To the Graduate Council:

I am submitting herewith a thesis written by Kent Russell Hersey entitled "Habitat Assessment for Potential Reintroduction of Black Bears to the Mobile-Tensaw Delta of Southwestern Alabama." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

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HABITAT ASSESSMENT FOR POTENTIAL REINTRODUCTION OF BLACK BEARS TO THE MOBILE-TENSAW DELTA OF SOUTHWESTERN ALABAMA

A Thesis Submitted for the

Master of Science Degree

The University of Tennessee, Knoxville

Kent Russell Hersey

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ABSTRACT

Black bears (*Ursus americanus*) have been extirpated from all but a few areas in southwestern Alabama, and the remaining enclaves are rapidly being lost to development. Adjacent to those remnant bear populations are extensive (>125,000 ha) bottomland hardwood forests in the Mobile-Tensaw Delta (MTD), but bears are nearly absent there. Reintroduction may be possible to reestablish black bears in the MTD and improve the viability of the overall bear population in southwestern Alabama. To determine whether a reintroduction effort is likely to succeed in the MTD, I assessed habitat quality, den site availability, and public support of a restoration effort. To evaluate the habitat quality of the MTD for bears, I compared it with similar alluvial habitats at White River National Wildlife Refuge (White River NWR), where the bear population is high. I then performed a flood simulation using GIS to assess the availability of safe ground dens in the MTD. Finally, I used the Bowman et al. (2004) model based on demographic variables (i.e., age, race, sex) to predict human attitudes towards black bear restoration efforts in the MTD and surrounding areas.

I collected data from overstory, midstory, and understory vegetation plots in the MTD and on the North and South management units at White River NWR. Using principal components analysis followed by principal variable selection, I determined that 9 variables associated with 5 principal components (hard mast, soft mast, den tree availability, large tree availability, and total basal area) best explained the variation among the 3 study areas. I detected differences among the study areas for 3 of those principal components (hard mast, soft mast, and den tree availability; *t* ranged from 2.71

to 5.70, $P \leq 0.001$). Flood simulations for various recurrence levels indicated that nearly all of the MTD floods each year with the only dry locations occurring along the Alabama River. The MTD and surrounding areas showed moderate public support for a black bear reintroduction (range = 25.4–73.8%).

Although my study revealed that hard and soft mast production in the MTD was lower than at White River NWR, a previously developed Habitat Suitability Index model and comparisons of hard mast basal area between the MTD (5.39 m^2/ha) and Tensas River National Wildlife Refuge (6.98 m^2/ha) suggested food resources in the MTD were adequate. A more serious deficiency of the MTD was the almost total lack of suitable den sites, a critical habitat component given the duration and severity of winter flooding there. Flood simulation models indicated that the northern portions of the MTD along the Alabama River were least likely to be inundated and, therefore, were most suitable for ground reintroduction sites. Given that only moderate support for black bear restoration efforts in the MTD was predicted, a strong public relations program will be critical for the reintroduction to be successful. Reintroduction of black bears could be successful in the MTD through the use of artificial denning structures, but long-term population viability will require changes in timber management practices to ensure that adequate tree dens are available.

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CHAPTER I

INTRODUCTION

Black bears (*Ursus americanus*) were once abundant in the forested regions of North America (Hall 1981). Since the early 1700s, however, large-scale changes in human land use have contributed to reduced bear populations and contraction and fragmentation of their range (Pelton 1982, Maehr 1984). The impact of those factors is particularly evident in the southeastern United States where black bears only occupy 20% of their historic distribution (Pelton and van Manen 1997). In the Southeast, urban sprawl and clearing of bottomland hardwoods have resulted in decreased suitable habitat, restricted access to critical food sources, and reduced genetic exchange among local bear populations (Pelton 1991).

Bears in southern Alabama are classified as Florida black bears (*U. a. floridanus*, Merriam 1896, Hall 1981). Land clearing for agriculture and urbanization has dramatically reduced and fragmented the range of this subspecies (Wooding et al. 1994). Today, the Florida black bear exists within 7 relatively disjunct populations in Alabama, Florida, and Georgia, making this distribution the most fragmented of all black bear subspecies (Kasbohm and Bentzien 1998). In southern Alabama, bears were common in the big swamps bordering the Tensaw and Mobile rivers, and a considerable number were killed by hunters each autumn (Howell 1921). By the early 1900s, however, black bears were extirpated from everywhere in Alabama except the swamps and lowlands of the southernmost counties (Howell 1921).

In 1990, the U. S. Fish and Wildlife Service (USFWS) was petitioned to list the Florida black bear as threatened under the provisions of the Endangered Species Act of 1973. The petition cited illegal hunting, loss and fragmentation of habitat, and road mortality as the major threats to the subspecies (Kasbohm and Bentzien 1998). In 1992, the USFWS found that "the petition to list the Florida black bear as a threatened species is warranted but precluded by work on other species having a higher priority for listing" (Wooding 1992).

In 1997, a federal court mandated a reexamination by the USFWS to list the Florida black bear. In 1998, after reviewing all available data, the USFWS ruled that federal listing of the Florida black bear was not warranted at that time (Kasbohm and Bentzien 1998). The USFWS reported that 4 of 7 distinct populations (Apalachicola National Forest, Ocala National Forest, Big Cypress National Preserve, and Okefenokee National Wildlife Refuge-Osceola National Forest) were viable and on public conservation lands that have long-term protection (Bentzien 1998). It was concluded that the continued existence of the Florida black bear was not threatened by the aforementioned factors alone or in combination, and as such, the Florida black bear was not endangered or likely to become so in the foreseeable future (Bentzien 1998). In December 2001, the federal judge for this case directed the USFWS to readdress the listing decision, citing inadequate regulatory measures (Kasbohm 2004). Recently, the USFWS has reexamined their 1998 ruling and concluded that the existing regulatory mechanisms applicable in 1998 are adequate and do not warrant listing of the Florida black bear (Kasbohm 2004).

Although the Florida black bear as a whole may not be in jeopardy, USFWS authorities acknowledge that some of the populations are small and declining (Bentzien 1998, J. Kasbohm, USFWS, personal communication). In a recent bear study in southwestern Alabama, Edwards (2002) found that breeding females existed in only a few, small, isolated areas, making the population highly susceptible to extinction. Additionally, the upland habitats and associated feeder streams comprising those areas were rapidly being converted to housing developments, thus increasing the risk of extinction for this population. Despite extensive surveys from 1998 through 2000, Edwards (2002) found a near absence of bears in the seasonally flooded bottomland hardwood forests of the adjacent Mobile-Tensaw Delta (MTD, Fig. 1). Edwards (2002) hypothesized that the combination of winter flooding and the past removal of den trees by loggers was a major factor limiting the number of bears in the MTD. Yet, because of that flooding, the extensive bottomlands in the MTD (>125,000 ha) may be protected from urban sprawl and development and, as such, may represent the only secure habitat base for future black bear populations in the region.

Bear reintroduction has been proposed for the MTD, and the practice has been successful at other locations in the Southeast (Smith and Clark 1994; Eastridge and Clark 2001; R. Eastridge, Arkansas Game and Fish Commission, personal communication; S. Reagan, U. S. Fish and Wildlife Service, personal communication). Because bears currently are not present in the MTD, 3 key elements need to be addressed to determine whether a reintroduction effort is likely to succeed in the area: habitat quality, den site availability, and public support for a restoration effort.

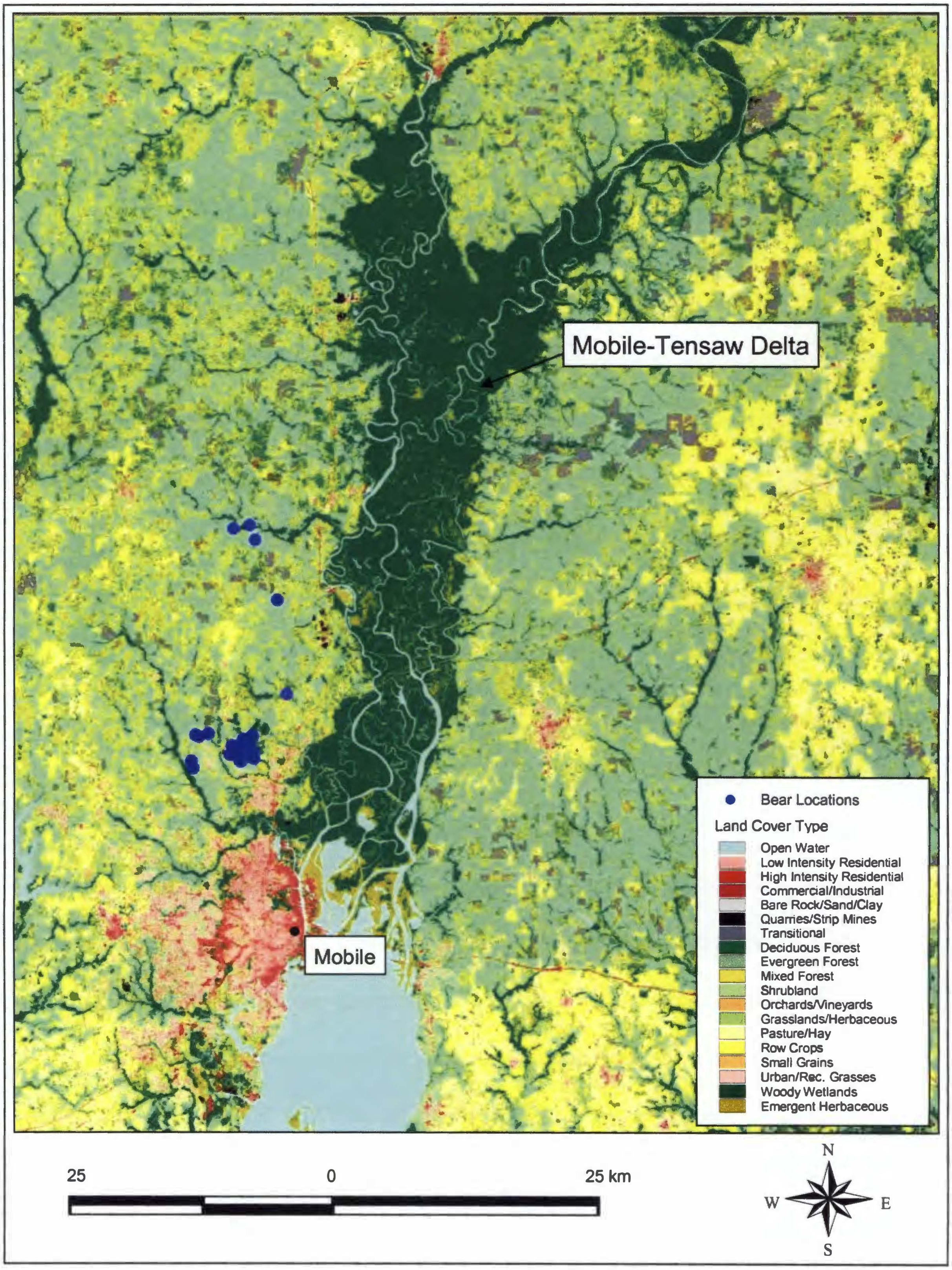

Fig. 1. Locations of black bears in southwestern Alabama (from Edwards 2002).

Habitat characteristics most important for black bears include food, cover, and den site availability (Landers et al. 1979, Pelton 1986, van Manen 1991, Zimmerman 1992). Summer and fall foods are considered to be the most important for bears. Summer diets are dominated by soft mast, whereas bears use a mixture of hard and soft mast foods in fall (Beeman and Pelton 1977, Eagle and Pelton 1983, Maehr and Brady 1984, Clark et al. 1987). Horizontal cover is needed for protection and denning and has been reported to be a critical habitat component for bears in the Southeast (Landers et al. 1979, Hamilton and Marchinton 1980, Hellgren and Vaughan 1989, Telesco 2003).

The extent to which flooding limits den sites in the MTD needs to be assessed. In forested wetland habitats, lack of topographic relief and seasonal flooding often reduce the availability of safe ground dens (Oli et al. 1997), indicating that den tree availability may be a critical habitat component. However, if suitable den trees are lacking, locations of safe ground dens may be extremely important for bears in the MTD.

Finally, public attitudes toward a restoration effort in the MTD are vitally important and should be addressed (Kellert 1985, Reading and Kellert 1993, Kellert 1994, Reading and Clark 1996). Reintroduction efforts often fail because the socioeconomic and political aspects of reintroduction programs are not adequately addressed (Griffith et al. 1989, Reading and Kellert 1993).

If all of these components in the MTD are judged to be suitable, bears from the adjacent declining population might be translocated, or additional bears from elsewhere within the range of the subspecies might be reintroduced, thereby augmenting and helping to bolster the viability of the remnant population. As an added benefit, demographic and genetic linkages with other Florida black bear populations might be created (Clark et al. 2002).

Like the MTD, White River National Wildlife Refuge (White River NWR) in eastern Arkansas is comprised of similar habitat types, is seasonally flooded, but, in contrast, has a dense bear population (Smith 1985, Oli et al. 1997, R. Eastridge, Arkansas Game and Fish Commission, unpublished data). By comparing habitat data collected at White River NWR with similar data from the MTD, deficiencies that may exist in the habitat for bears in southwestern Alabama could be identified. Additionally, GIS models have been used to delineate floodplains in other disciplines (e.g., urban development, Correia et al. 1999; flood disaster losses, Boyle et al. 1998) and could be applied to assess the availability of safe ground dens in the MTD. Finally, a model based on demographic variables (i.e., age, race, sex) was developed to predict human attitudes towards black bear restoration efforts in Mississippi (Bowman et al. 2004). Because of the close proximity and similar demographic composition of Alabama and Mississippi, that model should adequately reflect public support for bear restoration in the MTD and surrounding areas.

Objectives

The overall goal of my study was to determine whether the MTD is suitable for black bear reintroduction or, if not, identify deficiencies that need to be addressed. To accomplish that goal, I identified 3 main objectives:

1) Compare food, cover, and potential den trees available to black bears in the MTD with White River NWR, where bear densities are high;

2) Perform a GIS-based flood simulation to identify areas suitable for ground denning by black bears in the MTD; and
3) Predict public support for a restoration effort in the MTD and surrounding area based on the model developed by Bowman et al. (2004).

CHAPTER II

STUDY AREAS

Mobile-Tensaw Delta

The southwestern Alabama study area was centered on the MTD and was approximately 80,500 ha in size. The study area extended from Jackson, Alabama on the Tombigbee River and from Claiborne, Alabama on the Alabama River southward to I-65 and included parts of Baldwin, Clarke, Mobile, Monroe, and Washington counties (Fig. 2). The MTD is formed by the confluence of the Alabama and Tombigbee rivers, which combine to form the Mobile River, which in turn divides into its major distributaries, the Middle and Tensaw rivers. More than 80% of the study area is privately owned, most of which is intensively managed for timber. The remainder of the study area is located on the publicly owned Upper Delta Wildlife Management Area.

The MTD is in the temperate rainforest zone (Bailey 1995). The climate is subtropical and characterized by long, hot, humid summers and short, mild winters (National Oceanic and Atmospheric Administration [NOAA] 1978). Mean daily temperatures range from 2 to 16°C in January and from 21 to 34°C in July (NOAA 2000). Annual mean precipitation for the study area is 158 cm (NOAA 2000). Almost all precipitation in southern Alabama is rain, which occurs throughout the year. Snowfall in the study area is rare. Thunderstorms account for nearly all of the precipitation during the summer months (NOAA 1978). Winter and spring are the wettest seasons with March precipitation averaging 16.8 cm, whereas fall is the driest season with October precipitation averaging 7.5 cm (NOAA 2000). Flooding occurs in late winter and early

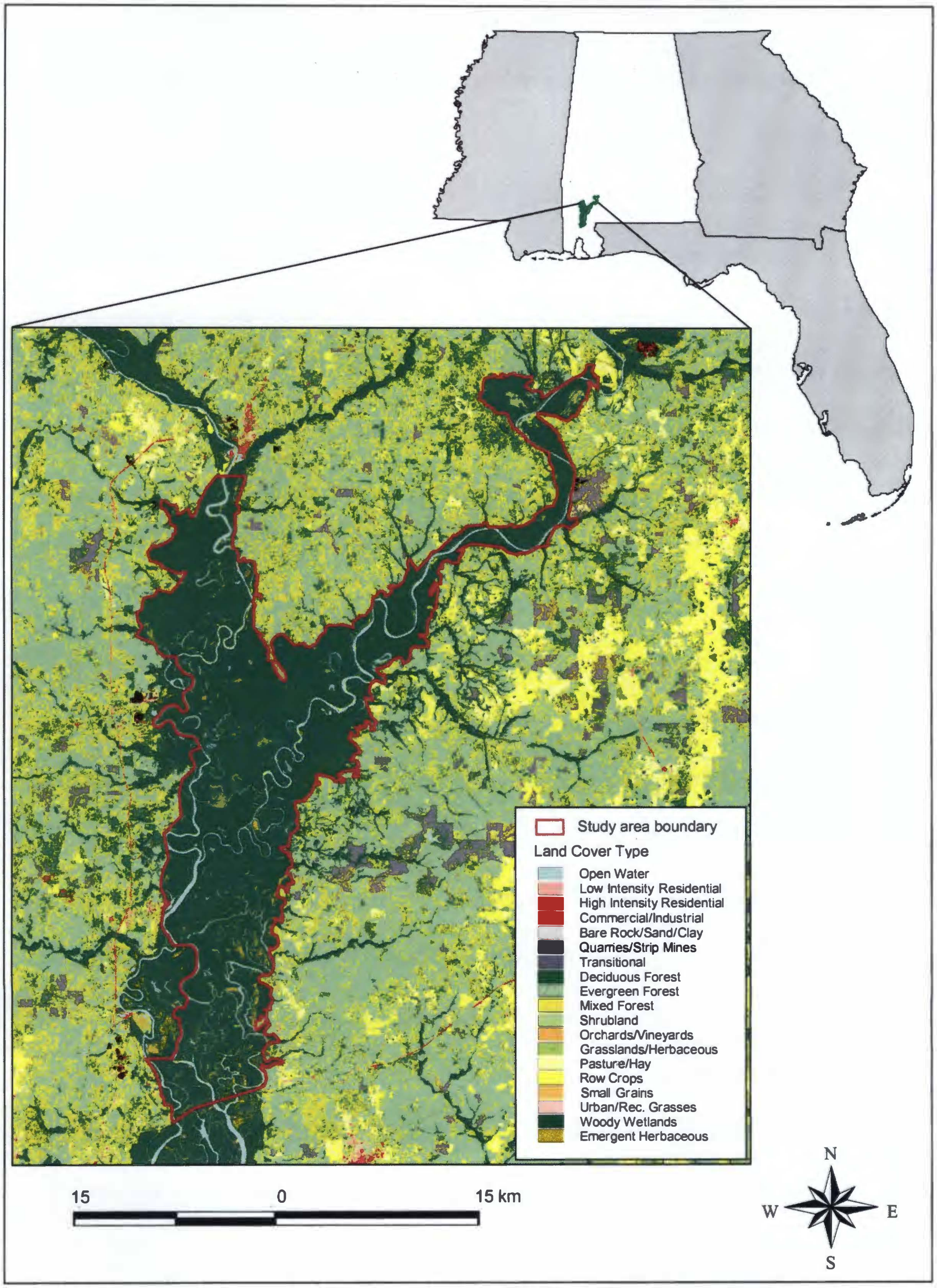

Fig. 2. Mobile-Tensaw Delta study area, southwestern Alabama, 2002–2003.

spring, with March being the month of greatest flood frequency. Hurricanes occasionally strike the coastal area between July and November, bringing heavy wind and rain (NOAA 1978).

