

**ECOLOGY AND CONSERVATION OF LOUISIANA BLACK BEARS IN THE TENSAS
RIVER BASIN AND REINTRODUCED POPULATIONS**

A Thesis

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by

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ABSTRACT

Louisiana black bears (*Ursus americanus luteolus*) exist in 3 isolated populations in Louisiana and are listed as a threatened subspecies under the United States endangered species act. In order to establish a population of black bears in central Louisiana and to promote connectivity among existing populations 11 adult females and 28 cubs were reintroduced to suitable habitat on Lake Ophelia National Wildlife Refuge. We captured and monitored females in the Tensas River Basin (TRB) in northeast Louisiana for use in these reintroduction efforts and to study their ecology. Specifically, I studied the food habits, space use, habitat selection, and denning behavior of female bears in the TRB and reintroduced populations. Within the TRB bears exist in 2 subpopulations (Tensas and Deltic) which inhabit highly variable landscapes. Bears on Tensas inhabit a large ($>300 \text{ km}^2$) contiguous block of bottomland hardwood forest, whereas bears on Deltic inhabit small ($<7 \text{ km}^2$) forest fragments surrounded by a matrix of agricultural fields. Bears in the TRB ate an omnivorous diet dominated by plant foods that shifted to exploit seasonally available foods. Important food items included: herbaceous vegetation, soft mast, corn, acorns, and beetles. Spring home ranges and core areas on Tensas differed between females with and without cubs. Ranges of females on Tensas were larger than those on Deltic, and ranges of reintroduced females were larger than both TRB subpopulations. Habitat selection patterns also differed as females on Tensas selected swamps and regenerating forests at most spatial scales and during most seasons, whereas Deltic females selected upland and lowland forests. Lake Ophelia females selected upland and lowland forests when establishing home ranges, but did not exhibit non-random habitat use within home ranges. In the TRB, parturient females used tree dens more frequently than ground dens, whereas non-parturient used tree and ground dens with similar frequency. Tensas den sites were closer than

expected to swamps, water, and regenerating forests, whereas Deltic den sites were closer than expected to upland and lowland forests. I discuss the results in relation to fragmentation, forest management practices, and conservation.

CHAPTER 1. INTRODUCTION, GENERAL METHODS, CAPTURE AND REINTRODUCTION RESULTS

INTRODUCTION

The Louisiana black bear (*Ursus americanus luteolus*) was once distributed across much of Louisiana, west Texas, and east Mississippi (Hall 1981) but only 3 isolated populations remain. These 3 populations exist in Louisiana's Mississippi Alluvial Valley, with 1 in the Tensas River Basin and 2 in the Atchafalaya River Basin (Figure 1.1). Extensive habitat loss and excessive harvest are probably the 2 major causes of reduction in range and population numbers of this subspecies (Neal 1992). Indeed, habitat available to Louisiana black bears had been reduced by over 80% by 1980, primarily due to clearing of forests for agriculture (Neal 1990). Bear hunting seasons in Louisiana were closed from 1964-1974, re-opened in some areas from 1975-1987, and have been closed until the present day since 1987 (Hammond 1989). In 1992 the Louisiana black bear was listed as threatened under the United States endangered species act (Neal 1992).

Across the United States the range of black bears is becoming increasingly fragmented by habitat loss and degradation, and these problems are especially evident in the southeastern United States (Hellgren and Maehr 1992, Hellgren and Vaughan 1994). There is a paucity of information regarding the effects of fragmentation on the ecology and behavior of black bears, although it has the potential to affect populations in both severe and subtle ways (Hellgren and Maehr 1992). In the Tensas River Basin population (TRB) in Louisiana, bears remain in 2 subpopulations that differ greatly in degree of fragmentation and amount of forested habitat (see below, Study Area). Previous researchers have studied bears in the TRB, but these studies have suffered from small sample sizes and have not explicitly examined differences in the ecology of bears inhabiting the 2 subpopulations. The close proximity of 2 subpopulations inhabiting

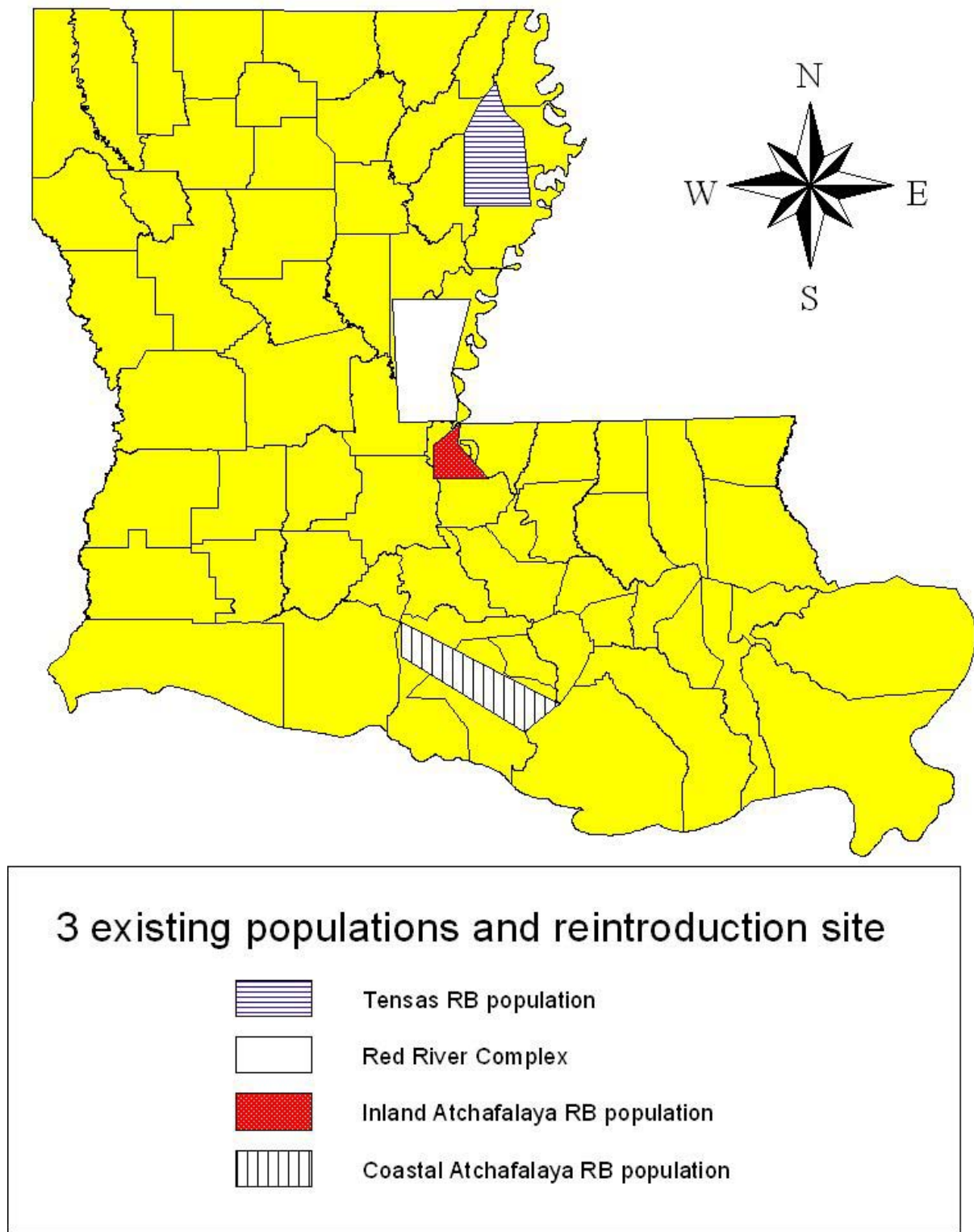


Figure 1.1. 3 existing populations of Louisiana blacks bears: Tensas River Basin, Inland and Coastal Atchafalaya River Basins. Also shown is Red River Complex reintroduction area.

different landscapes of severe and moderate fragmentation, but otherwise similar environmental conditions, provided an effective setting to investigate the effects of fragmentation on black bear ecology.

In 2001, a multi-agency restoration program was begun to reintroduce bears to the east-central portion of Louisiana, referred to as the Red River Complex (RRC; Figure 1.1). During the winters of 2001 and 2002, 5 adult females and 12 cubs were relocated from 2 of the existing populations to the Red River Wildlife Management Area as part of a feasibility study (Van Why 2003). Results of these efforts were favorable (see Van Why 2003) and in June of 2002 we began intensively trapping and radiocollaring black bears in the TRB for use in restoration efforts and ecological study. During 2003-2004 an additional 11 adult females and 28 cubs were relocated from the TRB to Lake Ophelia National Wildlife Refuge (LONWR). I monitored bears intensively in both the TRB and LONWR to gain a better understanding of the ecology of Louisiana black bears in existing and reintroduced populations.

OBJECTIVES

There were 4 major goals for this research: (1) to gather baseline ecological data on bears in the TRB to increase our understanding of black bears in general and Louisiana black bears in particular, (2) compare the ecology of bears in 2 subpopulations of the TRB subjected to different levels of habitat fragmentation, (3) populate the central portion of Louisiana with black bears to promote gene flow and connectivity among existing populations, and (4) intensively monitor reintroduced bears to evaluate success of these efforts and investigate behavior of relocated bears. Specifically, I studied bears in the TRB and reintroduced populations with the following objectives:

1. Describe the diet of Louisiana black bears.

2. Document and investigate sources of variation in space use of adult female bears.
3. Investigate habitat use at multiple spatial scales for adult female bears.
4. Investigate the following aspects of female denning behavior: den type use, site characteristics, and landscape-level selection.

ORGANIZATION OF THESIS

Chapter 1 gives a general introduction to the study subspecies, description of study areas, overall objectives and general methodology of the project, and a brief description of the results and outcomes of capture and reintroduction efforts. Each of the 4 specific objectives described above is addressed in a self-contained chapter (Chapters 2-5). Methods common to multiple chapters (e.g., black bear capture and radio-telemetry) are described in Chapter 1 to avoid redundancy. Chapter 6 provides conclusions about ecology of Louisiana black bears, conservation/management recommendations, and suggestions for future research on this subspecies.

Use of First Person

I use the first person singular for most of the thesis because it is a single author publication and because I performed and/or supervised research activities, including fieldwork and data analysis. However, my use of the first person is not meant to imply that I personally performed all tasks described herein. In particular, the spring, summer, and fall trapping activities described below were often performed without my involvement. Also, the reintroduction captures and translocations generally involved assistance from a variety of project and non-project personnel. In Chapter 1, I use first person plural to describe capture and reintroduction activities to reflect this assistance and the fact that these activities were very much a “group effort”. For the remainder of the thesis I use first person singular.

GENERAL METHODS

Study Areas and Populations

The Tensas River Basin is located in Northeast Louisiana in the western floodplain of the Mississippi River (Figure 1.1). The TRB study area and population can be divided into 2 smaller areas and subpopulations which are separated by US I-20 and extensive agricultural lands which are mostly devoid of forested habitat (Figure 1.2). The Tensas River National Wildlife Refuge and surrounding private lands (referred to as Tensas) are part of a relatively large ($>300 \text{ km}^2$) contiguous tract of bottomland hardwood forest surrounded by agricultural areas, although the bears we studied only inhabited approximately 290 km^2 of forest and other habitats. The second study area within the TRB (referred to as Deltic) is north of I-20 where bears inhabit small, isolated woodlots surrounded by large expanses of agricultural land. The bears I studied from Deltic inhabited a 60 km^2 area, which included 2 main forested tracts, Wade Bayou (6.9 km^2) and Bluecat (6.4 km^2), and adjacent “satellite” forested areas and agricultural fields. It should be noted that several other small ($<11 \text{ km}^2$) forested tracts exist in this area and are known to be used by bears, but the relative habitat quality and reported levels of bear activity in these tracts appears to be lower than in Bluecat and Wade Bayou (Marchinton 1995, Anderson 1997, Beausoleil 1999).

We reintroduced bears to LONWR in central Louisiana, which is located approximately 115 km from the southern portion of Tensas. The bears released in this area currently inhabit both refuge and private lands and I refer to these areas collectively as Lake Ophelia, whereas when referring specifically to the refuge I will use the abbreviation LONWR. The Red River winds around Lake Ophelia creating convenient borders to the west, north, and east of the study area (Figure 1.3). Habitat types are similar in the 3 study areas where the forested areas are

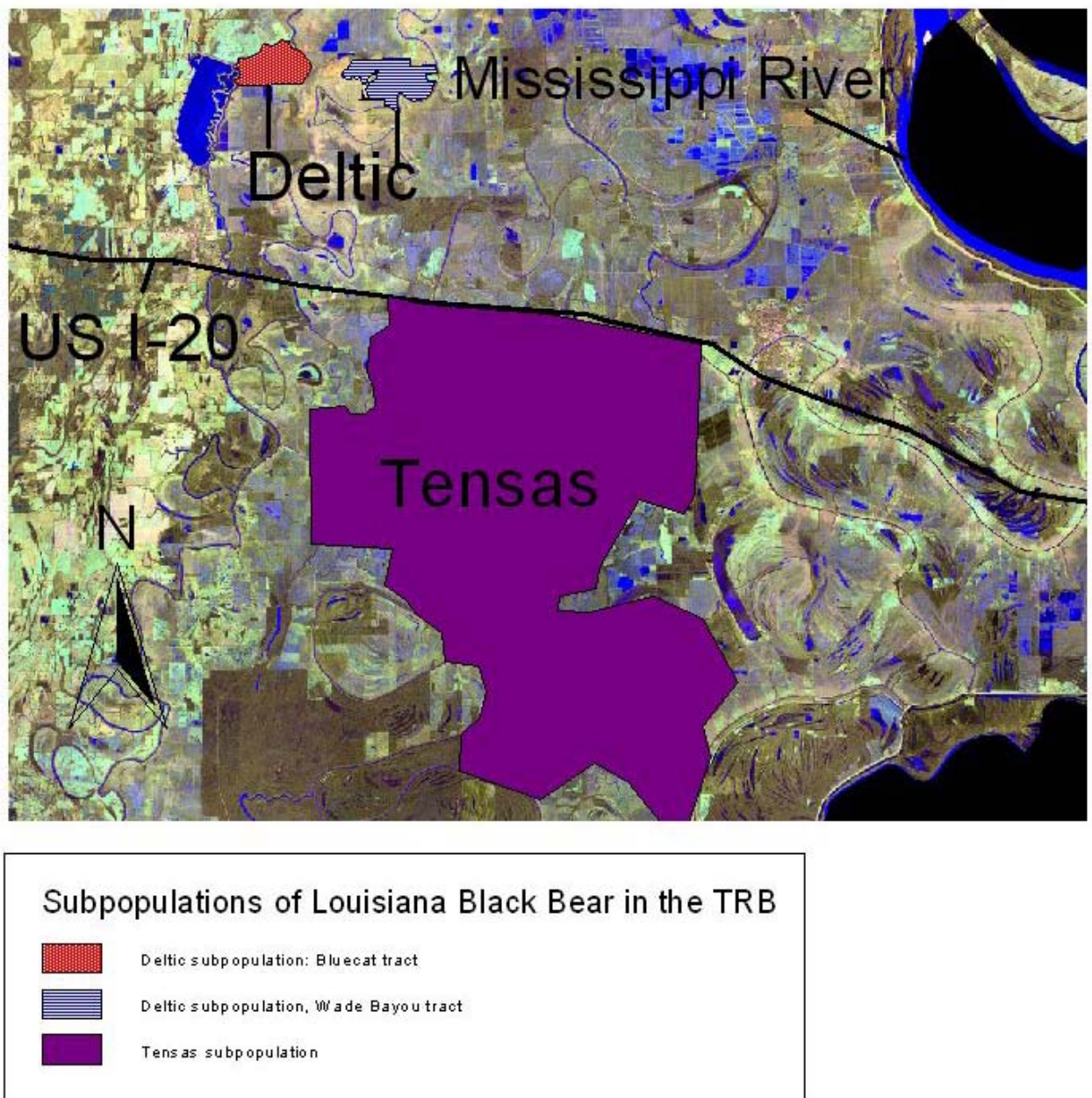


Figure 1.2. Subpopulations of Louisiana black bears in the Tensas River Basin (TRB), showing the 2 Deltic tracts (Bluecat and Wade Bayou), Tensas, US highway I-20, and the Mississippi River.



Figure 1.3. Lake Ophelia, 2003-2004 Louisiana black bear reintroduction site, showing the Red River surrounding study area to west, north, and east.

almost exclusively bottomland hardwoods, interspersed with cypress-tupelo swamps and fragmented by agricultural fields. Detailed descriptions of habitat composition of the study areas are given in Chapter 4. Principal land uses in these areas include farming, hunting, logging and conservation easements. Primary overstory species include: willow oak (*Quercus phellos*), water oak (*Q. nigra*), nuttall oak (*Q. texana*), overcup oak (*Q. lyrata*), sweetgum (*Liquidambar styraciflua*), sugarberry (*Celtis laevigata*), American elm (*Ulmus americana*), sweet pecan (*Carya illinoensis*) and baldcypress (*Taxodium distichum*). Principal understory plant species include palmetto (*Sabal minor*), greenbrier (*Smilax* spp.), black- and dewberry (*Rubus* spp.), and poison ivy (*Toxicodendron radicans*). Other carnivores common to the study areas include: coyotes (*Canis latrans*), bobcats (*Lynx rufus*), river otters (*Lontra canadensis*), raccoons (*Procyon lotor*), and striped skunks (*Mephitis mephitis*). One noticeable difference between the fauna of the TRB and Lake Ophelia is that wild hogs (*Sus scrofa*) are common at Lake Ophelia, but absent from the TRB.

Despite the close proximity of Tensas and Deltic, current and past differences in forest management practices, as well as topographical/hydrological differences, have resulted in differences in the plant species composition of mature forests in the 2 study areas. Prior to being converted to a wildlife refuge, “high-grading” was the dominant timber harvesting practice on Tensas, meaning that the most economically valuable trees were removed periodically. Since being acquired by the federal government in 1980, very little forest management or timber harvesting has occurred on the refuge. The combination of past and recent practices has resulted in relatively low species diversity in the overstory and a closed canopy. The lack of sunlight reaching the forest floor coupled with regular flooding events on Tensas have resulted in low diversity and abundance in the understory, which is open or dominated by palmetto throughout

most of the refuge. Conversely, Deltic is actively managed to promote hard-mast production with regular selective harvests to thin the overstory. This allows sunlight to penetrate the forest canopy and has resulted in dense growth of soft-mast producing understory species such as blackberry, American beautyberry (*Callicarpa Americana*), pokeberry (*Phytolacca americana*), pawpaw (*Asimina parviflora*), and muscadine (*Vitis rotundifolia*). In addition, much of Deltic is topographically higher and therefore less prone to flooding than Tensas, which also allows for dense understory growth on Deltic.

Black Bear Capture and Handling

We captured black bears in the TRB from 17 June to 13 November 2002, 16 May to 15 November 2003, and 20 May to 11 Aug 2004. In addition, 7 bears used in this study were captured and radiocollared by United States Fish and Wildlife Service personnel during April and June 2002. We caught bears with modified Aldrich spring-activated foot snares (Johnson and Pelton 1980a) and culvert traps. We immobilized captured bears using Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) hydrated with 1.6 cc H₂O at a targeted dosage of 4-5 mg/kg. We fitted females ≥ 80 lbs with mortality-sensitive radiocollars (Advanced Telemetry Systems, Isanti, Minnesota, USA and Telonics, Mesa, Arizona, USA). We estimated age using tooth wear, body size and condition, and in some cases extracted a premolar to estimate age by counting cementum annuli. Bears were marked with 2 plastic ear tags and a “pit-tag” microchip placed under the skin between the shoulder blades. We collected ear tissue, hair, and/or blood from all bears captured for DNA analysis.

Reintroduction

We used the winter “soft-release” technique (Eastridge and Clark 2001) to reintroduce bears to LONWR. This technique involves relocating adult female black bears and newborn

cubs from winter dens and releasing them into artificial den boxes in the reintroduction site. This technique is considered a “soft-release” because maternal constraints of female black bears with new born cubs require them to restrict movements during winter and early spring. Presumably during this period the females become acclimated to the new habitat in the release areas (Eastridge and Clark 2001). Additional information regarding this technique and its effectiveness are available elsewhere (Eastridge and Clark 2001, Clark et al. 2002, Van Why 2003, Wear 2003).

