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Mammalian herbivory of hardwood seedlings on afforestation areas of the lower Mississippi Alluvial Valley

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MAMMALIAN HERBIVORY OF HARDWOOD SEEDLINGS ON AFFORESTATION AREAS OF THE LOWER MISSISSIPPI ALLUVIAL VALLEY

By

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The Mississippi Alluvial Valley (MAV) has undergone losses of bottomland hardwood forests due to agricultural conversion. Hardwood establishment on marginal croplands has been proposed to mitigate effects of deforestation and related loss of carbon-capture potential. However, a possible concern with reforestation is low seedling survival from mammalian herbivory. I surveyed two afforested fields in the MAV of northwest Mississippi to assess damage and mortality from four herbivores on nine species of hardwood seedlings (*n* = 868). Percentage survival of seedlings was 35%. Mortality of seedlings caused by herbivores was: hispid cotton rat (*Sigmodon hispidus;* 6.45%), rabbit ((*Sylvilagus spp.;* 1.95%), pine vole (*Microtus pinetorum;* 2.99%), and white-tailed deer (*Odocoileus virginiana; 0*.69%). Of surviving seedlings (n = 316), 10.82% were damaged by cotton rats, pine vole (2.99%), rabbit (8.06%), and deer (7.02%). Green ash (*Fraxinus pennsylvanica*), water oak (*Quercus nigra*), and Nuttall oak (*Quercus nuttallii*) had greatest survival.

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CHAPTER I

INTRODUCTION

Bottomland hardwood forests once dominated the Lower Mississippi Alluvial Valley (LMAV; Dickson 2001). This ecosystem supports a diverse array of floral and faunal species. Thirty-four species of concern rely on bottomland hardwood ecosystems (Dickson 2001). These species are listed due to rarity, restricted distribution, unknown, or decreasing population trends (Mississippi Museum of Natural Science 2005). To date, over 80% of the LMAV's bottomland hardwoods have been lost to agriculture, pine plantation forestry, and urban development (Dickson 2001). Restoration of bottomland hardwood forests have been proposed for recovery of rare fauna and flora, enhancement of habitat for wintering waterfowl, and increased potential for sequestration of atmospheric carbon dioxide (Owens et al. 1999). Carbon sequestration by hardwood forests is especially important due to the growing concern about possible negative consequences of global climate change from increases in atmospheric carbon dioxide and decreases in soil carbon storage caused by deforestation and land use changes (Cooper 1983). Afforestation of fallow fields and marginal crop land are approaches proposed to reduce accumulation of atmospheric carbon (Owens et al 1999). Afforestation is the establishment of forests through planting of trees in areas that have not supported forests for decades.

One concern with afforestation efforts is mammalian herbivory damage and resulting mortality of hardwood seedlings (Stanturf et al. 2001). Deer, rodents, and rabbits may damage trees through persistent herbivory, but information is sparse on damage to seedlings from herbivory on afforestation sites of the southeastern United States. Few studies have assessed survival of trees planted for carbon sequestration in the LMAV, and most private organizations only monitor small plots within planted areas once every five years (James 2001). Monitoring standards, in most cases, do not exist (James 2001). Wildlife management areas (WMA) and national wildlife refuges evaluate survival with non-standardized sampling procedures (James 2001). Typically, these methods do not provide reliable information on cause of mortality or survival rates. Identifying which tree species are not damaged or killed by mammalian herbivores may benefit future afforestation efforts by providing prescriptions that yield greater seedling survival, economic returns, and afforestation successes. Therefore, the objectives of this research were as to:

- report incidence of mammalian herbivory damage on seedlings of nine tree species on two afforestation sites in the LMAV,
- report seedling mortality of tree species and identify mammal species causing damage,
- investigate potential influences of vegetation cover during spring and summer on number of seedlings damaged and/or killed by herbivores.
- determine relationship between seedling survival and various treatments of site preparation, and
- determine hispid cotton rat abundance and habitat associations on study sites.

Literature Review

Mammalian herbivory damage and resulting mortality of hardwood seedlings has been reported by Stanturf et al. (2001). Deer (Family Cervidae), rodents (Order Rodentia), and rabbits (*Sylvilagus* spp.) may damage or kill trees through persistent herbivory; however, feeding activities by various species of herbivores may cause various impacts to hardwood seedlings depending on age and size of seedling, location of feeding on the seedling, and frequency of foraging by the herbivore (Gill 1992, Stanturf et al. 2001).

In eastern North America, herbivory by white-tailed deer (*Odocoileus virginianus*) can impact regeneration of trees and influence tree species composition of forested communities (Holladay et al. 2006). White-tailed deer can damage seedlings and saplings by fraying and browsing. Fraying damage is the removal of bark by the deer rubbing it's antlers against the stem during scent marking or velvet removal. This activity can cause damage to planted and naturally colonizing trees (Schloeth 1968). For example, Gill (1992) reported that roe deer (*Capreolus capreolus*), a native to Europe and Asia Minor, have been known to cause fraying damage to every tree in widely spaced broadleaf stands. The term 'browsing' in the context of forest damage refers to all forms of feeding damage other than bark stripping (Gill 1992). Deer are selective foragers and some studies report that only the current year's growth is removed and browsed shoots are unlikely to be re-browsed until new growth has formed (Holloway 1967, Severinghaus and Severinghaus 1982). Most browsing by deer occurs at an intermediate level between ground and full reach of the animal. This foraging pattern usually results in smaller size and larger size trees being relatively unimpacted by browsing (Holloway 1967, Loyttyniemi and Piisila 1983).

The rabbit (*Sylvilagus* spp.) is considered a habitat generalist with an extensive geographic range that covers the eastern two-thirds of the United States (Conway et al.1974, Hanson et al. 1969, Lord 1963). Rabbits and hares can damage trees by either browsing or stripping bark (Gill 1992). During summer, rabbit damage to woody plants is minimal because of the abundance of preferred grasses, legumes, and forbs. During winter, however, rabbits can cause severe damage to tree seedlings by pruning, barking, and girdling stems and shoots. This herbivory often increases seedling mortality (Geis 1954, Meiners and Martinkovic 2001). Because rabbits damage seedlings in several ways, they can be a significant hindrance to establishment of tree seedlings (Margaret et al. 2001).

The pine vole (*Microtus pinetorum*) is one of the primary herbivores in old field habitats (Cadenasso and Pickett 2000). Vole damage to tree seedlings usually occurs during the dormant season of fall and early spring when green vegetation is sparse. Herbivory by voles can inhibit the establishment of tree seedlings, especially when vole populations are relatively dense (Pusenius and Ostfield 2000, Sharew and Kays 2006). Vole damage is usually patchy and will show annual variation (Radvanyi 1980, Bang and Dahlstrom 1982, Nakatsu 1987). Reports from Scandinavia have shown that up to 20,000 ha of seedlings can be damaged in one year from vole foraging (Hansson and Zejda 1977, Teivainen 1984).

Hispid cotton rats (*Sigmodon hispidus*) are generalist herbivores that feed primarily on grasses but will include dicotelydons in their diet (Goertz 1965, Fleharty and Olson 1969, Kincaid and Cameron 1982). Hispid cotton rats feed on seedlings by snipping them off at the base and cutting them into small sections causing seedling mortality (Elbroch 2003). To date, little information is available concerning herbivory of oak seedlings by hispid cotton rats.

Land use practices over the last several centuries have produced a highly fragmented landscape within the LMAV, which is dominated by forest-old field edges (Dickson 2001). Previous studies suggest that small mammals are sensitive to changes in the structural complexity of vegetation and interspersion of different plant growth forms because these factors can alter risk of predation (M'Closkey and Fieldwick 1975, Alder 1985, Lima and Dill 1990). Furthermore, populations of some herbivores, such as white-tailed deer have increased due, in part, to habitat modifications associated with changing land uses (Russel et al. 2001). Identifying habitat parameters that are important in influencing the distribution of various mammal species could provide management guidelines for altering habitat to reduce herbivore occurrence (Levin 1992, Murcia 1995, Lidicker 1995). Manson et al. (1999) found that capture probabilities of voles were greatest in grass and forb-dominated microhabitats and in old field zones most distant from edges. Potential exists for detection of similar relationships between rodent herbivores, such as cotton rats, and vegetation structure in afforested fields.

CHAPTER II

STUDY AREA AND METHODS

Study Area

Study sites were located in Washington and Bolivar Counties in Mississippi on lands owned by Entergy Power Company. Each site was planted with 7,848 hardwood seedlings of nine species during winter, 2006. Species included common persimmon (*Diospyros virginiana*), green ash (*Fraxinus pennsylvanica*), eastern cottonwood (*Populus deltoides*), red mulberry (*Morus rubra*), American sycamore (*Platanus occidentalis*), Nuttall oak (*Quercus nuttallii*), willow oak (*Quercus phellos*), water oak (*Quercus nigra*), and sawtooth oak (*Quercus acutissima*). Prior to planting, these sites were abandoned cropland used for livestock grazing and hay production.

The Washington County site (33º 20’ 58” N, 91º 7’ 40” W) was located near Greenville, MS and was divided into three planting parcels (Fig 2.1.). Dominant vegetation of these parcels was Johnsongrass (*Sorghum halepense*) and common broomsedge (*Andropogon virginicus*). Cover type of adjacent land was hardwood forest <30 years old (Sumerall 2007). Dominant soils were sandy loams (Vanderford 1962).

The Bolivar County site (33º 47’ 49” N, 90º 42’ 59” W) was located in Cleveland, MS and is divided into nine planting parcels (Fig 2.2.). Dominant vegetation of these parcels was tall fescue (*Festuca arundinacea*) and Brazil vervain (*Verbena brasiliensis*;

Sumerall 2007). Adjacent land was composed of urban development and cropland. The dominant soil was Sharkey clay (Vanderford 1962).

Methods

Project Overview

This study was one of four projects designed to evaluate several aspects of hardwood afforestation including effects of mammalian herbivory on hardwood seedlings, financial analysis of long-term benefits of timber production, available wildlife habitat provided during successional stages, and amount of carbon sequestered over time (Sumerall 2007). This experiment was designed as a 6 x 2 x 2 completely randomized factorial design using six tree species mixes, two fertilizer treatments (fertilized vs. non-fertilized), and two vegetative competition treatments (chemical control vs. no chemical control; Sumerall 2007). Each combination of the factorial design will be referred to as afforestation regimes. Three replications of each afforestation regime were placed at two sites, resulting in 7.28 ha at the Greenville and Cleveland sites. Seedlings were planted using 3.05 m x 3.05 m spacing, which is similar to spacing prescribed for other afforestation efforts in the LMAV. This resulted in 109 seedlings per 0.101 ha plots and about 327 seedlings per regime at each site. Bareroot seedlings of all species were planted with a planting shovel, except for eastern cottonwood, 1-0 (1 year in nursery, 0 years as a nursery outplant). Eastern cottonwood seedlings were 30.5-40.6 cm cuttings inserted directly into the ground and pushed down to proper planting depth (Sumerall 2007). Planting at each site was conducted by contracted planting crews whose work was overseen by Richard Maiers and Janet Dewey of Mississippi State University (Sumerall 2007).

Analysis

I tested the following hypotheses at a significance level of $\alpha = 0.05$.

Mortality of seedling among treatments

$H_{0:}$ Mortality of seedlings was similar among treatment types.

H_1:Mortality of seedlings was not similar among treatment types.

Test: Chi Square Test (Conover 1980).

Mortality of Planted Seedlings in Relation to Herbivory.

H_0: Mortality associated with herbivory was similar among tree species.

H_1: Mortality associated with herbivory was not similar among tree species.

Test: Manley's Alpha Preference Index (Heisey 1985), Kolmogorov-Smirnov (K-S) Test (STATISTIX 2000).

Relationship Between Seedling Survival/Mortality and Environmental Factors.

H_0: Survival or mortality of each individual tree of each species that were killed and/or damaged by herbivores was not influenced by native vegetation or non-native vegetation coverage.

H_1: Survival or mortality of each individual tree of each species that were killed and/or damaged by herbivores was influenced by native vegetation or non-native vegetation coverage.

Test: Logistic Regression (Kutner et al. 2004).

The dependent response variable, tree survival (living or dead), was the binary response.

Relationship of Cotton Rats With Vegetation Microsite Characteristics.

H_0: Cotton rat density was not influenced by vegetation and microsite characteristics.

H_1: Cotton rat density was influenced by vegetation and microsite characteristics.

Test: K-S Test (STATISTIX 2000).

I compared my observed distribution of cotton rats based on trap data to a random distribution to determine if vegetation height or distance from field age affected cotton rat distribution.

Treatment Effects on Seedling Survival

I tested 4 treatments were regarding planted seedlings. These treatments included control (no fertilizer or herbicide application), slow-release fertilization, chemical competition control (herbicide), and a fertilizer and herbicide combined treatment. Half of seedlings received fertilization by ground application of slow release tablets shortly after planting (Sumerall 2007). The chemical composition of the fertilizer was 15:10:20 (Nitrogen: Phosphorous: Potassium) and was chosen based on soil samples. Additionally, half of seedlings received chemical competition control in the form of Goal® 2XL at a rate of 1.91 / 0.4 sprayed ha with the surfactant Latron® AG98 included at a rate of

0.25% volume/volume. Initial herbicide application occurred in May 2006 (post-emergent), and herbicide plots received a second application of the same treatment in August 2006. Herbicide application rates and timing were selected after consultation with a silvicultural and herbicide specialist. Thus, 25% of seedlings from each species mix received one of the following: fertilizer only, herbicide only, fertilizer and herbicide, and no fertilizer or herbicide (control) (Sumerall 2007). A chi-squared test of homogeneity was used to test for differences in mortality rates of all seedling species combined among treatments with study sites as replicates (Conover 1980). I could not determine differences in mortality rates among treatments by tree species, because sample sizes were too small (< 10).

Evaluation of Herbivory

I randomly selected seedlings (n = 434) from each study site to monitor herbivory. Randomly selected seedlings were a sub-sample of seedlings previously selected for the parent project. All tree selections were performed using Microsoft Excel random selection feature. Six tree species were planted in mixtures on both sites. Each species mixture had four treatment options applied randomly (Table 2.1.). Fifteen seedlings from each treatment option in each planting mixture comprised my sub-sample. I marked each tree with a PVC pipe and a pin flag. Pin flags were tagged with plot letter and tree number. I measured tree height and identified each seedling to species following methods of Sumerall (2007). Trees were inspected for survival and herbivory damage during 2006 and 2007. Herbivory damage by mammalian species was monitored during

May, August, and September of 2006 and 2007. Mammalian species responsible for damage were determined according to methods described by Elbroch (2003).

I used the Kolmogorov-Smirnov test to determine if mammalian herbivores were foraging on tree seedlings at random (STATISTIX 2000). Because the Cleveland study site was encompassed by a high-fence that excluded deer as a possible herbivore, they were not included in herbivore analyses for that site. I analyzed feeding patterns by season and over the entire study. For each analysis, I constructed an expected distribution pattern of seedling selection if herbivores were foraging on seedling species at random and compared my observed seedling selection to the random pattern. All foraging signs on seedlings were included as herbivore damage whether the herbivory resulted in seedling mortality or the seedling survived. When number of damaged seedlings was large enough (>10 seedlings damaged), I analyzed data on feeding patterns for mammalian herbivores by tree species. If it was determined by the Kolmogorov-Smirnov test that foraging patterns were not random, I used Manly's alpha selectivity index to investigate which seedling species were selected more often by mammalian herbivores (Heisey 1985).

Vegetation Sampling

I conducted vegetation measurements surrounding planted seedlings during May and August of 2006 and 2007. Vegetation plots were 1-m^2 hoops centered on seedlings. Percent coverage of herbaceous vegetation and of woody vegetation within circular plots was recorded along with stem counts of woody vegetation according to methods described by Hayes et al. (1981). Distance of each seedling to nearest field edge was also measured and recorded using laser range finders. Field edge was described as the point where area planted to trees met the unplanted areas; typically unplanted areas on these study sites were hardwood forests. I used logistic regression to model effects of dominant species and forms of vegetation on mortality and damage of tree seedlings by season (Kutner et al. 2004, SAS Institute Inc. 2004). These models were generated for testing relationships between coverage of native and non-native vegetation and potential for seedlings to be killed or damaged by herbivores. Initially, regression models were generated for seedlings that exhibited mortality from feeding herbivores. Next, models were generated for all seedlings that died from herbivory and those that exhibited signs of herbivory but did not die. Separate analyses were conducted for each study site location due to the potential influence of fencing on white-tailed deer at the Cleveland site. Vegetation sampling plots centered on seedlings were used as experimental units. Number of trees, and therefore sample size, varied by season depending on number of seedlings found. I used the stepwise selection procedure to enter explanatory variables into models (SAS Institute Inc. 2004). In one set of analyses, I used dominant species (common broomsedge, Bermudagrass, tall fescue, Johnsongrass, Brazil vervain, narrowleaf vetch) of vegetation as independent explanatory variables, and in a separate set of analyses, I used vegetation form (bare ground, forb, grass, legume, sedge, vine, woody) as explanatory variables. In both analyses, percentage of bare ground was used as an explanatory variable when no vegetation was present. Not all independent explanatory variables were used in each analysis, because some species of vegetation were not always present due to seasonal differences in plant growth and senescence (Table 2.2). Collinearity among independent variables was assessed for each analysis with Pearson's correlation coefficient (STATISTIX 2000). Variables were removed if coefficients were ≥0.70. The statistical tests used in my analyses did not require the assumption of normal distribution for independent variables (Morrison 2005), therefore, no tests of data normality or data transformations were required.