The MTD study area lies in the Outer Coastal Plain Mixed Province, which is characterized by flat or gently rolling terrain (Bailey 1995). Elevations within the MTD ranged from 0.6 m to 15.2 m above mean sea level. Sluggish streams, marshes, swamps, and lakes are numerous. Soils are mainly Ultisols, Spodosols, and Entisols with most being wet, acidic, and low in major plant nutrients. The soils are derived from coastal plain sediments ranging from heavy clay to gravel, with sandy materials predominant. Silty soils mainly occur in the lower areas, whereas sands are prevalent in the hilly areas (Bailey 1995).

Vegetation associations within the Delta mainly consist of seasonally flooded bottomland hardwoods and permanently flooded swamp forests, whereas upland pine and mixed-hardwood pine forests are predominant outside the study area. Overstory species within the MTD include bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), sweetgum (*Liquidambar styraciflua*), sugarberry (*Celtis laevigata*), green ash (*Fraxinus pennsylvanica*), laurel oak (*Quercus laurifolia*), Nuttall oak (*Q. nuttallii*), overcup oak (*Q. lyrata*), water oak (*Q. nigra*), willow oak (*Q. phellos*), red maple (*Acer rubrum*), American elm (*Ulmus americana*), and water hickory (*Carya aquatica*). Understory species within the MTD include deciduous holly (*Ilex decidua*), dwarf palmetto (*Sabal minor*), switchcane (*Arundinarea gigantea*), pepper-vine (*Ampelopsis arborea*), poison ivy (*Toxicodendron radicans*), greenbriers (*Smilax* spp.), grapes (*Vitis* spp.), and blackberries (*Rubus* spp.).

The MTD and surrounding areas support a wide variety of terrestrial and aquatic wildlife. The area supports >300 bird species, >100 of which nest in the area. The MTD also hosts >40 mammal, 69 reptile, 40 amphibian, and >125 fish species. Game species include white-tailed deer (*Odocoileus virginianus*), feral swine (*Sus scrofa*), raccoon (*Procyon lotor*), eastern gray squirrel (*Sciurus carolinensis*), eastern fox squirrel (*S. niger*), eastern cottontail (*Sylvilagus floridanus*), swamp rabbit (*S. aquaticus*), bobwhite quail (*Colinus virginianus*), eastern wild turkey (*Meleagris gallopavo*), mourning dove (*Zenadia macroura*), and various waterfowl species. After years of protection, American alligators (*Alligator mississippiensis*) are again common in the MTD. Federally threatened and endangered species in the area include the bald eagle (*Haliaeetus leucocephalus*), wood stork (*Mycteria americana*), and gopher tortoise (*Gopherus polyphmus*).

White River National Wildlife Refuge

White River NWR is about 65,000 ha in size and includes portions of Arkansas, Desha, Monroe, and Phillips counties in eastern Arkansas (Fig. 3). White River NWR is located in the Lower Mississippi Alluvial Valley and is the largest tract of bottomland hardwoods under single ownership in the U. S. The refuge encompasses 145 km of the White River and has >300 lakes and ponds interconnected by a matrix of streams, bayous, and sloughs. Vegetation associations inside the refuge are similar to those of the MTD, mainly consisting of seasonally flooded hardwoods and permanently flooded swamp forests. Outside the refuge, land use is dominated by agriculture, with rice and soybeans being the primary crops.

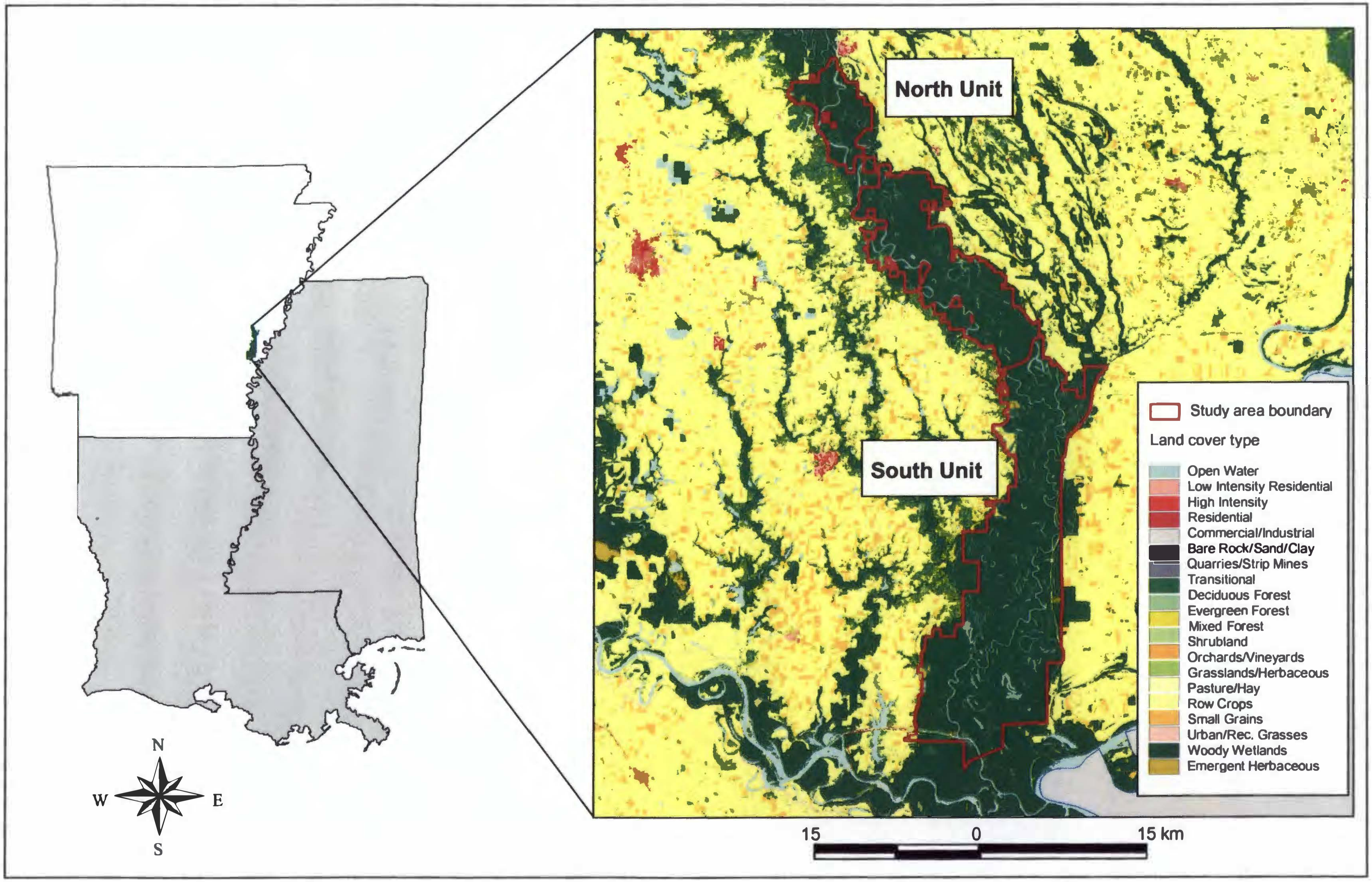

Fig. 3. White River National Wildlife Refuge, Arkansas, 2003.

White River NWR is divided into North and South management units. The South Unit is about 43,000 ha in size and has the highest bear density on the refuge (R. Eastridge, Arkansas Game and Fish Commission, unpublished data). The South Unit has been under federal ownership since the establishment of the refuge in 1935. The North Unit is about 22,000 ha, most of which was acquired from Potlatch Timber Company in 1993. Timber on the North Unit has been selectively harvested 3 times since 1970 (Jeff Denman, U. S. Fish and Wildlife Service, personal communication). The South Unit is considered high quality alluvial bear habitat, whereas the North Unit is considered to be suitable but of lesser quality, based on lower bear population densities there (R. Eastridge, Arkansas Game and Fish Commission, unpublished data).

The climate of the region is similar to southwestern Alabama with long, hot, humid summers and short, mild winters (NOAA 1978). Mean daily temperatures range from -1 to 10°C in January and from 22 to 34°C in July (NOAA 2000). Weather patterns for the 2 study areas also are similar. Annual mean precipitation at White River NWR is 131 cm (NOAA 2000). Most precipitation in eastern Arkansas is rain, which occurs throughout the year. Snowfall in the study area is generally light and remains on the ground only briefly. Like southwestern Alabama, winter and spring are the wettest seasons with March precipitation averaging 14.2 cm (NOAA 2000). Late summer and early fall are drier with August precipitation averaging 5.7 cm (NOAA 2000). Severe thunderstorms are common from March to May, with frequent tornado activity (NOAA 1978).

White River NWR lies within the Lower Mississippi Riverine Forest Province, a flat to gently sloping broad floodplain made up of alluvium and loess (Bailey 1995).

Most of the area is flat, with slopes averaging <13 cm/km (Bailey 1995). Elevations at White River NWR range from 40.8 to 48.2 m above mean sea level. The only noticeable slopes are terrace scarps and natural levees that sharply rise to several meters above adjacent bottomlands or stream channels. Flooding from the White River annually inundates about 75% of the refuge, usually through winter and spring. Soils of the region are a mosaic of Inceptisols in alluvial bottomlands; Alfisols occur in areas of loess, and Mollisols are found in swampy areas (Bailey 1995).

At White River NWR, vegetation occurs along a continuum of decreasing flood tolerance from the lowest to the highest elevations (Fredrickson and Heitmeyer 1988, Smith 1996, Richardson 2000). In the wettest areas, bald cypress, water tupelo, and overcup oak dominate. At moderately wet sites, Nuttall oak, green ash, sweet pecan (*Carya illinoiensis*), and water hickory are more prevalent. On the driest sites of the floodplain, red maple, sweetgum, cherrybark oak (*Q. pagoda*), and willow oak are dominant. Annual flooding of the refuge tends to limit understory density, but heavy seedbanks are present. Understory species that are common include deciduous holly, green ash, overcup oak, American elm, sugarberry, swamp privet (*Forestiera acuminata*), and buttonbush (*Cephalanthus occidentalis*).

The high productivity of the floodplain system supports many species of terrestrial and aquatic animals. The refuge hosts >200 bird, >45 mammal, 53 reptile, and 23 amphibian species. Game species include white-tailed deer, black bear, raccoon, eastern gray squirrel, eastern fox squirrel, eastern cottontail, swamp rabbit, and eastern wild turkey. Waterfowl hunting is a popular activity on the refuge. Common species taken include mallard (*Anas platyrhynchos*), blue-winged teal (*A. discors*), green-winged teal (*A. acuta*), American wigeon (*A. americana*), common pintail (*A. acuta*), and wood duck (*Aix sponsa*). Non-game species include a variety of shorebirds, wading birds, neotropical migrant songbirds, raptors, reptiles, amphibians, and fishes. Federally listed species include the threatened bald eagle.

CHAPTER III

MATERIALS AND METHODS

Habitat Assessment

Vegetation Plots. Prior to my study, Bowman (1999) had developed a Habitat Suitability Index (HSI) model for black bears in Mississippi, and forest inventory data had been collected at White River NWR in conjunction with its timber management program (J. Denman, U. S. Fish and Wildlife Service, unpublished data). Consequently, I established sampling protocols that enabled me to calculate variables used in the model developed by Bowman (1999) and use existing White River NWR data. In addition to the variables in the HSI model (i.e., measures of hard and soft mast production), I collected data on canopy closure, horizontal cover, and den tree availability for comparison among the areas.

To be consistent with the White River NWR forest inventory data, I used a cluster sampling structure to conduct habitat sampling in the MTD (Ratti and Garton 1996). Each plot consisted of 5 subplots: a central plot and 4 satellite plots (Fig. 4). Although systematic sampling was used at White River NWR, I used randomized sampling in the MTD because I was unsure of the number of plots I would ultimately need to sample. The use of random plots ensured that the entire study area would be evenly sampled (i.e., unbiased) regardless of the cutoff point. I used the running mean approach to assess sampling effort in the MTD (Mueller-Dombois and Ellenberg 1974). Random plots were established in the MTD with ArcView® GIS Version 3.2 (Environmental Systems Research Institute Redlands, California).

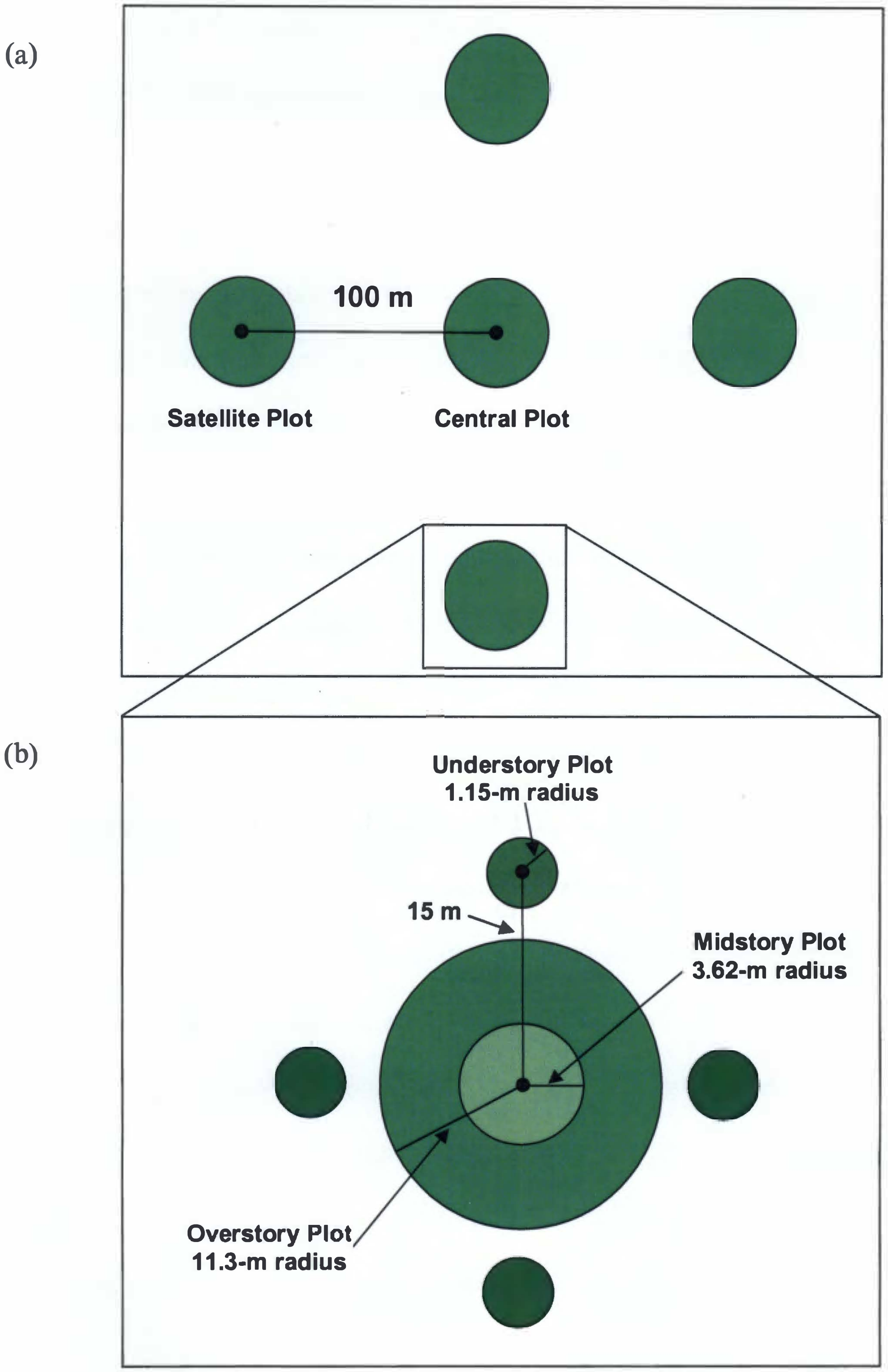

Fig. 4. Black bear habitat sampling plot structure used in the Mobile-Tensaw Delta study area, Alabama, 2002–2003: (a) cluster sampling structure showing all 5 subplots, and (b) overstory, midstory, and understory plots comprising each subplot.