We located winter dens for all radiocollared females in the TRB during February and March 2003 and 2004 to assess reproductive condition. We selected 5 and 6 females with newborn cubs in 2003 and 2004, respectively that could be feasibly captured and removed from dens for reintroduction purposes. We immobilized bears with a dart rifle, pistol, or blowgun using drugs and dosages described earlier. Each adult captured for relocation was fitted with a new radiocollar and cubs were sexed and marked with pit-tags. DNA samples were taken from adults and cubs. We placed the females and their cubs into a transport box in the bed of a pick-up truck and drove them to LONWR. At LONWR, we re-immobilized the adult in the transport box, carried the bears via All Terrain Vehicle to release sites, and placed the adult and cubs into artificial den boxes. We placed litter from the original den into the box to provide familiar scents and left the area with the adult still immobilized. We used den boxes that were essentially “dog-houses” made of wood, with an open front, a swinging rear door that was screwed shut upon release, and windows on both sides for ventilation. Windows and doors were blocked with downed wood and debris to prevent cubs from leaving the den before the adult had recovered from immobilization. We placed den boxes at the release sites 2-4 weeks before release to

reduce human scent. We selected sites for the boxes that were in relatively remote forested areas, with dense ground and/or overhead cover, and on high ground to prevent flooding.

Radio-Telemetry and Home Range Estimation

I estimated bear locations via triangulation using a hand held receiver (TR-2 and TR-4, Telonics; R4000, ATS; and TRX-2000S, Wildlife Materials, Carbondale, Illinois, USA) and a 2-element H-antenna (Telonics). I determined the observer location using a Global Positioning System (GPS) and collected data from fixed or temporary telemetry stations. For all analyses, I only used location estimates obtained using ≥ 3 bearings collected within 20 minutes, with angles between consecutive bearings $\geq 30^\circ$, and with angles between the 2 outermost bearings $\leq 145^\circ$. To assess telemetry error I estimated the location of collars placed at fixed locations unknown to the observer ($n = 4$) and of bears denning in tree cavities ($n = 3$). The mean distance from estimated location to true location was 134.9 m (SE = 43.4, $n = 7$, range = 3.2 - 268.2). Specific information about the sampling design and frequency used for both study areas will be discussed in Chapter 3, but in general bears were located a minimum of 3 times a week and 12 times a month, and often much more frequently. However, not all locations obtained in the field were used for home range estimation due to unacceptable error polygons or violations of angle and time-limit requirements. I located bears during all hours of the day and night. I converted telemetry data into location estimates using the program LOAS 3.2 (Ecological Solutions Software, Urnäsch, Switzerland) and entered the UTM coordinates into a database. I estimated 95% home ranges and 50% core areas using fixed kernel estimators (Seaman and Powell 1996, Powell et al. 1997) for 37 female black bears between the TRB (source) and Lake Ophelia (reintroduced) populations. These home ranges and core areas were estimated using the Animal Movement and Spatial Analyst extensions in Arcview 3.3 (Environmental Systems Research

Institute, Redlands, California, USA). Locations used for home range estimation were separated by at least 8 hours to ensure some level of independence between data points, although Powell et al. (1997) noted that all telemetry data are probably autocorrelated because animals presumably make decisions on where to travel based on past movements. However, kernel estimators are generally believed to be robust against violations of independence (Swihart and Slade 1997) and I observed bears traveling the length of their home ranges in fewer than 8 hours on multiple occasions so I assumed that 8 hours between consecutive locations would be sufficient for my analyses.

RESULTS OF CAPTURE AND REINTRODUCTION EFFORTS

Capture

During spring, summer, and fall capture efforts from 2002-2004 in the TRB, we caught a total of 113 individuals in 158 capture events during 2195 trapnights. On Tensas, we captured 30 females, 26 males, and 5 cubs. On Deltic, we captured 28 females, 15 males, and 9 cubs. The sex is not given for cubs because many (7 of 16) were released from culverts without handling and sex was unknown. We obtained a sample of known litter sizes ($n = 23$) from the TRB from 2001-2005 during winter capture efforts on Deltic (mean = 2.22, SE = 0.28, $n = 9$) and Tensas (mean = 2.57, SE = 0.27, $n = 14$; Table 1.1).

Reintroduction

During March of 2003 and 2004 we captured 11 adult females and their 28 cubs in winter dens and reintroduced them to LONWR (Table 1.2). One adult female abandoned her 3 cubs in 2003, 3 days after release. We recovered these cubs from the artificial den box and they were placed into the dens of 2 females known to have cubs in the TRB. Although the fate of these cubs is unknown, both females appeared to initially accept the cubs and 1 of the adult “foster”

Table 1.1. Sizes and sex of known litters (n) from Tensas and Deltic subpopulation in the Tensas River Basin, northeast Louisiana from 2001-2005. Shown are number of litters (n), mean litter size (\bar{X}), standard error (SE), range of litter sizes, and number of males and female cubs. Note: sex was unknown for 2 litters (4 cubs total) on Tensas.

Subpopulation	n	\bar{X}	SE	Range	Males	Females
Tensas	14	2.57	0.27	1-4	14	12
Deltic	9	2.22	0.28	1-3	14	12
Total	23	2.43	0.24	1-4	28	24

Table 1.2. Summary of Louisiana black bears reintroduced to Lake Ophelia National Wildlife Refuge 2003-2004 including, bear ID number (D = from Deltic, T = from Tensas), date of relocation, number and sex of cubs, last known survival of translocated cubs, and current location and status of adult female. Note: cub survival information is based on opportunistic sighting and represents minimum number alive at time of sighting.

ID	Date	cubs	cub survival	current location and status
D8	3/14/03	1m, 1f	1 cub, 11/03	Lake Ophelia
T6	3/17/03	3m, 1f	2 cubs, 8/03	state of Mississippi, 5 cubs 1/05
T3	3/20/03	2m, 1f	1 yearling, 5/04	Lake Ophelia
T13	3/24/03	1m, 2f	2 cubs, 8/03	Lake Ophelia
D6	3/26/03	0m, 3f	cubs abandoned, 4/03	home range \approx 60km from LONWR
T7	3/17/04	4m, 0f	2 cubs, 11/04	Lake Ophelia
T9	3/19/04	3m, 0f	3 cubs, 10/04	Lake Ophelia
D14	3/22/04	1m	1 cub, 8/04	\approx 80 from LONWR
D17	3/24/04	1m	1 cub, 11/04	Lake Ophelia
D2	3/30/04	0m, 2f	1 cub, 6/04	Lake Ophelia
T21	3/30/04	1m, 1f	2 cubs, 7/04	\approx 40km from LONWR

females was seen with 5 cubs in May 2003. We do not know the size of her original litter, but litters of 5 bears have not been reported in the TRB and we assumed that at least 1 of the cubs seen was not her own. No other abandonment occurred in 2003 or 2004 and all of the other released females raised at least 1 cub into its first summer or fall. Exact cub survival rates were impossible to determine but survival appears to have been relatively high based on opportunistic visual sightings and den visits (Table 1.2). Three of the reintroduced bears left Lake Ophelia before 1 June following release and moved distances >60 km (Table 1.3). One bear remained at Lake Ophelia until October before moving >36 km from the study area (Table 1.3). Three of these bears moved north or northeast and the path they followed was within 21 degrees of the azimuth from their release sites to the original den where they were captured for translocation (Table 1.3). The remaining 7 bears have remained at Lake Ophelia until February 2005 (i.e. writing of this thesis) and despite extensive exploratory movements, these bears appear to have established home ranges in the study area (Table 1.2). All winter dens of reintroduced females have been visited to assess reproduction, and to date 1 female is known to have reproduced after reintroduction. This female (Bear T6, Table 1.2) had a litter of 5 cubs (2 female, 3 male) in winter 2005 and to my knowledge this is the largest litter ever reported for Louisiana black bears.

Table 1.3. Movements of reintroduced female Louisiana black bears that left Lake Ophelia release area during 2003-2004. Shown are straight line distances (km) and compass bearings (degrees) from release site to the farthest documented location, the straight line distance from release site to original den site in Tensas River Basin (TRB) where each bear was captured for translocation, and the difference (degrees) between the direction the bear traveled and direction back to original den in TRB.

Bear ID	<u>Release site - farthest location</u>		<u>Release site – TRB den</u>		Difference in bearings
	Distance	Bearing	Distance	Bearing	
D6	60.2	33.5 (northeast)	149.5	16.0	17.5
T6	62.0	113.8 (southeast)	130.1	25.4	88.4
D14	86.7	1.1 (north)	149.5	17.3	16.2
T21	36.3	38.6 (northeast)	140.3	18.3	20.3

CHAPTER 2. DIET OF BLACK BEARS IN THE TENSAS RIVER BASIN

INTRODUCTION

Black bears are opportunistic omnivores that eat a wide variety of plant and animal foods across their geographic range (Landers et al. 1979, Maehr and Brady 1984, Hellgren and Vaughan 1988, Boileau et al. 1994, Bull et al. 2001). Although black bears are classified taxonomically in the order Carnivora, virtually all studies have found black bear diets to be dominated by foods of plant origin (Pelton 2000). Most studies have shown that bears eat a variety of hard and soft mast, herbaceous vegetation, insects and other animals, and that changes in diet usually reflect changes in the seasonal availability of foods on the landscape (Landers et al. 1979, Hellgren and Vaughan 1988, Roof 1997, Pelton 2000, Bull et al. 2001). In areas where bears and agricultural activities are in close proximity, as they are in the TRB, bears often consume large amounts of cereal grains such as corn, wheat, and oats (Landers et al. 1979, Hellgren and Vaughan 1988, Anderson 1997, Weaver 1999). Food availability has the ability to influence space use (Powell et al. 1997), habitat preferences (Amstrup and Beecham 1976), and reproduction (Rogers 1987) of black bears and therefore knowledge of the dietary patterns of bears is important when studying the ecology of populations.

Although food habits of bears have been studied extensively across their geographic range, the omnivorous and opportunistic nature of this species necessitates population-specific studies of diet for meaningful ecological study and conservation planning. Furthermore, knowledge of the food habits of local populations is required to understand black bear habitat relationships (Bull et al. 2001). Two studies during the 1990's provided information about Louisiana black bear food habits in the TRB (Anderson 1997, Weaver 1999). However, because of annual variation in the diet of black bears and potential changes in the habitat over time,

studies of black bear diet should be conducted simultaneously with space and habitat use studies in order to maximize the utility of such research. Therefore, I collected and analyzed black bear scat from the TRB during trapping and monitoring efforts to describe the diet of this population and complement space use and habitat selection analyses.

METHODS

I collected fresh black bear scats while conducting other activities throughout the study areas in the TRB from June 2002-August 2004. I found scats opportunistically ($n = 183$), collected scat from traps ($n = 54$), and at den sites ($n = 14$). Traps were baited with pastries rather than “natural” bear foods (see Chapter 1, General Methods) and this prevented me from confusing foods consumed at the trap site with foods consumed elsewhere when analyzing trap scats. In fact, no bait remains were found in the scats due to complete digestion of pastries. I placed each scat sample in a plastic bag, recorded the date and study area (Tensas or Deltaic), and stored them in a freezer until they were analyzed. I processed each scat by thawing at room temperature and rinsing the fecal material through a 0.706 mm mesh sieve (# 25, Fisher Scientific, Hampton, New Hampshire, USA). Remains of food items were dried at 60° C, placed into plastic bags, and stored until they were identified. I identified each food item to species or lowest possible taxonomical category using a reference collection of seeds and other plant parts obtained from the study area, a collection of mammal hair at Louisiana State University, and plant identification manuals (Martin and Barkley 1961, Radford et al. 1968, Miller and Miller 1999). Scientific names of all food items identified are provided in Table 2.1. Throughout the text I used common names when referring to species, but if only Genus was known and there were >1 possible common names I used the Genus name (e.g., *Rubus* for black and dewberries)

I calculated 3 statistics to describe black bear diet: frequency of occurrence, percentage frequency, and percentage volume. Frequency of occurrence was defined as the total number of scats in which a given food item was found. Percent frequency was the frequency of occurrence divided by the total number of scats analyzed. Percentage volume was the proportion of each scat comprised of a given food item estimated by ocular assessment. Percentage volume was averaged over all scats to calculate the proportion of each food item in seasonal or overall diets. Frequency of occurrence and percentage frequency should give estimates of the relative frequency that each food item was consumed by bears. Percentage volume was calculated to estimate the proportion of each food item in the diets of bears, but these estimates should be viewed cautiously because of inherent biases due to differential digestion of food items (e.g., flesh is often digested more completely than vegetation; Hatler 1972, Boileau et al. 1994) .

I separated results by season to describe seasonal diets of bears in the TRB and pooled all years because of small seasonal samples sizes within years. I recognized the following seasons, which relate to seasonal black bear behavior and food availability: winter (February-March, denning period), spring (April and May, post-denning period), summer (June-August, breeding period), and fall (September-November, hyperphagia). No scats were collected during December and January. Given that I found differences in space use (see Chapter 3), habitat selection (see Chapter 4), and den site selection (see Chapter 5) between females on Tensas and Deltic, I suspected that there might also be differences in diet. Summer and fall are seasons during which feeding appears to have the greatest influence on fitness of black bears (Rogers 1987, Powell et al. 1997), and I also had the largest sample sizes during these seasons. For these reasons, I limited comparisons of the diets of bears on Tensas and Deltic to summer and fall

scats. I used Shannon's diversity index (H') to qualitatively compare diversity of the major food types eaten by bears on Tensas and Deltic during summer and fall (Zar 1999).

RESULTS

I identified 48 different food items (30 plant, 18 animal) in 251 individual scats (Table 2.1). Foods of plant origin dominated the diet during every season making up 85.4% of the volume, compared with 12.2% animal matter and 2.4% from debris. Corn made up the greatest percentage volume of summer (33.3%), fall (30.6%), and total (26.5%) scats. Beetles were the food item that occurred in the greatest number of scats ($n = 131$), but made up only 4.1% of the volume. *Rubus* was the most important spring food comprising 32.6% of volume and appearing in 5 of 9 scats. *Rubus* was also important during summer and made up 13.6% of volume, second only to corn. After corn and beetles, pokeberry appeared in the most scats during summer (44%, $n = 41$). During fall, acorns and palmetto fruit were important and made up 18.7% and 15.4% of the volume and appeared in 50.4% and 53.9% of 113 scats, respectively. In winter, the diet was dominated by grass and herbaceous vegetation which combined to account for 58% of the volume and one or the other item appeared in 69% of 36 winter scats. Acorns were also important winter food and comprised 18.5% of volume and appeared in 42.6% of 36 winter scats.

There appeared to be differences in summer and fall diets of bears on Tensas and Deltic. During summer, Tensas bears fed more heavily on *Rubus*, whereas pokeberry and dogwood were more important to bears on Deltic (Table 2.2). During summer the major food items consumed by bears on Deltic ($H' = 0.66$) were qualitatively more diverse than foods consumed by bears on Tensas ($H' = 0.57$). During fall the main food items on Tensas were corn, acorns, and palmetto fruit, as these 3 foods comprised >70% of the volume found in scats. Bears on Deltic used a

Table 2.1. Percentage frequency of occurrence (freq) and percentage volume (vol) of items found in black bear scats in the Tensas River Basin in Northeast Louisiana, June 2002-August 2004.

	Spring ¹ <i>n</i> = 9		Summer ² <i>n</i> = 93		Fall ³ <i>n</i> = 113		Winter ⁴ <i>n</i> = 36	
	<u>freq</u>	<u>vol</u>	<u>freq</u>	<u>vol</u>	<u>freq</u>	<u>vol</u>	<u>freq</u>	<u>vol</u>
Plants								
<u>Agricultural</u>								
Corn (<i>Zea mays</i>)	0	0	73.1	33.3	50.0	30.6	2.8	2.8
Wheat (<i>Triticum aestivum</i>)	11.1	10.5	0	0	1.8	0.3	0	0
Oats (<i>Avena sativa</i>)	11.1	10.5	3.2	1.7	0	0	0	0
Soybeans (<i>Glycine max</i>)	0	0	0	0	0.9	<0.1	0	0
Milo (<i>Sorghum bicolor</i>)	0	0	0	0	0.9	<0.1	2.8	2.8
Other sorghum (<i>Sorghum</i> spp.)	0	0	2.1	0.6	0	0	0	0
Peanut (<i>Arachis hypogaea</i>)	0	0	0	0	0.9	0.8	0	0
<u>Tree fruit</u>								
Acorn (<i>Quercus</i> spp.)	11.1	1.7	15.1	3.0	50.4	18.7	44.4	18.5
Water hickory (<i>Carya aquatica</i>)	0	0	3.2	0.3	0	0	0	0

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Persimmon (<i>Diospyros virginiana</i>)	0	0	0	0	9.7	2.0	0	0
Sweetgum (<i>Liquidambar styraciflua</i>)	0	0	2.1	0.1	0	0	0	0
Dogwood (<i>Cornus</i> spp.)	0	0	12.9	6.5	7.9	1.1	0	0
Tupelo (<i>Nyssa</i> spp.)	0	0	1.0	<0.1	3.5	0.7	0	0
Hackberry (<i>Celtis tenuifolia</i>)	0	0	0	0	2.7	0.2	0	0
Pawpaw (<i>Asimina triloba</i>)	0	0	0	0	<0.1	0.2	0	0
<u>Shrub/Vine fruit</u>								
Black- and dewberry (<i>Rubus</i> spp.)	55.6	32.6	21.5	13.6	0	0	0	0
Palmetto (<i>Sabal minor</i>)	0	0	<0.1	< 0.1	54.0	15.4	19.4	5.3
Beautyberry (<i>Callicarpa americana</i>)	0	0	4.3	0.2	34.5	6.8	8.3	0.5
Pokeberry (<i>Phytolacca americana</i>)	0	0	44.1	6.1	19.5	1.93	2.8	<0.1
Muscadine (<i>Vitis rotundifolia</i>)	0	0	19.4	5.4	14.2	4.3	0	0
Other grapes (<i>Vitis</i> spp.)	0	0	2.2	< 0.1	5.3	1.1	0	0
Peppervine (<i>Ampelopsis arborea</i>)	0	0	4.3	1.4	0.9	<0.1	0	0
Virginia creeper (<i>Parthenocissus quinquefolia</i>)	0	0	2.2	<0.1	5.3	1.2	0	0
Greenbrier (<i>Smilax</i> spp.)	0	0	0	0	0.9	<0.1	0	0
Devil's walking stick (<i>Aralia spinosa</i>)	0	0	0	0	1.8	0.1	2.8	0.8
Viburnum (<i>Viburnum</i> spp.)	0	0	0	0	0.9	<0.1	0	0
Privet (<i>Ligustrum</i> spp.)	0	0	0	0	0.9	<0.1	2.8	0.1

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Loquat (<i>Eriobotrya japonica</i>)	0	0	1.1	<0.1	0	0	0	0
Unknown seed	0	0	2.2	0.8	1.8	<0.1	8.3	0.2
<u>Other Plant</u>								
Grass or sedge (Poaceae or Cyperaceae)	33.3	23.0	8.6	4.1	4.4	2.2	41.7	33.6
Herbaceous vegetation	11.1	6.4	2.1	0.7	4.4	2.1	30.6	25.3
Woody vegetation	0	0	2.2	0.2	0	0	0	0
Cocklebur (<i>Xanthium</i> spp.)	0	0	0	0	0.9	<0.1	2.8	0.1
Animals								
<u>Invertebrates</u>								
Beetle (Coleoptera)	66.7	6.3	54.8	2.9	51.3	3.0	44.4	4.0
Wasp/Bee (Hymenoptera)	0	0	9.7	1.0	7.1	1.1	2.8	1.5
Ant (Formicidae)	22.2	2.0	1.1	0.8	1.8	0.5	0	0
Grasshopper (Acrididae)	0	0	4.3	1.5	3.5	0.2	0	0
Fly (Diptera)	0	0	0	0	0.9	<0.1	0	0
Pill bug (Isopoda)	0	0	0	0	2.7	0.2	0	0
Snail (Gastropoda)	0	0	1.1	<0.1	0	0	0	0
Insect gall	11.1	0.2	2.1	0.2	0	0	0	0
Tick (Acarina)	0	0	1.1	<0.1	0	0	0	0

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Crawfish (<i>Procambarus</i> spp.)	22.2	1.7	3.2	1.0	0	0	0	0
Mussel (Unionoida)	0	0	0	0	0	0	2.8	<0.1
<u>Vertebrates</u>								
White-tailed deer (<i>Odocoileus virginianus</i>)	0	0	11.8	6.4	6.2	2.3	0	0
Rabbit (<i>Sylvilagus</i> spp.)	0	0	4.3	2.1	0.9	0.1	2.8	2.5
Virginia opossum (<i>Didelphis virginiana</i>)	0	0	0	0	0	0	2.8	1.7
Raccoon (<i>Procyon lotor</i>)	0	0	0	0	0.9	<0.1	0	0
Fox squirrel (<i>Sciurus niger</i>)	0	0	1.1	0.1	0	0	0	0
Other rodents (Rodentia)	0	0	1.1	<0.1	0	0	0	0
Passeriformes	0	0	0	0	0.9	<0.1	0	0
Unknown mammal	22.2	1.1	4.3	1.3	8.8	0.7	0	0
Unknown vertebrate	0	0	6.5	0.8	2.7	0.1	0	0
Other								
Debris	11.1	3.9	8.6	3.8	10.6	1.9	2.8	0.3

¹Spring = April-May, ²Summer = June-August, ³Fall = September-November, ⁴Winter = February-March

Table 2.2. Percentage frequency of occurrence (freq) and percentage volume (vol) of items found in black bear scats during summer and fall in the Tensas and Deltic subpopulations of Tensas River Basin in Northeast Louisiana, June 2002-August 2004.