Population Characteristics of Cotton Rats

To determine abundance of hispid cotton rats by mark-recapture methodology, I placed Sherman live traps (25.5 cm x 7.5 cm) in grids with 10-m spacing between traps (n = 238) in parcels 1, 2, and 3 at Greenville and in parcels 6, 8, and 9 at Cleveland (Figure 3). Trapping was conducted on both sites during March, November, and December in 2006. Trapping was conducted on both sites during November, December, January, February, and March in 2007 (Table 2.3.). Warm months were avoided due to fire ant activity. Traps were set for a period of four nights each month. Each trap was baited with a peanut butter-oat mixture (Goertz 1964). Traps were checked daily and re-baited after each capture. Cotton rats were removed, weighed, sexed, and marked with a single, 2-mm hole through the right ear. Recaptures were recorded and not marked a second time. Recorded data included species, age class, gender, weight, and capture status. Capture status was defined as previously caught or not previously caught. Number of individual cotton rats were totaled among capture periods, and total count was divided by study area size to estimate density. Distance from parcel edge to traps was measured to assess if trap location affected distribution of cotton rats within parcels. Parcels were defined as the area where seedlings were planted. During the capture survey in December 2006 capture period, I surveyed microhabitat conditions in a 5-m^2 rectangular area around each trap and recorded dominant species of vegetation by percent coverage and average height to assess if vegetation height affected distribution of cotton rats within parcels (Hayes et al 1981). I tested the relationship between cotton rat occurrence and vegetation height and distance from parcel edge using the Kolmogorov-Smirnov test. Average vegetation heights from microsites were placed in ten height categories in 15-cm increments to establish a distribution. Total number of cotton rats captured within each height category provided an observed distribution of captures. Next, by calculating number of traps within each vegetation height category, I was able to establish an expected number of captures by category assuming cotton rats were distributed within parcels at random. By comparing these distributions (observed vs. expected), I was able to determine if number of observed captures followed a random distribution pattern. Similarly, I arranged distances of traps from parcel edge in ten distance categories of 10-m increments to establish a distribution pattern. Subsequent steps used to determine if cotton rat distribution in parcels was random in relation to distance from edge were the same as with vegetation height. Analyses were done separately for each of the study sites.

Table 2.1. Seedling tree species composition for six mixtures planted in Cleveland and Greenville, Mississippi in February 2006 for the Entergy Afforestation Project.

Mix	Seedling Species Composition
A	Eastern cottonwood monoculture
B	Red mulberry monoculture
C	Mixed oak (33% willow, 33% water, 33% Nuttall
D	50% eastern cottonwood, 50% mixed oak (willow, water, Nuttall)
E	50% green ash, 50% mixed oak (willow, water, Nuttall)
F	NRCS[1] recommended mix (50% Nuttall oak, 20% green ash, and a 30% species mix of willow oak, water oak, common persimmon, and American sycamore)

[1]Natural Resource Conservation Service

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Table 2.2. Habitat variables used in logistic regression analyses for hardwood afforestation site in Greenville and Cleveland, Mississippi in 2006-2007.

Cleveland	
Season	Plant Genera[a] Independent Variables
Spring 2006	Bare ground, Fescue, Other, Verbena, Vetch
Summer 2006	Bermuda, Fescue, Other, Verbena
Spring2007	Bare ground, Fescue, Other, Verbena, Vetch
Summer 2007	Bermuda, Fescue, Other, Verbena
	Habitat structure Variables
Spring 2006	Bare ground, Forb, Grass, Legume, Sedge, Vine, Woody
Summer 2006	Bare ground, Forb, Grass, Sedge, Vine, Woody
Spring2007	Bare ground, Forb, Grass, Legume, Sedge, Vine, Woody
Summer 2007	Forb, Grass, Sedge, Woody
Greenville	
Season	Plant Genera[a] Variables
Spring 2006	Bare ground, Fescue, Johnson grass, Other, Vetch
Summer 2006	Broom sedge, Bermuda, Fescue, Other, Verbena
Spring2007	Bare ground, Johnson grass, Other, Vetch
Summer 2007	Bare ground, Johnson grass, Other
	Habitat structure variables
Spring 2006	Bare ground, Forb, Grass, Legume, Vine, Woody
Summer 2006	Bare ground, Forb, Grass, Vine, Woody
Spring2007	Bare ground, Forb, Grass, Legume, Woody
Summer 2007	Bare ground, Forb, Grass, Woody

[a]Bermudagrass (*Cynodon dactylon*), Broomsedge (*Andropogon virginicus*), Fescue (*Festuca arundinacea*), Johnsongrass (*Sorghum halepense*), Verbena (*Verbena brasiliensis*), Narrow-leaf vetch (*Vicia sativa nigra*).

Table 2.3. Trapping schedule for evaluation of hispid cotton (*Sigmodon hispidus*) rat abundance at Greenville and Cleveland, Mississippi 2006-2007.

Year	Month	Day			
2006	March	3rd	4th	5th	6th
2006	November	17th	18th	19th	20th
2006	December	9th	10th	11th	12th
2007	January	16th	17th	18th	19th
2007	February	9th	10th	11th	12th
2007	March	10th	11th	12th	13th
2007	November	16th	17th	18th	19th
2007	December	12th	13th	14th	15th

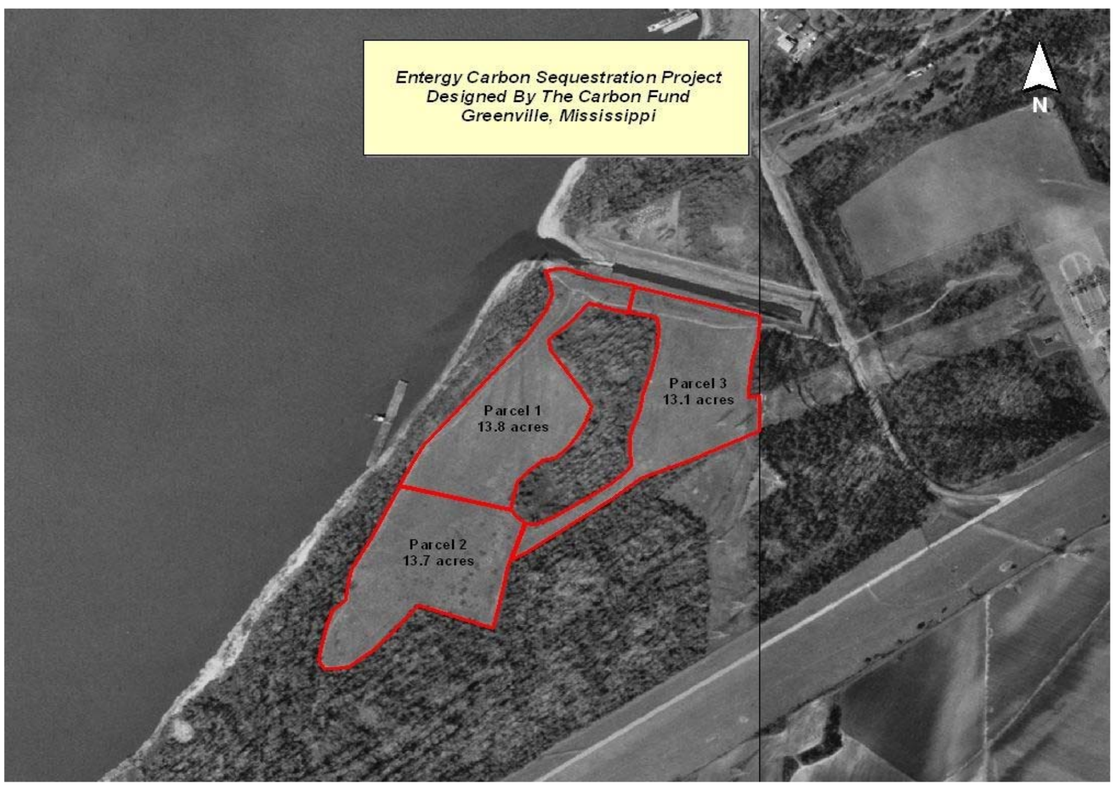


Figure 2.1. Study site for hardwood afforestation and herbivory study near Greenville Mississippi, 2006-2007.

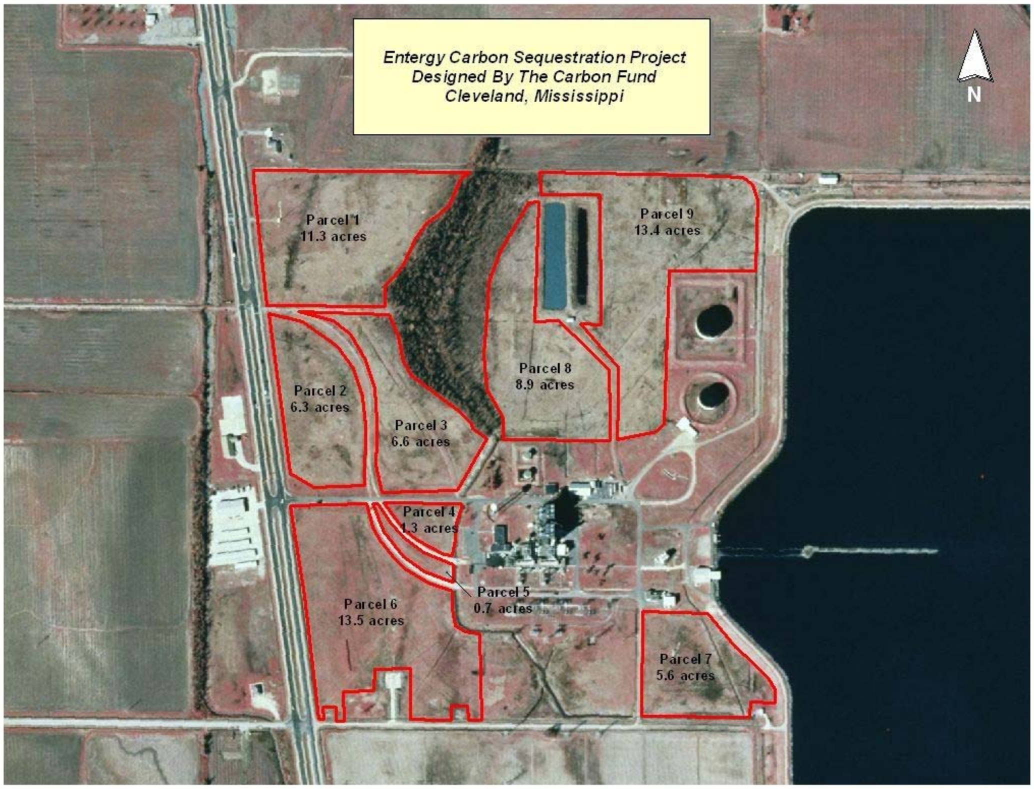


Figure 2.2. Study site for hardwood afforestation and herbivory study near Cleveland Mississippi, 2006-2007.

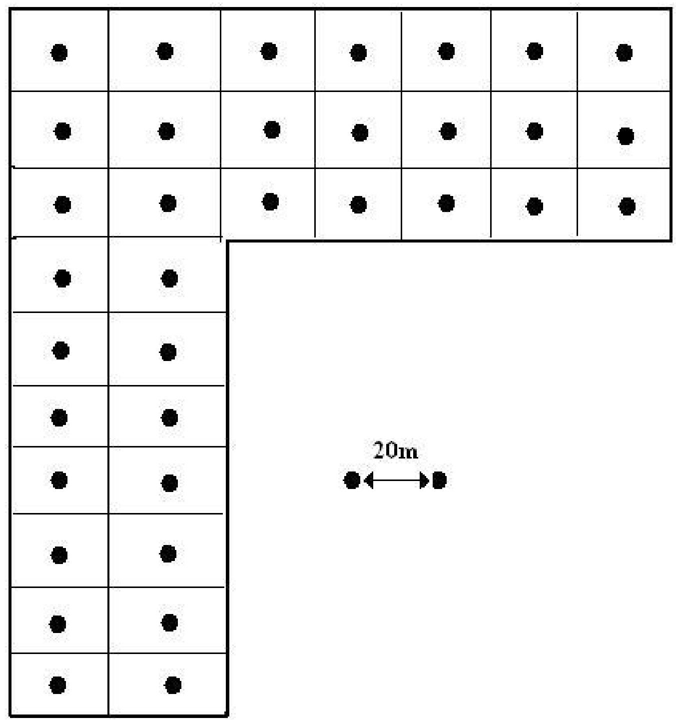


Figure 2.3. Diagram of trapping grid used to conduct capture-recapture study of hispid cotton rats on hardwood afforestation study sites in Greenville and Cleveland, MS 2006-2007.

CHAPTER III

RESULTS

<u>**Tree Seedling Mortality**</u>

Percentage survival of sampled tree seedling over the study period on both sites was 35.0% (*n* = 868). Percentage survival for each of the tree species was: 81.0% for *Fraxinus pennsylvanica* (*n* = 101), 7.0% for *Populus deltoides* (*n* = 191), 50.0% for *Diospyros virginiana* (*n* = 8), 41.0% for *Morus rubra* (*n* = 130), 66.0% for *Quercus nuttallii* (*n* = 128), 0.0% for *Quercus spp*. (*n* = 134), 23.0% for *Platanus occidentalis* (*n* = 13), 0.0% for Unknown (*n* = 45), 64.0% for *Quercus nigra* (*n* = 25), 55.0% for *Quercus phellos* (*n* = 86), and 0.0% for *Quercus acutissima* (*n* = 7; Table 3.1).

On the Cleveland study site, tree seedling survival was 36% (*n* = 432) over the study, and mortality caused by herbivory was 31% (*n* = 432). Survival of tree species ranged from a low of 10.0% for *P. deltoides* to a high of 81.19% for *F. pennsylvanica* (*n* = 54; Table 3.2). Of the oak species monitored, *Q. nuttallii* exhibited the greatest survival of 61.0% (*n* = 71; Table 3.2).

At the Greenville study site, seedling survival over all species was 34.0% (*n* = 436) over the study, and mortality caused by herbivory was 51.0% (*n* = 436). Survival by tree species was 81.0% for *F. pennsylvanica* (*n* = 47), 3.1% for *P. deltoides* (*n* = 96), 0.0% for *D. virginiana* (*n* = 2), 53.0% for *M. rubra* (*n* = 64), 74.0% for *Q. nuttallii* (*n* =

57), 0.0% for *Q. spp*. (*n* = 88), 67.0% for *P. occidetalis* (*n* = 3), 0.0% for Unknown (*n* = 19), 57.0% for *Q. nigra* (*n* = 14), 56.0% for *Q. phellos* (*n* = 39), and 0.0% for *Q. acutissima* (*n* = 7;Table 3.3).

Treatment Effects on Seedling Survival

Percentage mortality for all seedlings (*n* = 868) on both sites was 58.0% in control plots (*n* = 213 trees), 61.0% in herbicide treatment plots (*n* = 213 trees), 67.0% in fertilizer treatment plots (*n* = 222 trees), and 70.0% (*n* = 220 trees) in fertilizer/herbicide treatment plots (Table 3.4). There was no significant difference in mortality of seedlings among treatments ($\chi^2 = 1.63$, $df = 3$, $P = 0.653$). Control plots at Cleveland and Greenville sites exhibited some of the least seedling mortality (Tables 3.4.).

Evaluation of Herbivory

Percentage of tree seedlings that showed signs of herbivory over the study period on both sites was 41.0%. Signs of herbivory on planted seedlings varied by mammalian and seedling species. With data combined from both sites, herbivory rates from hispid cotton rat ranged from 0% on *P. deltoides* to 57.2% on *Q. phellos*. Herbivory from rabbits ranged from 1.6% on *P. deltoides* to 42.9% on *Q. phellos*. Herbivory from pine voles ranged from 0.0% on *P. deltoides* to 16.4% on *Q. nuttallii*. Herbivory by white-tailed deer ranged from 0% on *D. virginiana* to 21.1% on *Q. nuttallii* (Table 3.5).

