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# ASSESSMENT OF CURRENT STATUS OF BLACK BEAR POPULATIONS IN EAST TEXAS USING HAIR SNARES AND GENETIC MARK-RECAPTURE ANALYSIS

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The black bear (*Ursus americanus*) is the most widespread and abundant bear species in North America and once roamed in 49 of the 50 states. The wide distribution of the black bear along with perceived threats to livestock and other resources (e.g., beehives) by early European settlers made it a perceived pest. This, combined with use for food, hides, and oil, led to widespread exploitation of the black bear in the nineteenth and early twentieth centuries. This exploitation of the black bear, coupled with its low reproductive rate, led to a general decline of the black bear across the United States over this period. In the mid-1900s, increased game regulations and movement of population to urban centers resulted in reversals of this decline in many areas. Through natural repopulation and historic reintroduction programs, black bear populations are now expanding in many portions of their former range. As numbers have expanded interest and research has risen in the possibilities for black bear population re-establishment, monitoring, and management.

Due to concerns about health of populations and potential human-bear conflicts, assessment and monitoring is critical to management of many populations. However, the low population density, large home range size, and reclusive nature have produced difficulties in observation. These have led to a number of survey and research methods to determine bear ecology, abundance, and demographics. Hair snaring, fecal sampling, sardine can trap lines, darting, leg-hold traps, and culvert traps have all been used to ascertain population and genetic data on black bears across the North American continent (Abler 1988, Woods et al. 1999, Mowat and Strobeck 2000, Kendall et al. 2001, Warrillow et al. 2001, O'Neill 2003, Bales et al. 2005, Clark et al. 2005, Morzillo et al. 2005). Due to the large areas involved, use of an inexpensive and landscape level monitoring system is integral to monitoring an animal like the black bear. Other important issues related to black bears include identifying restoration areas, identifying habitats suitable for population expansion, or areas for nuisance bear releases. Combined with the expansion of many urban areas, it is their need for large areas of relatively undeveloped land that most often causes human/bear conflicts. In the eastern U.S., most bear populations are centered on public lands free of or with reduced human influence. The juxtaposition of these public land areas with the urban-wildland interface can lead to nuisance behaviors. Potential conflicts can hamper restoration and expansion of black bear populations and nuisance management is often a large part of management in areas with close interaction between humans and bears.

In East Texas the last black bears were considered extirpated by the late 1950's (Garner and Willis 1998). Since that time little research has been done on black bears or their habitat, despite increased numbers of threatened Louisiana black bears (*U. a. luteolus*) in Louisiana and ample evidence of expanding populations in adjacent Arkansas and Oklahoma (Boersen et al. 2003, Bales et al. 2005, BBCC 2005, Brown 2008). Monitoring data in the state is limited to sightings information collected and maintained by the Texas Parks and Wildlife Department. Two studies have been conducted in East Texas researching habitat suitability for black bears (Epps 1997, Garner and Willis 1998). A landscape level assessment of the presence of bears in East Texas hasn't occurred since the last bears were eradicated, and assessment of Northeast Texas habitat has not been conducted since 1994 (Garner 1994). The identification and monitoring of bear populations and quality habitats will be essential in the present and future management of bears in East Texas.

This study addressed the lack of information currently for Northeast Texas by assessing black bear presence, distribution, abundance, and population characteristics in the region. It also sought to identify and delineate quality habitats that hold potential for occupation by immigrating bears from the expanding populations in neighboring states. These goals will be achieved by applying established bear research protocols such as hair snaring and vegetative habitat assessment to the focal area of Northeast Texas (Van Manen 1991, Epps 1997, Garner and Willis 1998, Bittner et al. 2002, Waits and Paetkau 2005). The data collected will allow for the direction of future management, education, and outreach efforts by both public and private resource agencies.

## Objectives

The objectives in this study were to:

1. Determine bear habitat occupancy and use, with non-invasive genetic hair snares on selected lands in the Sulphur, Red, and Cypress river basins of Northeast Texas.
2. For bears residing in East Texas, obtain demographic data such as subspecific affinity, sex, and individual genotype using hair samples and genetic analysis.
3. Assess suitability of forested habitats in East Texas for occupancy by black bears using appropriate habitat models for this species.
4. Identify large contiguous forested blocks suitable for bear habitat and minimum viable populations of black bear in the region.

## Literature Review

### Biology of Black Bears

*Distribution and Habitat.*—Black bears at European settlement ranged from Alaska to Eastern Canada and south to Mexico. The black bear is a generalist omnivore and has been found in habitats from temperate rainforest to dry desert scrub and montane areas. Due to a variety of factors, including past market hunting, habitat degradation from logging, and lost habitat due to settlements and agriculture, their range has been reduced by as much as 75% since European settlement (BBCC 2005); Figure 1). Most areas that black bears occupy in North America contain relatively large contiguous blocks of undeveloped land. Black bears' typical habitat needs include escape cover, dispersal corridors, abundant and diverse natural foods, water, and den sites (BBCC 2005). Excellent habitat includes: areas with high summer mast production, abundant, mature hard mast producing vegetation, a diversity of mast producing species, large areas considered escape cover, minimum of five to ten percent of area in old growth forest available for denning, low open road density, and an acceptable distance from potential bear/human conflict zones (Van Manen 1991, Garner 1994, Mitchell and Powell 2003). Specific cover types that provide these requirements vary depending upon geographic location. In North Carolina, Landers et al. (1979) found that over the course of the year bears used Carolina bays, agricultural fields, sand ridges, hardwood swamps, and upland mixed forest. They also found that use of different habitats was affected by season and availability of food in that habitat during that season. Black bears in the Pisgah National Forest in North Carolina showed an affinity to non-harvested forests as compared to freshly harvested stands (Mitchell and Powell 2003). The use of regenerating areas is usually related to a higher occurrence and density of soft mast producing species in these areas. In west-central Florida, black bears were found to use habitats in direct correlation to their abundance on the landscape. Habitat use was concentrated in bottomlands, pine forest, herbaceous marsh, upland hardwoods and sandhills, and human dominated areas in decreasing order (Maehr et al. 2003). In Louisiana, Benson (2007) found that female Louisiana black bears used bottomland hardwood, regenerating forest, and swamp more often than other available habitats such as agriculture, travel corridors, water, and a classification of other land uses.

Black bears are the most numerous bear species on the North American continent. There are 16 recognized subspecies of black bears in North America (BBCC 2005). The Louisiana black bear (*Ursus americanus luteolus*) is of particular management concern due to its limited range and extirpation from most of that range. For that reason, it is listed under the Federal Endangered Species Act as a threatened species. The Louisiana black bear currently has stable, reproducing populations only in Louisiana, with a few individuals venturing into Mississippi. Texas currently has no breeding population of Louisiana black bears, but may be seeing a recent increase in individuals dispersing within its borders from Louisiana (BBCC 2005). Historically, the Louisiana black bear occupied the eastern third of Texas, east of and including Cass, Marion, Harrison, Upshur, Rusk, Cherokee, Anderson, Leon, Robertson, Burleson, Washington, Lavaca, Victoria, Refugio, and Aransas counties (Hall 1981). In Texas, any black bear is both state and federally protected due to similarity of appearance to the Louisiana black bear.

*Diet*—Black bears, while in the Order Carnivora, are largely herbivorous, with up to 90% of the black bears' seasonal diet consisting of vegetable matter (BBCC 2005). Black bear diets are variable across their geographic range, but typically consist of hard and soft mast, insects, vertebrates, arthropods, and herbaceous vegetation (Landers et al.

1979, Maehr and Brady 1984, Smith 1985, Rogers 1987, Bull et al. 2001, Benson 2005). Black bears are opportunistic and will take advantage of most natural and anthropogenic food sources available to them. Human-based foods can include agricultural crops, garbage dumps, beehives, and backyard bird feeders (BBCC 2005).

Black bears typically have three seasonal feeding periods each year. The negative foraging period occurs in early to mid-spring shortly after den emergence. During this period bears consume large amounts of grass and other herbaceous material due to the lack of other food sources. During this time bears will continue to lose weight despite feeding daily. After the negative foraging period at beginning of late spring or summer, bears will switch to a more opportunistic diet consisting of large amounts of berries, other soft mast, vertebrates, and arthropods. It is during this time that they begin to gain weight that was lost during denning. Bears will travel long distances to known high productivity sites for berries and other highly preferred foods (Rogers 1977). In the fall, black bears begin to consume large amounts of hard mast in preparation for denning. Hard mast is high in fat and carbohydrates, allowing bears to gain large amounts of weight quickly. This can be a critical period for bears, as studies have suggested a direct link between fall food production and bear reproductive capability, space use and habitat preference (Smith 1985, Rogers 1987, Schooley et al. 1994, Samson and Huot 1995, Oli et al. 1997, Maehr et al. 2003, Benson 2005).

The variability of available foods across the continental range of the black bear makes it difficult to generalize the importance of certain food items; however, black bears in the southeastern United States typically have the same general feeding patterns. Important food items for the black bear in the Southeastern United States range are:

pecans (*Carya illionensis*), acorns (*Quercus spp*.), hickory nuts (*Carya spp*.), blackberries (*Rubus spp*.), dewberries (*Rubus spp*.) , pokeweed (*Phytolacca americana*), blueberries (*Vaccinium spp*.), blackgum fruit (*Nyssa spp*.), pawpaw (*Asimina spp*.), wild grapes (*Vitis spp*.), elderberry (*Sambucus canadensis*), persimmon (*Diospyros spp*.), devil's walking stick (*Aralia spinosa*), thistle (*Cirsium spp*.), palmetto (*Sabal spp*.), greenbrier (*Smilax* spp.), colonial insects and agricultural crops (BBCC 2005). Landers et al. (1979) examined fecal samples as well as stomach contents from deceased bears in North Carolina and found that the bears' diet consisted of corn (*Zea* spp.), greenbrier fruit, stem, and leaves, *Peltandra virginica* stems, animal matter and beeswax, inner bark of trees, forb stems, bayberry flowers (*Myrica heterophylla*), red bay leaves (*Persea borbonia*), switchcane stems and leaves (*Arundinarea gigantea*), blueberry fruit and leaves, blackberry fruit, huckleberry (*Gaylussacia spp*.), grass, holly leaves (*Ilex spp*.), wild grapes, sweetbay fruit (*Magnolia virginiana*), possumhaw viburnum (*Viburnum nudum*), blackgum fruit, oak fruit, colonial insects and birds. On the White River National Wildlife Refuge bears utilized: green stems and leaves, grass, winter wheat, southern naiad (*Naja guadalupensis)*, oak flowers, common persimmon, common pokeberry (*Phytolacca americana*), dogwood (*Cornus* spp.), greenbrier, muscadine grape, peppervine (*Ampelopsis arborea*), possumhaw holly (*Viburnum nudum*), red mulberry (*Morus rubra*), Rubus spp., swamp privet (*Forestiera acuminata*), American lotus (*Nelumbo lutea*), oak acorns, ants, beetles, honey bees (insects and wax), insect larvae, yellow jacket, fish, muskrat, rabbit, and white-tailed deer (Smith 1985). Use of these food resources varies by season, as.bears will take advantage of the most readily available high energy resource.

Hard mast production and utilization has a high degree of influence on black bears' yearly life cycle in the southeastern United States. In years of mast failure, bears will often increase their movements in search of dependable high energy food resources (Maehr et al. 2003). Clark et al. (2005) in Great Smoky Mountains National Park found that in years with bad acorn yields bear visitation to bait stations had a higher incidence than in years of good mast production. This dependence on mast crops continues into the winter as bears must increase fat reserves in the fall to get through the winter in good condition. Female condition entering the den and dormancy is directly related to condition of the female and her reproductive success the following spring (Samson and Huot 1995, Oli et al. 1997). Schooley et al. (1994) found that denning chronology in Maine was directly correlated to beechnut crop abundance in their study area. In years when beechnuts were abundant denning was delayed and in low yield years denning occurred earlier. Schooley et al. (1994) suggested that bears transitioned to the denning period once a negative energy balance had been reached. The availability of seasonal foods to individual female black bears not only affects their condition but the condition of their young as well.

*Breeding Biology*—The black bear breeding season varies with latitude and climate across its range. In the southern portion of the range, breeding can start as early as May and continue until mid-August. Following fertilization, implantation of the zygote is delayed by as much as five months so that cubs are born while the mother is in the winter den. Female bears can reach reproductive maturity as early as two years of age in high quality habitats; however, it is more common for the female to be 4-6 years of age before reaching sexual maturity. In marginal habitat, females may not produce until their seventh year (BBCC 2005). Males can reproduce by the age of 2 but due to older, mature males out-competing younger males, breeding for males in dense populations usually does not occur until 4-5 years of age. Smith (1985) found that approximately one third of females in the White River NWR had reproduced by three years of age and all had reproduced by six years of age. Male bears all appeared to be sexually mature by four years of age in that population. Parturition in black bears occurs in January or February with 2-3 the most common litter size (range of 1-5). Cubs emerge in early March to late May with their mother depending on location, and weigh from 1.8-6.7 kilograms upon emergence. Cubs stay with the mother for a full year and even den with her again the following winter before typically dispersing the following summer at 1.5 years of age (Smith 1985, Schooley et al. 1994, Samson and Huot 1995, Oli et al. 1997, BBCC 2005). Thus, females successfully raising cubs reproduce only every other year.