	Summer ¹				Fall ²			
	Tensas (n = 34)		Deltic (n = 59)		Tensas (n = 96)		Deltic (n = 17)	
	freq	vol	freq	vol	freq	vol	freq	vol
Corn	50.0	29.9	86.4	35.3	53.1	34.2	29.4	10.6
Acorn	8.8	6.1	18.6	1.2	57.2	20.9	11.7	6.1
Dogwood	0	0	34.2	10.2	2.0	0.3	41.1	5.5
Black- and dewberry	44.1	26.9	8.5	6.0	0	0	0	0
Palmetto	0	0	3.3	<0.1	57.2	16.2	35.3	10.7
Beautyberry	0	0	6.8	0.3	29.1	5.0	64.7	16.7
Pokeberry	2.9	0.3	67.8	9.3	11.4	0.5	64.7	9.8
Muscadine	11.8	7.3	23.7	4.4	8.3	1.9	47.1	17.6
Beetle	38.2	2.2	64.4	3.4	49.0	2.9	64.7	3.6
White-tailed deer	8.8	4.1	13.6	7.8	6.3	2.1	5.9	3.4

¹Summer = June-August, ²Fall = September-November

more varied diet and the major food items were muscadine, pokeberry, palmetto, corn, and American beautyberry (Table 2.2). During fall the major food items consumed by bears on Deltic ($H' = 0.86$) were qualitatively more diverse than foods consumed by bears on Tensas ($H' = 0.66$), and this difference was more pronounced than in summer.

DISCUSSION

Food habits of bears in the TRB appeared to be similar to those of bears across the geographic range, in that the diet was dominated by plant matter and shifted to exploit seasonally available food items (Landers et al. 1979, Hellgren and Vaughan 1988, Roof 1997, Bull et al. 2001). The early spring diet was dominated by grasses, sedges, and other herbaceous material, and bears switched to *Rubus* as berries became available during May. The use of herbaceous vegetation during early spring, followed by a diet of berries during late spring and early summer has been reported by most diet studies of bears in the southeastern United States (Landers et al. 1979, Maehr and Brady 1984, Hellgren and Vaughan 1988, Pelton 2000). I also found oats, wheat, and beetles to be important spring foods for bears, which was consistent with other studies in the TRB (Anderson 1997, Weaver 1999). During summer, *Rubus* remained a major food item and was dominant until corn became widely available in late June. Pokeberry, muscadine, and white-tailed deer were also important and combined to account for 18% of the volume consumed during summer. During fall, corn remained the dominant food item, followed by acorns and palmetto fruit. Grasses, sedges, and herbaceous vegetation became important again during winter as high quality foods declined. The other consistent food items in winter scats were acorns, palmetto fruit, and beetles.

The dominance of corn in the summer and fall diet was reported previously for bears in the TRB (Anderson 1997, Weaver 1999), and use of this food has been reported in other black

bear populations inhabiting agricultural areas (Hellgren and Vaughan 1988, Maddrey 1995). During summer, bears in the TRB ate corn in agricultural fields as evidenced by frequent visual observations and telemetry locations of bears in and around cornfields. During fall, corn was available as waste left in fields and from feed stations established by hunters of white-tailed deer, and I observed bears eating corn from these sources on multiple occasions. White-tailed deer remains were only found in scats during summer and fall and their occurrence coincided with the fawning period and the deer hunting season. I suspect that bears were eating fawns opportunistically during summer and consuming deer during fall as carrion left by hunters, as has been suggested previously (Ozoga and Verme 1982, Hellgren and Vaughan 1988, Roof 1997).

Acorns are an important fall food for bears across the geographic range and are believed to play a pivotal role in black bear reproduction and for building sufficient fat reserves for winter dormancy (Bunnell and Tait 1981, Rogers 1987, Hellgren and Vaughan 1988, Powell et al. 1997, Pelton 2000). My results were similar to previous studies as acorns were among the most used foods during fall and winter. Palmetto fruit was another prevalent food item used by bears during these seasons, consistent with previous studies of diet in the TRB (Anderson 1997, Weaver 1999) and with reports of bears eating saw palmetto (*Serenoa repens*) in Florida (Maehr and Brady 1982, Maehr and Brady 1984, Roof 1997). As noted by Maehr and Brady (1982) in Florida, it is not clear whether the relatively extensive use of this food by bears in the TRB is due to selection of this food type or merely a result of its abundance on the landscape.

I found a relatively high proportion of animal matter in the diet compared with other scat analysis studies of southeastern black bears (Landers et al. 1979, Hellgren and Vaughan 1988). Studies that used stomach content analysis have generally found greater proportions of animal material in the diet of bears in this region (Landers et al. 1979, Maehr and Brady 1982, Maehr

and Brady 1984). In the TRB, Anderson (1997) found only 3% of the volume of scats from Deltic was animal material. Weaver (1999) found relatively high frequency (17%) of animal material in scats, chiefly beetles and deer, but did not present total percentage volume of animal remains in the scats. Much of the variation between my results and those of other studies could be due to annual variation in bear diets, lack of a systematic sampling design in scat collection of most studies (including the present study), and the relatively subjective nature of ocular assessments of percentage volume. However, there are at least 2 environmental factors that may cause bears in the TRB to exploit a greater proportion of animal foods. First, the high density of bears in the small habitat islands of Deltic may allow bears to locate fawns and carcasses more effectively. Second, the mild fall, winter, and spring temperatures of Louisiana may allow insects to survive the winter and thus remain available to bears throughout the year, as was suggested to occur in Florida (Maher and Brady 1984).

My results suggest that bears on Deltic ate a greater diversity of soft mast during summer and fall than bears on Tensas. I should point out that the sample sizes were unequal between study areas and that the number of fall scats analyzed for Deltic was small ($n = 17$). However, the fact that I found a more varied fall diet on Deltic, despite this small sample size, may suggest that it reflects actual differences in food habits, since one would expect a small sample size to reveal fewer food items than are actually being consumed. The observed dietary differences are also consistent with habitat variation between Tensas and Deltic, due to forest management strategies (see Chapter 1, Study Area). The frequent thinning of mature forests on Deltic creates openings in the canopy that have resulted in greater abundances and diversity of soft mast producing understory species in these forests relative to Tensas. This may explain why > 70% of the volume found in fall scats from Tensas was corn, acorns, and palmetto, whereas Deltic bears

ate a more balanced combination of muscadine, pokeberry, palmetto, corn, beautyberry, and acorns. These results should be confirmed with larger and less variable sample sizes between study areas, but if true, could partially explain differences in habitat use between females in the 2 subpopulations (see Chapter 4). Another striking difference was the greater use of *Rubus* by bears on Tensas during summer. Abundant patches of *Rubus* often grow in early successional stands (Litvaitis 2001), so the observed difference in the use of this food item may be due to the larger proportion of the Tensas study area that is comprised of early successional habitat (see Chapter 4).

CHAPTER 3. SEASONAL AND ANNUAL SPACE USE OF FEMALE BLACK BEARS IN TENSAS RIVER BASIN AND REINTRODUCED POPULATIONS

INTRODUCTION

Investigating space use of animals is useful for identifying factors that influence survival and reproduction (Burt 1943, Powell et al. 1997) and is therefore critical for management and conservation of endangered species. Home range size in black bears varies in relation to a number of factors including food resources (Rogers 1987, Powell et al. 1997), seasons (Pelton 2000), and habitat fragmentation and isolation (Maehr et al. 2003). Most studies have shown that black bears have relatively small home ranges during spring and that space use and movements increase in summer and fall in relation to food availability (Rogers 1987, Smith and Pelton 1990, Powell et al. 1997). Home ranges may be restricted in insular situations, including islands of land surrounded by water (Lindzey and Meslow 1977) and islands of forested habitat surrounded by matrices of unsuitable habitat (Anderson 1997, Maehr et al. 2003). For female bears another factor that potentially influences space use is reproductive status (i.e., whether or not the female has cubs of the year). Given the lack of mobility of black bear cubs in their first several months of life it has been suggested that female black bears with new born cubs may have smaller spring home ranges than females without cubs (Lindzey and Meslow 1977). Female brown bears (*Ursus arctos*) with cubs in Scandinavia had smaller annual home ranges than females without cubs (Dahle and Swenson 2003); however, although several researchers have investigated the effect of reproductive status of adult females on space use of black bears (Powell et al. 1997, Hirsch et al. 1999, Bartoskewitz 2001), no significant differences in home range size have been found.

Louisiana black bears in the TRB may be a good study system to examine the effects season and insularity on space use because of the food resources they utilize and landscape they

inhabit. Bears in the TRB use different food resources across seasons (Anderson 1997, Weaver 1999, see Chapter 2) and differences in location and dispersion of these foods could result in differences in seasonal home range sizes. For example, bears in the TRB feed heavily on corn from agricultural fields in the late summer and fall, and eat hard and soft mast during fall. Corn fields in agricultural habitats represent a highly concentrated and virtually limitless food supply, whereas hard and soft mast resources in forested habitats probably require more movement to exploit efficiently. Landscape differences between the Tensas (large, contiguous forest) and Deltaic (small, insular forests) subpopulations may also result in variation in home range sizes (Anderson 1997, Weaver 1999).

The effect of translocation on space use of black bears is unknown. Post-release movements of reintroduced bears are often large (Clark et al. 2002) but detailed studies of space use by reintroduced individuals are lacking. The winter soft release technique (see Chapter 1) appears to be effective at reducing post-release movements (Eastridge and Clark 2001), but except for a pilot study preceding the current project (Van Why 2003, $n = 3$ bears) home range sizes for bears released using this method have not been reported. Wear (2003) estimated home ranges of females reintroduced in Arkansas using the winter soft release technique for use in habitat use analyses, but did not report home range sizes. Therefore, estimating home ranges and investigating factors that effect the size of these estimates is important for monitoring and evaluation of reintroduction efforts. Assessing overlap in space use among reintroduced bears is also important to determine how spatial organization affects the potential carrying capacity of reintroduction sites.

I estimated home ranges and core areas for female black bears in the TRB and Lake Ophelia populations and investigated possible factors explaining variation in space use. Within

the TRB I tested the following hypotheses: (1) home ranges and core areas are smaller for females with cubs of the year than those without, (2) home ranges and core areas are smaller for females on Deltic than Tensas, (3) home ranges and core areas vary by season within study area. I also tested hypotheses 1 and 3 for reintroduced females at Lake Ophelia as well as the hypothesis that home range and core area sizes would be larger for reintroduced females than females on Deltic or Tensas. Finally, I investigated overlap in space use among bears on Tensas, Deltic, and Lake Ophelia to compare overlap between source and reintroduced populations.

METHODS

Sampling Design

Tensas River Basin

I selected 12 and 25 bears to track intensively during 2003 and 2004 respectively. I generally located bears in the TRB at least 3 times per week and always at least 12 times per month from early April to the third week of November. Not all of these bears were tracked from spring until the end of fall because of dropped collars ($n = 4$), bears that could not be located in the study area for periods of time ($n = 2$), and transmitter failure ($n = 1$). For bears with dropped or failed collars I did not estimate annual ranges and only estimated seasonal ranges for the seasons in which the bear was monitored for $\geq 67\%$ of the period. I did not estimate annual or seasonal ranges for bears that couldn't be located for periods of more than a few days because these home ranges were potentially biased. Seasonal ranges were estimated using 3 seasons during the non-denning period which relate to aspects of black bear ecology in the TRB: (1) spring (April-May), post-denning period with limited food availability, (2) summer (June-August), breeding season with agricultural food sources available, and (3) fall (September-November), pre-denning period characterized by hyperphagia. I used all locations that met the

telemetry and sampling protocol requirements (see Chapter 1) to estimate seasonal and annual ranges (Table 3.1). Although I generally used fewer locations to estimate spring ranges, these locations represent the same sampling intensity as summer and fall but over a shorter period of time (2 months instead of 3, Table 3.1).

Lake Ophelia

I monitored reintroduced bears intensively starting the day after release in mid- to late March and attempted to locate them at least once daily until mid -August of the same year. For all bears that stayed in the Lake Ophelia study area this was achieved with 2 exceptions in which I heard a signal but was unable to obtain a usable location. In both cases I returned early the next day and located the bear in the same general area. Therefore, I believe the home range estimates for spring and summer represent virtually unbiased documentation of space use by these females. During fall of the first year after release and for the entire monitoring period of the second year I located bears ≥ 3 times per week. I used the same seasons as described for TRB females to estimate seasonal ranges for reintroduced bears, except that spring ranges included locations from late March and fall ranges included ≤ 4 locations from December. I located bears more often during spring and summer of the first year to capture exploratory movements during this period (Table 3.1). All bears released at Lake Ophelia remained in the study area for at least 1 season except for 1 bear which abandoned her cubs. This bear subsequently established a range roughly 60 km to the northeast in July of 2003. I estimated home ranges and core areas for this bear in the new area for summer and fall 2003 and spring 2004 and these are the only ranges outside of the Lake Ophelia study area used in the home range analyses for reintroduced bears.

Table 3.1. Number of female bears (n) used for home range analyses and mean (\bar{X}), standard error (SE), and range for number of locations used to estimate seasonal and annual home range and core area estimates in TRB and Lake Ophelia populations.

	TRB				Lake Ophelia			
	n	<u>number of locations</u>			n	<u>number of locations</u>		
		\bar{X}	SE	range		\bar{X}	SE	range
Spring	28	32.5	2.3	22-56	11	65.2	6.2	70-88
Summer	27	46.4	3.4	28-81	9	71.1	7.2	33-103
Fall	24	33.1	0.3	28-36	8	32.2	1.0	29-37
Annual	24	113.5	6.2	87-171	8	162.6	14.3	78-224

Determination of Reproductive Status

Black bears give birth to cubs during January and early February (Pelton 2000), therefore I assessed reproductive status of females by visiting winter dens after 15 February and determining whether newborn cubs were present. This allowed me to compare space use of females with and without cubs during the subsequent monitoring year. I was generally unable to determine the exact litter size, thus reproductive status for this study reflects only whether ≥ 1 cub was known to be with the female. I describe den visit procedures in detail in Chapter 5. Two females lost their entire litters on unknown dates during the year. Both produced cubs the following winter and 1 was seen copulating with a male during July. For these bears I only used seasonal ranges in my analyses for which reproductive status was known with certainty. Cub survival was monitored using visuals obtained during radio tracking and trapping efforts, and by den visits the following winter. Since black bear cubs generally remain with their mother through their second winter (Lindzey and Meslow 1977), I was able to assess whether 1 or more cubs survived and remained with the mother during all seasons by visiting dens during the winter following the monitoring period and determining if yearlings were present.

Space Use Overlap

I assessed space use overlap for all females on Tensas, Deltic, and Lake Ophelia during 2004. The primary objective of this analysis was to determine if space use overlap was similar between females in the source and reintroduced populations. I did not investigate overlap in the TRB during 2003 because I did not monitor all adult females with radiocollars during this year, and I did not investigate overlap on Lake Ophelia during 2003 because only 3 females remained on the study area past May. I estimated overlap in seasonal home ranges and core areas by intersecting ranges of females that exhibited some overlap and determining the area of overlap

using Arcview. I then superimposed telemetry locations of each female on the overlap region and counted the number falling within this region. I divided the number of locations falling within this region by the total number of locations for that female to derive a proportion of each individual's locations within the overlap region (Chamberlain and Leopold 2000). I averaged these estimates to provide mean home range overlap estimates. For mean core area estimates, I included all females with some degree of home range overlap, thus bears displaying home range but not core area overlap received a 0 for core area overlap. I also calculated the percentage of radiocollared females on each study area that exhibited some home range overlap, and the percentage of possible dyads (all 2-female combinations with overlapping home ranges) that also had overlapping core areas. I did not assess space use overlap for reintroduced females during spring because space use overlap may have been influenced by the selection of artificial den sites for newly released females.

Statistical Analyses

All statistical tests were done using SAS 9.0 (SAS Institute, Cary, North Carolina, USA). I used non-parametric tests for all home range analyses because after separating bears by study area and reproductive status, sample sizes were small (≤ 20 bears per category). I used 2-sample Wilcoxon rank-sum tests to compare seasonal and annual home range and core area estimates between bears with and without cubs of the year within each study area. I compared seasonal home ranges within and across study areas using Kruskal Wallis (when $k > 2$) and Wilcoxon (when $k = 2$) tests. When overall differences were detected using Kruskal Wallis tests I used Wilcoxon tests for specific pairwise comparisons of interest. Statistical tests were considered significant when $P \leq 0.05$ and marginally significant when $0.10 < P > 0.05$. P values are presented for the reader's interpretation.

RESULTS

Tensas River Basin

Space Use in Relation to Reproductive Status

Females with cubs of the year had smaller spring ranges than females without cubs on Tensas (home range: $U = 51$, $n_1 = 8$, $n_2 = 12$, $P < 0.010$; core area: $U = 52$, $n_1 = 8$, $n_2 = 12$, $P = 0.012$, Table 3.2, Figure 3.1). This difference was not detected for spring home ranges on Deltic ($U = 33$, $n_1 = 6$, $n_2 = 8$, $P = 0.142$, Table 3. 2) and was marginal for core areas ($U = 31$, $n_1 = 6$, $n_2 = 8$, $P = 0.081$). Other mean seasonal home ranges and core areas did not differ by reproductive condition (all $P \geq 0.161$, Table 3.2). Therefore, in subsequent seasonal analyses all females were pooled for summer, fall, and annual estimates, whereas spring estimates were separated by reproductive condition.

Seasonal Space Use Across Subpopulations

Home ranges and core areas were larger on Tensas than on Deltic for females during spring without cubs, summer, fall, and annually (Home range: all $P \leq 0.032$, Core area: all $P \leq 0.047$, Tables 3.3 and 3.4). During spring, I did not detect differences between Tensas and Deltic females with cubs for home range ($U = 34$, $n_1 = 9$, $n_2 = 6$, $P = 0.116$, Table 3.3) or core area size ($U = 41$, $n_1 = 9$, $n_2 = 6$, $P = 0.456$, Table 3.4).

Seasonal Space Use Within Subpopulations

Within both Tensas and Deltic, I ran 2 separate tests to compare ranges across seasons, 1 using spring ranges for females without cubs and 1 using spring ranges for females with cubs. For Deltic, space use did not differ among seasons when I compared spring ranges of females without cubs with all other seasons (home range: $H_3 = 6.62$, $P = 0.306$; core area: $H_3 = 1.84$, $P = 0.606$), but when females with cubs were compared with all other seasons there were differences

Table 3.2. Mean (km²) seasonal and annual 95% home ranges (Hr) and 50% core areas (Ca) for female black bears in the Tensas River Basin subpopulations of Tensas and Deltic for females of differing reproductive status.

