling, crusting, and alopecia (hair loss) was documented in 18 cubs (22%, n = 81). This skin condition occurred in both Lynne and ONF cubs and was not associated with demodicosis occurring in adult bears. This condition was apparently only temporary; none of the cubs examined after den emergence were observed with it. One to 2 ticks on 3 cubs were the only ectoparasites found. In 2002, I documented mild nasal discharge in 5 litters (10 cubs); however, no adverse effects were noted subsequently.

During den visits, I observed a female cub from a litter of 2 cubs with a skeletal deformity. The cub had a domed cranium (possible hydrocephalus), shortened upper jaw, and 8 teats. Her serum was clear, indicating she had not suckled recently. She weighed 1.29 kg less than her male littermate (1.37 kg vs. 2.66 kg) and was noticeably weak. In a revisit 10 days later, she had gained 147 grams (littermate gained 550 grams) and appeared stronger.

Cub Survival

Of 38 radio-collared and 3 non-collared cubs monitored during 2002 and 2003, 20 cubs died during the first 9 months of life. One of the non-collared cubs that died was censored instead of counted as dead in the Kaplan-Meier survival analysis because of the length time between observations. Most (68%) of the cub mortality occurred during April – June (Fig. 3). Overall probability of survival to 9 months of age was 0.459 (95% CI: 0.31 to 0.68; Fig. 4). Probability of survival did not differ between cohorts ($\chi^2 = 0.29$, df = 1, $P = 0.59$), between ONF and Lynne ($\chi^2 = 0.62$, df = 1, $P = 0.43$), or between male and female cubs ($\chi^2 = 0.17$, df = 1, $P = 0.68$; Table 5). Although survival rate of cubs born to primiparous females was not statistically different from that of cubs born to multiparous females ($\chi^2 = 2.04$, df = 1, $P = 0.15$), the lack of significance may have been due to small sample size of cubs born to primiparous females (Fig. 5). Survival of cubs with body mass < 2 kg and ≥ 2 kg did not differ significantly ($\chi^2 = 0.02$, df = 1, $P = 0.89$; Table 5).

For the non-collared cubs of the 2000 and 2001 cohorts, I was able to determine the fate of 20 (11 M, 9 F) of the 40 cubs. I documented 8 (3 M, 5 F) mortalities, and verified that 12 (8 M, 4 F) cubs survived to 7-13 months. The fate of 20 other cubs (10 M, 10 F) was unknown. Of the 8 mortalities documented, 7 represented a complete loss of the litter.

Of the 20 mortalities documented in this study I attributed 7 to cannibalism, 4 to anthropogenic sources (direct and indirect vehicle-related mortality), 2 to malnutrition, 2 to abandonment, 1 to trauma, and 4 to unknown causes. Cannibalism also was suspected in 1 of the unknown cases; however, it was unclear if a bear killed the cub or consumed the carcass after death. In addition to the abovementioned cases of cannibalism, a radio-collared female and her cub(s) in ONF were killed and fed upon by a radio-collared male. I had verified the presence of cubs by listening for vocalization; however, the family was killed before the cubs were radio-collared. These cubs were not included in the estimation of survival rates. I recovered a few cub skull fragments at the den, but it was unclear if more than one cub had been present.

Of 40 non-collared cubs in 2000 and 2001, I was able to determine the cause of 4 of the 8 documented deaths. Two of the cub deaths were due to cannibalism, 1 due to vehicle-related mortality and 1 due to disease. In the cannibalism case, the whole family (the mother and 2 female cubs) was killed and fed upon immediately after den emergence by an adult, radio-collared male. The vehicle related mortality also included the death of the mother; a vehicle killed her 5 days prior to 1 of her 2 cubs being killed by a vehicle collision.

Discussion

Dynamics of many wildlife populations are heavily influenced by the reproductive rate and the rate at which young are recruited into the adult population. Obtaining reliable estimates of these parameters for large, long-lived carnivores, such as bears, can be a challenge due to the secretive nature of the animals and the length of the study required to collect necessary data. Recruitment rate, however, also depends upon survival of young, and identifying the causes of mortality can be crucial for management.

Typically, cub survival rates are obtained by comparing the number of cubs in a natal den to the number of yearlings the following winter. I found that this method was not appropriate for Florida black bears, because females with yearlings typically denned for only short periods, were easily aroused, and fled when approached making observations difficult. While labor intensive, the use of cub radio-collars provided data necessary for rigorous estimates of cub survival rates and also allowed determination of the causes of cub mortality.

Reproductive Parameters

The mean age of first reproduction (3.46 years) observed in my study population was comparable to those reported in other eastern black bear populations (Alt 1982, Freedman et al. 2003, Hellgren and Vaughan 1994, Maddrey 1995). Most females in our study area began reproducing at 3 or 4 years of age; however, 3 females began reproducing at age 2. Although not common, reproduction at 2 years of age also has been observed in other black bear populations (e.g. Pennsylvania: Alt 1989; North Carolina: Maddrey 1995). When ages are estimated from cementum annuli, there is potential for error, especially for the bears in southern regions whose cementum annuli are less distinct than they are in bears from further north. Therefore, it is possible that our age estimations are underestimated by 1 year. However, the age estimations of the 2-year old females were given a highest “certainty code”, suggesting that the age determination for those females was accurate (G. Mattson, personal communication).

The inter-litter interval (2.11 years) observed in our study is similar to inter-litter intervals reported for other black bear populations (Eiler et al. 1989, Hellgren and Vaughan 1989a, Kasbohm 1996, Noyce and Garshelis 1994). Because my study population experienced a high rate of complete litter loss, I also calculated the inter-litter interval by including the 1-year intervals due to complete losses of litter (1.89 years). Although most reports omit the 1-year intervals due to litter loss (Beck 1991, LeCount 1987, Swhwartz and Franzmann 1991), including them would provide a better estimate of the average inter-litter interval (McLaughlin et al. 1994). Inter-litter intervals exceeding 2 years have been attributed to food shortages in black bear populations (Eiler et al. 1989, McLaughlin et al. 1994, Miller 1994, Rogers 1976). However, in our study area, I documented only 3 instances in which a reproductively capable female did not produce cubs. The few lapses in the reproductive cycle appeared to be unrelated to food resources. On the contrary, following a mast failure in the fall of 2000 (McCown et al. 2004), all but 1 female of reproductive age without yearlings produced cubs. In addition, the mean litter size for cohort 2001 was the highest recorded in the 4-year study. These results may indicate that bears were able to shift to alternative foods and to locate small, isolated mast producing areas, an observation supported by the radio-telemetry data. Black bear behavioral plasticity to use alternative food sources to cushion the effects of hard mast failures has been reported in the Southern Appalachian Mountains, Tennessee (Eiler et al. 1989), Shenandoah National Park, Virginia (Kasbohm 1996), and Maine (McLaughlin et al. 1994).

Overall, the mean litter size of 2.08 (n = 39) for my study area was slightly smaller than the mean litter size of 2.60 (n = 81) previously reported (Wooding and Bukata 1996) for Florida bears, and the mean litter size of 2.56 (n = 595) for eastern bear populations (McDonald and Fuller 2001). The Wooding and Bukata (1996) estimate was derived from corpoa lutea counts in reproductive tracts collected from bear carcasses throughout Florida. Although examination of reproductive tracts is a widely used technique to determine litter size, the corpoa lutea data represent the maximum reproductive potential of a population and should be used with caution (Wooding and Bukata 1996). Similar to other eastern bear populations, the mean litter size for Florida black bears in our study was higher than the mean reported for western bear populations ($\bar{X}$ = 1.71, n = 418; Bunnel and Tait 1981).

Fluctuating food abundance, maternal condition and body size have been suggested as factors affecting litter size in black bear and other carnivore populations (Alt 1989, Brand and Keith 1979, Elowe 1987). However, some recent studies have indicated that litter size is relatively insensitive to maternal condition, and litter order is the most important factor (McDonald and Fuller 2001, Noyce and Garshelis 1994), and my results are consistent with this suggestion. When all litters were pooled, litter size was correlated with litter order, and age and size (mass, and body-measurements) of the mother. However, when first and subsequent litters were analyzed separately, the correlation between maternal age and size with litter size disappeared, although there was a considerable variation in age (5 – 13 years) and body mass (56 - 113 kg) among multiparous females.

Fecundity rate is another important parameter when considering population dynamics. The high variation in the fecundity rate between ages 7 and 8 (0.33, n = 9; and 0.94, n = 8 respectively) was probably due to the relatively small sample sizes. Age-specific fecundity rates for 3 and 4 year-olds in our study were lower than those reported for Smoky Mountain National Park (McClean and Pelton 1994) and North Carolina (Powell et al. 1996), although fecundity rates of other age classes compared favorably.

Cub Survival

In my study area, survival probability of cubs to 9 months of age was 46%. I was unable to attain annual survival rates because radio-collars either dropped or transmitters failed by the time cubs were 9 months of age. However, cubs are most vulnerable to mortality during the first 5 months of their life (Elowe and Dodge 1989, LeCount 1987). Although cub survival rates can vary considerably between populations and temporally within populations, the majority of studies reported over 55% cub survival for the first year (Table 6; see also reviews in Bunnell and Tait 1981, Freedman et al. 2003). Therefore, the survival rate of cubs in this study is lower than those reported for other black bear populations.

Several factors can influence survival rates of cubs. In Ocala, maternal experience appeared to affect survival. By week 25 after collaring, 79% of the cubs of primiparous females had died, compared to 42% of cubs of multiparous females that had died in the same period. Although the difference in survival rate of cubs born to primiparous and multiparous females was not statistically significant, it probably reflects a biological significance. Maternal experience has been shown to affect cub survival in other bear populations. For example, in Massachusetts, Elowe (1987) found that primiparous females lost their entire litters more often (57%) than multiparous females (7%). Similarly, in Pennsylvania, cub mortality occurred in 55% of the 11 initial litters, but only in 17% of 23 subsequent litters (Alt 1982). In Maine 29.4% of first litters were lost annually compared to 5.9% subsequent litters (McLaughlin et al. 1994).

In addition to maternal experience, differential survival of cubs has been attributed to sex of cubs (Elowe and Dodge 1989), litter size (Rogers 1976), nutrition through maternal condition (Eiler et al. 1989), and body size of cubs (Rogers 1976). Litter size, cub body-mass or sex did not appear to affect survival in our study area.

Timing and Causes of Mortality

Although cub mortality rates are available for many black bear populations, few studies have reported specific timing and causes of cub mortality. I found that cubs were most vulnerable to mortality at age 1.5 – 5 months; 68% of mortality occurred during that time. These results are similar to other studies where cubs were followed with radio-telemetry. In Arizona, LeCount (1987) found that the majority of cub mortality occurred within 60 days of den emergence. In Massachusetts, 76% of cub mortality occurred between 1.5 and 5 months of age (Elowe and Dodge 1989). Similarly, based on field observations, Alt (1982) and Rogers (1976) reported that most cub mortality occurred before the end of the breeding season.

In our study, more cubs died from cannibalism than any other cause. Cannibalism, defined as intraspecific predation, is a behavioral trait common to many species (Fox 1975). Among Ursidae, observations of cannibalism are rare, but have been reported for brown bears (Swenson et al. 2001) and black bears (Alt 1984b, Hellgren and Vaughan 1989a, LeCount 1987). However, the rarity of observations of bears killing cubs may be partly due to the small number of studies that have been able to determine the actual causes of death using radio-telemetry. It has been hypothesized that cannibalism of young by adult males is often a sexually selected behavior. By killing a genetically unrelated individual, the male eliminates another male's offspring and potentially increases his own reproductive success (Fox 1975, Polis 1981). This behavior has been suggested to occur in heavily hunted bear populations where immigration of young males was high due to older adult males being killed by hunters (LeCount 1987, Swenson et al. 2001).

In our study area, cannibalism was probably a response to the presence of vulnerable individuals, and the benefit gained was nutrition rather than potential mates. Including the 1 cannibalism case documented in 2000, 3 of the 7 attacks on a family occurred in or around natal dens. The predators were 2 resident, radio-collared adult males. In 2 instances, the females also were killed with their cubs. It is not intuitive that adult males would kill potential mates; instead, the explanation often given is that females were killed trying to defend cubs (Garshelis 1994). However, cannibalism in many species characteristically involves asymmetrical interaction: cannibals are relatively invulnerable to injury and death during a predatory attack on the victim (Polis 1981). This situation is the case when the victim is a cub and the predator is an adult bear, but adult females also may be more vulnerable during denning because of lethargy common to denned females. Male bears in Florida typically remain active throughout most of the winter (Wooding and Hardisky 1992) and food sources are limited during this period. Denning females may, therefore, be killed because of increased vulnerability, not just attempting to defend the cubs. Cannibalism on denning bears of both sexes and all age classes also has been reported in other black bear populations (Alt 1984b, Garshelis 1994, Hellgren and Vaughan 1989a, Tietje et al. 1986).