This ability to reproduce only every other year limits population growth and possibly increases the recovery time of black bear populations if over-exploited. The physical costs of rearing young for a female black bear can also limit overall population growth. Thus, habitats that contain a variety of high energy food resources may provide better litter rearing habitat than areas with less diverse food resources. Denning over the winter with numerous offspring can be physically detrimental to the female. Female bears in Quebec, Canada, with cubs lost twice as much weight as females without cubs or females with yearlings. Also, females with four cubs lost 20% more weight than females with two cubs. Within this population, heavier weight females were more successful breeders than lighter females. Females less than 56kg did not produce any young and lightweight females (between 56 and 77kg) with large litters were more likely to have underweight young (Samson and Huot 1995). The precise weight threshold for successful reproduction appears to vary by location, as three females weighing 43, 48, and 50 kg reproduced in an Arkansas population (Smith 1985). The extreme cold, longer denning periods, and limited food resources at emergence found in northern latitudes may require reproducing female bears in that region to have larger fat reserves than bears in southern latitudes.

*Denning Behavior*—Denning is an important part of a bear's life cycle. In some locations, bears can spend half of the year denning (Schooley et al. 1994). Bears are not true hibernators, but go through a period of dormancy known as carnivorean lethargy (Landers et al. 1979, Smith 1985, Oli et al. 1997, BBCC 2005). Dens and winter lethargy are important for reproduction as parturition occurs in the winter den. They also use dormancy in dens as a way to conserve energy during times of low food availability. Black bears will often consume hair, pine needles and other roughage prior to denning to create an anal plug that can be up to a foot long (Rogers 1981). This plug keeps them from defecating in their den while denning. Black bear dens are highly variable and may be found in rocky ledges, brush piles, uprooted trees, natural overhangs, dense thickets, hollow ground logs, hollow trees, snow embankments and burrows. Denning can begin as early as October in northern latitudes (Schooley et al. 1994) and as late as February in southern latitudes (Oli et al. 1997). Denning duration varies by location: in northern Minnesota denning occurred for 142 to 242 days, in Maine denning occurred for 134 to 197 days, in North Carolina on average for 100 days, and in Arkansas on average for 92.9 days (Rogers 1977, Landers et al. 1979, Schooley et al. 1994, Oli et al. 1997). Bears in northern latitudes tend to den longer than bears in southern latitudes. Differences were seen between sex and age classes as well, with males and non-pregnant females denning for shorter periods and pregnant females denning longer (Oli et al. 1997).

Den selection is important for bears as a den needs to provide protection and cover for the duration of the denning period. Choosing a den that is safe for the entire winter is especially critical in seasonally flooded wetlands. Bottomland hardwood forests which are seasonally flooded during the denning period have higher incidences of bears using tree dens rather than ground dens, presumably to avoid inundation of the den. In the Atchafalaya Basin in Louisiana, most bears use ground dens with tree dens important in flood prone areas. In the Tensas River basin in Louisiana, however, 70% of the bears use tree dens as it is more flood prone than the Atchafalaya area (BBCC 2005). In the Tensas River basin bears in uplands and regenerating stands used ground nests typically against the base of a tree or stump and surrounded by thick vegetation (Benson 2005). In swamps, bottomlands, and other areas categorized as wetlands, bears used tree dens. Tree dens were typically in trees that were 219 cm diameter at breast height (dbh), and the cavity was on average 14.4 m above the ground. Not surprisingly, the use of tree dens appeared to coincide with incidence of inundation for that habitat type (Benson 2005). Though cub survival and female condition between tree and ground denning females were not studied for long term effects of den selection, den type did not appear to affect litter size. Oli et al. (1997) found that in Arkansas's White River NWR up to 90% of the bears used tree dens. A few bears used multiple tree dens over the course of the winter with one female using 4 dens during one winter. Oli et al. (1997) also found that trees greater than or equal to 84 cm (33 inches) DBH were of adequate size to serve as tree dens for bears in seasonally flooded areas. Species of tree does not appear to be important in den selection as willow oak (*Quercus phellos*), water oak (*Quercus nigra*), nutall oak (*Quercus nutallii*), overcup oak (*Quercus lyrata*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), black tupelo (*Nyssa sylvatica*) and bald cypress (*Taxodium distichum*) all are apparently suitable in Louisiana (Smith 1985, Oli et al. 1997, Benson 2005). The only factor that appears to be an issue in den selection is overall size of the tree and cavity availability. The lack of available denning cover in flood prone areas could limit the reproductive potential of female bears inhabiting that area.

*Home Range and Movements*—Black bears have large home ranges (Table 1); this is an important challenge in managing, monitoring and conserving this species. They need large areas that provide food, den sites, loafing areas, water, and escape cover. Seasonally, habitat use and movements may be limited and concentrated near isolated patches of berries or oak trees; however, yearly movements are generally over much larger areas. Male black bears typically have home ranges 2 to 8 times larger than females (BBCC 2005). Adult males typically use 8,090 hectares (20,000 acres) and females use 2,024 hectares (5,000 acres) in Louisiana. One male in the Atchafalya Basin in Louisiana was tracked ranging over 34,412 hectares (85,000 acres) (BBCC 2005). Landers et al. (1997) found home ranges for male bears he monitored varying from as little as 387 hectares (955 acres) up to 18, 370 hectares (45,373 acres). Home ranges vary across the Southeast and can reflect anthropogenic and natural influences (see Table 1).

Bears need large areas on an annual basis, but use different areas within their range seasonally as food availability and the breeding activity change. The breeding season can cause male and female bears to move over larger areas searching for potential mates.  Bears may also make seasonal shifts in home range in response to localized and seasonal food resources: for example, bear movements shifted from uplands and agricultural fields during times of corn and berry production in the summer to bottomlands as oak and tupelo mast matured during the fall (Landers et al. 1979, Benson 2005).

Dispersal patterns also affect movement and can lead to increased competition.  In high density bear populations, female bears with female cubs will allow their offspring to occupy their natal home range.  The mother bear will then expand or move her home range to account for the territory lost to her yearlings, thus allowing for the establishment of her offspring in known adequate habitat.  Female bears typically will not tolerate male offspring in close proximity after family breakup during the second summer.  Dispersing male bears often travel to areas outside of any resident adult bear's territory to avoid conflict and will often have to travel long distances to do so (Bales et al. 2005).  Male bears in northern Minnesota dispersed 13-219km (average 61 km) away from natal territories (Rogers 1987).  This forced dispersal can lead to increased juvenile male bear mortality as the male searches for new resources and encounters roads, dumps, conflict with resident bears, or lack of food or other resources in unfamiliar territory.

*Conservation Status*—Black bear hunting seasons are currently in place or planned in Arkansas, Colorado, New Mexico, and Oklahoma; however, the species is federally protected in Louisiana, Mississippi, and Texas.  All black bear subspecies are protected in these states due to the similarity in appearance to the Louisiana black bear, which was listed as threatened in 1992 under the authority of the Endangered Species Act

(BBCC 2005). Listing of this species and concern for long-term conservation led to the formation of the Black Bear Conservation Committee (BBCC) in 1990 and has resulted in extensive and successful restoration efforts in Louisiana (Garner 1994, BBCC 2005). The Louisiana black bear is currently found in Louisiana in the Atchafalaya and Tensas river basins, in southwest Mississippi, and in White River NWR in Arkansas near the border with Louisiana (Garner 1994, Warrillow et al. 2001, Boersen et al. 2003, BBCC 2005). In Louisiana, efforts by the BBCC and governmental programs have helped in the enrolling of over 1,000,000 acres into the Conservaton and Wetland Reserve Programs in Louisiana and Mississippi since 1990 (BBCC 2005). The BBCC has enrolled the help of 60 different government, businesses, universities and organizations to help restore the Louisiana black bear throughout its historic range.

Texas Parks and Wildlife Department has recorded sightings data for black bears in East Texas since 1978 (Figure 2). There are currently no recognized breeding populations of black bears in East Texas (Garner 1994, BBCC 2005); however, sightings of black bears have been consistently increasing over time in the region. While sub-specific affinity of bears sighted in the area is unknown, most of East Texas is within the historic range of the Louisiana subspecies and all bears in East Texas are afforded both state and federal protection.

## Non-Invasive Genetic Sampling and DNA Analysis via Hair Snaring

*History and Application*— Genetic sampling is a relatively new undertaking in the field of wildlife management. Non-invasive genetic sampling (NGS) is an even newer technique that utilizes hair, feces, or other DNA sources without capturing, observing, or otherwise handling individual animals. This allows for the collection of important biological data with little to no disturbance to the animal population of interest. Non-invasive sampling was found in the literature first as a technique used to sample rare and elusive brown bears (*Ursus arctos*) in Europe (Hoss et al. 1992) and chimpanzee (*Pan troglodytes*) social structure (Morin and Woodruff 1992). This technique has been especially useful for carnivores due to their low population density and often secretive nature. Non-invasive techniques have been used to identify predators of sheep (*Ovis aries*) through saliva, infer Eurasian lynx (*Lynx lynx*) population numbers through hair-snares at scent stations, used as a way to monitor raccoon (*Procyon lotor*), marten (*Martes americana*), and fisher (*Martes pennanti*) through hair-snares, using scented hair-snares to determine ocelot (*Leopardis pardalis*) presence and population numbers, and determine the differences in scat and density of Mexican gray wolf (*Canis lupus baileyi*) and coyote (*Canis latrans*) (Belant 2003, Williams et al. 2003, Reed et al. 2004, Weaver et al. 2005, Schmidt and Kowalczyk 2006).

Due to their large ranges and low population density in most locations, black bears are particulary suited to NGS techniques. Instead of using traditional leg hold traps, culvert traps, or darting; hair snares serve as a non-invasive way to sample bear populations directly. Numerous studies on black bears have been conducted using hair snaring as a way to identify individuals, estimate abundance, and identify protected subspecies. The hairsnare setup for black bears is typically a double or single strand of barbed wire placed from 30-60 cm off the ground. The wire is stretched around trees typically in a square configuration with an attractant in the center (e.g. sardines, fish oil, pastries, berry extract). This technique is a cheaper and quicker way to sample a large geographic area with fewer personnel than traditional trapping methods. The hair collected is used to determine species and gender and to derive a unique genetic fingerprint using microsatellite DNA (mtDNA) markers. The DNA material is collected not from the hair itself, but from epidermis cells retained on the root of the hair. Grizzly bears (*Ursus arctos*) and black bears have been sampled successfully using this method (Woods et al. 1999, Mowat and Strobeck 2000, Kendall et al. 2001, Warrillow et al. 2001, Bittner et al. 2002, Boersen et al. 2003, Boulanger et al. 2004). By collecting samples over several trapping periods, mark-recapture techniques can be used to estimate abundance (reference). In addition to sex ratio and abundance estimates, genetic analysis has been used to analyze genetic drift and inbreeding within the Louisiana black bear's core areas in the Tensas River basin (Boerson et al. 2003).

However, there are potential problems with NGS using the microsatellite DNA markers that are typically used for these studies. The three common drawbacks to this methodology are low success rates due to degraded samples, contamination concerns, and microsatellite genotyping errors (Taberlet et al. 1999, Waits and Leberg 2000, Creel et al. 2003). Due to the unpredictable sample quality and quantity, low DNA amplification rate is something that cannot typically be avoided or predicted in NGS programs. Utilizing techniques that will provide adequate samples and placing potential NGS trap locations in high likelihood areas are the most efficient means to counteract the possibility of low success rates.

Contamination problems are generally associated with sample collection in the field and handling in the lab. They are elevated with NGS because the quantity of DNA is generally much less than in blood or tissue samples (Taberlet et al. 1999). As such, studies should be designed to ensure contamination is minimized. This is done by reducing the possibility of collection of two individuals from the same exact site on a trap or mixing of genetic samples. Collecting samples regularly and ensuring all genetic material is removed between samples will remedy most field contamination problems. Also, contamination by human DNA should be avoided if the species of interest is closely related to man and the possibility of human DNA being amplified is a concern. In order to eliminate contamination concerns during field collection the interval of time for sample retrieval should be adequate to prevent DNA degradation. In hot, humid environments DNA will degrade much faster than in arid, cold environmental conditions (Boersen et al. 2003). After collection proper storage of DNA material is essential in eliminating contamination and degradation risks of the genetic material. Waits and Paetkau (2005) detail various storage methodologies for both fecal and hair samples. Data replication and use of distinct mtDNA markers for the species of interest are integral in the successful analysis of genetic samples. Accounting for allelic dropout and false alleles are important laboratory procedures that need to be accounted for before final population estimates or individual identifications are made. Numerous studies have developed methods addressing these and other concerns with non-invasive genetic sampling (Taberlet et al. 1999, Miller et al. 2002, Paetkau 2003;2004, Piggott 2004, Waits and Paetkau 2005).