	Season							
	Spring		Summer		Fall		Annual	
	Cubs	No cubs	Cubs	No cubs	Cubs	No cubs	Cubs	No cubs
Tensas								
Hr	2.59**	7.46**	7.65	9.60	13.17	11.59	11.27	12.91
Ca	0.29**	1.65**	0.98	1.14	2.0	1.61	1.54	1.39
<i>n</i>	8	12	8	11	7	10	7	10
Deltic								
Hr	1.52	2.86	3.18	3.54	4.67	4.34	2.98	4.05
Ca	0.25*	0.48*	0.50	0.52	0.69	0.75	0.54	0.57
<i>n</i>	6	8	6	8	4	7	4	7

**indicates difference at $P \leq 0.05$, *indicates difference at $P < 0.10$

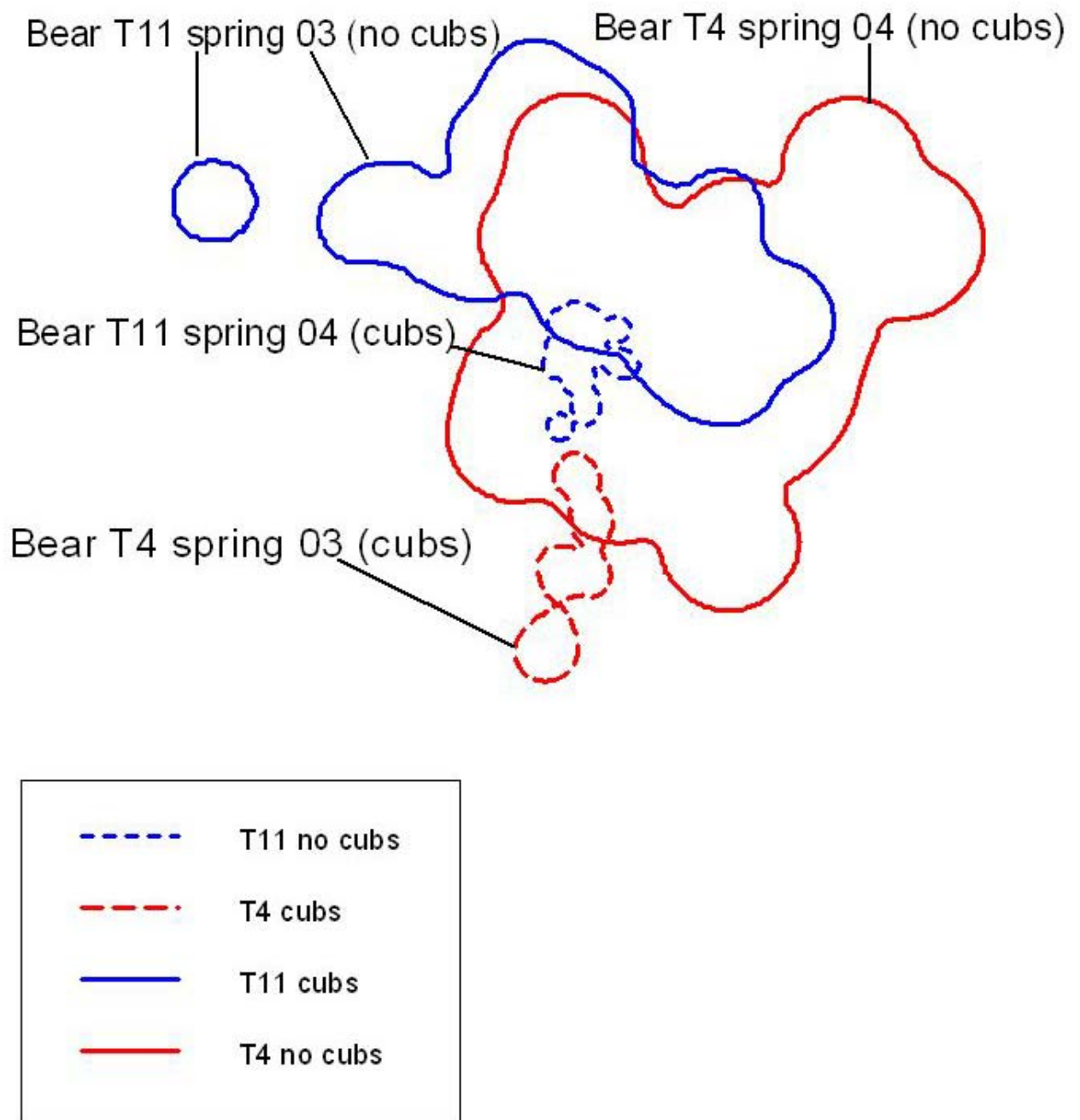


Figure 3.1. Spring 95% home ranges of Bears T4 and T11 with and without cubs in Tensas subpopulation in Tensas River Basin, Louisiana, 2003-2004.

Table 3.3. Seasonal and annual 95% fixed kernel mean (\bar{X}) home range estimates (km²) for Tensas and Deltic subpopulations, showing standard errors (SE), number of home ranges (n), and P values from pairwise tests in the Tensas River Basin, Louisiana during 2003-2004.

	Tensas			Deltic			P
	\bar{X}	SE	n	\bar{X}	SE	n	
Spring (cubs)	2.59	0.54	8	1.52	0.52	6	0.181
Spring (no cubs)	7.46	2.15	12	2.86	0.58	8	0.031
Summer	8.53	1.36	20	3.45	0.52	13	0.002
Fall	12.23	2.1	17	4.46	0.67	11	0.006
Annual	12.06	2.13	17	3.66	0.56	11	<0.0001

Table 3.4. Seasonal and annual 50% fixed kernel mean (\bar{X}) core area estimates (km²) for Tensas and Deltic subpopulations, showing standard errors (SE), number of core areas (n), and P -values for pairwise tests in the Tensas River Basin, Louisiana during 2003-2004.

	Tensas			Deltic			P
	\bar{X}	SE	n	\bar{X}	SE	n	
Spring (cubs)	0.29	0.06	8	0.25	0.09	6	0.662
Spring (no cubs)	1.65	0.52	12	0.48	0.11	8	0.047
Summer	1.04	0.15	20	0.54	0.08	13	0.052
Fall	1.82	0.33	17	0.73	0.16	11	0.019
Annual	1.44	0.35	17	0.56	0.12	11	0.006

(home range: $H_3 = 10.21$, $P = 0.017$; core area: $H_3 = 7.27$, $P = 0.064$). Spring Deltic home ranges and core areas for females with cubs were smaller than summer, fall, and annual ranges (home range: all $P < 0.022$, core area: all $P < 0.062$). For Tensas, there were marginal differences across seasons when spring ranges of females without cubs were compared with other seasons for home range ($H_3 = 6.58$, $P = 0.087$) but not core area ($H_3 = 2.98$, $P = 0.40$). Spring Tensas home ranges for females without cubs were smaller than annual ranges ($U = 122$, $n_1 = 12$, $n_2 = 17$, $P = 0.009$) and marginally smaller than fall ranges ($U = 142$, $n_1 = 12$, $n_2 = 17$, $P = 0.097$), but all other pairwise comparisons were not significant (all $P > 0.133$). When range sizes of females with cubs were compared with other seasons there were differences (home range: $H_3 = 15.98$, $P = 0.001$; core area: $H_3 = 15.33$, $P = 0.002$) as spring ranges for females with cubs differed from all other seasonal and annual estimates (home range: all $P < 0.002$, core area: all $P < 0.003$).

Lake Ophelia

Space Use in Relation to Reproductive Status

Females with cubs had smaller ranges during spring than females without cubs and the difference was marginally significant for home ranges (home range: $U = 44$, $n_1 = 10$, $n_2 = 4$, $P = 0.054$) but not core areas ($U = 29$, $n_1 = 10$, $n_2 = 4$, $P = 0.240$). Home range and core areas for other seasons did not differ between females with and without cubs (all $P > 0.28$).

Seasonal Space Use

I limited the Lake Ophelia analysis across seasons to females in the first year after release (all of which had cubs) because I only estimated ranges for 4 bears in their second year. Ranges for females with cubs in their first year after release differed by season for home range ($H_3 = 11.52$, $P = 0.009$) and core area ($H_3 = 16.26$, $P = 0.003$). Ranges during spring differed from all

other seasonal and annual means (home range: all $P < 0.009$, core area: all $P < 0.02$), whereas there were no differences among other seasons (all $P > 0.15$).

Space Use of Reintroduced vs. Source Populations

Home ranges and cores areas for females with cubs did not differ between Lake Ophelia and either Deltic or Tensas during spring (all $P > 0.18$, Table 3.5). All other seasonal home ranges on Lake Ophelia were larger than Deltic (all $P < 0.008$, Table 3.5) and larger or marginally larger than Tensas (all $P < 0.078$, Table 3.5). All Lake Ophelia seasonal mean core areas were larger or marginally larger than Tensas and Deltic (all $P < 0.073$), except annual core areas at Tensas ($P = 0.10$, Table 3.5).

Space Use Overlap

On Deltic, >87% of radiocollared females exhibited at least some amount of overlap with ≥ 1 radiocollared female during spring, summer, and fall 2004. On Tensas, >76% of radiocollared females exhibited some amount of overlap with ≥ 1 female during all seasons of 2004. Of the dyads with overlapping home ranges on Deltic, 30.7%, 30.0%, and 22.2% also exhibited core area overlap during spring, summer, and fall 2004 respectively. On Tensas, 30.0%, 41.3%, and 50% of dyads with overlapping home ranges also exhibited core area overlap during spring, summer, and fall 2004 respectively.

On Lake Ophelia 100% of females exhibited some overlap in home range with another radiocollared female during summer and fall 2004. Of dyads that exhibited home range overlap 25% and 14.7% also exhibited core area overlap during summer and fall 2004 respectively. Mean home range and core area overlap estimates for bears in TRB and Lake Ophelia are given in Table 3.6.

Table 3.5. Seasonal and Annual 95% fixed kernel home range estimates in km² for females reintroduced to Lake Ophelia during 2003-2004, showing means (\bar{X}), standard errors (SE), number of ranges (n), and the P values from pairwise comparisons with mean home ranges and core areas in the TRB source subpopulations of Tensas and Deltic.

	Home Range		Core Area		n	P vs. Tensas		P vs.Deltic	
	\bar{X}	SE	\bar{X}	SE		Hr	Ca	Hr	Ca
Spring (cubs)	5.09	1.8	0.74	0.29	10	0.633	0.573	0.180	0.428
Spring (no cubs)	13.73	5.47	1.09	0.25	4	0.078	1.000	0.008	0.073
Summer	21.3	6.15	2.95	0.69	12	0.019	0.008	<0.001	<0.001
Fall	27.29	8.23	5.23	1.66	11	0.033	0.051	<0.001	0.001
Annual	18.47	2.45	1.89	0.33	11	0.053	0.100	<0.001	<0.001

Table 3.6. Space use overlap (%) of home ranges and core areas of female black bears on Deltic, Tensas, and Lake Ophelia showing number of dyads exhibiting home range overlap (n), mean overlap (\bar{X}), standard error (SE), and range of individual overlap percentages during spring, summer, and fall 2004 in Louisiana.

	Home Range Overlap											
	Spring				Summer				Fall			
	n	\bar{X}	SE	range	n	\bar{X}	SE	range	n	\bar{X}	SE	range
Deltic	26	27.6	4.2	0-82.6	36	28.4	5.3	0-95.4	18	38.6	7.1	0-90.9
Tensas	48	36.3	4.2	0-95.8	46	51.5	4.4	0.2-92.8	40	43.4	4.5	0-88.2
Lake Ophelia	-	-	-	-	32	32.3	4.6	0-89.1	34	38.9	5.4	0-50.0

	Core Area Overlap											
	Spring				Summer				Fall			
	n	\bar{X}	SE	range	n	\bar{X}	SE	range	n	\bar{X}	SE	range
Deltic	26	1.0	4.2	0-35.7	36	10.9	4.5	0-87.5	18	9.8	5.2	0-83.3
Tensas	48	9.6	3.3	0-88.8	46	14.6	3.4	0-75.0	40	12.9	3.1	0-28.6
Lake Ophelia	-	-	-	-	32	11.0	4.6	0-97.2	34	3.4	1.7	0-50.0

DISCUSSION

Tensas River Basin

Several previous authors have suggested that female black bears with newborn cubs may use different home range sizes than females without cubs due to metabolic factors related to lactation or a mobility constraint imposed by young cubs (Lindzey and Meslow 1977, Powell et al. 1997, Bartoskewitz 2001); however, such a difference has not been documented. Hirsch et al. (1999) showed that females with cubs in Michigan exhibited smaller daily movements than females without, but did not report a difference in home range size. Powell et al. (1997) also found that females with cubs in North Carolina made smaller daily movements but found no difference in female home range size between females of differing reproductive status. Bartoskewitz (2001) found differences in habitat use, but not home range size between females with and without cubs in Mexico. I found that Tensas females without cubs had larger spring home ranges and core areas than females with new born cubs, but that there was no difference in home range and core area sizes for other seasonal or annual estimates. This suggests that females with cubs restrict the size of their space use during spring due to the immobility of young cubs and that this restriction does not extend past spring. The reduced movements during spring could also represent a strategy by females to maximize survival of offspring during the first few months of life. Black bear foods are often scarce during early spring and it may be beneficial to reduce movements during this period for females with cubs in order to conserve remaining energy reserves for lactation. Reducing movements would also allow cubs to use energy for growth and development rather than movement. By early summer when the cubs are larger and more mobile and abundant food sources (i.e. *Rubus* spp.) become available, the combination of these factors probably allows females with cubs to begin using similar sized

home ranges as females without cubs. Dahle and Swenson (2003) found that annual home ranges of female brown bears with cubs were smaller than those without cubs and speculated that the difference in home range size was probably strongest in spring and should disappear by fall when cubs are larger. Lindzey and Meslow (1977) suggested that female black bear movements may be restricted by cubs for up to 4 months after leaving winter dens. My results support these contentions but indicate that for black bears in the TRB the restricted space use does not continue beyond spring. I did not detect a similar difference in spring home ranges at Deltic and only a marginal difference for core areas.

My results comparing space use of Tensas and Deltic are mostly consistent with previous research which showed home ranges to be larger at Tensas (Weaver 1999). However, separating spring ranges by reproductive status may provide new insight into this relationship because spring ranges for females with cubs did not differ significantly between the two areas. It should be noted that sample size for this comparison was small, but this result could suggest that restrictions placed on females with newborn cubs during spring are more important than differences between the study areas, which influenced spring space use of females without cubs and in other seasons.

Tensas is a relatively large area of contiguous forested habitat, whereas bears inhabiting Deltic are largely confined to 2 habitat “islands” $< 7 \text{ km}^2$ each, surrounded by a matrix of agricultural lands. This limited habitat may mean that space use is necessarily restricted for Deltic bears, although differences in population density, food availability, and other factors between the two subpopulations also probably influence space use. Previous studies have found home range size of mammals to be negatively correlated with population density (Dahle and Swenson 2003; Kjellander et al. 2004). The Deltic tracts appear to be high quality habitat and

bears exist at high density in this subpopulation despite low overall abundance (Anderson 1997, Beausoleil 1999). Previous studies have estimated density at Deltic to be 1.43 bears/km² (Beausoleil 1999) compared with 0.36 bears/ km² on Tensas (Boersen et al. 2003). An inverse relationship between food availability and home range size has been reported for a variety of mammals (Taitt and Krebs 1981, Mares et al. 1982, Litvaitis et al. 1986) including black bears (Powell et al. 1997). Food availability may be greater on Deltic due to the close proximity of abundant agricultural food sources and forest management practices which have promoted hard and soft mast production (see Chapter 1, Study Area). Abundant food resources may allow individuals to survive and reproduce using smaller home ranges and for the subpopulation to remain at high density. However, reduced home ranges of bears on Deltic could also suggest that habitat saturation has occurred and this could result in fitness consequences for individuals and limit numerical growth of the subpopulation. Cub survival and recruitment rates are unknown for bears in the TRB, but limitation of available habitat and frustrated dispersal on Deltic could negatively affect recruitment and prevent numerical growth as has been suggested for other small, isolated populations of large carnivores (Maehr 1997). However, more research is necessary to adequately assess relationships among habitat limitation, space use, and reproductive success of females at Deltic.

My findings regarding variation in seasonal space use within subpopulations are mostly consistent with previous studies of black bears across North America (Lindzey and Meslow 1977, Powell et al. 1997, Pelton 2003), but are again more informative due to the separation of females by reproductive status. I found that spring home ranges of females with cubs were smaller than summer, fall, and annual home ranges for females throughout the TRB, whereas spring ranges of females without cubs did not differ from other seasonal ranges. Other studies,

which have not separated females by reproductive status, have mostly found spring home ranges to be smaller than other seasonal estimates and concluded that the differences were due to changes in food resources and mating activities among seasons (e.g., Rogers 1987, Smith and Pelton 1990, Powell et al. 1997). In the TRB, such differences appear to be less important than the influence of cubs of the year during spring. My results underscore the importance of considering reproductive status when investigating differences in seasonal home ranges of female black bears.

Lake Ophelia

Space use varied considerably among individuals and given the low sample size ($n \leq 10$) results should be interpreted cautiously. This variation ranged from extensive, directional movements > 80 km by 1 female (see Chapter 1, Table 1.3), to establishment of home ranges and core areas smaller than some observed in the source population. However, some important trends were observed and may suggest ways in which behavior of reintroduced females is similar and different from source females.

I detected a marginal difference in the size of spring home ranges between females of differing reproductive status at Lake Ophelia, similar to the observed difference at Tensas. This is particularly interesting because all bears with cubs at Lake Ophelia used in the analysis were bears in their first year after release and the spring home ranges represent their space use in the first few months. These were compared to bears without cubs which were in their second spring after release. It is reasonable to predict that first year bears (even with cubs) might use larger ranges due to exploratory movements and unfamiliarity with surroundings compared with second year bears (without cubs) that had been in the area for a year and were presumably relatively acclimated. Instead, newly released bears with cubs used smaller home ranges than second year

bears without cubs, which emphasizes that home range size during spring is strongly influenced by the presence of newborn cubs and that this is apparently more important than familiarity of surroundings in terms of modifying space use. This contention is further supported by the fact that the only reintroduced bear to make extensive movements away from the study area during spring was the female that abandoned its cubs. My results provide further support for the effectiveness of reintroducing female bears with newborn cubs during winter in terms of limiting movements away from the release site.

To avoid the added complexity of pooling bears in their first and second years after release and because of the small number of second year bears monitored, I limited the analysis of seasonal space use variation within Lake Ophelia to females in their first year of release (all of which had cubs). For these bears spring ranges were smaller than other seasonal ranges which did not differ from one another. Again, the constraint of raising cubs appeared to prevent females from using large ranges, even in unfamiliar habitat. With the onset of early summer this constraint was apparently lifted as many of the reintroduced bears generally began using larger home ranges than those documented in the source population.

All of the mean seasonal home range and core areas for reintroduced females were larger than means for females in either Tensas or Deltic with the exception of females with cubs during spring. Differences in home range size between Lake Ophelia and Deltic may be due to both a “reintroduction effect” of bears released into unfamiliar habitat and the restricted size of home ranges at Deltic, possibly due to habitat limitation, food availability, or density as discussed above. Therefore, comparisons between Lake Ophelia and Tensas may be more valid in terms of detecting the magnitude of the reintroduction effect on home range size given that they are both relatively large, contiguous areas of forested habitat. I expected that reintroduced bears would

use larger home ranges than those in both source subpopulations, but it is promising for the establishment of a population in the RRC that mean home range sizes at Lake Ophelia followed similar trends to those in the TRB with respect to seasonal variation and effects of reproductive status.

Space Use Overlap

Home range overlap among female black bears has been documented in many black bear populations across the United States (Amstrup and Beecham 1976, Lindzey and Meslow 1977, Garshelis and Pelton 1981, Smith and Pelton 1990). Space use overlap among reintroduced females appeared to be similar to overlap observed in the TRB, although direct comparison of overlap among study areas is difficult because of differences in the number of bears monitored. Core area overlap may have been slightly lower on Lake Ophelia, especially during fall, but even during this season we documented core area overlap as high as 50%. Furthermore, I documented extremely high (>97%) core area overlap between certain reintroduced individuals during summer. Van Why (2003) studied space use of 3 reintroduced female Louisiana black bears in a different study area within the RRC during 2001-2002. Van Why (2003) reported overlap of annual home ranges between 2 bears, but minimal (< 3.0 %) annual core area overlap for each individual. I found extensive overlap among reintroduced females for home ranges, and core area overlap as high as 97.2%. I suggest that the difference in the number of bears monitored likely explains the discrepancy in our findings.

Reintroduced females overlapped in time as well as space as I often located females in close proximity for consecutive days and weeks. From 28 May to 18 June 2004, bears D8 and T21 were located within approximately 300m of each other and often closer in the same 0.5 km² area during 22 daily, simultaneous locations. The only exception during this period was on 8

June when D8 was located approximately 1 km to the northwest of this area. Likewise bears D2 and D17 were generally <500m from one another during July 2004 based on daily, simultaneous locations. I suspect that highly concentrated food sources were the cause of these observations as D8 and T21 were using a regenerating stand with abundant blackberries (personal observation) and D2 and D17 were using a milo (cereal grain eaten by bears in Louisiana) field and adjacent forested stand during the periods that they were in close proximity. Previous studies have found that black bears tolerate close proximity of conspecifics (Young and Ruff 1982, Rogers 1987) and share portions of core areas (Samson and Huot 2001) around highly concentrated food sources. Tolerance of spatial overlap among reintroduced bears has important implications for current and future bear reintroduction because it suggests release sites will allow for a greater capacity of adult females than if exclusive home ranges and core areas were observed. It may also be important because if males are to be attracted to the reintroduction areas, then higher densities of females with overlapping home ranges should be more effective in attracting males and allowing them to breed with a maximum number of females. However, differences in abundance and dispersion of resources, genetic relatedness, and other factors can influence social organization of carnivores (Macdonald 1983, Packer et al. 1991) so this apparent tolerance of intrasexual overlap should be verified in different study areas.

CHAPTER 4. HABITAT SELECTION OF ADULT FEMALE BLACK BEARS IN THE TENSAS RIVER BASIN AND REINTRODUCED POPULATIONS

INTRODUCTION

Studies of habitat selection patterns of animals are important to identify areas and resources that contribute to the fitness of individuals and viability of populations (Fretwell and Lucas 1970, Powell et al. 1997). Habitat use of black bears has been studied across their geographic range and a great deal of variation exists in the specific habitats that are selected and avoided by individuals in different populations (Hellgren et al. 1991, Vander Heyden and Meslow 1999, Pelton 2000, Lyons et al. 2002). Several researchers have studied habitat use of black bears in bottomland hardwood forests of the southeastern United States (Jones and Pelton 1993, White 1996, Maehr et al. 2003), but habitat relationships of bears in these forests in Louisiana are not well understood. The need for studies of habitat use by Louisiana black bears is especially critical due to the lack of detailed information regarding their habitat relationships and because of their status as a federally threatened subspecies. Information regarding habitat use by this subspecies in existing and reintroduced populations will aid conservation efforts by identifying important habitats to protect and restore, as well as identifying areas of unoccupied habitat that may be effective release sites for ongoing reintroduction efforts.