Four cases of cannibalism that occurred after den emergence resulted in death of only cubs, not adult females. Although they occurred either before or during the breeding season, they did not result in complete loss of the litter, and the female, therefore, was not available for breeding. In 2 cases, 2 cubs out of litters of 3 cubs were killed. However, within individual families the cannibalisms occurred 3 and 4 months apart. It was unclear if the same bear attacked the family twice.

In most instances where I suspected or confidently identified the predator, it was an adult male. This observation is consistent with other reports that adult males are most often the predators (Bunnell and Tait 1981, Stringham 1983), although females occasionally kill cubs of other females (Garshelis 1994). I found evidence that 1 adult female (R189) with 2 cubs killed and consumed a 4-month old cub (R219) of another female. Prior to the death, cub R219 was separated from her mother for unknown reasons and joined the family group of R189. R219 was located with R189 and family for 3 days; on the 4th day her collar switched to mortality and her remains were found in a day bed, with indications she had been killed by a bear. Although I could not confirm that female R189 killed the cub, field signs and telemetry data indicated that the area was used by R189 and her cubs. What lead to the brief “adoption” is intriguing. In Alaska’s McNeil River sanctuary, two instances of an exchange of cubs among 5 different maternal females was observed in a population of brown bears (Erickson and Miller

1962, Glenn et al. 1974). To my knowledge, cub adoption without human intervention in black bears has not been documented.

Direct and indirect human-caused mortality accounted for most cub mortality in the Lynne area. From 2000 to 2003, 58% (n = 12) of radio-collared adult females in Lynne died due to anthropogenic factors, resulting in a high indirect mortality of cubs. At the time of death, five of the females had cubs and 1 was pregnant. Three of the deaths were due to bear-vehicle collisions. In one instance, a female with 9-month old cubs was killed while attempting to cross SR 40. I observed the cubs (1 M, 1 F) in the area where the mother was killed, and 5 days later the female cub was killed in the same area. The subsequent fate of the uncollared male cub was unknown. In another instance the mother was killed and her 2 4-month old cubs died approximately 1 month later from malnutrition. In the third instance, the subsequent fates of 2 9-month-old cubs were not known. Illegal kills accounted for the rest of the adult female deaths, and left 2 cubs orphaned. One illegal kill occurred in 2003, and her 5.5-month old cub (R217) was followed with telemetry until the collar dropped in late October. R217's survival supports the notion that the age of self-sufficiency of black bears is 5.5 months (Erickson 1959). Interestingly, abandonment of dens did not occur although 2 of the 7 females in Lynne denned within 100 meters of residential areas. In Massachusetts, Elowe (1987) found human disturbance near den sites to be the significant cause of cub mortality prior to den emergence.

I documented malnutrition as the cause of death of cubs (without loss of mother) in only 1 family. The mother was a primiparous female in fair condition (body mass 45 kg) prior to denning. The cubs died 1 day apart, 2 weeks after den emergence. Necropsy revealed that both cubs were severely dehydrated and malnourished. Although both cubs had grown slightly in length, they had lost weight (90 and 170 grams) since their capture 6 weeks prior to death, suggesting inadequate nourishment for an extended period. Both cubs had evidence of thymic medullary depletion and adreno-cortical hyperplasia, indicative of stress. In addition, both cubs had scattered acute degeneration of neurons suggesting dehydration. There was no evidence of infectious disease or other abnormalities.

Similar to other studies where cubs were followed with radio telemetry, I found that mortality of black bear cubs due to disease, abnormalities, or natural accidents was low in my study population (Elowe and Dodge 1989, Higgins Vashon et al. 2003, LeCount 1987). Mites associated with demodicosis were present in some of the cubs in Lynne (M. Cunningham, unpublished data); however, none of the cub mortalities were attributable to demodicosis. In the case of a cub with cranial and other deformities, the ultimate cause of death of the cub was unknown, although the cub was monitored daily. The cub died approximately 2 months after den emergence. The carcass showed characteristics of cannibalism (crushed skull etc.); however, it was unclear whether she was killed by a bear or consumed after death. The cub's mother and littermate were within 25 meters of the carcass when approached; no other bear was seen or heard in the area.

Management implications

As human population in Florida continues to increase, human disturbance, habitat reduction and fragmentation are an increasing risk for the long-term persistence of the black bear populations. Due to dispersal barriers, many of the remaining bear populations in Florida are demographically isolated (Wooding et al. 1994). Persistence of bear populations, therefore, may depend upon positive population growth independent of immigration (Freedman et al. 2003). Reproductive and cub survival data presented here can be used in construction of life-tables, in analyzing population viability, and in assessment of management practices. To estimate population growth and to assess habitat suitability, managers also need reliable estimates of mortality rates for all age classes.

My results showed that female Florida black bears begin reproducing early, and have reproductive rates similar to other Eastern bear populations. This condition is probably due to natural foods being available throughout most of the year, which enables bears to mature quickly and have relatively high reproductive rates. Although I found mortality of cubs to be relatively high in comparison to other black bear populations, the Ocala bear population appears to be growing. Hunting of bears in ONF ended over 40 years ago, and the bear population has steadily increased (Brady and McDaniel 1978, Harlow 1962, McCown et al. 2001, Wooding and Hardisky 1988). The relatively high density of black bears in ONF may contribute to the occurrence of cub cannibalism, however, this may be confounded by other factors. Density-dependent population regulation has not been demonstrated in black bear populations, although they have been studied across a 20-fold range of densities (Garshelis 1994). Thus, further research is needed to investigate causes of cub mortality in other Florida black bear populations occurring at different densities to test the idea that the high rate of cannibalism in my study area is in fact density dependent.

In addition to cannibalism, I found that anthropogenic factors were an important cause of cub mortality. Cubs were vulnerable to direct anthropogenic mortality throughout the first year of their lives; however, they also were vulnerable to mortality if the mother was killed during the first 5 months of their lives. Management actions to reduce adult female mortality, especially during spring to early summer when traveling with dependent young, should be encouraged. In urbanized areas, this may include increased public education on bears (some of the females were illegally killed) and reduced speed limits on roads that cross important bear habitats. Survival of adult females is recognized as the most important factor in growth of black bear populations (Freedman et al. 2003). The high adult female and cub mortality in Lynne suggest that while bears may continue to inhabit forested tracts in the Lynne area, it is less likely that another population suffering from a similar degree of human disturbance that is more isolated from a large donor population could sustain this level of mortality.

Although challenging, future studies should include long-term investigations on Florida black bear cub survival rates and causes of cub mortality among populations with different bear densities, and various degrees of anthropogenic presence. In addition, studies focusing on survival of yearlings are necessary to adequately assess the recruitment rate of bears into reproductive age classes. I also suggest that comprehensive demographic studies are needed to estimate reproductive parameters in all Florida black bear populations. Together with survival data, reproductive parameters can improve our understanding of population dynamics of bears in Florida. In addition, these data can be used to develop demographic models and population viability analysis of the Florida black bear.

Table 1. Mean, standard error (SE) and range of litter size of Florida black bears in north central Florida, USA. Data are presented by cohort (2000-03), study area (ONF, Lynne), and maternal reproductive experience (primiparous, multiparous). Litter sizes between different cohorts, locations or reproductive experiences did not differ significantly.

Variable	Mean ± SE	Range	*N*
Cohort			
2000	1.89 ± 0.20	1-3	9
2001	2.30 ± 0.15	2-3	10
2002	2.17 ± 0.24	1-4	12
2003	1.88 ± 0.30	1-3	8
Location			
ONF	2.03 ± 0.13	1-4	29
Lynne	2.20 ± 0.25	1-3	10
Experience			
Primiparous	1.63 ± 0.26	1-3	8
Multiparous	2.15 ± 0.13	1-4	26
Overall litter size	2.08 ± 0.11	1-4	39

Table 2. Age-specific fecundity rates (m_x) of radio-collared female black bears ≥ 2 years of age in north central Florida, USA, 1999-2003. Number of cubs is the total number of cubs (male and female). Fecundity was estimated as the number of daughters (Number of cubs/2) divided by the number of females in each age class.

Age class (years)	Females	Cubs	m_x
2	9	5	0.28
3	13	6	0.23
4	14	8	0.29
5	20	19	0.48
6	15	24	0.80
7	9	6	0.33
8	8	15	0.94
≥ 9	28	33	0.59
Overall	116	116	0.49

Table 3. Fecundity rates for north central Florida, USA, 1999-2003. Number of cubs is total number of cubs (male and female cubs). Fecundity was estimated as the number of daughters (No. of cubs/2) divided by the number of females in each age class.

Year	Females	Cubs	m_x
1999	15	8	0.27
2000	27	32	0.59
2001	29	23	0.40
2002	25	34	0.68
2003	20	19	0.48

Table 4. Mean, standard error (SE) and range of body mass (kg) of Florida black bear cubs in north central Florida, USA, 2000-2003. Significant differences in body mass within a group is indicated by an asterisk.

Variable	Mean ± SE	Range	No. of cubs
Sex			
Male	2.06 ± 0.08	0.85 – 2.86	39
Female	1.98 ± 0.09	0.53 - 2.92	42
Experience			
Primiparous	1.70 ± 0.19	0.80 – 2.90	13
Multiparous	2.09 ± 0.07	0.53 – 2.92	56
Litter size			
1	2.23 ± 0.24	1.21 – 2.90	7
2	2.12 ± 0.08	0.53 – 2.92	46
3	1.93 ± 0.12	0.80 – 2.75	24
4	1.09 ± 0.05*	1.00 – 1.22	4
Overall	2.02 ± 0.06	0.53 – 2.92	81

Table 5. Kaplan-Meier survival rates for Florida black bear cubs in north central Florida, USA, 2002 and 2003. Survival rates between variables did not differ significantly.

Variable	Cubs	Exposure weeks	Survival rate	95 % CI
Cohort				
2002	26	29.4	0.44	0.28 - 0.71
2003	15	25.3	0.56	0.34 – 0.92
Location				
ONF	26	29.4	0.45	0.29 – 0.71
Lynne	15	25.3	0.45	0.21 – 0.94
Sex				
Male	18	29.4	0.43	0.21 – 0.87
Female	23	25.0	0.48	0.31 – 0.75
Body mass				
< 2 kg	17	29.4	0.33	0.12 – 0.87
≥ 2 kg	24	21.4	0.52	0.35 – 0.77
Experience				
Primiparous	7	25.3	0.21	0.04 – 1.00
Multiparous	34	29.4	0.52	0.35 – 0.76
Overall	40	29.4	0.46	0.31 – 0.68

Table 6. Literature review of first year survival of black bear cubs in North America. Unless otherwise noted, estimates were obtained from comparing number of cubs in natal dens to number of yearlings the following winter.

Location	Survival (%)	Cubs	Reference
Nevada[a]	100	6	Beckmann and Berger (2003)
Dry Creek, AR	90	20	Clark (1991)
Pennsylvania	86	111	Alt (1982)
SNP[b], VA	73	40	Kasbohm (1996)
GSMNP[c], TN	62	29	Eiler et al. (1989)
Massachusetts	59	41	Elowe and Dodge (1989)[d]
West-central Colorado	56	39	Beck (1991)
New Mexico	55	148	Costello et al. (2003)
Sutsina, AK	54	73	Miller (1994)
Ontario	53	32	Kolenosky (1990)
Central Arizona	48	25	LeCount (1987)[d]
North-central Florida	46	41	This study[d]
White Rock, AR	31	13	Clark (1991)
Nevada[e]	17	18	Beckmann and Berger (2003)

[a] Wildland study area
[b] Shenandoah National Park
[c] Great Smoky Mountains National Park
[d] Survival rates were estimated from telemetry data
[e] Urban-interface study area