At Cleveland, herbivory by hispid cotton rats ranged from 0.0% on *F. pennsylvanica* to 36.4% on *Q. nigra*. Herbivory rates by rabbits ranged from 0.0% on *F.*

pennsylvanica to 33.3% on *D. virginiana*, and herbivory rates by pine voles ranged from 0.0% on *P. deltoids* to 36.2% on *Q. phellos* (Table 3.6). In spring of 2006, cotton rats (K-S Statistic = 0.29, *df* = 9, *P* = 0.0265) and all herbivores (K-S Statistic = 0.22, *df* = 9, *P* = 0.0165) showed a non-random pattern of foraging on tree seedling species, and rabbits (K-S Statistic = 0.22, *df* = 9, *P* = 0.3440) showed a random pattern of foraging on tree species. During summer 2006, cotton rats (K-S Statistic = 0.22, *df* = 9, *P* = 0.376) and all herbivores (K-S Statistic = 0.22, *df* = 9, *P* = 0.122) showed a random pattern of foraging on tree species. Sample size was too small for analysis for spring, summer, and fall 2007. When data were combined for the entire study period, cotton rats (K-S Statistic = 0.23, *df* = 9, *P* = 0.013) and all herbivores (K-S Statistic = 0.23, *df* = 9, $P \leq 0.001$) exhibited non-random patterns of foraging on tree species. Pine vole (K-S Statistic = 0.23, *df* = 9, *P* = 0.071) and rabbits (K-S Statistic = 0.21, *df* = 9, *P* = 0.069) exhibited random patterns of foraging on tree species.

At the Greenville study site, herbivory rates by hispid cotton rats ranged from 0% on *P. deltoides* to 57.2% on *Q. nigra*. Herbivory by rabbits ranged from 0.0% on *D. virginiana* to 42.9% on *Q. acutissima*. Herbivory by pine vole ranged from 0.0% on *F. pennsylvanica* to 12.3% on *Q. nuttallii*, and herbivory by white-tailed deer ranged from 0.0% on *D. virginiana* to 64.3% on *Q. nigra* (Table 3.7.). During spring of 2006, cotton rats (K-S Statistic = 0.22, *df* = 10, *P* = 0.313) and all herbivores (K-S Statistic = 0.19, *df* = 10, *P* = 0.133) showed a random pattern of foraging on tree seedling species. For summer 2006, cotton rats (K-S Statistic = 0.24, *df* = 10, *P* = 0.029) and all herbivores (K-S Statistic = 0.22, *df* = 10, *P* = 0.0256) showed non-random patterns of foraging on tree species. During summer 2007, white-tailed deer (K-S Statistic = 0.42, *df* = 10, $P = 0.002$) and all herbivores (K-S Statistic = 0.40, df = 10, $P \leq 0.01$) exhibited non-random patterns of foraging on tree species. In fall 2007, cotton rats (K-S Statistic = 0.42, *df* = 10, $P \leq 0.001$), rabbits (K-S Statistic = 0.42, df = 10, $P = 0.0004$), white-tailed deer (K-S Statistic = 0.35, df = 10, $P \leq 0.001$), and all herbivores (K-S Statistic = 0.39, *df* = 10, $P \leq 0.001$) showed non-random patterns of foraging on tree species. When data were combined for the entire study period, cotton rats (K-S Statistic = 0.23, *df* = 10, $P = 0.002$), pine vole (K-S Statistic = 0.44, *df* = 10, $P = .003$), rabbits (K-S Statistic = 0.35, *df* = 10, $P = 0.010$), white-tailed deer (K-S Statistic = 0.44, *df* = 10, $P = 0.001$), and all herbivores (K-S Statistic = 0.24, *df* = 10, $P \leq 0.001$) showed non-random patterns of foraging on tree species.

Manley's Alpha

At Cleveland site, *Q. nuttallii* was foraged on at greater rates than would have been expected at random by all mammalian species during each season except spring 2006 (Figures 3.1-3.5). *Fraxinus pennsylvanica* was never selected for during any season. *Populus deltoides* was not selected for during any season except for spring 2007. In most cases, analyses could not be conducted for each mammal species by each season because of small sample size (i.e., number of recorded incidents of herbivory were <20), so data were pooled across seasons. *Quercus nuttallii* was selected at a greater rate than random by all herbivores except hispid cotton rats. *Populus deltoides* was never selected for by any herbivore (Figures 3.6-3.9).

At the Greenville site, *Q. nuttallii* was selected for by all mammalian species during each season except summer 2006. *Fraxinus pennsylvanica* and *P. deltoides* were never selected for during any season (Figures 3.10-3.14). To estimate the selection of tree species by individual herbivore species, data from all seasons were combined. *Quercus nuttallii* was selected for by every herbivore except for hispid cotton rats. *Fraxinus pennsylvanica* and *P. deltoides* were never selected for by any species except white-tailed deer (Figures 3.15-3.19).

Vegetation

I found no correlation coefficients between habitat variables that were ≥ 0.70, so I did not remove any variables from analyses because of collinearity problems. Models developed for predicting herbivore-related, seedling mortality at the Cleveland study site using percent coverage of dominant plant species as independent variables were not significant for spring 2006, spring 2007, and summer 2007 (Tables 3.8-3.9). For summer 2006, *Andropogon virginicus* had a significant negative effect on seedling mortality caused by herbivores (Wald $\chi^2 = 5.01$, $P = 0.025$, $df = 1$, % concordant = 24.9, % tied = 65.0%), (Tables 3.10-3.11).

For modeling analyses of seedling damage caused by herbivores at Cleveland study site, no models were significant for spring 2006 and summer 2007. For summer 2006, *A. virginicus* had a significant negative effect on damage to seedlings (Wald $\chi^2 =$ 6.30, $P = 0.012$, $df = 1$, % concordant = 24.4, % tied = 62.3%). For spring 2007, other vegetation form had a significant positive effect on damage to seedlings (Wald $\chi^2 = 3.94$, $P = 0.047$, $df = 1$, % concordant = 56.2, % tied = 3.2%).

For modeling analyses of seedling mortality at Cleveland study site using percent coverage of vegetation form as independent variables (Tables 3.9), there were no significant results for summer 2007. For spring 2006, woody vegetation had a significant negative effect (Wald $\chi^2 = 6.33$, $P = 0.012$, $df = 1$, % concordant =42.9, % tied = 34.1) on seedling mortality related to herbivores and vines had a significant positive effect on seedling mortality caused by herbivores (Wald $\chi^2 = 3.86$, $P = 0.049$). For summer 2006, woody vegetation had a significant positive effect on seedling mortality caused by herbivores (Wald $\chi^2 = 6.51$, $P = 0.011$, $df = 1$, % concordant = 36.1, % tied = 40.0). For spring 2007, legumes had a significant negative effect on seedling mortality caused by herbivores (Wald $\chi^2 = 4.04$, $P = 0.045$, $df = 1$, % concordant = 57.0%, tied = 8.1).

For modeling analyses of seedling damage caused by herbivores at Cleveland study site using vegetation form as independent variables, there were no significant results for summer 2007. For spring 2006, woody vegetation had a significant negative effect on seedling damage by herbivores (Wald $\chi^2 = 6.00$, $P = 0.014$, $df = 1$, % concordant = 32.0, % tied = 53.8%). For summer 2006, woody vegetation had a significant positive effect (Wald $\chi^2 = 5.14$, $P = 0.023$, $df = 1$, % concordant = 45.4, % tied = 22.4%), and vines had a significant negative effect (Wald $\chi^2 = 3.85$, $P = 0.049$) on herbivore-related damage of seedlings. For spring 2007, vines had a significant positive effect on herbivore damage of seedlings (Wald $\chi^2 = 5.63$, $P = 0.0176$, $df = 1$, % concordant = 37.3, % tied = 45.1%).

For modeling analyses of seedling mortality at Greenville study site using vegetation species as independent explanatory variables (Table 3.8), no significant relationships were detected between species of plants occurring around seedlings and seedling mortality due to low rates of herbivory damage during spring and summer 2006 and summer 2007. For spring 2007, bare ground had a positive effect on seedling mortality caused by herbivores (Wald $\chi^2 = 8.35$, $P = 0.004$, $df = 1$, % concordant = 60.2, % tied = 24.1%).

For seedling damage at Greenville study site using vegetation species as independent variables, no relationships were detected between explanatory variables and seedling mortality due to low rates of herbivory damage during spring 2006, summer 2006 or 2007. For spring 2007, bare ground had a significant positive effect on seedling mortality (Wald $\chi^2 = 6.76$, $P = 0.0093$ $df = 1$, % concordant = 50.3, % tied = 30.3%).

No significant relationships were detected between seedling mortality related to herbivores and vegetation forms at Greenville study site during spring 2006 through summer 2007 due to low rates of seedling mortality (Table 3.9). For analyses modeling seedling damage at Greenville study site using vegetation form as independent variables, there were no significant results for spring 2006 and summer 2007 due to low rates of seedling mortality. For summer 2006, vines had a significant negative effect on seedling damage (Wald $\chi^2 = 4.20$, $P = 0.040$, $df = 1$, % concordant = 12.2, % tied = 83.4%). For spring 2007, bare ground had a significant positive effect on seedling damage caused by herbivores (Wald $\chi^2 = 7.79$, $P = 0.005$, $df = 1$, % concordant = 53.2, % tied = 28.3%).

Population Characteristics of Cotton Rats

Cotton rats were not marked in a manner which allowed abundance estimation by statistical methodology (e.g., Lincoln-Peterson estimation). Marking of cotton rats through ear piercing resulted in an inability to discern individuals due to ear mutilation that occurred naturally. For example, bite marks and tearing of ears occurred in most rats captured over the study period. However, I could determine how many individuals were captured at study sites during one capture period. On average, 25.8 rats were captured per sample period at Cleveland site and 64.0 rats were captured per sample period at Greenville site (Table 3.12). The maximum number of individual captures at both sites occurred in November 2007 with 89 at Cleveland site and 143 at Greenville site, resulting in estimated densities of 6.10 cotton rats/ha and 9.80 cotton rats/ha, respectively (Table 3.12.).

Cotton rats were distributed randomly in relation to vegetation height at Cleveland (K-S Statistic = 0.07, P = 0.706) and Greenville (K-S Statistic = 0.05, P = 0.264). Also, cotton rats were distributed randomly in relation to distance from parcel edge at Cleveland (K-S Statistic = 0.05, P = 1.000) and Greenville (K-S Statistic = 0.03, P = 1.000).

Table 3.1. Percentage of tree seedling mortality and damage by mammal species at Cleveland and Greenville, MS sites 2006-2007.

				Hispid Cotton Rat		Pine Vole		Rabbit		White-tailed deer		
Species	N	(%) Missing	(%) Other Mortality	(%) Mortality	(%) Damage	(%) Mortality	(%) Damage	(%) Mortality	(%) Damage	(%) Mortality	(%) Damage	(%) Survival
FP	101	8.91	6.93	0.00	3.96	0.99	0.00	0.00	2.97	1.98	3.96	81.19
PD	191	11.52	81.15	0.00	0.00	0.00	0.00	0.00	1.57	0.52	1.57	8.38
DV	8	25.00	25.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	62.50
MR	130	25.38	20.00	10.77	23.85	0.77	0.77	2.31	17.69	0.00	7.69	40.77
QN	128	14.84	3.91	5.47	13.28	5.47	10.94	3.13	18.75	0.78	20.31	68.75
Q spp.	134	42.54	32.09	14.18	5.22	6.72	2.99	4.48	0.75	0.00	0.00	0.00
PO	13	30.77	30.77	7.69	23.08	0.00	0.00	7.69	0.00	0.00	0.00	23.08
UNK	45	77.78	17.78	0.00	0.00	0.00	0.00	2.22	0.00	0.00	0.00	2.22
QNi	25	8.00	16.00	8.00	40.00	0.00	4.00	0.00	8.00	4.00	32.00	72.00
QP	86	12.79	8.14	11.63	24.42	9.30	6.98	2.33	10.47	1.16	11.63	58.14
QA	7	42.86	14.29	42.86	14.29	0.00	0.00	0.00	42.86	0.00	0.00	0.00

FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO-*Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

Table 3.2. Percentage of tree seedling mortality and damage by mammal species at Cleveland, MS site 2006-2007.

				Hispid Cotton Rat		Pine Vole		Rabbit		White-tailed Deer		
Species	N	(%) Missing	(%) Other Mortality	(%) Mortality	(%) Damage	(%) Mortality	(%) Damage	(%) Mortality	(%) Damage	(%) Mortality	(%) Damage	(%) Survival
FP	54	7.41	9.26	0.00	5.56	1.85	0.00	0.00	0.00	0.00	0.00	81.48
PD	95	6.32	83.16	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	10.53
DV	6	16.67	16.67	0.00	0.00	0.00	0.00	0.00	33.33	0.00	0.00	66.67
MR	66	25.76	34.85	9.09	10.61	1.52	1.52	0.00	22.73	0.00	0.00	28.79
QN	71	22.54	5.63	2.82	15.49	8.45	11.27	0.00	21.13	0.00	0.00	60.56
Q spp.	46	30.43	30.43	17.39	0.00	10.87	0.00	10.87	2.17	0.00	0.00	0.00
PO	10	40.00	40.00	10.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
UNK	26	73.08	23.08	0.00	0.00	0.00	0.00	3.85	0.00	0.00	0.00	0.00
QNi	11	0.00	27.27	0.00	36.36	0.00	9.09	0.00	0.00	0.00	0.00	72.73
QP	47	12.77	8.51	10.64	12.77	14.89	6.38	0.00	8.51	0.00	0.00	53.19

FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

Table 3.3. Percentage of tree seedling mortality and damage by mammal species at Greenville, MS site 2006-2007.

Species	N	(%) Missing	(%) Other Mortality	Hispid Cotton Rat (%) Mortality	Hispid Cotton Rat (%) Damage	Pine Vole (%) Mortality	Pine Vole (%) Damage	Rabbit (%) Mortality	Rabbit (%) Damage	White-tailed Deer (%) Mortality	White-tailed Deer (%) Damage	(%) Survival
FP	47	10.64	4.26	0.00	2.13	0.00	0.00	0.00	6.38	4.26	8.51	80.85
PD	96	16.67	79.17	0.00	0.00	0.00	0.00	0.00	1.04	1.04	3.13	6.25
DV	2	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
MR	64	25.00	4.69	12.50	37.50	0.00	0.00	4.69	12.50	0.00	15.63	53.13
QN	57	5.26	1.75	8.77	10.53	1.75	10.53	7.02	15.79	1.75	45.61	78.95
Qspp	88	48.86	32.95	12.50	7.95	4.55	4.55	1.14	0.00	0.00	0.00	0.00
QA	7	0.00	0.00	0.00	33.33	0.00	0.00	33.33	0.00	0.00	0.00	66.67
PO	3	84.21	10.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.26
Unk	19	14.29	7.14	14.29	42.86	0.00	0.00	0.00	14.29	7.14	57.14	71.43
QNi	14	12.82	7.69	12.82	38.46	2.56	7.69	5.13	12.82	2.56	25.64	64.10
QP	39	42.86	14.29	42.86	14.29	0.00	0.00	0.00	42.86	0.00	0.00	0.00
QA	7	10.64	4.26	0.00	2.13	0.00	0.00	0.00	6.38	4.26	8.51	80.85

FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO-*Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

Table 3.4. Number of seedlings and mortality rates by treatment regime at Greenville and Cleveland study site, MS 2006-2007.

	Control	Herbicide	Fertilizer	Fertilizer & Herbicide
Cleveland Seedling Metrics				
Total	106	109	106	107
Mortality	65	65	77	73
% Mortality	61%	60%	73%	68%
Greenville Seedling Metrics				
Total	107	104	116	113
Mortality	57	64	71	82
% Mortality	53%	62%	61%	73%
Cleveland and Greenville Seedling Metrics				
Total	213	213	222	220
Mortality	122	129	148	155
% Mortality	58%	61%	67%	70%

Table 3.5. Herbivory rate by mammal species at Cleveland and Greenville, MS sites 2006-2007.

Species	N	Hispid Cotton Rat (%)	Pine Vole (%)	Rabbit (%)	White-tailed Deer (%)
FP	101	3.96	0.99	2.97	5.94
PD	191	0.00	0.00	1.57	2.09
DV	8	0.00	0.00	25.00	0.00
MR	130	34.62	1.54	20.00	7.69
QN	128	18.75	16.41	21.88	21.09
Q spp.	134	19.40	9.70	5.22	0.00
PO	13	30.77	0.00	7.69	0.00
UNK	45	0.00	0.00	2.22	0.00
QNi	25	48.00	4.00	8.00	36.00
QP	86	36.05	16.28	12.79	12.79
QA	7	57.14	0.00	42.86	0.00

FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

Table 3.6. Herbivory rate by mammal species at Cleveland, MS sites 2006-2007.

Species	N	Hispid Cotton Rat (%)	Pine Vole (%)	Rabbit (%)
FP	54	5.56	1.85	0.00
PD	95	0.00	0.00	2.11
DV	6	0.00	0.00	33.33
MR	66	19.70	3.03	22.73
QN	71	18.31	19.72	21.13
Q spp.	46	17.39	10.87	13.04
PO	10	30.00	0.00	0.00
UNK	26	0.00	0.00	3.85
QNi	11	36.36	9.09	0.00
QP	47	23.40	21.28	8.51

FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

Table 3.7. Herbivory rate by mammal species at Greenville, MS sites 2006-2007.