## Use of Habitat Suitability Indices for Quality Habitat Delineation

A Habitat Suitability Index (HSI) is a tool used to identify habitat for a specific species and give it a rating of quality based on parameters that reflect various components of the animal's life cycle. HSI indices are valuable tools for wildlife professionals as accurate models allow for quick measurements of habitat parameters, helping a manager infer information habitat quality and make appropriate management decisions. They may eliminate the need for direct study of the animal, which would typically be more expensive. The most important step in the development of a HSI model is a thorough understanding of the life cycle and ecological needs of the species being targeted. Ideally, HSI model parameters are directly based on evidence produced by long term research for the species of interest. Studies that show food preferences and needs, diet variability between seasons, cover requirements, nesting requirements, water requirements, and other variables affecting behavior are used to help develop predictive models of habitat quality and availability.

In the Pacific Northwest of the United States, an HSI model was used to map potential encroachment areas for the Barred owl (*Strix varia*) upon the endangered Northern spotted owl's *(Strix occidentalis var. caurina)* historical range (Peterson and Robins 2003). Identification of areas most likely to be affected by the barred owl will allow managers to focus removal efforts on these areas. Other HSI models have been used to identify potential osprey (*Pandion haliaetus*) nesting areas, examine areas of potential range expansion for an endangered pygmy rabbit (*Brachylagus idahoensis*) sub-species, identify areas best suited for relocations of elk (*Cervus elaphus*) in New York, the feasibility of reintroduction of black bears into an ecosystem, and prediction of the minimum habitat characteristics necessary for endangered Indiana bat (*Myotis sodalis*) to be present. (Van Manen 1991, Didier and Porter 1999, Gabler et al. 2000, Toschik et al. 2006, Watrous et al. 2006).

Several HSI models have been developed for black bear management. These models have used various different techniques to analyze, quantify, and delineate quality habitats throughout the black bears' range. Habitat suitability data for black bears has been acquired in three ways: basic field measurements (Van Manen 1991, Epps 1997, Schroeder and Vangilder 1997, Forman and Alexander 1998, Mitchell and Powell 2003, Hersey et al. 2005, Kindall and Manen 2007, Reynolds-Hogland and Mitchell 2007), through GIS spatial analysis and remote sensing (Clark et al. 1993, Tankersley 1996, Mitchell et al. 2002, Larson et al. 2003, Hellgren et al. 2007), or through a combination of the two. The parameters included are fairly consistent among the various HSI models. Typical variables that are of interest for the black bear are hard mast coverage, hard mast production, hard mast diversity, soft mast coverage, distance to water, human disturbance factors, distance/density of roads, escape cover, slope, elevation, availability of den sites, and amount of area available for habitation by bears. These variables are then combined to form overall scores for habitat areas and used in decision making processes for bear management. These models have been used as a basis to identify possible habitat linkages, areas of possible range expansion, validation of HSI models using bear locations, identifying areas of quality habitat for future relocation efforts, and comparing habitat productivity and differences between two existing bear populations.

In East Texas, two HSI models have been used for the analysis of black bear potential habitat (Garner and Willis 1998 and Epps 1997). Garner and Willis adapted a HSI model developed by Van Manen (1991) for Kentucky and used the model to analyze habitats across East Texas. This model uses 8 variables, hard mast coverage, production, diversity, soft mast coverage, tree den availability, escape cover, road density, human/bear conflict zones, to determine overall habitat quality. Garner and Willis applied this model over 276,000 hectares in the Sulphur River basin, middle and lower

Neches river basin, and Big Thicket National Preserve in East Texas and found habitats to be suitable for bears. Epps (1997) focused his efforts on the Neches and Jack Gore Baygall units of the Big Thicket National Preserve (BTNP). Instead of using relative suitability scores, Epps used direct measurements to ascertain a possible carrying capacity for these areas. Using regression equations developed for oak and hickory seed production, Epps estimated total mast production and determined a black bear carrying capacity based on their late fall nutritional needs (Goodrum et al. 1971, Nixon et al. 1980). A measurement of the availability of tree dens and analysis of human disturbance factors were the other component of his study. He found BTNP provided adequate habitat and made an estimate that there was enough mast, dens, and human conflict free area available in the fall to support 48-86 bears.

## Part I: Estimation of Occupancy and Demographics for Black Bears in East Texas

Black bears were historically widespread across North America and within Texas (Hall 1981). The expansion of human development and associated exploitation of bear habitat and populations led to a long-term, significant decline in abundance across the black bear's range. Due to perceived loss of habitat and small remnant population size the Louisiana subspecies (*Ursus americanus luteolus*) was listed as federally threatened under the auspices of the Endangered Species Act in 1992. East Texas is within the historic range of *U. a. luteolus*, and a viable, reproducing black bear population has been absent from the east Texas landscape for greater than half a century (Fleming 1980). Since a low during the mid-20$^{th}$ century bear populations have expanded in the neighboring states of Arkansas, Louisiana, and Oklahoma. Concurrently, the number of reported bear sightings in East Texas has increased since Texas Parks and Wildlife Department began collecting these data in the early 1990's. Various studies have concluded there was adequate habitat to support at least small populations of black bears in the region (Epps 1997, Garner and Willis 1998).

The identification of suitable habitat blocks, an increase in the number of bear sightings reported to Texas Parks and Wildlife Department (TPWD), and the knowledge of expanding bear populations in neighboring states led to the development of a cooperative research project between TPWD and Stephen F. Austin State University (SFASU) to collect information on the black bear population, distribution, and habitat quality within Northeast Texas. Previously, TPWD data regarding black bear occurrence was limited to voluntary sightings information from the region. Although these data are suggestive of range and occurrence, they do not provide quantitative estimates of occupancy, distribution, or demography.

Noninvasive sampling with hair snares has been used regularly to gather both abundance and distribution data in black bear research due to its relative ease of implementation and low cost in comparison to traditional trapping efforts (Mowat and Strobeck 2000, Bittner et al. 2002, Boulanger et al. 2004, Waits and Paetkau 2005, Brown 2008). We implemented a hair snare survey in three major river systems of northeast Texas—the Red, Sulphur, and Cypress basins—in the summers of 2007 and 2008 in an attempt to better describe the current status of bears in the region. We chose this area of the state in response to the TPWD sightings database documenting a preponderance of sightings in this region over the last 5 years.

**Methods**

*Study Area*

Our study included multiple properties over a large area, and we have attempted to use a consistent terminology to refer to the various areas under examination. The focal area describes the overall region of concern and includes all of Northeast Texas that was available for sampling. The study areas are particular regions or areas that have been included in the sampling effort (e.g., the Cypress River Basin or Red River County). The study sites refer to individual parcels of land that were visited for the purposes of vegetation sampling and hair snare set up and monitoring (e.g., Caddo Lake National Wildlife Refuge or the Wright Patman Lake Corps of Engineers Land).

We used sightings data collected by Texas Parks and Wildlife Department from 1978 to the present to identify our focal area (Fig. 1). The focal area chosen had high occurrence of black bear sightings in relation to other portions of East Texas, particularly from 2001-2006. More specifically, the focal area for this study encompassed three river systems in northeast Texas and their tributaries, along with forest lands adjacent to these features. These river systems were chosen because they contained the largest blocks of contiguous forest in the region; the association of black bears with bottomland habitat in Louisiana is well known (Boersen et al. 2003, Benson 2005), and these systems will likely function as corridors for movement of black bears into East Texas. Most upland habitats adjacent to river systems in East Texas have been altered by human activity in some way. Thus, using river systems as the basis for habitat identification allowed for the selection of contiguous forested blocks, linked with travel corridors such as creeks, canals, and other wooded drainages. The three river systems included in the focal area are the Red River on the Oklahoma and Texas border from Lamar County to the Texarkana, the Sulphur River from Delta County to the Texas and Arkansas border, and the Cypress River Basin from Lake O' the Pines in Cass County to Caddo Lake in Marion and Harrison counties on the Texas and Louisiana border. The entire focal area consists of 5.8 million acres in the Northeastern portion of the state.

These three river systems were analyzed using ESRI ARCGIS 9.2 software to identify contiguous forested areas equal to or larger than 25 $km^2$. This size was used as it was deemed to be a minimum area needed for a single female bear to occupy an area and be free of human intrusion. Access was acquired through contact with private landowners or public agencies as available. Public and private lands were sampled as long as they met the minimum size and habitat requirements. We also sampled other areas within east Texas opportunistically if reliable bear sightings occurred on the property. We also included land ownerships contiguous with larger study sites where access was granted, even if they did not meet minimum size requirements by themselves.

Most of the focal region is considered part of the Piney Woods eco-region and is within the western Gulf coastal plain. Average rainfall in the area ranges from 98 cm to 134 cm. The area has hot, humid summers with an average high temperature in July from 33.8$^{o}$ C to 35$^{o}$ C and cool winters with an average low temperature in January from -0.5$^{o}$ C to 1$^{o}$ C. Uplands in the area consist primarily of natural and managed pine forest dominated by loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), and longleaf pine (*Pinus palustris*). Bottomlands in the region are dominated by hardwoods consisting of oaks (*Quercus* spp.), hickories (*Carya* spp.), blackgum (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and other species. Forests in the region are fragmented and interspersed with row crop agriculture, improved pastures, recently harvested pine plantations, reservoirs, and various rights-of-way. The far western portion of the focal area along the Sulphur and Red Rivers is considered part of the Post Oak Savannah and Blackland Prairie ecoregions. These regions contain fewer pine forests and consist of post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), pecan, and elm (*Ulmus* spp.) woodlands or savannahs with native grasslands. Row crop agriculture and improved pastures are important components of the landscape, as are hardwood bottomlands similar to those described above.

*Determining Occupancy and Genetic Sampling of Black Bears*

Using the identified forested blocks and study sites on which access was granted; we established a 1.6 km x 1.6 km cell grid system over all study sites. Using this grid, we established one hair snare location subjectively within each grid cell based on ease of access, perceived areas of bear activity, travel corridors, cover, or potential feeding areas. This design resulted in a density of 1 hair snare/2.56 $km^2$. This density of hair snares is equal to or greater than that reported in the literature ( 2.7-64 $km^2$; Woods et al. 1999, Mowat and Strobeck 2000, Boersen et al. 2003, Boulanger et al. 2004). We chose this density of hair snares to allow for a higher likelihood of sampling individuals from an assumed low density black bear population. Hair snares were constructed of two parallel strands of four-point barbed wire approximately 30 cm and 60 cm above the ground. In the center, approximately 1.5-2 m above the ground, we hung an olfactory attractant: generally three partially opened sardine cans. In Summer 2008, we added a sweet olfactory attractant such as molasses or fruit extract (Woods et al. 1999, Bittner et al. 2002, Boersen et al. 2003). We maintained hair snares for at least 4 weeks and checked every 7-10 days. Attractant was refreshed as necessary during weekly visits.

During weekly checks, we also collected all hair adhering to any part of the snare apparatus (e.g., barbs, wire, support trees). Hair found at snaring locations was examined and screened in the field to eliminate samples that were clearly from another species (e.g., raccoons). Although hair characteristics vary, the most common screening characteristics included banding, length, color, and texture. Any black or white hairs were placed inside a No.5 coin envelope, individually labeled with the snare location, location on wire (top/bottom), cardinal direction of snare wire, and collectors, and stored at room temperature with silica dessicants (Bittner et al. 2002). Previous studies have indicated that a minimum of three hairs are needed for reliable amplification and five hairs or more are optimal for genetic identification; however, we collected all hairs for later screening to identify viable samples (Waits and Paetkau 2005). After collection of the hair was complete, all collection sites (barbs) were burned using a propane lighter. Genetic analyses were performed at Wildlife Genetics International, Nelson, BC, Canada. In addition to species identification, we used genetic techniques to determine gender and derive a unique genetic fingerprint.

The snare results were tabulated as a series of one-week survey periods with presence of bear hair considered a positive, result and absence of bear hair a negative result. These presence-absence data were analyzed according to the methodology implemented in program PRESENCE (MacKenzie et al. 2002, MacKenzie 2005).

**Results**

Using the ArcGIS 9.2 software and satellite imagery, approximately 3,285 $km^2$ of habitat within 19 separate, contiguous forest habitat blocks were identified in the Northeast Texas focal area (Figure 2). Access was gained and sampling conducted on approximately 850$km^2$ of land ownership; consisting of 22 properties with different land owners combined as 18 study sites (Figure 3). In summer of 2007, 141 individual hair snaring locations were established, and were available for hair collection 4,814 trap nights. In summer of 2008, 191 individual hair snaring locations were established, and monitored for 5,550 trap nights. Over the course of the study each hair snaring location was checked a minimum of 4 times and a maximum of 13 occasions. Of the total 332 hair snares established 297 were checked for genetic samples 4 times, 30 were checked 5 times, and 5 were checked on greater than 5 occasions.

These trapping efforts resulted in the collection of 29 hair samples in summer of 2007 to be sent for analysis and 32 hair samples in summer of 2008. Of these samples one field-collected sample from summer 2007 came back positively identified as black bear.  Two positive controls—a preserved sample from a 1999 road-killed bear from near Mt. Vernon, TX on I-30, and one from a captive bear in the collection at the Ellen Trout Zoo in Lufkin, TX—also came back as positive black bears.  These three samples were all males with unique genotypes (Table 1).  No hair samples from 2008 were identified as black bears.