All data were collected at each subplot and then averaged to get a value for the plot as a whole. Satellite plots in the MTD were located 100 m from the central plot in each cardinal direction (N, S, E, and W), whereas satellite plots at White River NWR were located 80.5 m (i.e., 4 chains; 1 chain = 66 ft) away from the central plot in each cardinal direction. I used 100 m in the MTD because those points were easier to locate with our Global Positioning System than were points 80.5 m from the central plot, and because it was unlikely that the increased distance between subplots would bias the combined plot mean.

At White River NWR, officials collected no data for subplots that fell in water (i.e., lake or river). In the MTD, if any subplots were located in a river or lake, I moved the central plot in a cardinal direction to the closest bank and placed it ≥200 m from the water so that none of the subplots would be affected. This was done to maximize my sampling effort given the extended length of time required to reach many of those plots, again assuming this procedure produced no biases.

At each subplot, I recorded the cover type (oak-mixed hardwoods, cypress-tupelo, or disturbed) and collected data on canopy closure, overstory, midstory, horizontal cover, understory, and den tree availability. I estimated canopy closure using a Model A Spherical Densiometer (Lemmon 1956) by taking 4 densiometer readings per subplot, 1 in each cardinal direction. I then multiplied the readings by a correction factor of 1.04 to estimate the percentage of overhead area not occupied by the canopy (Lemmon 1956), using the difference between this value and 100 as an estimate of overstory density.

I sampled the overstory within 11.3-m radius plots (0.04 ha, Bowman 1999), recording species and diameter at breast height (DBH) for each live tree ≥12.7 cm DBH.

I recorded the crown class of each tree as dominant, codominant, intermediate, or suppressed. I also noted any cavities or bear sign (i.e., scratch marks) for each tree. I sampled the midstory within 3.62-m radius plots (0.004 ha, Bowman 1999), recording all live vegetation $\geq$1.5 m in height not included in the overstory plot. Data were recorded as a stem count by species. All vines above the required height also were included on the midstory plots.

I used a cover pole (Nudds 1977, Griffith and Youtie 1988) to estimate the amount of horizontal cover available to black bears. I took 4 cover-pole readings at each subplot, 1 in each cardinal direction. Each reading was taken 15 m away, with the observer standing at the plot center. I then sampled the understory at 4 locations per subplot, 1 in each cardinal direction. Each understory plot was located 15 m from the plot center and was 1.15 m in radius (0.0004 ha, Bowman 1999). I recorded the percent cover of all rooted vegetation <1.5 m in height that I deemed to be important bear foods (Smith 1985, Edwards 2002). I also recorded the phenologic code of each species (e.g., flowering, fruiting).

I conducted den tree searches within 100-m x 100-m plots (1 ha) in the MTD and within 80.5-m x 80.5-m plots (0.65 ha) at White River NWR; these den tree plots were centered on each of the subplots. I considered all trees $\geq$84 cm DBH (Johnson 1978), allowing for buttressing and taper, to be large enough for potential den trees. I recorded species, DBH, presence of a cavity, and visible bear sign (e.g., claw marks) for each tree. If a cavity was present, I recorded the size (0–15 cm, 15–30 cm, or >30 cm) and height of the cavity opening. I also recorded the cause of the cavity formation (e.g., lightning, windbreak, rot), aspect of the cavity entrance, and whether the cavity was above or below the first branch. Tree counts were then rescaled into densities.

From those plot measurements, I calculated total basal area, soft mast basal area, soft mast canopy cover (i.e., soft mast basal area/total basal area), hard mast basal area, hard mast basal area of mature trees, hard mast canopy cover (i.e., hard mast basal area/total basal area), canopy closure, den tree availability, and horizontal cover. Total basal area was used to determine whether overall stand stocking differed among study areas. Spring food is generally not considered to be limiting (van Manen 1991), so no measures of spring food were included in the habitat assessment. I considered soft mast variables to be measures of summer food availability and hard mast variables as measures of fall food availability. Hard mast basal area of mature trees was calculated using species-specific diameter limits, which were developed by Bowman (1999) and derived from literature review and expert opinion. I used canopy closure as a measure of the amount of light reaching the forest floor, which in turn can be used as an index of herbaceous understory growth. I assessed den tree availability using 3 variables: number of large trees, number of large trees with the presence of any cavity, and number of large trees with a cavity suitable for a bear (i.e., large opening, above flood line). Finally, I measured horizontal cover at 4 height strata (0.0–0.5 m, 0.5–1.0 m, 1.0–1.5 m, and 1.5–2.0 m) to estimate protective and denning cover.

Study Area Comparisons. To reduce the large suite of habitat variables, I performed a principal components analysis (PCA) on the correlation matrix using robust methods and a Varimax rotation using NCSS statistical software (NCSS 2001, Kaysville, Utah, USA). PCA involves a mathematical procedure that transforms a set of correlated response variables into a smaller set of uncorrelated variables. Thus, PCA allows the original variables to be replaced by a smaller set of underlying variables without losing any information (Johnson 1998). I performed the PCA on the correlation matrix instead of the variance-covariance matrix because the variables were on unequal footing (i.e., different units) and had different variances associated with them. Robust methods were used to minimize the influence of outliers. I used the Varimax rotation to improve the interpretation of the principal components. I used an eigenvalue cutoff of 0.7 (W. Seaver, University of Tennessee, personal communication) to determine the important principal components and used factor loadings to identify the variables associated with each component. I considered variables with factor loading scores ≥ 0.8 to be associated with the corresponding principal component. I then multiplied each principal component by the square root of its eigenvalue to ensure that each principal component would have the same variance as the corresponding eigenvalue (Johnson 1998). The significant principal components were then used in a principal variable selection to identify the components that contributed most to the differences among study areas.

I used pair-wise randomization tests based on 10,000 Monte Carlo simulations to examine the selected principal components in multivariate and univariate frameworks. Randomization tests are permutation tests that randomly mix the data for statistical inference (Edgington 1995). Initially, a test statistic is computed for the experimental data, then the data are permuted (i.e., rearranged) repeatedly and the test statistic is computed for each of the resulting data permutations. Those data permutations constitute the reference set for determining significance, the level of which is determined by the proportion of data permutations in the reference set that have test statistic values greater than or equal to the value for the experimentally obtained results (Edgington 1995). I chose to use randomization tests because the original set of variables lacked normality, and randomization tests do not require the normality assumption to be met. Additionally, randomization tests allow for multivariate comparison of the selected principal components. For multivariate comparisons, I used Hotelling's T^2 test statistic with Bonferroni procedures ($\alpha_{\text{Overall}} = 0.05$, $\alpha_{\text{Individual}} = 0.05/3$) to determine which study areas were different. If overall differences between areas were detected, I individually compared principal components using Student's t-tests with the Bonferroni adjustment.

Finally, Bowman (1999) developed a HSI model for black bears in Mississippi for habitat types similar to the MTD and White River NWR study areas. HSI models are best viewed as hypotheses of species-habitat relationships and are based on the premise that habitat suitability can be linked to habitat attributes by some functional relationship (Morrison et al. 1992). The relationship is depicted as HSI scores ranging from 0 to 1, representing "poor" to "good" habitat, respectively (USFWS 1981). The Bowman (1999) HSI model used logistic regression for model development and a stepwise variable selection to identify significant variables at a landscape level. The model used mean habitat characteristics for each cover type, which were pooled among study areas, to enter into the logistic equation (Bowman 1999). Three variables were found to be significant predictors of black bear habitat suitability in Mississippi: soft mast canopy cover, hard mast canopy cover, and hard mast basal area of mature trees, indicating that the model is largely a measure of food availability. The Bowman (1999) HSI model considered suitability values >0.40 to be suitable habitat for black bears. To apply the model to the MTD and White River study areas, I used Bowman's (1999) HSI values reported for bottomland hardwoods and clearcuts (0.883 and 0.276, respectively) combined with the percentage of each cover type to obtain overall HSI scores for each study area. I defined bottomland hardwoods as oak-mixed hardwoods or cypress-tupelo cover types. I pooled disturbed cover types and clearcuts.

Flood Simulation

To determine the extent to which areas suitable for ground dens may be limiting for bears in the MTD, I performed a flood simulation using Arcview GIS and Hydrological Engineering Center's River Analysis System (HEC-RAS, Brunner 2002*a*) software. HEC-RAS uses stream flow (m^3/sec) data in conjunction with digital elevation model (DEM) data to perform 1-dimensional hydraulic calculations for a full network of natural and constructed channels (Brunner 2002*a*). For the MTD, 3 gage stations were used to obtain stream flow data: Tombigbee River at Coffeeville Lock and Dam near Coffeeville, Alabama (USGS 02469761); Alabama River at Claiborne, Alabama (USGS 02429500); and Mobile River at Bucks, Alabama (USGS 02470630, Fig. 5).

I used 30-m DEM data as the baseline for the flood simulation analysis and used the HEC-GeoRAS software (Ackerman 2002) to create river analysis system (RAS) themes (stream centerline, channel banks, flow path centerlines, and cross-section cutlines) that were subsequently input into HEC-RAS. RAS themes were created for the Tombigbee, Alabama, and Mobile rivers. No RAS themes were created for the Tensaw and Middle rivers because no stream flow data were available. Cross-section cutlines were generally drawn between 200 and 300 m apart making sure that the lines stayed perpendicular to the flow of the river. Each cross-section cutline extended across the

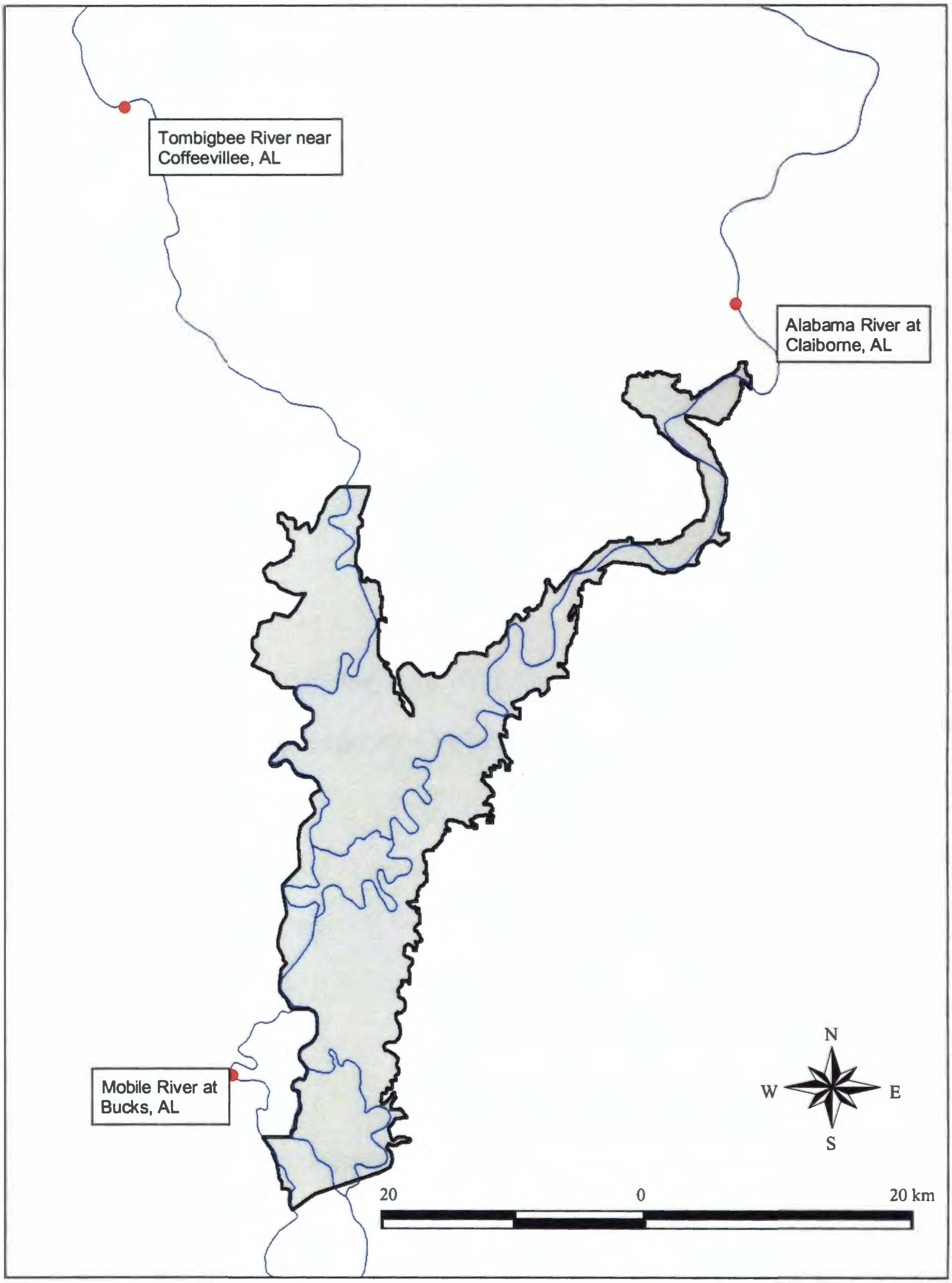

Fig. 5. USGS gage station locations for the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

entire floodplain and sampled the elevation every 100 m. Where 2 rivers were parallel to each other, I assumed that each river flooded equally and drew the cross-section cutlines so they were halfway between the 2 rivers.

For the HEC-RAS simulations, I performed flood simulations for 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year flood recurrence levels (Atkins 1996, Table 1). A flood recurrence level is the probability that a given flood event will be equaled or exceeded in any given year (Robinson et al. 1998). To perform the flood simulations, I used flood discharge levels obtained from the 3 USGS gage stations. I assumed that the stream flow on the northern reach of the Mobile River was equal to the stream flow at the mouth of the Tombigbee River plus the stream flow of the Alabama River at the Alabama River cutoff. Steady flow analysis was used to calculate water surface profiles assuming steady gradually varied flows (Brunner 2002*b*). The computational procedure is based on the solution of the 1-dimensional energy equation and was evaluated from 1 cross-section cutline to the next as

$$Y_2 + Z_2 + \frac{\alpha_2 + V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 + V_1^2}{2g} + h_e,$$

where

Y_1, Y_2 = depth of water at cross-section cutlines,

Z_1, Z_2 = elevation of the main channel inverts,

V_1, V_2 = average velocities (total discharge / total flow area),

α_1, α_2, = velocity weighting coefficients,

g = gravitational acceleration, and

h_e = energy head loss (Brunner 2002*b*).

Table 1. Peak discharge by selected recurrence level at selected gage stations in Alabama, 2002–2003

		Peak discharge for the indicated recurrence interval (m^3/s)							
River Name	Location	2-year	5-year	10-year	25-year	50-year	100-year	200-year	500-year
Tombigbee River	Coffeeville, AL	3,700	5,100	5,900	6,900	7,600	8,300	9,000	9,900
Alabama River	Claiborne, AL	3,800	4,900	5,600	6,400	6,900	7,400	7,900	8,500
Tombigbee River	Mouth at Mobile River	3,400	4,500	5,200	5,900	6,500	7,300	7,900	8,800
Alabama River	Mouth at Alabama River cutoff	4,200	5,200	5,800	6,400	6,800	7,100	7,600	7,900
Mobile River	North reach	7,600	9,700	11,000	12,300	13,300	14,400	15,500	16,700
Mobile River	South reach	7,800	10,300	11,700	13,400	14,500	15,600	16,600	17,900

Energy losses were evaluated by friction (Manning's equation) and contraction or expansion (Brunner 2002*a*). For the main channel, I assumed Manning's n to be 0.030, which is typical for excavated or dredged channels having grass and some weeds (Brunner 2002*a*). For waters outside the main channel, I assumed a Manning's n of 0.10 corresponding to heavy stands of timber with few downed trees, little undergrowth, and flow below the branches (Brunner 2002*a*). I assumed subcritical flow was comprised of gradual transitions and set contraction and expansion coefficients to 0.10 and 0.30, respectively (Brunner 2002*a*).

The HEC-RAS program assigned the height of flood water above mean sea level to each of the cross-section cutlines. I extended cutlines for the southern reach of the Mobile River eastward across the entire floodplain to compensate for the lack of data on the Tensaw and Middle rivers, assuming that the height of flood waters would be equal for the entire southern part of the Delta. I used the inverse distance weighted method in ArcGIS™ version 8.2 (Environmental Systems Research Institute Redlands, California) to interpolate between cutlines, resulting in a 30-m grid of flood-water heights. Using this grid, I subtracted the DEM grid from it to obtain a 30-m grid of flood-water-depth values, where any value ≤ 0 indicated a location that did not flood. I performed this calculation for each of the 8 flood recurrence levels.