Species	N	Hispid Cotton Rat (%)	Pine Vole (%)	Rabbit (%)	White-tailed Deer (%)
FP	47	2.13	0.00	6.38	12.77
PD	96	0.00	0.00	1.04	4.17
DV	2	0.00	0.00	0.00	0.00
MR	64	50.00	0.00	17.19	15.63
QN	57	19.30	12.28	22.81	47.37
Q spp.	88	20.45	9.09	1.14	0.00
PO	3	33.33	0.00	33.33	0.00
UNK	19	0.00	0.00	0.00	0.00
QNi	14	57.14	0.00	14.29	64.29
QP	39	51.28	10.26	17.95	28.21
QA	7	57.14	0.00	42.86	0.00

FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

Table 3.8. Mean and standard error of percent coverage of vegetation species used as habitat variables in logistic regression analyses averaged across seasons in Cleveland and Greenville, MS, 2006-2007.

	Cleveland		**Greenville**	
	Avg. % Mean	Standard Error	Mean	Standard Error
Broomsedge	21.36	2.56	35.66	4.46
Bare ground	31.67	1.91	23.66	2.38
Bermudagrass	14.00	6.00	35.68	5.04
Fescue	56.56	0.80	24.78	1.17
Johnsongrass	5.50	9.57	35.70	1.17
Other	13.47	0.53	10.16	0.35
Brazil vervain	9.89	1.46	0.11	2.97
Narrow-leaf vetch	12.32	0.99	22.57	1.04
Summer 2006				
Broomsedge	22.87	2.17	38.28	4.44
Bare ground	25.57	3.69	28.76	0.95
Bermudagrass	31.64	1.26	52.66	7.08
Fescue	41.99	1.55	0.00	0.00
Johnsongrass	10.55	1.38	51.97	1.30
Other	11.70	0.45	14.17	0.72
Brazil vervain	8.70	1.37	8.84	2.05
Narrow-leaf vetch	0.00	0.00	1.00	0.00
Spring 2007				
Broomsedge	15.15	1.32	23.85	4.72
Bare ground	16.94	1.26	18.91	1.22
Bermudagrass	48.75	22.58	0.00	0.00
Fescue	55.98	1.54	0.00	0.00
Johnsongrass	38.78	5.01	13.68	0.89
Other	8.27	0.31	18.05	0.63
Brazil vervain	7.67	0.83	13.71	3.35
Narrow-leaf vetch	21.13	1.03	26.47	1.94
Summer 2007				
Broomsedge	26.21	2.43	38.82	5.68
Bare ground	31.66	10.92	32.71	1.73
Bermudagrass	26.91	2.13	62.06	7.35
Fescue	59.14	2.09	0.00	0.00
Johnsongrass	7.00	0.00	52.74	1.79
Other	14.36	0.93	16.66	1.35
Brazil vervain	7.22	0.97	7.54	1.49
Narrow-leaf vetch	0.00	0.00	0.00	0.00

Broomsedge- *Andropogon virginicus*, Bermudagrass- *Cynodon dactylon*, Fescue- *Festuca arundinacea*, Johnsongrass- *Sorghum halapense*, Brazil vervain- *Verbena brasiliensis*, Narrow-leaf vetch- *Vica sativa nigra*

Table 3.9. Mean and standard error of percent coverage of vegetation forms used as habitat variables in logistic regression analyses averaged across seasons in Cleveland and Greenville, MS 2006-2007.

	Cleveland		**Greenville**	
	Avg. % Mean	Standard Error	Mean	Standard Error
Bare ground	31.67	1.90	23.76	2.41
Forb	8.61	0.75	7.00	0.30
Grass[a]	44.17	1.65	27.04	0.71
Legume	11.93	2.10	20.42	0.97
Sedge	15.76	0.96	16.00	2.74
Vine	15.97	1.34	17.90	2.67
Woody	17.80	1.49	21.62	2.22
Summer 2006				
Bare ground	25.57	2.94	28.76	0.95
Forb	7.41	0.36	8.55	0.60
Grass[a]	28.33	0.85	40.31	1.22
Legume	2.00	0.00	3.00	2.00
Sedge	8.27	0.73	0.00	0.00
Vine	23.04	1.71	16.00	2.28
Woody	18.88	1.45	27.33	2.46
Spring 2007				
Bare ground	16.94	1.25	18.91	1.22
Forb	6.80	0.37	12.09	0.59
Grass[a]	42.20	1.54	21.44	0.86
Legume	18.27	0.88	23.89	1.74
Sedge	11.31	1.07	12.40	3.58
Vine	7.76	0.60	30.00	0.00
Woody	9.52	0.92	14.26	2.13
Summer 2007				
Bare ground	31.66	10.92	32.71	1.72
Forb	6.65	0.72	9.25	0.87
Grass[a]	36.79	1.46	50.12	1.72
Legume	0.00	0.00	0.00	0.00
Sedge	8.55	1.82	8.88	0.95
Vine	0.00	0.00	0.00	0.00
Woody	20.87	1.62	27.74	2.68

[a] Dominated (>80% coverage) by Johnsongrass and Tall Fescue

Table 3.10. Models for determining relationships between seedling mortality and probability of seedling damage and explanatory variables of vegetation conditions at the bottomland hardwood afforestation site at Cleveland, MS. 2006-2007.

Cleveland Species
Mortality (p = probability of seedling death)
Summer 2006
Logit (p) = -0.9242 + (-0.0374 x % coverage of *Andropogon virginicus*)
Damage (p = probability of seedling death or damage)
Summer 2006
Logit (p) = -0.5477 + (-0.0359 x % coverage of *Andropogon virginicus*)
Spring 2007
Logit (p) = -1.5372 + (0.0146 x % coverage of other)
Cleveland Form
Damage (p = probability of seedling death or damage)
Spring 2006
Logit (p) = -1.3136 + (-0.05969 x % coverage of woody)
Summer 2006
Logit (p) = -0.7029 + (-0.0123 x % coverage of vine) + (0.0197 x % coverage of woody)
Spring 2007
Logit (p) = -1.4129 + (0.0555 x % coverage of vine)

Table 3.11. Models for determining relationships between seedling mortality and probability of seedling damage and explanatory variables of vegetation conditions at the bottomland hardwood afforestation site at Greenville, MS. 2006-2007.

Greenville Species
Mortality (p = probability of seedling death)
Spring 2007
Logit (p) = -3.7160 + (-0.0626 x % coverage of bare)
Damage (p = probability of seedling death or damage)
Spring 2007
Logit (p) = -2.5859 + (0.0437) x % coverage of bare
Greenville Form
Mortality (p = probability of seedling death)
Spring 2006
Logit (p) = -0.0653 + (-1.4387 x % coverage of woody) Logit (p) = 0.0197 + (-0.7096 x % coverage of vine)
Summer 2006
Logit (p) = -0.0225 + (-1.2516 x % coverage of woody)
Spring 2007
Logit (p) = 0.0236 + (-1.0186 x % coverage of legume)
Damage (p = probability of seedling death or damage)
Summer 2006
Logit (p) = -0.1266 + (-0.0524 x % coverage of vine)
Spring 2007
Logit (p) = -2.7013 + (0.0475 x % coverage of vine)

Table 3.12. Number of individual hispid cotton rats captured at Cleveland and Greenville, MS sites 2006-2007.

Cleveland		Greenville	
Month/Year	Individuals captured	Month/Year	Individuals captured
March 2006	2	March 2006	50
November 2006	31	November 2006	103
December 2006	12	December 2006	112
January 2007	5	January 2007	24
February 2007	1	February 2007	9
March 2007	2	March 2007	6
November 2007	89	November 2007	143
December 2007	64	December 2007	65

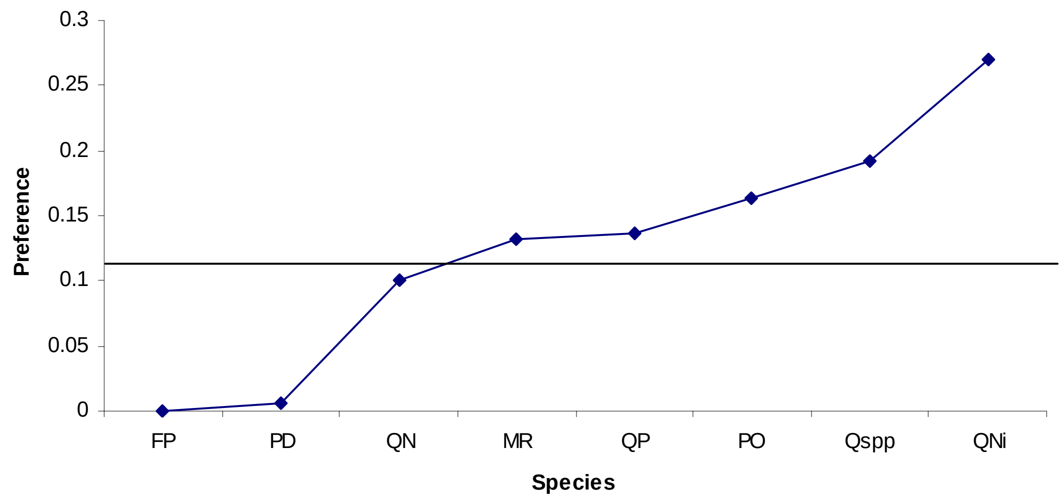


Figure 3.1. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Cleveland, MS study site, spring 2006.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

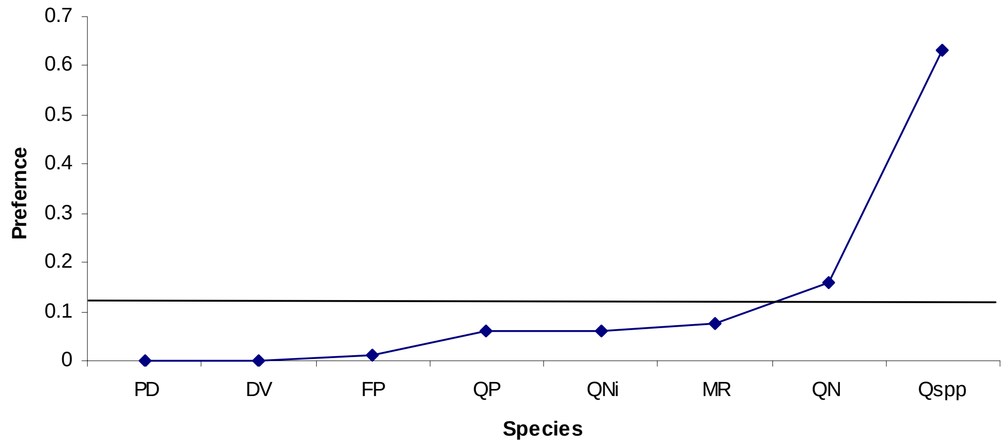


Figure 3.2. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Cleveland, MS study site, summer 2006.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

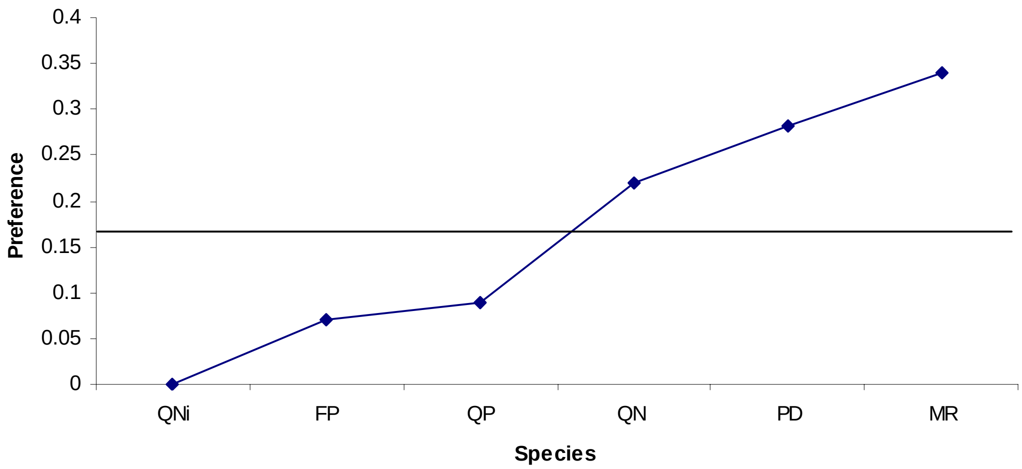


Figure 3.3. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Cleveland, MS study site, spring 2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.

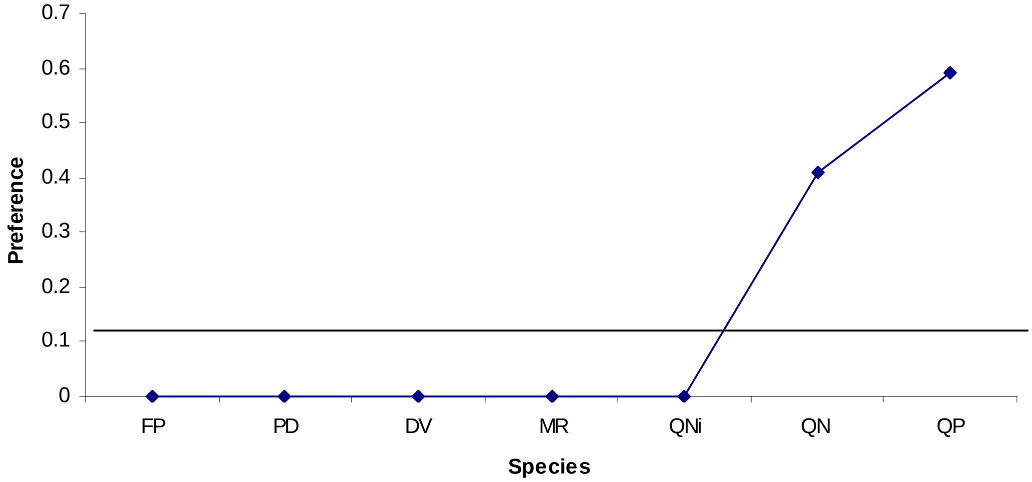


Figure 3.4. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Cleveland, MS study site, summer 2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.

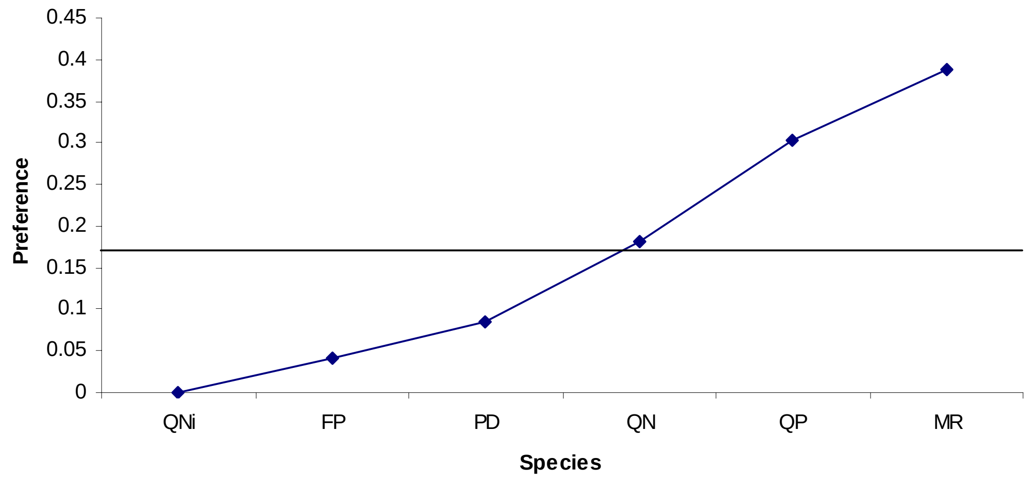


Figure 3.5. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Cleveland, MS study site, fall 2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, MR- *Morus rubra*, QN- *Quercus nuttallii*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.