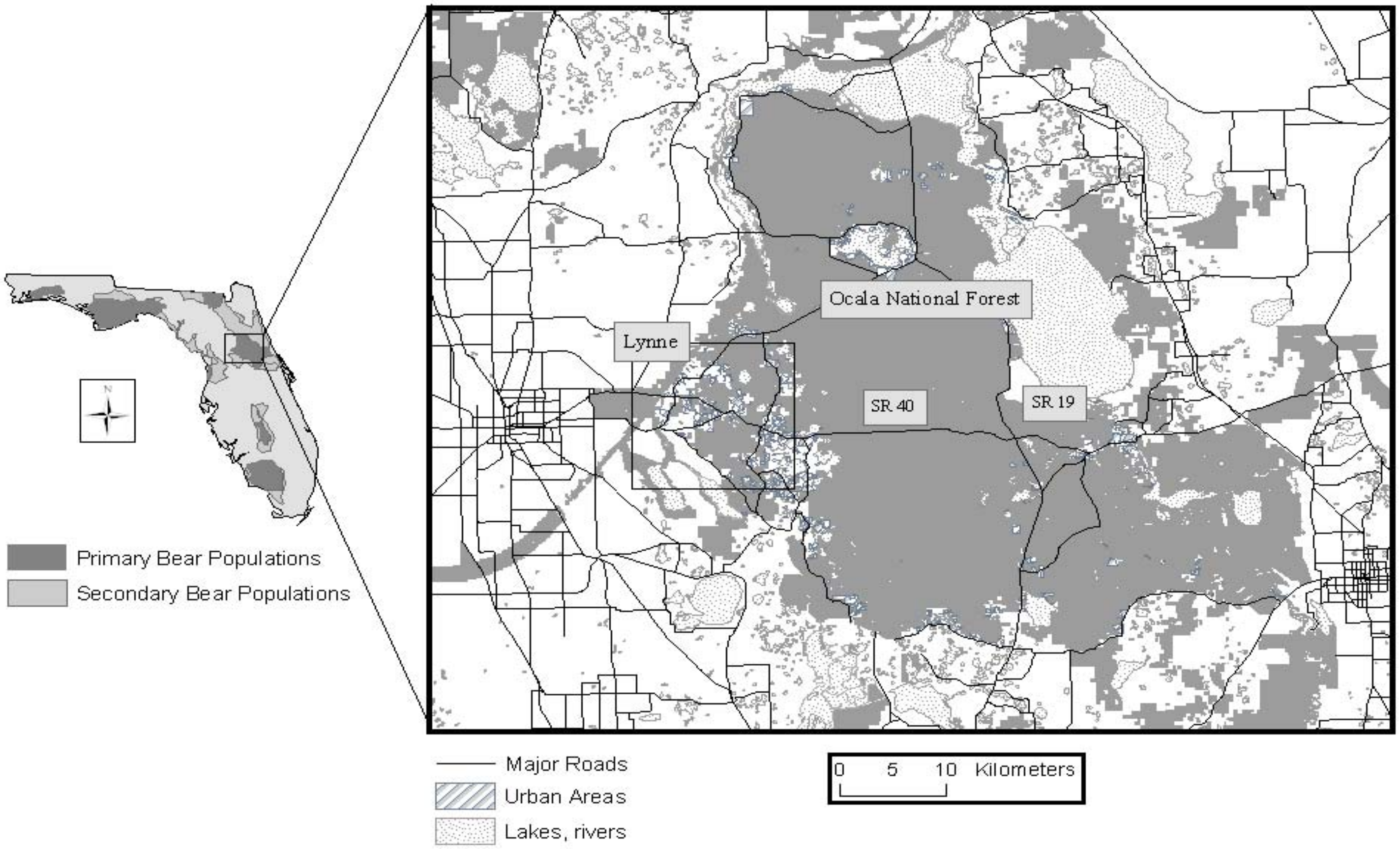

Figure 1. The Ocala National Forest and Lynne study areas in north central Florida, USA.

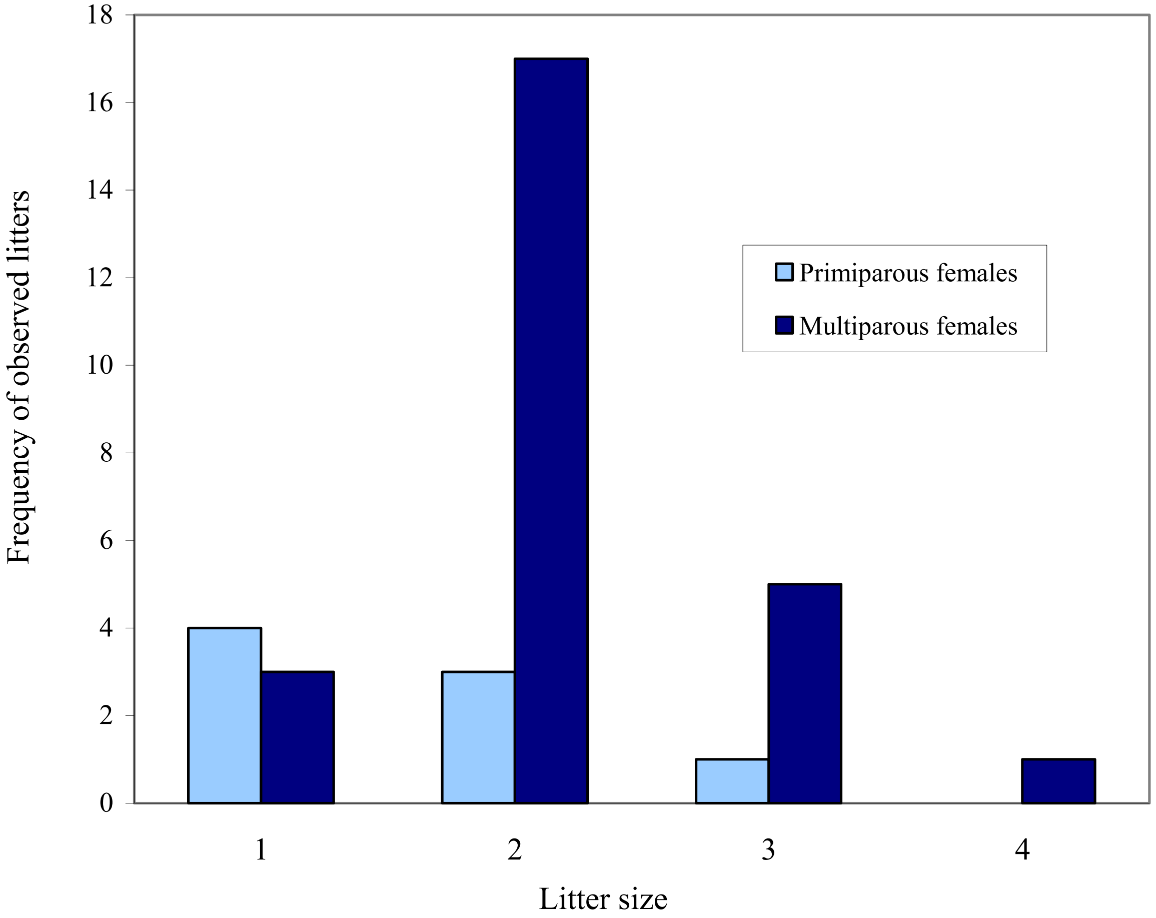

Figure 2. Frequency distribution of litter sizes for Florida black bears in north central Florida, USA, 2000-2003.

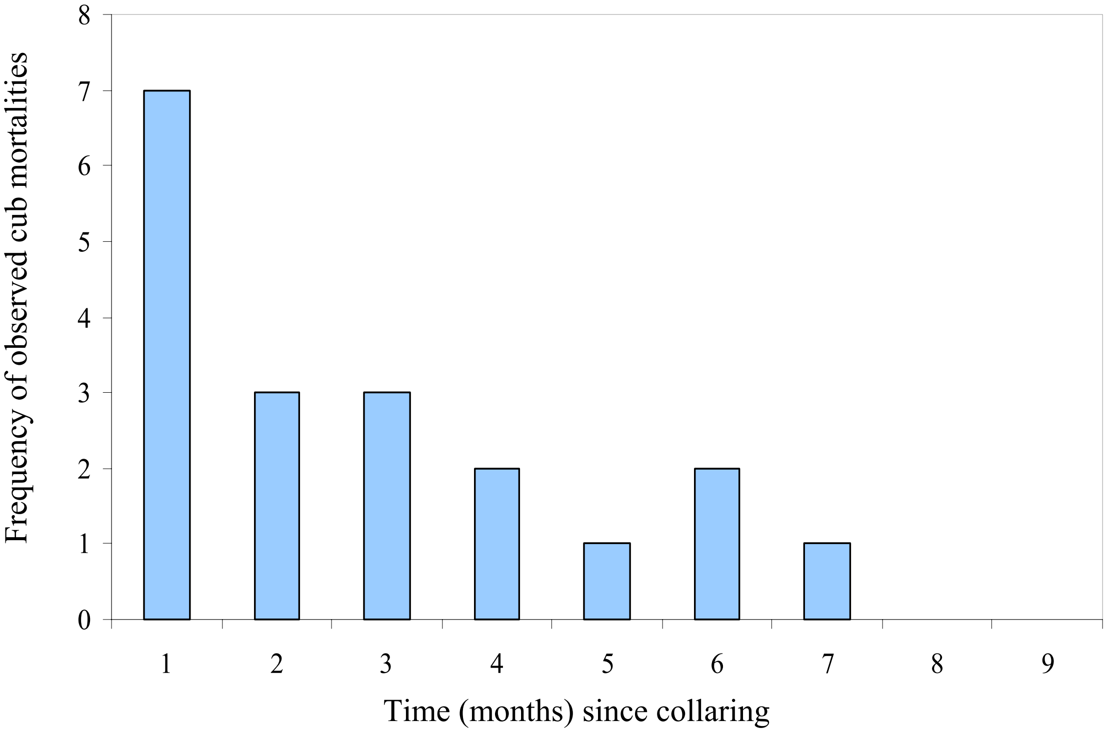

Figure 3. Number of Florida black bear cubs that died within 1-9 months after collaring in north central Florida, USA, 2002 and 2003.

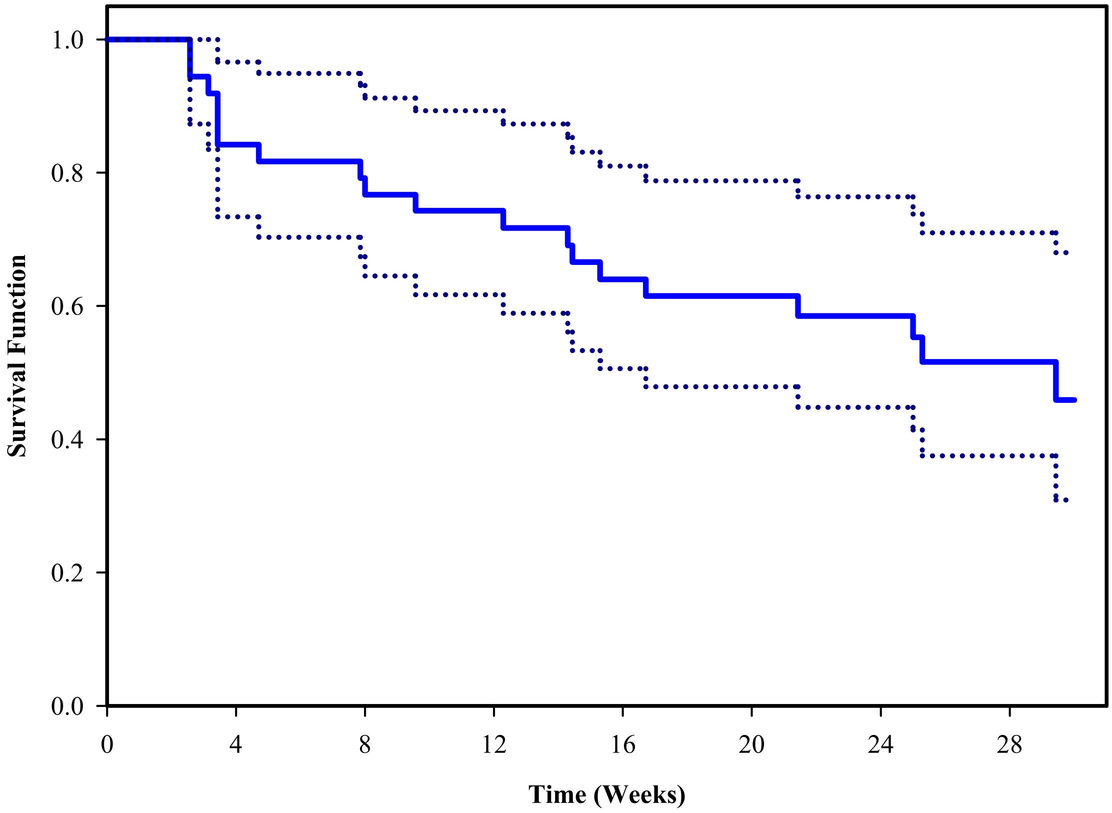

Figure 4. Kaplan-Meier survival curve for Florida black bear cubs in north central Florida, USA, illustrating survival in 2002 and 2003 combined. Time is given in weeks, beginning the week of radio-collaring (last week in March). The dashed lines indicate upper and lower 95% confidence intervals.

