ASSESSING THE IMPACT OF FERAL HOG POPULATIONS ON THE NATURAL RESOURCES OF BIG THICKET NATIONAL PRESERVE

A Thesis

by

PEDRO MAZIER CHAVARRIA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2006

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

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ABSTRACT

Assessing the Impact of Feral Hog Populations on the Natural Resources of
Big Thicket National Preserve.
(December 2006)
Pedro Mazier Chavarria, B.A., Pomona College, Claremont, CA
Chair of Advisory Committee: Dr. Roel R. Lopez

The Big Thicket National Preserve (BTNP) is a unit of the National Park Service (NPS) whose mission prioritizes conservation of its wildlands in the United States. One threat to natural resources of the BTNP has been impacts associated with feral hog (*Sus scrofa*) activities. Population numbers of this non-native game species have increased throughout Texas, including areas within the preserve. Recreational hunting permitted by the BTNP has served as a means of controlling hog numbers, although the reported amounts of hog damage to park resources appear to have increased in recent years. Population reduction of feral hogs and mitigation of their impacts require research that documents and validates feral hog impacts on park resources. Here, I evaluated (1) population trends of feral hogs for the past 20 years via data from hunter-card surveys and track-counts, and (2) feral hog impacts on native vegetation for 3 management units of the BTNP.

Results from my analysis suggest a nearly 3-fold increase in hog numbers throughout the preserve since 1981. The overall damage to vegetation from hog rooting or wallowing averaged to 28% among the 3 units of the BTNP. Landscape features such as topography, soil moisture, soil type, and dominant vegetative cover types were used

to predict hog damage. Floodplains had the most damage in the Big Sandy unit (45%), while flatlands were mostly impacted in the Turkey Creek unit (46%), and uplands in the Lance Rosier unit (32%). Vegetative cover was an important variable in explaining variation in hog damage throughout the 3 units of the preserve. Impacts were more widespread across different vegetative strata than previously believed. Study results also support the premise that hog damage in the BTNP parallels the increase in hog abundance over the past 20 years. A more aggressive program for population reduction of feral hogs and mitigation of their impacts is recommended for the BTNP to continue to meet its legal mandates for conservation.

DEDICATION

I dedicate this to my family, in every sense of the word—my parents, brother and sister, relatives, mentors, and friends throughout life—for without them my life experiences could not be called whole.

We must be Masters of our destiny,

Stewards of nature,

and servants of a greater Glory.

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Much appreciation goes to my advisors, Roel Lopez, Gillian Bowser, Nova Silvy, and Gerard Kyle, for providing me guidance throughout my course of studies. I thank Gillian Bowser for being a long-time mentor within the National Park Service (NPS), and in granting me opportunities to advance in my career and research at Big Thicket National Preserve (BTNP). Roel Lopez has half the graduate students in the Department of Wildlife and Fisheries Sciences (WFSC) under his wing, so I appreciate the time he takes for each and every one of us, and for lending a unique philosophical and cultural perspective to the department. Nova Silvy provided much sagely wisdom about wildlife techniques. Gerard Kyle always had an open door available when I needed to consult with him.

I also want to give thanks to the graduate students with which I interacted in the WFSC department—many of which provided encouragement and valuable insight into my research. I also appreciate the various undergraduate students that assisted me with surveys at BTNP. In addition, the fellows from the various cohorts of the Hispanic Leadership Program in Agriculture and Natural Resources (HLPANR) gave me many memorable moments—may the legacy of that program live on.

My thesis would not have been made possible without the cooperation of the different agencies that funded my research. The HLPANR fellowship program at Texas A&M University (TAMU) realizes the growing need to educate Hispanics in the sciences, so I respect the visionaries that initiated that program, including Dr. Manuel Pina of TAMU. The Gulf Coast Cooperative Environmental Studies Unit (GCCESU),

headed by Dr. Gillian Bowser, provided an opportunity for cooperative research with a Student Career Experience Program (SCEP) position at BTNP. A multitude of employees of BTNP provided logistical support—these include Superintendent Art Hutchinson, Chief of Resources Curtis Hoagland, Nellie Martinez, Leslie Dubey, Pollard Mobley, Leta Parker, and countless others. Thanks also to Dr. Robert Stanton, former director of the NPS, for the encouragement he provided me and that which he continues to provide to all future stewards of the NPS.

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CHAPTER I

INTRODUCTION*

The ecological integrity of native habitats worldwide is threatened by a diverse array of intentionally and incidentally introduced non-native species (Pimentel et al. 2001, Courchamp et al. 2003, Strauss et al. 2006). Of those intentionally introduced, perhaps none has become more widespread than variants of the domesticated and feral pig. Despite benefits that domesticated stocks of pigs have brought to agriculture, there are exceeding detriments associated with those that have gone feral (Corn et al. 1986, Coblentz and Baber 1987, Mayer et al. 2000, Ickes et al. 2001). Today, feral hog impacts are reported to be a serious cause of concern to the agricultural markets (Texas Department of Agriculture 2006), homeland security (United States Department of Homeland Security 2005, United States Animal Health Association 2005), as well as the preservation of natural resources and the conservation of native species worldwide. When considering their high reproductive rate and robust adaptability to a wide range of environmental climes, controlling their populations and mitigating for their impacts at landscape scales has become an overwhelming challenge for resource managers.

In southeast Texas, feral hogs have persisted and continue to proliferate since introductions by early European settlers in the 1800s (Synatzske 1979). Over a decade ago, the estimate of feral hogs numbers in Texas was reported to be 1 million animals (Taylor 1993), ranking second only to white-tailed deer (*Odocoileus virginianus*). Since

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* The format and style of this thesis follows *Journal of Wildlife Management*.
* Parts of this chapter, appearing in "A landscape-level survey of feral hog impacts to natural resources in Big Thicket National Preserve" by Chavarria et al., 2006, have been submitted to *Human-Wildlife Conflicts* and are pending review for publication

then, feral hogs have continued to disperse throughout Texas and conservative estimates number them between 1.5–2 million (Mapston 2004). The Texas Animal Damage Control Service (TADCS) acknowledges that, if not properly managed, feral hogs have the potential of causing extensive damage to native wildlife and their habitat, and agricultural resources (Beach 1993). These impacts are often compounded in regions that have a long history since initial introductions of feral hogs (Waithman et al. 1999). The increased need to address the issue of hog impacts to natural resources is pertinent particularly to areas of conservation concern, which include wildlife refuges, National Forests, and National Parks such as Big Thicket National Preserve (Singer 1981).

A unit of the National Park Service (NPS), the BTNP is mandated by Congress to protect its natural and cultural resources. This is explicitly stated in the NPS mission, outlined in the Organic Act of 1916, which is to "conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations". The potential threats that feral hogs pose to the resources of the BTNP are evident from studies done in similar ecosystems throughout the United States and in many units of the NPS (Singer 1981, NPS 1985, NPS 2000, NPS 2003). Although increasing occurrence of feral hog rooting disturbance to soils and vegetation or erosion damage from wallows have been identified, little action can be taken by NPS resource managers to resolve these problems if such impacts are not formally and scientifically documented. An evaluation of the feral hog population status

and an assessment of their impacts to the resources of the preserve thus are integral to building a legal "need for action" for resolving the problems associated with this species.

OBJECTIVES

The objective of my thesis is to evaluate the extent of the problem feral hogs pose to the natural resources of BTNP. First, I present an analysis of harvest data collected from various units of the preserve where hunting is permitted. These data are used to calculate trends in population growth rate for a 20-year period and estimate the current population status of hogs throughout the preserve. Second, I provide an impact assessment from a survey of hog damage to the soils and vegetation communities of the BTNP. The survey focused on documenting the extent and intensity of impact to 3 units of the BTNP in which hog numbers and hog damage are reported to be the highest. Lastly, I provide management recommendations for controlling feral hog numbers, for mitigating the damage they cause to resources, and for continued monitoring of hog impacts in the BTNP.

STUDY SITE

The BTNP, first of the National Preserves, was established in October 1974 and is located north of Beaumont in the Pineywoods region of southeast Texas (Fig. 1.1). The preserve comprises 12 units in Jefferson, Liberty, Hardin, Polk, Tyler, Jasper, and Orange counties—a combined area of about 39,322 ha with units ranging in size from 223–10,452 ha (Fig. 1.2). The preserve is found 1.5–137m above sea level (BTNP 1996). The climate of the area is warm-temperate and almost subtropical, receiving 140 cm of precipitation per year (BTNP 1996). The BTNP was originally protected for its

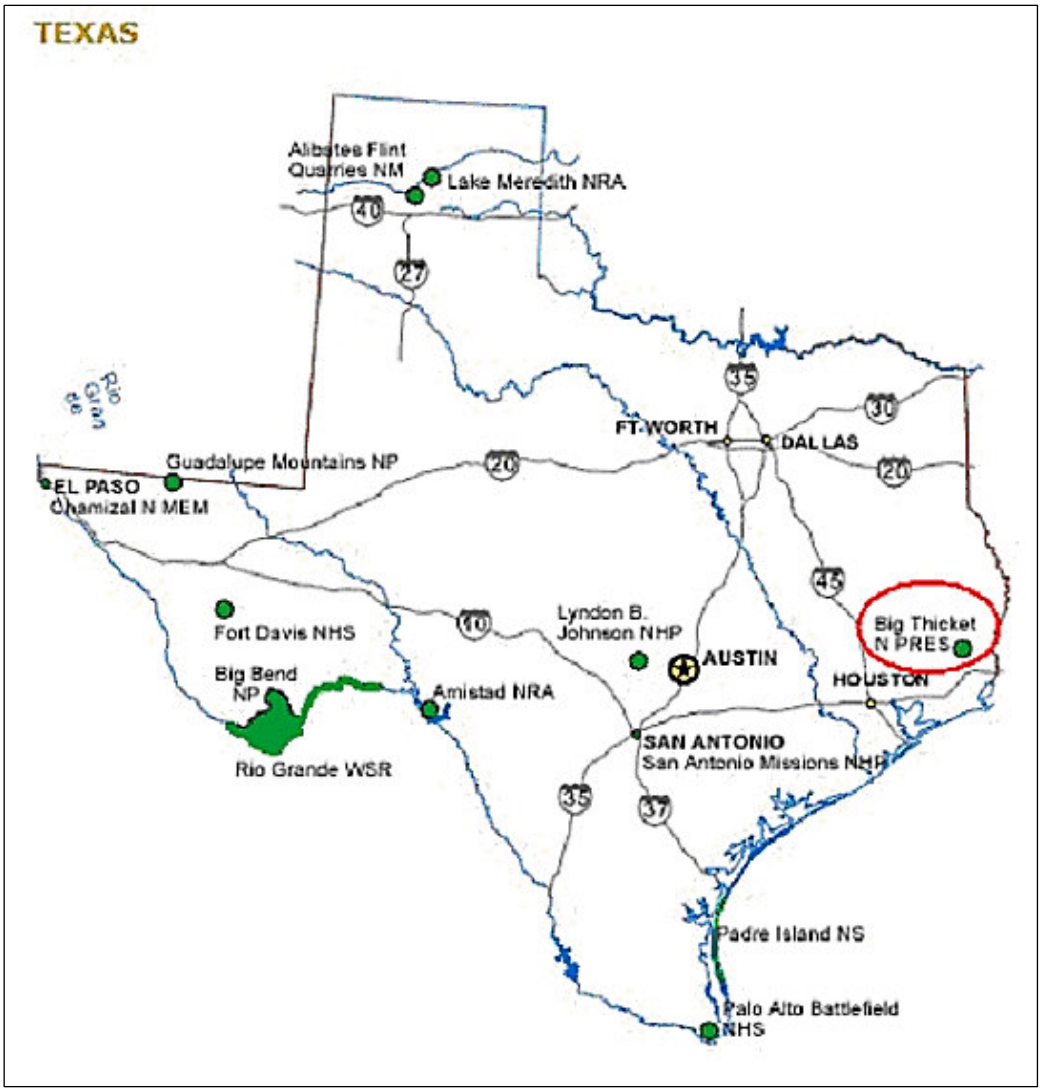

Figure 1.1. National Park Service units in Texas, 2006. Big Thicket National Preserve in red ellipse. (NPS 2006)

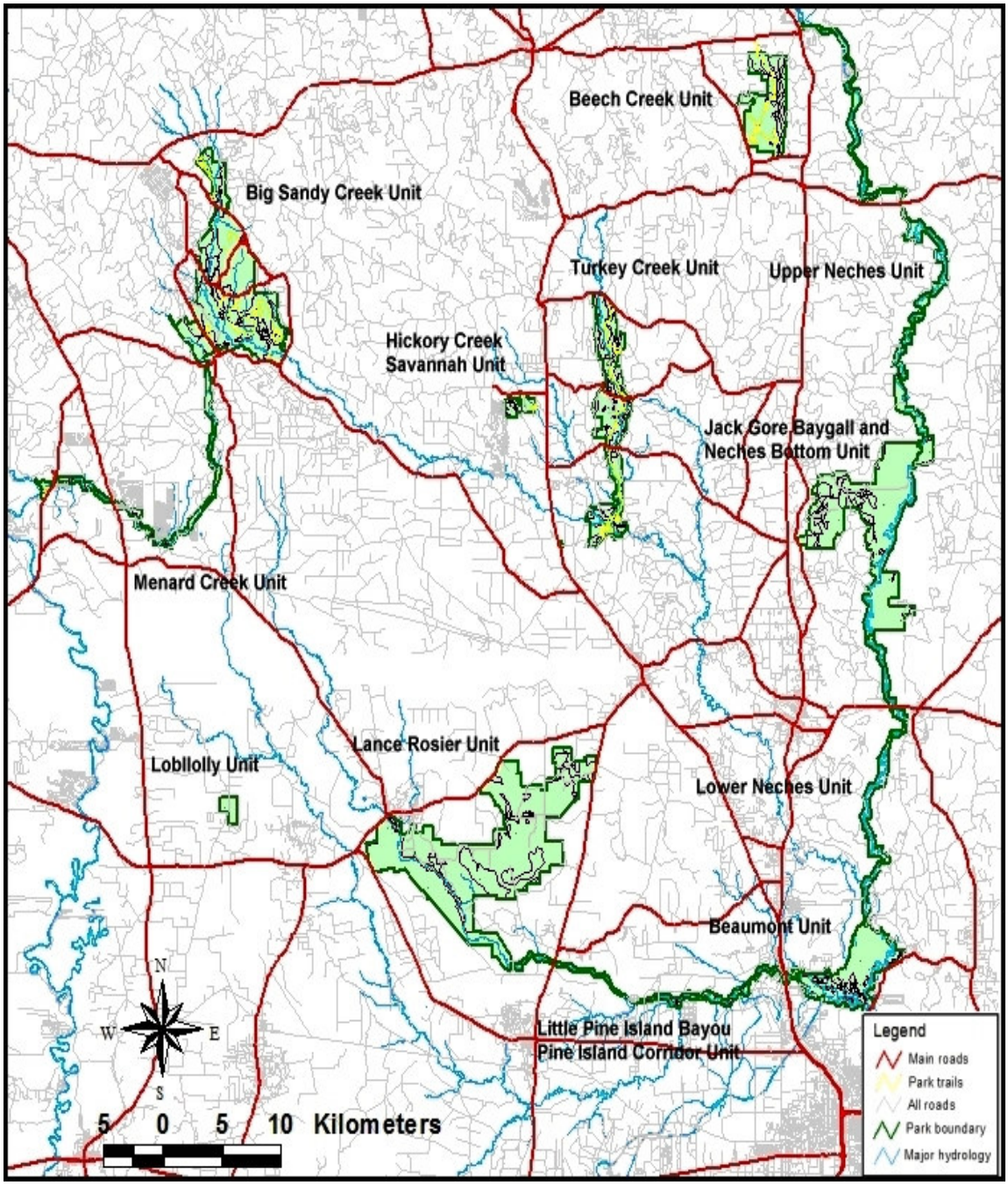

Figure 1.2. Management units (12) of the Big Thicket National Preserve, Beaumont, Texas, 2006.

exceptional diversity in fauna and flora—considered an "ecological crossroads" because of its merging of the southeast swamps, pineywood forest, post-oak belt, Great Plains, and coastal prairies (BTNP 1996). In 1978, the United Nations Education, Science, and Cultural Organization (UNESCO) also recognized and designated BTNP as a Biosphere Reserve. In addition, the National Parks Conservation Association (NPCA) currently lists the BTNP as one of America's 10 "Most Endangered National Parks".

Vegetation patterns within the BTNP's region are generally correlated with soil texture gradients ranging from fine sandy soils to very fine clays (BTNP 1996). Marks and Harcombe (1981) categorized the vegetation composition of the BTNP into 4 broad types: uplands, slopes, floodplains, and flats. Uplands comprise of ridges dominated by pine forests and mixed oak-pine woodlands. They are generally composed of well-drained soils with high sand content, except in upland flats consisting of wetland savannahs where high clay content is present. Dominant overstory species in the uplands consist of longleaf pine (*Pinus palustris*), bluejack oak (*Quercus incana*), loblolly pine (*P. taeda*), with understories of sweetbay (*Magnolia virginiana*), and wax myrtle (*Myrica cerifera*). Slopes, on the other hand, form the transition zone between uplands and floodplains, with dominant vegetation generally consisting of hardwood species and interspersed pines. Dominant overstory species in the slopes typically include loblolly pine, short-leaf pine (*P. echinata*), southern red oak (*Q. falcata*), sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandifolia*), and southern magnolia (*M. grandiflora*). Understories of slopes may include Flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), and American holly (*Ilex opaca*). Like

uplands, soils in slopes drain well but moisture holds tends to hold better in the lower slopes, which results either from run-off from higher elevations or because of greater exposure to seasonal flooding.