I validated the model using the height of water marks data collected at each of the vegetation subplots. Subplots located in clearcuts with no large trees to show water marks were assumed to flood if the surrounding subplots showed water marks and no major elevation changes were noted. Because subplots were not independent, I randomly selected 1 subplot per plot to use in the validation. I obtained the overall correct classification rate, sensitivity (proportion of flooded plots that were predicted to flood), specificity (proportion of dry plots that were predicted to be dry), false positive rate (proportion of predicted floods that were dry), and false negative rate (proportion predicted to be dry that were flooded). Additionally, I used points known to stay dry to assess the legitimacy of the model. Known dry points included Bottle Creek Indian Mound Complex located on Mound Island, Choctaw Bluff, and Seaboard Bluff (Fig. 6).

Public Support

Public support is vital to the success of a reintroduction effort (Reading and Kellert 1993, Kellert 1994, Reading and Clark 1996). To predict the amount of public support for black bear restoration in southwestern Alabama, I used a spatially explicit model developed for Mississippi (Bowman et al. 2004). The model was based on mail surveys of Mississippi land owners and used a logistic equation to predict the probability of a person supporting a reintroduction event based on their age, sex, and race (Fig. 7). I used 2000 U. S. Census Bureau data for block groups to determine support for reintroducing bears into the MTD. Because reintroduced bears can travel great distances (Eastridge and Clark 2001, Wear 2003), predicted support was calculated for all counties in Alabama, Florida, and Mississippi that were within 100 km of the MTD. I used 100 km because net movements of reintroduced black bears rarely exceeded this distance when soft-release techniques were used (Eastridge and Clark 2001, Wear 2003). Predicted percentage of residents $\geq$18 years old in each block group supporting a reintroduction was calculated as

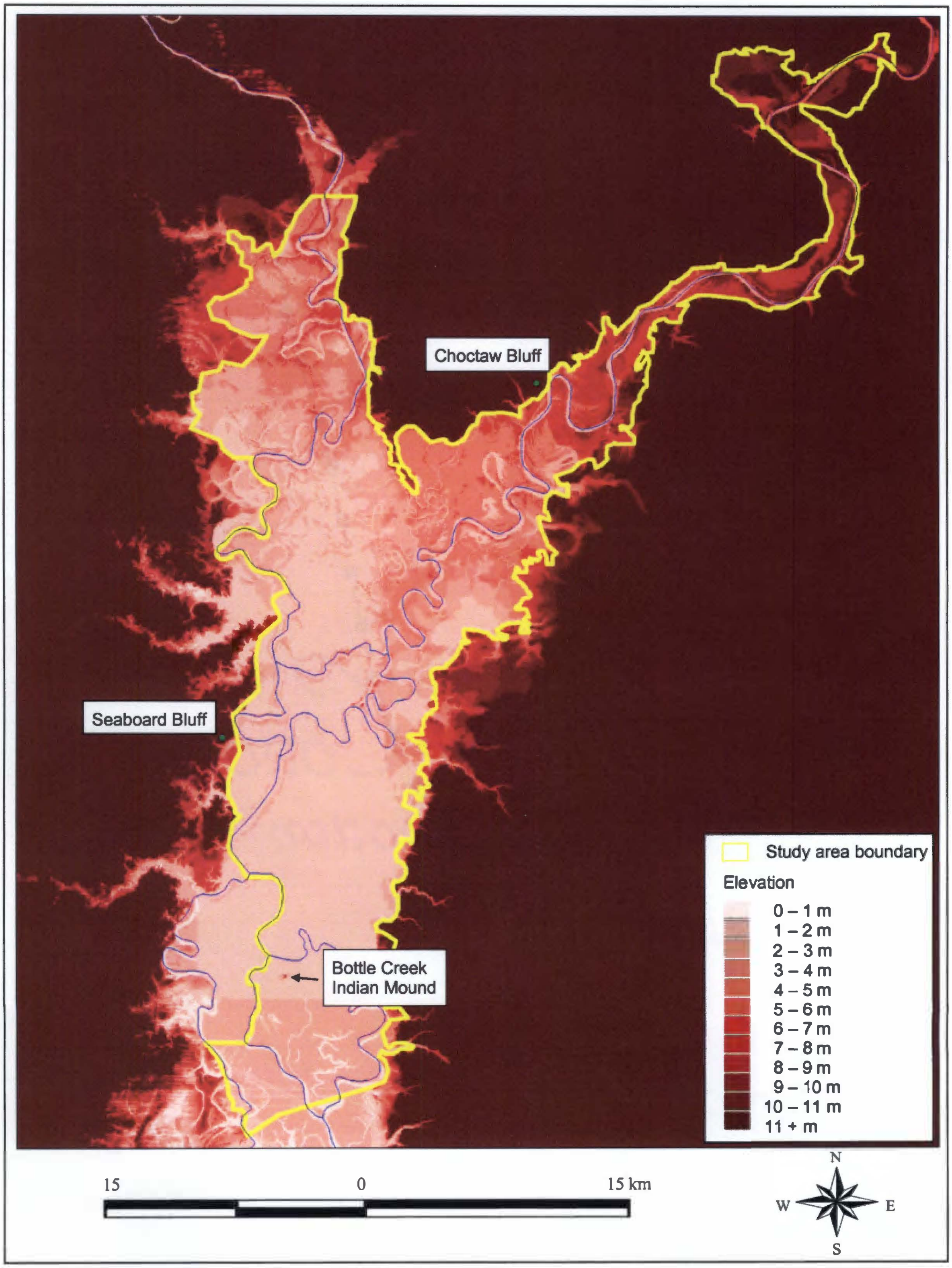

Fig. 6. Locations of known dry points in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

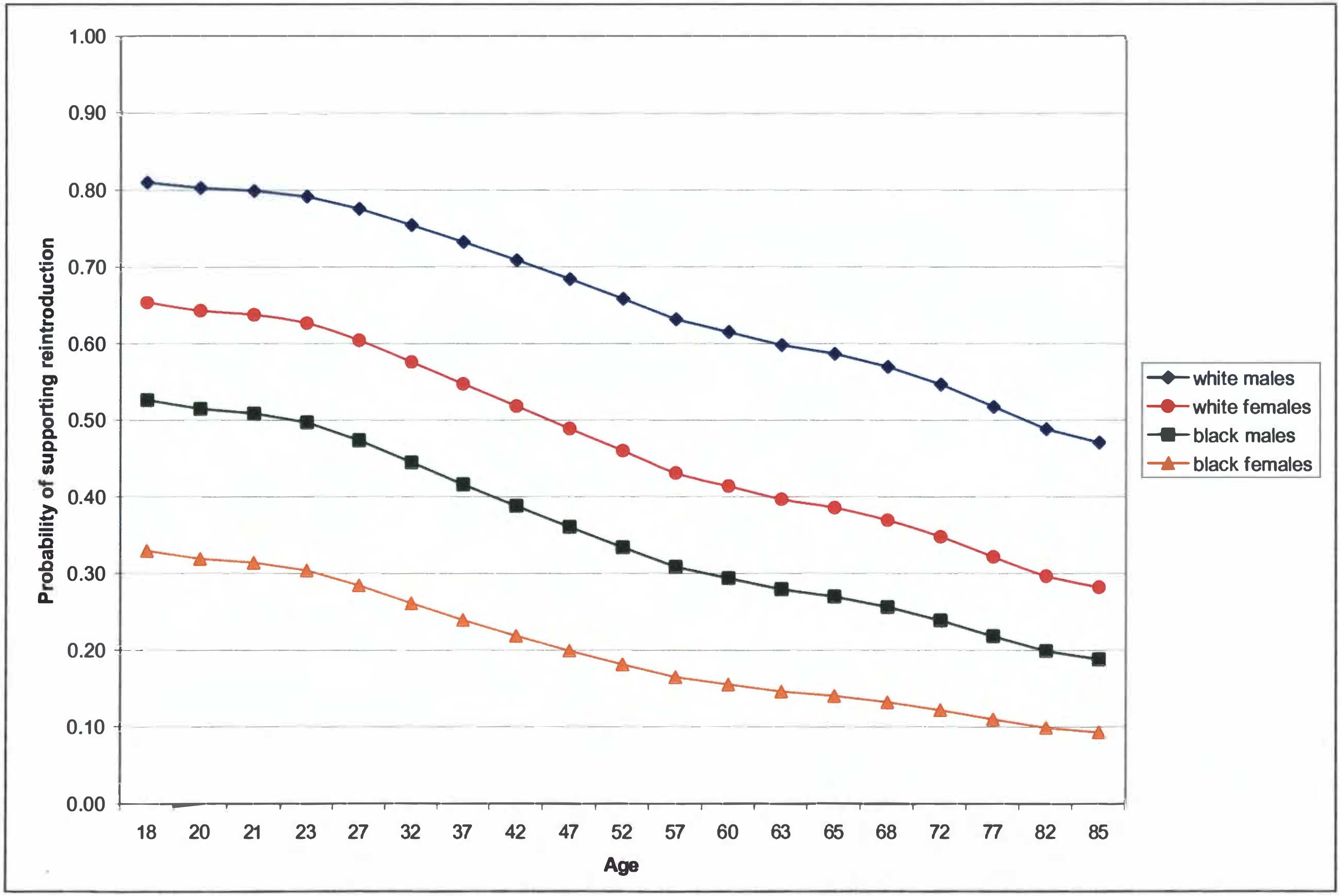

Fig 7. Probability of support of black bear reintroduction by age, sex, and race (from Bowman et al. 2004).

$$S_j = \frac{\sum_{i=1}^{d} p_i n_{ij}}{N_j} \times 100,$$

where

S_j = predicted percentage of the j^{th} block group residents supporting restoration,

d = demographic group (e.g., white males age 18),

p_i = probability of support for the i^{th} demographic group,

n_{ij} = number of individuals in the j^{th} block group for the i^{th} demographic group,

and

N_j = total population $\geq$18 years old of the j^{th} block group (Bowman et al. 2004).

I used ArcView GIS to assign each S_j to its respective block group.

CHAPTER IV

RESULTS

Habitat Assessment

I collected overstory, midstory, and understory data at 51 plots in the MTD during summer 2002 and 2003 (Fig. 8), whereas White River NWR personnel collected data at 93 plots (39 on the North Unit and 54 on the South Unit; Fig. 9) from June 2000 to December 2002. During summer 2003, I revisited 23 and 43 of those plots on the North and South units, respectively, and collected data on den tree availability, canopy closure, and horizontal cover.

In the Mobile-Tensaw Delta, I found 2 trees showing bear markings, both located on the northern part of the Upper Delta Wildlife Management Area (Fig. 8). The first tree was a water tupelo with a DBH of 97.1 cm. The second tree was a water oak with a DBH of 87.2 cm. The markings were scarred over indicating that they were not recently made. Neither tree had visible cavities. In June 2003, I found a bear scat in the northeastern part of the study area just outside the delta region (Fig. 8). Blackberries were the dominant food comprising the scat, along with some insect matter.

I identified 7 principal components that accounted for 95.0% of the variation in the data at the 3 study areas (Table 2). The first component (which I termed horizontal cover) contained all 4 horizontal cover variables. The second component (hard mast) contained hard mast basal area, hard mast basal area of mature trees, and hard mast canopy cover, and the third component (soft mast) contained soft mast basal area and soft mast canopy cover. The fourth component (den tree availability) included number of

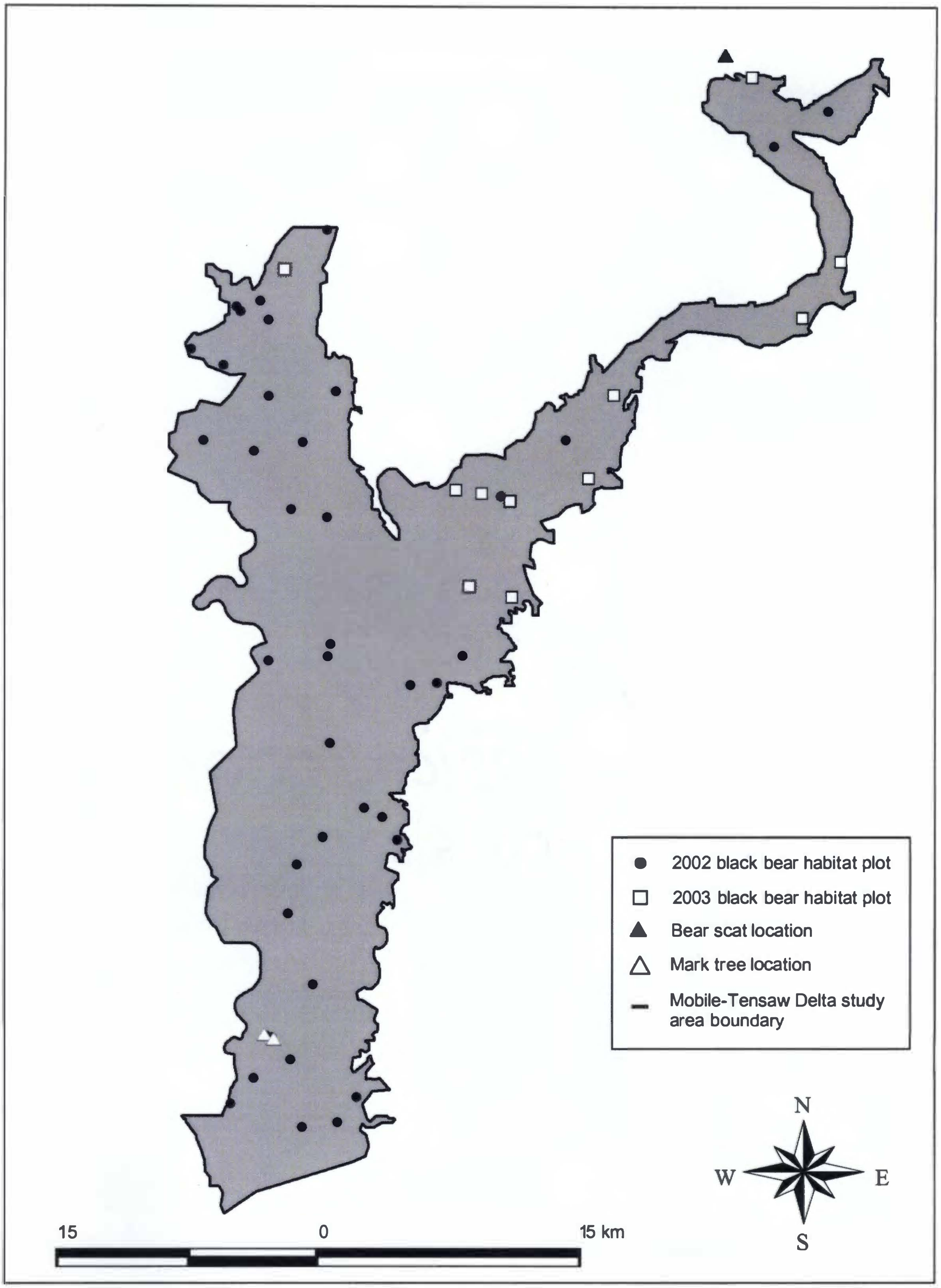

Fig. 8. Mobile-Tensaw Delta study area plot and bear sign locations, Alabama, 2002–2003.

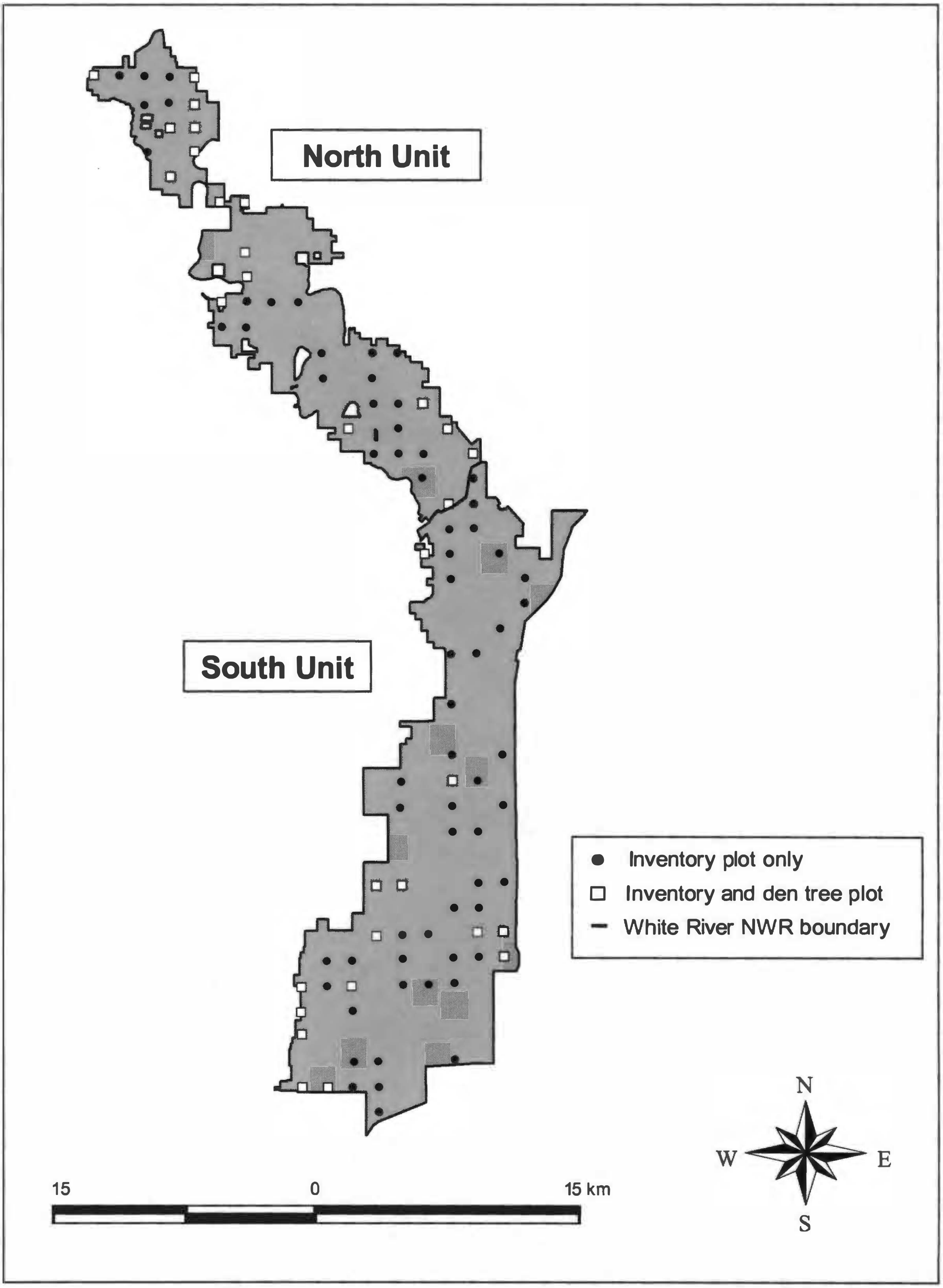

Fig. 9. North and South unit plot locations, White River NWR, Arkansas, 2000–2003.