All sampling data organized as 1 week sampling intervals were entered into Program PRESENCE.  With one positive detection over the two years, we were unable to derive reliable detection probability or occupancy estimates.

**Discussion**

The limited success of the hair snare sampling was not surprising.  The focal area is in the early stages of recolonization by black bears and bears are both widely dispersed and likely to be transient.  We did not determine the subspecific affinity of the bear sampled in Red River County; however, it is most likely to be *U. a. americanus.* Breeding populations in Oklahoma are within 30 miles of the sample location and the bear population within the Ouachita National Forest is demographically young and apparently expanding (Bales et al. 2005, Brown 2008).

A preponderance of males is typical for expanding bear populations (Schwartz and Franzmann 1992).  Subadult male bears have much higher dispersal rates than females or adult males.  They may be are excluded from their natal territories by their mother or mature male bears.  It is common for these young bears to move distances over 20km (Rogers 1977;1987).

The idea that Red River County and its vicinity are in the early stages of recolonization is consistent with TPWD sightings information.  Photographic evidence and reliable sightings in the region have not revealed aggregations of multiple bears (e.g., a female and cubs or yearlings) typical of a reproducing population. Some bears in photographs appear to be mature, indicating that they are staying in the area at least until early adulthood. Portions of Red River County have had regularly documented evidence of bears since 2006 on the same properties.

Prior to the initiation of this study, the current status of black bears in the region was unclear. Although the TPWD sightings database provided valuable anecdotal information, these data were not quantitative and the likelihood of a bear going undetected was unknown. Our expectation was that we would document additional bears that had gone undetected through the existing sightings database; however, the extensive hair snaring effort did not document any bears that were previously undetected. A black bear was both sighted and recorded on a remote camera in the area of our hair snare at the time we collected our bear sample. Although we were unable to derive reliable detection probability estimates, our design was such that it was unlikely a bear in the area would go undetected. If we conservatively assume a bear will be detected 10% of the time by a hair snare in its home range for a week, the chance of its going undetected by our methods (4 hair snares per home range and 4 weeks) is less than 20%. At a weekly per-snare detection probability of 30%, the chance of going undetected is less than 1%.

Thus, it appears that the current system of investigating and documenting sightings by the general public provides an effective index to black bear distribution. These data could not be used to definitely define the range or estimate abundance but a program of public information gathering being substantiated by coordinated university research and natural resource agency efforts every 7-10 years would be a legitimate short-term monitoring program.

This study covered approximately 25% of the total area of contiguous forest blocks (> 25 $km^2$) identified (850$km^2$ of 3,285$km^2$). In effect 75% of identified suitable habitat was never visited or sampled. If the remainder of the contiguous forest supports a density of bears similar to that we documented, then the maximum number of bears occupying the region is in the range of 5-10. The TPWD sightings data list 5 Category I sightings (sightings which can be substantiated with physical evidence such as tracks, hair, pictures, etc) in the focal area from September 2009- December 2009 (Ricky Maxey, TPWD personal communication).

Thus, the overall success of our sampling efforts was limited, but the potential for bears to persist outside our sampling area has to be recognized. As such the economical and appropriate choice for black bear population monitoring would appear to be the collection and analysis of sightings data from the public; coupled with the knowledge, coinciding investigations, and observations of resource professionals.

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**Part II: Assessment of Habitat Suitability of East Texas for Black Bears**

Habitat Suitability Indices (HSI) for ecological and species specific habitat assessments are well utilized tools for making wildlife management decisions (Didier and Porter 1999, Gabler et al. 2000, Larson et al. 2003, Peterson and Robins 2003, Toschik et al. 2006). These analyses incorporate both landscape/habitat features and species related biological requirements to assign a rating for habitat quality across large geographic areas. This method serves as a way to predict use or availability of habitat for wildlife species without the time, expense, or unpredictability of searching or trapping for the animals.

The use of HSI models for assessment of black bear habitat has been widespread in the Southeastern United States (Van Manen 1991, Tankersley 1996, Mitchell et al. 2002, Kindall and Manen 2007). This research has been used to identify habitat linkages, delineate suitable habitat for reintroductions, and prioritize areas for conservation efforts. Each of the Southeastern states contains a bear population, with breeding populations documented in Arkansas, Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee. Texas, specifically the eastern portion of Texas, remains as one of the largest unoccupied areas of apparently suitable black bear habitat in the southeast.

The eastern portion of Texas is the western extent of the southeastern forest type. It is a natural crossroads of ecosystems and as such also served as the historic range of 2 subspecies of black bear: the American black bear (*Ursus americanus americanus*) and the Louisiana black bear (*Ursus americanus luteolus*). This is particularly relevant in light of the Louisiana black bear’s listing in 1992 as threatened under the auspices of The Endangered Species Act (BBCC 2005).

The use of HSI models to evaluate black bear habitat within East Texas has been conducted in the past (e.g., Epps 1997, Garner and Willis 1998). These studies focused on either specific areas (Big Thicket National Preserve) or were conducted greater than 10 years ago. With increasing black populations in adjacent states and increasing numbers of bear sightings in East Texas, Texas Parks and Wildlife Department (TPWD) deemed it necessary to reevaluate habitats for black bears in the region. The first priority was assigned to northeastern Texas due to the preponderance of recent (within 5 years) black bear sightings in this area (Fig. 1). The primary objective of this portion of the study was to assess habitats within Northeast Texas for suitability of long term habitation by black bears. We used an HSI model developed for the Southern Appalachians (Van Manen 1991) and used previously in East Texas to derive quantitative estimates of habitat suitability in the region (Garner and Willis 1998). These analyses would not only provide a “snapshot” of black bear habitat suitability in the region but also allow comparison with previous surveys to estimate how much habitats have changed.

**Methods**

*Study Area*

Our study included multiple properties over a large area, and we have attempted to use a consistent terminology to refer to the various areas under examination. The focal area describes the overall region of concern and includes all of Northeast Texas that was available for sampling. The study areas are particular regions or areas that have been included in the sampling effort (e.g., the Cypress River Basin or Red River County). The study sites refer to individual parcels of land that were visited for the purposes of vegetation sampling and hair snare set up and monitoring (e.g., Caddo Lake National Wildlife Refuge or the Wright Patman Lake Corps of Engineers Land).

We used sightings data collected by Texas Parks and Wildlife Department from 1978 to the present to identify our focal area (Fig. 1). The focal area chosen had high occurrence of black bear sightings in relation to other portions of East Texas, particularly from 2001-2006. More specifically, the focal area for this study encompassed three river systems in northeast Texas and their tributaries, along with forest lands adjacent to these features. These river systems were chosen because they contained the largest blocks of contiguous forest in the region; the association of black bears with bottomland habitat in Louisiana is well known (Boersen et al. 2003, Benson 2005), and these systems will likely function as corridors for movement of black bears into East Texas. Most upland habitats adjacent to river systems in East Texas have been altered by human activity in some way. Thus, using river systems as the basis for habitat identification allowed for the selection of contiguous forested blocks, linked with travel corridors such as creeks, canals, and other wooded drainages. The three river systems included in the focal area are the Red River on the Oklahoma and Texas border from Lamar County to the Texarkana, the Sulphur River from Delta County to the Texas and Arkansas border, and the Cypress River Basin from Lake O' the Pines in Cass County to Caddo Lake in Marion and Harrison counties on the Texas and Louisiana border. The entire focal area consists of 5.8 million acres in the Northeastern portion of the state.

These three river systems were analyzed using ESRI ARCGIS 9.2 software to identify contiguous forested areas equal to or larger than 25 $km^2$. This size was used as it was deemed to be a minimum area needed for a single female bear to occupy an area and be free of human intrusion. Access was acquired through contact with private landowners or public agencies as available. Public and private lands were sampled as long as they met the minimum size and habitat requirements. We also sampled other areas within east Texas opportunistically if reliable bear sightings occurred on the property. We also included land ownerships contiguous with larger study sites where access was granted, even if they did not meet minimum size requirements by themselves.

Most of the focal region is considered part of the Piney Woods eco-region and is within the western Gulf coastal plain. Average rainfall in the area ranges from 98 cm to 134 cm. The area has hot, humid summers with an average high temperature in July from $33.8^{o}$ C to $35^{o}$ C and cool winters with an average low temperature in January from $-0.5^{o}$ C to $1^{o}$ C. Uplands in the area consist primarily of natural and managed pine forest dominated by loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), and longleaf pine (*Pinus palustris*). Bottomlands in the region are dominated by hardwoods consisting of oaks (*Quercus* spp.), hickories (*Carya* spp.), blackgum (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and other species. Forests in the region are fragmented and interspersed with row crop agriculture, improved pastures, recently harvested pine plantations, reservoirs, and various rights-of-way. The far western portion of the focal area along the Sulphur and Red Rivers is considered part of the Post Oak Savannah and Blackland Prairie ecoregions. These regions contain fewer pine forests and consist of post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*), pecan, and elm (*Ulmus* spp.) woodlands or savannahs with native grasslands. Row crop agriculture and improved pastures are important components of the landscape, as are hardwood bottomlands similar to those described above.

*Implementing the HSI Model*

Using the HSI model developed for the southern Appalachians and used again in Texas, habitat was assessed for each study site, in each river basin, and across the focal area (Van Manen 1991, Garner and Willis 1998). Vegetation data were collected at randomly located sampling points within each study site boundary at a density of approximately 1 per 1.28 $km^2$.

At each sampling point over-story trees, soft mast producing species, vegetation density readings, and GPS location were recorded. We analyzed the habitat data using the HSI model and methods developed by Van Manen (1991), with modifications (detailed below) to better fit East Texas. The HSI model utilizes eight variables to determine habitat value. Each variable was assigned a score, between 0.00 and 1.00 with 1.00 being optimal; scores were based on vegetation data from random plots or using landscape-level analysis in ArcGIS 9.2 (ESRI, Inc.). These eight variables are combined into three sections (food component, cover component, and human impact component) that were calculated separately before being combined for an overall HSI score. The eight variables within these three sections were calculated as follows:

1) **Summer food availability**: Summer food availability was determined using 4, 5x5 meter plots. Relevé plots were established with the point centered quarter method (Mueller-Dombois and Ellenberg 1974), in which a 5x5 meter subplot was established using the nearest tree to plot center in that quarter as the southeast boundary marker for the relevé plot. We recorded all summer soft mast producing

species within the relevé plots and calculated a total percentage cover score from 0-100 (%) in 5% increments. All soft mast producing plant species from the ground to the upper canopy were given a coverage score. Upon completion of data collection for each study site, the coverage data were averaged for each study area to determine soft mast coverage. We then assigned a final HSI score for this variable. Habitat was considered optimal and given an HSI value of 1.0 when soft mast producing species are ≥10% or greater of the cover component.

2) **Fall food availability**: Fall food availability was measured using a 0.04 hectare plot around plot center. All trees greater than 15 cm diameter at breast height (DBH) were measured and recorded by species. Basal area was calculated for all species and the proportion of hard mast producing species was determined for the each plot. Fall food availability was assigned a score of 1.0 (optimal) if 40% or more of the basal area consisted of fall mast producing species, including oaks, hickories, American beech (*Fagus grandiflora*), black walnut (*Juglans nigra*), and black/swamp tupelo (*Nyssa* spp.).

3) **Fall food productivity**: We used the data collected in the 0.04 hectare plot to calculate fall food productivity also. Although Van Manen (1991) used tree age to calculate mast productivity, data for this region suggest that production data (Goodrum et al. 1971, Nixon et al. 1980) are more strongly correlated with tree size (DBH) than tree age. Therefore, we used DBH measurements to determine fall food productivity. At ≥40.6 cm DBH fall mast production was more consistent and greater volume for oaks and hickories, the two most abundant fall mast producing genera in East Texas (Goodrum et al. 1971, Nixon et al. 1980). The HSI value for fall food

productivity was determined by calculating the percentage of mast producing species in each plot that were equal to or greater than 40.6 cm at DBH. This variable is given a score of 1.0 if between 40 and 60% of hard mast producing trees (of all species) were of DBH 40.6 cm or greater.

4) **Fall Food Diversity**: Fall Food Diversity is a measure of the number of hard mast groups available for consumption by black bears. These groups were divided into Red Oak (Eurythrobalanus), White Oak (Leucobalanus), Hickory (*Carya* spp.), and a miscellaneous group containing other species such as American beech, black walnut, and swamp/black tupelo. The basal area measurements for these groups were determined using the data collected in the 0.04 hectare plot. Codominance (as measured by proportion of basal area) of two or more distinct hard mast groups yielded an optimal HSI of 1.0 for fall food diversity.

5) **Protection cover**: Protection cover was measured using a vegetation cover pole placed 15 m from the observer in each directional quarter (Nudds 1977, Griffith and Youtie 1988). Density readings were analyzed by the percentage of readings that were in impenetrable understory, defined as readings that score 4-5, on a 0-5 scale of vegetation density with a 0 reading being completely visible and a 5 reading being entirely obscured by vegetation (Griffith and Youtie 1988). Based on cover pole measurements, if impenetrable understory vegetation comprised between 25-50% of the measurements, this variable received a score of 1.0.