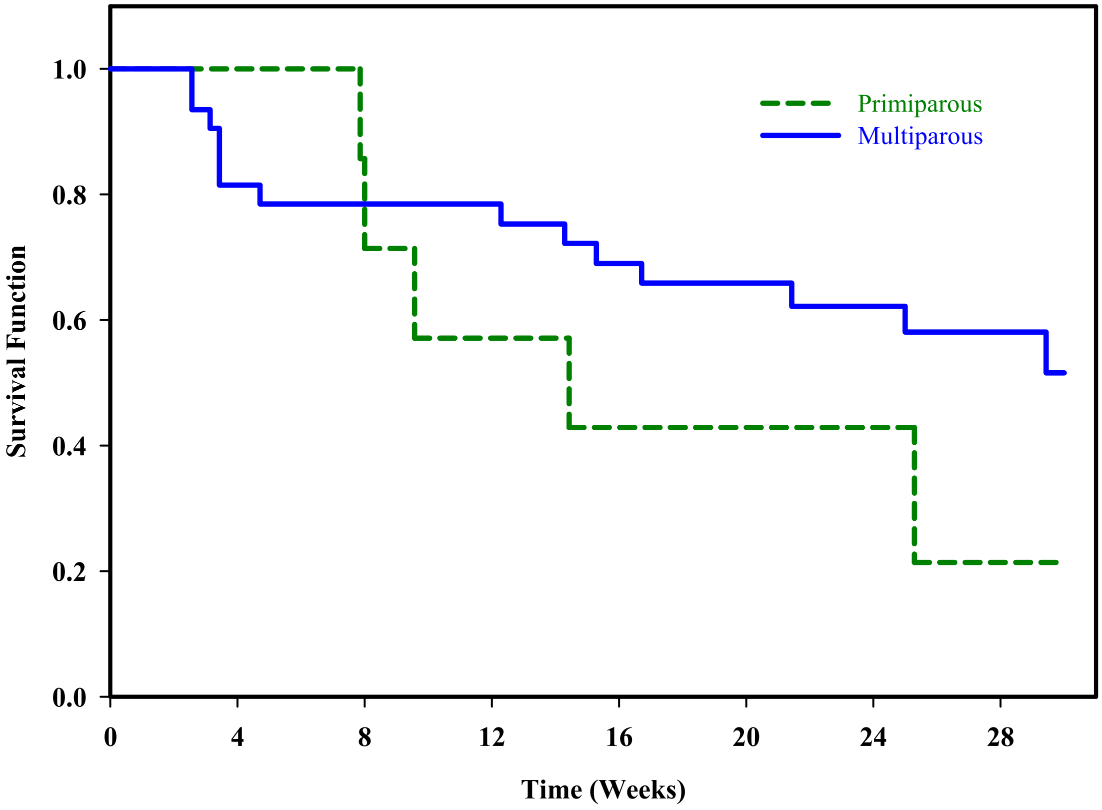

Figure 5. Kaplan-Meier survival curves for Florida black bear cubs in north central Florida, USA, comparing survival of cubs born to primiparous (n = 7 cubs) and multiparous (n = 34 cubs) females in 2002 and 2003. Time is given in weeks, beginning the week of radio-collaring (last week in March).

CHAPTER 3
DENNING ECOLOGY OF FEMALE BLACK BEARS IN NORTH CENTRAL FLORIDA

Introduction

Denning, or winter dormancy, in bears is thought to have evolved in response to seasonally occurring periods of adverse weather and lack of food resources (Hayes and Pelton 1994). Denning is obligatory for parturient females as birth and early maternal care of altricial young occurs during winter dormancy (Alt 1983, Hellgren 1998). Denning is not, however, compulsory for all bears. In North American polar bear (*Ursus maritimus*) and some brown bear (*U. arctos*) populations, for example, males may remain active during all or part of the winter if sufficient food is available (Ramsay and Stirling 1988, Van Daele et al. 1990). In the southern ranges of black bears (*U. americanus*), winter activity has been observed in adult males, non-parturient females and sub-adults (Graber 1990, Hellgren and Vaughan 1989a, Weaver and Pelton 1994, Wooding and Hardisky 1992).

While denning, bears cease all ingressive and eliminative functions, and are in a lethargic state or deep sleep (Nelson et al. 1983). Disturbance during this period can lower fitness of the denning females by increasing energy expenditure if the bear is forced to relocate, and may cause cub abandonment (Alt 1984a, Elowe and Dodge 1989, Linnell et al. 2000, Oli et al. 1997). The period with potential for disturbance to denning bears varies by region; duration of denning for parturient female black bears can vary from 3 months in Tennessee (Johnson and Pelton 1980) to 7 months in Alaska (Smith et al. 1994). Types of dens used by black bears also vary considerably among populations, as different habitats provide different denning options (Hayes and Pelton 1994, Johnson and Pelton 1981). Thus, population-specific knowledge of denning habitat requirements and chronology is important to formulate appropriate black bear management strategies (Hightower et al. 2002).

In the Southeastern Coastal Plain, black bears predominately use ground nest dens (Hamilton and Marchinton 1980, Hellgren and Vaughan 1989a, Weaver and Pelton 1994, White et al. 2001, Wooding and Hardisky 1992). Recent studies have found that the habitat characteristics surrounding nest dens differ from those of random points, and thick, dense vegetation may be essential for providing protection from weather elements and disturbance (Lombardo 1993, Martorello and Pelton 2003). Knowledge of the habitat characteristics of suitable den sites may therefore be particularly important in southern regions where bears predominantly use nest dens. However, only limited information is available regarding habitat characteristics of den sites and other aspects of denning ecology of the Florida black bear (*U. a. floridanus*) (Seibert 1995, Wooding and Hardisky 1992).

The Florida black bear, a threatened subspecies of the North American black bear, currently occurs in 8 relatively isolated sub-populations, largely due to land conversion for agriculture and development (Eason 2000). Florida's rapidly growing human population and commercial/residential development continues to encroach upon natural habitat, and conservation and management efforts of the Florida black bear require a thorough understanding of all aspects of the species' ecology. To that end, I investigated denning ecology of female Florida black bears in north central Florida. The objectives were to: (1) document den types used, (2) determine denning chronology, and (3) investigate habitat characteristics of den sites and test if habitat characteristics of den sites differed from those of random points.

Study Area

The study was conducted in Ocala National Forest (ONF) and in the adjacent residential community of Lynne, in north central Florida (Fig. 6). The study was centered along State Road 40 (SR 40) and extended approximately 6 km north and south of SR 40 between the Oklawaha River and State Road 19. The study area encompassed approximately 400 km^2 and covered the central portion of ONF and Lynne.

The Ocala bear population is one of the major sub-populations of bears in Florida. The community of Lynne is located on the western boundary of ONF. It contains residential and commercial development interspersed with parcels of forest service lands.

The major vegetation types are: 1) swamps and marshes along the Oklawaha and St. Johns Rivers; 2) pine flatwoods between the rivers and central ridge; 3) mixed hardwood swamps; and 4) dune-like interior ridges of sand pine and scrub oaks interspersed with numerous lakes, ponds and prairies (Aydelott et al. 1975).

The sand pine/scrub oak community is managed as a commercial crop within ONF with several timber harvesting compartments. Stand age ranges from recently harvested clear cuts (0-2 years) to mature stands (≥ 25 years). In addition to timber, ONF is managed for recreation and wildlife resources. With the exception of 4 designated wilderness areas, the ONF contains an extensive grid of forest service maintained roads, off-road vehicle roads and forest trails.

Methods

Bears were captured with Aldrich spring-activated foot snares during July 1999 – May 2003. Bears were immobilized with 1:1 mixture of Tiletamine hydrochloride and Zolezepam hydrochloride (Telazol ®) administered at 3.0 - 4.5mg/kg of estimated body weight via remote injection gun. Standard morphometric measurements were collected (McCown et al. 2001) and the first pre-molar was extracted for age determination (Willey 1974). A subset of captured bears was fitted with a radiocollar equipped with mortality and activity sensor (150-151 Mhz; Telonics, Mesa, Arizona). A leather spacer was inserted in each collar to allow collars to fall off after approximately 2 years. Bears were released where captured, except on few occasions when safety was a concern, i.e., other bears were seen or heard while handling the captured bear. Following release, bears were radio-tracked from the ground or air 1-7 times a week.

I estimated den entry date as the midpoint between the last date of recorded movement and the first date in the den. Bears were classified as stationary when successive telemetry locations were < 400 m apart of each other, or when I was not able to detect movement. Based on test collars, the 400-m radius included 95% of locations (M. Moyer, unpublished data). I also approached all den sites on foot to verify denning status, although some of the non-parturient females moved before I could locate the den.

Den emergence date was defined as the midpoint between the last location of bear in a den and the first location away from the den (O'Pezio et al. 1983). I considered bears to be denning as long as they occupied a den, even if they changed den locations. I performed all statistical analyses using SAS (SAS institute, Inc. Cary, N.C). I used the Kruskal-Wallis test to compare den entry, exit and duration of denning of female black bears with respect to year, reproductive status, and reproductive experience (primiparous, multiparous).

I visited natal dens from March to April and dens of non-parturient females from January to April. I did not immobilize females; they typically left the den shortly after I approached within the viewing distance. I determined litter size, sex and mass of cubs. After bears left dens, I visited the den sites and obtained Universal Transverse Mercator System (UTM) coordinates of den sites with a Garmin etrex (Garmin International, Olathe, Kansas) Global Positioning System (GPS). I classified dens as ground nests, excavations or tree dens. I measured dimensions and other relevant features and noted the bedding material and local habitat characteristics. I assigned forest cover type and stand age, if appropriate, to each den site by overlaying their UTM coordinates on digitized forest cover maps for ONF dens and Florida Gap Project habitat maps for Lynne with ArcGIS (ESRI, Redlands, CA). Each forest cover type also was verified with field observations during den visits. Habitat was classified into 6 habitat types in ONF (Table 7) and 11 habitat types in Lynne based on dominant overstory species (Table 8). I used the Gap habitat maps for Lynne because the United States Forest Service (USFS) cover did not provide data on private forests.

Several studies have shown that female black bears do not select den sites at random (Hayes and Pelton 1994, Klenzendorf et al. 2002, Oli et al. 1997, Pelton et al. 1980). Thus, I used Chi-square test to test the null hypothesis that black bears' use of habitat type for denning does not differ from its availability. I estimated use by calculating the proportion of dens in each habitat. I estimated availability in 2 ways: proportion of random points and proportion of radio-telemetry locations within each habitat. Random points (1000 in ONF, 540 in Lynne) were assigned into the study area with animal movement extension in ArcView. Radio telemetry locations (2691 in ONF, 821 in Lynne) included locations of all females throughout the study. I excluded points that fell in unknown habitat type or water bodies. If the null hypothesis was rejected ($\alpha = 0.05$), I used 95% Bonferroni confidence intervals around the proportions of use of each habitat type to identify habitats that were used disproportionately to their availabilities (Alldredge and Ratti 1992).

Results

Denning Chronology

During 1999-2003, I monitored 35 females for 61 den years. I determined denning chronology for 34 parturient den years, and 17 non-parturient den years. Six of the non-parturient females remained active through the winter or denned for short periods not detected by telemetry.

Parturient females exited dens later ($\chi^2 = 34.7$, df = 1, $P < 0.0001$), and denned longer ($\bar{X} = 113 \pm 3.3$ days) than non-parturient females ($\bar{X} = 54 \pm 5.7$ days; $\chi^2 = 30.28$, df = 1, $P < 0.0001$; Table 9). Den entry dates did not differ between parturient and non-parturient females ($\chi^2 = 2.19$, df = 1, $P = 0.139$). Den entry and exit dates of parturient females differed significantly among years ($\chi^2 = 12.3$, df = 3, $P = 0.006$; $\chi^2 = 14.4$, df = 3, $P = 0.002$), but duration of denning did not ($\chi^2 = 4.8$, df = 3, $P = 0.187$). Among parturient females, primiparous females entered dens on average 28 days later than multiparous females ($\chi^2 = 8.71$, df = 1, $P = 0.003$). However, exit date and total denning period did not differ between the 2 groups ($\chi^2 = 3.27$, df = 1, $P = 0.07$; $\chi^2 = 1.53$, df = 1, $P = 0.22$). Denning exit, entry, or duration of denning of non-parturient females did not differ among years (Table 9).

Den Type

I located 53 dens; 42 of these were used by parturient females, and 11 by non-parturient females. Solitary females, or those with yearlings, typically left the den when I approached, making location of these dens difficult. Thirty-four (81%) of the parturient females denned in ground nests, 7 (17%) in excavations and 1 (2%) in a tree den. All of the non-parturient females denned in ground nests. Ground nests were typically oval shape, and dimensions averaged 71 x 56 x 23 cm (length x width x depth). Bedding material consisted of dry deciduous leaves, palmetto leaves, pine needles or other litter common to the site. Dimensions of the excavated dens averaged 96 x 74 x 100 cm (height x width x depth). Entrances to excavated dens were half-moon shape and bedding consisted of sand, and all but 2 excavated dens were in sandy soil. The only bear that used a tree den was a 10-year-old female with a litter of 3 cubs. The tree den was in a 134 cm dbh black gum (*Nyssa sylvatica*). The den was 11.3 meters above ground, in a fork of 4 major limbs. The fork offered a natural, irregularly shaped depression 112 cm in length, 43 to 74 cm in width and 38 to 112 cm in depth. The den had no overhead protection other than the trees' branches and leaves. Bedding included palm fronds and black gum leaves.