Moisture holds best in soils with lower sand content in floodplains located along major BTNP creeks. Narrow floodplains have greater representation of pine stands than broad floodplains, but hardwoods are dominant in both cases. The dominant overstory species include loblolly pine, southern magnolia, water-oak (*Q. nigra*), water tupelo (*Nyssa aquatica*), common baldcypress (*Taxodium distichum*), laureal oak (*Q. larifolia*). Midstory species include ironwood (*Carpinus caroliniana*) and the understory often contain Gulf Sebastian-bush (*Sebastiana fruticosa*). Floodplains with the most poorly drained soils consist of wetland baygall or cypress-tupelo swamps (Marks and Harcombe 1981); these are perennially flooded and hold standing water much of the year.

Flatlands are aggregated near floodplains but have lower stature hardwood assemblages with dense and diverse understories (Marks and Harcombe 1981). These low-lying areas will flood seasonally but have soils that moderately drain. Dominant overstory species include Swamp chestnut-oak (*Q. michauxii*) and sweetgum. Dwarf palmetto (*Sabal minor*) and red maple are represented in the understory.

CHAPTER II

ANALYSIS OF THE POPULATION STATUS OF FERAL HOGS IN BIG THICKET NATIONAL PRESERVE[†]

SYNOPSIS

A growing concern in the BTNP has been the increase in reported sightings of feral hogs throughout the preserve. Potential competition with native fauna, and hog damage to natural resources are just few factors that work against the conservation objectives of the BTNP. Validation of increases in hog numbers and their damage is essential to move towards management actions that can resolve these problems. The preserve employs several methods which can be used to validate these claims. Periodic examination of the status of game populations is conducted by the BTNP through analysis of harvest-card surveys from their recreational hunting program. These surveys provide data that can be used to examine population trends of reported game species and are essential for maintaining sustainable harvest of game populations in the BTNP.

To determine the population trends of feral hogs and white-tailed deer, I evaluated the harvest-survey data for a 20-year period. In addition, track-count surveys also were conducted to provide an alternate means of assessing population trends of these 2 game species. Study results from harvest data found stable population trends for white-tailed deer, with only a slight decline in growth rate in recent years. Feral hog harvest data, however, shows a consistent positive increase in growth rate and nearly a

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[†] Part of this chapter is reprinted with permission from "An assessment of white-tailed deer (*Odocoileus virginianus*) and feral hog (*Sus scrofa*) populations at Big Thicket National Preserve, Texas", Chavarria et al. 2006, Pages 67-70, *In* D. Harmon. editor. People, Places, and Parks: Proceedings of the 2005 George Wright Society Conference on Parks, Protected Areas, and Cultural Sites: The George Wright Society.

3-fold increase in feral hog numbers over the 20-year period ($P < 0.001$). Track-count indices for feral hogs support observed population increases from harvest data. Evidence of competition between feral hogs and white-tailed deer is inconclusive from my data and further research is necessary. Claims of increasing feral hog numbers in the preserve are supported from analysis of harvest-effort and track-count indices. Management actions for population reduction of feral hogs will likely be necessary to reduce increases in feral hog per-capita impact damage to resources throughout the preserve.

INTRODUCTION

The BTNP is the first preserve established by Congress and was set aside primarily to protect its biological diversity as opposed to its scenic or recreational resources (NPS 1996). The preserve's enabling legislation, however, also mandates that recreational hunting be permitted within its boundaries (NPS 1996). Since 1981, recreational sport hunting for white-tailed deer (*Odocoileus virginianus*), squirrel (*Sciurus niger* and *S. carolinianus*), rabbit (*Sylvilagus* spp.), and feral hog (*Sus scrofa*) has been allowed on 6 management units within the BTNP. But for the BTNP to fulfill its underlying mission, continual field monitoring of game species and evaluation of harvest trends are both essential for maintaining sustainable harvest of game populations and adhering to conservation objectives.

Periodic reviews of the condition of game species in the preserve is done through analysis of harvest trend data (i.e., hunter-card surveys). A permit system, administered by park staff, is used to regulate hunting activity by designating a specific number of

permits to 6 units of the preserve. Harvest trends are evaluated from hunter-survey cards, and allowable permits vary according to sustainable game harvest population estimates determined by the preserve's resource managers. The last evaluation, conducted in 1989, assessed the population status of game and furbearing animal and was used to develop a comprehensive management plan for all game species (Fagre et al. 1989). Harvest recommendations proposed for the 6 management units have not varied significantly since then. However, no evaluations of the population trends of hunted game species in the BTNP have been conducted since those done by Fagre et al. (1989).

An updated assessment was conducted in 2004 of the population trends of both small and large game species in the preserve. The emphasis of this chapter, however, is only on large game species—white-tailed deer (*Odocoileus virginianus)* and feral hog (*Sus scrofa*). Both of these species are highly preferred by game hunters in the Big Thicket region and regulation of permits revolves mostly around harvest trends of these 2 species. In addition, both of these species are large herbivores and may present a considerable source of damage to native vegetation if their population numbers are overabundant. The preserve harbors several sensitive, rare, threatened, and endangered plant species and is likewise mandated to protect them from anthropogenic or natural threats, including excessive herbivory, which may be detrimental to their persistence in the ecosystem.

In addition to controlling excessive impacts of herbivory to native vegetation, both white-tailed deer and feral hog share similar diet characteristics that may induce interspecific competition for resources (Hellgren 1993). Although both white-tailed deer

and feral hog numbers throughout Texas continue to rise, the reproductive rate and litter size of feral hog is substantially higher than that of white-tailed deer (Hellgren 1993). Tracking the population trends of these 2 species may be important for noting if competition between these 2 species is occurring. Population trends observed from harvest data also may provide indirect evidence of competition. The particular focus would be to observe if diminishing numbers of white-tailed deer occur in areas where the growth rate and abundance of feral hogs is consistently higher than those of deer.

The objective of this chapter is to summarize harvest data collected by BTNP staff from hunter-card surveys. Second, I evaluated population trends, specifically relative abundance and population growth rate, of hunted games species (i.e., white-tailed deer and feral hogs) from harvest data. Lastly, I evaluated changes in population indices of white-tailed deer and feral hogs collected by Fagre et al. (1989) to current estimates using identical methods.

METHODS

Harvest data have been collected by BTNP staff since 1981 through information gathered from hunter-survey cards. The hunter-card surveys (Appendix A – copy of permit), submitted by individual hunters, note the quantity of large and small game harvested for a given unit, the number of trips made to that unit, and other wildlife observations. These cards are an integral part of regulating hunting activities on the BTNP and are part of the preserve's permit system. Permits are administrated by park staff and given on a first-come, first-serve basis, but participating hunters must submit the survey cards at the end of the season or will otherwise relinquish their right to renew

their permit the following season. This system generally results in a high survey return or response rate and thereby a large proportion of data for evaluation of harvest trends.

The hunting permits allow for the take of several species of small and large game within specific areas of 6 units within the Preserve. These units include the Big Sandy Creek (BSU), Beech Creek (BCU), Lance Rosier (LRU), Beaumont (BEA), Jack Gore Baygall (JGB) and Neches Bottom (NBU) units (Fig. 1.2). The maximum allowable permits designated to each unit depend on sustainable game harvest population estimates determined by the Preserve's resource managers (NPS 1980) and recommendations made by Fagre et al. (1989). Individual hunters are only allowed to register for 1 unit of the BTNP but can make multiple trips to that unit within that season. For all the years included in the analyses, the animals harvested on BTNP were taken during the hunting season, defined as the opening date of the State of Texas fall hunting season through the second Sunday in January.

The BTNP harvest-card data spans from 1981–2003, but some years (e.g., 1983) were omitted from analyses because of insufficient or missing data for several of the BTNP units. Data were categorized into 5-year periods (i.e., 1980–1984, 1985–1989, 1990–1994, 1995–1999, and 2000–2003). For reference, periods are referred to by the first year of data collected (e.g., 1980 = 1980–1984).

Population Trends From Harvest/hunter Effort

Harvest/hunter effort is a measure of the number of animals harvested per unit of hunter effort and can be used as an index of population abundance (Caughley and Sinclair 1994). Such data can be used to compare relative differences in abundances

between different time frames and between different management units when some basic assumptions are met. The first assumption is that no significant changes in hunting regulations and hunting practices have occurred between years (i.e., periods) and between units of the BTNP. Secondly, data should be standardized to ensure that relative comparisons are made between different units and different time frames. Once indices of population abundance are determined from harvest/hunter effort, it is then possible to calculate the exponential rate of growth of each species between different periods. This is done by transforming that data to the natural growth equation, as discussed in the analysis section.

Population Indices from Track-counts

Fagre et al. (1989) used and recommended the use of track-counts for game surveys in BTNP. His methods were replicated in my study during the 2004 season, from June-September, to assess changes in the density and distribution of animals surveyed. These track counts are normally conducted in June–July (third quarter) for game species such as white-tailed deer, hogs and squirrels (Fagre et al. 1989). All tracks are identified to species when possible. Fagre et al. (1989) originally surveyed Beech Creek (BCU), Beaumont (BEAU), Big Sandy (BSU), Jack Gore Baygall-Neches Bottom (JGB), Lance Rosier (LRU), and Turkey Creek (TCU) units (Figs. 2.1–2.4). The information presented here excludes the Beaumont and Beech Creek units.

Track counts were conducted by setting short-width transects along the center or shoulders of infrequently traveled dirt roads within the BTNP. These transects are prepared by dragging a 1.2 m x 2.4 m flexible-tine harrow behind a vehicle (Fagre et al.

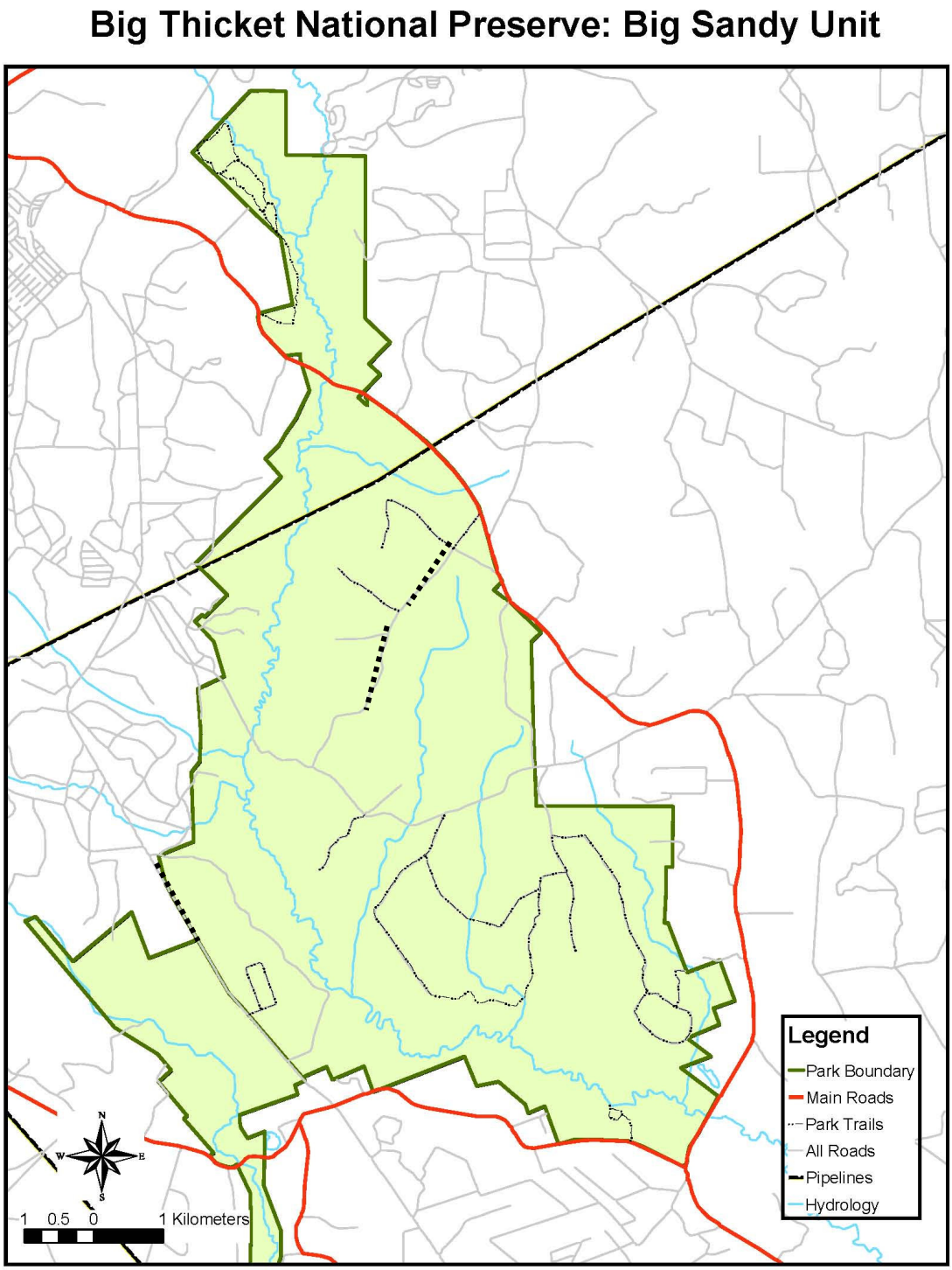

Figure 2.1. Track count transects (represented by black dashed lines) for the Big Sandy Unit, Big Thicket National Preserve, 2004.

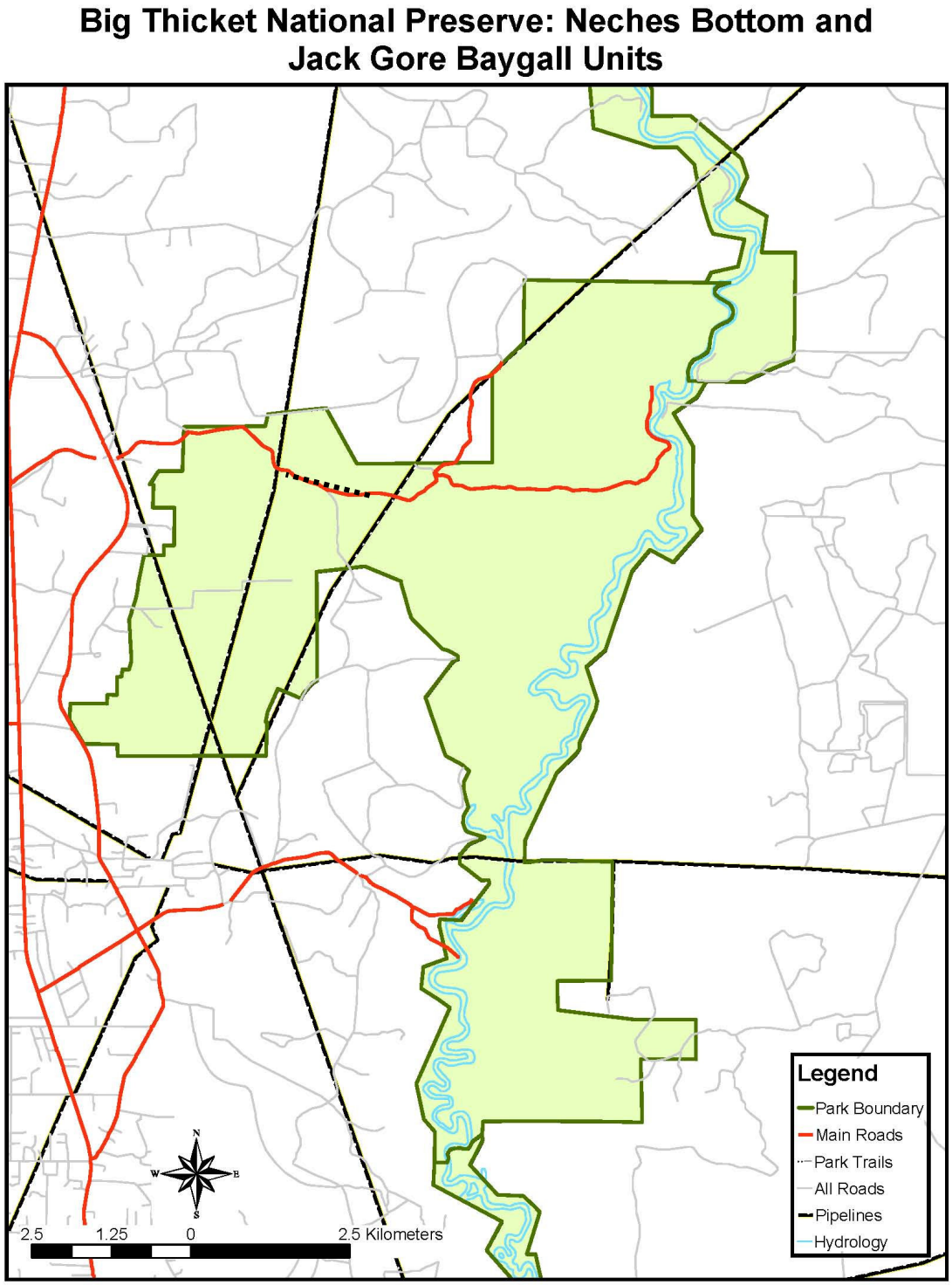

Figure 2.2. Track count transects (represented by black dashed line) for the Neches Bottom/Jack Gore Baygall Unit, Big Thicket National Preserve, 2004.