6) **Tree den availability:** Tree den availability was documented using the data from the 0.04 hectare plot. The number of potential den trees was documented and then divided by the total number of random vegetation plots for that study site. This

will give the relative proportion of tree dens for the study area. Van Manen (1991) stated optimum tree den availability is thought to occur in areas where 5-10% of the area contained well distributed old growth hardwood. These areas received a 1.0 score; score decreased as old growth became more than 10% of forest due to decreases in food and protection requirements. Garner (1994) measured this variable using trees greater than 100 years of age; however, tree size (DBH) may be a better measure of den suitability than age. Tree age is not directly correlated to DBH, and DBH appears to be a limiting factor in the use of den trees for black bear. A DBH of 84 cm was the minimum size used by denning bears in White River NWR; therefore, we used a 84 cm DBH limit to define a suitable den tree (Oli et al. 1997).

7) **Open road density**: Open public road density was calculated using ArcGIS 9.2 by summing the length of federal, state, and county, and other public paved surface roads within a study area. This number was then divided by the total study area sampled to attain a road density estimate in road km per $km^2$. Only roads that are within or border the study sites were considered for these calculations.

On the Pisgah National Forest in North Carolina bears avoided areas that had $0.5km/km^2$ and higher densities of open improved roads (Brody 1984). Van Manen (1991) used this value as a marker of when bears would begin to stop "efficiently exploiting their habitat". Open road density is considered to be optimal when no roads are present and the HSI score sharply decreases as roads increase.

8) **Human/Bear Conflict Zones:** Human/bear conflict zones were measured using ArcGIS 9.2. A 2.8 km buffer was placed around potential human conflict areas, including concentrations of housing, towns, agriculture operations, campsites, and

garbage dumps. This buffer distance reflects Van Manen’s (1991) statement that a typical female black bear will not travel more than 2.8 km from their core area. Study sites that have 0-15% of the land area in potential human/bear conflict zones will be given a score of 1.0.

The 8 component variable scores were then combined to give an overall HSI score for the study site (Tables 1 & 2). Individual properties within a river system were combined and all vegetation plots taken into account to assign an overall HSI score for that study area and within the three major river basins. Further measurement specifics and explanations are available in Van Manen (1991), Garner and Willis (1998), and Tables 1 & 2.

*Identify Core Areas of Black Bear Habitat*

Using a combination of the satellite imagery to identify large forested areas and HSI model results, core habitat areas were defined. These areas could be used as areas to monitor for immigrating bears that enter from neighboring states in the future. They also can be evaluated for future use as areas of potential reintroduction efforts. Productive areas will have high overall scores from the HSI model and be large enough to provide habitat for a minimum viable population of 50 bears (Franklin 1980, Soule 1980). This population size would be of adequate size to prevent or minimize the possibility of inbreeding or other detrimental effects of small population size in the short term.

Using the HSI model, we assigned overall suitability scores for all surveyed study sites. If areas were capable of supporting a minimum of 50 bears from relocation efforts or natural repatriation they were deemed suitable core habitat areas. These areas were a minimum of 300km$^2$ based on the estimate of female Louisiana black bear average home range size and 50 individual bears. We used satellite imagery and spatial analysis to delineate suitable areas that had high scores from the HSI model, met the size criteria, and also exhibited stable ownership and land use patterns. Furthermore, we used the HSI model to identify habitat variables that limit current suitability for black bears and that could be managed and improved for black bear habitat within the focal region.

## Results

### *Assess Habitat using HSI Model*

Using the ArcGIS 9.2 software and satellite imagery, approximately 3,285$km^2$ of habitat within 19 separate, contiguous forest habitat blocks were identified in the Northeast Texas focal area (Figure 2). Access was gained and sampling conducted on approximately 850$km^2$ of land ownership; consisting of 22 properties with different land owners combined as 18 study sites for HSI calculations (Figure 3). In summer of 2007 and 2008, a total of 799 random vegetation plots were established. These random plots were used to calculate overall habitat suitability scores that varied widely across study sites; from 0.43-0.78 out of a possible 1.0 overall score on the 18 study sites visited (Figure 4 and Table 3). The 3 components that were combined to formulate the overall score were variable across properties. The food component scores ranged from 0.42-0.89 across study sites, with the average being 0.75 (Table 3). Cover component scores averaged 0.87, with a range of 0.44-1.00 among study sites (Table 3). Human impact scores were the lowest overall and appeared to be the most important limiting factor. The human impact component scores averaged 0.27, with a range of 0.00-0.47 between study sites. There were 5 separate sites that scored a 0.00 for the human impact component (Table 3).

When study sites were combined into study areas by river basin, scores ranged from 0.59-0.73 out of a possible 1.0 (Tables 4 & 5). The amount of land area sampled and number of vegetation plots were inconsistent across study areas as land access was not equally distributed between river basins. This was due in part to the location of various land owner holdings and access to public and industrial timber lands. (Table 6)

*Identification and Delineation of Quality Habitat*

Based on the results of our analysis two areas appear to be capable of supporting black bear populations long-term. The first area is in Northern Red River County roughly centered on Pecan Bayou, a tributary of the Red River. The second area is along the middle and eastern portions of the Sulphur River from White Oak Creek Wildlife Management Area east to the Arkansas border.

The northern Red River County area consists of a contiguous forested area of approximately 597 $km^2$. With adjacent habitats, we estimated about 975 km2 of habitat suitable for black bears (Figure 5). This forested area is approximately double the minimum area theoretically needed to support a minimum viable population. The large habitat size, high HSI scores on properties visited, and proximity to breeding bear populations in Oklahoma and Arkansas (less than 35km) combine to make this area a high priority for future management, monitoring, and education efforts. (Figure 6)

The area identified along the Sulphur River is approximately 754$km^2$ in size, and 535$km^2$ is forested. This area runs for 75 km from White Oak Creek WMA to the Arkansas border. It is intersected by roads at only 4 locations along this stretch and large portions, 340$km^2$, are owned in perpetuity by governmental agencies. The continuity of landownership, property size, and road density make this an appealing area for bear management (Figure 4). This area also has a history of high habitat suitability for black bear. In 1994-96 habitat was assessed in this area and was found to have an overall HSI score of 0.76 using the same Van Manen model. (Garner and Willis 1998) Twelve years later during our assessment in Summer of 2008 this area again scored well using Van Manen's HSI model with an overall score 0.71 for the Sulphur River Basin (Table 6).

**Discussion**

The various study sites across Northeast Texas scored higher overall than anticipated. The areas visited varied in their land uses from multi-use Federal government lands, state wildlife management areas, cattle ranches, recreational properties, hunting clubs, timber production operations, and any combination of the above. It was therefore pertinent to identify, using the HSI scores as a base, variables that were most limiting in the long and short term to immigrating black bear population establishment for Northeast Texas.

*Variables Deemed Non-Limiting within the HSI*

Across sites both summer food and escape cover variables of the HSI scored well. The abundance of rainfall and interspersion of open areas (logging decks, cattle pastures, natural openings, wetlands, etc) with wooded habitat left a multitude of edge habitat available for soft mast producing shrub and vine species to proliferate. The most common soft mast producing species encountered were: wild grape (*Vitis* spp.), greenbriar (*Smilax* spp)., American beautyberry (*Callicarpa americana*), dogwood species (*Cornus* spp.), poison ivy (*Toxicodendron radicans*), black berry (Rubus spp.), blue berry (*Vaccinium* spp.), pepper vine (*Ampelopsis arborea*), rattan (*Berchemia scandens*), common persimmon (*Diospyros virginiana*), and Virginia creeper

(*Parthenocissus quinquefolia*) (Table 7). Other studies across the Southeastern states have documented the use of these species by black bears (Landers et al. 1979, Smith 1985, BBCC 2005, Benson 2005). The abundance and quality of summer food species for black bears make clear that the availability of food during the growing season is not limiting. On every site that vegetation sampling was conducting during the study the HSI variable for summer food received a score of 1.00 (Table 3).

The cover component, which included both the tree den availability and escape cover variables, was also deemed a non-limiting factor in the establishment of bear populations. The initial logging of Northeast Texas that occurred during the late $19^{th}$ and early $20^{th}$ centuries eliminated most large stands of old-growth forest from the landscape. The lone exception we encountered during the course of the study was the 140 hectare Lennox Woods Preserve, managed by the Nature Conservancy. This area has never been logged according to Conservancy records, which date to pre-1870. The majority of the forest-types encountered on study sites were $2^{nd}$, $3^{rd}$, and sometimes $4^{th}$ or even $5^{th}$ generation re-growth from previous harvesting. This repetitive cutting, often done in a time before forest best management practices, limited the number of available large diameter den trees. Our study used 84 cm dbh (Oli et al. 1997) as the minimum diameter for a tree to be considered suitable for use as a tree den. It was rare to encounter these trees across the landscape and consequently few areas scored well in the tree den component of the HSI (Table 3).

However, Northeast Texas is not limited with den sites as areas had high escape cover components (Table 3). Of the 18 study sites visited 13 had HSI scores of 0.90 or higher, and properties that scored lower were often assigned lower scores as a result of vegetation densities deemed too thick. This subtraction from the suitability score was deemed necessary as dense vegetation impacts plant competition and thereby food production. Large areas of switchcane, greenbriar thickets, young re-growth of pine plantations or bottomland, and other vegetation communities that were present seemed to provide adequate cover to serve as den sites for bears. This is without taking into consideration logging slash, abandoned buildings, and other natural or man made cover. The use of these sites has been documented for other bear populations and tree dens do not appear to be necessary for successful parturition (Schooley et al. 1994, Oli et al. 1997, Benson 2005) In flood prone areas tree dens may be a limiting factor for reproduction, but in all sites visited higher elevations out of the flood plain within bottomland areas were in close proximity as an alternative den location. Furthermore, most timber producing properties now protect trees along watersheds leaving streamside management zones (SMZ's). These SMZ's can provide suitable den trees in the future.

*Variables for Future Management Emphasis and Monitoring*

Fall food variables had the most emphasis placed upon them within this particular HSI model. Therefore, small differences in fall mast producing species measurements could result in quite a different HSI score across study sites. The majority of the study sites had scores above 0.75 for Fall Food availability, but 10 of 18 properties had scores below 0.50 for Fall Food productivity (Table 3). Most study sites visited contained a diverse mixture of hard mast producing species but there were relatively few areas dominated by trees capable of producing large, consistent mast crops. Trees a minimum of 40.6 cm at DBH or larger based upon past research in East Texas were deemed necessary to produce the amount and consistency of mast desired (Goodrum et al. 1971). The proportion of large diameter trees capable of producing consistent, large mast crops varied across properties. Areas that had a history of land use geared towards pine production tended to have fewer mast producing trees present as a percentage of trees sampled in total. In most areas sampled, with the exception of some private lands in Red River County and public lands along the Sulphur River, forest stands capable of producing large mast crops were generally restricted to flood prone areas or areas that had been specifically set aside as wildlife production areas.

Fall productivity of large diameter mast producing species could prove important in the fate of the establishment of black bear in Northeast Texas. While large trees were not common, they were found in sufficient abundance to produce adequate mast crops for turkeys, squirrels, deer, and wild hogs in the sites visited. Although having a forest consisting entirely of 40cm or greater trees may be optimal, the ability of numerous smaller trees to produce an adequate mast crop should not be discounted. Furthermore, just as the management of SMZ's will benefit the development of tree dens it may also lead to an increase in large diameter mast producing species.

The diversity of fall hard mast producing species is another issue of management priority within areas visited. The mast groups were divided into the red oak, white oak, hickory, and a miscellaneous group for comparisons of relative co-dominance based upon basal area. In all, 13 of the 18 study sites visited had a community dominated by only one mast group (i.e., no codominance). This lack of mast production diversity resulted in lower HSI scores for those properties. Red oak was the dominant mast group across most of the sites. This lack of diversity is a concern when looking at mast diversity as a hedge against total mast failure in any given year due to differences in breeding morphology and mast development in different mast producing species groups.

The availability of shelled corn from wildlife feed stations scattered across the area may contribute to fall food availability but is difficult to quantify. Hunting over bait is legal in Texas, and feeders are spread across the landscape in most rural areas. Use of corn feeders by bears has already been documented in Northeast Texas by game cameras.

The knowledge of the relationship between animals and seasonal fall mast crops allows for careful consideration of circumstances when making important forest management decisions. The recommendations for properties are geared towards the private landowner as public lands visited were in general acquired within the last 50 years and most within the last 20 years. Thus management strategies developed by the public entities (US Corps of Engineers, TPWD, USFWS, Nature Conservancy) on properties in Northeast Texas to increase diversity and productivity of hard mast species are only now beginning to reach their goals and objectives. The ability to instill in private landowners the importance of maintaining tracts or pockets of older age class forest that contain diverse, mature hard mast producing tree species will be integral in providing quality habitats to black bear across Northeast Texas. The removal of large diameter mast producing trees across the landscape would make difficult the task of replacing this high energy food source. The development and implementation of guidelines via the Texas Forestry Association or Texas Forest Service can prove effective through recommendations to landowners. The leaving of hard mast species greater than 25 cm DBH within pine production areas and other sites should allow for moderate mast crops to be produced when 10-15 trees per acre are present (Goodrum et al. 1971, Nixon et al.