Much of the variation in habitat use of bears across North America is probably attributable to differences in habitat types, climate, food availability, topography, and other differences across geographic areas. Human-induced changes to the landscape such as forest management and clearing of land for agriculture or development, also may affect habitat use of bears (Hellgren and Maehr 1992, Mitchell and Powell 2003). Forest fragmentation appears to have negatively affected the maintenance of viable populations of black bears in the southeastern

United States (Hellgren and Maehr 1992, Hellgren and Vaughan 1994, Rudis and Tansey 1995). However, little is known about the effect of fragmentation on habitat use by black bears in highly fragmented areas where populations still persist. Therefore, comparative studies in areas with relatively high and low degrees of habitat fragmentation in close proximity, preferably within a single population of bears, are needed to properly assess the effects of fragmentation on habitat use of this species.

Landscape differences between Tensas and Deltic make the TRB an effective study population to examine habitat relationships of Louisiana black bears and to assess the effects of forest fragmentation on habitat use by black bears. At the landscape level, Deltic is unique because the subpopulation exists at the highest population density reported for black bears (Beauosoeil 1999) despite the fact that forested habitats make up <40% of available habitat and most bears exist in 2 isolated woodlots that are <7 km² each. The Tensas subpopulation appears to be larger in size but lower in density (Beauosoeil 1999, Weaver 1999, Boersen et al. 2003) and bears inhabit a relatively large (>300 km²), contiguous tract of bottomland hardwoods. In addition to the obvious landscape-scale differences between Tensas and Deltic, differences in forest management practices, topography, and hydrology have resulted in stand-level differences in forested habitats that also may have implications for black bears (see Chapter 1, Study Area). The close proximity of the 2 study areas provided an excellent opportunity to investigate differences in habitat use in relation to fragmentation and landscape variation under otherwise similar environmental conditions. I studied habitat use by female Louisiana black bears with 2 main objectives: (1) Describe seasonal habitat use patterns for females in the TRB and reintroduced population; (2) Evaluate the effects landscape-scale fragmentation and stand-level habitat differences between Tensas and Deltic on seasonal habitat use of females. To accomplish

these objectives I quantified habitat use and availability at 2 spatial scales for females on Tensas, Deltic, and Lake Ophelia during non-denning months (April-November) in 2003-2004.

METHODS

Habitat Classification

I developed a Geographic Information System (GIS) for each of the 3 study areas using Digital Ortho Quarter Quadrangle (DOQQ) aerial photographs. I delineated the study areas into 8 habitat types: upland forest, lowland forest, swamp, water, agriculture, regenerating forest, corridor, and other (Table 4.1). I used aerial photographs, ground surveys, and landowner consultations to classify habitat types throughout each study area and digitized each habitat patch using Arcview 3.3. Individual study areas differed slightly by year as some habitat patches were converted from one habitat type to another (e.g., upland to regenerating forest after a clearcut) and thus I developed year-specific habitat maps for use with annual black bear data. The extent of each GIS was determined by determining the area necessary to encompass the home ranges of all females monitored in each study area.

Almost 80% of both study areas in the TRB were composed of upland bottomland hardwood and agricultural habitats, but despite the close proximity of Tensas and Deltic (≈ 9 km), important landscape differences existed (Table 4.2). The most prevalent habitat types on Tensas were upland bottomland hardwoods (47.6%) and agriculture (26.8%, Table 4.2). However, Deltic was overwhelmingly dominated by agriculture (58.7%), with upland bottomland hardwoods making up a much smaller proportion of available habitat (19.6%, Table 4.2). These differences in the proportion of forested and agricultural habitats between 2 subpopulations in close proximity allowed me to investigate potential variation in black bear habitat use due to

Table 4.1. Descriptions of 8 habitat types used to investigate habitat selection of female Louisiana black bears in the Tensas River Basin population in northeast Louisiana and Lake Ophelia in central Louisiana, 2003-2004.

Upland forest	Bottomland hardwood forests in relatively high elevation sites not subject to frequent or lengthy flooding.
Lowland forest	Bottomland hardwood forests in relatively low elevation sites subject to seasonal or annual flooding.
Swamp	Forested areas generally flooded throughout the year. Dominant vegetation includes baldcypress, tupelo, willow, and other flood tolerant taxa.
Water	Bodies of water including lakes, rivers, bayous, sloughs, and ditches.
Agriculture	Areas devoid of forest used for crop production. Common crops grown include corn, soybeans, cotton, wheat, and rice.
Regenerating forests	Early successional (0-12 years) forests planted with trees or regenerating naturally characterized by open canopy and dense understory of shrubs, vines, and/or saplings.
Corridor	Narrow (<250 m), linear forested patches in width which connect larger forested tracts. Often found along waterways or in agricultural areas.
Other	Open areas including pastures and food plots, human structures such as hunting camps and farm buildings, roads, parking areas, and other habitats.

Table 4.2. Summary of total area (km²) and composition (%) of 8 habitat types for Tensas, Deltic, and Lake Ophelia study areas in Louisiana during 2003-2004.

	Habitat															
	Upland		Lowland		Swamp		Water		Ag ^a		Regen ^b		Corridor		Other	
Study Area	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%
Tensas ^c	137.7	47.6	16.8	5.8	3.5	1.2	10.4	3.6	77.5	26.8	33.7	11.6	5.5	1.9	4.3	1.5
Deltic ^d	11.7	19.6	2.8	4.6	1.0	1.7	1.9	3.3	34.9	58.7	3.4	5.7	2.5	4.2	1.3	2.1
Lake Oph. ^{e,f}	47.2	27.5	16.5	9.6	10.5	6.2	21.5	12.5	26.0	15.1	38.5	22.4	1.6	0.9	9.7	5.6

^a Agriculture

^b Regenerating forest

^c Area and percentages of each habitat type remained constant during 2003-2004

^d Area and percentage of ag and regen differed slightly (<0.5km² and <1.0% for each habitat) between 2003-2004 and mean of 2 years is shown

^e Lake Ophelia

^f Area and percentage of upland, lowland, and regen differed slightly (<1km² and <0.5% for each habitat) between 2003-2004 and mean of 2 years is shown

fragmentation under otherwise similar environmental conditions.

Habitat Selection Analysis

I used a Euclidean distance-based approach to investigate seasonal habitat selection of black bears (Conner and Plowman 2001, Conner et al. 2003). I examined habitat selection at 2 spatial scales similar to Johnson's (1980) 2nd (selection of habitat for home range within the study area) and 3rd (selection of habitats within the home range) orders of selection. For 2nd order selection, I compared distances from random points in each individual home range with distances from random points throughout the study area to the nearest representative of each habitat type. For 3rd order selection, I compared distances from estimated bear locations with distances from random points generated throughout each home range to the nearest representative of each habitat type (Conner et al. 2003, Perkins and Conner 2004). A distance of 0 was used for the distance to habitats containing bear locations or random points. I generated large numbers of random points (approximately 1 random point/m²) from uniform distributions to ensure robust mean expected distances for the Tensas ($n = 290,000$), Deltic ($n = 60,000$), and Lake Ophelia ($n = 170,000$) study areas. The number of random points falling in each home range varied depending on size of home ranges (Tensas: $\bar{X} = 11,204$, $SE = 1473$; Deltic: $\bar{X} = 3289$, $SE = 320$; Lake Ophelia: $\bar{X} = 17,148$, $SE = 3647$). Distances from random points and bear locations to each habitat type were calculated using the X-Tools and Geoprocessing extensions in Arcview 3.3. For each bear in each season I created a vector of 8 distance ratios (1 ratio for each habitat type) for both scales of selection. For 2nd order selection, these ratios were the mean distance of random points in the home range divided by the mean distance of random points throughout the study area. For 3rd order selection, these ratios were the mean distance of bear locations divided by the mean distance of random points throughout the home range. For

reintroduced females, I did not investigate selection during spring because habitat use during their first spring of release (7 of 10 reintroduced spring ranges) was probably strongly influenced by my selection of their artificial den sites.

For 3rd order selection I generally included all locations used to estimate each bear's seasonal home range (TRB range: 22-811, Lake Ophelia range: 27-103, see Table 3.1, Chapter 3) for my analyses. However, bear locations that fell outside of the GIS were excluded from the analysis (TRB: total of 2 locations excluded from 2 bears, Lake Ophelia: total of 24 locations excluded from 5 bears). All bears included in the analyses were adult females known to have reproduced previously.

Statistical Analyses

I used multivariate analysis of variance (MANOVA) to test hypotheses that habitat selection did not differ from random in the 3 study areas. For the TRB, I used a hierarchical approach in which I combined data from Tensas and Deltic and investigated 2nd and 3rd order selection with subpopulation as a main effect to determine if females selected habitats differently on the 2 study areas. When significant results were found, I used separate MANOVA models for Tensas and Deltic to test for overall habitat selection within each season with reproductive status as a main effect. Because reproductive status affected space use during spring (see Chapter 3), I was interested to determine if similar influences existed for seasonal habitat selection. When significant reproductive status effects were detected I further partitioned data by this parameter. I did not include reproductive status as a main effect in Lake Ophelia analyses due to insufficient sample sizes of females without cubs.

If the mean of the 8 ratios differed from a vector of 1 (MANOVA was significant) I used univariate *t*-tests on each habitat type to determine which were selected and avoided. Distance

ratios significantly <1 indicate selection whereas ratios significantly >1 indicate avoidance (Conner and Plowman 2001, Conner et al. 2003). I ranked these habitats in order of preference based on the magnitude and direction of the t -statistics for these tests.

RESULTS

I used estimated bear locations and random points from 96 seasonal home ranges for 28 adult female black bears (16 Tensas, 12 Deltic) for the TRB habitat selection analyses. I used estimated bear locations and random points from 34 seasonal home ranges from 10 reintroduced female black bears to investigate habitat selection at Lake Ophelia.

Tensas River Basin

2nd Order Habitat Selection

When establishing seasonal home ranges Tensas and Deltic females used habitats differently (i.e., there was a significant subpopulation effect, $F_{8,88} = 15.68$, $P < 0.001$). Therefore, I partitioned data to examine seasonal habitat selection within each subpopulation. Tensas females exhibited nonrandom habitat use when establishing seasonal home ranges (Spring: $F_{8,12} = 30.39$, $P < 0.001$; Summer: $F_{8,11} = 4.62$, $P = 0.011$; Fall: $F_{8,9} = 6.89$, $P = 0.005$), but reproductive status did not affect 2nd order selection (Spring: $F_{8,12} = 1.10$, $P = 0.428$; Summer: $F_{8,11} = 0.60$, $P = 0.762$; Fall: $F_{8,9} = 1.26$, $P = 0.3681$). Tensas females selected swamp, lowland, and regenerating forests during spring (Table 4.3). During summer and fall they selected swamp, water, agriculture, regenerating forest, and corridor habitats (Table 4.3).

Deltic females also exhibited nonrandom habitat use when establishing seasonal home ranges (Spring: $F_{8,5} = 397.97$, $P < 0.001$; Summer: $F_{8,4} = 161.15$, $P < 0.001$; Fall: $F_{8,2} = 51.15$, $P = 0.019$), but reproductive status did not affect 2nd order selection during any season (Spring: $F_{8,5}$

Table 4.3. Matrix of habitats in Tensas subpopulation of TRB ranked in order of preference for female black bears based on t-tests between habitat type distance ratios of used and random locations for 2nd and 3rd order seasonal habitat selection in Northeast Louisiana, 2003-2004. Rankings were determined by relative magnitude of *t*-statistics.

	Habitats							
	Up	Low	Swp	Wat	Ag	Reg	Cor	Oth
2nd Order								
Spring	4	2** ⁺	1*** ⁺	5	7	3** ⁺	6	8
Summer	8	7	3** ⁺	2*** ⁺	5** ⁺	1*** ⁺	4** ⁺	6
Fall	8	7	4* ⁺	2** ⁺	5* ⁺	1*** ⁺	3** ⁺	6
3rd Order								
Spring ^a	7	8	2** ⁺	1** ⁺	5	4	6	3
Summer	2** ⁺	6	1** ⁺	3** ⁺	8	4* ⁺	5	7
Fall	2	5	6	4	8	1	3	7

* 0.10 < P < 0.05, ** 0.05 < P < 0.0001, *** P < 0.0001, ⁺ habitat selection, ⁻ habitat avoidance

^a3rd order spring habitat selection rankings are for females with cubs only, females without cubs did not select habitats during spring at this scale.

Up = upland forest, Low = lowland forest, Swp= swamp, Wat = water, Ag = agriculture, Reg = regenerating forest, Cor = corridor, Oth = other.

= 1.83, $P = 0.261$; Summer: $F_{8,4} = 0.11$, $P < 0.996$; Fall: $F_{8,2} = 1.07$, $P = 0.568$). When establishing home ranges, Deltic females selected upland and lowland forest and avoided agriculture and corridor habitats during all seasons (Table 4.4). During spring, Deltic females also selected regenerating forests (Table 4.4).

3rd Order Habitat Selection

Within home ranges Tensas and Deltic females used habitats differently (i.e., there was a significant subpopulation effect, $F_{8,88} = 3.74$, $P < 0.001$). Therefore, I partitioned data to investigate habitat use within each subpopulation. Tensas females exhibited nonrandom habitat use within their home ranges use during each season (Spring: $F_{8,12} = 2.97$, $P = 0.044$; Summer: $F_{8,11} = 2.85$, $P = 0.055$; Fall: $F_{8,9} = 4.09$, $P = 0.025$), and reproductive status affected 3rd order habitat selection only during spring (Spring: $F_{8,12} = 2.31$, $P < 0.093$; Summer: $F_{8,11} = 1.03$, $P = 0.466$; Fall: $F_{8,9} = 0.90$, $P = 0.555$). Therefore, I partitioned females with and without cubs to analyze spring habitat use patterns for Tensas. Females with cubs exhibited nonrandom habitat use during spring ($F_{8,1} = 272.13$, $P = 0.047$), whereas females without cubs did not ($F_{8,4} = 1.19$, $P = 0.462$, Table 4.3). Tensas females with cubs selected swamps and water during spring (Table 4.3). During summer, Tensas females selected swamps, water, regenerating and upland habitats (Table 4.3). Despite exhibiting non-random habitat use during fall, none of the 8 habitat types were significantly selected. This apparent contradiction is likely due to the higher power of the multivariate MANOVA used for the overall test in relation to the less powerful univariate t -tests used for testing individual habitats.

Deltic females exhibited nonrandom habitat use within their home ranges during each season (Spring: $F_{8,5} = 7.15$, $P < 0.022$; Summer: $F_{8,4} = 5.95$, $P = 0.051$; Fall: $F_{8,2} = 177.96$, $P = 0.006$), but reproductive status did not affect 3rd order selection during any season (Spring: $F_{8,5} =$

0.46, $P = 0.468$; Summer: $F_{8,4} = 0.39$, $P = 0.879$; Fall: $F_{8,2} = 0.57$, $P = 0.768$). During spring, Deltic females avoided other, corridor, and agriculture habitats within their home ranges (Table 4.4). During summer, Deltic females selected upland and lowland, but avoided regenerating forests (Table 4.4). During fall, Deltic females selected upland and lowland forests, but avoided agriculture habitats (Table 4.4).

Lake Ophelia

Reintroduced females exhibited nonrandom habitat use when establishing summer ($F_{8,3} = 68.04$, $P = 0.015$) and fall ($F_{8,2} = 35.22$, $P = 0.007$) home ranges. During both of these seasons females selected upland and lowland forests when random points in the home ranges were compared to those throughout the study area (Table 4.5). However, I did not detect nonrandom habitat use within the home ranges of reintroduced females during summer ($F_{8,3} = 2.63$, $P = 0.230$) or fall ($F_{8,2} = 1.35$, $P = 0.492$).

DISCUSSION

Tensas River Basin

The landscapes of Tensas and Deltic provide female black bears with the same suite of available habitat types, but vary greatly in terms of the area and proportional availability of these habitats. Tensas is dominated by a large ($>150 \text{ km}^2$) contiguous tract of bottomland hardwood forest with agricultural areas on the periphery. Deltic is dominated by vast expanses of agricultural fields, which surround 2 isolated bottomland hardwood tracts that contain $<15 \text{ km}^2$ of forested area combined. Another difference is the greater availability of early successional forests (i.e. regenerating forest habitat type) on Tensas (11.7%) compared with Deltic (5.7%). I observed significant variation in habitat selection patterns between the 2 subpopulations, indicating that bears exhibit plasticity in habitat selection when faced with different

Table 4.4. Matrix of habitats available to black bears in Deltic subpopulation of TRB ranked in order of preference based on t-tests between habitat type distance ratios of used and random locations for 2nd and 3rd order seasonal habitat selection in Northeast Louisiana, 2003-2004. Rankings were determined by relative magnitude of t-statistics.

	Habitats							
	Up	Low	Swp	Wat	Ag	Reg	Cor	Oth
2nd Order								
Spring	1*** ⁺	2** ⁺	4	6	8** ⁻	3* ⁺	7** ⁻	5
Summer	1*** ⁺	2*** ⁺	4	5	8** ⁻	3	7** ⁻	6
Fall	1*** ⁺	2*** ⁺	4	5	8** ⁻	3	7** ⁻	6
3rd Order								
Spring	3	1	2	4	6* ⁻	7** ⁻	5	8** ⁻
Summer	1*** ⁺	2** ⁺	5	3	7	8** ⁻	4	6
Fall	1*** ⁺	2* ⁺	4	3	8* ⁻	6	5	7

* 0.10 < P < 0.05, ** 0.05 < P < 0.0001, *** P < 0.0001, ⁺ habitat selection, ⁻ habitat avoidance
Up = upland forest, Low = lowland forest, Swp= swamp, Wat = water, Ag = agriculture, Reg = regenerating forest, Cor = corridor, Oth = other.

Table 4.5. Matrix of habitats from Lake Ophelia reintroduction area ranked in order of preference for reintroduced female black bears based on *t*-tests between habitat type distance ratios of used and random locations for 2nd order summer and fall habitat selection in central Louisiana, 2003-2004. Rankings were determined by relative magnitude of *t*-statistics.

	Habitats							
	Up	Low	Swp	Wat	Ag	Reg	Cor	Oth
Summer	1*** ⁺	2** ⁺	4	8	7	6	5	3
Fall	1*** ⁺	2** ⁺	3	7	8	4	5	6

* $0.10 < P < 0.05$, ** $0.05 < P < 0.0001$, *** $P < 0.0001$, ⁺ habitat selection, ⁻ habitat avoidance
Up = upland forest, Low = lowland forest, Swp= swamp, Wat = water, Ag = agriculture, Reg =
regenerating forest, Cor = corridor, Oth = other.

configurations of the same habitat types under otherwise similar environmental conditions.

Tensas females consistently selected swamps and regenerating forests across seasons and scale. Swamps in the TRB are mainly baldcypress-tupelo communities which contain tall, large-diameter baldcypress trees with hollow cavities. Cavities in baldcypress trees are the most common type of dens used by females in this population (58.8% of all dens, see Chapter 5) and are therefore a valuable resource. Tensas females selected swamps when establishing home ranges during all seasons, despite the fact that dens are only used by bears during winter and early spring. Parturition and early maternal care occur in winter dens and lack of adequate den sites can result in reproductive failure or cub mortality (Hamilton and Marchinton 1980, Alt 1984a, Weaver and Pelton 1994). Availability of secure den sites in seasonally flooded woodlands may be especially important due to the lack of safe ground dens (Oli et al. 1997). Given the importance of adequate den sites to the fitness of female bears, females on Tensas may maintain home ranges close to swamps year-round to ensure access to these resources when they become necessary. The strong selection of swamps within home ranges for females with cubs during spring is probably a reflection of their use of baldcypress trees as winter dens combined with reduced spring movements of parturient females (see Chapter 3). The selection of swamps within home ranges during summer could suggest that these habitats provide benefits for bears in addition to dens or it could simply mean that many females are still using areas relatively close to their former dens during early summer.

Regenerating forests were most likely selected because these habitats contain abundant soft mast resources, which represent important food items for bears across their geographic range (Rogers 1987, Boileau et al. 1994, Roof 1997, Stratman and Pelton 1999) and in the TRB (Weaver 1999, this study, Chapter 2). Females selected home ranges with regenerating forests

during all seasons and selected this habitat within their home ranges during summer. Soft-mast is eaten by bears in the TRB from late-spring through winter (see Chapter 3) and thus it makes sense for bears to maintain home ranges containing habitats where these resources are abundant. The selection of regenerating forests within home ranges during summer was probably due to the availability of *Rubus* spp. in these habitats during early summer. *Rubus* spp. dominates the diet of Tensas bears during early summer (see Chapter 2), as they are the first abundant food source after the limited food availability of winter and before corn becomes widely available later in summer.