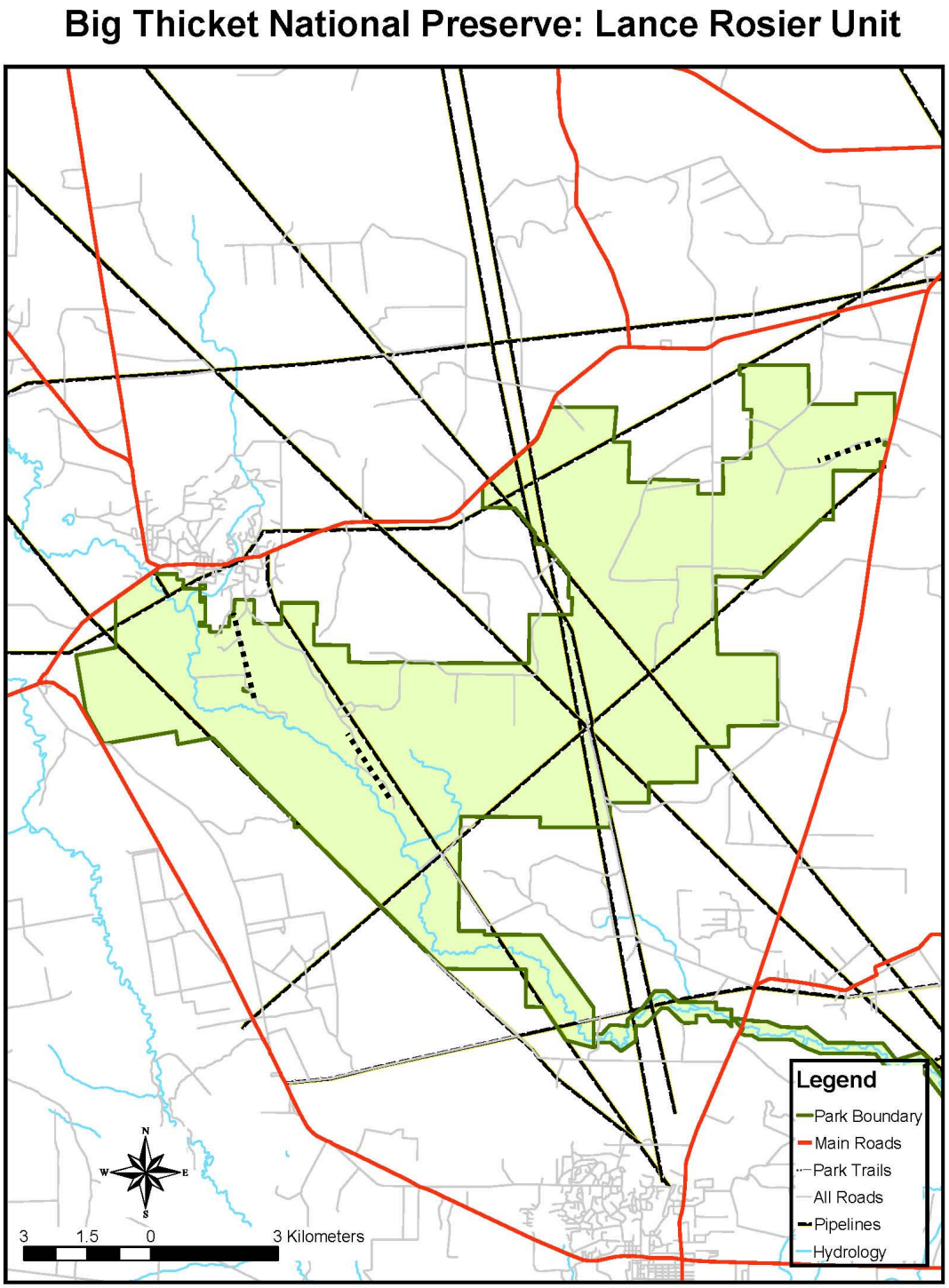

Figure 2.3. Track count transects (represented by dashed black lines) for the Lance Rosier Unit, Big Thicket National Preserve, 2004.

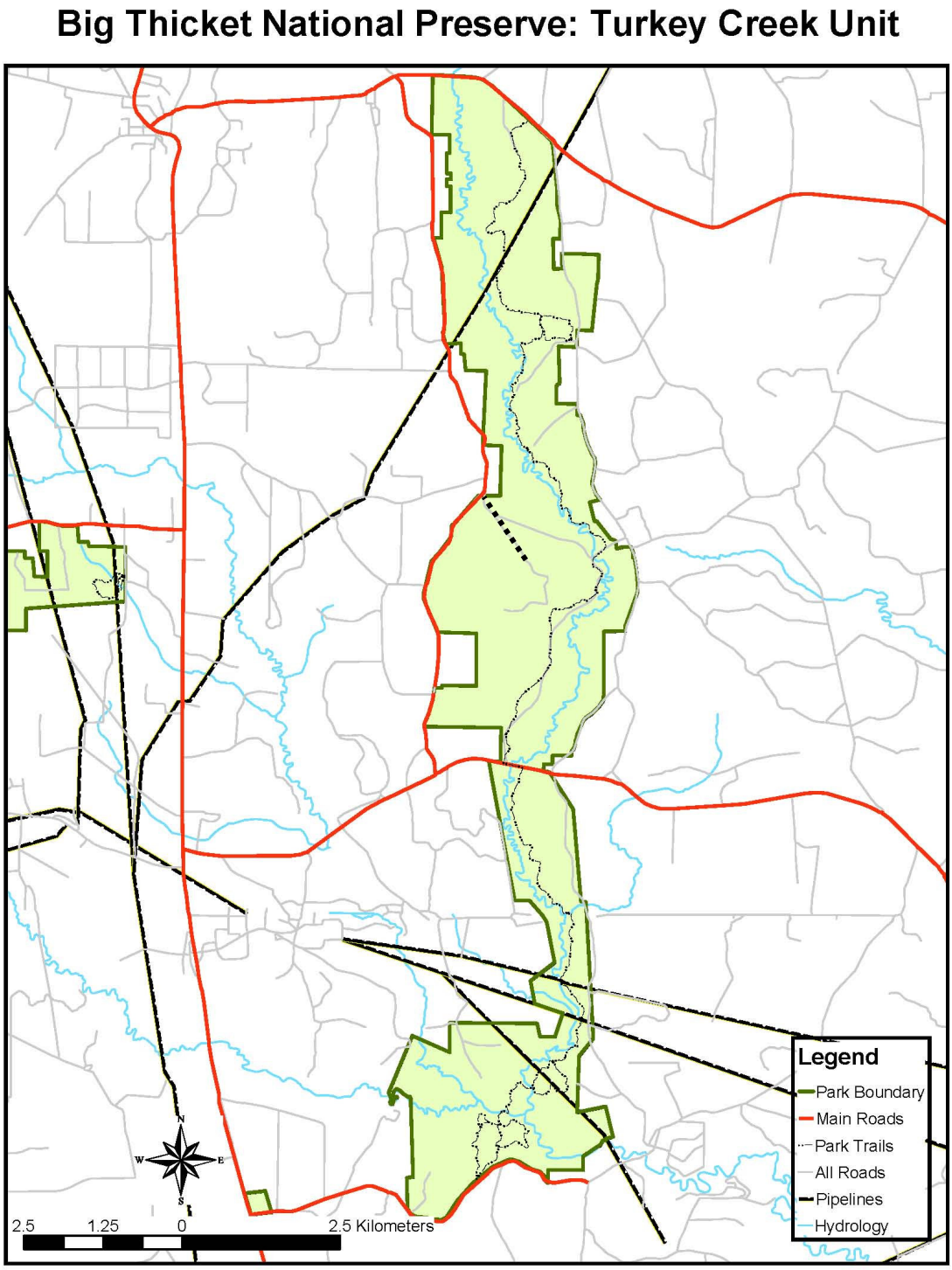

Figure 2.4. Track counts (represented by black dashed line) for the Turkey Creek Unit, Big Thicket National Preserve, 2004.

1989) and are 1.2-m wide with length varying from 0.8–2.4 km within each unit. Typically, 2–3 passes are needed to create a smooth and readable tracking surface. These surfaces are examined on foot once every 24 hours for 3 days, and tracks from the previous day are dragged clean for the consecutive reading. The number of times each species crosses perpendicularly across the width of a transect is recorded. These data are then transformed to the total number of crossings of each species per kilometer.

Data Analysis

Population trends from hunter/harvest effort. —For analysis, hunter effort was first standardized by the total number of trips reported by individual hunters, then by the total number trips reported by all hunters for a given unit. Harvest/hunter effort was then calculated as the total number of each species harvested divided by the total number of hunting trips made to each unit on the preserve. For analysis, data were transformed to number of game harvested per 100 trips for each species, unit, and period in the BTNP. These harvest indices were then used as relative measures of population abundance. Since annual estimates of hunter/harvest were averaged by period, they could be used to track changes in population abundance for each species and each unit over time when comparing between periods (Caughley and Sinclair 1994). Indices of population abundance were subsequently used to calculate the exponential rate of population growth (r) using the equation: $r = ln\ (N_{t+1}/\ N_t)$, where the natural log (ln) of the projected future population size (N_{t+1}) is divided by (N_t) the estimate of the current population estimate (Caughley and Sinclair 1994).

The Shapiro-Wilk statistic (SPSS 2003) was used to determine if harvest effort and population growth estimates (r) were normally distributed; non-normal data were transformed to log(Y+1) to meet assumptions of a parametric ANOVA. I compared harvest effort and population growth estimates (r) among units and periods using an ANOVA and Tukey's mean separation test when F-values were significant ($P < 0.05$).

RESULTS

Hunting Program Statistics

The hunter-card survey return rate was high, with over 59% of participating hunters submitting harvest data for use in this analysis. The average number of hunters and average number of permits issued for each unit in the preserve have not changed significantly over the 25-year period for which the data were analyzed (Table 2.1); this fulfills the first assumption for which analysis of these data can be used to compare population trends between units and between periods.

Harvest Effort and Population Growth Rates

Harvest effort for white-tailed deer appears to be relatively stable ($r \approx 3$) in recent years, suggesting the deer population is stable under current harvest rates. In general, the average number of harvested white-tailed deer has decreased slightly over the past 10 years (Fig. 2.5), with an average of 248±144 deer harvested from 1981–1993 and an average of 228±42 harvested from 1993-2003, remaining at or slightly below bag limits (4 deer, all seasons combined) regulated by Texas Parks and Wildlife. By contrast, the average number of feral hogs harvested in the BTNP have increased dramatically, by nearly three-fold ($P < 0.001$) over the past 20 years (Fig. 2.6); an

average of 111±69 hogs were harvested from 1981–1993, and an average of 250±102 hogs were harvested from 1993-2003. Increased field observations of feral hogs in the preserve also support the premise that population numbers have increased. Feral hog population numbers have generally increased in all the units where hunting is permitted.

In comparing harvest effort among periods and units, there were differences in effort for white-tailed deer for units ($P < 0.001$) and periods ($P = 0.005$). Harvest effort in the Beech Creek (2.07 deer/100 trips) and Lance Rosier (1.73 deer/100 trips) units were lower than that in the Neches Bottom unit (4.36 deer/100 trips); all others were fairly similar (2.24–3.52 deer/100 trips). Harvest effort for white-tailed deer was lower (1.31 deer/100 trips) in the 1980 period, but similar (2.94–3.24 deer/100 trips) in all other periods (Fig. 2.7). The population growth rate for white-tailed deer has declined (r= -0.097) slightly in recent years, but remained relatively stable(r= 0.159) over the past 20 years (Fig. 2.8). Harvest effort for feral hogs has more than tripled, from 0.381 hogs/100 trips in period 1980 to 3.344 hogs/100 trips in period 2000, over the past 20 years (Fig. 2.7). Similarly, the population growth rate for feral hogs has consistently increased, with an average r =0.4460, over the past 20 years (Fig. 2.8).

Track-count Indices

The average number of tracks/kilometer for white-tailed deer has slightly increased in the BTNP as a whole when comparing estimates from 1987 (4.4 tracks/kilometer) to those obtained in 2004 (5.8 tracks/kilometer) (Fig. 2.9). These increases have been observed mostly in the BSU (5.8 tracks/kilometer in 1987 to 8.7 tracks/kilometer in 2004) and JGB (1.1 tracks/kilometer in 1987 to 3.7 tracks/kilometer

in 2004). Average tracks/kilometer in the TCU has remained relatively stable, and slightly declined in the LRU. For feral hogs, the average number of tracks/kilometer in the BTNP as a whole has more than tripled, from 0.5 tracks/kilometer in 1987 to 2.1 tracks/kilometer in 2004 (Fig. 2.10). Slight declines were observed in the TCU (0.8 tracks/kilometer in 1987 to 0 tracks/kilometer in 2004) and LRU (1.3 tracks/kilometer in 1987 to 1.2 tracks/kilometer in 2004), but large increases in tracks/kilometer were represented in the BSU (0 tracks/kilometer in 1987 to 5.8 tracks/kilometer in 2004) and JGB (0 tracks/kilometer in 1987 to 1.2 tracks/kilometer in 2004).

DISCUSSION

An inference on the population status of white-tailed deer and feral hogs, from 1980–2003, was established from both harvest-effort and track-count indices. The two indices were consistent with each other in representing the general trends observed for population numbers of white-tailed deer and feral hog. White-tailed deer populations have remained relatively stable and feral hog numbers have increased in the preserve as a whole. Wildlife observations reported by park visitors, hunters, and rangers also support the trends observed from both of these indices—with particular emphasis on increased sightings of feral hogs throughout many management units of the BTNP.

In analyzing both indices, care must be given to understand how both types of indices can be used to draw inferences to population trends of both of these game species. At first glance, for example, track-count indices for white-tailed deer seem proportionately higher than those observed for feral hogs. One might be tempted to infer from this that the proportions of tracks must somehow reflect actual numbers of hogs

Table 2.1. Hunting zone demographics[a] (number of permits, return rates, active hunters, number of trips) by management units determined from hunter card surveys on the Big Thicket National Preserve, Texas, 1981–2003.

Management Unit	Allowable Permits	Avg. Permits Issued	Avg. Return (%)	Active Hunters (%)	Avg. Total Trips
Beech Creek	150	220	61	87	5
Beaumont	200	194	62	92	11
Big Sandy	400	448	66	92	19
Jack Gore Baygall	400	382	64	89	19
Lance Rosier	900	960	61	87	37
Neches Bottom	150	177	59	89	5

[a]Allowable number of permits refers to current (2004) limits. The average number of permits issued accounts for permits issued from 1981–2003. Some averages calculated are greater than those currently allowable because previous permit limits may have been higher in previous years. *Average return* = average hunter survey return rate (%). *Active hunters* = of surveys returned, the average active number of hunters (hunted at least 1 day). *Average total trips* = the average number of trips made to the park for hunting activities.

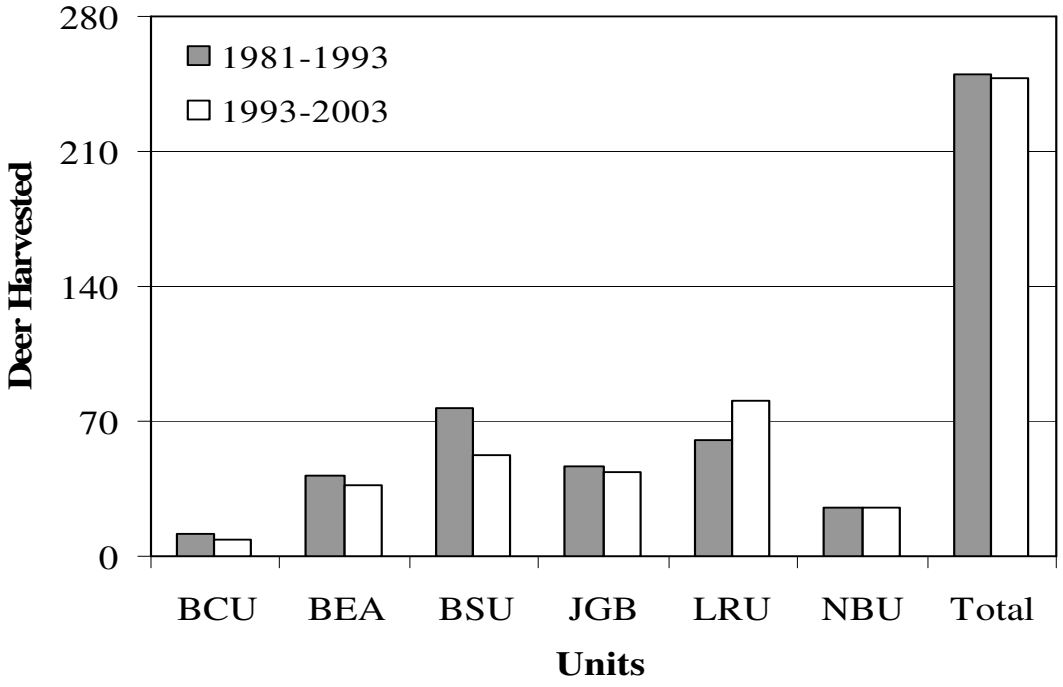

Figure 2.5. Average number of white-tailed deer harvested in Big Thicket National Preserve, Texas, 1981–2003.