Table 2. Habitat variables associated with each principal component obtained from principal components analysis, 2002–2003.

Principal component number	Generalized category	Associated variables	% variation explained
1	Horizontal cover	Horizontal cover (0.0 – 0.5 m) Horizontal cover (0.5 – 1.0 m) Horizontal cover (1.0 – 1.5 m) Horizontal cover (1.5 – 2.0 m)	26.85
2	Hard mast	Hard mast basal area Hard mast basal area of mature trees Hard mast canopy over	19.86
3	Soft mast	Soft mast basal area Soft mast canopy cover	14.01
4	Den tree availability	Number of large trees with any cavity Number of large trees with a cavity suitable for a bear	13.24
5	Canopy closure	Canopy closure	7.33
6	Large tree availability	Number of large trees	6.45
7	Total basal area	Total basal area	7.31

large trees with any cavity and number of large trees with a cavity suitable for a bear. The fifth, sixth, and seventh components consisted of single variables: canopy closure, large tree availability, and total basal area, respectively.

The principal variable selection indicated that 5 principal components (hard mast, soft mast, den tree availability, large tree availability, and total basal area) best explained the variation in the data (combined $R^2 = 0.46$; Table 3). Using those 5 principal components, I detected overall differences between the MTD and the North Unit ($T^2_{5,\,29.4} = 29.54$, $P = 0.001$) and the MTD and the South Unit ($T^2_{5,\,60.6} = 92.49$, $P < 0.001$; Table 4). I found no overall difference between the North and South units, although the test statistic neared the significance level ($T^2_{5,\,57} = 15.55$, $P = 0.020$). The MTD had lower values for the hard and soft mast principal components (t ranged from 2.47 to 3.79, P ranged from <0.001 to 0.015) than the North Unit, but I found no differences between den tree availability, large tree availability, and total basal area, although the test statistic for den tree availability approached statistical significance (t ranged from 0.49 to 2.15, P ranged from 0.028 to 0.627). I found lower values for the hard mast, soft mast, and den tree availability principal components (t ranged from 2.71 to 5.70, $P \leq 0.001$) in the MTD than at the South Unit, but no differences between large tree availability and total basal area were detected (t ranged from 1.07 to 1.14, P ranged from 0.253 to 0.287). I detected no differences in any of the principal components between the North and South Units, although the test statistics for hard mast and large tree availability again neared statistical significance (t ranged from 0.66 to 2.24, P ranged from 0.030 to 0.504).

Based on the vegetation plots, I estimated that the MTD was comprised of 65.1% oak-mixed hardwoods, 18.8% cypress-tupelo, and 16.1% disturbed cover types. At

Table 3. Change in R^2 associated with the principal variable selection, 2002–2003.

Principal components in model	Cumulative R^2	Change in R^2	Associated principal components
1	0.24	0.243	Hard mast
2	0.37	0.124	Hard mast Soft mast
3	0.43	0.064	Hard mast Soft mast Den tree availability
4	0.45	0.015	Hard mast Soft mast Den tree availability Large tree availability
5	0.46	0.015	Hard mast Soft mast Den tree availability Large tree availability Total basal area
6	0.47	0.006	Hard mast Soft mast Den tree availability Large tree availability Total basal area Canopy closure
7	0.47	0.003	Hard mast Soft mast Den tree availability Large tree availability Total basal area Canopy closure Horizontal cover

Table 4. Overall and individual principal component comparisons among the Mobile-Tensaw Delta, Alabama, White River North Unit, Arkansas, and White River South Unit, Arkansas study areas, 2002–2003.

Principal component category	Mobile-Tensaw Delta vs. White River North *P*-value	Mobile-Tensaw Delta vs. White River South *P*-value	White River North vs. White River South *P*-value
Overall	<0.001	<0.001	0.020
Hard mast	0.015	<0.001	0.031
Soft mast	<0.001	<0.002	0.490
Den tree availability	0.028	0.001	0.492
Large tree availability	0.099	0.291	0.030
Total basal area	0.634	0.253	0.504

White River NWR, the North Unit was comprised of 93.8% oak-mixed hardwoods and 6.2% disturbed, whereas the South Unit was comprised of 99.3% oak-mixed hardwoods and 0.7% disturbed. Based on the Bowman (1999) HSI values and the above cover type percentages, I calculated overall HSI scores of 0.786, 0.846, and 0.879 for the MTD, North Unit, and South Unit, respectively (Table 5).

Flood Simulation

Flood simulations for the various recurrence levels indicated that nearly all of the MTD floods each year, even at 2-year flood stream flows (Fig. 10–13). With the exception of Bottle Creek Indian Mound, the entire southern portion of the MTD was flooded. In the northern part of the MTD, no dry areas along the Tombigbee River existed, although areas with shallow water were present at lower flood stages. Along the Alabama River, a few dry areas were present. Where flood stages reached the 100-year level, virtually all of the MTD was flooded.

The model performed well with overall correct prediction rates of 92.5%, 100.0%, and 94.1% for 2002, 2003, and both years combined, respectively (Table 6). Correct prediction of flooding (sensitivity) was similar (range = 92.5–100.0%). None of the selected 2002 subplots were observed to be dry, so no 2002 data were available to validate the specificity of the model. In 2003, the 1 selected subplot observed to be dry was correctly predicted (specificity). False-positive rates ranged from zero to 7.5%, whereas none of the subplots showed a false-negative. The known dry areas (Bottle Creek Indian Mound, Choctaw Bluff, and Seaboard Bluff) did not become inundated during any of the flood simulations.

Table 5. Calculated HSI scores for the Mobile-Tensaw Delta, Alabama, White River North Unit, Arkansas, and White River South Unit, Arkansas study areas, 2002–2003.

Study area	Cover type	Cover type %	Bowman HSI value	Area HSI score
Mobile-Tensaw Delta	Bottomland hardwoods	83.9	0.883	0.786
	Disturbed	16.1	0.276	
White River North Unit	Bottomland hardwoods	93.8	0.883	0.846
	Disturbed	6.2	0.276	
White River South Unit	Bottomland hardwoods	99.3	0.883	0.879
	Disturbed	0.7	0.276	

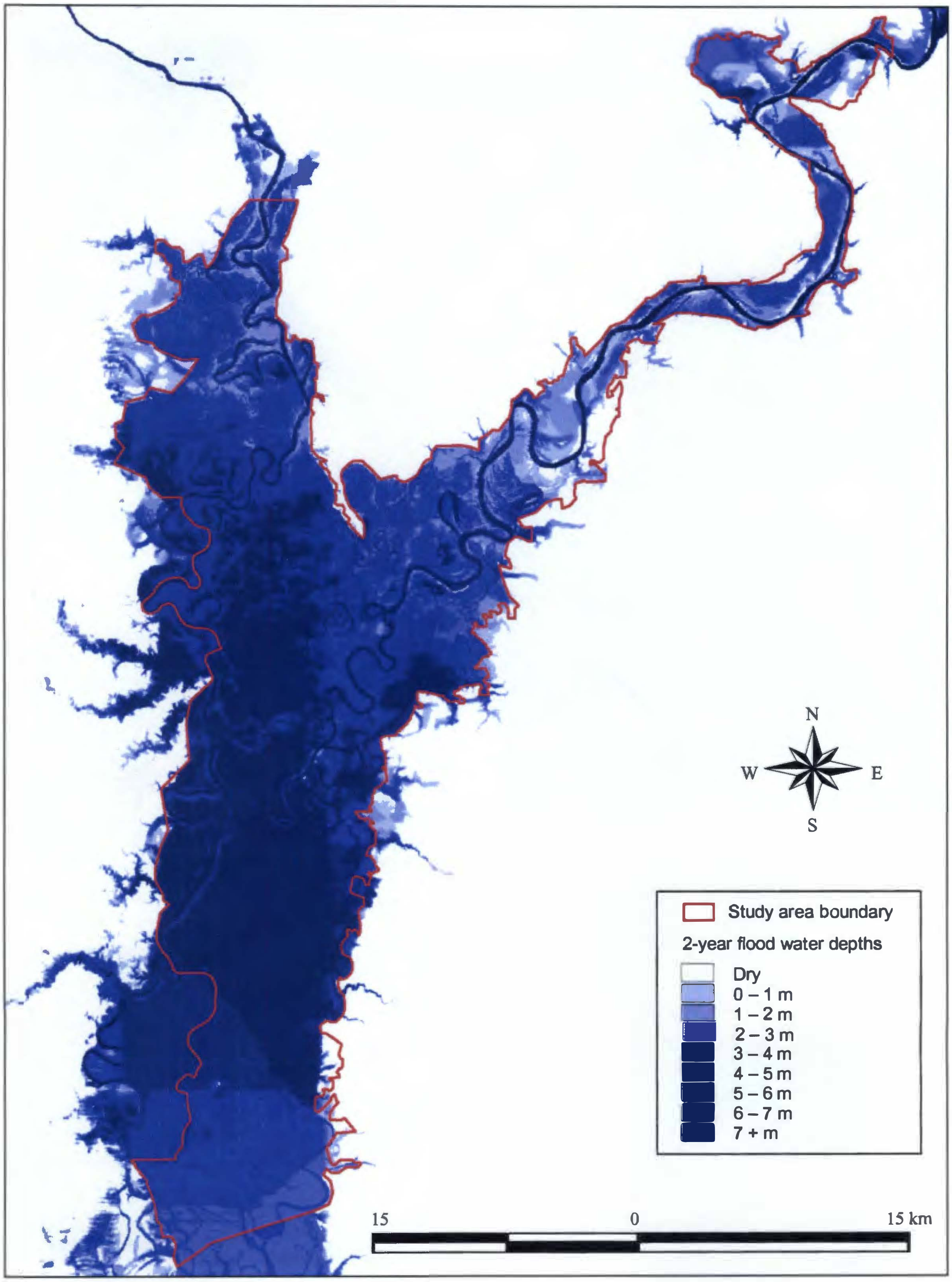

Fig. 10. Water levels for 2-year flood stream flows in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

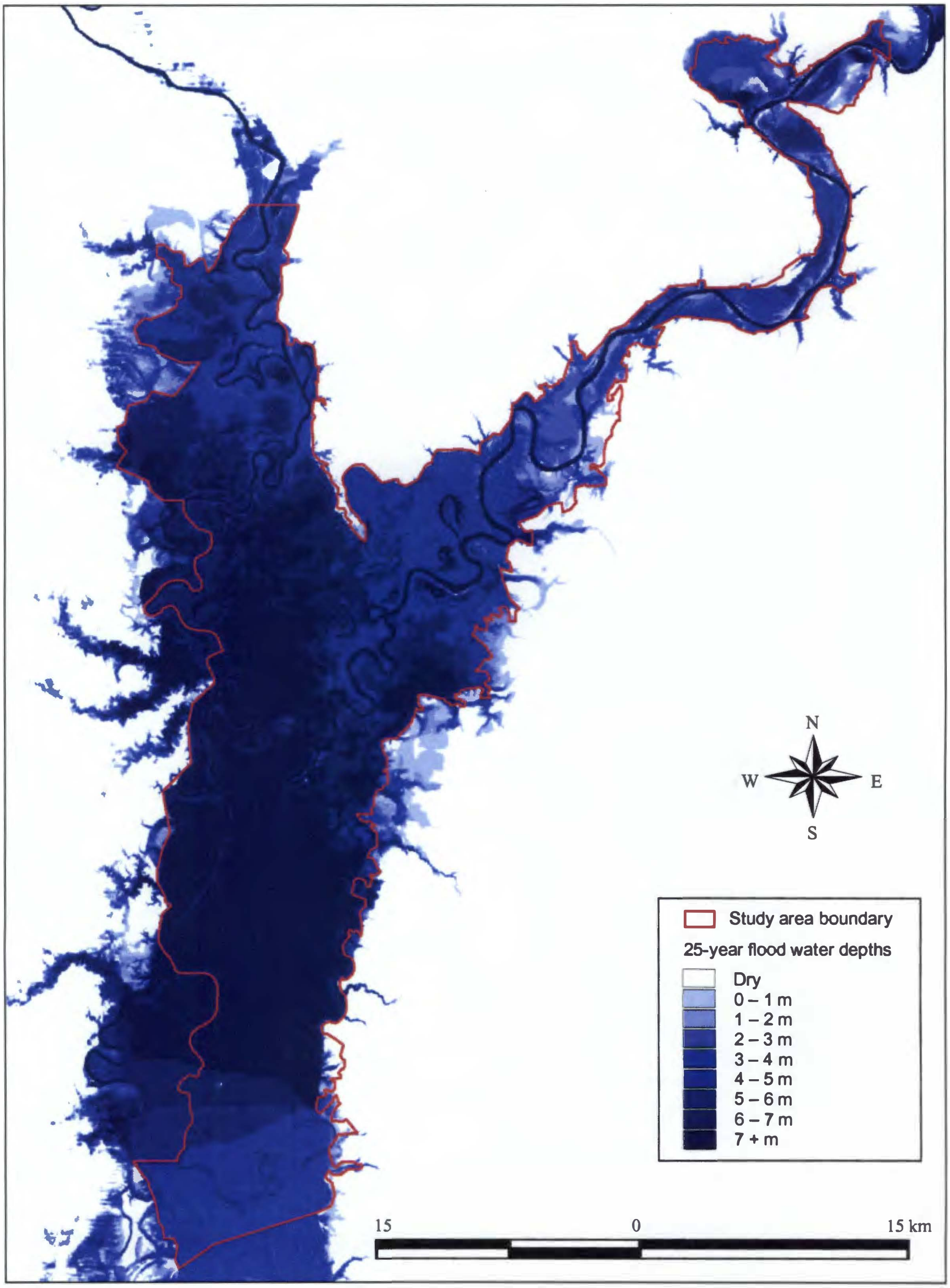

Fig. 11. Water levels for 25-year flood stream flows in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

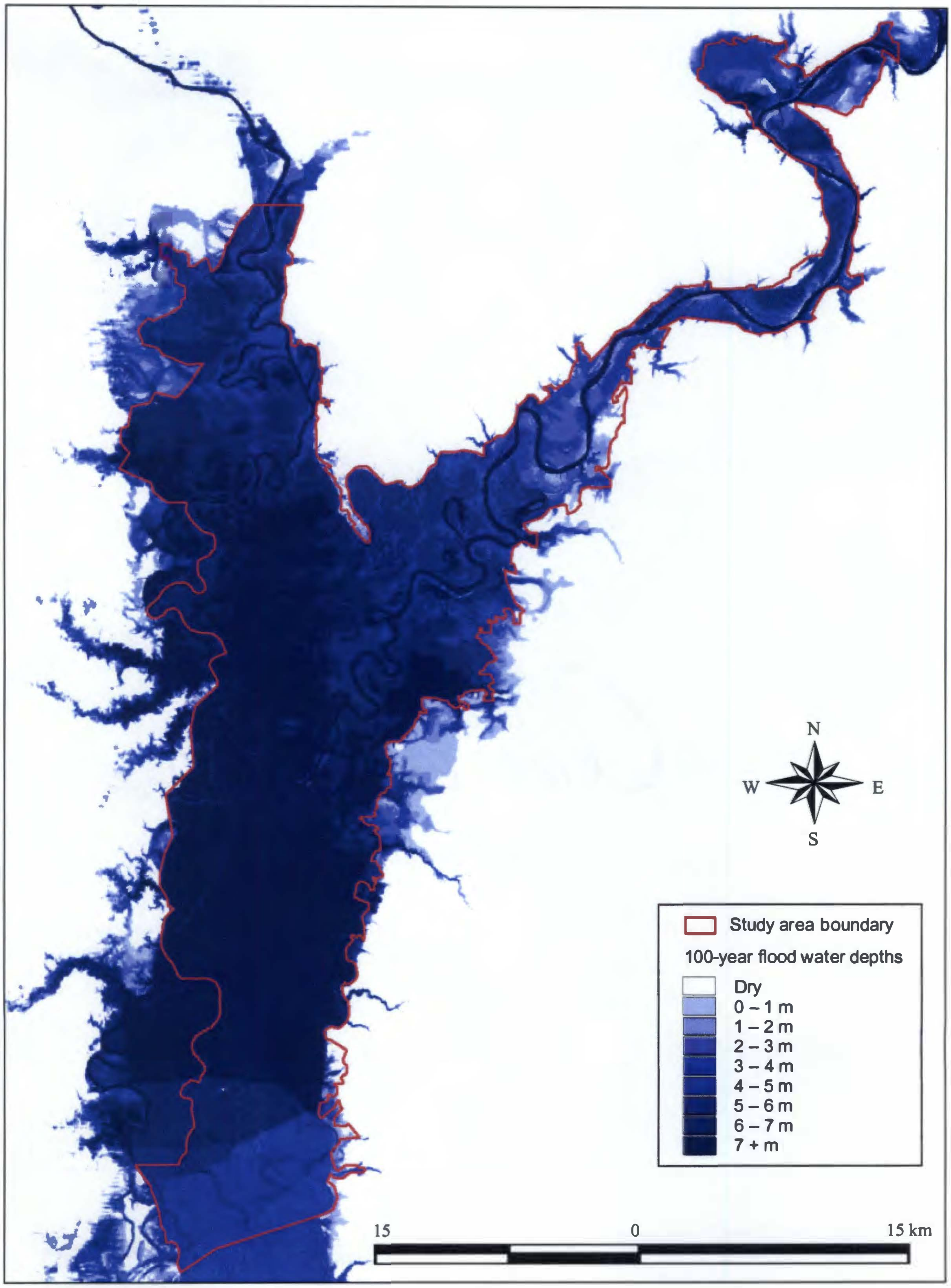

Fig. 12. Water levels for 100-year flood stream flows in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