Den Habitat

I determined habitat characteristics of 46 den sites, 32 in ONF and 14 in Lynne. In ONF, all forest covers except 0-7 year old sand pine stands were used (Fig. 7, Fig. 8). In Lynne, only 2 of 11 forest cover types were used for den sites; 9 dens were located in pine flatwoods and 5 in swamp habitat (Fig. 9, Fig. 10). In ONF, proportion of dens in different habitats differed from the expected proportions based on the distribution of random points ($\chi^2 = 19.25$, df = 6, P = 0.004) and telemetry locations ($\chi^2 = 13.59$, df = 6, P = 0.035). Bonferroni 95 % confidence intervals did not show statistical preference or avoidance of specific habitats except for the habitats that had no dens ($P > 0.05$). Similarly, in Lynne, proportion of dens in different habitats differed from the expected proportions based on the distribution of random points ($\chi^2 = 21.78$, df = 9, P = 0.01) and telemetry locations ($\chi^2 = 15.81$, df = 6, P = 0.015). Bonferroni 95 % confidence intervals did not show statistical preference or avoidance of specific habitats except for the habitats where no dens were located ($P > 0.05$). It should be noted that 15 out of 20 dens used by parturient females in mesic-hydric habitats occurred in ecotones; therefore, assigning a single habitat type for a den was problematic. Five of the 20 dens in mesic-hydric habitat were located next to lakes or ponds. None of the non-parturient female dens were located in ecotones.

Although I did not measure microhabitat characteristics, dens of parturient females were characterized by thick, dense midstory and ground cover vegetation. In sand pine forests, this vegetation generally consisted of scrub palmetto (*Sabal etonia*) or Florida rosemary (*Ceratiola ericoides*) thickets. In the wetter habitats, den sites were in thickets of fetterbush (*Lyonia lucida*) and saw palmetto (*Serenoa repens*). Dens of females with yearlings and solitary females occurred within the same macrohabitats as parturient females, however, microhabitats of non-parturient females were typically characterized by less dense understory, and therefore, greater visibility.

Discussion

Denning in bears is hypothesized to be an adaptation to lack of food and adverse weather conditions during winter months (Johnson and Pelton 1980). In Florida, mild climate and sufficient food availability throughout winter allow denning to be elective for non-parturient female and male black bears. However, regardless of climatic conditions or food availability, denning is obligatory for parturient females because birth and early maternal care occurs during denning.

The average denning duration of parturient females (113 days) recorded in this study is similar to those reported for Florida black bears ($\bar{X}$ = 129 days, n = 2;Wooding and Hardisky 1992) and for black bears in Great Dismal Swamp of Virginia and North Carolina ($\bar{X}$ = 119 days, n = 6; Hellgren and Vaughan, 1989). Denning period was slightly longer in northeastern Louisiana ($\bar{X}$ = 142 days, n = 9; Weaver and Pelton 1994). The relationship between denning chronology and reproductive states observed in this study was consistent with other studies throughout North America; parturient females generally den longer than non-parturient females (Kasbohm et al. 1996, Oli et al. 1997, Schooley et al. 1994, Wathen 1983).

Some non-parturient females remained active throughout the winter, and those that did den behaved differently from denning parturient females. Non-parturient females fled upon approach and did not return to the original den sites. Linnell et al. (2000) hypothesized that bears in milder climates have a lower threshold to disturbance than bears inhabiting northern habitats because the cost of abandonment is smaller. The results of this study support that hypothesis for non-parturient females. For parturient females, the cost of complete den abandonment would obviously be high if it resulted in cub mortality. The site fidelity of parturient females in our study area appeared to reflect this potential cost.

Characteristics of den sites also differed depending on reproductive status of females. Around the den sites of parturient females, no evidence of feeding or other use was found. In contrast, the majority of den sites of non-parturient females had evidence of feeding (e.g., pulled saw/scrub palmetto shoots) or other activities (bear trails) surrounding the nests. Solitary females, or those with yearlings, therefore appeared to periodically feed and move short distances while denning. Similarly, in south central Louisiana, Hightower et al. (2002) observed fresh scats near winter bedding sites of females with yearlings. Evidence of feeding also was reported for bears in the Tensas River basin, Louisiana (Weaver and Pelton 1994).

Ground nests were the most common den type in north central Florida; over 80 % of the dens were ground nests. The prevalence of ground nests was consistent with other Southeastern Coastal Plain black bear studies (Hellgren and Vaughan 1989b, Hightower et al. 2002, Martorello and Pelton 2003, Oli et al. 1997, Wooding and Hardisky 1992). In this study, 5 of the 7 excavated dens occurred in sand pine habitat where probability of flooding was negligible. Use of tree dens has been documented in southeastern black bears populations (Hellgren and Vaughan 1989b, Weaver and Pelton 1994, White et al. 2001). However, the intense land use in my study area has probably resulted in few suitable den trees. This fact was evident in ONF where only 1 of 53 documented dens occurred in a tree. The tree den occurred in the Juniper Wilderness area, which is inaccessible to logging.

Although tree or excavated dens likely provide more protection from weather and disturbance than ground nests, bears have apparently adapted by using thick vegetation as a substitute for the protection that a tree or excavated den might provide. Thick vegetation surrounding ground nests has been qualitatively described elsewhere (Hamilton and Marchinton 1980, Hellgren and Vaughan 1989b, Hightower et al. 2002). In North Carolina, Martorello and Pelton (2003) measured microhabitat characteristics surrounding ground nests. They found that bears selected for greater shrub height, stem density, and cover density than if selection was random. I observed similar microhabitat characteristics in this study; majority of the ground nests of parturient females were in dense vegetation with low visibility. However, non-parturient females denned in less dense vegetation. This may be related to the difference in the function of the den for females in different reproductive status. For females with cubs, the dens should provide the maximum concealment because detection and disturbance could lead to cub mortality through abandonment or predation. Lactating females are energetically strained, and being forced to move can increase energy expenditure and weight loss (Tietje and Ruff 1980). For non-parturient Florida black bear females, the availability of food resources and ease of escape, as yearlings are capable of fleeing the den whereas altricial cubs are not, may be the most important factors.

Although the hypothesis of no selection was rejected, Bonferonni Z-statistic indicated that there was no evidence for preference or avoidance of a habitat for denning, except where no dens were located. The lack of selection of particular habitat for dens suggests that microhabitat characteristics may not be substantially different in the intensively managed and highly fragmented habitats. In Lynne, lack of selection may also be confounded by females selecting ecotones for denning habitat. In addition, the habitat types that had no dens associated with them occurred in small proportions. Thus, the reason there were no dens in certain habitats may have been due to the low availability of those habitats. Nevertheless, parturient females appeared to select for dense vegetation, regardless of dominant overstory.

Management Implications

The information on denning chronology reported in this study can assist managers in decisions regarding land use in Florida black bear habitats. Prescribed burning and timber harvest should be avoided in habitats suitable for denning from mid-December to mid-April. If prescribed burning or logging is unavoidable, it should be carried out early in the denning season, so that pregnant females can leave disturbed areas prior to giving birth. Off-road activity also should be minimized, as it is likely to cause more disturbance than predictable-route activity, such as a regularly used roads.

The availability of suitable den sites does not appear to be a limiting factor in the ONF and Lynne study sites. As in other areas where tree dens are scarce, black bears in north central Florida have adapted to use ground nests. Although open nests cannot provide the thermoregulatory benefits offered by enclosed dens, dense vegetation can provide structural security, and reduce heat loss from wind (Hellgren and Vaughan 1989, Hayes and Pelton 1994). In the mild winters of northern Florida, however, the protection from weather is probably not as critical as protection from disturbance that dense vegetation can provide. However, bears might use tree dens if suitable den trees are available, and protection of potential den trees should be encouraged because of the added security tree dens provide against predators. This could be accomplished by both private and public owners of the land by protecting large snags and cavity trees from harvest, and by managing for potential den tree species such as cypress and black gum.

Table 7. Habitat classes used for Ocala National Forest, Florida, USA. Habitat classes used in this study were based on combining similar habitat from 9 different habitat classes determined by United States Forest Service.

Habitat Type	Description
Sand Pine	Forests dominated by sand pine (*Pinus clausa*). Understory of scrub oak. Found on dry, sand ridges. Grouped into 3 age-classes; ≥ 25 years, 8-24 years and 0-7 years.
Scrub	Broad-leaved scrublands. Dominated by various scrubby oaks and other xeriphytic species, such as, *Quercus chapmanii, Q. geminata,* and *Q. myrtifolia.* Also included upland mixed evergreen/ cold-deciduous forests.
Pine Flatwoods	Mesic-hydric pine forest compositional group. Slash pine (*Pinus elliottii*) flatwoods with scattered bays such as loblolly bay (*Gordonia lasianthus*). Combined with pond (*P. serotina*) and longleaf pine (*P. palustris*).
Wet Hardwoods	Dominated by sweetbay (*Magnolia virginiana*), red maple (Acer rubrum), swamp tupelo (Nyssa sylvatica). Combined with laurel oak (*Q. hemisphaerica*) and willow oak (*Q. phellos*).
Prairie	Combination of all open prairies; sawgrass (*Cladium mariscus*), forb emergent marsh and dry prairies.

Table 8. Habitat classes used for Lynne study area, Florida, USA. Habitat classes were acquired by combining from 31 different habitat classes recognized by the Florida Gap Project for the area.

Habitat Type	Description
Pine Flatwoods	Mesic-hydric pine forest compositional group. Slash pine (*Pinus elliottii* var. *elliottii*) flatwoods with scattered bays such as sweetbay (*Magnolia virginiana*), loblolly bay (*Gordonia lasianthus*).
Swamp Forest	Deciduous and evergreen swamp forests; black gum (*Nyssa biflora*), red maple (*Acer rubrum*), green ash (*Fraximus pensylvanica*).
Cypress Forest	Cypress communities dominated by *Taxodium ascendens* and *T. distichum.*
Live Oak	Live oak (*Quercus virginiana*) woodlands.
Sand Pine	Forests dominated by sand pine (*Pinus clausa*). Understory of scrub oak. Found on dry, sand ridges. Grouped into 3 age-classes; ≥ 25 years, 8-24 years and 0-7 years.
Scrub	Broad-leaved scrublands. Dominated by various scrubby oaks and other xeriphytic species, such as, *Quercus chapmanii, Q. geminata,* and *Q. myrtifolia.* Also included upland mixed evergreen/ cold-deciduous fores
Prairie	Combination of all open prairies; sawgrass (*Cladium mariscus*), forb emergent marsh and dry prairies.
Developed	Commercial and residential urban areas, recreational areas. Row crops, farm roads, structure, pasture.

Table 9. Denning chronology of female Florida black bears in north central Florida, USA, 1999-2003. Den entry dates, emergence dates and duration of denning are given for each year, and pooled years, by reproductive status (parturient, non-parturient), and reproductive experience (primiparous, multiparous) for pooled years.

	Den entry dates			Den emergence dates			Denning duration (days)			
Group	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Range
1999 –2000										
Parturient	19 Jan	4.5	8	28 Apr	3.5	6	103	4.1	6	89-111
Non-parturient	--[a]			--			--			
2000-2001										
Parturient	18 Dec	5.4	10	14 Apr	1.8	8	114	6.9	8	74-135
Non-parturient	1 Jan	5.9	12	1 Mar	3.7	12	61	7.0	11	28-95
2001-2002										
Parturient	19 Dec	5.4	11	14 Apr	3.3	12	116	6.2	11	87-143
Non-parturient	29 Jan	9.8	3	12 Mar	5.0	3	43	9.9	3	29-62
2002-2003										
Parturient	2 Jan	7.8	8	1 May	4.7	8	121	4.4	8	103-138
Non-parturient	7 Jan	6.2	3	16 Feb	14	3	41	20	3	9-79
Pooled years										
Parturient	28 Dec	3.5	37	19 Apr	2.2	35	113	3.3	34	62-143
Non-parturient	6 Jan	4.9	18	1 Mar	3.7	18	54	5.7	18	9-95
Primiparous	20 Jan	8.7	7	30 Apr	6.8	6	106	8.6	6	74-137
Multiparous	23 Dec	3.3	30	17 Apr	2.1	28	116	3.1	27	87-143