1980). This, coupled with management within SMZ's, should allow for greater mast production around pine production areas.

*Limiting Variables Identified within the HSI*

Within the HSI model no component scored as consistently low as the human impact component. The human impact component was comprised of the road density variable and human/bear conflict area variable. Across study sites and study areas the human/bear conflict variable scored 0.00 at all visited (Table 3). Analysis revealed that based upon satellite imagery that in all sites ≥75% of land area was within 2.8 km of a human conflict zone (chicken houses, subdivisions, houses, bee hives, deer camps, etc.). This serves as a reminder of how densely populated most of Northeast Texas is. Road densities were also well over the limit set by Van Manen on many sites as 6 of 18 sites scored 0.00 for that variable.

To further refine the influence of road density on bears, we conducted a GIS analysis of road and population densities for several U.S. counties that have growing bear populations in Oklahoma, Arkansas, and New Jersey. We calculated total Federal, state, and county road lengths in each county divided by the total land area within the county. Population density data were gathered using the US Census information from the year 2000. All of these counties had healthy or expanding bear populations, and all but Sussex County, NJ had bear seasons in 2009. The comparison showed that most of the focal area counties had a higher human population than neighboring Oklahoma and Arkansas counties. However, Sussex County, New Jersey's population density almost tripled the highest density county in the focal area and is still supporting a bear population (Table 8). Sussex County, NJ was used as a possible upper limit of what would be considered possible for a black bear to inhabit with the related road and human population densities. Road densities across counties were relatively similar with all of the counties analyzed having a road density above the 0.5km/km$^2$ threshold that was used by the HSI model (Table 8).

This comparison brings up interesting arguments as to the suitability of the Northeast Texas focal area overall. Food and Cover variables scored well across sites, and it was the human component of the HSI that typically lowered suitability scores. Although Northeast Texas is not a vast wilderness capable of rapid, contiguous colonization by immigrating bears, these habitats can provide necessary life requirements for a bear with pockets of habitat free of human intrusion and impact. This is true for most of the areas black bear occupy across the Southeast. The bears are restricted to areas that allow them to thrive and are isolated from other bear populations. The few exceptions are bears in the Ouachita and Ozark National Forests of Arkansas and Oklahoma as these are very large public land holdings that allow for freedom of movement not seen in most other southeastern states. States such as Louisiana, Florida, Georgia, and parts of coastal North Carolina have bear populations that are located within highly fragmented and localized habitats that are largely free from immigration and emigration. (Landers et al. 1979, Seibert 1993, Benson 2005, Dobey et al. 2005) This would lead one to believe that although conditions are not ideal; they are conducive to the establishment of a bear population. This is particularly true in areas of northern Red River County and the Sulphur River drainage as both of these areas contain relatively low road densities, and consequently much lower population densities in relation to other counties in the focal area.

*Identification and Delineation of Quality Habitat*

The use of the HSI model and land ownership patterns allowed for the designation for priority areas to be designated as hot spots for monitoring and education efforts. The data gathered during the study and the coupling of black bear sightings data made this task fairly straightforward. Northern Red River County and the lands along the Sulphur River and White Oak Creek drainages stand out as areas worthy of designation. These areas contain relatively large, stable land ownerships and a history of black bear sightings. The obvious motive of selecting these areas because of bear activity is also substantiated by their high HSI scores.

Other areas to the northwest along the Sulphur River, to the west along White Oak Creek, and to the north of Wright Patman Lake have forested blocks that are separated by Interstate 30 and therefore not considered contiguous. It is assumed that I-30 serves as a hindrance to bear movements much as I-20 serves as a barrier in Louisiana. For example, a male bear was killed by a vehicle along I-30 near Mt. Vernon, TX in May 1999.

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Table 1. Van Manen's Habitat Suitability Index Calculations for the Eight Variables within the Model.

| Variable | Calculations | | | |
|---|---|---|---|---|
| **Food** | | | | |
| | **0-9.9 (%)** | **10-100 (%)** | | |
| **Summer Food** | $V_1$ = (X)*10 | $V_1$ =1.0 | | |
| | **0-15 (%)** | **15.1-39.9 (%)** | **40-100 (%)** | |
| **Fall Food Availability** | $V_2$ = 0.0 | $V_2$ = ((X) - 0.15)*4 | $V_2$ = 1.0 | |
| | **0-39.9 (%)** | **40-60 (%)** | **60.1-79.9 (%)** | **80%-100(%)** |
| **Fall Food Productivity** | $V_3$ = (X) * 2.5 | $V_3$ = 1.0 | $V_3$ = 1- (((X) - 0.60) * 5) | $V_3$ = 0.0 |
| | **1 group** | **2 or more groups** | | |
| **Fall Food Diversity** | $V_4$ = 0.5 | $V_4$ = 1.0 | | |
| **Cover** | | | | |
| | **0-24.9 (%)** | **25-50 (%)** | **50.1-100 (%)** | |
| **Protection Cover** | $V_5$ = (X) * 4 | $V_5$ = 1.0 | $V_5$ = 1.0 - (((X) - 0.50) * 2) | |
| | **0-4.9 (%)** | **5-10 (%)** | **10.1-100 (%)** | |
| **Tree Den Availability** | $V_6$ = (X) * 20 | $V_6$ = 1.0 | $V_6$ = (-0.556 * (X)) + 1.0556 | |
| **Human Impact** | | | | |
| | **0.0-0.6 (km/km$^2$)** | **0.61(km/km$^{2)}$ and greater** | | |
| **Open Road Density** | see table in Van Manen (1991) | $V_7$= 0.0 | | |
| | **0-15 (%)** | **15.1-25 (%)** | **25.1-100 (%)** | |
| **Human/Bear Conflict Zones** | $V_8$ = 1.0 | $V_8$ = 1 - (((x) - 0.15) * 10) | $V_8$ = 0.0 | |

Where X = the percentage of the variable in decimal numeration

Table 2. Calculation for Overall Habitat Suitability Score using Van Manen's (1991) Model for the Southern Appalachians

| Component | Calculation |
|---|---|
| Fall Food Component for Overall Food | $\text{Fall Food}_{(FF)} = \dfrac{V_{2FFA}+V_{3FFP}+V4_{FFD}}{3}$ |
| **Overal Food Component** | $HSI_{Food} = (V_{1SF} * (FF)^{2})^{1/3}$ |
| **Cover** | If $V_{5TD} > V_{6PC}$<br>$HSI_{Cover} = \dfrac{V_{5TD} + V_{6PC}}{2}$<br>If $V_{5TD} \leq V_{6PC}$<br>$HSI_{Cover} = V_{6PC}$ |
| **Human Impact** | $HSI_{Human\ Impact} = \dfrac{(V_{7RD} + V_{8CZ})}{2}$ |
| **Overall** | $HSI_{Overall} = \dfrac{(HSI_{Food} * 2) + HSI_{Cover} + HSI_{Human\ Impact}}{4}$ |

**Table 3.** Habitat Suitability Index by Variable, Component, and Overall Suitability Score for Individual Study Sites Visited in Northeast Texas during Summer 2007 & 2008.

| **Study Area** | **Index Variables** | | | | | | | | | | | **Overall** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Summer Food (v1) | Fall Food Availability (v2) | Fall Food Productivity (v3) | Fall Food Diversity (v4) | **Food Component Score** | Protection Cover (v5) | Tree Den Sites (v6) | **Cover Component Score** | Open Road Density (v7) | Human/Bear Conflicts (v8) | **Human Impact Component Score** | **HSI Score** |
| RRAAT | 1.00 | 0.37 | 0.68 | 0.50 | **0.65** | 0.44 | 0.00 | **0.44** | 0.45 | 0.00 | **0.23** | **0.49** |
| RRBAR | 1.00 | 1.00 | 0.23 | 1.00 | **0.82** | 0.99 | 1.00 | **0.99** | 0.00 | 0.00 | **0.00** | **0.66** |
| RRCCR | 1.00 | 1.00 | 0.38 | 1.00 | **0.86** | 0.92 | 0.96 | **0.94** | 0.93 | 0.00 | **0.47** | **0.78** |
| RRDGWR | 1.00 | 1.00 | 0.53 | 1.00 | **0.89** | 0.67 | 0.00 | **0.67** | 0.78 | 0.00 | **0.39** | **0.71** |
| RREGR | 1.00 | 1.00 | 0.59 | 0.50 | **0.79** | 1.00 | 0.00 | **1.00** | 0.00 | 0.00 | **0.00** | **0.64** |
| RRFJH | 1.00 | 0.00 | 0.30 | 0.50 | **0.42** | 0.68 | 0.00 | **0.68** | 0.44 | 0.00 | **0.22** | **0.43** |
| RRGTALW | 1.00 | 0.73 | 0.67 | 1.00 | **0.86** | 0.98 | 0.00 | **0.98** | 0.53 | 0.00 | **0.27** | **0.74** |
| Pat Mayse WMA | 1.00 | 1.00 | 0.45 | 1.00 | **0.87** | 0.78 | 1.00 | **0.89** | 0.00 | 0.00 | **0.00** | **0.66** |
| Caddo Lake NWR & WMA | 1.00 | 0.41 | 0.43 | 0.50 | **0.59** | 1.00 | 0.00 | **1.00** | 0.00 | 0.00 | **0.00** | **0.55** |
| CBABO | 1.00 | 0.56 | 0.75 | 0.50 | **0.72** | 0.59 | 1.00 | **0.79** | 0.78 | 0.00 | **0.39** | **0.65** |
| CBBMB | 1.00 | 1.00 | 0.15 | 0.50 | **0.67** | 0.85 | 1.00 | **0.93** | 0.76 | 0.00 | **0.38** | **0.66** |
| CBCBS | 1.00 | 1.00 | 1.00 | 0.50 | **0.89** | 0.56 | 0.00 | **0.56** | 0.94 | 0.00 | **0.47** | **0.70** |
| CBDTR | 1.00 | 1.00 | 0.78 | 0.50 | **0.84** | 0.94 | 1.00 | **0.97** | 0.00 | 0.00 | **0.00** | **0.66** |
| CBERH | 1.00 | 1.00 | 0.48 | 0.50 | **0.76** | 0.86 | 0.99 | **0.93** | 1.00 | 0.00 | **0.50** | **0.74** |
| CBFBC | 1.00 | 0.64 | 0.39 | 0.50 | **0.64** | 0.75 | 1.00 | **0.88** | 0.00 | 0.00 | **0.00** | **0.54** |
| SRASP | 1.00 | 1.00 | 0.45 | 0.50 | **0.75** | 1.00 | 1.00 | **1.00** | 1.00 | 0.00 | **0.50** | **0.75** |
| Wright Patman COE Land | 1.00 | 1.00 | 0.53 | 0.50 | **0.77** | 1.00 | 0.30 | **1.00** | 0.44 | 0.00 | **0.22** | **0.69** |
| White Oak Creek WMA | 1.00 | 1.00 | 0.35 | 0.50 | **0.73** | 0.92 | 0.45 | **0.92** | 0.83 | 0.00 | **0.42** | **0.70** |

**Table 4. Area description and number of established vegetation plots for each study area in Northeast Texas, Summer 2007 & 2008.**

| Study Area | Area(hectares) | Area (acres) | Number of Vegetation Plots |
|---|---|---|---|
| Northern Red River County | 25,293 | 62,499 | 396 |
| Sulphur River Drainage | 30,757 | 76,000 | 233 |
| Cypress River Basin | 8,903 | 22,000 | 134 |
| Pat Mayse WMA, Lamar County | 2,995 | 7,400 | 36 |
| Total | 67,948 | 167,899 | 799 |

**Table 5. Habitat suitability index for each model variable investigated for study areas of Northeast Texas, Summer 2007 & 2008, and Van Manen 1991 Big South Fork Area comparison.**

| Study Area | Index Variables | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Summer Food (v1) | Fall Food Availability (v2) | Fall Food Productivity (v3) | Fall Food Diversity (v4) | Protection Cover (v5) | Tree Den Sites (v6) | Open Road Density (v7) | Human/Bear Conflicts (v8) |
| Northern Red River County | 1.00 | 0.75 | 0.50 | 1.00 | 0.89 | 0.30 | 0.77 | 0.00 |
| Sulphur River Drainage | 1.00 | 1.00 | 0.46 | 0.50 | 1.00 | 0.36 | 0.66 | 0.00 |
| Cypress River Basin | 1.00 | 0.71 | 0.50 | 0.50 | 0.95 | 1.00 | 0.00 | 0.00 |
| Pat Mayse WMA, Lamar County | 1.00 | 1.00 | 0.45 | 1.00 | 0.78 | 1.00 | 0.00 | 0.00 |
| Sulphur River Garner and Willis 1998 | 1.00 | 1.00 | 0.93 | 0.50 | 0.76 | 0.00 | 0.73 | 0.30 |
| Big South Fork, KY/TN | 0.73 | 1.00 | 0.74 | 0.80 | 0.66 | 0.00 | 0.94* | 0.29 |