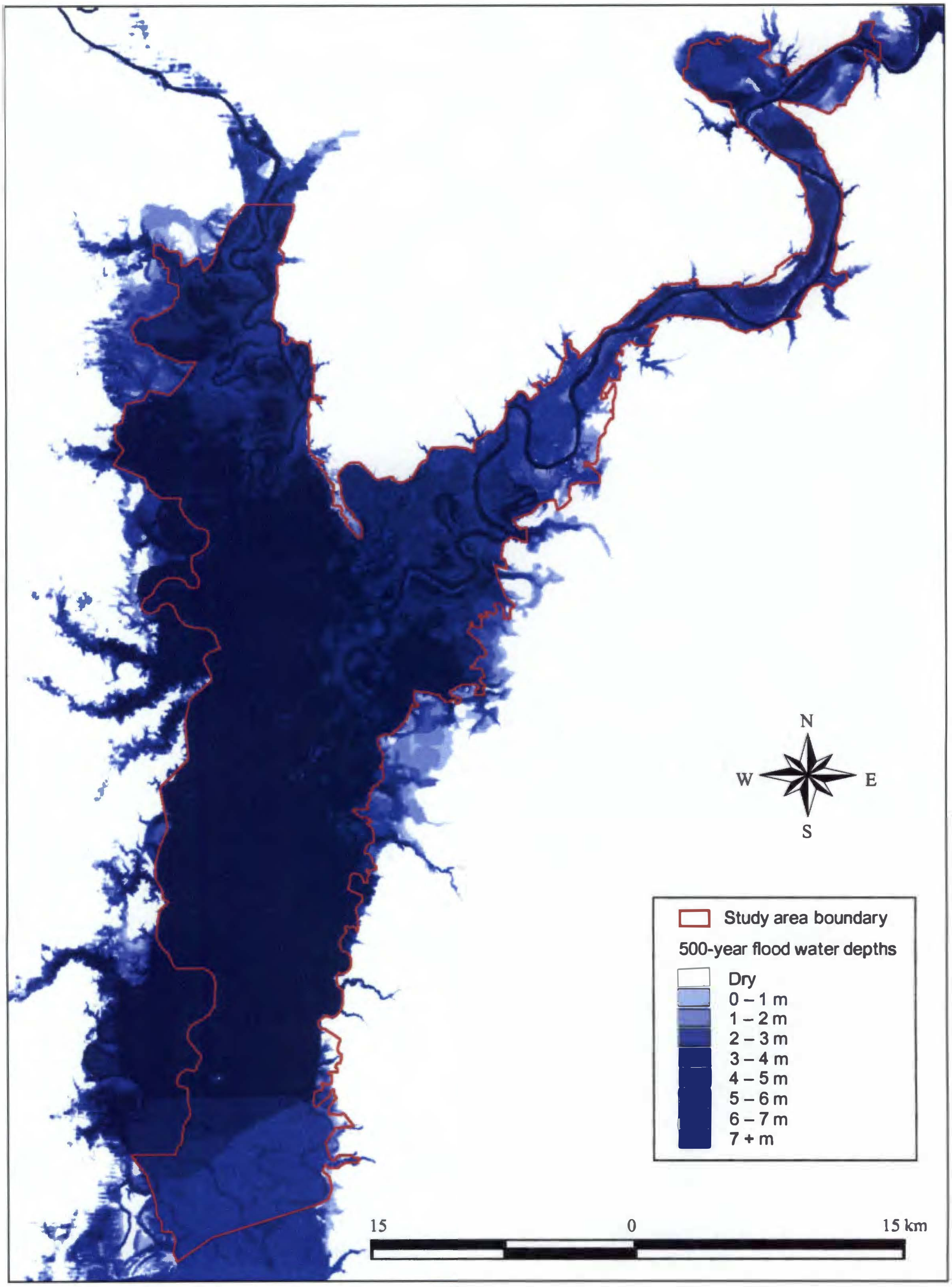

Fig. 13. Water levels for 500-year flood stream flows in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

Table 6. Verification of the HEC-RAS flood simulation model to predict flooding based on water-marks at habitat plots in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

Subplots	n	% correct	% sensitivity[a]	% specificity[b]	% false positive[c]	% false negative[d]
All years	51	94.1	94.0	100.0	6.0	0.0
2002	40	92.5	92.5	—	7.5	0.0
2003	11	100.0	100.0	100.0	0.0	0.0

[a] Correct prediction of a flooded pixel

[b] Correct prediction of a dry pixel

[c] Flooded pixel predicted, but actually dry

[d] Dry pixel predicted, but actually flooded

Public Support

Overall, the MTD and surrounding areas showed moderate support for a black bear reintroduction with the majority of block groups predicting support in the 40–49% and 50–59% categories (Fig. 14). The percentage of support for the entire area ranged from 25.4% to 73.8%, whereas support within the MTD ranged from 34.8% to 57.3%. Generally, suburban areas tended to have the highest predicted percentage of support, whereas inner city and extreme rural areas tended to have the lowest predicted percentages of support.

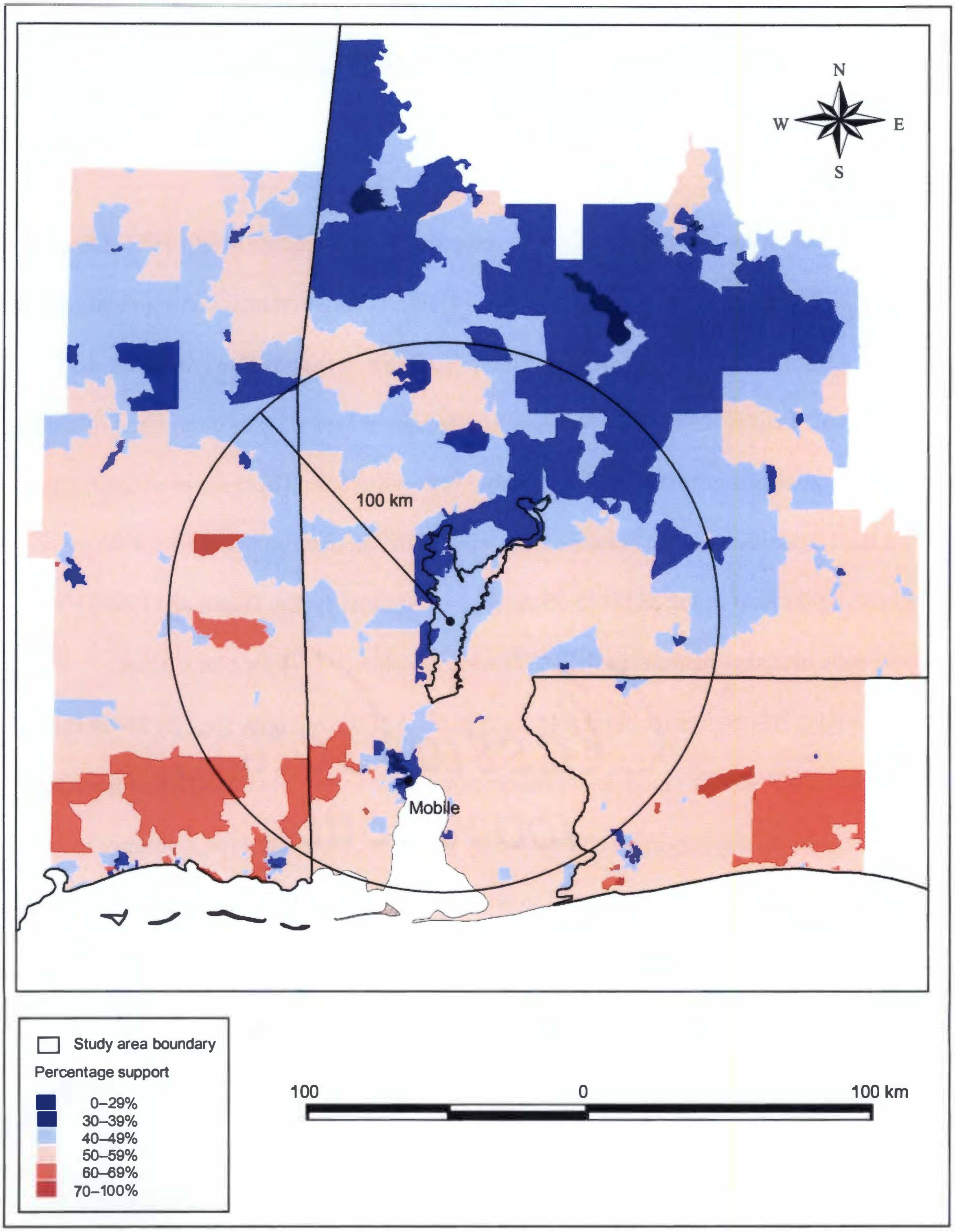

Fig. 14. Predicted percentage of residents by block group living in the Mobile-Tensaw Delta, Alabama and surrounding areas supporting a black bear reintroduction based on logistic regression (Bowman et al. 2004).

CHAPTER V

DISCUSSION

Habitat Assessment

White River NWR is considered exceptional bear habitat (Smith 1985, Oli et al. 1997, R. Eastridge, Arkansas Game and Fish Commission, personal communication), so it is not surprising that my estimates of food resources in the MTD were lower. In comparison, Tensas River National Wildlife Refuge in Louisiana is comprised of similar alluvial bottomland cover types, has a viable bear population (Boersen et al. 2003), but has a hard mast basal area of mature trees of 6.98 m^2/ha (from Shropshire 1996), only slightly higher than in the MTD (5.39 m^2/ha). Additionally, the Bowman (1999) HSI model indicated that habitats in the MTD were suitable (≥ 0.4) for black bears. Interestingly, HSI scores for food resources in the MTD were only slightly lower than at White River NWR. HSI models are relative rather than absolute measures of minimum habitat requirements, however, and markedly lower but adequate food resources in the MTD would result in only a slightly lower HSI score. Thus, food resources in the MTD appear to be adequate to support black bears.

Forest management practices on the 3 study areas best explain the observed differences in food availability (Table 7). Clearcutting is extensively used to harvest timber in the MTD and those clearcut stands often are replaced by sweetgum, an invasive, shade-intolerant species. Whereas the regrowth of sweetgum contributes to total basal area, it is not a mast-producing species and its presence decreases the amount of hard and soft mast available in those stands in the MTD. In contrast, selection

Table 7. Habitat variable means and standard deviations for the Mobile-Tensaw Delta, Alabama, White River North Unit, Arkansas, and White River South Unit, Arkansas study areas, 2002–2003.

	Mobile-Tensaw Delta		White River North Unit		White River South Unit	
	Mean	SD	Mean	SD	Mean	SD
Total basal area (m^2/ha)	30.46	22.01	24.61	6.35	25.67	8.33
Hard mast basal area (m^2/ha)	6.50	5.85	9.60	4.76	14.42	5.77
Hard mast basal area of mature trees (m^2/ha)	5.39	5.33	8.31	4.06	12.35	5.42
Hard mast canopy cover (%)	27.78	23.50	40.10	17.70	58.45	21.86
Soft mast basal area (m^2/ha)	1.41	2.05	4.93	4.96	4.64	4.20
Soft mast canopy cover (%)	7.56	13.34	19.76	15.22	18.13	13.98
Large trees (trees/ha)	0.91	1.05	0.85	1.01	1.87	1.45
Large trees with any cavity (trees/ha)	0.13	0.21	0.18	0.32	0.34	0.52
Large trees with a cavity for a bear (trees/ha)	0.00	0.00	0.13	0.26	0.26	0.46

cuttings and uneven-aged regeneration methods are used on the South Unit of White River NWR to retain substantial numbers of trees in a variety of diameter classes that are designed to facilitate oak regeneration (J. Denman, U. S. Fish and Wildlife Service, personal communication). Consequently, hard and soft mast measures on the South Unit were high. The North Unit at White River NWR was managed by 66-cm diameter-limit cutting prior to 1993, meaning that only trees $\geq$66 cm DBH were harvested (J. Denman, U. S. Fish and Wildlife Service, personal communication). Thus, hard mast species, generally being larger than soft mast species, were more likely to be removed on the North Unit, explaining why I found higher point estimates for the hard mast variables on the South Unit ($P = 0.031$). Conversely, soft mast species were rarely harvested, explaining why I was unable to detect any difference between soft mast on the North and South Units, but found more soft mast on the North Unit than in the MTD.

Cover type differences between the 3 areas also may contribute to differences in food availability. I found a larger proportion of disturbed areas in the MTD (i.e., clearcuts) than on either management unit at White River NWR. Although those disturbed areas contained thick understory vegetation, there were few overstory trees to contribute food resources. Additionally, the cypress-tupelo cover type in the MTD did not occur at White River NWR. Those cypress-tupelo swamps, although potentially good denning habitat, contained few hard or soft mast species.

I located many den trees with cavities suitable for bears on the South ($\bar{x} = 0.26$ trees/ha) and North units ($\bar{x} = 0.13$ trees/ha), but was unable to find any such den trees in the MTD. Bowman (1999) assumed den sites were not limiting in Mississippi and did not include this variable in his model. However, the availability of adequate den sites can be critical in forested wetlands, where lack of topographic relief and seasonal flooding reduces the availability of safe ground dens (Oli et al. 1997). Tree dens are thought to be preferred by bears over other den types when available (Hamilton and Marchinton 1980, Weaver and Pelton 1994), and extensive use of tree dens by bears in bottomland hardwoods subject to flooding has been reported (Smith 1986, Weaver and Pelton 1994, Anderson 1997, Oli et al. 1997, White et al. 2001, Dobey et al. 2002). By using tree dens, bears increase energy savings (Johnson et al. 1978), minimize likelihood of disturbance (Johnson and Pelton 1981), and may enhance neonate survival (White et al. 2001).

The lack of den trees combined with differences in flood regimes between the MTD and White River NWR raise additional concerns in the MTD. Flooding of the White River is caused from the backing up of the Mississippi River and occurs from late November through May. High water usually persists throughout this time period with water levels remaining fairly constant. In contrast, flooding in the MTD is caused by heavy rains in the Mobile River Basin. Although flooding occurs over a similar time frame, flood waters in the MTD continually rise and fall. White River NWR is already inundated when bears select den sites; however, the MTD may not be. This could cause bears in the MTD to select sites that later flood, which could lead to increased den abandonment and cub mortality (Alt 1984).

Differences in den tree availability also can be explained by differing management practices on the 3 study areas. Most of the MTD is privately owned, and many landowners use their forests as a source of income. Those landowners view large trees showing signs of rot or decay as unhealthy (i.e., poor growing stock, poor genetic quality) and, consequently, usually remove those large trees. In contrast, selection cuttings and uneven-aged regeneration methods on the South Unit resulted in the retention of substantial numbers of large-diameter-class trees (66–100 cm; J. Denman, U. S. Fish and Wildlife Service, personal communication). On the North Unit, diameter-limit cutting methods resulted in only large trees being removed. Those contrasting forest management practices help explain why I observed higher numbers of large trees ($P = 0.030$) on the South Unit compared with the North Unit, but found no difference in large tree availability between the MTD and the North Unit. However, because cavity trees were not actively being removed from the stands as in the MTD, I detected no differences in cavity tree availability between the North and South units.

Flood Simulation

The flood simulation performed well at identifying dry areas; no false-negative pixels were reported. False-positive events occurred, however, indicating that the model may be slightly overestimating the flooding in the MTD. This overestimation may be because only 3 gage stations were available to obtain streamflow data. The MTD is a large complex floodplain system, and the limited amount of data may have oversimplified the model causing an increase in predicted water depths. Regardless of the cause of the overestimation, for the purposes of this simulation, it is preferable to underestimate the number of dry sites rather than underestimate the number of flooded ones.