[a] No data

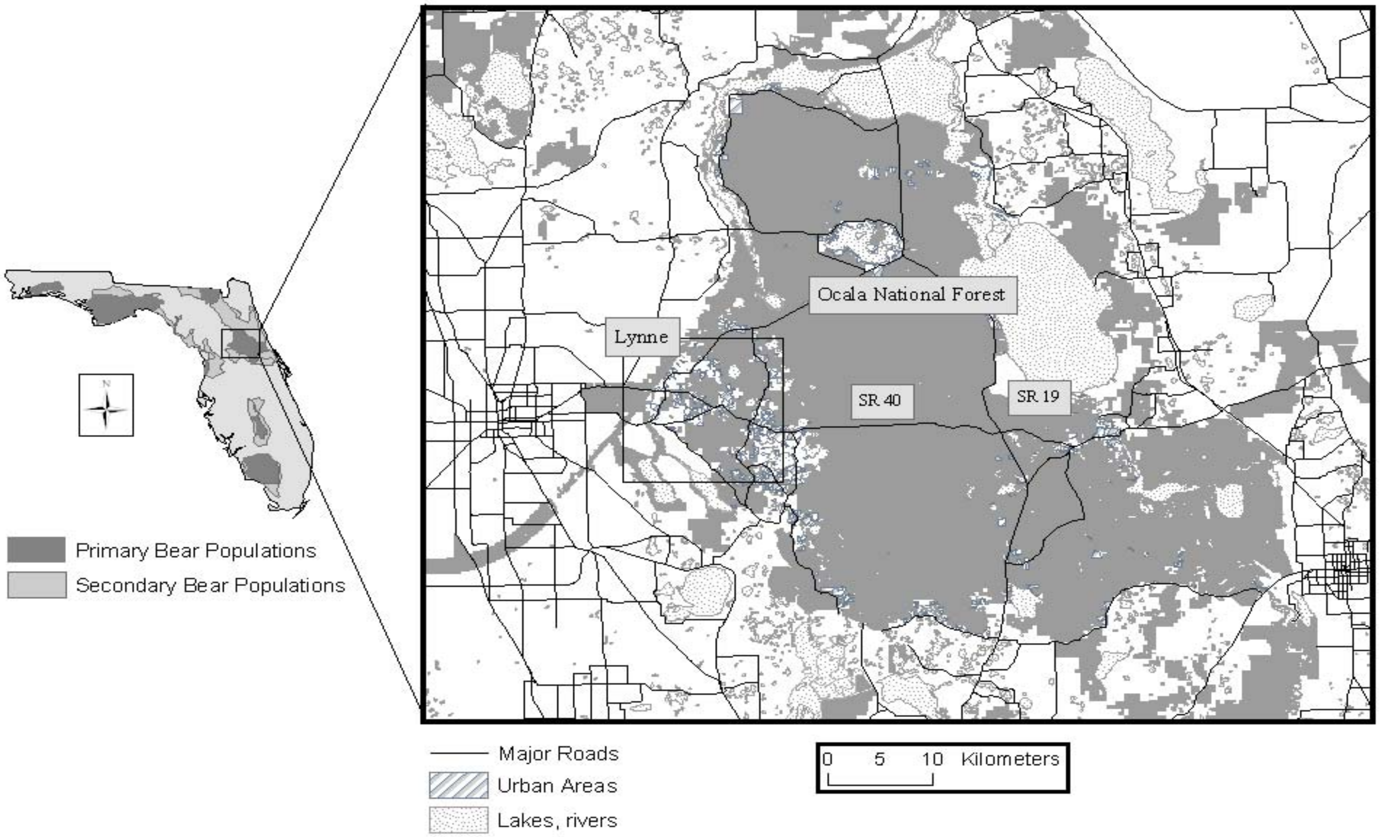

Figure 6. The Ocala National Forest and Lynne study areas in north central Florida, USA.

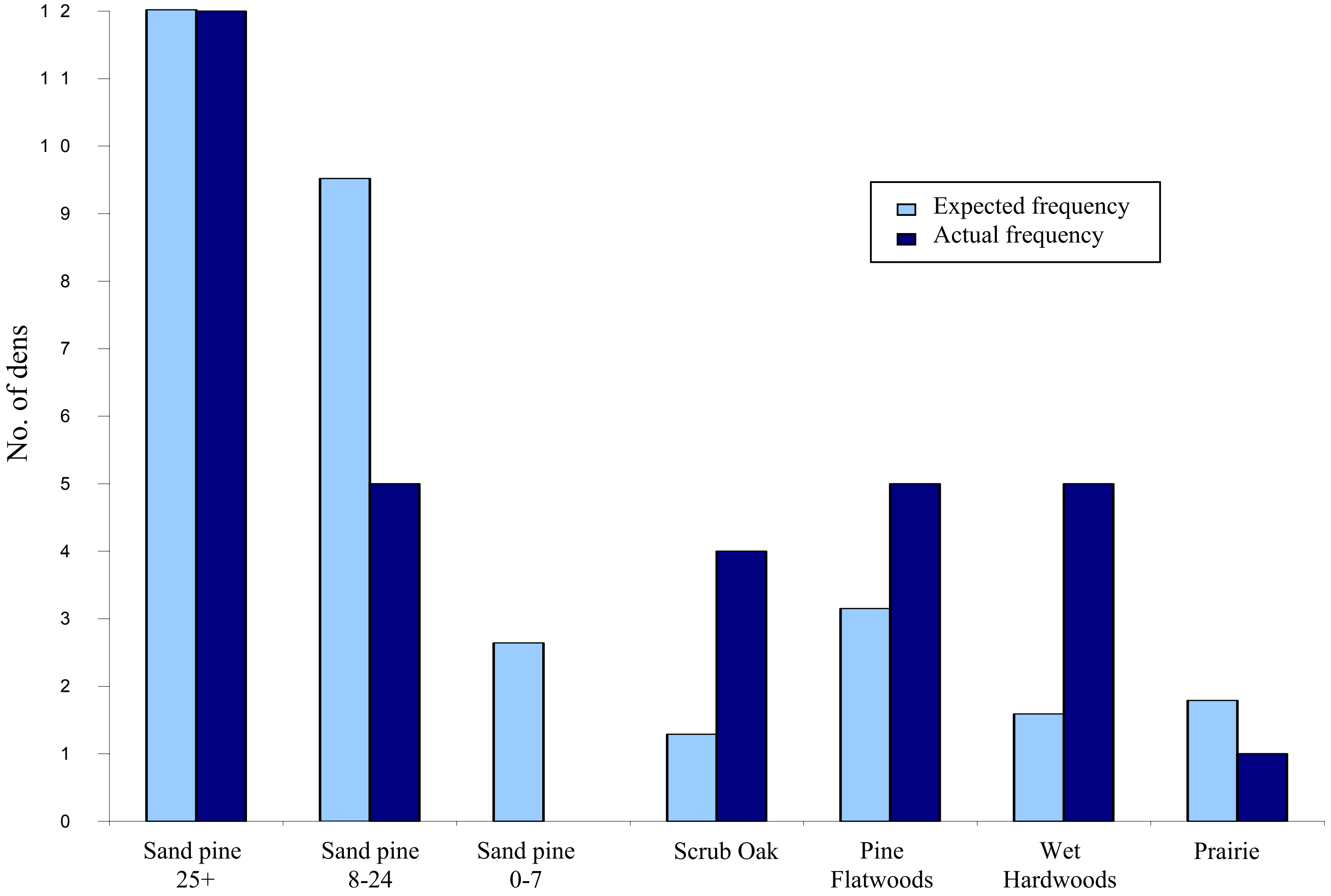

Figure 7. Expected and actual frequencies of female Florida black bear dens in different habitat types in Ocala National Forest, north central Florida, USA in 2000-2003. Expected frequencies were calculated from the availability of each habitat type based on random points.

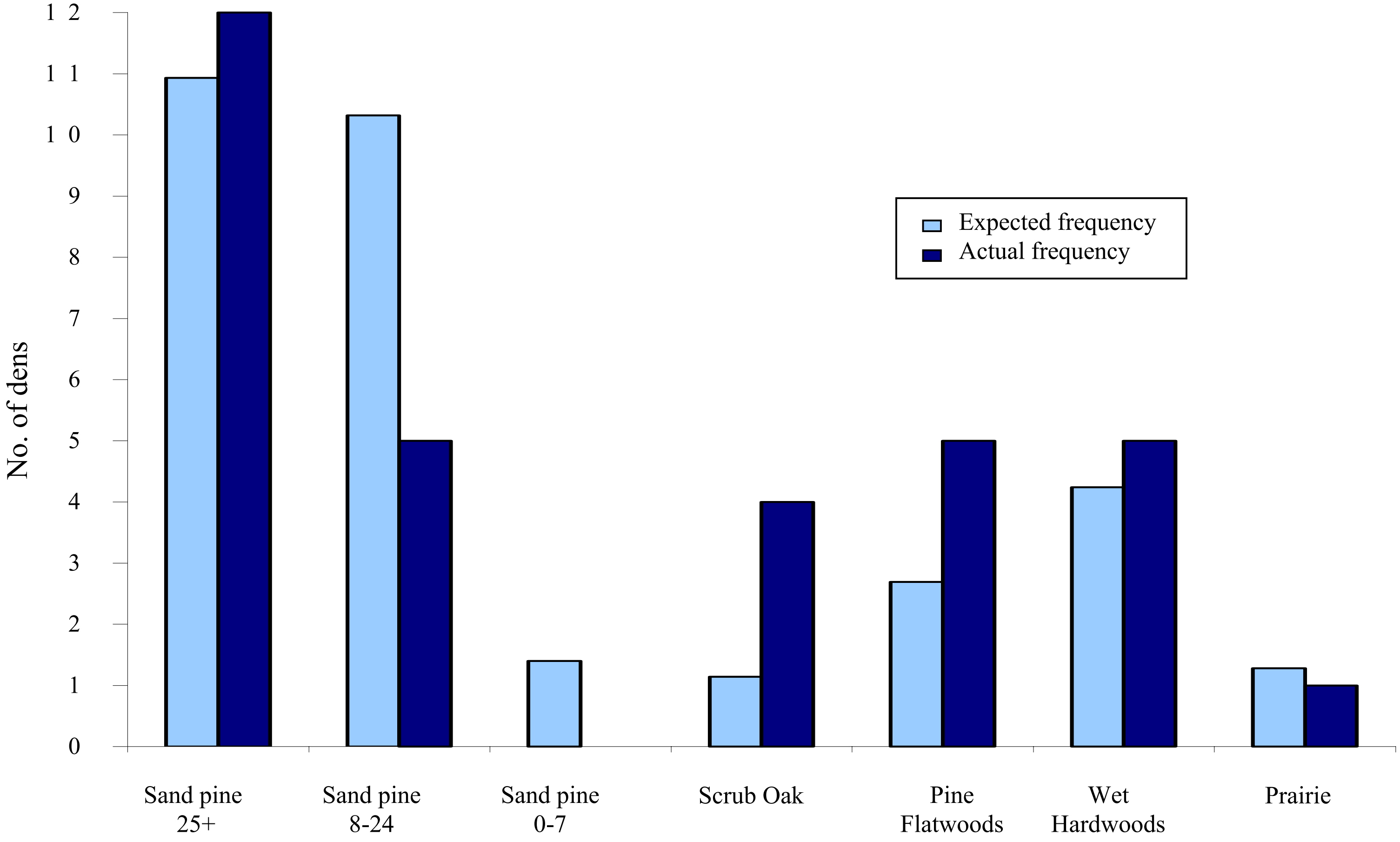

Figure 8. Expected and actual frequencies of female Florida black bear dens in different habitat types in Ocala National Forest, north central Florida, USA in 2000-2003. Expected frequencies were calculated from the availability of each habitat type based on telemetry locations.