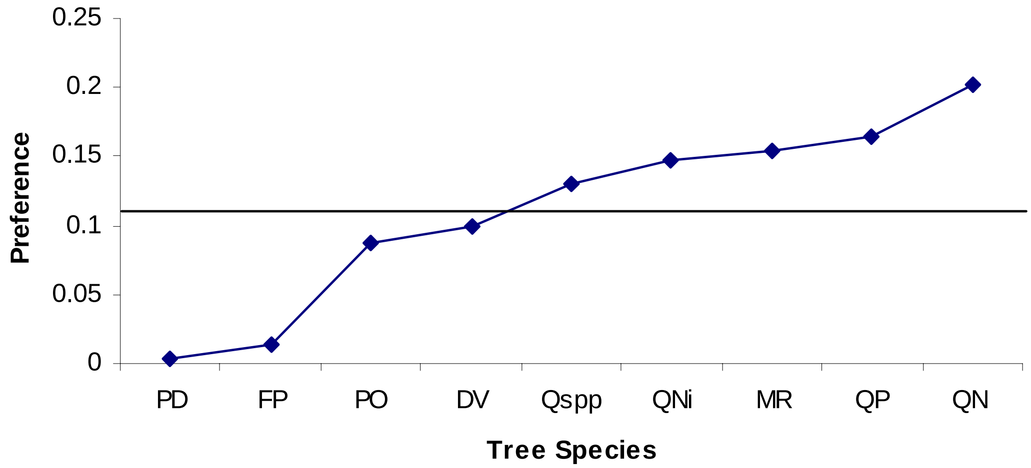


Figure 3.6. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Cleveland, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

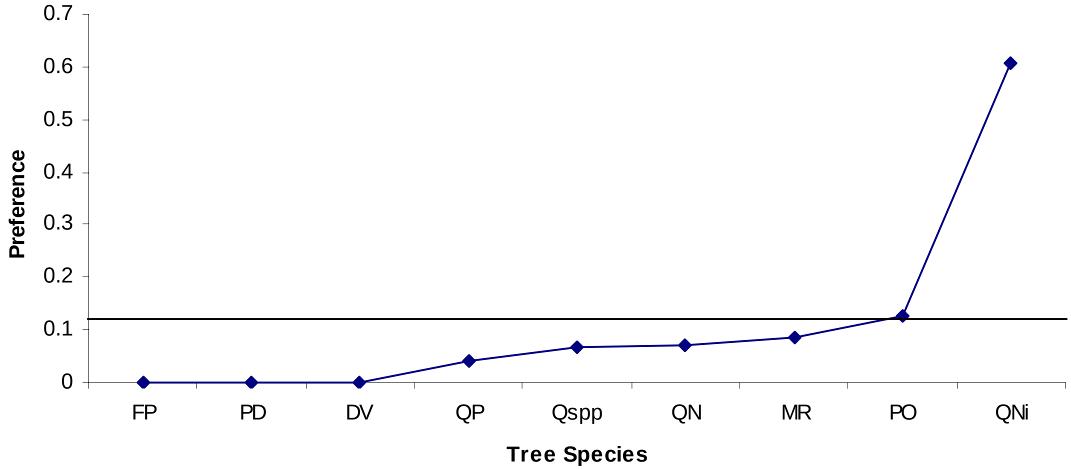


Figure 3.7. Manley's alpha selectivity index[1] for relative selection of tree species[2] by hispid cotton rats at Cleveland, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

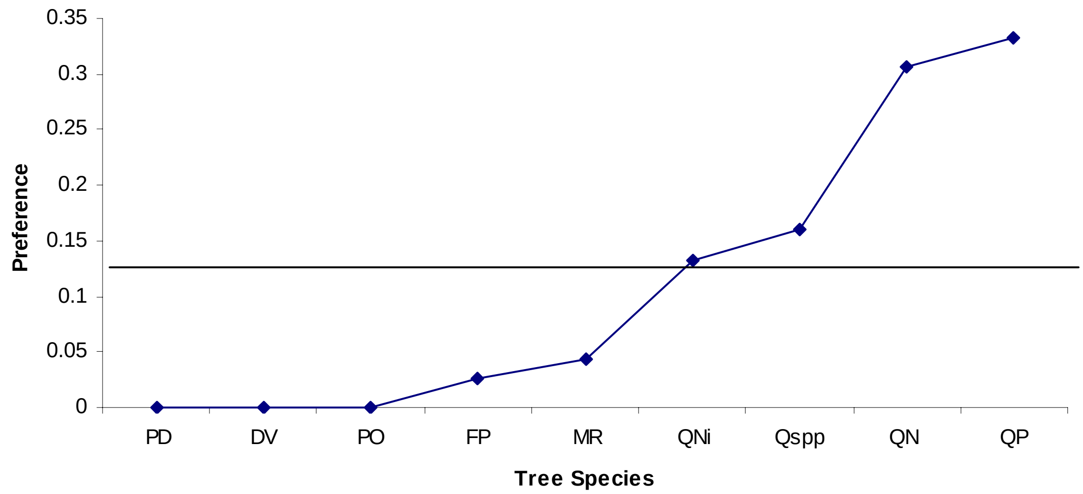


Figure 3.8. Manley's alpha selectivity index[1] for relative selection of tree species[2] by pine voles at Cleveland, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

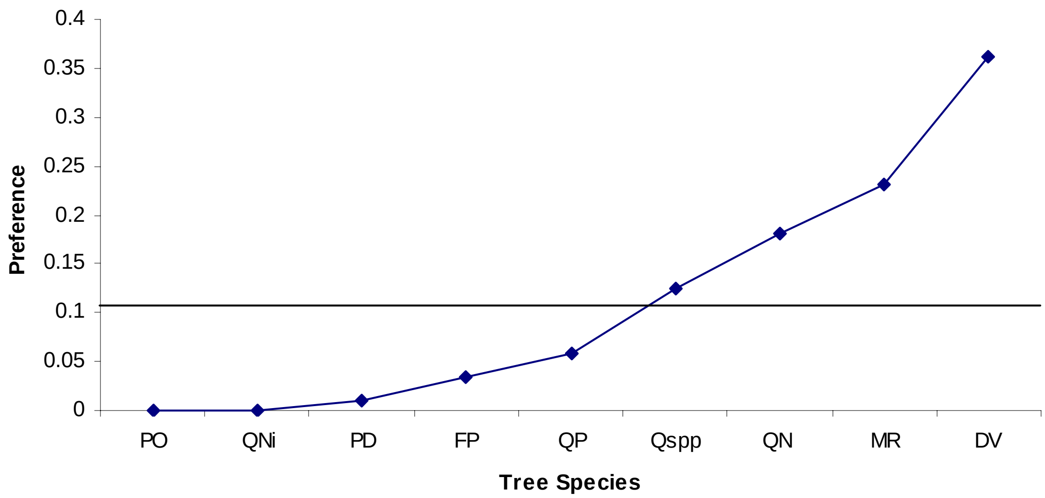


Figure 3.9. Manley's alpha selectivity index[1] for relative selection of tree species[2] by rabbits at Cleveland, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2]FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3] *Quercus spp*., PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3] Q spp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

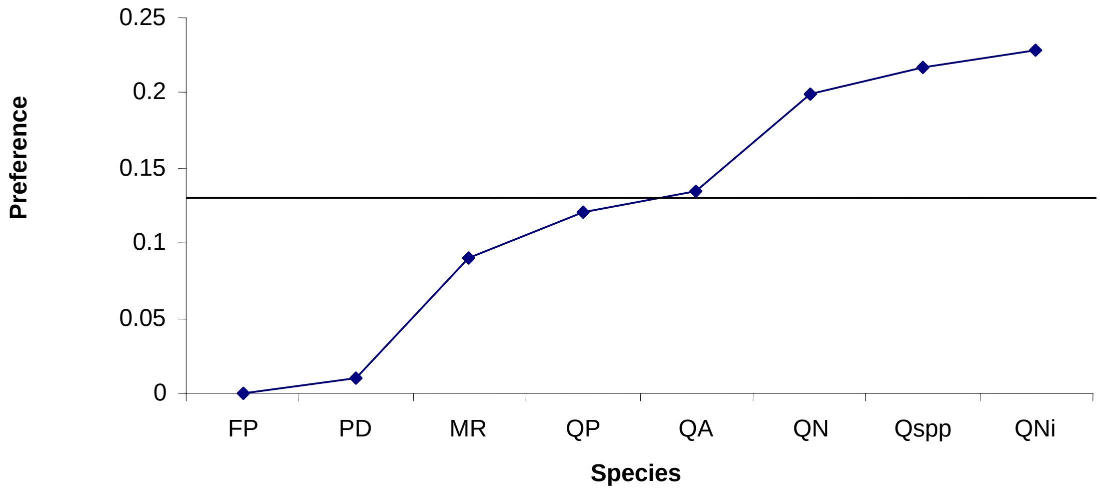


Figure 3.10. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Greenville, MS study site, spring 2006.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2]FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3] *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3] Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

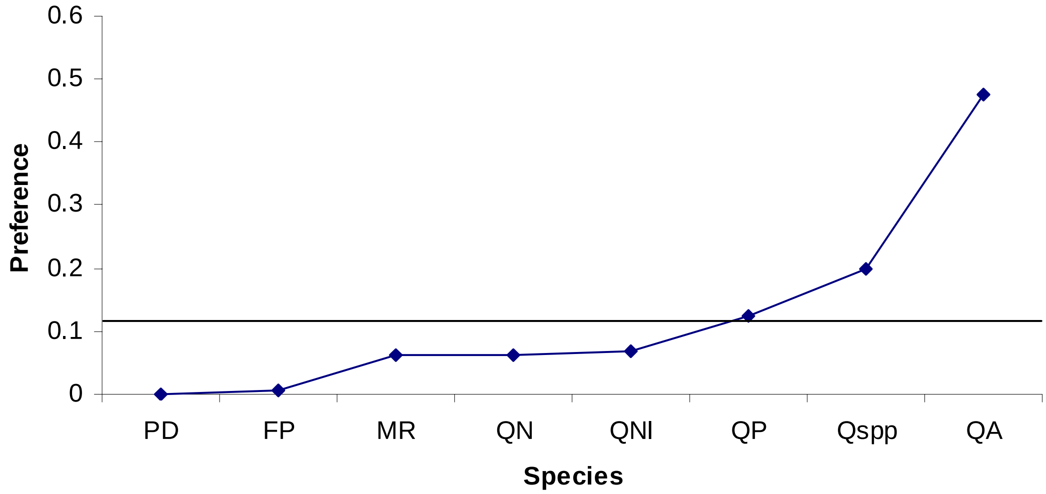


Figure 3.11. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Greenville, MS study site, summer 2006.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2]FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3] *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3] Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

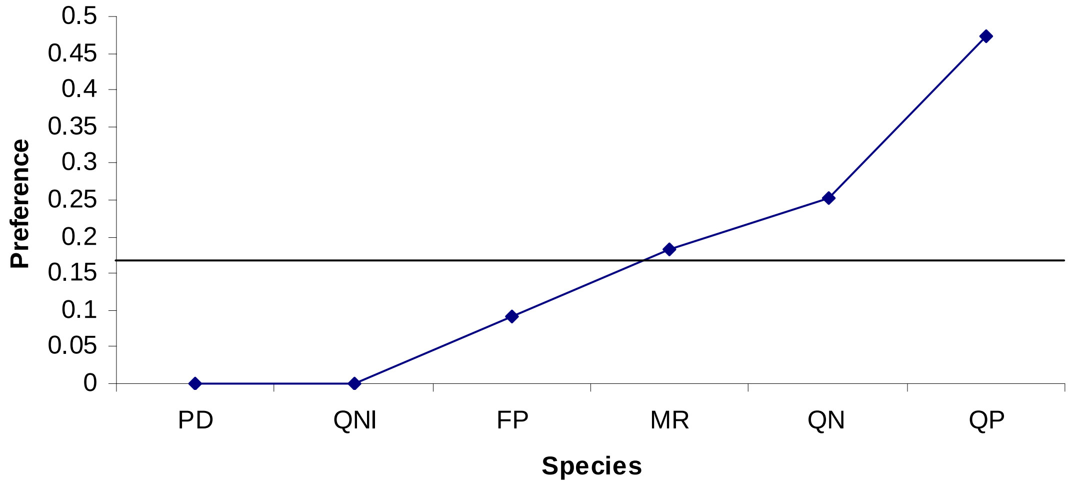


Figure 3.12. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Greenville, MS study site, spring 2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2]FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.

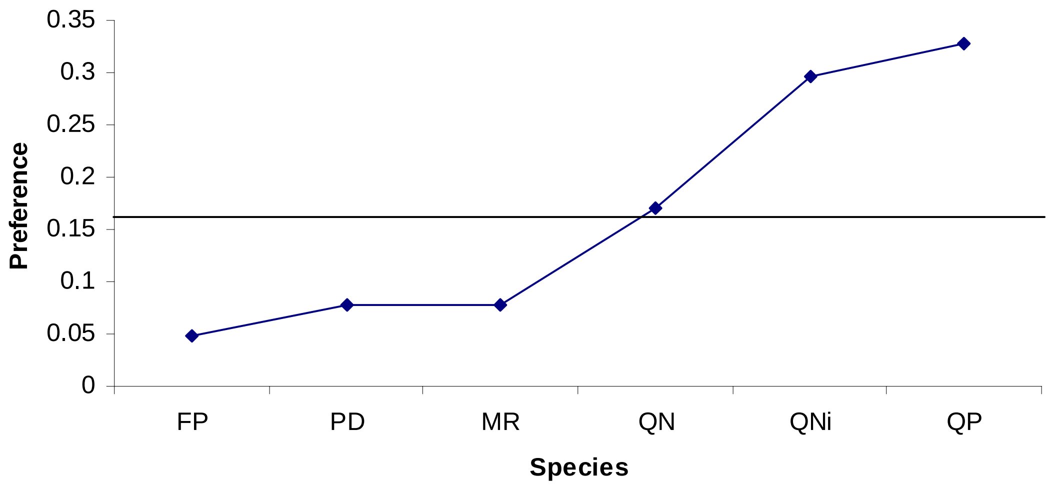


Figure 3.13. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Greenville, MS study site, summer 2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2]FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.

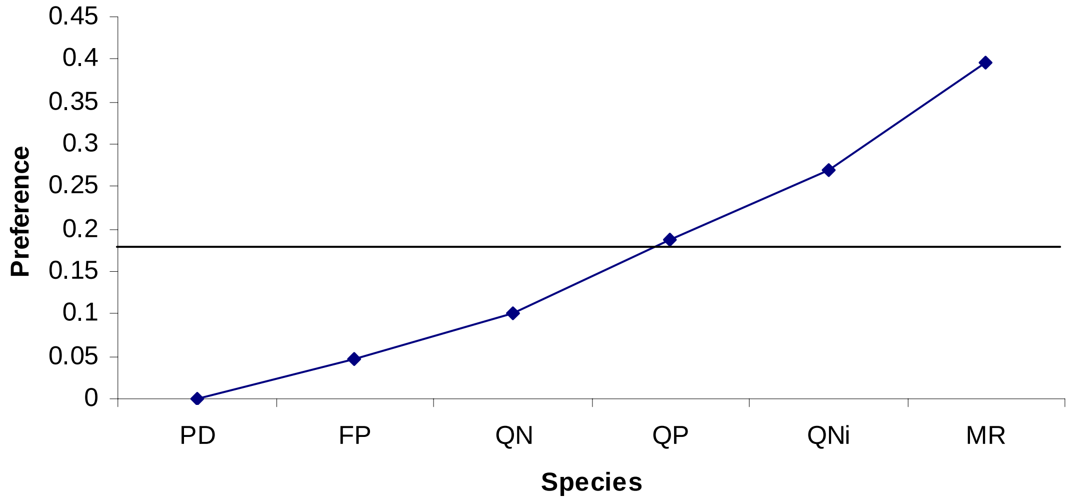


Figure 3.14. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Greenville, MS study site, fall 2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2]FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.