Because of the lack of den trees in the MTD, safe ground denning locations are needed for reintroduction sites. To be considered a potential reintroduction site, it is important that areas do not become inundated during winter flooding. This will help to minimize the chance of den abandonment and maximize cub survival. The model indicated that areas along the Alabama River have the greatest potential as ground denning locations. Flood simulations for the 2-and 5-year flood recurrences indicated the greatest number of potential reintroduction sites; however, some of these areas still flood regularly. Flood recurrence levels $\geq$25 years, however, indicated few potential reintroduction locations. Using the 10-year flood recurrence level to determine potential dry areas, the upper section of Alabama River has10–12 potential ground denning locations, which could be used in winter reintroductions (Eastridge and Clark 2001, Fig. 15). Those sites have large areas that stay dry, are >100 m away from the river, and have low human densities surrounding them (range = 1.70–3.50 people/km^2). Additionally, those sites are all in close proximity to the interface between bottomland hardwoods and upland pine forests. This interface has been documented to be an important habitat component for bears in other areas (Dobey et al. 2002, Wear 2003) and may prove to be necessary for bears in the MTD. It is important to visit those sites to identify habitat characteristics and assess accessibility. Also, it will be important to identify and contact landowners of potential reintroduction sites and surrounding areas to obtain permission and determine their attitudes towards black bears.

Public Support

The Bowman et al. (2004) model predicted that less than half of the residents living within the MTD and immediate surroundings are likely to support a reintroduction effort. However, a survey conducted by researchers at Auburn University found that

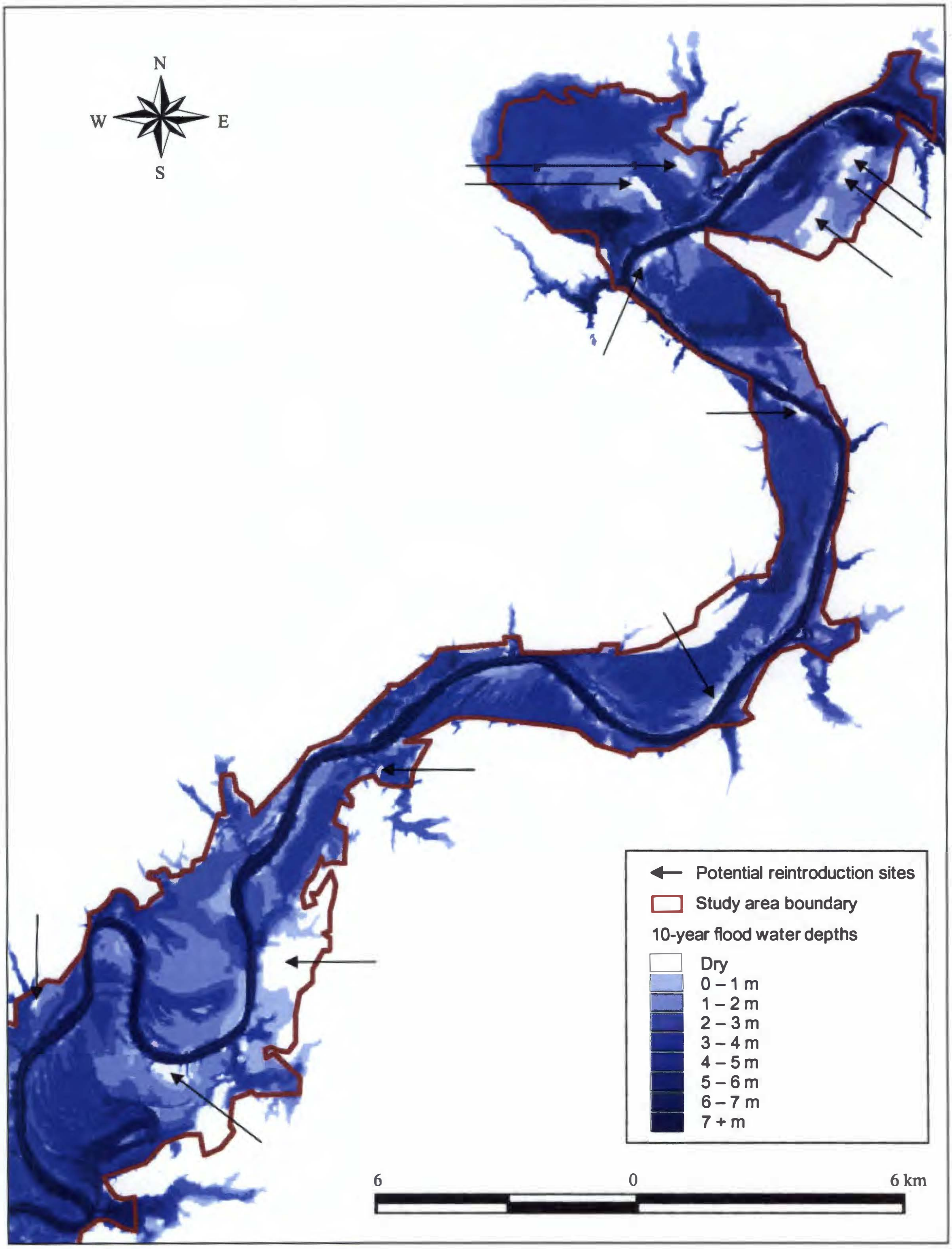

Fig. 15. Potential ground denning locations near the Alabama River in the Mobile-Tensaw Delta study area, Alabama based on 10-year flood recurrence levels, 2002–2003.

various stakeholder groups (e.g., cattlemen, Nature Conservancy members, beekeepers, conservation officers, and wildlife biologists) in Alabama were generally supportive of bear reintroduction (Underwood 2002). Additionally, it is possible that the Bowman et al. (2004) model underestimated the attitudes of residents towards black bears in southwestern Alabama. Since its formation in 1997, local efforts of the Alabama Black Bear Alliance (ABBA) have likely increased support for restoration. ABBA is a partnership among state and federal wildlife agencies, conservation groups, the academic community, and forest industry whose mission is to promote awareness and conservation of the black bear in Alabama through education, research, and habitat management. ABBA has successfully solicited and gained support from public and private entities when there was little interest in the Alabama black bear. ABBA has also played an essential role in coordinating research, funding, and in-kind support, as well as increasing public awareness for the black bear in southwestern Alabama.

Many of the residents of the MTD and surrounding areas are dependent on natural resource extraction, particularly logging, for their living. Previous findings have indicated that residents employed in this and similar industries often fear reintroductions due to possible restrictions that may be placed on them (Reading and Kellert 1993, Kellert 1994). Consequently, it may be important to implement a survey specific for the residents of the MTD to determine their actual attitudes towards bear reintroduction. Those results could then be used in conjunction with the results of the Bowman et al. (2004) model and the Underwood (2002) results to determine the suitability of the MTD for black bear restoration.

CHAPTER VI

MANAGEMENT IMPLICATIONS

My observations of limited bear sign in the MTD agree with Edwards (2002) findings of few bears in the delta region. Therefore, reintroduction may be needed to reestablish a self-sustaining population of bears in the MTD. Although I found less food resources in the MTD than White River NWR, the biological question is whether or not the MTD is still capable of supporting a viable population of black bears. White River NWR has one of the highest densities of black bears in North America (Oli et al. 1997, R. Eastridge, Arkansas Game and Fish Commission, personal communication), suggesting that the habitat quality there is better than in most other areas that currently sustain bears. Additionally, HSI scores ($\geq$ 0.4, Bowman 1999) and comparisons with Tensas National Wildlife Refuge indicate that food resources should be adequate. Consequently, I predict that bears could find sufficient food in the MTD, although home ranges would be expected to be larger and population densities lower than at White River NWR.

The most striking difference in black bear habitat suitability between the MTD and White River NWR was the lack of suitable den trees. Although it is not economically feasible to adopt management practices used at White River NWR on private lands, den site availability in the MTD would greatly improve over time if landowners could be convinced to leave a few large, low-value trees (i.e., poor growing stock, low-value species). Overcup oak and bald cypress are the most common species used for denning by bears at White River NWR (R. Eastridge, Arkansas Game and Fish Commission, unpublished data). Both of these species are common in the MTD, indicating that tree species composition should not affect the formation of den trees. Additionally, the formation of den trees could be accomplished in the time required for tree cavities to form (8–30 years, Carey and Sanderson 1981) because some large trees already are present, and tree growth in the MTD is rapid (Mader 1990).

In the near term, however, I feel that a reintroduction or translocation could be successful in the MTD if suitable den sites can be provided. Researchers at Felsenthal National Wildlife Refuge in Arkansas have had success reintroducing bears via artificial den structures placed on dry ground (Wear 2003). The most suitable locations to place artificial den structures occur along the Alabama River. However, those dry areas are limited and additional den sites may need to be provided for bears to use in the years following reintroduction. To accomplish this, it may be possible to place artificial structures in trees, above flood stage throughout the MTD. In areas with limited den sites, it is likely that den reuse would be high (Alt 1984, Schwartz et al.1987, Hayes 1990), indicating that relatively few of these structures would be needed. Nevertheless, I view the lack of suitable den sites as the greatest biological obstacle to reestablishing black bears in the MTD.

The MTD and surroundings areas were predicted by the Bowman et al. (2004) model to have moderate support for a black bear reintroduction. However, moderate support may not be adequate for a reintroduction to be successful, indicating that a strong public relations program may be necessary to increase public support. The MTD has a low human population density, which would allow for any individual concerns about the reintroduction to be more easily be addressed. Additionally, the low human population density minimizes the chances of nuisance activity by bears in the area. The majority of the land in the MTD is owned by relatively few people, indicating that these individuals will likely be most affected and should be given highest priority in efforts to gain support. However, the attitudes of small landowners must also be considered as they could significantly affect the success of the reintroduction.

Sociological considerations are crucial to recovery efforts and must be considered as a means of increasing the likelihood of successful species reintroduction programs (Reading and Kellert 1993). Bears are charismatic animals that are viewed positively by most North Americans (Kellert 1994). Typically, wildlife managers have been far too conservative in acknowledging the public's support for bears (Kellert 1994). Instead, it is important for wildlife managers to realize the positive attitudes people have towards bears and use them to enhance recovery efforts.

Black bear reintroduction into the MTD appears to be a legitimate option to help bolster the existing southwestern Alabama bear population. Although bears would be reintroduced into the MTD, the additional bears would be an augmentation to the existing southwestern Alabama bear population as a whole; therefore, minimizing the legal requirements associated with the restoration effort. Before reintroduction can take place, a source population of other Florida black bears needs to be identified. Because of their expanding populations and their proximity to the MTD, bears from the Apalachicola National Forest in Florida or the Okefenokee-Osceola ecosystem in northern Florida and southern Georgia are the most likely candidates to be used for the reintroduction. Additionally, an environmental assessment must be completed to determine the impact that black bears could have on the MTD and surrounding areas. However, this can be informal because releases would be to augment an existing population rather than to reestablish a new one and because no federal lands are involved. Finally, the reintroduction effort needs to include proper monitoring to estimate population growth, survival, and reproduction. That information will help refine population growth projections important for determining the ultimate success or failure of the reintroduction program (Eastridge and Clark 2001).

CHAPTER VII

SUMMARY

1. Hard and soft mast food resources in the MTD, although lower than food resources at White River NWR, appear to be adequate to support black bears.
2. The most notable difference in black bear habitat suitability between the MTD and White River NWR was the almost total lack of suitable den trees, a critical habitat component given the duration and severity of winter flooding there.
3. Flood simulation models indicated that the northern portions of the MTD along the Alabama River hold the greatest potential as suitable ground reintroduction sites.
4. Application of the Bowman et al. (2004) model revealed moderate support for black bear restoration efforts in the MTD, indicating that a strong public relations program will be critical for the reintroduction to be successful.
5. Reintroduction or translocation of black bears could be successful in the MTD if suitable den sites can be provided either through changes in management practices or through the use of artificial denning structures.

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APPENDICES

Appendix A. Variable means for habitat plots in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

Table A.1. Means for hard mast, soft mast, and canopy closure variables for habitat plots in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
AL006	2003	1	12.82	9.61	0.00	75	0.00	0	87.5
AL011	2002	5	16.28	12.09	9.83	72	0.12	1	76.0
AL023	2002	5	26.32	3.87	2.68	15	0.44	2	90.2
AL032	2002	5	46.14	2.90	2.90	6	0.13	0	86.0
AL038	2003	5	12.54	2.16	1.75	17	0.00	0	66.3
AL044	2003	5	15.28	0.00	0.00	0	0.60	4	87.1
AL049	2002	5	17.07	2.25	1.37	13	7.07	41	75.0
AL055	2002	5	72.80	0.51	0.51	1	4.88	7	88.3
AL062	2002	5	17.55	5.40	4.44	31	7.64	44	82.9
AL063	2003	5	22.79	5.21	4.26	23	0.50	2	91.7
AL064	2002	5	18.87	4.39	4.39	23	3.35	18	86.6
AL074	2002	5	31.88	9.49	9.49	30	0.00	0	88.3
AL080	2002	5	48.12	8.06	7.64	17	0.00	0	82.1
AL095	2002	5	29.71	15.57	14.23	52	0.00	0	89.7
AL098	2003	4	24.97	17.62	17.08	71	0.41	2	90.2

Table A.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
AL099	2002	5	29.67	10.04	8.74	34	0.33	1	81.6
AL121	2002	5	9.65	0.00	0.00	0	0.00	0	43.4
AL122	2002	5	90.71	0.32	0.32	0	3.49	4	87.6
AL125	2002	5	32.10	15.35	15.17	48	5.97	19	86.1
AL132	2002	5	13.03	6.54	6.21	50	4.70	36	88.9
AL152	2003	4	24.64	11.04	10.56	45	0.76	3	84.9
AL157	2003	5	39.59	24.85	21.69	63	1.93	5	86.8
AL162	2003	5	33.98	6.36	6.36	19	0.89	3	88.8
AL167	2002	5	20.96	5.11	3.86	24	1.28	6	91.7
AL172	2003	5	8.72	0.25	0.00	3	1.90	22	46.8
AL176	2002	5	9.30	7.09	4.61	76	0.56	6	79.0
AL183	2002	5	8.42	2.56	1.74	30	5.45	65	63.9
AL236	2003	5	22.96	8.29	4.96	36	0.41	2	80.1
AL244	2003	5	14.89	8.74	7.13	59	0.00	0	78.3
AL267	2002	5	8.58	4.36	2.73	51	1.20	14	91.2

Table A.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
AL275	2002	5	37.31	15.65	11.80	42	0.90	2	88.9
AL278	2002	5	0.27	0.00	0.00	0	0.00	0	56.5
AL283	2002	5	41.78	9.49	8.17	23	5.76	14	89.4
AL295	2002	5	74.57	19.29	16.96	26	1.00	1	88.9
AL296	2002	5	13.16	5.76	4.80	44	0.00	0	67.8
AL317	2002	5	16.68	6.47	4.89	39	3.56	21	81.0
AL342	2002	5	10.61	0.00	0.00	0	1.39	13	32.8
AL346	2002	5	13.76	6.86	6.60	50	0.00	0	82.1
AL354	2002	5	27.22	10.45	7.77	38	0.00	0	89.7
AL357	2002	5	23.37	4.12	3.35	18	0.31	1	86.7
AL365	2002	5	21.96	14.71	13.67	67	1.46	7	90.4
AL376	2002	5	9.27	3.77	2.74	41	1.58	17	85.6
AL412	2002	5	73.55	0.41	0.00	1	0.00	0	90.8
AL441	2002	5	64.91	4.32	3.75	7	0.00	0	89.7
AL443	2002	5	66.71	0.83	0.83	1	0.00	0	90.9

Table A.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
AL450	2002	5	48.82	0.00	0.00	0	0.68	1	91.5
AL461	2002	5	54.78	6.46	4.58	12	0.00	0	89.7
AL472	2002	5	67.76	0.00	0.00	0	0.00	0	92.7
AL473	2002	5	0.00	0.00	0.00	0	0.00	0	84.4
AL481	2002	5	58.72	0.21	0.00	0	0.77	1	93.2
AL483	2002	5	47.17	12.51	10.57	27	0.66	1	91.5

Table A.2. Means for horizontal cover and den tree availability variables for habitat plots in the Mobile-Tensaw Delta study area, Alabama, 2002–2003.