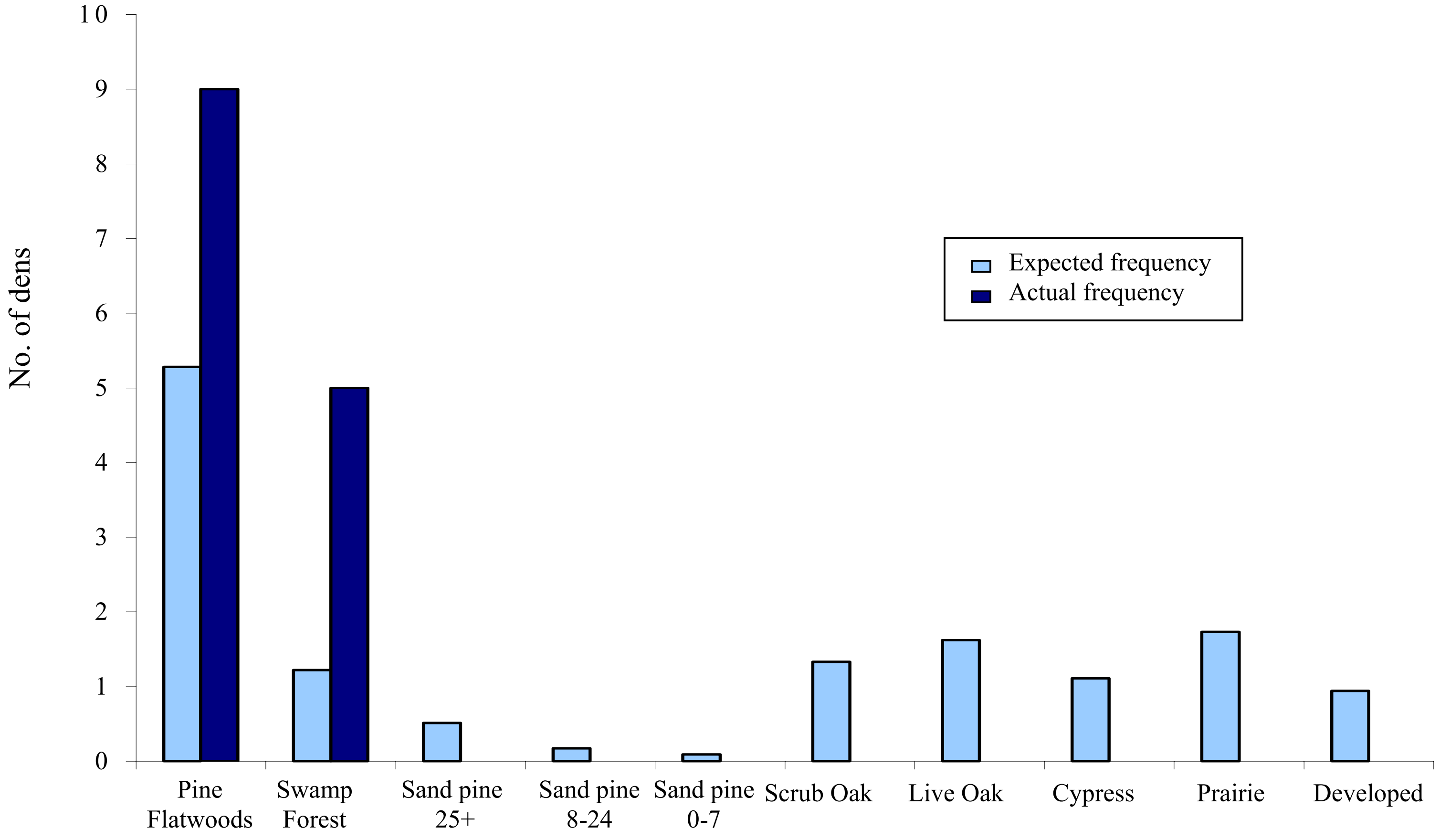

Figure 9. Expected and actual frequencies of female Florida black bear dens in different habitat types in Lynne, north central Florida, USA. Expected frequencies were calculated from the availability of each habitat type based on random points.

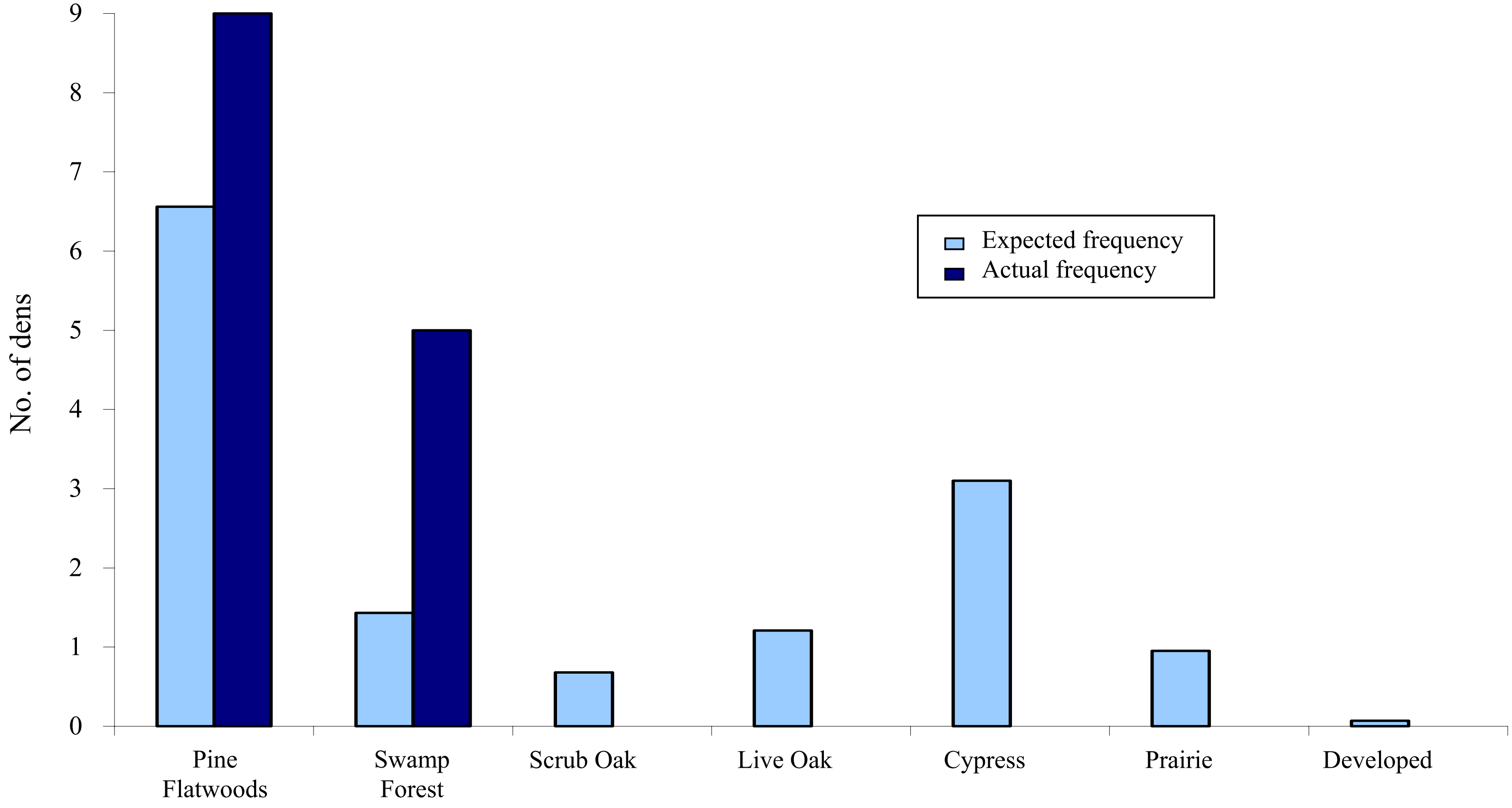

Figure 10. Expected and actual frequencies of female Florida black bear dens in different habitat types in Lynne north central Florida, USA. Expected frequencies were calculated from the availability of each habitat type based on telemetry locations.

CHAPTER 4
CONCLUSION AND MANAGEMENT RECOMMENDATIONS

Data on reproductive and survival parameters are important for management of remnant Florida black bear populations. Additionally, birth and early maternal care occurs during denning and data on denning ecology also can be beneficial. In this thesis, I have used data from a 4-year study to provide rigorous estimates of reproductive parameters and cub survival, and to investigate denning ecology of female Florida black bears.

Conclusion

Overall, data on cub and litter characteristics suggest that Florida black bears in ONF and Lynne produced healthy litters, with reproductive rates comparable to those of other southeastern black bear populations. Most females began reproducing at 3-4 years of age. This finding is similar to other areas where food is available for much of the year, which allows females to grow and mature quickly (Alt 1982, Hellgren and Vaughan 1989a, Maddrey 1995). The mean litter size of 2.08 was slightly lower than those reported for most southeastern populations (McDonald and Fuller 2001), but higher than those reported for western black bear populations (Bunnell and Tait 1981). Fecundity rate averaged 0.49. Age specific fecundity rates for 3 and 4-year olds in my study were lower that those in North Carolina (Powell et al. 1996), although other age classes compared favorably.

The cub survival rate of 46% to 9-months of age in my study was among the lowest reported for North American black bears (Chapter 2, Table 6). Because this was the first cub survival study conducted in Florida, it is difficult to say if this rate is representative of other Florida black bear populations or of long-term fluctuations that may occur. Although not statistically significant, cubs born to primiparous females had lower survival than those born to multiparous females, an observation that has been reported for other black bear populations (Alt 1982, Elowe and Dodge 1989, McLaughlin et al. 1994). Causes of cub mortality included cannibalism, direct and indirect mortality from vehicle collisions, abandonment, malnutrition, accidents and illnesses. Mortality due to cannibalism was high, but I found no evidence to suggest that it was due to sexually selective infanticide (e.g. brown bears [*Ursus arctos*]: Swenson et. al. 2001; see review in Fox 1975). Instead, the benefit gained appeared to be nutrition, and not potential mates. Anthropogenic causes also contributed to cub mortality, both directly through road mortality, and indirectly through orphaning.

In my study population, parturient females denned for an average of 113 days, while non-parturient females denned for a shorter period or remained active throughout the winter. Most parturient females denned in ground nests but few used excavated ground dens, and one female used a tree den. All non-parturient females used ground nests. I found no evidence that female Florida black bears select for, or against, a particular habitat type for denning. This finding may indicate that most habitats in my study area provided the habitat characteristics that would provide suitable den sites (dense vegetation). It also could indicate that there were no big differences in habitat characteristics among habitat types. However, dens were not located in younger sand pine, indicating that older growth forest was preferred when available. In addition, the wetter habitats (pine flatwoods, swamp habitat) where many dens were located, typically are not harvested. Dens did not occur in slash pine plantations.

Management Recommendations

Cub mortality rate in ONF and Lynne is high compared to most black bear populations. As the human population in this area increases, the probability of cub mortality from direct or indirect anthropogenic causes also is likely to increase. The Ocala bear population sustained 54.2% (N = 1219) of vehicle-related mortalities recorded during 1976-2003, and 80 of 133 (60%) mortalities due to vehicles in 2003 (http://wld.fwc.state.fl.us/bear/roads). In Lynne, a contemporaneous study found that survivorship among Lynne females (0.744) mimicked rates of a heavily exploited population (McCown et al. 2004).

Thus, I recommend management actions that reduce cub mortality by reducing the direct cub mortality due to vehicles, and the indirect mortality that occurs when mothers are killed by vehicles. Deaths of adult females in Lynne caused 6 dependant cubs to be orphaned. The high adult female and cub mortality in Lynne suggests that while bears may continue to inhabit the forested tracts of Lynne, it is less likely that another population suffering from a similar mortality that is more isolated from a large donor population could sustain this level of mortality. Efforts should be made to reduce vehicle mortality of bears (e.g., bear crossing signage, underpasses), especially in areas with high number of vehicular collisions. In addition, increased public education and awareness regarding bears can facilitate positive attitudes toward bears, and increased compliance on agency policy and laws regarding nuisance bear behavior. More severe penalties and law enforcement efforts to deter illegal killing of bears also may be beneficial.

Denning is a critical period for parturient females and her cubs, as birth and early maternal care take place during this time. I recommend that management efforts be undertaken to reduce prescribed burning and timber harvest in areas suitable for denning from mid-December to mid-April. If winter burning and timber management are unavoidable, I recommend that these activities be performed early in the denning season, so that pregnant females can leave disturbed areas prior to giving birth.

Land managers should avoid practices that might reduce mast-producing vegetation. Fall mast provides an important source of nutrition to pregnant females. The ability to access nutritional resources in the fragmented habitat of Lynne is important and should be considered. Access to habitats that provide alternative food sources during mast failures is important, and any road construction and other development plans should take this into consideration.

Recommendations for Further Research

Further research is needed to investigate if the low survival rates of cubs found in this study represent the long-term trend in ONF and Lynne. Research on cub survival in other Florida black bear populations experiencing varying degrees of anthropogenic impacts and bear densities would allow for improved understanding of how these factors affect survival of cubs. Cub radio-collars provide a useful tool to estimate survival rates and to identify causes of mortality.

A study investigating yearling survival rates is needed to adequately assess the recruitment rate of bears into the reproductive age class. The expandable radio-collar design used in this study (Higgins Vashon et al. 2003) could be modified for use on yearlings.

Also I suggest that comprehensive demographic studies are needed to estimate reproductive parameters and to perform demographic and survival population viability analyses. Such studies could provide valuable insight into the growth and extinction parameters, and allow investigation into the influence of alternative management strategies on the dynamics and persistence of the Florida black bear populations. As Florida's human population continues to increase, further habitat reduction and fragmentation are an increasing risk for the long-term persistence of the black bear populations. Thus, understanding the dynamics of bear populations will become increasingly important for prudent bear management and conservation efforts.

APPENDIX A
CHARACTERISTICS OF FLORIDA BLACK BEAR CUBS

Table 10. Florida black bear cub characteristics in Ocala National Forest and Lynne, Florida, 1999-2003. Data is presented by cub and mother identification, study area (ONF, Lynne), cohort, capture date, sex, estimated birth date, weight (grams), total length (cm), chest (cm), and neck (cm).