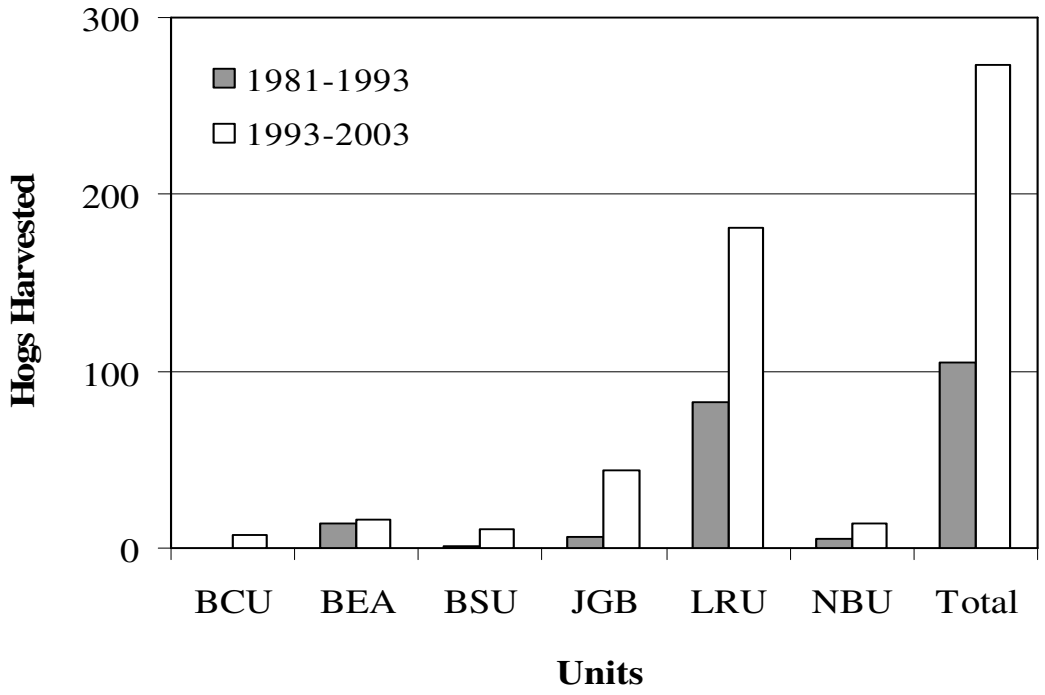

Figure 2.6. Average number of feral hogs harvested in Big Thicket National Preserve, Texas, 1981–2003.

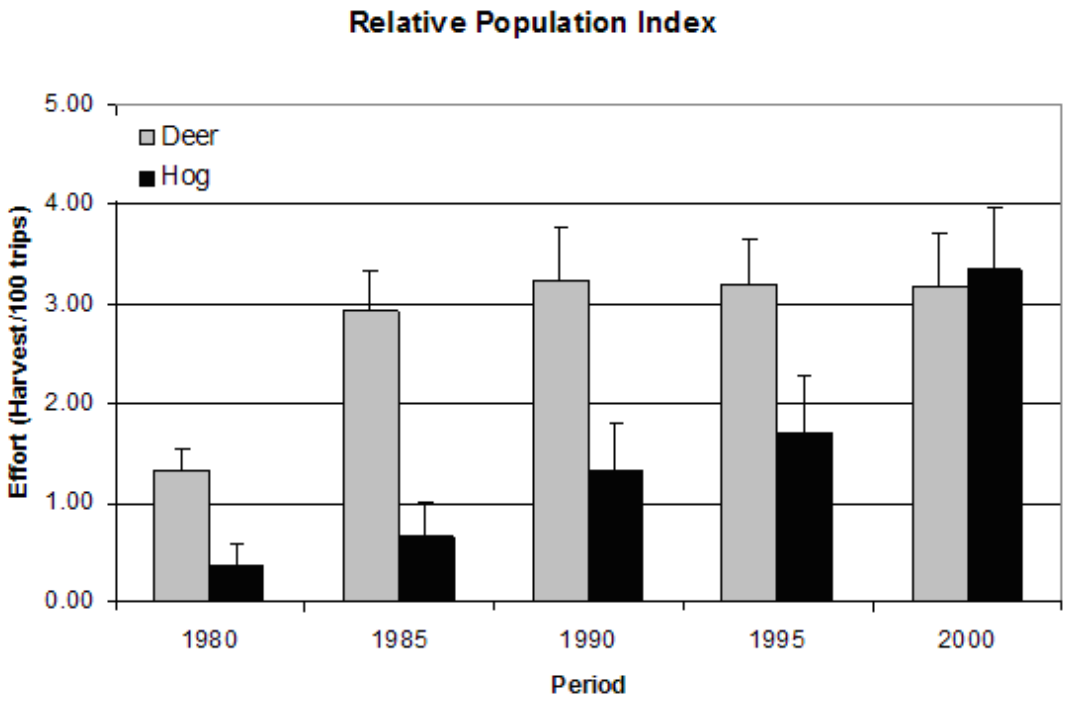

Figure 2.7. Hunter/harvest effort rates of white-tailed deer and feral hogs in Big Thicket National Preserve, Texas, 1981–2003.

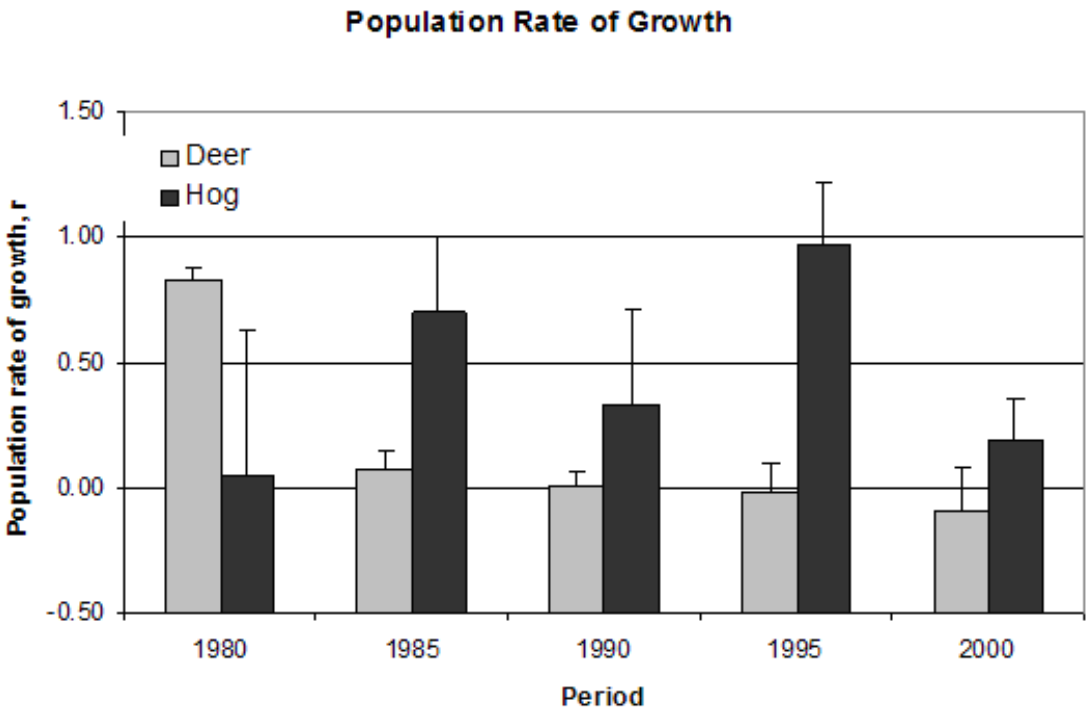

Figure 2.8. Population growth rates (*r*) of white-tailed deer and feral hogs in Big Thicket National Preserve, Texas, 1981–2003.

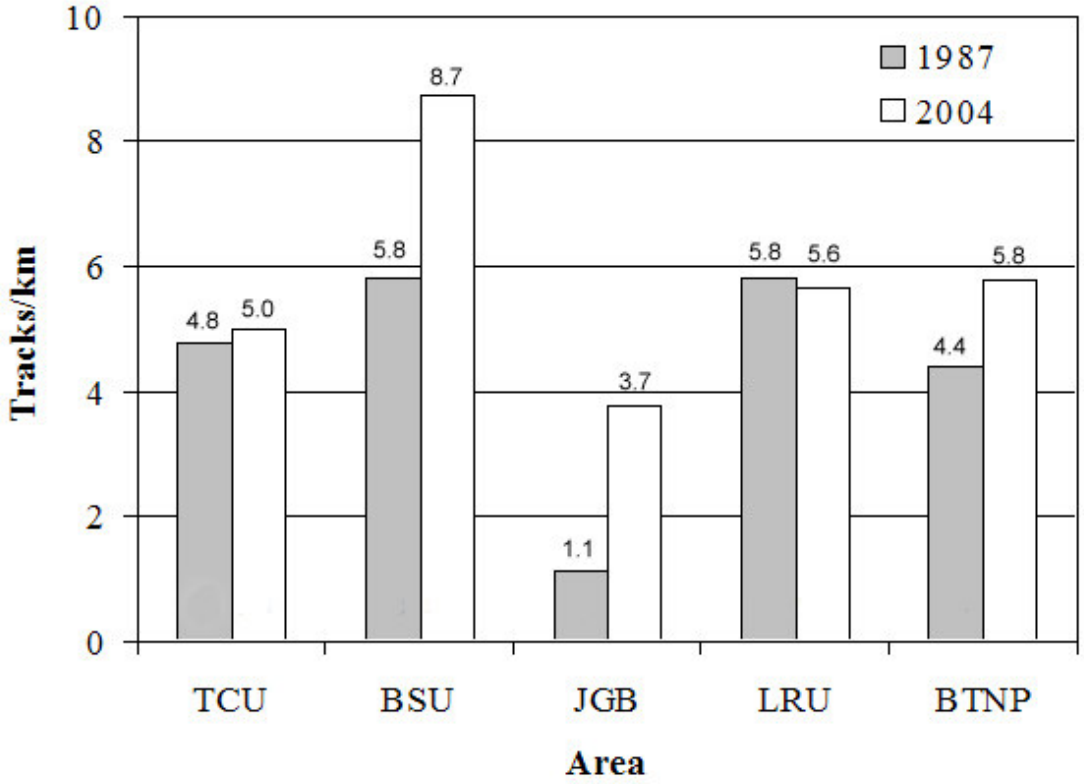

Figure 2.9. Track-count indices, or average tracks/km, of white-tailed deer in Big Thicket National Preserve, Texas, 1981–2003.

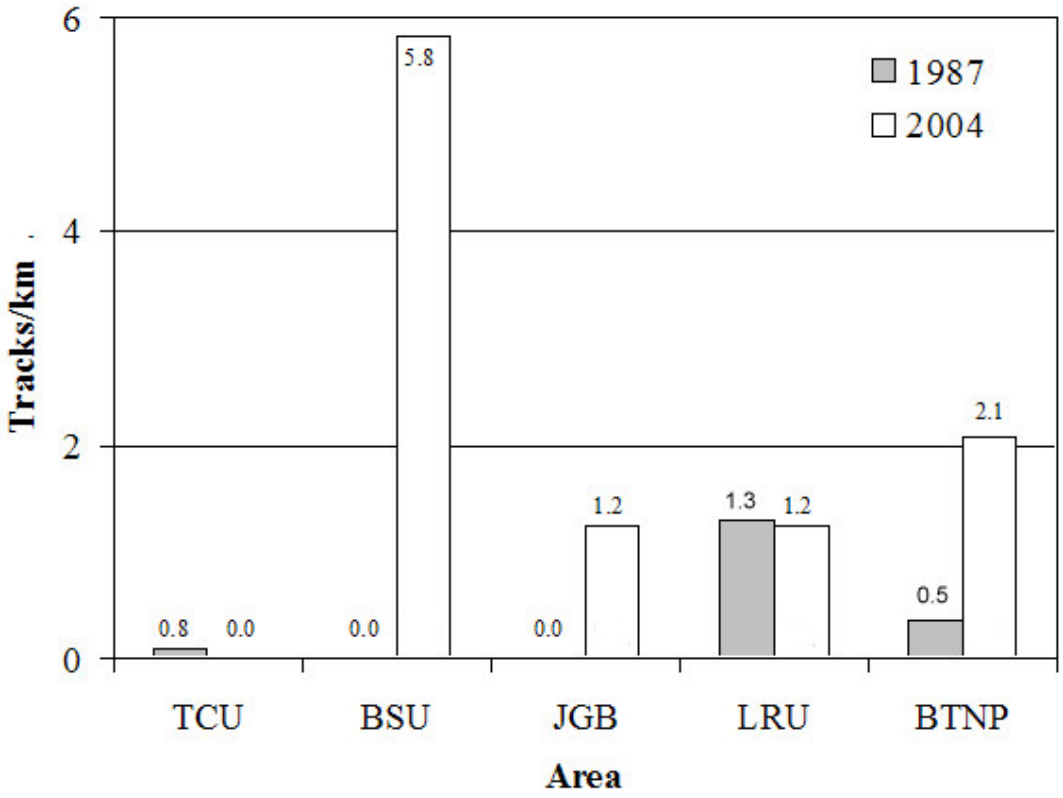

Figure 2.10. Track-count indices, or average tracks/km of feral hogs in Big Thicket National Preserve, Texas, 1981–2003.

and deer similar to harvest-effort. Data from track-count indices slightly contradict the proportional increases in hog numbers observed from the harvest-effort index, in which the number of hogs has nearly tripled over the past 2 decades. But the fact of the matter is that both indices do support similar trends, just in a different manner.

There are several ways to explain this discrepancy between proportions observed in harvest-effort and track-count indices. First, it can be argued that changes in hunter's preference for certain game species may have influenced an increase in take of hogs. In this study, I assume that hunter preference for games species in the BTNP has not changed much over the 20-year period since the culture of the region surrounding the BTNP has always had a strong preference for both game species. Second, shifts in behavior and movement patterns of white-tailed deer or feral hog may have influenced the number of crossings of these species in the particular areas where the track-count transects were conducted. It isn't within the scope of this study to estimate how changes in movement patterns, particularly within small-scale periods could have affected the results. In this study, I assume that movement patterns of those 2 game species remained fairly consistent within management units given that no drastic fragmentation or alteration of the habitat, which may impact animal movement patterns, has been undertaken by BTNP management. Since the track-count transects were conducted consistently in the same areas over a 20-year period, reliable estimates of population trends can be provided when comparing the track-count indices within each management unit over a large temporal scale.

After considering the previously stated assumptions to be legitimate, one must then consider the difference between the harvest-effort index and track-count index in terms of what their numbers really reflect. For one, the harvest-effort index provides a clearer picture of actual numbers of deer and hogs since the data reflects actual proportions of animals removed from the population. The one factor that one must be cautious of, however, is that there are bag limits regulating take of deer while there is unrestricted take of feral hog. This means that the harvest-index is sensitive to declines in deer numbers below the bag limit, but not sensitive to increases in deer numbers above bag limits. The harvest-effort index for feral hogs, therefore, is more likely to reflect actual population trends than the index for deer because the harvest-effort index will plateau and reach its maximum at a bag limit for deer, but will not for feral hogs. Since the focus of this study is on feral hogs, the harvest-effort index serves as an appropriate instrument to gauge population trends in feral hogs.

The problem encountered for bag limits in the harvest-effort index is resolved through the use of the track-count index. When assumptions about the long-term stability of animal movement patterns within management units are met, the track-count index is more sensitive to comparing changes in numbers of animals since it does not plateau at artificial numbers restricted by bag limits. As discussed earlier, this is especially pertinent to white-tailed deer, where the harvest-effort index may suggest that population numbers are merely stable ($r \leq 0$) when they may in fact be increasing ($r > 0$). These same criteria apply to feral hogs. However, one aspect that track-count indices are sensitive to is variation of animal movement patterns across different taxa.

The track-count indices account for number of crossings along designated transects—mostly along dirt roads—and thereby are more likely to reflect changes in numbers of a given taxa or species (i.e., through number of crossings observed) for which a large portion of their movement patterns include dirt roads as part of their habitat. In the case of white-tailed deer and feral hogs, both species have been observed to cross dirt roads, use dirt roads as travel corridors, and sometimes approach the edge of dirt roads for water or forage. But there are other aspects to consider when using track-count indices.

The frequency with which different species cross dirt roads, and thereby a track-count transect, is likely to vary. This is especially true when comparing track-counts between different species such as coyotes (*Canis latrans*), raccoons (*Procyon lotor*), squirrels (*Sciurus* spp.), or white-tailed deer and feral hogs (Fagre et al. 1989, Chavarria et al. 2004)—all of which have different physiological requirements, diet preferences, habitat preferences, and thereby different movement patterns within similar habitats. When considering track-count indices for feral hogs, therefore, one must note that their secretive nature often deters them from using roads as travel corridors as often as those they establish along riparians, creeks, and within habitat with open understories. White-tailed deer, on the other hand have a strong preference for foraging in open habitat (i.e., savannahs, prairies, open grasslands), and biologists often take advantage of this behavior for conducting road-side spotlight counts (Garton et al., 2005). This may explain why track-counts of feral hogs are proportionately lower in comparison to those for white-tailed deer. When comparing track-counts within species and between periods,

however, hog tracks have increased more than 100% within most units, and thereby coincide with patterns of increasing numbers as those observed in harvest-effort indices.

MANAGEMENT IMPLICATIONS

The hunter-survey card system is an effective means of obtaining reliable estimates of harvested game and should continue to be implemented. One item that can be improved in the survey cards is additional questions that require hunters to provide information about the gender and age classes of the game they harvest. Although the cards do inquire about the number of bucks and does harvested, such information is not yet required for feral hogs. Having hunters provide information about the number of sows, boars, and piglets harvested could provide data that can be used for modeling the population dynamics of hogs in the BTNP.

Along similar lines, the BTNP also should incorporate questions that ask hunters about their hunting preference for certain game species. Harvest preference has not been examined extensively in the BTNP, though demographic data exists in the database. This study assumes that hunter demographics have remained relatively consistent over the 20-year period, but changes are likely to occur over larger time periods. Analysis of hunter preference is recommended for the analysis of hunter-effort data over the next 20 years. This will be needed to satisfy assumptions necessary for comparing data sets between larger temporal scales.