Tensas females selected agricultural habitats when choosing summer and fall home ranges indicating that females shifted their home ranges closer to agricultural fields during summer and fall, presumably in order to exploit abundant food resources (i.e. corn). Most cornfields were harvested during late august in the TRB, but waste corn was often left in fields and I observed bears feeding on this food item during fall on several occasions. Studies of food habits of bears in the TRB have found summer and fall diets to be dominated by agricultural crops and particularly corn (Anderson 1997, Weaver 1999, this study, Chapter 2).

Deltic females exhibited different patterns of habitat selection which likely reflect landscape differences between the two study areas. When choosing home ranges, Deltic females selected upland and lowland forests and avoided agriculture and corridor habitats during all seasons. This is not surprising given that despite the overwhelming prevalence of agricultural habitat on Deltic, 11 of 12 Deltic females maintained home ranges that were centered in 1 of the 2 main forested tracts (Bluecat and Wade Bayou). Carr et al. (2002) found a similar pattern for Asiatic black bears (*Ursus thibetanus*) inhabiting an agriculturally fragmented landscape in Japan as bears selected home ranges in forested habitats in areas with relatively low proportions

of agricultural habitat. My findings underscore the importance of the remaining forested habitat of Deltic, where >60% of the landscape is devoid of trees. On Tensas, where upland and lowland forests are readily available and make up most of the landscape, these habitats were not selected during most seasons. Deltic females also selected upland and lowland forests within their home ranges (during summer and fall) and avoided agricultural habitats at this scale during spring and fall. Agriculture was not avoided during summer which is likely the result of the bears moving closer to agricultural fields to exploit food resources as they become available.

Two notable differences in selection patterns between females in the two subpopulations warrant further discussion. First, swamps were consistently selected by females at Tensas but not Deltic. Although both study areas were comprised of similar proportions of this habitat and females from both subpopulations use den trees located in swamps (see Chapter 5), swamps appear to be distributed more evenly on Tensas. The majority of swamp habitat (69.6%) on Deltic was located in 2 relatively large patches in Wade Bayou (see Appendix 2) and the clumped distribution of this habitat probably prohibited many Deltic bears from maintaining home ranges containing swamps or that were close to this habitat type. Indeed, females with home ranges in the Bluecat tract ($n = 5$) had little or no access to swamps, denned in other habitat types (J.F. Benson, unpublished data), and apparently selected habitats without regard for swamps. On Tensas, swamps are distributed more evenly throughout the study area which probably facilitated the year-round selection I observed (see Appendix 1).

Second, regenerating forests were selected during most seasons at both scales on Tensas, but were avoided within Deltic home ranges during spring and summer. I suggest this discrepancy is explained by differences in forest management practices and age classes of regenerating stands between Tensas and Deltic. Several researchers have suggested that bears

may not use early successional forests in areas where foods available in these habitats are also available in mature forests (Landers et al. 1979, Litvaitis 2001). Many soft-mast producing species in the TRB can be found in mature forests (i.e. upland and lowland habitat types) if sufficient sunlight is allowed to penetrate the forest canopy. Differences in current and past forest management practices between Tensas and Deltic, as well as topographical differences (see study area, Chapter 1), have resulted in greater abundances and diversity of understory plant species used by bears as food resources (e.g, pokeberry, muscadine, pawpaw) within the mature upland and lowland forests on Deltic relative to Tensas. These differences in resources are reflected in the diets of bears on Tensas and Deltic (see Chapter 2). This may explain why Deltic females selected upland and lowland forests during all seasons, but generally did not select regenerating forests. The lower abundance and diversity of understory species in mature forests on Tensas probably require bears to select regenerating forests to obtain these foods, which is consistent with our findings. Also, the regenerating forest habitat type used in our analyses was a relatively broad habitat category that contained regenerating forests of a variety of ages. Most (>80%) of the regenerating forest on Deltic was formerly agricultural habitat that was recently replanted to trees during the winters of 2002-2003 and thus it was still open and contained no trees besides saplings. Regenerating forests on Tensas were of a variety of ages (0-12 years) and included a >5 km² patch of regenerating habitat that was planted in 1991-1992. This patch was used extensively by 7 of 16 Tensas females and was an area of high female home range overlap, perhaps indicating high habitat suitability for female bears. Bears may prefer these older regenerating forests that provide greater structural cover (i.e. from small and medium sized-trees) to recently planted regenerating habitats that differ very little from open fields in terms of vertical vegetative structure.

In conclusion, I have documented different habitat selection patterns for females in 2 study areas in close proximity within the same population. I suggest these results are primarily due to differences in the availability of forested habitat, forest management practices, and the dispersion of swamp habitat patches between Tensas and Deltic. My results have implications for the conservation and restoration of this subspecies because they indicate flexibility in habitat selection behavior of bears within a single population. The ability to adapt behavior to efficiently exploit resources in different landscapes should improve the ability of bears to successfully establish populations after reintroduction. This adaptability has also probably contributed to the persistence of bears on Deltic despite limited forested habitat. However, long-term persistence of small populations of large carnivores in areas of severe habitat limitation is tenuous at best and current habitat restoration efforts (i.e. reforestation) should be continued to provide additional forested lands and potential habitat linkages among the Deltic tracts, and between Tensas and Deltic.

Lake Ophelia

Results from the habitat use analyses of reintroduced bears were limited, probably due mainly to the small sample size. The Lake Ophelia study area is comprised of 37.1% upland and lowland forest, meaning that the availability of mature bottomland hardwoods is intermediate between Tensas (53.4%) and Deltic (24.2%). During summer and fall females selected upland and lowland forests when choosing home ranges, and did not avoid any habitat types. This reinforces the importance of forested habitat for bears at the landscape level, which is consistent with other studies of bear habitat relations (Hellgren and Maehr 1992, Hellgren and Vaughan 1994, Rudis and Tansey 1995, Carr et al. 2002). That bears did not select habitat within their home ranges is likely a result of the small number of bears monitored. However, another

possibility is that reintroduced females may locate suitable habitat to establish home ranges (i.e. in areas with high proportion of bottomland hardwoods) and then essentially sample the habitats within their home ranges randomly due to unfamiliarity with the area. If this is true, then as reintroduced individuals become more experienced and familiar with the release areas, perhaps over a period of several years, presumably selection patterns for habitats conferring the greatest fitness benefits would develop. In Arkansas, Wear (2003) found that reintroduced bears preferred some habitat types relative to others within home ranges, but did not report whether overall 3rd order selection occurred. Future research in the RRC with larger sample sizes and habitat use data from bears that have occupied home ranges in release areas for multiple years should provide a better understanding of habitat selection behavior of reintroduced bears.

CHAPTER 5. DEN TYPE USE AND DEN SITE SELECTION OF FEMALE BLACK BEARS IN TENSAS RIVER BASIN AND REINTRODUCED POPULATIONS

INTRODUCTION

Winter dormancy by black bears appears to be an adaptation to cold temperatures and decreased food availability during winter (Lindzey and Meslow 1976, Johnson and Pelton 1980b). Black bears use dens during winter throughout their geographic range; however, there is considerable variation in denning behavior among populations in different habitats and geographic areas (Klenner and Kroeker 1990, Schooley et al. 1994, Oli et al. 1997). Female black bears give birth to cubs in winter dens and, therefore, lack of suitable den sites is critical to the individual fitness of females and to the dynamics and viability of populations (Morse 1937, Hamilton and Marchinton 1980, Alt 1984a; 1984b, Oli et al. 1997). Therefore, an understanding of den selection behavior is essential for the conservation of small and threatened populations of bears.

Most studies of denning behavior of bears in the southeastern United States have focused on denning chronology and duration, microhabitat characteristics, and den types (Hellgren and Vaughan 1989, Wooding and Hardinsky 1992, Weaver and Pelton 1994, Oli et al. 1997, White et al. 2001, Hightower et al. 2002, Klenzendorf et al. 2002). However, I am aware of no studies that have investigated den site selection of black bears at the landscape level in relation to available habitats. Also, although it has been noted that individual den preference by parturient females may be more specific than that of other bears (Alt 1984b), few studies have examined the influence of reproductive status on choice of den type and site selection. Additionally, variation in den types and microhabitat characteristics at den sites across the southeastern United States (Hellgren and Vaughan 1989, Weaver and Pelton 1994, Klenzendorf et al. 2002, Ryan and Vaughan 2004) requires population-specific studies for use in conservation and

management. Specifically, information regarding den use and selection by the federally threatened Louisiana black bears is lacking and previous studies of the denning behavior of this subspecies have been plagued by small sample sizes and incomplete datasets (Weaver and Pelton 1994, Hightower et al. 2002). Therefore, I investigated den selection behavior at multiple spatial scales by Louisiana black bears with 3 main objectives: (1) determine types of dens used by females and factors influencing choice of den type, (2) describe the microhabitat characteristics of den sites, and (3) investigate den site selection in relation to habitat types available throughout the TRB. The first 2 objectives pertain to females in the TRB and reintroduced females, however the analysis for objective 3 was only conducted for females in the TRB because of small samples and inadequate habitat information for some reintroduced dens.

METHODS

Den Visits

I attempted to locate dens for all radiocollared females in the TRB during February and early March 2003-2004 to assess reproductive status and investigate denning behavior. Dens of reintroduced females were located during February and March 2003-2005. For each den there were 4 main goals of the visit: (1) assess reproductive status of female as either with cubs, with yearlings, or alone, (2) obtain spatial coordinates at the den site for use in den selection analyses, (3) record microhabitat characteristics, and (4) record descriptive data about den characteristics and bear behavior. Female black bears generally give birth to cubs in January or early February (Pelton 2000) and den visits were timed to ensure that I did not visit dens before cubs of the year were born to prevent misclassification of reproductive status. I visited dens of females that were not eligible to reproduce (females known to have cubs during the preceding fall) starting 1 February and visited dens of the remaining females starting 15 February. I located bears by

radio-telemetry and then walked into the estimated location to obtain a visual. Bears were found in 2 types of dens: elevated tree cavities or ground dens. The actual space that bears occupied at ground dens was usually a bed made with vegetation and I refer to these as “nests”, whereas I refer to the general area surrounding and including the nests as “dens”.

For bears denning in tree cavities, a GPS point was used to determine the location and I revisited the den later in winter to climb the tree and assess reproductive status. At den trees I identified the tree to species, measured diameter at breast height (Dbh), estimated tree height and height of the entrance to the cavity using a clinometer, and recorded the percentage of water surrounding the tree. I also estimated canopy closure using a densiometer (Lemmon 1956) by taking 4 readings from equidistant points around the tree, with the densiometer held at elbow height and my back against the tree. Occasionally cubs could be clearly heard crying or nursing while working on the ground allowing for assessment of reproduction without climbing the tree. I returned in late February and early March to climb all trees for which reproductive status was unknown using ropes and ascenders. I climbed to the entrance of the cavities and attempted to obtain visual and/or auditory confirmation of the presence or absence of cubs. When cubs were heard and not seen I was confident in the assessment, but when no cubs were heard I attempted to obtain a visual on the bear and den to determine if cubs or yearlings were present.

For ground dens, I approached, attempted to obtain a visual, and assessed reproductive status of the bear. Females denning alone or with yearlings sometimes flushed from the den as I approached but females with cubs of the year always remained at the den site. If the female flushed, I located the nest, determined if there was a tree within 1m of nest, identified the species, estimated height and measured Dbh of these trees. I also took 4 canopy closure readings with a densiometer from equidistant points, facing the nest from the outside with my feet at the

edge. When bears remained at the den site as I approached, I stopped within 3-30m, obtained a GPS location, took a compass bearing to the bear, and estimated the distance from observer to bear. All females with cubs of the year in ground dens were targeted for reintroduction purposes (see Chapter 1) and the dens were re-visited for capture. During the capture attempt I determined the location using a GPS at the nest and recorded microhabitat characteristics. When females with yearlings or lone females remained at the den site during the initial visit I returned between 30 March and 2 April, determined the location using a GPS, and recorded the microhabitat characteristics if dens were unoccupied. I also generally drew a detailed picture, took a digital photograph, and wrote a description of the den site. This information was used later to help describe characteristics of den sites such as species of vegetation used for the nest, general shape and size of nests, and structural characteristics of the den site.

Den Reuse

To estimate den reuse, I calculated the percentage of all dens located in 2003 that were also occupied by a collared bear during 2004. Dens located during 2003 that were not occupied by collared individuals during 2004 were not checked for reuse. Thus, my estimates of reuse should be conservative because if I had checked all dens located in 2003 the percentage could only have increased.

Den Site Selection

I modified the Euclidean distance-based approach for assessing non-random habitat use (Conner and Plowman 2001, Conner et al. 2003, see Chapter 4) for use in den site selection analyses. My objective was to investigate selection of den sites in relation to habitat types available within the study area (2nd order selection). The distance-based approach was an effective method for this objective because it provided an assessment of whether distances from

den sites to each habitat type were different than expected distances based on a large number of random locations placed within the study area.

I used distance-based analyses identical to those described for seasonal 2nd order habitat selection (see Chapter 4) except that the vector of 8 distance ratios was created using the distance from the den location to the closest representative of each habitat type divided by the mean distance to the same habitat type from all random points falling within the study area. The habitat type in which the den site was located received a 0 for distance. I intersected the den and random locations with the year-specific GIS for each study area and calculated the distances to each habitat type using Arcview as described in Chapter 4. I used the same number of random locations for each study area as in Chapter 4. All dens used in the den selection analyses (36 Tensas, 30 Deltic) were used by bears ≥ 3 years and I excluded 2 dens from Tensas used by females that were yearlings at the time of capture and 2 years old at time of denning, because juveniles may exhibit different denning behavior than adults (Oli et al. 1997).

Statistical Analyses

I developed a log-linear model using the PROC GENMOD statement in SAS to test the hypothesis that use of den-type (tree or ground) was influenced by TRB subpopulation (Tensas or Deltic) and/or reproductive status of females (parturient or non-parturient). I used this model to investigate possible significant 2-way interactions among den-type, subpopulation, and reproductive status.

I used multivariate analysis of variance (MANOVA) to test hypotheses that den site selection did not differ from random in the TRB. I used a hierarchical approach in which I combined data from Tensas and Deltic and investigated 2nd order selection with subpopulation as a main effect. When significant subpopulation effects were found I partitioned data by

subpopulation and investigated den site selection with reproductive status, den type, and the reproductive status \times den type interaction as fixed main effects. When overall tests were significant I used univariate t -tests to identify specific habitats that were selected or avoided and to rank importance of habitats.

RESULTS

Tensas River Basin

Den Type Use

I noted an interaction between den type and reproductive status ($\chi^2_1 = 4.0$, $P = 0.046$), but there were not interactions between study area and reproductive condition ($\chi^2_1 = 0.05$, $P = 0.819$) or study area and den type ($\chi^2_1 = 0.26$, $P = 0.609$). Parturient females tended to use tree dens ($n = 23$) with greater frequency than ground dens ($n = 6$), whereas non-parturient females appeared to use tree ($n = 19$) and ground dens ($n = 18$) with similar frequency.

Microhabitat Characteristics and Den Reuse

During 2003-2004 I located 68 dens (44 tree, 24 ground dens) of 45 individual females in the two TRB subpopulations (Tensas = 38, Deltic = 30, Table 5.1). Tree dens were most often found in swamp or water habitat (73.7%), whereas ground dens were most often found in upland or regenerating habitat (83.3%, Table 5.2). Of 22 different tree dens used by females in the TRB in 2003, 7 (31.8%) were reused during 2004 (4 Tensas, 3 Deltic), including 3 cases of the same individual occupying the same tree (2 Tensas, 1 Deltic; Table 5.1). No ground dens in the TRB were reused. Forty-three of 44 den trees were identified to species and 39 (90.1%) were baldcypress trees. Of the remaining 4 den trees identified, there were 2 willow oaks (both at Tensas), 1 eastern cottonwood (*Populus deltoids*; Deltic), and 1 water oak (Deltic). Trees used by bears were characterized by large diameters and vertical heights (Table 5.3). Thirty-two of 44

Table 5.1. Den types used by female Louisiana black bears in Tensas and Deltic subpopulations of Tensas River Basin in Louisiana during winters of 2003-2004.

	Tree	Ground	No Den	Reused Trees
Tensas	25	13	3	4 of 12 (33.3%)
Deltic	19	11	2	3 of 10 (30.0%)
Total	44	24	5	7 of 22 (31.8%)

Table 5.2. Habitat types containing occupied female black bear dens in Tensas River Basin, Louisiana during 2003-2004 shown by den type and subpopulation.

	Habitats								
	Up	Low	Swp	Wat	Ag	Reg	Corr	Oth	Total
Tensas									
Tree	3	6	11	5	0	0	0	0	25
Ground	7	0	0	0	0	5	1	0	13
Deltic									
Tree	6	0	5	7	0	0	1	0	19
Ground	8	3	0	0	0	0	0	0	11
Total	24	9	16	12	0	5	2	0	68

Table 5.3. Microhabitat characteristics of den sites for female black bears showing the number of dens examined for this characteristic (n), means (\bar{X}), and standard errors (SE) in Tensas and Deltic subpopulations of the TRB, Louisiana during 2003-2004.

Variables	Subpopulation					
	Tensas			Deltic		
	n	\bar{X}	SE	n	\bar{X}	SE
Tree Dens:						
Dbh (cm)	25	219.0	9.3	17	191.3	16.8
Tree height (m)	25	26.6	1.8	18	19.7	2.3
Cavity height (m)	25	14.4	2.5	17	10.6	1.6
Canopy closure (%)	25	53.8	3.2	19	48.3	2.6
Ground Dens:						
Canopy closure (%)	8	47.3	11.4	11	48.1	5.7
Dbh* (cm)	6	44.1	10.9	9	56.5	12.6
Tree height* (m)	5	18.1	6.0	9	24.8	3.7

* Dbh and tree height of closest tree (all ≤ 1 m) to ground nest

(72.7%) den trees were completely surrounded by water (19 Tensas, 13 Deltic), 3 (6.8%) were partially surrounded by water (1 Tensas, 2 Deltic), and 9 (20.5%) were on dry ground (5 Tensas, 4 Deltic).

Ground dens were generally nests, roughly circular in shape, approximately 1 m in diameter, made with herbaceous and/or woody vegetation in shallow depressions in the soil, and positioned close to some form of vertical woody structure. Twelve of 21 ground nests (6 Tensas, 6 Deltic) that I described were composed of palmetto fronds that were torn from nearby living plants. The remaining nests were less elaborate and composed of switchcane (*Arundinaria gigantea*) and/or woody debris ($n = 8$, 4 Tensas, 4 Deltic) or lacked vegetation ($n = 1$). Twenty of 23 ground dens (data not recorded at 1 ground den) were at the base of a tree, snag, or stump within 1 m of den nest (Table 5.3). Five ground dens (4 Deltic, 1 Tensas) were positioned within piles of logging slash and other large woody debris. Two ground dens made use of dense briar patches (*Rubus* spp., 1 Tensas, 1 Deltic) for vertical structure and ground dens in general were found in areas of thick palmetto, *Rubus* spp., and switchcane undergrowth.

Den Site Selection

I used 66 (36 Tensas, 30 Deltic) dens from 45 female black bears for den site selection analyses. When comparing den sites with random points throughout the study area in terms of distance to each habitat type (2nd order selection); Tensas and Deltic females selected den sites differently (i.e., there was a subpopulation effect, $F_{8,56} = 12.98$, $P < 0.001$). Therefore, I partitioned dens by subpopulation to examine 2nd order den selection. Tensas females exhibited non-random den site selection ($F_{8,24} = 33.02$, $P < 0.001$) and this selection was affected by the type of den used ($F_{8,24} = 4.85$, $P = 0.001$). Reproductive status ($F_{8,24} = 0.46$, $P = 0.869$) and the reproductive status \times type ($F_{8,24} = 0.56$, $P = 0.801$) interaction did not affect den site selection.

Therefore, I partitioned Tensas dens by type of den to investigate specific selection patterns. Females using both tree ($F_{8,14} = 106.44$, $P < 0.001$) and ground ($F_{8,5} = 11.63$, $P = 0.008$) dens exhibited selection. Tensas females using tree dens selected den sites closer to swamp, water, upland, lowland, and regenerating forest habitats when compared to random points throughout the study area (Table 5.4). Tensas females using ground dens selected sites closer than expected to swamp, water, and regenerating forest (Table 5.4). Females using both types of dens selected sites farther than expected from agriculture (Table 5.4).

Deltic females also exhibited 2nd order den site selection ($F_{8,19} = 21.56$, $P < 0.001$), but selection was not affected by den type ($F_{8,5} = 1.44$, $P = 0.242$), reproductive status ($F_{8,19} = 1.0$, $P = 0.465$), or the reproductive status \times type interaction ($F_{8,19} = 1.02$, $P = 0.453$). Deltic females selected den sites that were closer to upland, lowland, and regenerating forests and farther from agriculture and corridor than expected when compared with random points throughout the study area (Table 5.4).