* differs from Van Manen as only improved roads were used for calculations

**Table 6. Habitat suitability indices for habitat components and overall HSI values by study areas in Northeast Texas, 2007 & 2008 and KY/TN Van Manen 1991, for comparison.**

| Study Area | Habitat Component | | | Overall HSI |
|---|---|---|---|---|
| | Food | Cover | Human Impact | |
| Northern Red River County | 0.83 | 0.89 | 0.39 | 0.73 |
| Sulphur River Drainage | 0.76 | 1.00 | 0.33 | 0.71 |
| Cypress River Basin | 0.69 | 0.97 | 0.00 | 0.59 |
| Pat Mayse WMA, Lamar County | 0.87 | 0.89 | 0.00 | 0.66 |
| Sulphur River Drainage Garner & Willis 1998 | 0.87 | 0.76 | 0.52 | 0.76 |
| Big South Fork, KY/TN | 0.82 | 0.66 | 0.62* | 0.73* |

* differs from Van Manen reported score since only improved roads were used in calculations

Table 7. Soft Mast Species Encountered by River Basin Across All Study Sites during Vegetation Sampling.

| Common Name | Scientific Name | Cypress River Basin | Sulphur River Basin | Red River Basin |
|---|---|---|---|---|
| Peppervine | *Ampelopsis arborea* | + | + | + |
| Devil's walking stick | *Aralia spinosa* | + | + | |
| Paw-paw | *Asimina* spp. | + | + | + |
| Alabama supplejack | *Berchemia scandens* | + | + | + |
| American beautyberry | *Callicarpa americana* | + | + | + |
| Dogwood species | *Cornus* spp. | + | + | + |
| Hawthorn species | *Crataegus* spp. | + | + | + |
| Common persimmon | *Diospyros virginiana* | + | + | + |
| Carolina buckthorn | *Frangula caroliniana* | + | | + |
| Privet species | *Ligustrum* spp. | | + | |
| Spicebush | *Lindera benzoin* | | | + |
| Red mulberry | *Morus rubra* | + | + | + |
| Virginia creeper | *Parthenocissus quinquefolia* | + | + | + |
| Pokeberry | *Phytolacca americana* | + | + | |
| Plum species | *Prunus* spp. | + | + | + |
| Blackberry species | *Rubus* spp. | + | + | + |
| Dwarf palmetto | *Sabal minor* | + | | |
| Elderberry | *Sambucus canadensis* | | | + |
| Greenbriar species | *Smilax* spp. | + | + | + |
| Sweetleaf | *Symplocos tinctoria* | + | | |
| Poison ivy | *Toxicodendron radicans* | + | + | + |
| Blueberry species | *Vaccinium* spp. | + | + | + |
| Possumhaw | *Viburnum* spp. | + | + | + |
| Grape species | *Vitis* spp. | + | + | + |
| Prickly ash | *Zanthoxylum clava-herculis* | | | + |

Table 8. Human Impact and Road Density Comparisons between Focal Area Counties and Neighboring States with Bear Populatior

| County | State | Road Length (km) | Road Density ($km/km^2$) | Population (2000 census) | Population Density |
|---|---|---|---|---|---|
| Bowie | TX | 1,871.23 | 0.81 | 89,306 | 38.83 |
| Camp | TX | 587.53 | 1.14 | 11,549 | 22.51 |
| Cass | TX | 2,244.80 | 0.92 | 30,438 | 12.54 |
| Delta | TX | 646.57 | 0.90 | 5,327 | 7.43 |
| Franklin | TX | 658.08 | 0.89 | 9,458 | 12.76 |
| Harrison | TX | 1,872.32 | 0.80 | 62,110 | 26.68 |
| Hopkins | TX | 1,940.73 | 0.96 | 31,960 | 15.78 |
| Lamar | TX | 2,098.54 | 0.88 | 48,499 | 20.42 |
| Marion | TX | 797.00 | 0.81 | 10,941 | 11.09 |
| Morris | TX | 634.22 | 0.96 | 13,048 | 19.77 |
| Rains | TX | 629.29 | 1.05 | 9,139 | 15.21 |
| Red River | TX | 1,568.34 | 0.58 | 14,314 | 5.26 |
| Titus | TX | 1,004.58 | 0.94 | 28,118 | 26.43 |
| Upshur | TX | 1,542.78 | 1.01 | 35,291 | 23.17 |
| Wood | TX | 1,896.53 | 1.13 | 36,752 | 21.84 |
| Sussex | NJ | 3,215.26 | 2.38 | 144,166 | 106.79 |
| LeFlore | OK | 4,755.92 | 1.16 | 48,109 | 11.71 |
| Latimer | OK | 1,251.20 | 0.67 | 10,692 | 5.72 |
| McCurtain | OK | 7,630.42 | 1.59 | 34,402 | 7.17 |
| Pushmataha | OK | 3,374.92 | 0.93 | 11,667 | 3.22 |
| Choctaw | OK | 2,080.52 | 1.04 | 15,432 | 7.66 |
| Oklahoma Bear Area | OK | 5,401.81 | 0.98 | n/a | n/a |
| Scott | AR | 2,476.44 | 1.07 | 10,996 | 4.75 |
| Montgomery | AR | 2,095.34 | 1.04 | 9,245 | 4.57 |
| Polk | AR | 2,699.10 | 1.21 | 20,229 | 9.09 |

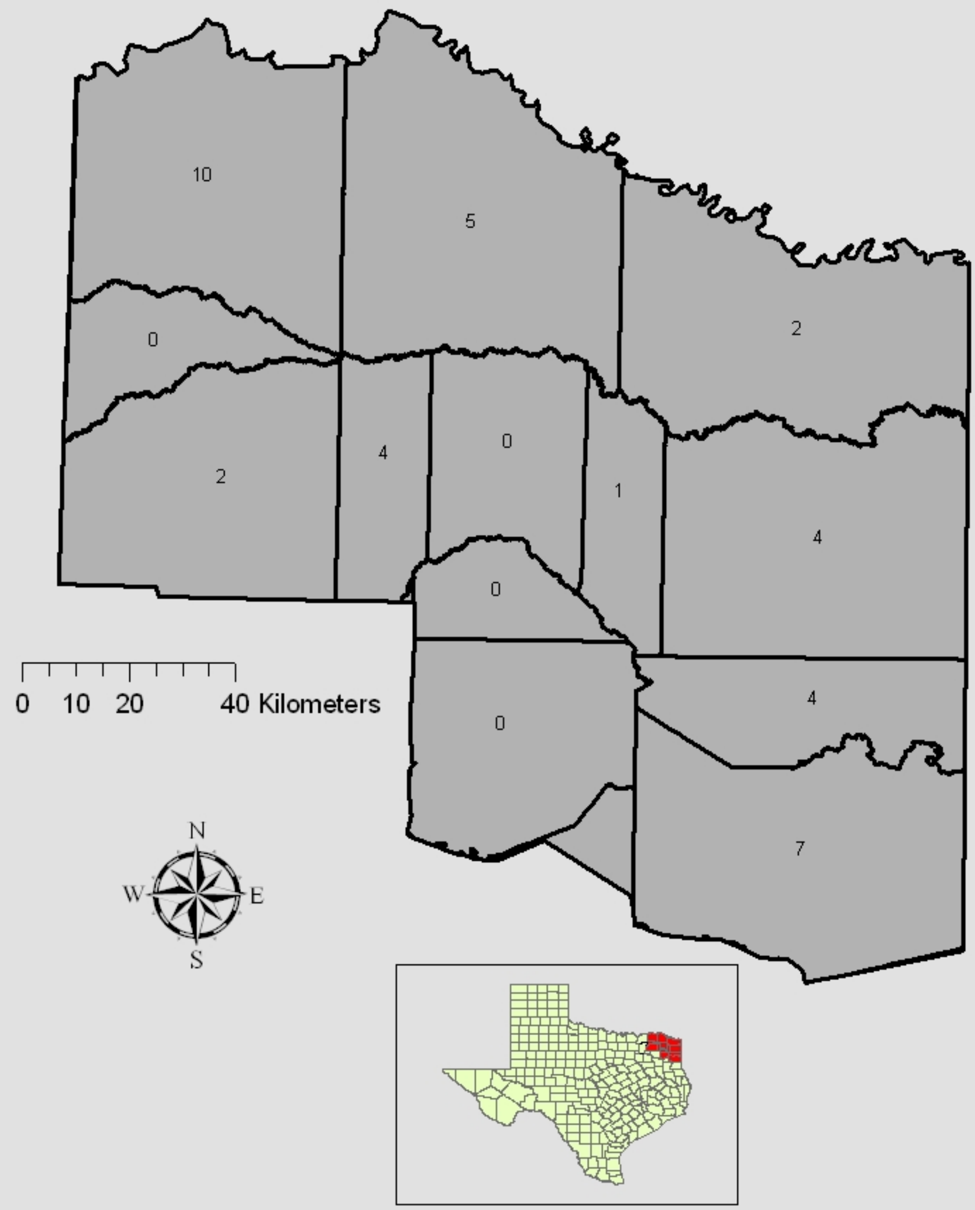


Figure 1. Northeast Texas Focal Area and Bear Sightings Data 1978-2007 as Reported to TPWD.

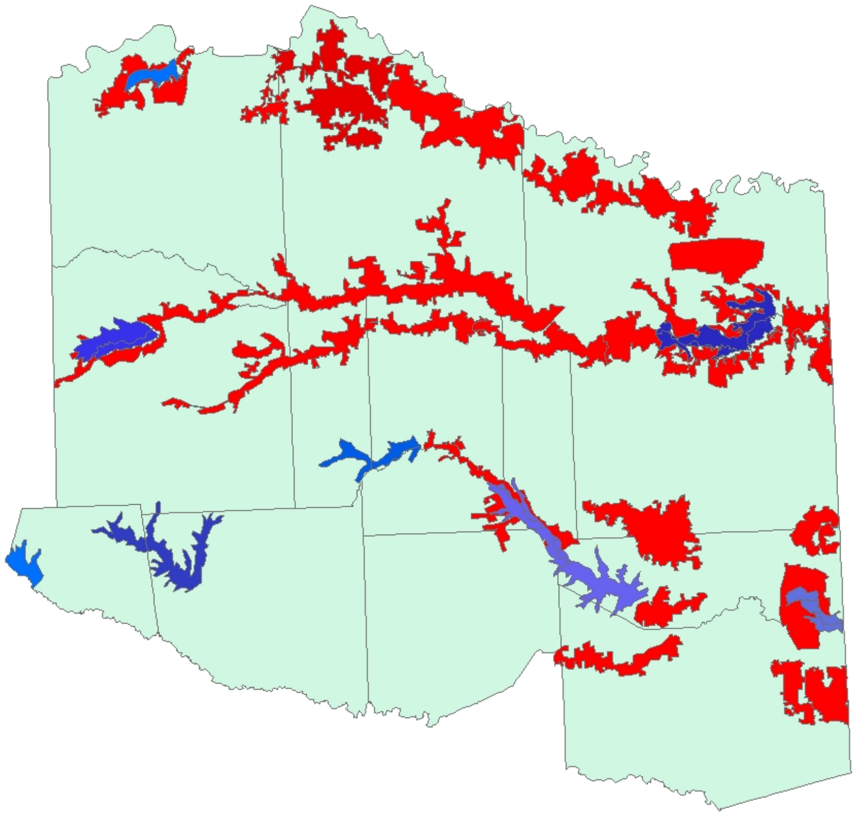

Figure 2. Contiguous Forested Blocks Within Northeast Texas as Identified using NAIP 2004 1m imagery and ESRI ArcMap 9.2