The use of harvest-effort and track-count indices provides cost-effective and efficient means of determining the population status of game species when alternative methods are costly or unavailable for BTNP management. Overall, both the harvest-

effort indices and track-count indices in this analysis supported similar trends in population numbers for white-tailed deer and feral hogs, though care should be given when making direct inferences of population numbers when one index is used independent of another. As mentioned previously, a more robust data set can result by obtaining, from hunter-harvest cards, information about hunter game preferences and information about the age class and gender of all the species they harvest. Further, the hunter-harvest index undermines sensitivity to increases of species for which there are bag limits, so correction factors need to be instituted to resolve this problem. The hunter-survey cards includes a question for reporting wildlife sightings, so hunters should be encouraged to report the total number of deer they saw per trip in addition to the number of deer they harvested. This would allow for a correction factor to be integrated into the harvest-effort index for white-tailed deer.

The track-count index remains as an alternative to the harvest-effort index, but consistency in methodology is key to allowing adequate comparison between large time frames. One drawback encountered from track-count transects in this study was that they cannot be replicated further in the same areas as those formerly surveyed by Fagre et al. (1989). The last track-count transects were surveyed in 2004 but could not be replicated hereafter because dirt roads have since been overlain with rock or paved-over by NPS management. Although an alternative solution to such problems is to create track-count transects along the edge of those roads, the grade and profile of many of the roads formerly surveyed had been altered such that it would not permit pursuit of that alternative. If the track-count method is to be continued by the BTNP, new transects

need to be designated in roads that permit the preparation of a readable track surface. Future analysis of track-count indices could thus be made by comparing results replicated within these newly designated transects.

This study suggests that feral hog numbers have increased significantly over the past 20-years and that management measures should be taken for population reductions if their numbers create conflicts with the conservation and preservation efforts of the BTNP. Populations of white-tailed deer appear stable under both harvest-effort and track-count indices, but alternative field methods for deer census (i.e., passive-triggered cameras) should be employed to provide reliable estimates for comparison. A slight decline ($r < 0$) in the population growth rate was observed for period 2000 for white-tailed deer but it is difficult to discern from the data if this is directly or indirectly related to competition with hogs as a result of the consistent increase in hog numbers ($r > 0$). A close examination of the population trends of white-tailed deer over the next 5-year period is warranted to note if their numbers continue to decline. I also recommend that the BTNP consider conducting research about potential competition for food resources and competitive interactions between white-tailed deer and feral hogs.

CHAPTER III

SURVEY OF FERAL HOG IMPACTS TO THE NATURAL RESOURCES OF THE BIG THICKET NATIONAL PRESERVE[‡]

SYNOPSIS

Management measures for controlling the impact of exotic species in conservation areas like the Big Thicket National Preserve (BTNP) often require documented evidence for a legal need for action. The BTNP is faced with escalating numbers of feral hogs throughout the past 20 years and increased damage to resources resulting from hog rooting and wallowing activities. Hog impacts on resources have gone largely undocumented in the BTNP and research was needed to examine the extent and intensity of those impacts across various vegetation communities. In this study, I surveyed hog impacts to the natural resources of the BTNP from April–September 2005 in 3 management units: Lance Rosier, Big Sandy, and Turkey Creek. I developed a survey method using random stratified sampling by vegetation type to assess impacts from hog damage to resources at a landscape scale.

Survey results note that the overall damage to vegetation from hog activities averaged to 28% between the 3 units of the BTNP. Landscape features such as topography, soil moisture, soil type, and dominant vegetative cover types were used to predict hog damage. Floodplains had the most damage in the Big Sandy unit (45%), while flatlands were mostly impacted in the Turkey Creek unit (46%), and uplands in the

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[‡] Parts of this chapter, appearing in "A landscape-level survey of feral hog impacts to natural resources in Big Thicket National Preserve" by Chavarria et al., 2006, have been submitted to *Human-Wildlife Conflicts* and are pending review for publication

Lance Rosier unit (32%). Results from ordinal logistic regression determined that horizontal obstruction of vision (i.e., percent vegetation cover) was an important predictor of amount of hog damage in all 3 units; open habitat within disturbed sites and dense habitat just outside disturbed sites coincided with more hog damage. The results support the premise that hog damage in the BTNP parallels the increase in hog abundance over the past 20 years. Impacts are more widespread across different vegetative strata than previously believed. Spatial analysis from this study can be used by the BTNP to determine where management actions are warranted for controlling hog impacts to sensitive resources in the BTNP.

INTRODUCTION

The control of feral hogs on the BTNP depends, to a large extent, on their public recreational hunting program which also permits hunting of white-tailed deer and other small game species. A recent analysis of harvest data collected by park managers from the recreational hunting program suggests that numbers of hogs have increased significantly within the past 20 years (Fagre et al. 1989, NPS 2001, Chavarria et al. 2004). As a consequence, feral hog populations throughout the preserve, having gone unchecked by any formal feral animal control program (NPS 1996, NPS 2001), and seemingly unaffected by yearly public recreational harvest hunts (Chavarria et al. 2004), have continued to be a source of negative impacts on park resources.

Miller (1993) describes the many forms of damage caused by feral hogs as "rooting and feeding on forest regeneration sites, row crop and pasture lands and food plots or plantings for wildlife; damage to ponds, tanks, springs and water holes; damage

to wild ecosystems and threats to biodiversity; competition with other preferred wildlife species game and non-game; predation on other wildlife and domestic animals; and, disease threats to domestic livestock and humans." Some of the affected resources within the park boundaries may potentially include rare and federally-listed endangered plants such as Texas trailing phlox (*Phlox nivalis* var. *texensis*), and white firewheel (*Gaillardia aestevalis* var. *winkleri*) (BTNP 1996). Although negative feral hog impacts such as rooting disturbance to soils and vegetation, or erosion damage from wallows can be easily identified, little action can be taken by local governments and resource managers to resolve such problems if those impacts are not formally and scientifically documented. In the BTNP, the extent of visible hog damage to resources has not been fully documented or evaluated.

The feral hog management plan drafted by the BTNP (2001) recommended several research objectives concerning feral hog impacts which needed to be addressed. Of these, the preserve is interested in identifying the population dynamics of feral hogs and their relation to various types of vegetation complexes within the BTNP. Second, the BTNP needs to identify and quantify both immediate and long-term damages to the native flora and fauna caused by feral hogs. Third, both immediate and long-term damages to the soils and waters of the preserve resulting from activities of feral hogs need to be documented. Last, the BTNP needs to assess whether feral hog populations are significantly impacting and/or changing the various natural vegetation communities.

In this study, I document and evaluate feral hog impacts to the vegetation communities of BTNP. I describe a large-scale survey method used to determine impact

assessment of hog damage (i.e., rooting and wallowing) to vegetation types within the preserve. I examine how hog damage varies with landscape factors such as topography and proximity to roads and water sources. I also document microhabitat characteristics such as soil types, vegetative cover, and stem density of impact sites within the various vegetation sub-types. Using these approaches, I evaluated landscape and microhabitat vegetative structure characteristics that predicted increases in hog damage relevant to control of feral populations (e.g., biological opinion for federal agency).

STUDY AREA

The BTNP is located north of Beaumont in the Pineywoods region of southeast Texas and comprises 12 management units. Of these management units, the 3 units with the highest reported hog damage were surveyed—the Big Sandy Unit (BSU), Lance Rosier Unit (LRU), and Turkey Creek Unit (TCU). A brief description of these units is provided below.

Big Sandy Creek Unit

The BSU (Fig. 3.1) lies about 25.7 km east of Livingston, Texas along FM 1276 in Polk County. Major hydrological features of this unit include Big Sandy Creek, which runs roughly North-South through the entire length of the unit, and Menard Creek, which cuts through the southwest corner. The ecosystem in this unit is comprises mostly slopes (4,720 ha), with some floodplains (519 ha) and uplands (398 ha). There are 3,581 ha available for hunting in BSU with a limit of 400 permits issued annually.

Lance Rosier Unit

The LRU (Fig. 3.2) is located approximately 8 km southwest of Kountze, Texas east of FM 770 in Hardin County. Major hydrological features include the Little Pine Island Bayou and Black Creek drainages. Slopes compose the majority of that habitat (6,193 ha), with a good representation of flatlands (2,750 ha), some floodplains (1,134 ha) and uplands (374 ha). There are approximately 8,498 ha available for hunting with a limit of 900 permits issued annually.

Turkey Creek Unit

The TCU (Fig. 3.3) is located about 17 km north of Kountze, Texas, on FM420. The major hydrology in this unit includes Turkey Creek, which divides the unit roughly north-south, as well as Village Creek and Hickory Creek. Vegetation types consist of 1,694 ha of slopes, 1,069 ha of floodplains, 327 ha of uplands, and 88 ha of flatlands. Hunting is not permitted within the TCU because of safety regulations imposed for recreational purposes.

METHODS

Vegetation Sampling

The extent and intensity of rooting and wallowing activities by feral hogs was surveyed from April–September 2005 in the BSU, LRU, and TCU units of the preserve. Vegetation surveys consisted of walking along strip transects consisting of fixed 10 m-wide by approximately 1-km-long segments. Transect locations (Fig. 3.1-3.3) were selected from a set of randomly generated locations using the NPS-AKSO AlaskaPak Functions Pack extension random point generator function in ArcView 3.2a (ESRI

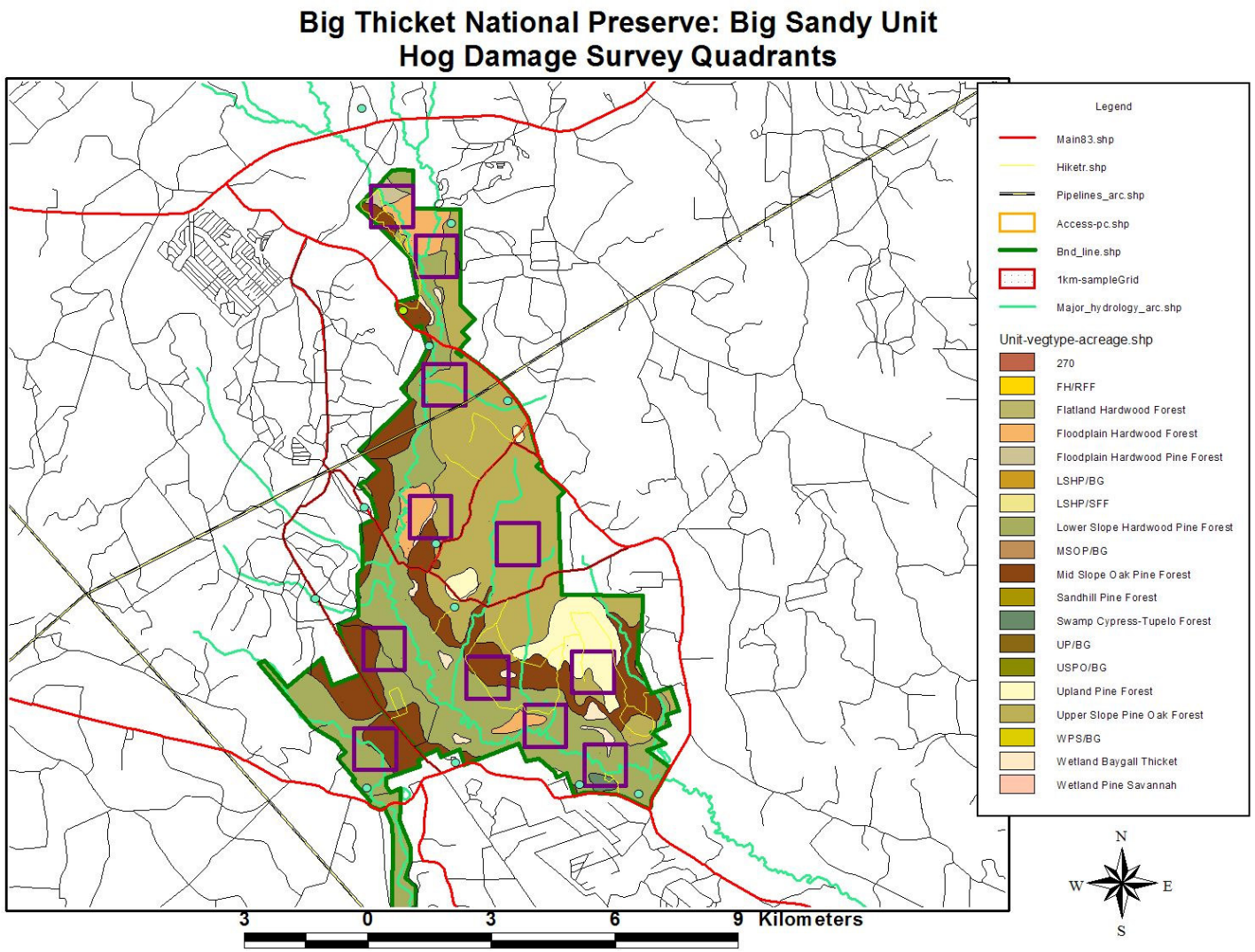

Figure 3.1 Vegetation map of Big Sandy unit of the Big Thicket National Preserve, Beaumont, Texas. Dark squares in the map represent locations of belt-transects surveyed.

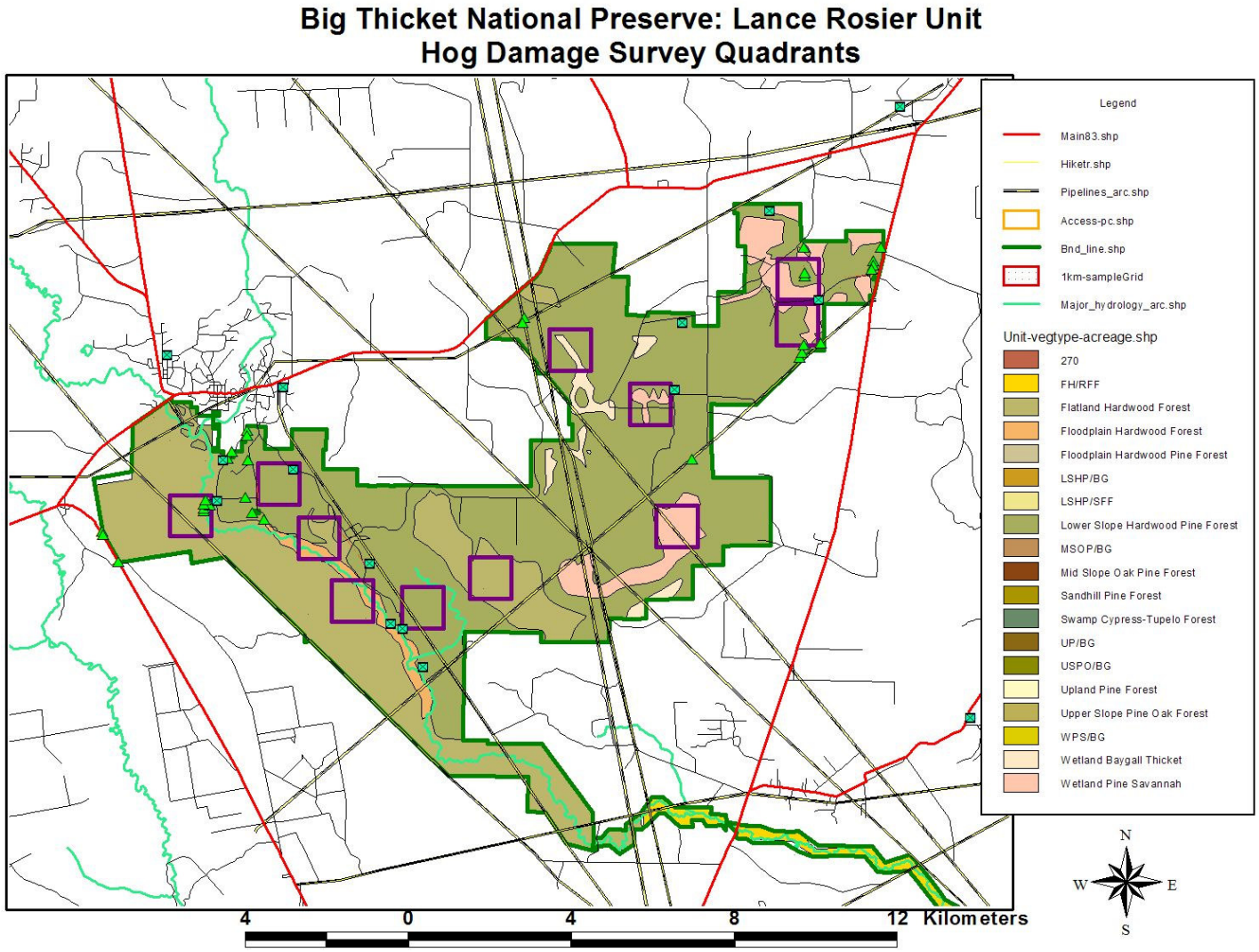

Figure 3.2 Vegetation map of Lance Rosier unit of the Big Thicket National Preserve, Beaumont, Texas. Dark squares in the map represent locations of belt-transects surveyed.