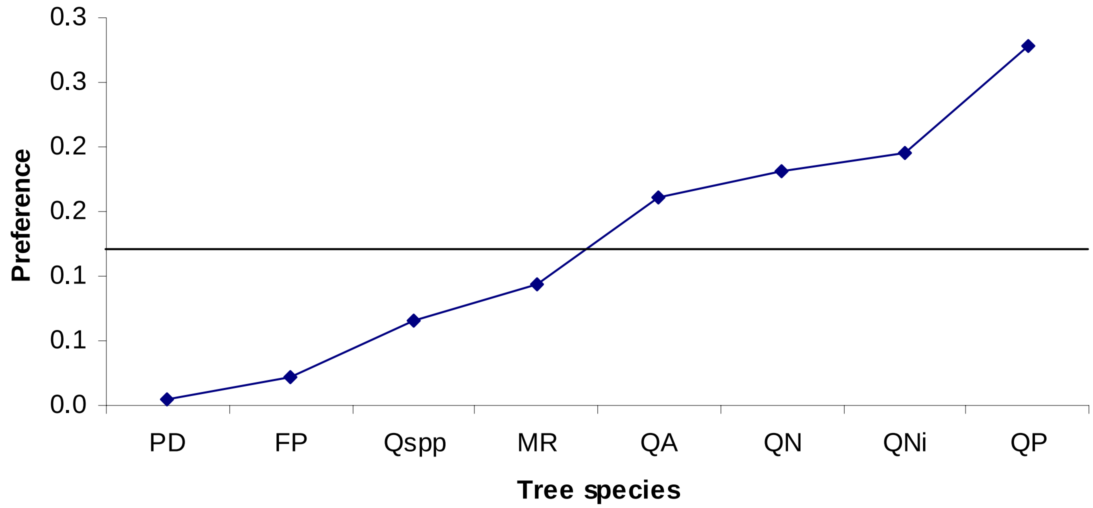


Figure 3.15. Manley's alpha selectivity index[1] for relative selection of tree species[2] by all mammals at Greenville, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2]FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3] *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]spp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

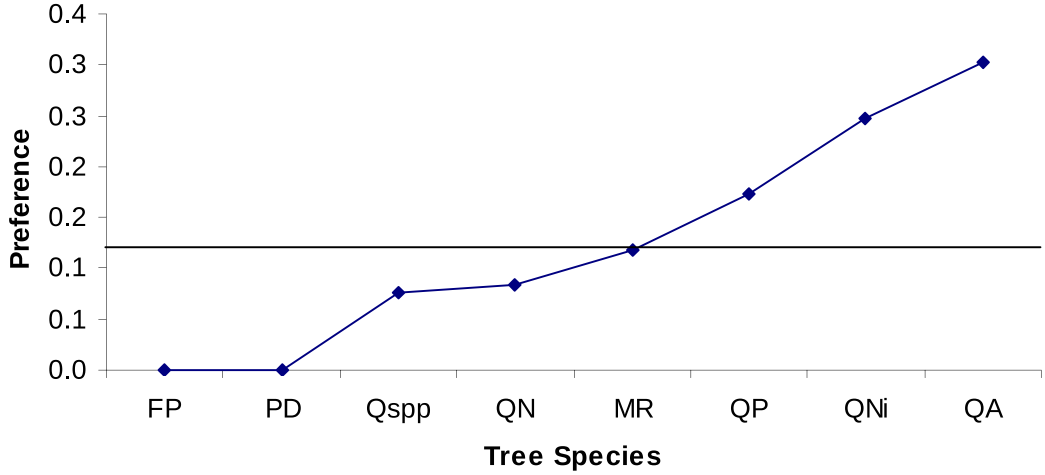


Figure 3.16. Manley's alpha selectivity index[1] for relative selection of tree species[2] by hispid cotton rats at Greenville, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

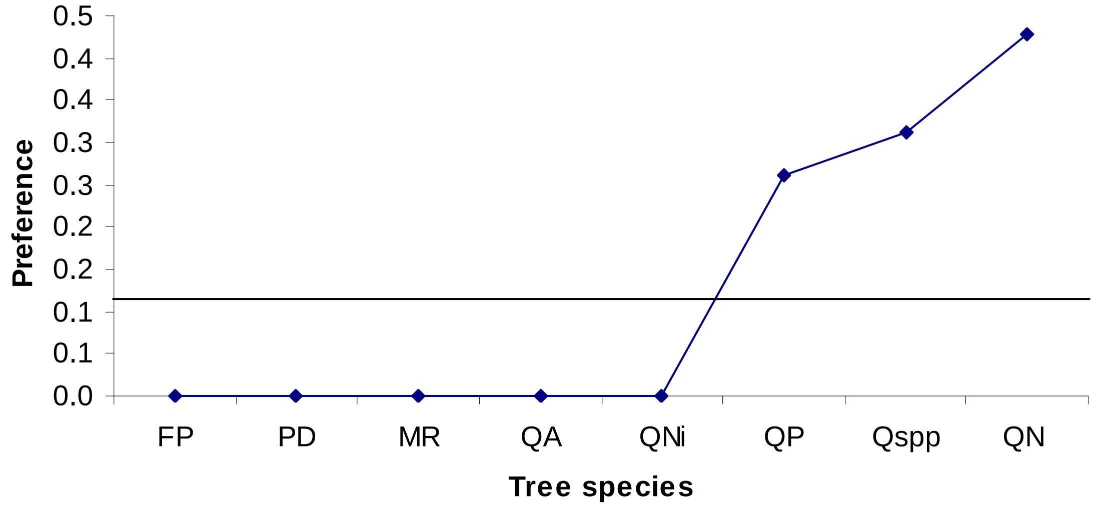


Figure 3.17. Manley's alpha selectivity index[1] for relative selection of tree species[2] by pine voles at Greenville, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

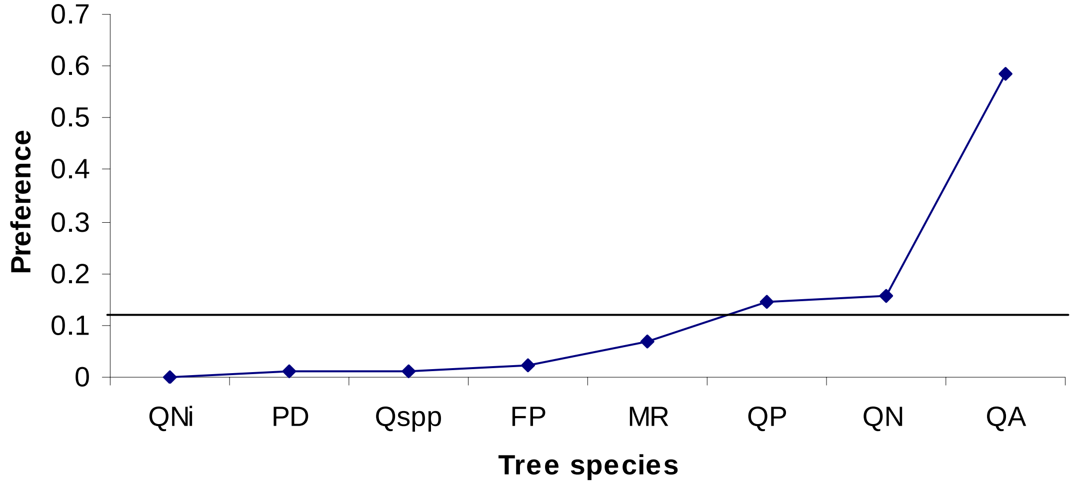


Figure 3.18. Manley's alpha selectivity index[1] for relative selection of tree species[2] by rabbits at Greenville, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

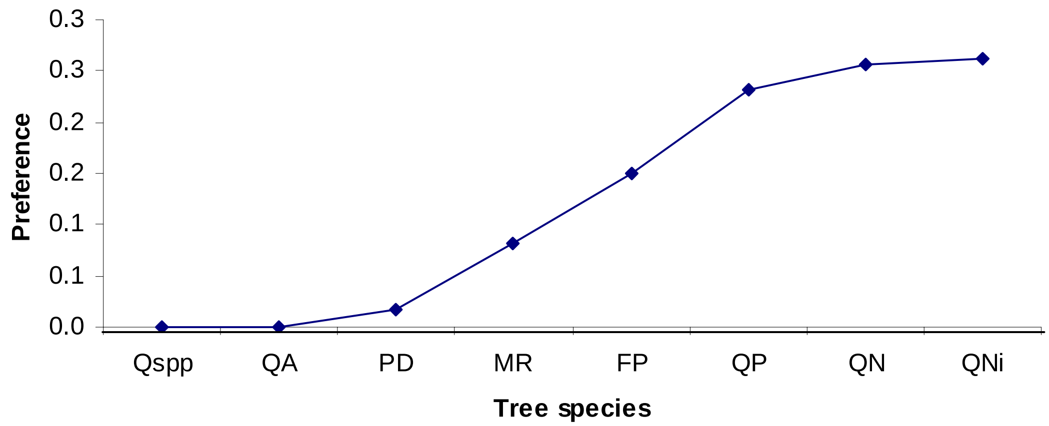


Figure 3.19. Manley's alpha selectivity index[1] for relative selection of tree species[2] by white-tailed deer at Greenville, MS study site, 2006-2007.

[1] Tree species above the preference line were selected more often than would be expected at random and species below the line were less often than would be expected at random.
[2] FP-*Fraxinus pennsylvanica*, PD- *Populus deltoides*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[3]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[3]Qspp- Seedlings known to be oak but could not be identified to species due to age, mortality, or decomposition.

CHAPTER IV

DISCUSSION

Treatment Effects on Seedling Survival

Overall seedling survival at both sites was poor; rates were 36.0% and 34.0% for Cleveland and Greenville, Mississippi, respectively. Factors such as interspecific competition and mammalian herbivory potentially contributed to poor survival. The findings of my study are similar to those reported by James (2001) for afforestation attempts in the LMAV of the southeastern United States.

Sites at Cleveland and Greenville were dominated by non-native vegetation, such as Johnsongrass and tall fescue. No site preparation (subsoiling) was performed at either site due to logistical limitations (underground piping) at the Delta Steam Electric Generation Station in Cleveland. When data were combined for both sites, eastern cottonwood had the least survival at 8.4%. These results are consistent with observations reported on seedlings planted in areas that lacked adequate site preparation and competition control (Personal comm.. A. Ezell, Department of Forestry, Mississippi State University). Furthermore, poor survival of cottonwood was potentially due to compounding factors other than herbivory including species response to environmental conditions. During this study, only one eastern cottonwood (n = 191) died from herbivory. Robison et al. (2006) stated that complete control of competing vegetation was essential when establishing eastern cottonwood stands due to its low tolerance of shade. Johnsongrass was a major vegetative component at Greenville study site. Stanturf and Portwood (1999) listed Johnsongrass as a serious deterrent to eastern cottonwood stand establishment. Implementation of proper site preparation would likely enhance survival of eastern cottonwood cuttings considering they were less affected by herbivory than *Quercus* seedlings.

With data combined from both sites, green ash seedlings had survival of >80.0%. These results are consistent with the results reported from Ezell and Shankle (2004) and Sumerall (2007). Green ash is an early successional species that is adapted to colonizing old field habitats. Clatterbuck (1999) found that green ash was a tenacious species and continued to resprout and grow even when affected by the fungi, *Fuslcoccum* spp., mowing and deer rubbing. Groniger and Babassana (2002) stated that green ash seedlings had 95.0% survival (n = 60) by the end of a two-year study.

With data combined from both sites, 40.8% of red mulberry seedlings survived in my study, which was among the least survival rates for an individual tree species. Sumerall (2007) reported greater survival from red mulberry at 60.0%. Sumerall (2007) also reported red mulberry as a prolific resprouter. Waldrop et al. (1984) found that red mulberry is a prolific sprouter and produced on average 6.2 sprouts per cut stem. I also recorded large numbers of resprouts of red mulberry on both sites (n = 40). This species possibly could have greater survival rates if competition from surrounding vegetation had been decreased. Greater survival rates for red mulberry recorded by Sumerall (2007) were potentially related to the fact that my surveys were conducted an additional year after Sumerall (2007) completed his survival studies. I submit that longer duration of monitoring may reveal more information on survival rates of planted seedlings, such as red mulberry (Schoenholtz et al. 1999). Therefore, I recommend 5 to 6 years of post-planting monitoring for adequate assessment of seedling survival on LMAV sites.

A total of 380 oak seedlings were selected for the study of which 134 were not identifiable to species due to decomposition, lack of identifiable characteristics, or herbivory. Of 380 oaks, 156 (41.0%) survived during the study. Survival of water oak seedlings was 72.0%, however, due to the small sample size (n = 25), it was difficult to conclude that this was a representative survival rate for this species. Nuttall seedling survival was 68.0% with a sample size of 128 from both sites combined. Willow oak seedlings had 68.0% survival with a sample size of 86.

Studies conducted by Ezell and Shankle (2004) found that proper site preparation and competition control can produce oak seedling survival rates of > 90.0% during years with sufficient rainfall. Also, Ezell and Hodges (2002) found that failure to remove competing vegetation can cause almost complete mortality for oak seedlings. By using effective herbaceous weed control, survival of oak seedlings during the first year post-planting can be increased as much as 44.0% (Ezell et al. 2007). Due to the absence of site preparation at both study sites**,** survival of oak seedlings was potentially less than what could have been achieved if site preparation had been used. Ezell and Shankle (2004) found that agricultural and old field sites developed unfavorable soil conditions for hardwood seedlings after decades of cultivation and grazing had compacted soil. Ezell and Shankle (2004) stated that site preparation by subsoiling can have a positive effect on seedling survival, because increased growth rates lead to a shorter period of time in which seedlings are vulnerable to herbivory. However, my study did not investigate different site preparation techniques. This study was a component of a larger study that was designed two years prior to my study's implementation. Therefore, I recommend that future studies be designed in a manner that can evaluate site preparation and vegetation control measures in bottomland hardwood afforestation sites.

Herbivory

Herbivory by Four Herbivorous Mammals

I found that selected herbivores exhibited non-random patterns of foraging among tree species. A combination of foraging data by all herbivores from three sample periods (spring, summer, and fall) showed that certain tree species were more likely to be fed upon than others. When data for herbivore species were analyzed separately, each showed a different preference for specific species of seedlings. In the context of this analysis, I defined the term "preferred" as a tree species that was foraged on at a greater rate than would be expected by random selection by herbivores according to methods defined by the Kolmogorov-Smirnov Test (STATISTIX, 2000). In results by season, which included ten analyses, all herbivores combined exhibited foraging preferences for Nuttall and willow oaks in seven of the ten analyses, and red mulberry was preferred in five of the ten analyses. Seedling species that were not selected as frequently as would be expected by random selection by herbivores included green ash (not preferred in any analysis), eastern cottonwood (not preferred in eight analyses), and water oak (not preferred in six analyses).

Eastern cottonwood had one seedling mortality related to herbivory. Green ash seedlings had only three seedling deaths that could have been related to herbivory from 101 seedlings on both study sites. These two species were not preferred by herbivores evaluated in this study. Schoenholtz et al. (1999) found that oak seedlings were at risk of herbivory soon after planting and that most damage and mortality was attributed to rodents. Water oak seedlings had only three herbivory-related deaths, but 23 recorded cases of herbivory damage. Nuttall seedlings had 19 herbivory-related deaths and 81 cases of herbivory damage. Willow oak seedlings had 21 herbivory-related deaths and 46 cases of herbivory damage. Foraging preferences were not detected for water, Nuttall, and willow oaks when analyses of herbivory from all four herbivore species were pooled; however, nonrandom foraging patterns were detected for these tree species when analyses were conducted on data for individual herbivore species over all seasons combined.

Cotton Rat Herbivory

Hispid cotton rat populations can fluctuate over time ranging from 28-373 animals/ha, and greatest amounts of herbivory damage can occur during population peaks (Cameron and Eshelman 1996). Hispid cotton rats are known to damage many different types of crops including alfalfa, grains, grasses, vegetables, peanuts, sugar cane, and sweet potatoes (Cameron and Spencer 1981, Clark 1986). Romero et al. (1978) found that cotton rats inflict a great deal of damage to Honduran sugar cane fields. Although herbivory from cotton rats and subsequent damage to oak seedling has not been studied to a great extent, findings of this study indicate that these rodents can have a negative impact on tree seedling survival. For example, I found that when data were combined across seasons by individual herbivores, hispid cotton rats preferred water oak over all other species. Furthermore, hispid cotton rats damaged 48.0% of water oak seedlings (*n* = 25).

Vole Herbivory

In Great Britain, voles have been known to cause 100% seedling loss over 9.3 ha and 41% losses over 81 ha (Gosling 1933). Ostfeld and Canham (1993) reported than in southeastern New York, 80% of red maple and white ash seedlings had been killed by voles within one month after planting. Power et al. (1996) stated that voles are a keystone species and contribute to shaping plant communities and ecosystems. My findings indicated that pine voles selected for Nuttall oak and willow oak more than other tree species included in the study. Although vole damage was not as extensive during my study as was documented by other researchers, pine voles damaged 16.4% of Nuttall oak (*n* = 128) and 16.3% of willow oak (*n* = 86) seedlings. The most extensive vole damage reported in literature occurred in colder climates during winter when food was scarce thus leaving tree seedlings vulnerable to damage (Gosling 1933, Power et al. 1996).

Rabbit Herbivory

Geis (1954) recorded that cotton-tail rabbits (*Sylvilagus floridanus*) damaged or killed 89.0 % of 212 young oaks on the Kellogg bird Sanctuary in Battle Creek, Michigan. Dugger et al. (2004) reported 85.0% of oak seedlings (*n* = 2,367) had been clipped or girdled by cotton-tail rabbits in two years. My results indicated that rabbits preferred Nuttall oak seedlings over other species and that cotton-tails are more destructive than pine voles, but mortality at my sites was less than other researchers have reported. Nuttall oak (*n* = 128) experienced 21.9% herbivory from rabbits. As with vole damage, extensive rabbit damage also occurred in regions with harsh winters that restrict amounts of other foods and leaves seedlings vulnerable to damage (Geis 1954).

White-tailed Deer Herbivory

Small mammals cause a variety of damage to planted seedlings, but they are often considered less damaging than deer (Gill 1992). This conclusion is not supported by my results. Deer did not have access at the Cleveland study sites, because it was surrounded by a deer proof fence. I submit that this fencing contributed to low herbivory rates by deer on this site. However, I recorded deer herbivory of seedlings at the Greeneville site. I found that white-tailed deer preferred Nuttall, willow, and water oaks. White-tailed deer damaged 21.1% of Nuttall oaks (*n* = 128), 12.8% of willow oaks (n=86), and 36.0% of water oaks (*n* = 25). My findings were similar to those reported by Holladay et al. (2006). I hypothesized that seedling heights was a factor in herbivory by deer during my study. Miller et al. (1982) stated that browse susceptibility of seedlings depends on their height in relation to height of surrounding vegetation. During most of my study, vegetation overtopped seedlings, and they did not grow above other vegetation until the end of the study, which is when most herbivory by deer occurred.