Cub #	Female	Area	Cohort	Capture Date	Sex	Est. Birth Date	Weight (grams)	Total length (cm)	Chest (cm)	Neck (cm)
R054	R032	ONF	2000	03/07/00	F	01/24/00	1810	43.2	24.3	16.5
R055	R032	ONF	2000	03/07/00	M	01/24/00	1790	45.5	23.8	16.5
R056	R037	ONF	2000	03/08/00	M	02/08/00	1850	44.7	25.6	17.4
R057	R037	ONF	2000	03/08/00	F	02/08/00	1510	40	22.5	15.5
R058	R034	ONF	2000	03/09/00	M	01/26/00	1960	42	26	20
R059	R034	ONF	2000	03/09/00	M	01/26/00	2110	45	26	18
R060	R011	ONF	2000	03/10/00	M	02/03/00	1570	46.4	24	15.8
R061	R011	ONF	2000	03/10/00	M	02/03/00	1610	44.5	25	17.5
R062	R043	ONF	2000	03/11/00	F	01/28/00	1750	40.5	25.4	17.4
R063	R043	ONF	2000	03/11/00	F	01/28/00	1720	40.5	24	16.5
R064	R010	ONF	2000	03/15/00	M	02/01/00	2320	48	27.4	18
R065	R016	ONF	2000	03/16/00	M	01/19/00	2235	49	26.2	17.5
R066	R016	ONF	2000	03/16/00	F	01/19/00	2235	50.5	28	18.5
R067	R016	ONF	2000	03/16/00	M	01/19/00	2235	50.2	26.2	18.7
R069	R047	ONF	2000	03/21/00	M	01/24/00	2735	49	29.2	18.7
R070	R047	ONF	2000	03/21/00	F	01/24/00	2335	50	26.8	17.5
R071	R020	ONF	2000	03/22/00	F	02/15/00	1210	38.2	21.4	14.3
R112	R039	ONF	2001	03/09/01	M	02/02/01	970	39	19.8	13
R113	R039	ONF	2001	03/09/01	F	02/02/01	530	33.5	16	11.1

Table 10. Continued

Cub #	Female	Area	Cohort	Capture Date	Sex	Est. Birth Date	Weight (grams)	Total length (cm)	Chest (cm)	Neck (cm)
R114	R108	Lynne	2001	03/10/01	F	[a]	1900	46	26	18
R115	R108	Lynne	2001	03/10/01	F	[a]	2150	46	27	19
R116	R108	Lynne	2001	03/10/01	M	[a]	1750	38	27	17
R117	R101	Lynne	2001	03/14/01	F	01/17/01	1850	46.5	26	18
R118	R101	Lynne	2001	03/14/01	M	01/17/01	1900	46	25.3	17.7
R120	R031	ONF	2001	03/15/01	M	01/25/01	1600	47	25.5	18
R121	R031	ONF	2001	03/15/01	F	01/25/01	1750	45	24	17.3
R122	R082	Lynne	2001	03/17/01	F	01/27/01	2250	47	27.8	17.6
R123	R082	Lynne	2001	03/17/01	M	01/27/01	2450	49	30	22
R124	R010	ONF	2001	03/21/01	M	01/24/01	2855	54	32.5	21
R125	R010	ONF	2001	03/21/01	M	01/24/01	2855	51	29	19
R126	R032	ONF	2001	03/22/01	F	[a]	2350	53	30.5	20
R127	R032	ONF	2001	03/22/01	F	[a]	2450	47	32	21
R128	R111	ONF	2001	03/23/01	M	01/26/01	2350	50	26.5	19
R129	R111	ONF	2001	03/23/01	M	01/26/01	2750	50	29	19.5
R130	R111	ONF	2001	03/23/01	M	01/26/01	2600	50	27.5	19
R131	R074	Lynne	2001	03/26/01	M	01/15/01	2660	47	28	20
R132	R074	Lynne	2001	03/26/01	F	01/15/01	2600	47	29.5	20
R133	R099	ONF	2001	03/27/01	F	02/06/01	2700	51	30	21
R134	R099	ONF	2001	03/27/01	F	02/06/01	2550	54	29	20
R160	R011	ONF	2002	03/18/02	F	02/04/02	1000	37	19	12.5
R161	R011	ONF	2002	03/18/02	F	02/04/02	1220	39.5	22	15

[a] No Data

Table 10. Continued

Cub #	Female	Area	Cohort	Capture Date	Sex	Est. Birth Date	Weight (grams)	Total length (cm)	Chest (cm)	Neck (cm)
R162	R011	ONF	2002	03/18/02	M	02/04/02	1000	[a]	[a]	[a]
R163	R011	ONF	2002	03/18/02	F	02/04/02	1150	38	21.5	14.5
R164	R082	Lynne	2002	03/19/02	F	01/29/02	2125	50	27	18
R165	R082	Lynne	2002	03/19/02	F	01/29/02	2375	.	.	.
R166	R020	ONF	2002	03/19/02	M	01/22/02	2035	51	24.5	17
R167	R020	ONF	2002	03/19/02	M	01/22/02	2140	45.5	28	17.5
R168	R047	ONF	2002	03/20/02	F	01/16/02	2385	50.5	26.5	17
R169	R047	ONF	2002	03/20/02	F	01/16/02	2525	46	29	20.5
R170	R047	ONF	2002	03/20/02	M	01/16/02	2735	44	30.5	19.5
R171	R149	Lynne	2002	03/21/02	M	02/07/02	2040	47.5	24.5	17
R172	R149	Lynne	2002	03/21/02	M	02/07/02	1390	44	24.2	15.5
R173	R149	Lynne	2002	03/21/02	F	02/07/02	1740	46	25.3	16.5
R174	R146	ONF	2002	03/22/02	M	01/25/02	2550	51	28	18.5
R175	R146	ONF	2002	03/22/02	F	01/25/02	2400	46.5	29	19.5
R176	R143	Lynne	2002	03/25/02	F	01/28/02	1790	49.5	23.7	16
R177	R143	Lynne	2002	03/25/02	M	01/28/02	1860	44	26.3	16.6
R178	R030	ONF	2002	03/26/02	F	01/22/02	2360	46	28.5	19.5
R179	R030	ONF	2002	03/26/02	F	01/22/02	2040	45	27.3	18.5
R180	R109	ONF	2002	03/27/02	F	01/16/02	2850	50	28.8	18.8
R181	R109	ONF	2002	03/27/02	M	01/16/02	2750	49.5	28.5	17.9
R182	R043	ONF	2002	03/28/02	M	01/31/02	2240	45.2	27.1	18.5
R183	R145	ONF	2002	04/01/02	M	01/21/02	2150	45.5	28.3	17.7

[a] No Data

Table 10. Continued

Cub #	Female	Area	Cohort	Capture Date	Sex	Est. Birth Date	Weight (grams)	Total length (cm)	Chest (cm)	Neck (cm)
R184	R145	ONF	2002	04/01/02	F	01/21/02	2350	48	27.5	17
R185	R147	Lynne	2002	04/05/02	M	02/08/02	1550	39	22.1	16
R205	R080	Lynne	2003	03/28/03	M	01/31/03	1590	46	23	16
R206	R080	Lynne	2003	03/28/03	F	01/31/03	2159	47.5	26	17.5
R207	R080	Lynne	2003	03/28/03	M	01/31/03	1648	41	23	16
R208	R189	ONF	2003	03/31/03	F	01/27/03	2920	49	31	20
R210	R195	ONF	2003	04/01/03	F	01/29/03	2655	50.4	31.4	19.8
R211	R195	ONF	2003	04/01/03	F	01/29/03	1365	46	25	15.5
R212	R198	ONF	2003	04/02/03	F	01/28/03	1530	41.5	22	16.5
R213	R198	ONF	2003	04/02/03	M	01/28/03	1630	41	23	15
R214	R086	Lynne	2003	04/03/03	M	03/13/03	850	39.2	28.2	13.5
R215	R086	Lynne	2003	04/03/03	F	03/13/03	800	38	19	12.7
R216	R086	Lynne	2003	04/03/03	F	03/13/03	800	35.9	19.7	13
R217	R197	Lynne	2003	04/07/03	M	02/03/03	2800	50.5	28.5	19.5
R218	R031	ONF	2003	04/08/03	F	02/17/03	2560	49	30.2	18.8
R219	R137	ONF	2003	04/21/03	F	[a]	2900	[a]	[a]	[a]

[a] No Data

APPENDIX B
DEN ENTRY, EXIT, AND DURATION OF DENNING OF FEMALE FLORIDA BLACK BEARS

Table 11. Den entry date, exit date and duration of denning (days) of female Florida black bears in Ocala National Forest and Lynne, Florida, 1999-2003. Data is presented by female number, reproductive status and cohort.

Female #	Reproductive Status	Cohort	Den entry date	Den exit date	Duration (days)
R010	parturient	2001	12/30/00	04/14/01	135
R010	non-parturient	2002	01/25/02	03/03/02	37
R011	parturient	2000	01/19/00	04/19/00	91
R011	non-parturient	2001	12/22/00	03/09/01	91
R011	parturient	2002	01/05/02	04/01/02	87
R016	parturient	2000	01/10/00	04/28/00	109
R016	non-parturient	2001	12/15/00	02/17/01	64
R020	parturient	2000	02/07/00	04/09/00	62
R020	non-parturient	2001	12/30/00	03/05/01	95
R020	parturient	2002	01/13/02	04/12/02	90
R030	non-parturient	2001	01/09/01	03/03/01	29
R030	parturient	2002	12/23/01	04/12/02	126
R031	parturient	2001	01/14/01	04/20/01	97
R031	parturient	2003	12/28/02	04/19/03	138
R032	parturient	2000	01/11/00	05/01/00	111
R032	parturient	2001	12/30/00	04/06/01	127
R034	parturient	2000	01/17/00	04/15/00	89
R036	non-parturient	2001	01/13/01	02/28/01	46
R037	parturient	2000	01/15/00	05/05/00	111
R037	non-parturient	2001	01/06/00	03/07/00	61
R039	parturient	2001	12/20/01	[a]	[a]
R043	parturient	2000	01/22/00	05/06/00	105
R043	parturient	2002	12/30/01	03/31/02	121
R047	parturient	2000	01/08/00	[a]	[a]
R047	non-parturient	2001	12/23/00	03/03/01	86
R047	parturient	2002	12/29/01	04/21/02	141
R074	parturient	2001	12/16/00	04/16/01	123
R075	non-parturient	2001	12/22/01	02/09/01	49
R080	non-parturient	2001	01/20/01	03/31/01	71

[a] No Data

Female #	Reproductive Status	Cohort	Den entry date	Den exit date	Duration (days)
R080	parturient	2003	12/13/02	04/19/03	123
R082	parturient	2001	12/19/00	04/10/01	120
R082	parturient	2002	[a]	04/21/02	[a]
R086	non-parturient	2001	01/20/01	02/17/01	28
R086	parturient	2003	02/01/03	05/29/03	118
R099	parturient	2001	01/31/01	04/14/01	74
R099	non-parturient	2002	02/17/02	03/17/02	29
R101	parturient	2001	12/23/00	04/07/01	121
R105	non-parturient	2001	01/10/01	03/02/01	52
R108	parturient	2001	12/16/00	04/07/01	114
R109	non-parturient	2001	01/06/01	03/02/01	56
R109	parturient	2002	12/30/01	03/26/02	116
R111	parturient	2001	12/23/01	[a]	[a]
R137	non-parturient	2002	01/31/02	03/17/02	62
R137	parturient	2003	01/22/03	05/09/03	108
R143	parturient	2002	01/06/02	05/01/02	116
R145	parturient	2002	01/05/02	04/04/02	90
R146	parturient	2002	01/05/02	04/21/02	107
R146	non-parturient	2003	01/18/03	01/27/03	9
R147	parturient	2002	12/26/01	04/20/02	137
R147	non-parturient	2003	12/28/02	03/16/03	79
R149	parturient	2002	12/26/01	04/26/02	143
R189	parturient	2003	12/23/02	04/23/03	137
R195	parturient	2003	01/01/03	05/03/03	123
R197	parturient	2003	01/01/03	04/26/03	116
R198	parturient	2003	01/21/03	05/03/03	103
R201	non-parturient	2003	01/05/02	02/08/02	35

[a] No Data

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BIOGRAPHICAL SKETCH

Elina Päivikki Garrison was born on 28 January 1972 in Revonlahti, Finland. She grew up on a horse farm with her parents, two sisters and a brother. Her interest in wildlife was shaped by the magic of countless hours spent exploring the wilderness that was her backyard and by books that took her to faraway places. Her compassion for animals was built by the friendships she shared with the family horses, ponies, dogs, cats and other animals that came to cross her path in life. She moved to the United States with her family when she was 13. She graduated from Lake Worth High School in 1989 and enrolled in Palm Beach Community College in fall 1989. She received her Associate of Arts degree in spring 1992. In August 1996, she came to University of Florida (UF) and received her Bachelor of Science degree in wildlife ecology and conservation in May 1998. After graduation, she worked for the Florida Fish and Wildlife Conservation Commission and was fortunate to know and benefit from the outstanding field biologists with whom she worked. In August 2001, she began her graduate work at UF in the Department of Wildlife and Conservation. She received her Master of Science degree in May 2004. She lives with her husband, Jim, in Keystone Heights, Florida.