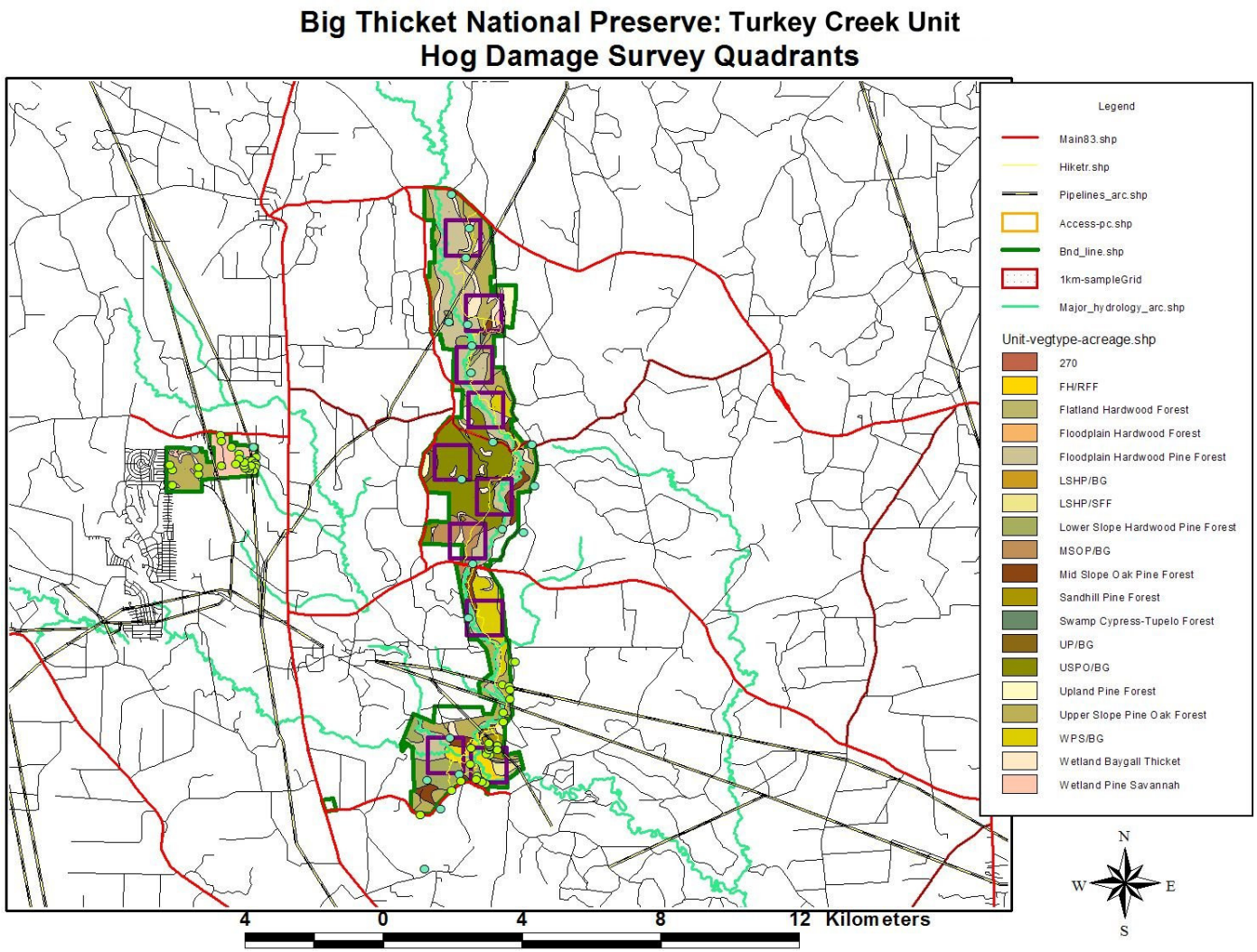

Figure 3.3 Vegetation map of Turkey Creek unit of the Big Thicket National Preserve, Beaumont, Texas. Dark squares in the map represent locations of belt-transects surveyed

2000). Total area surveyed varied by unit, but about 24–40 transects were surveyed in each unit. These segments covered a random stratified sample (Krebs 1999, Higgins et al. 2005) of each major vegetation type. Distance to water (i.e., creeks, rivers) and distance to park roads, oil and gas pipelines, and park recreational trails also were implemented in the design. To reduce design bias to water sources, half the transects were placed in close proximity (0–50 m) to major hydrological sources (i.e., creeks, rivers) while others were placed away (about 500 m or more) from these water sources. To reduce design bias to roads and trails, half the transects were placed in close proximity (0–50 m) to park roads while others were placed away (about 500 m or more) from park roads. All transect locations were buffered 100 m from the park boundary.

Locations of hog sign were geo-referenced with a Garmin Legend GPS unit. The GPS locations of hog damage were merged with the vegetation-type shapefiles in ArcView to associate the area of impact and intensity of damage within each vegetation type. The area of each patch of hog disturbance was calculated as the area of a simple polygon: the longest length of a patch multiplied by the width through its center would give an estimate of disturbance in square meters. The sum area of all patches of hog disturbance within the strip transects produced estimates of total area impacted for a given unit of the preserve (e.g., LRU). The XTools extension in ArcView facilitated calculation of total area surveyed and was instrumental for determining the proportions of damage occurring within each major and minor vegetation type. A graduated symbol scheme (i.e., a circle with a cross-bar within it) in ArcView was used to index range of damage for each patch of hog disturbance; the “natural breaks” feature for the graduated

symbol was used to represent 4 intervals of area impacted: (1) 0–140 m^2, (2) 141–350 m^2, (3) 351–700 m^2, and (4) 701–2000 m^2.

Indices of Hog Impact Sites

In addition to the approximate dimensions (i.e., length and width) of disturbance to soils and vegetation, hog damage at each site was indexed according to sign type and damage intensity. Sign type, especially that representing damage from hog activity, conforms to descriptions found throughout the literature (NPS 1985, Miller 1993); these included sightings of live hogs, tracks and/or feces, wallowing areas, and rooting areas.

Measuring intensity of impact. Intensity of hog damage, based on depth of soil disturbance, where x represents the depth of disturbance for an individual patch, was indexed as follows: 1 = 0.635 cm < x < 2.54 cm, 2 = 2.54 cm < x < 10.16 cm, 3 = 10.16 cm < x < 20.32 cm, 4 = 20.32 cm < x < 30.48 cm, 5 = x > 30.48 cm. Depth of soil disturbance for each impact site was visually estimated by comparing the soil level of disturbed patches with the soil level of normal (undisturbed) areas closest to the impact site. In instances where the accuracy of the approximation was in doubt, 2–4 points of reference within the disturbed area were measured and averaged to provide a better estimate of depth of disturbance.

Determining age of disturbance. The exact age of hog disturbance is difficult to determine unless the disturbed area was monitored before and up to the time that the impact occurred. Therefore, age of hog disturbance in this study is a rough visual approximation. Engeman et al. (2001) describes a method of roughly estimating the age of hog impact. A more detailed method is considered in this study. Approximate age of

hog impact was indexed into 5 categories: 1 = fresh, 2 = recent (1–7 days old), 3 = up to 1 month old; 4 = older than 1 month; and 5 = year old. Factors considered in aging hog disturbance included, (1) amount of vegetative litter on top and/or surrounding the disturbance, (2) amount of vegetative regrowth within and surrounding the disturbance, (3) moisture of the soil inside and surrounding the area of disturbance, and (4) weather trends (i.e., rainfall, flooding, extreme heat or cold, and extreme winds) that occurred at the moment and up to several months before the survey information was gathered. Sign indexed as "fresh" consisted of a moist depression on substrate with less than 10% litter covering the sign, and with a greater proportion of barren ground to vegetation within the disturbed area. Sign indexed as "recent" was considered to be about 1–7 days old with some moisture (at least 25-75% of normal) remaining on substrate, up to 50% litter covering sign, and little to no herbaceous regrowth in the area of impact. Hog sign that was considered over 1 week to 1 month old was represented by little to no moisture (less than 25% of normal) remaining on substrate, more than 50% litter covering the sign, and with some herbaceous regrowth and limited recovery of perennials in the impact site. Damage older than 1 month to less than 1 year was considered to have no moisture remaining on substrate, more than 75% litter covering the sign, and with extensive herbaceous regrowth and moderate recovery of perennials within the site. Any hog disturbance considered to be equal to or older than 1-year old was represented by no moisture remaining on substrate, more than 90% litter covering the sign, and with extensive herbaceous cover and moderate to high recovery of perennials within the impact site.

Trends in weather were used to make estimated corrections or adjustments to the index value of age of hog sign. Sign detected during a period of heavy rainfall that would normally be indexed as "fresh", for example, would be assigned a higher index value (i.e., older classification) unless hogs were seen actively creating the disturbance during the survey. Lower amounts of precipitation would influence the adjustment of the index value less. In cases where flooding was known to have occurred in the area prior to the survey, approximating the age of hog disturbance by moisture would be difficult and unreliable, so factors such as recovery of vegetation or percent litter covering the sign were used instead.

Microhabitat Characteristics of Impact Sites

Basal area measurements. There are several ways to measure vegetation cover in forest ecosystems (Avery and Burkhart 1994, Higgins et al. 2005). One such measurement involves calculating the stem density of an area through measurement basal area (BA) of surrounding vegetation. The BA is measured by adopting a variation of the Bitterlich variable radius method (Higgins et al. 2005) through the use of a clear glass prism. As noted by Higgins et al. (2005), this method records the number of trees whose trunks appear displaced when viewed through the prism. The total stem count at each sample point is multiplied by a basal area factor (BAF) of the prism (in this case, it being a prism of BAF 10)—giving the total basal area of stems per unit of area (Higgins et al. 2005). The BA measurement was taken for every geo-referenced feral hog impact site in the study.

Horizontal obstruction of vision. Escape or shelter cover is an essential component of habitat for all wildlife. Vegetative cover provides such shelter for feral hogs in the BTNP and this can be measured the horizontal obstruction of vision (HOV) that surrounding vegetation provides. To measure HOV, a variation of the Robel range-pole method (Higgins et al. 2005) was used to measure percent vegetation cover—or the portion covering the 2-m long Robel range-pole. To correct for variation of HOV within any given direction from a given point, the HOV is calculated by averaging measurements from the 4-cardinal directions, as consistent with most point-sampling methods (Avery and Burkhart 1994, Higgins et al. 2005). Two measurements of HOV were taken for each impact site: the first was taken within a 1-m radius of the impact site and will be referred to as "inside HOV", and the second was taken for a 10-m radius immediately around the impact site and will be referred to as "outside HOV". Ultimately, the measurements obtained from the HOV were used to analyze how the amount of cover around a point of hog activity varies by vegetation type and sign type.

Data Analysis

Spatial analysis of distribution of hog damage. Geo-referenced points of hog impact sites were associated with landscape characteristics of the BTNP in ArcView. Implemented in the survey design, the proximity of impact sites to water sources, roads, trails, specific vegetation types, and soil types could be discerned from ArcView shapefiles provided by the BTNP. Other components of the landscape such as topography and soil type were verified in field surveys as well as from results from ordination methods discussed by Marks and Harcombe (1981).

Ordinal logistic regression. Components describing hog sign, such as sign type, sign age, and damage type, were collected as interval or categorical data in the field and each were generally indexed into 3 to 4 categories. Total area of each impact site was also treated as interval data, as described earlier, using the "natural breaks" function in ArcView. To facilitate analysis, BA and HOV also were converted to intervals. BA intervals consisted of low (0–50 BA), moderate (51–100 BA), high (101–150 BA), and very high (151–200 BA). HOV intervals of percent cover consisted of low (0–25% HOV), moderate (26–50% HOV), high (51–75% HOV), and very high (76–100% HOV). Similarly, vegetation types were reduced to 4 broad categories (Marks and Harcombe 1981), implementing a rough ordinal progression of categories in respect to topography: floodplains =1, flatlands =2, slopes =3, uplands =4.

Because most of the data were collected as interval or categorical data, I evaluated the results using an ordinal logistic regression to determine how the different factors in the study (i.e., sign age, sign type, vegetation type, BA, HOV) predicted the total amount of hog damage found throughout the BTNP. Logistic regressions were conducted in software program MINITAB 12.2 (Minitab Inc., State College, Pennsylvania). The index of total hog damage was treated as the response variable with sign type, sign age, damage type, BA, inside HOV, and outside HOV as terms included the model. Sign type and vegetation type were not continuous predictors but, instead, categorical predictors, so they were modeled as "factors". Independent tests were conducted for each individual unit (i.e., BSU, LRU, TCU). Significance of factors in

each test was set at $P \leq 0.05$. Graphical output of logistic regression was conducted for comparison in SPSS 12.01 (SPSS Inc, Chicago, Illinois).

RESULTS

Spatial Distribution of Impact Sites

The BTNP was damaged primarily from rooting in areas consisting of wetlands and hardwood bottomlands. Hog wallows, as is generally expected, were concentrated near more mesic or wet areas where major hydrological sources were present, but also were occasionally found near ephemeral waters sources such as ponds and seasonal floodplains. Impact damage from tracks, where hogs seemed to have consistent travel corridors, also represented an extensive source of low-impact damage throughout the preserve, primarily in areas with poorly drained soils. The overall percent area damaged throughout the 3 units averaged 28%.

The BSU represented the highest percent area damaged of the 3 units surveyed with 34% being affected. Of this damage, the highest proportions of damage were observed mostly in wet and mesic sites of lower elevation. Floodplains had the most damage (45%), followed by slopes (35%), and then uplands (4 %). Floodplain habitat consisting of wetland baygall thickets, which has very poorly drained soils and denser understories, was impacted the most (67%). A similar habitat with poorly-drained soils in the floodplains—the swamp-cypress tupelo forest—had 46% damage. Better-drained floodplains where hardwoods and pine are dominant also had much disturbance (50%). Floodplains where hardwoods were more abundant relative to pine had 42% damage. Higher slopes composed primarily of oak-pine forests had more damage (41%), in

comparison to mid-slopes (29%) or lower-slopes (33%). The highest elevation habitat, however, composed primarily of upland pine forest, was the least affected (4%).

The TCU was second in percent area damaged, with 28% being affected. Flatlands, with poorly drained soils, and dominated by hardwood cover, had the highest proportion of damage (46%). Slopes in the TCU had about as much damage (27%) as the floodplains (27%). The upper-slopes composed of pine, oak, and baygall cover had higher damage (29%) than upper-slopes without baygall (19%). Mid-slope vegetation with oak-pine cover had more damage (50%) in comparison to the upper-slopes and lower-slopes dominated by hardwoods (28%), and lower-slopes dominated by pine (19%). Floodplains with mixed hardwood-pine forest had nearly as much damage (27%) as wetland baygall thickets (22%). No evidence of damage was detected within swamps dominated by cypress-tupelo forest. The uplands averaged the least amount of damage (8%). Most damage in the uplands occurred in the wetland pine savannah (12%), rather than areas with mesic upland pine (0%) or xeric sandhill pine stands (2%).

The LRU had the lowest percent area damaged of the 3 units, with 21%. Like the other units, most damage was concentrated in “wet” sites. The uplands (33%) showed the highest proportion of damage—all of which was represented by wetland pine savannah. Lower-slopes dominated by hardwood and pine represented the next highest amount damage (21%), followed by floodplains (15%). Most damage in the floodplains was found in wetland baygall thickets (25%), rather than those dominated mostly by hardwoods (7%). The flatlands in the LRU, where hardwood cover is dominant, had nearly as much damage (14%) as floodplains.

Predictive Factors of Impact Sites

Intensity indices of hog damage generally had higher values represented in more mesic and wet vegetation types. The average rooting index rarely exceeded type 2 or 3 level damage, but exceptionally high index values of 4 and 5 were occasionally found near major hydrological sources, seasonal floodplains and drainages, ephemeral ponds, or in areas with soft clay-like soil substrates. The average index values for intensity of damage ranked highest for the BSU (mean index value = 3), with LRU having low to moderate intensity (mean index value = 2.52), and TCU having low intensity (mean index value = 2.14). Damage type was not found to be a significant predictor of total area of damage in the BSU, or TCU, but was significant in the LRU ($Z = -2.84$, $P < 0.005$). The coefficient for damage type in the LRU was -0.5715, with an odds ratio of 0.56; the negative coefficient and odds ratio less than 1 indicate that lower levels of damage tend to be weakly associated with higher values of total area of impact.

As discussed earlier, hog damage was widespread throughout the various vegetation types, and varied by management unit. With the exception of wetland pine savannahs, higher incidence of low damage intensity was observed in uplands and slopes. However, disturbed patches within uplands and slopes represented wider intervals of damage (i.e., from 0–1,000 m^2). Vegetation type was found to be a significant predictive factor for damage, however, only in the TCU. The uplands in the TCU were significantly ($Z = 1.99$, $P < 0.05$), associated with lower areas of impact (coefficient = 2.878, odds ratio = 17.79).

In general, impact sites with a high intensity index value consisted mostly of localized damage with low areas of impact (i.e., 0–140 m^2), and were represented by lower index values (i.e., fresher damage) for age of disturbance for most of the BTNP. Areas recently impacted by hog damage—those having an age index value of 3 or less—rarely exceeded the damage interval of 141–350 m^2. Impact zones with higher age indices had higher damage interval values (351–1,000 m^2). This is likely explained by expansion of damage around the perimeter of previously disturbed areas resulting from the continued visitation of hogs to those impact sites. Despite these trends, logistic regression did not find age of impact to be a significant predictor of area of impact.

Sign type was a significant predictor of total damage in all 3 units. For the BSU, hog rooting ($Z = -2.27$, $P < 0.05$) was weakly associated with greater area of impact (coefficient = -1.5158, odds ratio = 0.22). Hog wallows in the BSU showed a trend towards a strong association with lower area of impact (coefficient = 2.211 , odds ratio = 9.12) but was not significant ($Z = 1.72$, $P = 0.085$). For the LRU, hog wallows were strongly associated (coefficient = 2.5994, odds ratio = 13.46) with lower area of impact ($Z = 3.58$, $P < 0.001$). Similar results for hog wallows were noted for the TCU ($Z = 2.17$, $P < 0.05$) with a strong association with lower amounts of damage (coefficient = 4.023, odds ratio = 55.85).