Mowing vegetation to a low height can limit small mammals from inhabiting planted areas. Cameron and Spencer (1983) found that cotton rats preferred patches with shrubs present, and they found that removal of shrubs decreased the population of hispid cotton rats. Ostfeld et al. (1997) found that voles and hispid cotton rats preferred a dense herbaceous layer and fed more readily in densely vegetated areas**,** because cover decreased risk of predation. Other studies have suggested that browsing by white-tailed deer increases as herbaceous cover decreases**,** because seedlings become more apparent (Buckley et al. 1998, Castleberry et al. 2000, and Dubois et al. 2000). However, hypotheses have been advanced that submit that seedlings were more resistant to deer browsing than clipping by small mammals (Stange and Shea 1998). Decreasing vegetative cover will likely increase growth of hardwood seedlings, allowing them to reach heights above browsing level (Kormanik et al. 2002).

Tree shelters are known to protect seedlings from browsing, improve survival and accelerate height growth (Clatterbuck 1999). However, no tree shelters were used during this study. This practice is a viable option for herbivory deterrence, although the cost is likely to be prohibitive for large-scale afforestation projects (Allen and Boykin 1991, Graveline et. al. 1998).

Much of the damage and mortality that I documented was on oak seedlings. Green ash and the remaining eastern cottonwood seedlings were avoided by herbivores. This may be due, in part, to their adaptive traits as early colonizers in early successional environments (Dickson 2001). Johnson and Burkhardt (1976) found natural eastern cottonwood stands containing thousands of stems per acre establish quickly and exhibit intraspecific competition though high genetic diversity among individuals. This colonization approach enables particular trees to out compete their cohorts by accelerated growth. This strategy of accelerated growth could possibly limit amounts of herbivory**,** because stem size would be too large to be consumed by smaller rodents.

Seedling mortality may have resulted from several causes including herbivory, drought, planting error, seedling quality, and competition with other vegetation. Ezell et. al. (2004) found that variables such as seedling quality, planting quality, and herbaceous control**,** must be addressed if high survival is desirable. Oak seedlings should preferably be no smaller than 12.7 mm diameter and 45.7 cm height (A. Ezell, Mississippi State University, Personal communication). Many of the oak seedlings planted at my study sites were lower quality planting stock. Average diameters and heights, respectively, at the time of planting for species in question are as follows: eastern cottonwood 23.1 mm and 24.9 cm, green ash 21.2 mm and 112.7 cm, Nuttall oak 13.6 mm and 109.8 cm, water oak 11.5 mm and 95 cm, willow oak 10.9 mm and 88.8 cm, and red mulberry 9.4 mm and 135.2 cm. (Sumerall 2007). Although height seemed sufficient, diameter was below or close to being below recommended size. Seedling quality is related to seedling survival. Smaller diameter seedlings were likely to be more susceptible to cutting by smaller herbivores. Planting methods were not of high quality. I observed many eastern cottonwood cuttings planted in an inverted position. In the past this planting problem has been documented by Clewell and Lea (1990) and Kennedy (1993). Also, seedlings were planted during a drought year, and it is known that sufficient rainfall is necessary for high survival of oak and cottonwood seedlings (Jones 1995). Rainfall amounts during 2005 were below average (< 114 cm) on Greenville and Cleveland sites (Mississippi State University Department of Geosciences, 2009). I submit that drought periods of 2005 during the first growing season could have negatively impacted seedling survival. Furthermore, it has been found that by using proper herbicides, oak survival can be increased during drought years by reducing the competition for available soil moisture (Ezell et al. 2007). In years of average rainfall, herbicide treatments can increase expected survival by 25%, during drought years these techniques may increase survival by 40%, and during extreme drought years these techniques may increase survival by 75% (Ezell et al. 2007).

Many studies have evaluated survival of hardwood seedlings. Krinard and Kennedy (1987) observed 69-97% survival rates of their seedlings in the LMAV. Despite successes, many afforestation attempts have been unsuccessful (James 2001). Schweitzer et al. (1999) found that only 23% of the land planted with one-year nursery stock of bareroot seedlings had at least 100 trees/0.404 ha. after three growing seasons. The goal of most planting programs is to have at least 309 trees/ha surviving after three growing seasons (Schoenholtz et. al.1999).

During my study, survival rates of tree seedlings were < 50% for any treatment regime. Herbicide and fertilizer treatments usually enhanced seedling survival, but I observed only one case where herbicide and/or fertilizer treatments had greater survival than control plots (Miller 1993, Ezell 1995). Several explanations may be offered for this result. Plot spacing was an inadequate distance to ensure that fertilizer did not enter control plots during heavy rainfall events (Binkley et al. 1999). Therefore, from a treatment standpoint, the plots were not independent and fertilizer effects were not isolated in individual plots. If this was the case, the mortality rates that were detected in my study may have been influenced among treatment regimes. Across all four treatment regimes mortality rates were similar and ranged from 53-74%. Other vegetation may have benefited from fertilizer and, as a result, negatively influenced seedlings. Also, the herbicide used in this experiment was chosen because of its compatibility with eastern cottonwood. Eastern cottonwood establishment is a rigorous proposition. Once it has been established, oak seedlings can be inter-planted after the second growing season (A. Ezell, Personal communication). Both of these seedlings require different herbicides to effectively control competing vegetation, and as mentioned earlier vegetation control is a key component when establishing both oak and cottonwood seedlings. The optimal herbicide used for controlling vegetation in many oak plantings is *OustXP* **®** but it will harm cottonwood seedlings (Ezell and Hodges 2002). The only broadleaf herbicide that can be applied over top both cottonwood and oak is *Goal2XL* **®.** This herbicide is primarily effective in reducing broadleaf herbaceous plants whereas, *Oust XP* **®** is capable of controlling both broadleaf forbs and grasses. In this study, grasses were Johnsongrass, bermudagrass, Fescue, and Sedges.

Vegetation Sampling

Competition from herbaceous vegetation has traditionally been a problem in old field plantings of hardwoods (McCormick and Bowersox 1997). Common broomsedge (*Andropogon virginicus*) was the only plant species that had a significant effect on herbivore damage to tree seedlings damage and tree survival. In summer 2006, seedling mortality and damage was related negatively to increased coverage of broomsedge (i.e., increased coverage caused increased survival of seedlings). In contrast, Rice (1972) found that common broomsedge is known to compete vigorously with surrounding vegetation. Although broomsedege does compete with surrounding vegetation, it is a bunch grass and it does not overtop and shade out seedlings as do vines and shrubs (Miller and Miller 1999). Some studies have found that hispid cotton rats prefer dense cover (Ostfeld et al. 1997; Schnurr et. al. 2004). Common broomsedge on my sites provided dense ground cover for hispid cotton rats without shading out seedlings. According to Miller and Miller (1999) and Randolph et al. (1991), broomsedge is a desired summer food of hispid cotton rats. Areas that provide dense coverage of common broomsedge could fulfill the dietary needs of hispid cotton rats providing an alternative food source that might limit herbivory of seedlings. Conversely, areas with dense coverage of invasive agronomic grasses such as Johnsongrass do not provide sufficient dietary needs of hispid cotton rats. Both Johnsongrass and broomsedge exert allelopathic control on the growth of seedlings and, shade out seedlings, unlike native bunch grasses such as broomsedge (Putnam and Tang 1986). Old field sites that are not dominated by agronomic grasses and contain native grasses, such as bluestems and bunch grasses, provide excellent habitat for cotton rats, rabbits and other small mammals (Yarrow and Yarrow 1999). Areas dominated by native vegetation provide food plants for herbivores, such as voles and cotton rats, in areas planted to hardwood seedlings.

Several vegetation forms had significant effects on seedling damage and survival. Coverage of woody and herbaceous vines**,** such as peppervine (*Ampelopsis arborea*), yellowjasmine (*Gelsemium sempervirens*), blackberry (*Rubus* spp.) and Japanese honeysuckle (*Lonicera japonica*), influenced the seedling damage by herbivores during spring and summer periods. During spring, greater coverage of woody vines was associated with greater mortality and damage in tree seedlings. Dillenburg et al. (1993) found that root competition associated with vines had the greatest negative effect on tree seedling survival. Damage to seedlings from herbivores in woody plant cover was variable during different seasons. During summer, seedling damage was less extensive in dense coverage of woody vines than in spring and fall. Similar findings have been reported by Wilson and Shure (1993) who found that removal of shrubby vegetation increased growth of black locust seedlings. During spring, I detected less tree seedling damage and mortality in denser coverage of woody vegetation; whereas, seedling damage and mortality was greater in areas with greater coverages of woody vegetation during summer. Additionally, tree seedling mortality increased with greater percent coverage of bare ground and legumes during spring.

Management Implications

Except for tree shelters and herbicide application, there are few modern hardwood afforestation methods to deter mammalian herbivores (A. Ezell, Personal communication). There are several methods which may lessen herbivore damage. Throughout this study as seedlings grew, herbivory from small mammals decreased. Stem size increased and seedlings were not available as a food source. However, as seedlings grew larger they were more accessible to foraging and fraying by white-tailed deer. Gill (1992) found that vulnerability to herbivory damage differed among tree species and damage occurs within certain age and size classes. I found that some tree species were not selected as food by herbivores. By properly planting seedling mixtures of fast growing pioneer species that are not preferred by herbivores such as eastern cottonwood and green ash, will aid in afforestation success. Selection of these less palatable tree species could result in less damage to newly planted seedlings and greater tree survival over time. However, this approach could limit availability of hard and soft mast producing trees for wildlife in later successional stages (Yarrow and Yarrow 1999). In many cases, tree species undesirable to small mammalian herbivores do not produce hard mast needed for many forest dwelling wildlife species (Yarrow and Yarrow 1999).

Small mammals have been successfully controlled with pesticides in the past; however, impacts to non-target species and pollution of ground and surface water are issues associated with this approach (Jorgensen and Fredrica 1992). Furthermore, many non-target animals that might be impacted negatively by pesticides are predators of small herbivorous mammals (Conover 2002). Rodent control also can be achieved with methods described by Radvanyi (1980).

Natural predators also may be used to control small mammal populations. In the past, sugarcane farmers in Florida have used artificial boxes to attract barn owls (*Tyto* alba) to sugarcane fields (Colvin 1986). Barn owls consume black rats (*Rattus* rattus) that destroy crops. Colvin (1986) found that one barn owl can consume as many as 1,000 rodents including voles and cotton rats in one year. This approach could reduce small mammal herbivores in early successional afforestation sites of the Mississippi River Delta.

Quality tree seedlings and planting coupled with proper site preparation techniques, such as subsoiling and herbicide application, could potentially provide desirable results in the form of herbivory reduction and survival of seedlings. Areas that have been grazed or farmed previously are usually compacted and would benefit from subsoiling procedures. Proper planting of quality seedlings (12.7 mm in diameter, 45.7 cm in height) combined with the correct herbicides tailored to the species being planted and competition at the planting site will likely contribute to seedling survival through reduced herbivory and reduced competition. As the locations of planting sites change so will the prescription of tree species to be planted, and the species of herbivores will differ between habitats. Because of these site variations there is no magic species mix that will deter herbivory. Each herbivore discussed in this paper preferred a different tree species in which to feed, but to feed, small mammals need cover. If herbicides are used correctly, cover could be reduced, and in turn, herbivory should decrease. When the large seedling size is combined with herbicide application it could provide a smaller window of time in which herbivores can damage seedlings.

Study Design Improvements

There are many ways in which this study could be improved. This research was conducted as a part of a larger study so the over all design could not have been changed for my research. Examples of the overall design that would have been better changed are as follows: quality seedlings, quality planting, correct herbicides, and tree mixes. Tree mixes were composed of several seedling species that react differently to different herbicides, so compromise had to be made for the type of herbicide chosen. Species of seedlings planted should have all been compatible with the best herbicide available for use in controlling selected vegetation. The estimates of herbivory preference could have been improved if an equal number of seedling species had been chosen for sample sizes. Due to the previously set experimental design, different species mixtures occurred in different treatment plots. Additionally, high levels of vegetative growth and inabilities to locate seedlings during all sampling periods produced challenges in setting and retaining equal numbers of tree seedlings during the study. Cotton rat populations could have been better defined in terms of density, but my marking techniques did not allow me to identify individual cotton rats that were captured over time. Each cotton rat should have been marked individually using toe clipping or ear tags, so that date of capture on a monthly basis could have been determined (Davis 2000). If proper marking techniques had been used, program CAPTURE could have been used to accurately estimate population size on a per hectare basis (Davis 2000).

Seedling Herbivory Extrapolation

I estimated seedling mortality and damage from herbivores on all planted trees at my study sites from 2006–2007. By projecting herbivory rates from my sample (n = 868) onto the entire population of planted seedlings (n = 15,696) I could potentially be able to provide an estimate of total amount of damage within the entire afforestation area. At the Cleveland site, my calculations indicated that a possible 872 seedlings died of herbivory and 1,544 seedlings were possibly damaged by herbivory (n = 7,848). At Greenville, 1,026 seedlings may have died of herbivory and 1,962 were possibly damaged by herbivory (n = 7,848).

LITERATURE CITED

Alder, G.H. 1985. Habitat selection and species interactions: an experimental analysis with small mammal populations. Oikos 45: 38-39.

Allen, J.A. and R. Boykin. 1991. Tree shelters help protect seedlings from nutria (Louisiana) Restoration Management Notes 9(2): 122-123.

Bang, P. and P. Dahlstrom. 1982. Collins guide to animal tracks and sign. Collins, London, UK.

Binkley, D., H. Burham, and H.L. Allen. 1999. Water quality impacts of forest fertilization with nitrogen and phosphorus. Forest Ecology 121: 191-213.

Buckley, D.S., T.L. Sharik, and J.G. Isebrands. 1998. Regeneration of northern red oak: positive and negative effects of competitor removal. Ecology 79: 65-78.

Cadenasso, M.L.and S.T.A. Pickett. 2000. Linking forest edge structure to edge function: mediation of herbivore damage. Journal of Ecology 88: 31-44.

Cameron, G.N. and R.D. Eshelman. 1996. Growth and reproduction of hispid cotton rats (*Sigmodon hispidus*) in response to naturally occurring levels of dietary protein. Journal of Mammalogy 77(1): 220-231.

Cameron, G.N. and S.R. Spencer. 1981. *Sigmodon hispidus*. Mammal Species 158: 1-9.

Cameron, G.N. and S.R Spencer.1983. Behavioral dominance and its relationship to habitat patch utilization by the hispid cotton rat (*Sigmodon hispidus*). Behavioral Ecology and Sociobiology 13: 27-36.

Castleberry, S.B., W.M. Ford, K.V. Miller, and W. P. Smith. 2000. Influence of herbivory and canopy opening size on forest regeneration in a southern bottomland hardwood forest. Forest Ecology and Management 131: 57-64.

Clark, J.P. 1986. Vertebrate pest control handbook. California Department of Food and Agriculture, Sacremento, California, USA.

Clatterbuck, W.K. 1999. Effects of tree shelters on growth of hardwood seedlings after seven growing seasons. Tenth Biennial Southern Silvicultural Research Conference, Shreveport, Louisiana, February 16-18, 1999.Clewell, A.F. and R. Lea. 1990. Creation and restoration of forested wetland vegetation in the southeastern United States. Pages 195-232 *in* J. A. Kusler and M. E. Kentula, editors. Wetland creation and restoration: the status of the science. Island Press, Washington, D.C., USA.

Colvin, B.A. 1986. Barn owls: their secret habits. Illinois Audubon 216: Spring 1986.

Conover, M. 2002. Resolving human-wildlife conflicts. The science of wildlife damage management. CRC Press LLC, Boca Raton, Florida,USA.

Conover, W. J. 1980. Practical nonparametric statistics. Second edition. John Wiley and Sons, New York, New York, USA.

Conway, C.H., K.C. Sadler, and D.H. Hazelwood. 1974. Geographic variation in litter size and onset of breeding in cottontails. Journal of Wildlife Management 38: 473-481.

Cooper, C.F. 1983. Carbon storage in managed forests. Canadian Journal of Forest Research 13: 155-166.

Davis, E.D. 2000. Handbook of census methods for terrestrial vertebrates. CRC Press. Pages. 178-179.

Dickson, J.G., editor. 2001. Wildlife of southern forests: habitat and management. Hancock House Publishers, Blaine, Washington, USA.

Dillenburg, L.R., D.F. Whigham, A.H. Teramura, and I.N. Forseth. 1993. Effects of below and aboveground competition from the vines *Lonicera japonica* and *Parthenocissus quinquefolia* on the growth of the tree host *Liquidambar styraciflua*. Oecologia 93: 48-54.

Dubois, M.R., A.H. Chappelka, E. Robbins, G. Somers, and K. Baker. 2000. Tree shelters and weed control: effects on protection, survival and growth of cherrybark oak seedlings plated on a cutover site. New Forests 20: 105-118.