Non-Denning Behavior

I classified 5 females monitored during 2003-2004 as not denning (68 dens were used out of 73 possible if each female had denned during both years monitored). Of these, 3 were relatively young females (estimated ages ≤ 3 years old) that had most likely not reproduced previously, whereas 2 were adults known to have produced offspring previously. One of the older females had 2 yearlings with her during the winter that she did not occupy a den, whereas the other was a lone female. All parturient females exhibited denning behavior. Periodic monitoring of all non-denning bears indicated that movements > 1 km between subsequent locations were common. All females monitored in the TRB for both years denned during ≥ 1 winter.

Table 5.4. Habitats available to denning female black bears in the Tensas and Deltic subpopulations of TRB ranked in order of preference based on relative magnitude of t -statistics of univariate tests for 2nd order den site selection. Tensas selection preferences were separated by den type because females using tree and ground dens selected den sites differently ($F_{8,24} = 4.85$, $P = 0.001$).

	Habitats							
	Up	Low	Swp	Wat	Ag	Reg	Cor	Oth
Tensas (tree)	3**** ⁺	4**** ⁺	2**** ⁺	1**** ⁺	8*** ⁻	5*** ⁺	6	7
Tensas (ground)	6	4	3* ⁺	1** ⁺	8* ⁻	2** ⁺	5	7
Deltic (all dens)	2**** ⁺	1**** ⁺	4	6	7**** ⁻	3** ⁺	8**** ⁻	5

* $0.10 < P < 0.05$, ** $0.05 < P < 0.0001$, *** $P < 0.0001$, ⁺ habitat selection, ⁻ habitat avoidance
Up = upland forest, Low = lowland forest, Swp= swamp, Wat = water, Ag = agriculture, Reg = regenerating forest, Cor = corridor, Oth = other.

Dens of Reintroduced Bears

I located 15 dens (7 tree, 8 ground) for 9 reintroduced females from 2003-2005. I did not find dens for 4 reintroduced females during 2005. Of these, 2 bears apparently did not establish dens, 1 was likely using a ground den but flushed as I approached and I was unable to locate it due to dense understory conditions, and 1 was likely in a ground den but did not flush, and was not revisited as of the writing of this thesis. All 7 den trees were baldcypress and 5 were completely surrounded by water. Two of 3 tree dens were occupied by the same female in consecutive years. Microhabitat characteristics of den trees used by reintroduced bears are summarized in Table 5.5. Of 8 ground dens located, 5 were in very dense briar (*Rubus* spp.) patches and structure of 4 of these dens was a combination of briars and logging slash. Of the remaining 3 ground dens, 1 was in an area of dense, live palmetto plants, and 2 were in elaborate piles of logging slash. Only 8 of 15 dens of reintroduced females fell within the Lake Ophelia GIS and thus I did not have a sufficient sample size to conduct a den site selection analysis for these bears.

DISCUSSION

At the finest scale of den selection, individual bears choose the type of den to be used and in the TRB the choices can be divided into 2 main den types: ground and tree dens. Den types were used similarly by females on Tensas and Deltic, but reproductive status affected den type use as females with cubs used tree dens more often than ground dens. Although many studies have investigated den type use in relation to sex, age, and/or study area effects (Oli et al. 1997, Bull et al. 2000, White et al. 2001, Ryan and Vaughan 2004), few have investigated the effect of reproductive status on female den type use (but see Hightower et al. 2002, Klenzendorf et al. 2002). In the mountains of western Virginia, reproductive status did not affect the frequency of

Table 5.5. Microhabitat characteristics of tree dens used by reintroduced female black bears showing number of trees measured (n), means (\bar{X}), and standard errors (SE) in central Louisiana during 2003-2005.

Variables	n	\bar{X}	SE
Dbh (cm)	7	218.3	28.7
Tree height (m)	7	23.2	1.5
Cavity height (m)	7	9.6	1.5
Canopy closure (%)	7	34.6	6.8

den types used among tree, rock-excavation cavity, or open-ground dens (Klenzendorf et al. 2002). Hightower et al. (2002) also did not detect differences in use of tree and other den types for the Inland and Coastal Atchafalaya populations of Louisiana based on reproductive status. However, Hightower et al. (2002) acknowledged the low statistical power of their tests due to small sample sizes and they were only successful in determining reproductive status in 61% of den visits, making their results difficult to interpret. In the TRB, Weaver (1999) found that most (78%) of pregnant females denned in trees, but did not have a sufficient sample size to formally test effects of reproductive status on den type use. Weaver (1999) also found that Deltic bears in general did not frequently den in trees, and I suggest that the discrepancy between our findings can be attributed to the small number of dens located in the former study. Also, most Deltic bears monitored by Weaver (1999) inhabited the Bluecat tract, where swamp habitat is lacking and fewer bears den in trees compared with Wade Bayou (J.F. Benson, unpublished data).

I found that parturient females throughout the TRB were more likely to den in trees, suggesting that tree cavities may be superior natal dens. Previous studies have concluded that tree dens are more energy efficient than ground dens (Johnson et al. 1978, Wathen et al. 1986) and provide better protection from flooding (Alt 1984a). Oli et al. (1997) suggested that natural selection should favor those individuals choosing tree dens in seasonally flooded habitats because of energy efficiency and protection from flooding. Oli et al. (1997) further proposed that the increased energy efficiency of tree dens would allow parturient females to conserve energy for use in fetal development and lactation, and my results are consistent with these hypotheses.

There was considerable variation in the microhabitat characteristics at ground dens in the TRB; however, dens in dense understory created by palmetto, *Rubus* spp., or switchcane growth

appeared to benefit females by providing cover from visual detection and making it difficult for humans or predators to approach the den without being heard. Previous researchers have reported dense understory conditions at ground dens in the TRB and other populations of southeastern black bears (Landers et al. 1979, Johnson and Pelton 1981, Hellgren and Vaughan 1989, Wooding and Hardinsky 1992, Weaver et al. 1990). Use of logging slash and woody debris has also been reported frequently (Hellgren and Vaughan 1989, Weaver et al. 1990, Oli et al. 1997, White et al. 2001, Hightower et al. 2002).

The most important microhabitat feature at tree dens is obviously the presence of a suitable den tree (Oli et al. 1997). My results suggest that suitable den trees in the TRB are usually tall, large diameter bald cypress trees with elevated cavities, often surrounded by water. Bears inhabiting seasonally flooded bottomland hardwood forests in southern Arkansas generally used oak trees of lesser diameter and height, and with lower cavity entrances than the den trees I located (Oli et al. 1997). Large, mature oaks with hollow cavities are not common in the TRB due to removal of these trees during previous timber harvest activities; however, large baldcypress trees remain, primarily in swamps, lakes, bayous, and other habitats containing standing water.

High incidence of den reuse may suggest that availability of den sites in an area is limited (Tietje and Ruff 1980, Johnson and Pelton 1981, Alt 1984b). My estimate of den reuse was conservative, as described in the methods, and therefore may not be directly comparable to other studies. However, because these estimates are conservative I compared them with previous findings and acknowledge that den reuse in the TRB could be higher than I estimated. As noted by Ryan and Vaughan (2004) most studies have found reuse of black bear dens to be <10% (Jonkel and Cowan 1971, Tietje and Ruff 1980, Alt 1984b, Kolenosky and Strathearn 1987,

Weaver and Pelton 1994, Godfrey 1996, Oli et al. 1997, Klenzendorf et al. 2002), whereas the overall rate of den reuse (ground and tree dens considered) in the TRB was >22%. The only published report of a higher rate of den reuse that I am aware of was on Long Island, Washington, where den reuse was >50% (Lindzey and Meslow 1976). When considering only tree dens, the rate of reuse in the TRB was higher, as 32% of den trees I located in 2003 were also occupied by radiocollared females during 2004, compared with other studies that reported <5% reuse of den trees (Alt 1984b, Oli et al. 1997, Klenzendorf et al. 2002, Ryan and Vaughan 2004). The relatively high percentage of reused den trees that I documented suggests that den trees may be limited in the TRB.

At the landscape level, females on Tensas and Deltic selected den sites differently in relation to available habitat types. On Tensas, females denning in trees selected habitats differently than those denning on the ground. Tensas females using tree dens selected sites closer than expected to swamps, water, upland, lowland, and regenerating forests. More than 85% of tree dens on Tensas were located in swamp, water, or lowland forest habitats, probably because large cypress trees are present in these habitat types. These are the lowest elevation habitats that are subjected to varying degrees of annual and seasonal inundation, and are suitable for flood tolerant trees such as bald cypress (Mitsch and Gosselink 2000). The selection of sites closer than expected to upland forests by females using tree dens on Tensas probably reflects the use of cavities in several oak trees growing in this habitat type, as well as the fact that baldcypress swamps, lowland forests, and water containing tree dens were relatively small habitat patches surrounded by larger patches of upland forests (see Appendix 1).

Tensas females using ground dens selected regenerating forests, water habitats, and showed marginal selection for swamps. Ground dens were often located in regenerating habitats,

probably due to the thick understory of palmetto, switchcane, and *Rubus* spp. in these habitats, all of which appeared to be important plant species used for nest material and vertical structure at ground dens. Ground dens located in forests regenerating after timber harvest have been reported in other studies (Hellgren and Vaughan 1989, Weaver and Pelton 1994, White et al. 2001, Hightower et al. 2002). However, regenerating forests were also selected by Tensas females using tree dens and Deltic females using both den types, suggesting that there are benefits to denning close to these habitats irrespective of den type. *Rubus* spp. shrubs are abundant in early successional habitats (Litvaitis 2001) and berries from these plants are the first abundant food source available after the denning period and the most important food in the spring diet of bears in the TRB (see Chapter 2). I suggest bears in the TRB may select dens closer than expected to regenerating forests to ensure access to these food resources when they become available after den emergence. Water and swamp habitats may provide water and succulent vegetation for females denning on the ground during and after denning. Alternatively, these habitats may provide access to tree dens if ground dens become inundated. I did not investigate the use of multiple dens during a single winter, but previous studies in southeastern bottomland hardwoods have documented this behavior (Oli et al. 1997, Weaver 1999). In areas prone to flooding, such as the TRB, it may benefit females to select ground dens close to habitats containing abundant den trees (swamp and water habitats) in case flooding prevents them from safely denning on the ground.

In addition to selecting regenerating forests as noted above, Deltic females selected upland and lowland forests and avoided agriculture and corridor habitats. This pattern of selection is similar to habitat selection observed on Deltic during spring, summer, and fall (see Chapter 4). It likely reflects the fact that most dens were within the two main forested tracts of

Bluecat and Wade Bayou rather than in the matrix of agricultural habitat and associated corridors surrounding these woods.

Reintroduced females appeared to exhibit similar denning behaviors as females in the source populations. Tree dens were in baldcypress trees and often surrounded by water. Ground dens were either open nests in areas with dense understory or in logged areas in piles of woody debris. The almost equal use of tree and ground dens by reintroduced females probably reflects the fact that all but 1 reintroduced dens were occupied by non-parturient females, given that my analysis showed that non-parturient females in the TRB used ground and tree dens with similar frequency.

In conclusion, I found that parturient females in the TRB used tree dens more frequently than ground dens. Previous authors have suggested that successful reproduction can occur in ground dens in flood-prone southeastern forests if sufficient ground cover and dry sites are available (Hellgren and Vaughan 1989, White et al. 2001). In southeastern Arkansas, in an area where bears den in trees when suitable cavities are available, females using ground dens and trees dens had similar litter sizes (White et al. 2001). White et al. (2001) suggested that logging activities which resulted in slash piles in higher elevation sites could mitigate the detrimental effect of removing potential den trees. I agree that this recommendation should be considered in areas where logging has reduced the availability of suitable den trees, but believe that management to maintain den trees should be emphasized wherever possible to aid in the conservation of Louisiana black bears. Although litter sizes may be similar for bears in ground and tree dens, the effect of these different den choices on cub development and recruitment is unknown. Females in tree dens may accrue energy savings of >15% compared with bears in other den types (Johnson and Pelton 1978) which could have important consequences for cub

growth and survival. The unpredictable nature of water levels and flooding events in the Mississippi Alluvial Valley and the fact that flooded den sites can result in cub mortality (Alt 1984a) also suggest that tree cavities provide safer natal dens. White et al. (2001) also suggested a more subtle way in which the absence of den trees in an area may affect female fitness and population productivity. They found a positive relationship between female age and ground den elevation, and suggested that older females may learn to use ground dens at higher elevations from experiencing flooded dens at lower sites earlier in life. If successful natal ground denning in flood-prone areas is dependent on learned behavior resulting from loss of litters by younger females, this could delay the age of first successful reproduction and negatively affect cub survival, recruitment, and population growth (White et al. 2001). I suggest that forest management practices that retain large diameter baldcypress and oak trees will be most effective in maintaining successful denning opportunities for Louisiana black bears in the TRB and RRC.

CHAPTER 6. CONCLUSIONS AND MANGAGEMENT IMPLICATIONS

TENSAS RIVER BASIN

Previous authors suggested that differences existed in various aspects of ecology between bears inhabiting Tensas and Deltic (Anderson 1997, Beausoleil 1999, Weaver 1999). I explicitly tested hypotheses regarding the comparative ecology of the 2 subpopulations, and despite the close proximity and similar environmental conditions of Tensas and Deltic, it appears that females exhibit different patterns of feeding, space use, habitat selection, and denning behavior. The adaptability of black bears appears to allow for plasticity in their behavioral responses to variation in landscape and habitat at multiple spatial scales within a single population. My results are useful for beginning to understand the effects of fragmentation and habitat management on diet, space-use, and habitat selection, and for developing a sound conservation strategy for the black bears in the Tensas River Basin.

The most obvious difference between the landscapes of Tensas and Deltic is the amount of forested habitat. Bears on Tensas inhabit a relatively large ($>300 \text{ km}^2$) contiguous forest, whereas the bears on Deltic inhabit smaller ($<7 \text{ km}^2$) patches of forest in a landscape that is predominantly agricultural. Deltic represents an extreme case of habitat fragmentation and the subpopulation has maintained extremely high population densities and persisted under these conditions for several decades. Deltic females use smaller home ranges and core areas than females on Tensas, and I also documented differences in habitat and den site selection. Deltic females strongly selected upland and lowland forests at all spatial scales, whereas Tensas females showed more variation but consistently selected swamps and regenerating forests.

I suggest that these differences in behavior are the result of the influence of landscape and habitat variation on at least 2 spatial scales. At the landscape scale, the lack of available

forested habitat may limit the size of home ranges and probably accounts for the 2nd order habitat and den selection differences. Although Deltic females were occasionally located in adjacent agricultural fields and several females were known to travel extensively in forested corridors outside of the 2 main tracts, the home ranges of most females on Deltic were almost exclusively confined to either Bluecat or Wade Bayou. The mean annual home range size for females on Tensas was $>12 \text{ km}^2$; thus, even if Deltic females used the entire area of the tract they inhabited, their home ranges would only be about 50% of this size. In fact, the mean annual home range size for females on Deltic was $<4 \text{ km}^2$. Similarly, females on Deltic selected upland and lowland forests for their home ranges and den sites from habitats available throughout the study area. It is not surprising that bears would show strong selection for forests, given that most of the study area is unsuitable habitat, devoid of trees, and that females restricted most of their activities to the 2 major forested areas.

Habitat differences at a finer scale also may be important in modifying space use, habitat selection, and diet. Current and past forest management practices in the 2 study areas have resulted in differences in the forests of Tensas and Deltic in terms of food availability for bears. Anderson (1997) noted the abundance and diversity of hard and soft mast in the Deltic tracts, especially in Bluecat and Wade Bayou. Likely due to the diversity of food available within the upland and lowland forests, females on Deltic selected these habitats within their home ranges and ate a wide range of soft mast during summer and fall, along with other foods. During late summer and fall, bears on Tensas ate a narrower diet of mainly corn, palmetto, and acorns. Females on Tensas selected regenerating forests within their home ranges, probably to exploit soft mast which is less available in mature forests on Tensas during summer and fall.

Stand-level habitat differences and resulting variation in food availability could also have influenced space use. Abundant food resources are often negatively correlated with home range size in mammals (Taitt and Krebs 1981, Taitt 1981, Mares et al. 1982, Litvaitis et al. 1986), including black bears (Powell et al. 1997). If the upland and lowland forests on Deltic provided an abundance and diversity of hard and soft mast, females may have acquired sufficient energy for survival and reproduction in a smaller area. As noted by Anderson (1997), the proximity of superabundant agricultural resources to the Deltic tracts represented a virtually limitless food supply and could have influenced home range size. On Tensas, bears eating mainly corn, *Rubus* spp., palmetto, and acorns may have needed larger home ranges to exploit resources dispersed across the landscape in different habitat types. Palmetto fruit and acorns were available in upland and lowland forests, *Rubus* spp. were abundant in regenerating forests, and corn in agricultural fields. Additionally, the larger size of forested habitat patches on Tensas probably required many females to travel farther to feed on corn, especially females with home ranges located farthest from edges. In comparison, even females inhabiting the center of Bluecat or Wade Bayou were relatively close to forest edges bordering agricultural fields.

Highly abundant and clumped food resources in the small, isolated woodlots of Deltic raise interesting questions regarding the effects of fragmentation on space use and population persistence of black bears. Previous authors have suggested that large, contiguous blocks of habitat may be necessary to maintain viable populations of black bears (Hellgren and Vaughan 1994, Rudis and Tansey 1995). Fragmentation may reduce habitat productivity because patches within a fragmented forest may lack the full range of habitats found in the original area (Wilcove et al. 1986, Hellgren and Maehr 1992). This can lead to increased movements and home range sizes if bears need to travel relatively large distances to find suitable habitats to meet resource

requirements. Indeed, Mollohan and LeCount (1989) found that a combination of natural and human-induced forest fragmentation led to increased home range size and movements of bears to locate suitable habitat. The density of bears was also lower in this area relative to a neighboring area that was not as fragmented (Mollohan and LeCount 1989). However, if food is abundant and diverse, as it appears to be on Deltic, then fragmentation may have the opposite effect and lead to smaller home ranges and increased population density even in areas with very little remaining habitat. This could explain the space use patterns and high density of bears observed on Deltic, with food as the mitigating factor. Hellgren and Maehr (1992) noted that greater diversity and abundance of food could result in smaller home ranges and facilitate demographic stability for bears. Thus, the effects of landscape-level variation in habitat (i.e. fragmentation and limited forested area) on black bears may depend on stand level characteristics of the remaining forest fragments. If food is sufficiently abundant and diverse it may be possible for a relatively large number of bears to require less space and persist in areas with extremely limited forested habitat, as they have at Deltic. This explanation could have broad implications for the conservation of small populations of black bears inhabiting areas of increasing fragmentation because it suggests that through effective stand-level habitat management, it may be possible to decrease the amount of total forested area needed to allow persistence. I believe it is the combination of superabundant food in adjacent agricultural fields and a diversity of abundant soft and hard mast within the forests that allows for the unique situation on Deltic. This phenomenon may allow bears to persist on Deltic until current and future habitat restoration efforts (e.g., Wetland Reserves Program) are successful in substantially increasing the amount of forested land in the area. I caution land managers that these ideas do not reduce the need to protect and restore large, contiguous blocks of forested habitat for black bears in Louisiana and

elsewhere, but may provide a strategy for managing bears in areas where habitats are already highly fragmented. However, as noted by Hellgren and Vaughan (1994), data relating vegetation trends with bear population dynamics are necessary to determine if specific habitat management strategies are of conservation value for bears.

Little is known about the long-term viability of isolated populations of black bears (Hellgren and Vaughan 1994). The short duration of the present study (<3 years) and difficulty in determining critical population parameters such as cub survival and recruitment prevented me from determining exact consequences of isolation of the Deltic subpopulation. Although abundant and diverse food resources may allow Deltic to persist as a small and dense subpopulation, the isolation and limited habitat of Deltic likely make successful dispersal difficult and probably limit recruitment of offspring produced on Deltic. Even in high quality habitat, with abundant natural and agricultural foods, habitat saturation will occur in fragments if dispersal is frustrated. This situation will prevent the subpopulation from expanding and leave it susceptible to extinction, whereas an increase in available habitat would probably provide space for dispersing juveniles to establish breeding ranges and allow the subpopulation to increase numerically. Reforestation efforts around Bluecat and Wade Bayou began in 2002 and the 2 tracts will be virtually connected when these recently planted forests have matured. This should facilitate movement of bears between the 2 tracts, although Louisiana highway 577 and social constraints may still restrict movement to some degree. When this habitat linkage is achieved, it would be interesting to test hypotheses regarding whether restricted space use on Deltic is a function of limited habitat or highly abundant and clumped food resources. Continuing and expanding these reforestation efforts should have a positive effect on the viability of the Deltic subpopulation. Given the importance of corn as a food resource for bears in the TRB and its

probable role in maintaining high densities of bears on Deltic, I suggest that linking the current tracts with forested habitat interspersed with agricultural fields will allow increased movement and successful dispersal of bears, while maintaining abundant food resources.