Basal area was not a statistically significant factor for predicting damage for the LRU, but was for the BSU and TCU. The BSU noted significance ($Z = -1.99$, $P < 0.05$) with lower BA associated greater area of impact (coefficient = -0.4440, odds ratio = 0.64). Similarly, the TCU noted significance ($Z = -2.38$, $P < 0.05$) for lower BA

associated with greater area of impact (coefficient = -0.9170, odds ratio = 0.40). For all 3 units, however, percent vegetative cover was an important factor in predicting amount of damage. For the TCU, only outside HOV was significant ($Z = -2.02$, $P < 0.05$), noting that lower percent cover was associated with more damage (coefficient = -0.3836, odds ratio = 0.68). In the BSU, inside HOV was significant instead ($Z = 2.09$, $P < 0.05$); higher percent cover was strongly associated with lower amounts of damage (coefficient = 0.4639, odds ratio = 1.59). For the LRU, both inside HOV ($Z = 2.60$, $P < 0.005$) and outside HOV ($Z = -4.14$, $P < 0.001$) were significant. The same general trend was supported for both cases: high percent cover inside the area of impact was associated with more less damage (coefficient = 0.7371, odds ratio = 2.09), and low percent cover outside the area of impact was associated with high levels of damage (coefficient = -0.6246, odds ratio = 0.54).

DISCUSSION

High proportions of hog damage were observed throughout the 3 units of the preserve and the damage was generally widespread rather than concentrated entirely within specific vegetation types. Those vegetation types categorized broadly as floodplains or flatlands have been documented to have the most hog damage in many NPS units (NPS 1985, NPS 2000), and similar results were observed in this study. Although feral hogs throughout the world tend to have strong associations with wet habitats (Hellgren 1993) or those with abundant and proximate water sources, seasonal flooding of such low elevation habitats, or a reduced abundance of specific food resources within those habitats, often elicit in hogs an evasive migratory response to

higher elevations (Belden 1972, NPS 1985). Differences in how hogs respond to these selective pressures may be different between the BSU, LRU, and TCU since flood regime dynamics, soil drainage, topography, and the abundance or type of resources upon which hogs may forage may differ significantly between units.

An example of this altitudinal shift in habitat use by hogs could be inferred from the results from the BSU where, although the highest proportion of damage was observed within the floodplains, the damage observed in the slopes was only about 10% lower than that in the floodplains. BSU had the highest proportion of damage within the slopes in comparison to slopes of other units. There may be several explanations for this observation—it may simply be related to a higher density of hogs within the BSU in proportion to its total area, because unique resources are found in BSU slopes that are not present in the other units, or because the soils in the BSU generally drain better than those of other units, thereby supporting a greater diversity or abundance of plant species upon which feral hogs may forage. The least damaged vegetation type in the BSU was the uplands—represented by the upland pine forest—which probably harbors a low resource value for hogs both in terms of available water resources and forage. Logistic regression results did not find upland vegetation types to be a significant predictor of lower amounts of damage, but most evidence points to a clear contrast between sites with lower topography (i.e., floodplains and slopes) and higher topography (i.e., uplands).

By contrast, the LRU had the highest concentration of damage within the uplands. The difference between the BSU and LRU being that wetland pine savannah

rather than upland pine forest was represented solely in the LRU. In this case, wetland pine savannah may support a higher quality of resources for hogs. Wetland pine savannah is characterized by having an herbaceous layer dominated extensively by wetland herbs (Marks and Harcombe and 1981), as opposed to upland grasses and legumes found in upland pine. Ephemeral water sources are also more likely to be found in wetland pine savannah, where soil drainage is slower than most soils of the BSU. These ephemeral water sources provide hogs both a source of drinking water and habitat that aids in thermoregulatory activities. But another explanation for high impact within the wetland pine savannah may also be related to its relative location within the LRU. Results from the survey show that little damage was observed in the wetland pine savannah that occurred in the northeast-most section of the LRU; a road bisects this habitat and moderate amounts of traffic occur there due to its relatively close location to the park boundary and surrounding human communities. This may have some impact on hog avoidance behavior, especially in seeking refuge from hunting pressures—whether from seasonal hunting or illegal poaching. By contrast, the wetland pine savannah habitat most impacted in the LRU was nestled close to the center of the unit, where surrounding escape cover provided by other vegetation subtypes is extensive, and where there are no roads that provide easy access to the general public. Overall, results from logistic regression supported the spatial results, which note that hog damage was evenly distributed between the 4 major vegetation types and that vegetation type alone did not serve as a strong predictor of amount of observed hog damage.

The proximity of roads or trails to habitat types also may be used to predict where hog impacts are likely to occur. Although hogs use trails, pipelines, and roads as travel corridors, as sources of water from drainage at road edges, or foraging sites on vegetation that spring near road edges, the decreased amount of escape cover and increased risk of contact with humans generally deters their use of these corridors. In the BSU, a trail which receives few visitors throughout the year had over 10% rooting damage on the trail itself. A greater number of impact sites in BTNP, however, are generally located further from rather than closer to trails. In the TCU, one of the most visited units for recreation purposes, an extensive network of hiking trails run throughout the unit, especially within the southernmost portion of the unit. Hogs may avoid confrontations with park visitors by selectively foraging in areas where least contact is likely to occur. The highest proportion of damage observed in the TCU was within the flatlands—much of which is located away from trails. But this damage also lay in close proximity to creeks, so proximity to a water source, better escape cover, or a better quality or greater abundance of resources near the creeks also may have influenced habitat use by hogs in these areas.

The wetland pine savannah within the TCU was not as severely affected as that found in the LRU. The small patch sizes of this habitat, along with its sparse distribution throughout the unit may limit access to and thereby the impact that hogs may cause in this habitat type. Like the BSU, wetland baygall thicket and floodplain hardwoods were moderately impacted in the TCU. The greatest proportions of damage were found, however, amongst the flatlands and slopes. In these cases, it is important to

consider flood regime dynamics and soil drainage as they relate to specific plant communities. In the TCU, high banks line several of the creeks that cross through the unit, but extensive flooding from run-off typical occurs more in floodplains than flatlands. Like the BSU, hogs may respond to seasonal flooding of these habitats by retreating to alternate food sources within the slopes of TCU. In some cases, like the proportion of damage observed specifically within the mid-slopes of oak-pine forest, the damage exceeded that observed in other vegetation subtypes. Mid-slopes in the TCU, located in transition zones between higher slopes and floodplains, hold more moisture than slopes but are protected from excessive seasonal inundations along the floodplains. These transition zones are buffered from extremes of moisture content in the soils and likely harbor higher abundances and greater diversities of plant species year-round. As observed in the upland pines of the BSU, though, it is vital to consider the abundance and the quality of the resources available in a habitat to better predict why hog impacts from rooting occur in greater proportions in certain areas more than others. The sandhill pine forest in the TCU provides low abundance and low quality of herbaceous cover upon which hogs may forage; this may explain why the lowest impacts were observed in this habitat. Results from logistic regression also support these generalizations made for vegetation types in the TCU—that amount of hog damage in uplands is predicted to be lower in comparison to floodplains, flatlands, and slopes.

In addition to the area of impact, it is important to consider intensity of damage from hog rooting or wallows. Most of the damage in the 3 units consisted of large areas of low intensity impact. Sites of high intensity damage were generally localized, near

fresh water sources, and of low area of impact. According to results from logistic regression, however, intensity of impact was found to be a significant predictor of hog damage only in the LRU. Much of this might be attributed to high intensities of impact found in the wetland pine savannah habitat type.

MANAGEMENT IMPLICATIONS

Surveys of feral hog damage to large management units, like those of BTNP, must first consider how aspects of feral hog biology (i.e., diet, behavior) affect the distribution of those areas they impact. Their spatial distribution and use of available habitat is affected by selective pressures that affect them seasonally. For example, hogs may avoid habitat where they are exposed to increased hunting pressure, so their impacts may shift to habitats they would not regularly use in the absence of those pressures. Avoidance behavior may explain why a greater proportion of damage was observed in wetland pine savannah in the center, rather than in the fragmented periphery of the LRU. But the focus cannot be placed solely on large-scale variables such as vegetation type to predict where hog damage is occurring. Taking note of microhabitat characteristics, such as percent cover, therefore, is important for understanding the distribution and shifts in the distribution of hog damage even within vegetation types.

Aspects of plant phenology may be a better temporal determinant of where hog disturbance is likely to occur (NPS 1985) than avoidance pressure from hunting. Hogs migrate to different habitats to make use of emerging seasonal forage. When resources within floodplains and wetlands (e.g., forbs, herbs) are not abundant, hardwoods in the slopes provide substantial mast, roots, tubers, seeds, and herbs upon which they may

feed. The type, abundance, and quality of vegetation resources that hogs use are dependent on physical characteristics of the landscapes. Gradients of landscape variables such as proximity to water sources, topography, soil type, and soil moisture impact the species composition (i.e., vegetation types) and distribution of plant communities (Marks and Harcombe 1981). The full range of these variables must be integrated in the survey design to understand hog impacts at a landscape scale. Important predictors of hog movement between floodplains and slopes in the BTNP may be driven by flood regime dynamics which, in turn, determine which areas are likely to be rooted. However, topography alone, as in the case of upland pine and wetland pine savannah, is not a good predictor of hog impact. Soil moisture and type impact species richness, diversity, and abundance of plants in the BTNP (Marks and Harcombe 1981). The quality and abundance of resources within and between vegetation types thus should be compared to better evaluate the distribution of hog impacts. Feral hogs also rely heavily on moist soils for thermoregulatory activities (i.e., wallowing); so, characteristics of soil rather than vegetation type may serve as better predictors of some types of damage over others.

From a management perspective, it is important to understand how badly areas are rooted and wallowed by feral hogs in terms of depth of ground disturbance. The deeper feral hogs root into the ground, the more likely the root hairs or rhizomes are exposed to the natural elements; this may lead to suspended growth, delayed recovery, or mortality of plants (Bratton 1975) from exposure or because of subsequent herbivory by hogs or other animals upon those exposed roots. In addition, flood debris and leaf litter

serve as protective cover for small vertebrates and invertebrates and also aid in the regeneration and succession of various plant species. Large scale feral hog uprooting of these protective layers, even at low to moderate intensities of impact, may adversely affect the native ecological processes of the ecosystem.

Evaluating impact damage was facilitated by integrating the use of indices in data collection. Indexing methods provide an efficient means of describing spatial characteristics of the species monitored (Engeman et al. 2000, Engeman 2005). When used in conjunction with GIS, impact zones associated with landscape features can be used to model and predict areas damaged by hogs. Zones with high densities of hog disturbance, large intervals of area damaged, or high severity index values can assist resource managers in identifying "feral hog hot-spots", or areas of management concern. This is important for assessing the risk that proximity of hog damage poses to the conservation of sensitive biotic, abiotic, and cultural resources. The methods presented from this survey provide an efficient and practical means to conduct large-scale impact assessments of hog damage to natural resources. Continued monitoring of impact zones over broad temporal scales is essential to accurately document the recovery response of vegetation and evaluate the efficacy of feral hog population reduction measures in reducing impacts to natural resources.

CHAPTER IV

SUMMARY AND CONCLUSIONS

SYNOPSIS

The purpose of this chapter is to highlight benefits and recommend some improvements to those methods employed in this study, review the research results, and discuss the management implications relevant to the BTNP. Based on the results of my study, the following is offered to the BTNP to aid in the planning process for meeting their conservation objectives. The chapter is divided into 2 parts: (1) a review of methods and applications for future research, and (2) final impact assessment. Recommendations are based on results discussed in previous chapters (Chapters II-III).

REVIEW OF METHODS

Hunter Survey Cards and Track-counts

The use of hunter-survey cards for collection of harvest data is a cost-effective and practical means of collecting information which can be used to draw inferences to the population trends of game species. The system employed by the BTNP encourages a high survey return rate by allowing renewal of a permit in the following season only if the survey card was returned from the previous season. The result is a large source of harvest data and diverse demographic database of participating hunters.

One drawback to the hunter-survey card system is that the BTNP depends largely on this database to draw inferences to population trends of their game species. Since bag limits are instituted for white-tailed deer, harvest-effort is not sensitive to positive changes in harvest numbers above bag limits. As discussed earlier, track-count transects

resolve this problem since it is not subject to artificial limits of hunting regulations. However, the bias of track-count transects lies in that tracks of certain species are more likely to be represented than others, and only comparisons of changes in population indices within a species and not between species can be drawn. Using multiple methods for estimating population trends allows cross-comparison of indices and is necessary to draw better conclusions. Alternative field methods for examining population trends of game species, along with continued used of track-counts and harvest-card surveys, should be considered for comparison (Connelly et al. 2005). Of these, mark-recapture techniques through the use of passive-triggered cameras would provide an effective means for long-terms studies (Roberts 2004). Although there is a costly initial investment in camera equipment to consider, the long-term benefits outweigh the costs especially when this will be used for analysis of sustainable game harvest quotas for the preserve's permanent recreational hunting program.

Vegetation Sampling

Feral hog damage was evaluated for 4 major vegetation classifications: floodplains, flatlands, slopes, and uplands. The research design, however, integrated most representative vegetation sub-types described by Marks and Harcombe (1981). Vegetation sub-types were merged into broadly defined categories because of insufficient sample size for evaluating impacts at smaller scales. Time, budget, and little field crew support were limiting factors in this study; the field surveys were mostly a one researcher effort. Future monitoring efforts by larger field crews can pursue analysis of impact damage at smaller scales using the same methods described for this large-scale

survey. A potential benefit for replicating these surveys as smaller scales would allow for analysis of how hog impact varies with respect to distance to water sources, trails, and park roads within the vegetation sub-types. Some trails in the park are visited or used for recreation at higher rates than others, so amount of impact is likely to vary with respect to hog avoidance behavior of heavily visited areas. With respect to distance to water, seasonal variation of moisture related to rainfall, flood dynamics, and temperature may impact availability of water sources for use by hogs. Characteristics of hydrology may vary within vegetation sub-types, and smaller-scale surveys would allow for more detailed analysis of vulnerable areas within those vegetation sub-types.

In addition to replicating surveys at smaller scales within vegetation sub-types, effort by BTNP management should be made to replicate surveys for hog damage at larger temporal scales. The hog impact survey in this study focused on a particular season (i.e., summer) within one year, and hog impacts to vegetation are known to vary by season (NPS 1993, Belden 1972). Hog impacts will also fluctuate depending on the total number and population dynamics of hogs. With more research, the impacts of hogs can be modeled as they relate to their population dynamics. This would provide BTNP management with a means of evaluating the efficacy of their measures for population reduction of hogs as they relate to reduction of impacts to park resources.

Indices of Hog Impact

Data collection of the large-scale survey in the field was facilitated by collecting and categorizing data into indices or intervals in the field. Indices provide an efficient means of data collection, but the shortcomings are reduction in fine-scale accuracy in

data analysis. One means to improve this in future surveys is to improve precision of measurements, such as depth of ground disturbance and area of impact. This is facilitated most when efforts are made to survey affected habitat at smaller scales.

When considering age of impact, these indices were generalized based on my personal observation of comparative rates of vegetative recovery within habitat impacted and not impacted by hogs, as well as information gathered from the literature review. Improving the frequency of surveys, and monitoring vegetative recovery within affected habitat in broad temporal scales would allow BTNP management to evaluate rates of vegetative recovery as they relate to hog impacts. Paired-plot comparisons between habitat with hog exclosures (i.e., pig-proof fencing) and habitat without exclosures would facilitate in research efforts for determining actual rates of vegetative recovery within habitat affected and unaffected by hog damage.

Spatial Analysis of Hog Impacts

Targeting mitigation of impact sites at large-scales can be complicated when budget, time, and limited personnel are limiting factors. Spatial analysis of predictive factors of hog impacts from this study aid in identifying problem areas at a landscape-scale, but mitigating for impacts eventually requires ground-truthing of those sites slated for management action. Results from transects surveyed in this study, however, provide BTNP management with a baseline inventory of areas that may need mitigation.