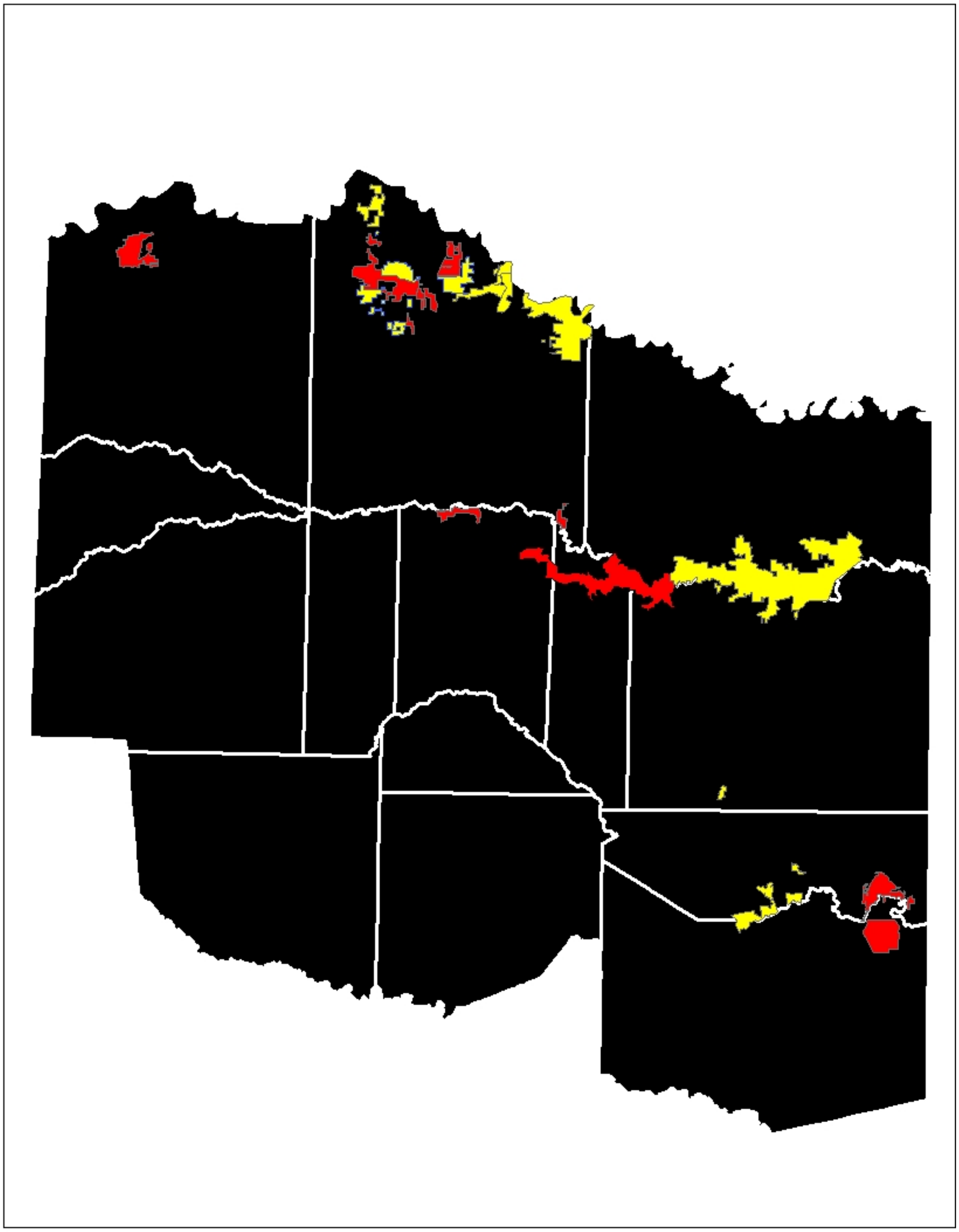

Figure 3. Study Sites Visited across the Northeast Texas Focal Area by Year

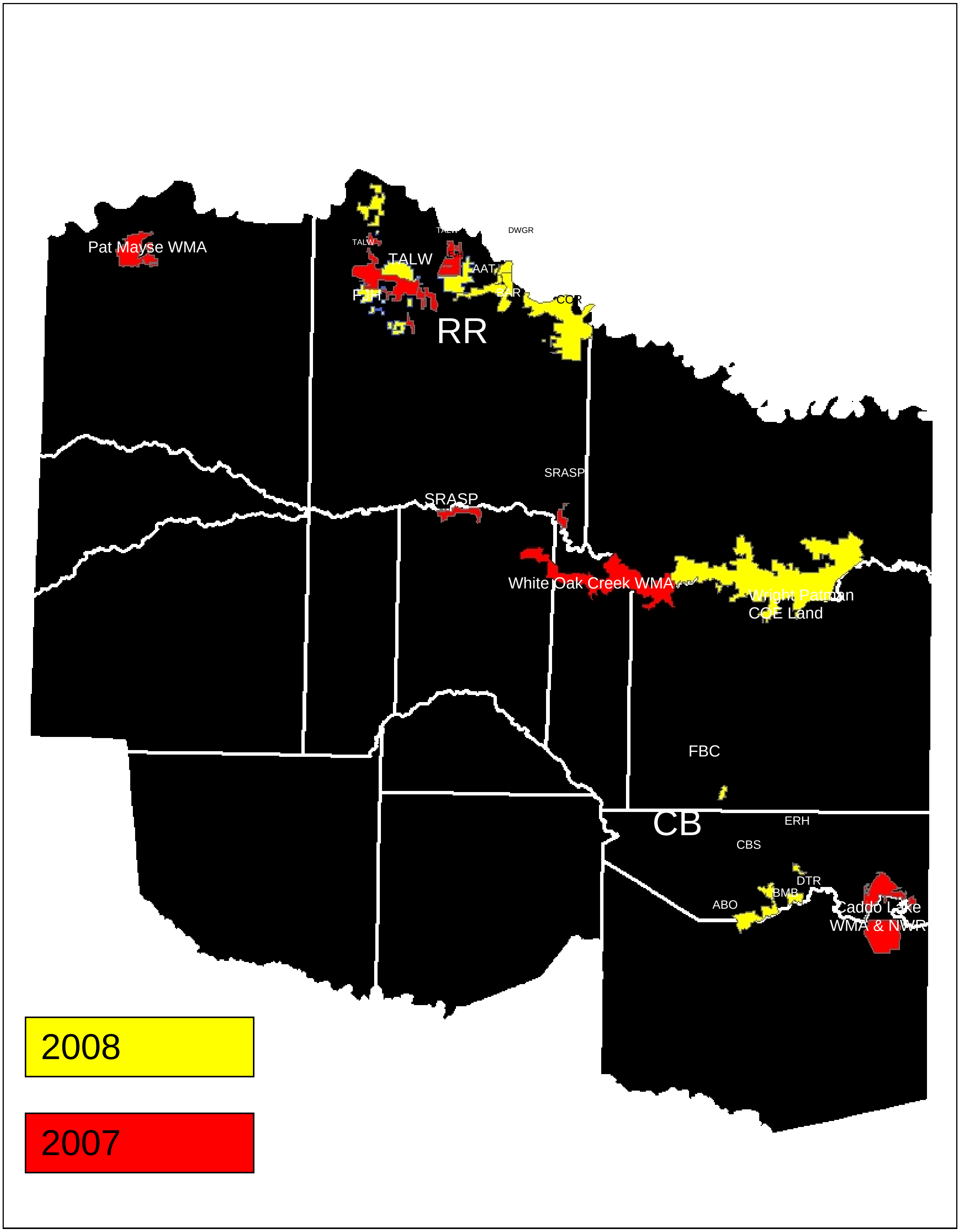


Figure 4. Study Sites Visited across the Northeast Texas Focal Area by Year and HSI Identification

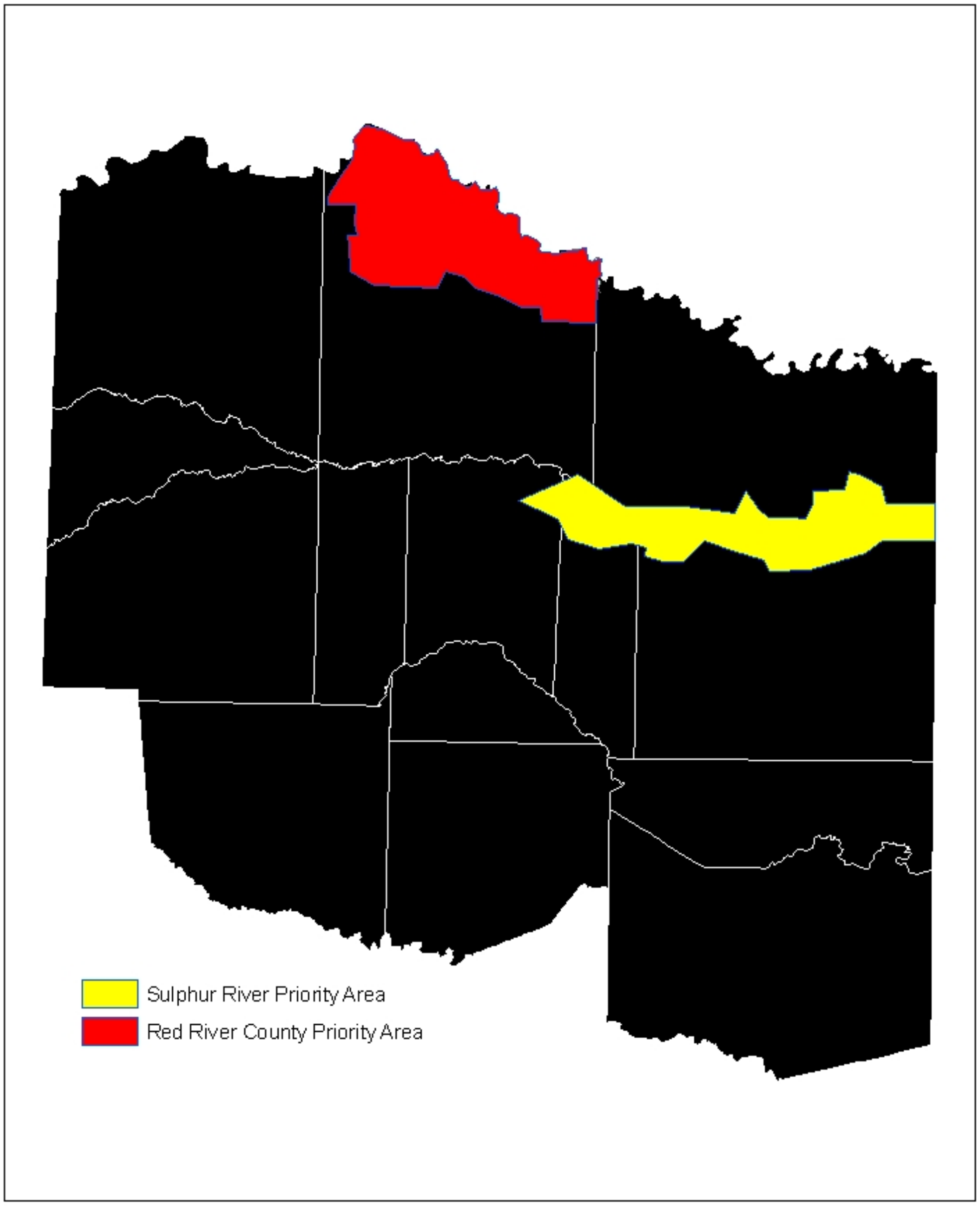


Figure 5. Priority Areas for Future Monitoring and Education as Identified During Course of Study.

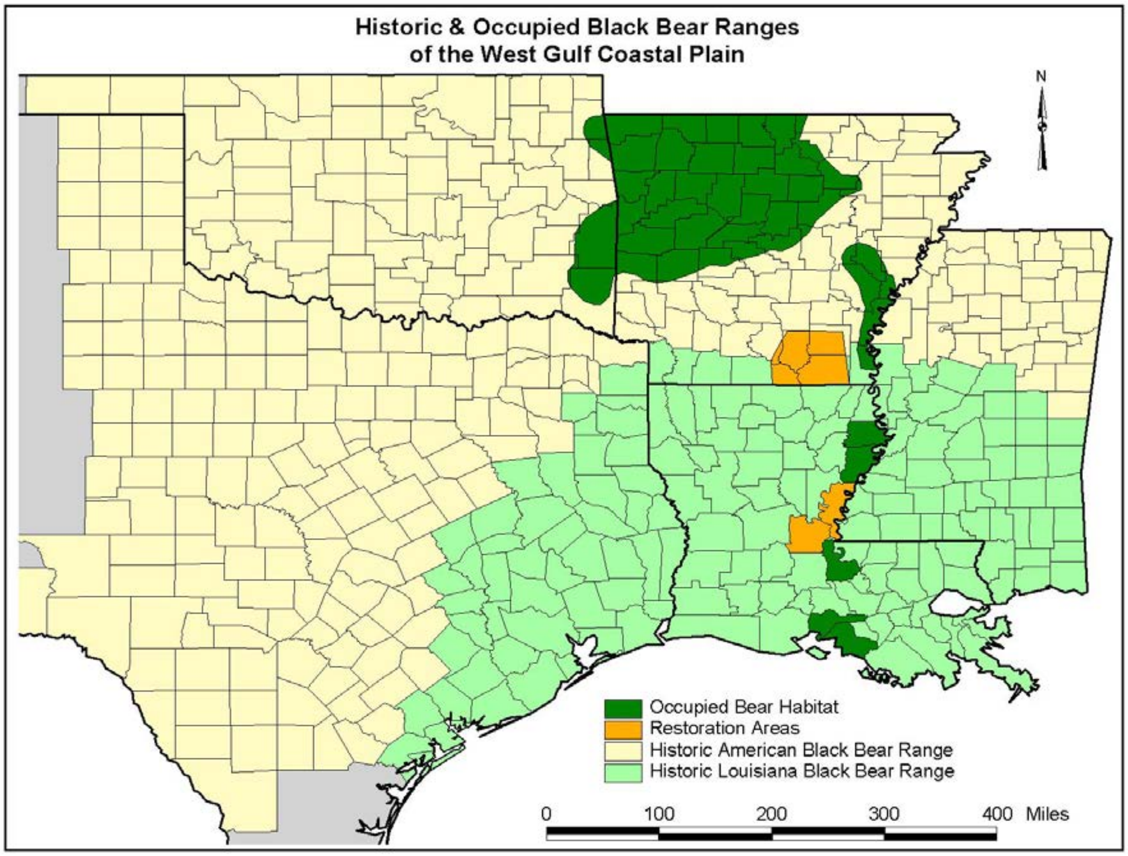


Figure 6. Current and Former Ranges of Black Bear in West Gulf Coastal Plain, Courtesy of BBCC.