Although I do not suggest that Tensas and Deltic are completely isolated from one another, it appears that movement of bears between the subpopulations is relatively rare. Bears have been trapped, marked, and monitored using radio-telemetry in the TRB for >14 years, but to my knowledge only 1 movement of a bear between Tensas and Deltic has been documented (Weaver 1999). Bears killed by vehicular collisions are occasionally found on US I-20, which separates the 2 subpopulations, indicating that bears are attempting dispersal and are probably successful on occasion. This highway and the lack of forested habitat between the subpopulations are probably the major impediments to successful dispersal. Dispersal and gene flow between Tensas and Deltic are not well understood, but because as few as 1 successful dispersal event per generation may be necessary to prevent genetic isolation and differentiation between subpopulations (Spieth 1974, Lewontin 1974), major differences in the current genetic composition of Tensas and Deltic are unlikely. However, linking the 2 subpopulations would be beneficial for promoting successful dispersal of juveniles from the potentially saturated Deltic tracts to larger, lower density forests on Tensas. Also, facilitating dispersal could allow for the subpopulations to “rescue” each other if environmental or demographic stochasticity were to result in critically low numbers or local extinction. Reforestation could provide habitat corridors to promote connectivity between Tensas and Deltic, and highway over- or underpasses could be strategically connected with these corridors to allow for successful highway crossings. Bears in Louisiana have been documented using narrow (<10m) strips of vegetation to travel through inhospitable habitats such as open fields (Van Why 2003, J.F. Benson, unpublished data). Thus,

creating corridors may not require major changes to the landscape. The cost of highway over- or underpasses can be prohibitive, but bears have been documented using these structures elsewhere (Foster and Humphrey 1995) and even 1 or 2 might be effective if combined with habitat corridors that could serve to “funnel” bears across the barrier.

REINTRODUCTION

It is too soon to adequately assess the success or failure of the reintroduction efforts; however, the results of the monitoring efforts offer some reasons for optimism. If this project is to succeed, 3 major objectives must be met. First, females released into the RRC must establish home ranges in central Louisiana or western Mississippi. Second, females must breed and successfully raise cubs within this targeted area. Third, successful dispersal events between existing and reintroduced populations must occur to achieve connectivity and promote gene flow. Presently, we have begun to achieve the first objective as at least 14 of 16 adult females released from 2001-2004 remain in the targeted reintroduction area. Of the 11 reintroduced females whose movements were described in this thesis, 7 have established home ranges <6 km from their release site. The other 4 bears have moved farther distances (see Chapter 1), but these movements are actually beneficial to the goals of the project in at least 2 ways. First, these long distance movements through the fragmented habitats of Louisiana have shown that bears are able to disperse through this landscape. Second, with bears moving both north and south from the release sites, bears are now distributed between the core of the RRC and both the TRB and Inland Atchafalaya populations. This should increase the likelihood of movement between reintroduced and existing populations. The current situation is a relatively dense nucleus of adult females ($n = 9$) around Lake Ophelia and Red River WMA, and also bears ($n = 5$) distributed to the north, southeast, and west. Given that the project is relying on dispersing males finding these

females, their current arrangement on the landscape seems fortuitous because it may increase the likelihood of males encountering them.

The monitoring efforts have shown that bears appear to be behaving relatively “normally” in their first years after release. Their home ranges are larger than those of bears in the TRB, but this is to be expected for animals released into unfamiliar habitat. For at least 8 of 11 adults released during 2003-2004, their movements and space use are confined to predictable areas and patterns, even if they are using greater home ranges and core areas than bears in the source population. Reintroduced females also appear to be exhibiting denning behavior similar to bears in the source population. Only 2 reintroduced bears did not use dens during 2003-2004, and 1 of these was a female that was known to have not used a den in the TRB prior to her translocation. There appears to be adequate ground and tree den sites at Lake Ophelia, although reuse of the same dens by the same individuals was relatively high. Three females denned on Lake Ophelia during 2003, 2 in elevated tree cavities and 1 on the ground in a slash pile. Interestingly, the 2 females that used trees reused the same trees during 2004 and the remaining female denned in a slash pile within 25 m of her den from the year before. With only 3 bears it is impossible to draw meaningful conclusions from this behavior, but I offer several possible explanations that should be investigated by future research. It is possible that reintroduced bears are still relatively unfamiliar with the release area and may exhibit increased fidelity for dens. If a female finds an acceptable den during her first year it may be adaptive to reuse it rather than attempting to locate a new den in unfamiliar habitat. Another possibility is that females prefer to use dens that they have used previously and the reason it doesn't occur more frequently in established bear populations is due to the greater density of bears. In established populations, previously used dens may often be occupied by other bears and thus unavailable for reuse.

Currently on Lake Ophelia, the low density of bears may facilitate reuse of dens. Alternatively, den sites could be limited on Lake Ophelia or the apparent site fidelity could simply be an artifact of small sample size. Continued monitoring of denning behavior in the TRB and reintroduced population should provide a clearer understanding of den selection and reuse by female black bears. Finally, results of habitat selection analyses showed that bears are selecting upland and lowland forests when establishing home ranges, but habitat selection within the home ranges was not detected. Future analyses with larger sample sizes will provide a more complete assessment of habitat selection by reintroduced females.

It is too early to adequately assess the success of the second objective of achieving successful breeding and cub survival within the reintroduced population. One reproductive event has occurred and gives reason for optimism because it was a 5-cub litter (Bear T6, see Chapter 1), the largest ever reported for Louisiana black bears. It is interesting to note that this reproduction appears to have occurred as a result of the female “finding” a male rather than the reverse. T6 left Lake Ophelia in May 2003, crossed the Mississippi river in March or April 2004 and wandered extensively before mating in summer 2004. After crossing the Mississippi river, she made large movements between successive telemetry locations obtained during spring and summer (25.7 km from 11 April- 28 May and 19.2 km from 28 May-July14). I received pictures from a private landowner taken over a 2 week during mid-July of a collared bear (presumably T6) and a much larger bear (presumably a male) at a deer feeder at a location very close to the 14 July location. She made smaller movements from July until winter as the distances between successive locations were 0.25 km, 9.4 km, and 1.5 km on 31 August, 5 November, and 17 February, respectively. Her largest movements were during early spring and summer, coinciding with the onset of estrus, and seem to indicate that she was searching for a male during this

period. At least 11 females reintroduced during 2001-2004 should be in estrus during summer 2005 and determining their reproductive status during winter 2006 will allow for a better assessment of whether successful breeding is occurring in the reintroduction areas.

The third objective is to promote connectivity and gene flow between the reintroduced and existing populations. At this point it is impossible to know if this will be achieved, but my documentation of large scale movements (see Chapter 1) has shown that bears are able to navigate through the fragmented landscape of central Louisiana and cover large distances. It should be noted that the movements of recently released bears in unfamiliar habitats may be quite different than movements of bears under normal conditions (Clark et al. 2002). However, given that males are generally the dispersing sex and are capable of moving large distances (Rogers 1987, Elowe and Dodge 1989), it was encouraging to simply document that the bears are capable of dispersing through this landscape. The daily locations I obtained on bears making such movements are being incorporated into planning of private land easement programs in Louisiana to protect and enhance these corridors for future black bear dispersal (D. Fuller, US Fish and Wildlife Service, personal communication).

At this stage of the reintroduction program, it appears that the objectives are being met and that a population of bears in central Louisiana is in the beginning stages of becoming established. Continued monitoring and documentation of the ecology and population dynamics of this new population will be essential to determine the success of the project and to provide valuable information that may guide bear restoration efforts elsewhere. Additionally, the novel situation presented by releasing bears into unfamiliar habitats in areas with extremely low densities of bear allows for natural experiments that could provide important insights into the behavioral ecology of bears. Presumably, bears in the reintroduced populations are free from

many of the social constraints of established populations because of the lower density, which makes it an ideal setting to study behaviors such as natal dispersal, home range dynamics, and habitat use. When larger sample sizes are available, comparisons of behavior of reintroduced bears and those at varying levels of density in established populations (e.g., Tensas and Deltaic) could lead to a better understanding of how social structure influences these behaviors in black bears.

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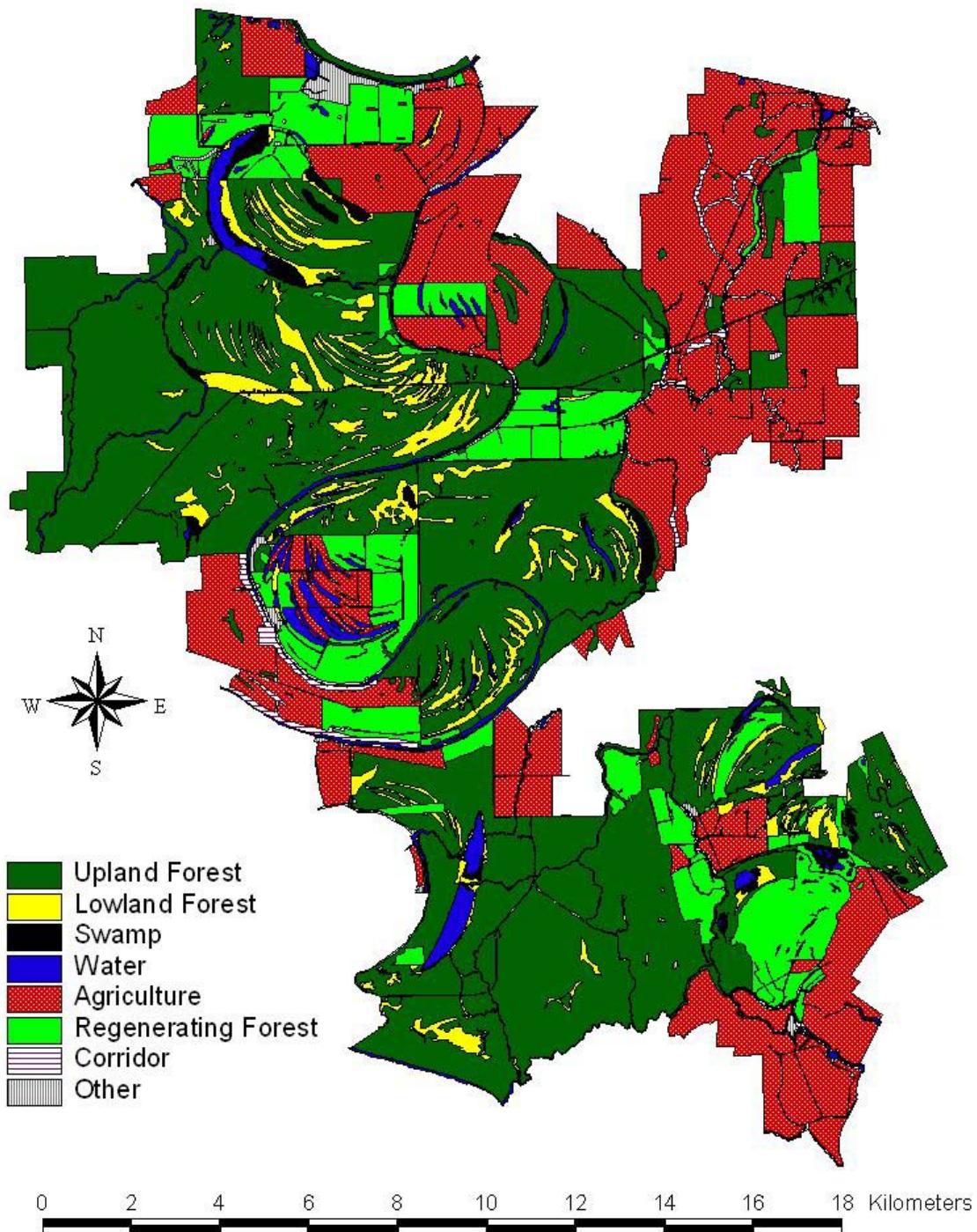
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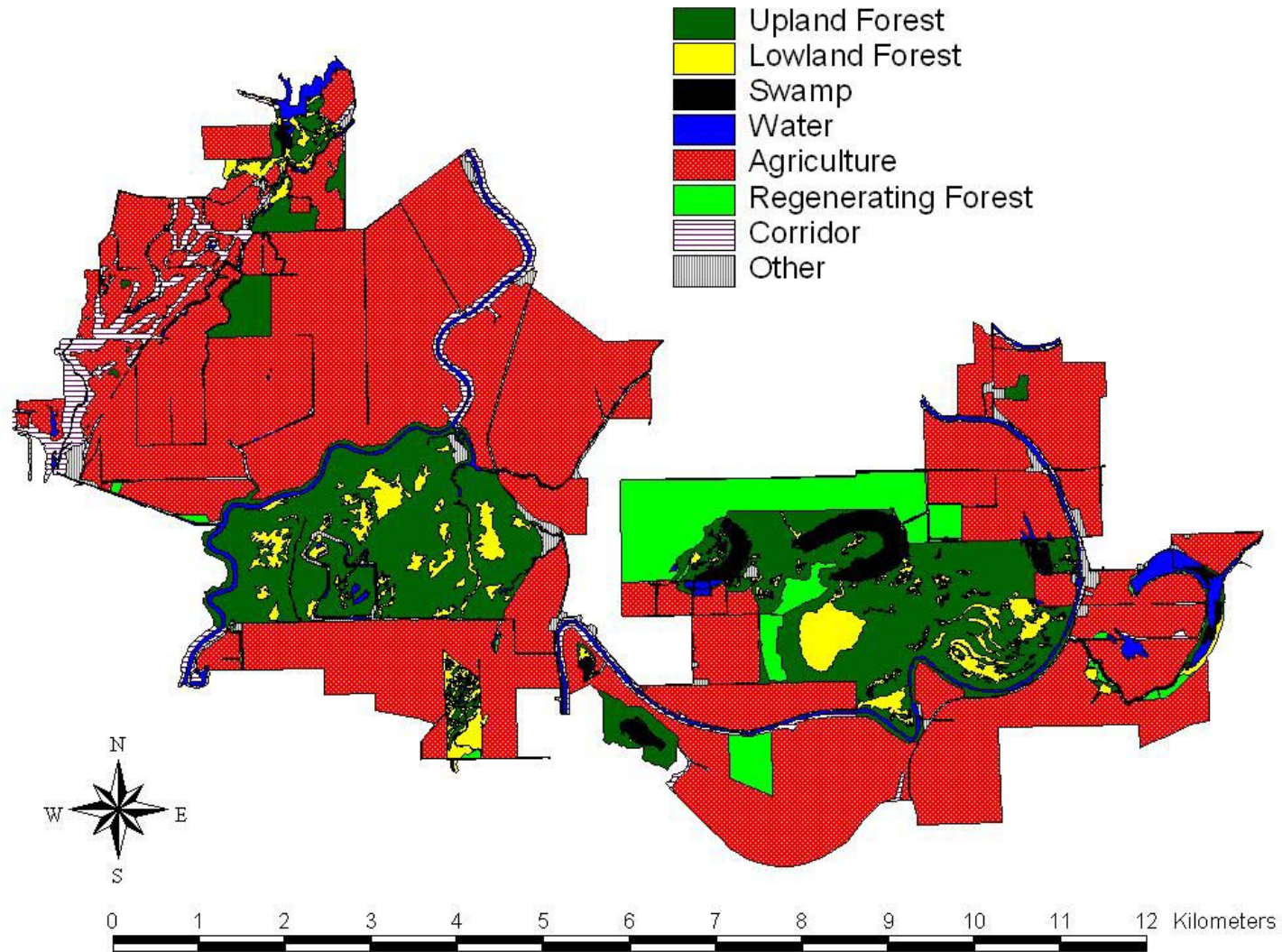
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APPENDIX 1



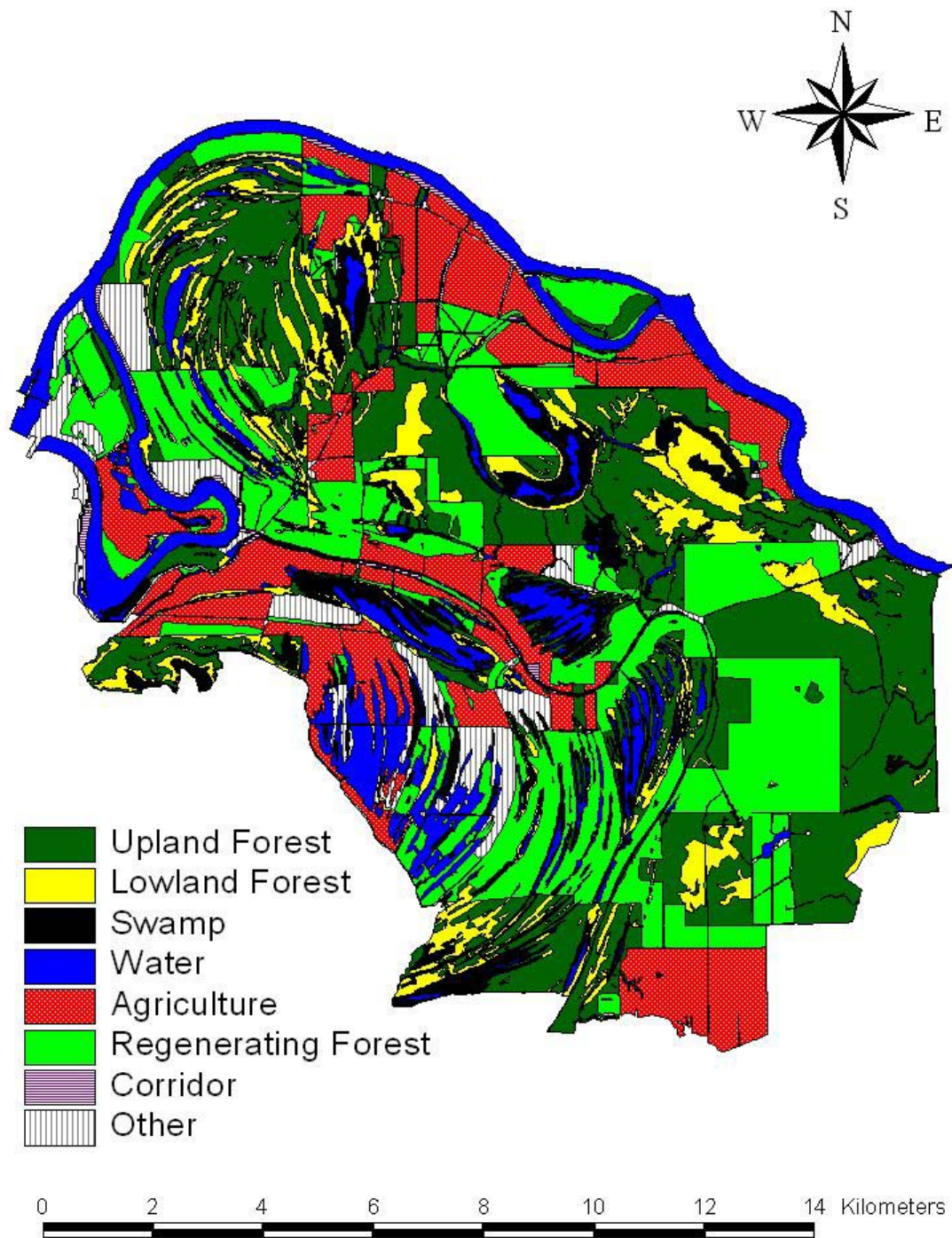
Appendix 1. GIS habitat type map for Tensas study area (2003-2004) in the Tensas River Basin, Louisiana showing the 8 habitat types.

APPENDIX 2



Appendix 2. GIS habitat type map for Deltic study area (2003) in the Tensas River Basin, Louisiana showing the 8 habitat types.

APPENDIX 3



Appendix 3. GIS habitat type map for Lake Ophelia study area (2004) in central Louisiana showing the 8 habitat types.

VITA

John Benson was born in New York City on 27 December 1971 to David and Lee Benson. He grew up in New York, Massachusetts, Colorado, San Francisco, and London, before moving to northeastern Connecticut where he attended high school. John attended the University of Connecticut from 1990-1995 where he earned a Bachelor's degree in history. After living and working in San Francisco for 3 years, John became interested in wildlife ecology and conservation. He entered the wildlife program at Humboldt State in northern California in 1998. While earning a Bachelor of Science degree in wildlife, John also worked on a variety of wildlife research projects with sea birds, red foxes, and mountain lions.

After earning his B.S., he worked with sea ducks on the tundra and barrier islands of Alaska, polar bears on sea ice north of Alaska, and Canada lynx in the north Maine woods. John began graduate work at Louisiana State University in June of 2002. He spent a total of 17 months over 2.5 years capturing, tracking, and studying black bears in the flooded bottomland hardwood forests and swamps of northern and central Louisiana. John will be awarded the degree of Master of Science in wildlife in May 2005.