To facilitate identification of areas most affected by hog damage, an indexing system was developed in ArcView (Fig. 4.1). This system can be used to identify areas of management concern, or “feral hog hot-spots”, by either extent of damage or

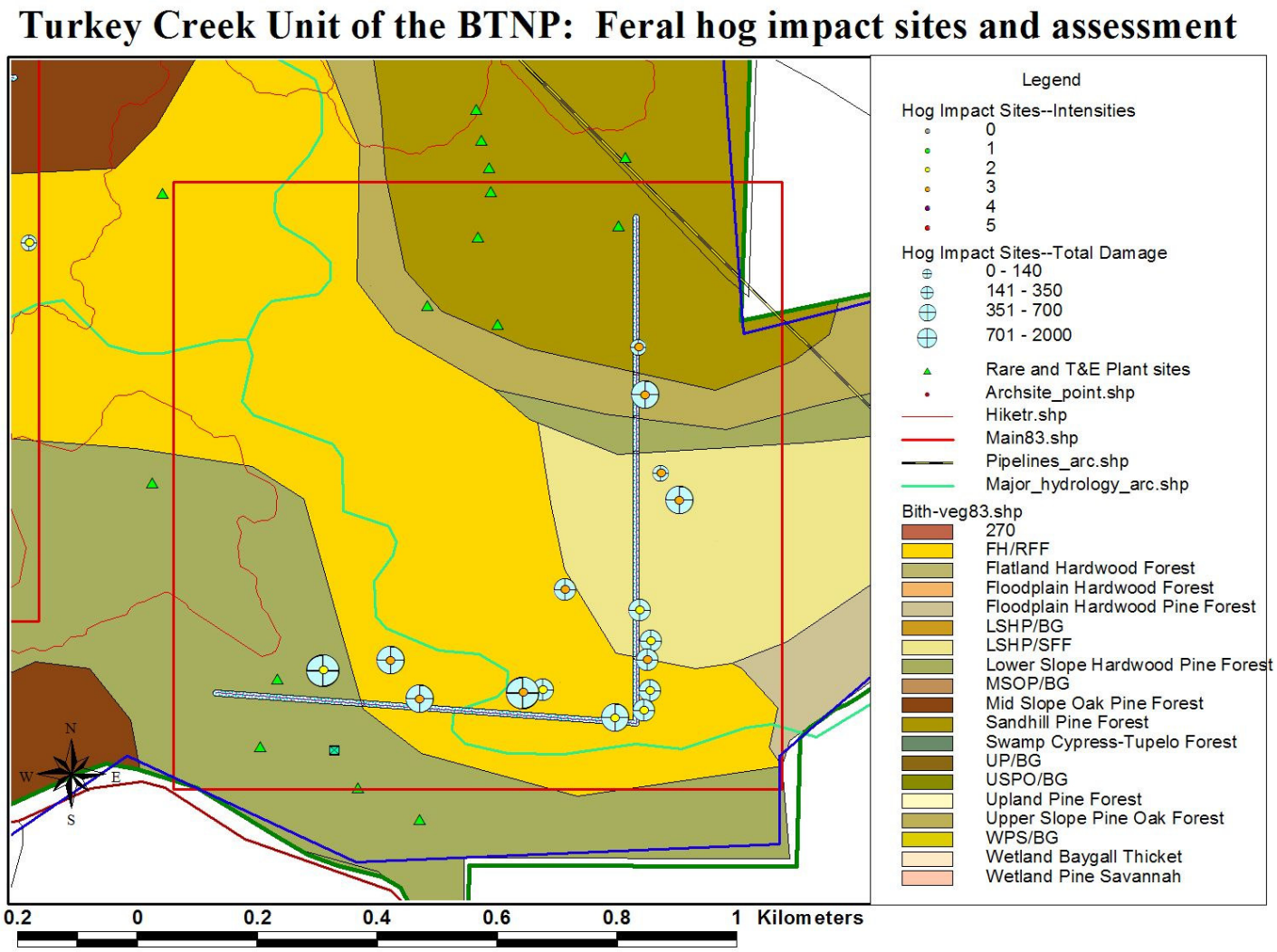

Figure 4.1. Hog impact survey results for a transect in the Turkey Creek unit of the Big Thicket National Preserve, Beaumont, Texas. Indices of total damage and damage intensity were used for impact assessment.

intensity of damage. Extent of damage is identified graphically according to the size of circles with crossbars, which represent the four "natural break" intervals of hog damage; the amount of damage increases as the crossbars get larger, so managers may concentrate mitigation efforts depending on total area (i.e., dimension) of impact. Managers may also refer to intensity of impact, as a premise for management action. Impact sites were indexed for intensity of impact based on 5 intervals of depth of ground disturbance. These intervals were color-coded to represent severity of damage: green = lowest intensity, yellow = low intensity, orange = moderate intensity, purple = high intensity, red = very high intensity. Integrating both indexes for decision making is facilitated from analysis of the ArcView map output. Sites with larger crossbars and hotter (e.g., red) colors, especially those in proximity to sensitive natural and cultural resources, likely warrant more mitigation effort.

FINAL IMPACT ASSESSMENT

Regardless of population numbers of feral hogs, visible damage to park resources is more of a concern than merely preserving the aesthetics of the park, but also an issue of preserving the ecological integrity of the natural systems within those protected boundaries (NPS 1996, NPS 2001, NPS 2003). Feral hog impacts in the BTNP have gone largely undocumented, especially at a landscape scale, making it difficult for resource managers to validate the full extent of the problem for estimating costs to mitigate those impacts. Results from this study, however, note that (1) feral hog numbers have dramatically increased in the BTNP, and (2) feral hogs are responsible for about 28% of damage to natural resources in 3 of its larger management units. Though

the preserve's recreational hunting program serves as a means of population reduction of feral hogs, trends suggest that this alone is not effective for reducing the population growth rate, and thereby the associated impacts of feral hogs.

The enabling legislation of the BTNP currently does not permit other means of controlling feral hog numbers other than through its recreational hunting program (NPS 1980, NPS 1996, NPS 2001). Based on results from this study, I conclude that a more aggressive program is needed for population reduction of feral hogs. Further research into the population dynamics of hogs and continuous monitoring of vegetation recovery is necessary to determine the success of any proposed management actions for controlling feral hog numbers and their associated impacts to resources in the BTNP.

LITERATURE CITED

Avery, T. E., and H. E. Burkhart. 1994. Forest Measurements. 4th edition. McGraw-Hill, Inc. New York, New York, USA.

Beach, R. 1993. Depredation problems involving feral hogs. *In* C.W. Hanselka and J.F. Cadenhead, editors. Feral swine: a compendium for resource managers. Proceedings of a conference, Texas Agricultural Extension Service, Texas Animal Damage Control Service, Texas Parks and Wildlife Department, USDA-APHIS, USA. < http://texnat.tamu.edu/symposia/feral/> accessed 7 October 2006.

Belden, R. C. 1972. Rooting and wallowing activities of the European wild hog (*Sus scrofa*) in the mountains of east Tennessee. M.S. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Bratton, S. P. 1975. The effects of the European wild boar, *Sus scrofa,* on Gray Beech forest in the Great Smoky Mountains. Ecology 56:1356–1366

Caughley, G., and A. R. E. Sinclair. 1994. Wildlife ecology and management. Blackwell Science, Malden, Massachusetts, USA.

Chavarria, P. M., R. R. Lopez, G. Bowser, and N. J. Silvy. 2006. An assessment of white-tailed deer *(Odocoileus virginianus)* and feral hog *(Sus scrofa)* populations at Big Thicket National Preserve, Texas. Pages 67–70 *in* D. Harmon, editor. People, Places, and Parks: Proceedings of the 2005 George Wright Society Conference on Parks, Protected Areas, and Cultural Sites: The George Wright Society. Hancock, Michigan, USA.

_____. 2006. A landscape-level survey of feral hog impacts to natural resources of the Big Thicket National Preserve. Human-Wildlife Conflicts (submitted)

_____, A. M. Munoz, and R. R. Lopez. 2004. Assessment of hunting management plan for the Big Thicket National Preserve. Report submitted to Big Thicket National Preserve. Contract Number: J7148030001, H50000020271 mod 006. TAES Account: 06-502876-8894-FB. Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas, USA.

Coblentz, B. E., and D. W. Baber. 1987. Biology and control of feral pigs on Isla Santiago, Galapagos, Ecuador. Journal of Applied Ecology 24:403–418.

Connelly, J. W., J. H. Gammonley, and J. M. Peek. 2005. Harvest management. Pages 55–59 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. The Wildlife Society, Bethesda, Maryland, USA.

Corn, J. L., P. K. Swiderek, B. O. Blackburn, G. A. Erickson, A. B. Thiermann, and V. F. Nettles. 1986. Survey of selected diseases in wild swine in Texas. Journal of American Veterinary Medical Association 189:1029–1032.

Courchamp, F., J. L. Chapuis, and M. Pascal. 2003. Mammal invaders on islands: impact, control and control impact. Biological Reviews 78:347–383.

Engeman, R. M. 2005. Indexing principles and a widely applicable paradigm for indexing animal populations. Wildlife Research 32:203–210.

_____, B. Constantine, M. Nelson, J. Woolard, and J. Bourassa. 2001. Monitoring changes in feral swine abundance and spatial distribution. Environmental Conservation 28:235–240.

_____, and G. W. Witmer. 2000. IPM strategies: indexing difficult to monitor populations of pest species. Vertebrate Pest Conference 19:183–189.

Environmental Systems Research Institute (ESRI). 2000. Arcview 3.2A GIS software. Redlands, California, USA.

Fagre, D. B., D. J. Schmidly, N. J. Silvy, J. W. Dragoo, D. L. Rakestraw, and R. J. Stapper. 1989. Assessment of population status and management of big game, selected small game, and furbearing animals on five National Park Service areas. Draft Final Report, Contract #: CA7029-6-0002. Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas, USA.

Garton, E.O., J. T. Ratti, and J. H. Giudice. 2005. Research and Experimental Design. Pages 55–59 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. The Wildlife Society, Bethesda, Maryland, USA.

Hellgren, E. C. 1993. Biology of feral hogs. *In* C.W. Hanselka and J.F. Cadenhead, editors. Feral swine: a compendium for resource managers. Proceedings of a conference, Texas Agricultural Extension Service, Texas Animal Damage Control Service, Texas Parks and Wildlife Department, USDA-APHIS, USA. < http://texnat.tamu.edu/symposia/feral/> accessed 7 October 2006.

Higgins, K. F., K. J. Jenkins, G. K. Clambey, D. W. Uresk, D. E. Naugle, J. E. Norland, and W. T. Barker. 2005. Vegetation sampling and measurement. Pages 528–541 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. The Wildlife Society, Bethesda, Maryland, USA.

Ickes, K., S. Dewalt, and S. Appanah. 2001. Effects of native pigs (*Sus scrofa*) on woody understory vegetation in a Malaysian lowland rain forest. Journal of Tropical Ecology 17:191–206.

Krebs, C. J. 1999. Ecological methodology. Second edition. Harper and Row, New York, New York, USA.

Mapston, M. E. 2004. Feral hogs in Texas. Texas Cooperative Extension, Wildlife Services, Texas A&M University, College Station, Texas, USA.

Marks, P. L. and P. A. Harcombe. 1981. Forest vegetation of the Big Thicket, Southeast Texas. Ecological Monographs 51:287–305

Mayer, J. J., E. A. Nelson, and L. D. Wike. 2000. Selective depredation of planted hardwood seedlings by wild pigs in a wetland restoration area. Ecological Engineering 15:S79–S85

Miller, J. E. 1993. A national perspective on feral swine. *In* C.W. Hanselka and J.F. Cadenhead, editors. Feral swine: a compendium for resource managers. Proceedings of a conference, Texas Agricultural Extension Service, Texas Animal Damage Control Service, Texas Parks and Wildlife Department, USDA-APHIS, USA. < http://texnat.tamu.edu/symposia/feral/> accessed 7 October 2006.

MINITAB Inc. 1998. MINITAB 12.2. State College, Pennsylvania, USA.

National Park Service (NPS). 2006. National Park Service units in Texas. <http://home.nps.gov/applications/parksearch/state.cfm?st=tx> accessed 7 October 2006.

_____. 2003. Pinnacles National Monument: feral pig eradication plan environmental assessment. Paicines, California, USA.

_____. 2001. Big Thicket National Preserve: feral hog management plan. Beaumont, Texas, USA.

_____. 2000. Congaree Swamp National Park: feral hog impact monitoring, management plan development, and initial management for COSW. NRPP Study Plan. Columbia, South Carolina, USA.

_____. 1996. Resources management plan for Big Thicket National Preserve. Beaumont, Texas, USA.

_____. 1985. European wild hogs in Great Smoky Mountains National Park, Gatlinburg, Tennessee, USA.

_____. 1980. Big Thicket National Preserve: general management plan. Beaumont, Texas, USA.

Pimentel, D., S. McNair, J. Janecka, J. Wightman, C. Simmonds, C. O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino, and T. Tsomondo. 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems & Environment 84:1–20.

Roberts, C. W. 2004. Estimating density of Florida Key deer. M.S. Thesis. Texas A&M University, College Station, Texas, USA.

Singer, F. J. 1981. Wild pig populations in National Parks. Environmental Management 5:263–270.

SPSS, Inc. 2003. SPSS Base 12.0.1. SPSS, Inc., Chicago, Illinois, USA.

Strauss, S.Y, C. O. Webb and N. Salamin. 2006. Exotic taxa less related to native species are more invasive. Proceedings of the National Academy of Sciences 103(15):5841–5845.

Synatzske, D. R. 1979. Status of the feral hog in Texas. Unpublished report., Texas Parks and Wildlife Department. Austin, Texas, USA.

Taylor, R. B. 1993. History and distribution of feral hogs in Texas. *In* C.W. Hanselka and J.F. Cadenhead, editors. Feral swine: a compendium for resource managers. Proceedings of a conference, Texas Agricultural Extension Service, Texas Animal Damage Control Service, Texas Parks and Wildlife Department, USDA-APHIS, USA. < http://texnat.tamu.edu/symposia/feral/> accessed 7 October 2006.

Texas Department of Agriculture. 2006. Press release, 24 January 2006. <http://www .agr.state.tx.us/media/press_releases/0106/com_012406.htm> accessed 15 March 2006.

United States Department of Homeland Security. 2006. Daily Open Source Infrastructure report. 9 January 2006. <http://www.globalsecurity.org/security/ library/news/2006/01/dhs_daily_report_2006-01-09.pdf > accessed 24 May 2006.

United States Animal Health Association. 2005. Report of the Subcommittee on Pseudorabies: Implications of feral swine expansion: expansion of feral swine in the United States and potential implications for domestic swine. <http://www. usaha.org/committees/reports/2005/report-prv-2005.pdf> accessed 24 May 2006.

Waithman, J. D., R. A. Sweitzer, D. Van Vuren, J. D. Drew, A. J. Brinkhaus, I. A. Gardner, and W. M. Boyce. 1999. Range expansion, population sizes, and management of wild pigs in California. Journal of Wildlife Management 63:298–308

APPENDIX

Permit No.
DP-02/03-127

Big Thicket National Preserve
2002-2003 Hunter's Report

Copy

(PLEASE TYPE OR PRINT CLEARLY)

Number of trips to the Preserve this season: _____

Number of animals taken: Deer (Buck) ____ Deer (Doe) ____ Squirrel ____ Rabbits ____ Hogs ____
Waterfowl ____ Deer Sighted ____ Wildlife Sightings (Species)_____

Failure to fully complete and return this report by March 3, 2003, will disqualify you from receiving a permit next year. There will be no grace period allowed for the return of this card

Name _____ _____ _____
(First) (Middle) (Last)

Address _____

City, State, Zip _____

Texas ID/Driver's License Number _____

Date of Birth _____ Phone _____

Comment: _____

For information or assistance call (409)839-2689

Example of hunter survey card used to collect harvest data from the recreational hunting program at the Big Thicket National Preserve, Beaumont, Texas.

Track Count Data Sheet

Location: _____ Date: _____ Time: _____

Route: _____

Observers: _____

Cloud Cover: _____ % Temperature: _____

Precipitation: (1) current (2) past 24 hrs Humidity: _____ %

(3) 2-3 days (4) last week Wind Speed/Vector: _____

	Easting	Northing
Transect Start		
Transect End		

Bed Condition: _____

Prepared Date: _____ Time: _____

Read Date: _____ Time:

DISTANCE

SPECIES	0 to 0.25 k	0.25 to 0.5 k	0.5 to 0.75 k	0.76 to 1.0 k	Live Sightings
Deer					
Feral Hog					
Dog-like Canid					
Fox-like Canid					
Raccoon					
Opossum					
Armadillo					
Spotted Skunk					
Striped Skunk					
Hognosed Skunk					
Bobcat					
Mountain Lion					
Ringtail					
Rabbit					
Rodent (Mice)					
Rodent (Rat)					
Bird (Sparrow)					
Bird (Roadrunner)					
Bird (Waterfowl)					
Bird (Raptor)					
Human					

Comments: _____

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Example of datasheet used for track-count transects.

Feral Hog Survey Datasheet
Big Thicket NP

Location: _____ Date: _____ Start time: _____ End time: _____

Route: _____

Observers: _____

Cloud Cover: _____ % Temperature: _____

Precipitation: (1) current (2) past 24 hrs Humidity: _____ %

(3) 2-3 days (4) last week (5) none Wind Speed/Vector: _____

Transects	Easting	Northing
Start		
End		

Survey Location Comments: _____

Measurable Disturbance

Vegetation Density (Prism) Horizontal OV (%)/height.

	Easting	Northing	Sign Type	Sign Age	Damage Type	Length	Width	Basal Area	Inside Zone	Outside Zone
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										

Sign Type Legend: 1=Live hog, 2=Tracks, 3=Wallows, 4=Rooting, 5=Dead hog

Damage Type Legend: 1= 0.25 to 1.0 inch, 2= 1.0 < x < 4.0 in., 3= 4.0 < x < 8.0 in, 4= 8.0 < x < 12.0 in., 5= x > 12.0 in.

Sign Age Legend: 1= Fresh, 2= Recent (1-7 days), 3= Month old, 4= older than 1 month, 5= year old

Example of datasheet used for survey of feral hog impacts to the natural resources of the Big Thicket National Preserve, Beaumont, Texas.

VITA

Pedro Mazier Chavarria

BACKGROUND

Parents: Rosario Guadalupe Mazier and Pedro Edgardo Chavarria

Permanent Address: 2118 W. Scott Ave., Los Angeles, CA 90026

Birthplace: Santa Ana, El Salvador, Central America

EDUCATION

Master of Science, Wildlife and Fisheries Sciences, Texas A&M University, 2006.

Bachelor of Arts, Biology, Pomona College (Claremont Colleges), 1999.

WORK EXPERIENCE

Wildlife Biologist (SCEP), Big Thicket National Preserve, National Park Service, Beaumont,Texas. 2004–2006.

Biological Science Technician, Channel Islands National Park, National Park Service, Ventura, California. 2002–2004.

Biological Science Technician, Joshua Tree National Park, National Park Service, Twenty-nine Palms, California. 2000–2002.

Research Assistant (REU), Department of Biology, Pomona College (Claremont Colleges), Claremont, CA. 1995-1998.