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
AL006	3.25	2.25	3.00	2.75	0.00	0.00	0.00
AL011	3.50	3.20	2.95	2.60	0.40	0.00	0.00
AL023	4.15	3.85	3.25	3.35	1.00	0.20	0.00
AL032	4.15	3.90	3.90	3.40	1.80	0.20	0.00
AL038	4.80	2.60	1.55	1.40	0.20	0.00	0.00
AL044	2.95	2.75	2.95	3.25	0.00	0.00	0.00
AL049	4.80	4.30	4.05	4.55	0.00	0.00	0.00
AL055	1.90	1.50	1.50	1.70	3.80	0.80	0.00
AL062	3.70	3.20	2.80	2.75	2.40	0.00	0.00
AL063	5.00	5.00	4.85	4.75	0.20	0.00	0.00
AL064	3.70	3.35	3.30	3.60	1.80	0.00	0.00
AL074	4.20	3.60	3.05	3.55	1.80	0.20	0.00
AL080	2.80	2.10	1.95	2.10	0.80	0.40	0.00
AL095	2.75	1.75	1.75	2.00	0.20	0.20	0.00
AL098	2.81	2.38	2.31	2.69	0.25	0.00	0.00

Table A.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
AL099	4.75	4.35	4.15	4.10	0.60	0.00	000
AL121	4.60	3.45	3.20	2.90	1.00	0.00	0.00
AL122	2.70	2.10	2.30	2.60	4.80	0.60	0.00
AL125	4.25	3.20	2.40	2.55	3.80	0.20	0.00
AL132	4.70	3.85	4.20	4.35	0.00	0.00	0.00
AL152	4.06	2.69	2.75	2.69	1.25	0.00	0.00
AL157	2.75	2.05	2.35	2.65	0.80	0.00	0.00
AL162	3.80	2.65	2.40	2.55	1.00	0.00	0.00
AL167	4.25	3.65	3.55	3.75	1.20	0.20	0.00
AL172	4.00	3.85	3.90	3.70	1.00	0.00	0.00
AL176	4.80	4.65	4.65	4.70	0.40	0.00	0.00
AL183	4.60	4.10	3.90	4.00	1.80	0.00	0.00
AL236	2.95	2.50	2.45	2.40	0.20	0.00	0.00
AL244	3.45	2.95	2.65	2.80	0.20	0.20	0.00
AL267	4.45	4.15	4.50	4.35	1.00	0.20	0.00

Table A.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
AL275	3.75	2.65	2.80	2.90	1.40	0.60	0.00
AL278	5.00	4.70	4.60	4.55	0.00	0.00	0.00
AL283	3.45	3.25	2.65	2.60	1.20	0.80	0.00
AL295	2.15	1.20	1.25	1.40	2.40	0.60	0.00
AL296	3.25	3.35	3.30	3.00	0.40	0.00	0.00
AL317	4.50	3.75	3.35	3.50	0.20	0.00	0.00
AL342	4.80	4.80	4.70	4.65	0.20	0.20	0.00
AL346	4.30	4.40	4.50	4.35	0.80	0.00	0.00
AL354	3.40	3.15	2.85	2.70	0.20	0.20	0.00
AL357	4.75	4.55	4.55	4.40	0.80	0.00	0.00
AL365	4.65	3.45	3.30	2.85	1.80	0.20	0.00
AL376	4.90	4.60	4.60	4.65	1.20	0.20	0.00
AL412	4.35	3.10	2.65	2.45	0.00	0.00	0.00
AL441	3.40	2.90	2.75	2.65	0.60	0.00	0.00
AL443	2.45	1.70	1.70	1.55	0.60	0.20	0.00

Table A.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
AL450	3.85	3.10	2.80	2.80	0.80	0.20	0.00
AL461	3.65	2.80	2.25	2.30	0.00	0.00	0.00
AL472	3.50	2.35	2.05	1.56	0.00	0.00	0.00
AL473	5.00	5.00	5.00	5.00	0.00	0.00	0.00
AL481	4.65	3.65	3.45	3.40	0.00	0.00	0.00
AL483	5.00	4.90	4.70	4.40	0.20	0.00	0.00

Appendix B. Variable means for habitat plots on the North Unit of the White River National Wildlife Refuge, Arkansas, 2000–2003.

Table B.1. Means for hard mast, soft mast, and canopy closure variables for habitat plots on the North Unit of White River National Wildlife Refuge, Arkansas, 2000–2003.

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
WR001	2000	5	31.58	19.99	17.18	63	6.89	22	
WR002	2003	5							88.5
WR003	2000	5	35.33	6.64	4.99	19	22.10	63	90.5
WR004	2000	4	28.96	4.68	4.30	16	3.97	14	86.4
WR005	2000	5	3.93	0.86	0.86	22	0.00	0	
WR006	2000	3	26.58	10.96	10.96	41	8.50	32	87.3
WR007	2000	5	29.07	5.88	4.23	20	1.61	6	90.5
WR008	2000	5	19.54	7.82	6.99	40	7.74	40	
WR009	2002	5	25.11	15.13	12.02	60	3.23	13	
WR010	2002	5	28.44	18.46	13.20	65	0.81	3	
WR012	2002	5	19.79	12.13	11.01	61	4.10	21	
WR014	2002	5	26.49	11.11	10.04	42	1.21	5	89.5
WR016	2002	5	35.02	18.41	15.05	53	2.43	7	
WR017	2000	5	26.38	6.11	4.77	23	2.38	9	
WR018	2002	5	22.52	6.10	3.93	27	8.12	36	

Table B.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
WR025	2000	5	26.50	12.53	11.94	47	1.58	6	
WR029	2000	4	20.92	4.85	4.85	23	8.02	38	
WR031	2002	5	25.82	6.08	4.51	24	3.80	15	91.3
WR032	2000	5	24.59	17.41	14.78	71	0.60	2	86.7
WR033	2000	5	20.67	2.34	2.18	11	6.97	34	89.0
WR034	2000	5	11.78	6.56	6.56	56	0.60	5	
WR038	2000	3	22.86	15.23	9.53	67	0.00	0	72.5
WR039	2000	3	29.67	19.37	14.47	65	0.51	2	87.8
WR040	2000	5	21.12	10.77	9.48	51	1.80	9	91.5
WR041	2002	5	4.71	2.28	1.59	48	1.21	26	
WR043	2000	5	31.56	5.67	4.70	18	11.13	35	91.2
WR046	2002	5	45.42	13.21	9.69	29	11.42	25	
WR047	2000	4	20.68	6.80	6.22	33	5.87	28	89.4
WR049	2000	5	25.45	11.70	11.70	46	6.79	27	91.1
WR052	2002	4	21.80	14.07	10.03	65	4.63	21	

Table B.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
WR053	2000	5	17.51	8.58	8.16	49	4.96	28	88.7
WR054	2000	4	20.74	7.30	6.25	35	3.83	18	86.4
WR056	2002	3	35.79	23.31	19.58	65	11.12	31	
WR058	2000	5	31.09	15.64	13.54	50	7.66	25	87.0
WR060	2000	5	33.98	16.06	13.63	47	4.72	14	
WR061	2002	5	32.28	17.88	13.17	55	5.60	17	
WR063	2000	3	25.52	7.75	7.75	30	1.13	4	84.8
WR064	2000	5	21.09	12.13	12.13	57	5.64	27	87.5
WR065	2000	5	27.35	13.34	12.92	49	4.21	15	94.2
WR068	2003	4							79.9
WR070	2000	5	26.41	9.42	8.89	36	5.37	20	

Table B.2. Means for horizontal cover and den tree availability variables for habitat plots on the North Unit of White River National Wildlife Refuge, Arkansas, 2003.

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
WR001							
WR002	4.30	3.95	4.25	4.50	0.00	0.00	0.00
WR003	4.25	3.80	3.75	4.30	0.30	0.00	0.00
WR004	4.13	3.69	3.06	3.00	3.79	0.00	0.00
WR005							
WR006	3.25	1.92	1.92	2.42	0.00	0.00	0.00
WR007	4.35	4.20	4.30	4.10	0.30	0.00	0.00
WR008							
WR009							
WR010							
WR012							
WR014	4.60	4.25	4.40	4.75	0.00	0.00	0.00
WR016							
WR017							
WR018							

Table B.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
WR025							
WR029							
WR031	4.45	4.40	4.30	4.35	0.00	0.00	0.00
WR032	4.10	3.10	3.25	3.30	0.30	0.00	0.00
WR033	3.40	2.85	3.60	2.95	0.61	0.00	0.00
WR034							
WR038	4.50	3.42	3.08	3.17	1.01	1.01	0.51
WR039	4.17	3.33	3.42	3.50	0.00	0.00	0.00
WR040	4.80	4.90	4.95	4.80	0.91	0.61	0.30
WR041					0.91	0.30	0.00
WR043	4.40	2.65	3.10	3.75	0.00	0.00	0.00
WR046							
WR047	4.05	3.75	4.20	4.00	0.91	0.91	0.91
WR049	3.85	3.45	3.80	4.00	0.91	0.00	0.00
WR052							

Table B.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
WR053	4.40	3.90	4.05	3.75	0.30	0.00	0.00
WR054	4.60	3.80	3.60	3.65	0.61	0.00	0.00
WR056							
WR058	4.30	3.15	2.70	2.65	3.33	0.61	0.61
WR060							
WR061							
WR063	3.50	2.50	2.80	2.40	1.21	0.00	0.00
WR064	4.00	3.55	3.70	3.90	1.52	0.30	0.30
WR065	5.00	4.65	4.60	4.65	0.91	0.00	0.00
WR068	3.25	1.75	2.00	2.56	3.03	0.00	0.00
WR070							

Appendix C. Variable means for habitat plots on the South Unit of the White River National Wildlife Refuge, Arkansas, 2000–2003.

Table C.1. Means for hard mast, soft mast, and canopy closure variables for habitat plots on the South Unit of White River National Wildlife Refuge, Arkansas, 2000–2003.

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
WR066	2000	5	19.44	17.04	15.42	88	1.40	7	87.3
WR069	2003	5							91.5
WR073	2000	4	43.59	11.55	9.25	27	0.27	1	84.2
WR074	2000	5	39.98	7.82	7.82	20	18.02	45	88.0
WR077	2002	5	29.97	22.13	19.83	74	1.81	6	87.1
WR079	2000	5	29.75	13.39	9.60	45	3.89	13	84.9
WR080	2000	4	34.28	6.15	5.68	18	9.43	28	
WR082	2000	5	23.72	17.05	16.35	72	0.99	4	72.2
WR085	2002	5	17.44	13.33	10.93	76	0.89	5	85.8
WR086	2000	5	25.10	21.93	20.22	87	1.24	5	83.4
WR087	2002	5	34.81	19.19	18.29	55	9.02	26	
WR091	2000	5	18.57	13.38	12.79	72	2.63	14	89.2
WR095	2000	5	24.49	14.99	14.68	61	4.45	18	90.5
WR096	2000	5	54.29	13.43	12.48	25	3.58	7	86.2
WR102	2002	4	29.20	14.64	12.50	50	7.73	26	88.6

Table C.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
WR107	2000	5	23.46	13.74	11.36	59	5.87	25	87.4
WR109	2000	5	16.80	10.70	8.48	64	4.13	25	87.6
WR112	2002	5	24.08	16.05	15.78	67	4.15	17	90.6
WR113	2002	5	30.98	25.23	22.86	81	3.22	10	
WR115	2002	5	34.30	20.85	19.59	61	7.33	21	90.5
WR117	2000	5	9.08	3.62	2.13	40	1.96	22	74.4
WR119	2000	5	35.44	23.33	20.63	66	5.20	15	90.7
WR121	2002	5	26.96	20.30	16.60	75	2.79	10	88.4
WR124	2000	5	26.66	15.51	13.63	58	5.08	19	
WR125	2000	4	34.39	26.41	9.17	77	4.28	12	89.8
WR134	2000	5	24.21	7.94	7.66	33	11.99	50	88.0
WR135	2000	5	21.63	16.73	15.95	77	3.87	18	82.2
WR138	2000	5	21.12	15.26	14.14	72	3.18	15	
WR139	2000	2	22.93	17.48	16.64	76	0.00	0	
WR141	2000	4	18.33	10.69	7.46	58	1.03	6	82.4

Table C.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
WR142	2002	5	21.74	13.64	11.20	63	2.50	12	85.1
WR145	2002	4	25.98	16.94	4.79	65	0.00	0	
WR149	2002	5	24.68	22.74	21.90	92	0.57	2	84.1
WR150	2000	5	30.19	20.80	18.48	69	0.24	1	82.1
WR151	2002	2	26.42	23.31	13.47	88	0.00	0	
WR154	2000	5	22.48	1.24	1.01	6	0.17	1	
WR155	2000	5	29.92	12.24	11.18	41	13.54	45	
WR156	2000	5	30.61	8.76	6.41	29	11.88	39	81.4
WR158	2003	3							90.0
WR160	2000	5	27.66	18.21	16.88	66	3.82	14	87.3
WR161	2000	5	23.92	5.51	5.51	23	3.79	16	85.6
WR164	2000	5	30.23	18.54	16.62	61	6.91	23	86.4
WR165	2000	5	23.07	15.43	13.76	67	3.25	14	88.9
WR166	2000	5	17.48	12.45	8.58	71	2.22	13	87.4
WR169	2000	5	19.04	14.03	13.48	74	1.97	10	86.7

Table C.1. (continued)

Plot number	Year	Total subplots	Total basal area (m^2/ha)	Hard mast basal area (m^2/ha)	Hard mast basal area of mature trees (m^2/ha)	Hard mast canopy cover (%)	Soft mast basal area (m^2/ha)	Soft mast canopy cover (%)	Canopy closure (%)
WR170	2000	4	23.79	17.69	14.02	74	0.00	0	
WR176	2000	3	16.12	12.18	8.01	76	2.76	17	89.0
WR178	2000	3	20.06	4.43	2.17	22	1.92	10	
WR186	2000	5	20.62	13.48	11.23	65	1.12	5	
WR188	2000	5	15.51	5.74	5.74	37	4.52	29	88.3
WR191	2000	5	25.33	14.32	10.66	57	7.66	30	81.6
WR192	2000	1	22.25	22.25	22.25	100	0.00	0	87.1
WR196	2003	5							88.2
WR197	2002	3	19.45	1.54	0.00	8	6.08	31	86.0
WR198	2002	5	40.49	27.13	22.10	67	12.20	30	
WR199	2002	5	30.67	8.61	7.71	28	17.05	56	
WR200	2000	5	25.46	7.66	6.77	30	14.57	57	90.1

Table C.2. Means for horizontal cover and den tree availability variables for habitat plots on the South Unit of White River National Wildlife Refuge, Arkansas, 2003.

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
WR066	4.30	3.80	3.55	3.90	0.76	0.00	0.00
WR069	3.05	2.20	2.95	3.30	3.33	0.30	0.30
WR073	3.61	3.64	3.31	3.00	2.53	0.51	0.51
WR074	2.88	1.75	2.25	2.38	3.03	0.76	0.00
WR077	2.85	1.40	1.50	2.00	3.94	1.21	0.30
WR079	3.38	3.06	2.69	2.75	0.61	0.00	0.00
WR080							
WR082	4.85	4.40	3.85	4.15	1.21	0.00	0.00
WR085	2.90	2.45	2.80	2.70	1.21	0.30	0.30
WR086	3.70	2.80	2.55	2.35	5.46	1.52	0.91
WR087							
WR091	4.65	4.15	4.15	4.25	3.33	0.61	0.30
WR095	2.70	2.25	2.45	2.15	1.21	0.00	0.00
WR096	3.13	2.38	2.50	1.75	0.00	0.00	0.00
WR102	3.25	2.69	2.19	2.50	2.65	0.00	0.00

Table C.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
WR107	4.50	3.65	3.15	3.05	1.52	0.30	0.30
WR109	4.35	2.85	2.65	2.60	2.73	0.00	0.00
WR112	3.70	3.30	3.40	3.25	0.91	0.30	0.30
WR113							
WR115	3.55	3.20	3.05	3.00	1.82	0.30	0.30
WR117	3.50	3.45	2.95	3.00	0.30	0.00	0.00
WR119	2.75	1.88	1.81	1.94	1.89	1.52	1.52
WR121	2.75	1.95	2.20	2.05	2.42	0.30	0.30
WR124							
WR125	3.56	2.88	3.00	3.38	0.38	0.38	0.38
WR134	4.75	4.45	4.55	4.60	1.21	0.00	0.00
WR135	2.25	2.00	1.65	2.10	2.42	0.61	0.30
WR138							
WR139							
WR141	4.17	3.75	3.92	3.92	0.51	0.00	0.00

Table C.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
WR142	4.30	4.05	3.10	3.15	1.21	0.00	0.00
WR145							
WR149	3.90	2.35	2.55	2.80	1.52	0.30	0.30
WR150	4.15	3.00	2.95	2.95	1.21	0.30	0.30
WR151							
WR154							
WR155					1.89	0.00	0.00
WR156	4.00	3.30	3.45	3.45	2.12	0.30	0.30
WR158	3.67	3.00	3.08	2.33	1.52	1.52	1.52
WR160	2.95	2.35	2.55	2.80	2.73	0.00	0.00
WR161	4.15	2.85	2.75	2.55	1.52	0.30	0.30
WR164	2.75	2.15	2.00	2.00	2.42	0.30	0.30
WR165	2.15	1.90	2.35	2.45	4.24	0.61	0.30
WR166	3.20	2.35	2.00	2.15	0.61	0.61	0.30
WR169	3.85	3.65	4.05	4.15	0.30	0.00	0.00

Table C.2. (continued)

Plot number	Horizontal cover 1 (0.0–0.5 m)	Horizontal cover 2 (0.5–1.0 m)	Horizontal cover 3 (1.0–1.5 m)	Horizontal cover 4 (1.5–2.0 m)	Large trees (trees/ha)	Large trees with any cavity (trees/ha)	Large trees with a cavity for a bear (trees/ha)
WR170							
WR176	2.83	1.83	2.00	1.92	2.02	0.00	0.00
WR178							
WR186							
WR188	5.00	5.00	5.00	4.75	1.52	0.00	0.00
WR191	3.20	2.60	2.55	2.50	6.67	2.42	2.42
WR192	3.83	3.25	3.00	3.00	0.00	0.00	0.00
WR196	2.05	1.65	1.70	1.70	2.73	0.61	0.00
WR197	4.75	4.42	4.50	4.58	0.00	0.00	0.00
WR198							
WR199							
WR200	3.20	2.40	3.00	3.15	2.73	0.00	0.00

VITA

Kent Russell Hersey, son of Kenneth and Patricia Hersey, was born in York, Pennsylvania on July 29, 1978. He attended Dallastown Area High School and graduated in June 1996. He received a Bachelors of Science degree in Wildlife and Fisheries Science and a minor in Forest Science from the Pennsylvania State University in December 2000. After graduation, he spent a year conducting forest inventory for the Pennsylvania Bureau of Forestry. Kent began his graduate research in January 2002 at the University of Tennessee in Knoxville. His graduate research focused on examining the habitats of the Mobile-Tensaw Delta region of southwestern Alabama to determine their suitability for black bears. He received his Master of Science degree in Wildlife and Fisheries Science in August 2004.