Dugger, S., D.C. Dey, and J.J. Milspaugh. 2004. Vegetation cover affects mammal herbivory on planted oaks and success of reforestation on Missouri River bottomland fields. Page 594 *in* Proceedings of the 12th biennial southern silvicultural research conference. Connor, Kristina F. editor. U.S. Department of Agriculture, Forest Service, Southern Research Station General Technical Report SRS-71, Asheville, North Carolina, USA.

Elbroch, M. 2003. Mammal tracks and sign: a guide to North American species. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Ezell, A.W. 1995. Importance of early season competition control in establishing eastern cottonwood (*Populus deltoides*) plantations. Pages 94-97 *in* Proceedings of the 8th biennial southern silvicultural research conference. M.B. Edwards, editor. U.S. Department of Agriculture, Forest Service, Southern Research Station General Technical Report SRS-1, Asheville, North Carolina, USA.

Ezell, A.W., J.D. Hodges, and A.J. Londo. 2004. Understanding difference between hardwood and conifer management. Tree Farmer 23 (2): 6-9.

Ezell, A.W. and J.D. Hodges. 2002. The importance of competition control for restoration of oaks in the Southern United States. Pages 134-136 *in* Proceedings of IUFRO conference on restoration of boreal and temperate forests. Gardiner, E.S.; Breland, L.J., comps. Documenting forest restoration knowledge and policies in boreal and temperate ecosystems. Danish Centre for Forests, Landscape and Planning Report No. 11.

Ezell, A.W. and M.W. Shankle. 2004. Effects of subsoiling and competition control on first year survival and growth of four hardwood species. Pages 571-573 *in* Proceedings of the 12th biennial southern silvicultural research conference. U.S. Department of Agriculture, Forest Service, Southern Research Station General Technical Report SRS-71, Asheville, North Carolina, USA.

Ezell, A.W., J.L. Yeiser, and L.R. Nelson. 2007. Survival of planted oak seedlings is improved by herbaceous weed control. Weed Technology 21(1): 175-178.

Fleharty, E.D., and L.E. Olson. 1969. Summer food habits of *Microtus ochrogaster* and *Sigmodon hispidus.* Journal of Mammalogy 50: 475-486.

Geis, A.D. 1954. Rabbit damage to oak reproduction at the Kellogg Bird Sanctuary. Journal of Wildlife Management 10: 423-424.

Gill, R.M. 1992. A review of damage by mammals in north temperate forests: I Deer. Forestry 65:2.

Goertz, J. W. 1964. The influence of habitat quality upon density of cotton rat populations. Ecological Society of America. 34:359-381.

Goertz, J.W. 1965. Reproductive variation in cotton rats. The American Midland Naturalist 74: 329-340.

Gosling, A.H. 1933. Damage by voles. Journal of Forest Communication 12: 66-68.

Graveline, B.D., G.R. Wells, S.E. Schlarbaum, and H.A. Fribourg. 1998. Growth and protection of selected northern red oak seedlings planted on old field sites. Pages 257-262 *in* Proceedings of the 9th biennial southern silvicultural research conference. T. A. Waldrop, editor. U.S. Department of Agriculture, Forest Service, Southern Research Station General Technical Report SRS-20, Asheville, North Carolina, USA.

Groninger, J.W. and D.A. Babassana. 2002. Accelerating planted green ash establishment on an abandoned soybean field. Pages 270-272 *in* Proceedings of the 11th biennial southern silvicultural research conference. U.S. Department of Agriculture, Forest Service, Southern Research Station General Technical Report SRS-48.

Hanson, J.C., J.A. Bailey, and R.J. Siglin. 1969. Activity and use of habitat by radio-tagged cottontails during winter. Transactions of the Illinois State Academy of Science 62: 294-302.

Hanson, L. and J. Zejda. 1977. Plant damage by bank voles (*Clethrionomys glareolus Schreber*) and related species in Europe. EPPO Bulletin 7: 223-242.

Hayes, R., L.C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Fish and Wildlife Service, United States Department of the Interior., Washington, D.C., USA.

Heisey, D.M. 1985. Analyzing selection experiments with log-linear models. Ecology 66:1744-1748.

Holladay, C.A., C. Kwit, and B. Collins. 2006. Woody regeneration in and around aging southern bottomland hardwood forest gaps: effects of herbivory and gap size. Forest Ecology and Management 223: 218-225.

Holloway, C.W. 1967. The effect of red deer and other animals on naturally regenerated scots pine. Thesis, University of Aberdeen, Aberdeen, Scotland.

James J.P. 2001. Afforestation of bottomland hardwood forests in the lower Mississippi Alluvial Valley: trends, planting techniques, and monitoring recommendations. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Johnson, R.L. and E.C. Burkhardt. 1976. Natural cottonwood stands-past management and implications for plantations. Pages 20-29 *in* Bart A. Thielges and Samuel B. Land, Jr., editors. Proceedings of the symposium on eastern cottonwood and related species. Sept. 28-Oct. 2, 1976, Greenville, MS. Southern Forest Experiment Station, New Orleans, Louisiana, USA.

Jones, J.C. 1995. Vegetative succession, edaphic characteristics and annelid densities on reclaimed disposal areas of the Tennessee-Tombigbee Waterway. Dissertation, Mississippi State University, Mississippi State, Mississippi, USA..

Jorgensen, P.R. and J. Fredricia. 1992. Migration of nutrients, pesticides, and heavy metals in fractured clayey till [Agricultural sites and analysis of clay reveal effect of fractures on permeability of clay and transport of pesticides through ground water flow]. Geotechnique 42: 67-77.

Kennedy, H.E., Jr. 1993. Artificial regeneration of bottomland oaks. Pages 241-249 *in* Oak regeneration: serious problems, practical recommendations. Oak Regeneration Symposium, Knoxville, Tennessee, September 8-10, 1992. D. L. Loftis and C. E. McGee, editors. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station General Technical Report SE-84, Asheville, North Carolina, USA.

Kincaid, W.B. and G.N. Cameron. 1982. Dietary variation in three sympatric rodents on the Texas coastal prairie. Journal of Mammalogy 63: 668-672.

Kormanik, P.P., S.S. Sung, D. Kass and S.J. Zarnoch. 2002. Effect of seedling size and first-order lateral roots on early development of northern red oak on a mesic site: eleventh-year results. Pages 332-337 *in* Proceedings of the 11th biennial southern silvicultural research conference. U.S. Department of Agriculture, Forest Service, Southern Research Station General Technical Report SRS-48..

Krinard, R.M. and H.E. Kennedy. 1987. Fifteen-year growth of six planted hardwood species on Sharkey clay soil. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station Forestry Research Note SO-336, New Orleans, Louisiana, USA.

Kutner, M.H., C.J. Nachtsheim, and J. Neter. 2004. Applied linear regression models. Fourth edition. McGraw Hill, New York, New York, USA.

Levin, S. A. 1992. The problem of pattern and scale in ecology. Ecology 73:1943-1976.

Lidicker, W.Z., editor, 1995. Landscape approaches in mammalian ecology and conservation. University of Minnesota Press, Minneapolis. USA.

Lima, S.L. and L.M. Dill. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology 68: 619-640.

Lord, R.D. Jr. 1963. The cottontail rabbit in Illinois. Technical Bulletin III. Illinois Department of Conservation 94.

Loyttyniemi, K. and N. Piisila. 1983. Moose (*Alces alces*) damage in young pine plantations in the forestry board district Uusimaa-Hame. Folia Forestalia 553.

Margaret, S.D., B.R. Parresol, and S.P. Winston. 2001. The effects of herbivory by white-tailed deer and additionally swamp rabbits in an old-growth bottomland hardwood forest. Pages 49-64 *in* U.S. Department of Agriculture, Forest Service, Southern Research Station General Technical Report SRS 42, Asheville, North Carolina, USA.

Manson, R.H., R.S. Ostfield, and C.D. Canham. 1999. Responses of a small mammal community to heterogeneity along forests-old-field edges. Landscape Ecology 14: 355-367.

M'Closkey, R.T. and B. Feldwick. 1975. Ecological separation of sympatric rodents (*Peromyscus* and *Microtus*). Journal of Mammalogy 56: 119-129.

McCormick, L.H. and T.W. Bowersox. 1997. Grass or fern competition reduce growth and survival of planted tree seedlings. Pages 286-293 *in* Proceedings of the 11th central hardwood forest conference. Pallardy, Stephen G.; Cecich, Robert A.; Garrett, H. Gene; Johnson, Paul S., editors. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station General Technical Report NC-188, St. Paul, Minnesota, USA.

Meiners, S.J. and M.J. Martinkovic. 2001. Survival of and herbivore damage to a cohort of *Quercus rubra* planted across a forest- old- field edge. The American Midland Naturalist 147: 247-255.

Miller, G.R., J.W. Kinnard, and R. P. Cummins. 1982. Liability of saplings to browsing on a red deer range in the Scottish Highlands. Journal of Applied Ecology 198: 194-195.

Miller, J.H. 1993. Oak plantation establishment using mechanical, burning, and herbicide, treatments. Pages 264-289 *in* Oak regeneration: serious problems, practical recommendations. Oak Regeneration Symposium, Knoxville, Tennessee, September 8-10, 1992. D. L. Loftis and C. E. McGee, editors. U.S.D.A. Forest Service, Southeastern Forest Experiment Station General Technical Report SE-84, Asheville, North Carolina, USA.

Miller, J.H. and K.V. Miller. 1999. Forest plants of the southeast and their wildlife uses. Southern Weed Science Society, Auburn, Alabama, USA.

Mississippi Museum of Natural Science. 2005. Mississippi's Comprehensive Wildlife Conservation Strategy. Mississippi Department of Wildlife, Fisheries and Parks, Mississippi Museum of Natural Science, Jackson, Mississippi, USA.

Mississippi State University Department of Geosciences, Office of the Mississippi State Climatologist, 2009. May 5. <http.www.msstate.edu/dept/geosciences/state climatologist.htm> Accessed May 5, 2009.

Morrison, D.F. 2005. Multivariate statistical methods, 4th edition. Brooks/Cole Thomson Learning, Inc. Belmont, California, USA.

Murica, C. 1995. Edge effects in fragmented forest: implications for conservation. Trends In Ecology and Evolution 10: 58-62.

Nakatsu, A. 1987. Yearly changes in the ratio and amount of damage caused by *Clerhrionomys rufocanus bodfordiae* to forest by tree species and age classes in the natural forests in Hokkaido. Annual report of the Hokkaido Branch Forestry and Forest Products Research Institute, Sapporo, Japan 67-72.

Ostfeld, R.S. and C.D. Canham. 1993. Effects of meadow vole population density on tree seedling survival in old fields. Ecology 74 (6): 1792-1801.

Ostfeld, R.S. R.N. Manson, and C. D. Canham. 1997. Effects of rodents on survival of tree seeds and seedlings invading old fields. Ecology 78 (5): 1531-1542.

Owens, K.E., D.D. Reed, A.J. Londo, A.L. Maclean, and G.D. Mroz. 1999. A landscape level comparison of pre-European settlement and current soil carbon content of a forest landscape in upper Michigan. Forest Ecology and Management 113:179-189.

Power, M.E., D. Tilman, J.A. Estes, B.A. Menge, W.J. Bond, L.S. Mills, G. Daily, J.C. Castilla, J. Lubchenco, and R. T. Paine. 1996. Challenges in the quest for keystones. BioScience 46: 609-620.

Putnam, A.R. and C. Tang. 1986. The science of allelopathy. John Wiley and Sons, New York, New York, USA.

Pusenius, J. and R.S. Ostfeld. 2000 Effects of stoat's presence and auditory cues indicating its presence on tree seedling predation by meadow voles. Oikos 91 (1): 123-130.

Radvanyi, A. 1980. Control of small mammal damage in the Alberta oil sands reclamation and afforestation program. Forestry Science 26: 687-702.

Randolph, J.C., G.N. Cameron, and J.A. Wrazen. 1991. Dietary choice of a generalist grassland herbivore, *Sigmodon hispidus.* Journal of Mammalogy 72: 300-313.

Robinson, T.L., R.J. Rousseau and J. Shang. 2006. Biomass productivity improvement for eastern cottonwood. Biomass and Bioenergy 30(3): 735-739.

Romero, A.G., G.T. Sandoval, J. Sernasecundino, and V.M.A. Ramirez. 1978. Damages caused by cotton rat, *Sigmodon hispidus zanjonensis*, on sugar cane in San Pedro Sula, Hoduras. Vertebrate Pest Conference Proceedings. Collection Proceedings of the 8th Vertebrate Pest Conference. University of Lincoln, Nebraska. 1978.

Rice E.L. 1972. Allelopathic effects of *Andropogon virginicus* and its persistence in old fields. American Journal of Botany 59 (7): 752-755.

Russell, F.L., D.B. Zippin, and N.L. Fowler. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations, and communities: a review. American Midland Naturalist 146: 1-26.

SAS Institute Inc. 2004. Base SAS 9.1 Procedures Guide. Version 9.1.2. SAS Institute Inc., Cary, North Carolina, USA.

Schloeth, R. 1968. Analysis of rubbing and fraying by red deer in an alpine habitat (Swiss National Park). Swiss Commission for Natural Sciences 11:75.

Schoenholtz, S.H., J.A. Stanturf, J.A. Allen, and C.J. Schweitzer. 1999. Afforestation of agricultural lands in the lower Mississippi alluvial valley: the state of our understanding. Ecology and management of bottomland hardwood systems: the state of our understanding: 413-431.

Schoenholtz, S.H., J.P. James, R.K. Kaminski, B.D. Leopold, and A.W. Ezell. 2001. Afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley: status and trends. Wetlands 21: 602-613.

Schweitzer, C.J., E.S. Gardiner, J.A. Stanturf, and A.W. Ezell. 1999. Methods to improve establishment and growth of bottomland hardwoods artificial regeneration. Pages 209-214 *in* 12th Central Hardwood Forest Conference. U.S.D.A. Forest Service, Southern Research Station General Technical Report SRS-24, Asheville, North Carolina, USA.

.

Severinghaus, C.W. and J.D. Severinghaus. 1982. Providing white cedar as winter browse for deer without incurring overbrowsing. New York Fish and Game Journal 29: 45-64.

Sharew, H. and J.S. Kays. 2006. Vole damage control in forest plantations. Northern Journal of Applied Forestry 23: 297-300.

Shnurr, J.L., C.D. Canham, R.S. Ostfeld, and R.S. Inovye. 2004. Neighborhood analysis of small-mammal dynamics: impacts on seed predation and seedling establishment. Ecology 85(3): 741-755.

Stange, E.E. and K.L. Shea. 1998. Effects of deer browsing, fabric mats, and tree shelters on *Quercus rubra* seedlings. Restoration Ecology 6 (1) 29-34.

Stanturf, J.A.and C.J. Portwood. 1999. Economics of afforestation with eastern cottonwood (*Populus deltoids*) on agricultural land in the lower Mississippi alluvial valley. Tenth Biennial Southern Silvicultural Research Conference Shreveport, Louisiana. Feb 1999.

Stanturf, J.A., S.H., Schoenholtz, C.J., Schwweitzer, and J.P., Shepard. 2001. Achieving restoration success: myths in bottomland hardwood forests. Restoration Ecology 9:189-200.

STATISTIX. 2000. STATISTIX for Windows, Version 7. Analytical Software, Tallahassee, Florida, USA.

Sumerall, D.C. 2007. Financial and biological impacts of small mammal herbivory on carbon plantations in the Mississippi Delta. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Teivainen, T. 1984. The damage risk and the extent of vole damage in forest populations in Finland. Pages 573-587 *in* Proceedings of the Conference on Vertebrate Pest Control Elvetham Hall, Hampshire, UK, ICI Plant Protection Division.

Vanderford, H.B. 1962. Soils of Mississippi. Mississippi State University, Mississippi Agricultural Research Station, Starkville, Mississippi, USA.

Waldrop, T.A., E.R. Buckner, and J.A. Muncy. 1984. Cultural treatments in low-quality hardwood stands for wildlife and timber production. Pages 493-500 *in* Proceedings of the 3rd biennial southern silvicultural research conference. Shoulders, Eugene, editor. USDA, Department of Agriculture, Forest Service, Southern Research Station General Technical Report SO-54, New Orleans, Louisiana, USA.

Wilson, A.D. and D.J. Shure. 1993. Plant competition and nutrient limitation during early succession in the southern Appalachian mountains. American Midland Naturalist 129: 1-9.

Yarrow, G.K. and D.T. Yarrow. 1999. Supplemental plantings as wildlife food source. Pages 363-383 *in* G.K. Yarrow and D. T. Yarrow, editors. Managing wildlife: on private lands in Alabama and the Southeast. Sweetwater Press, Birmingham, Alabama, USA.

APPENDIX A

SUMMARY OF HERBIVORY-RELATED MORTALITY AND DAMAGE TO TREE SEEDLINGS AT CLEVELAND, MS FIELD SITE

A.1. Number of tree seedlings killed or damaged by mammal species at Cleveland site, spring 2006.

Species	*N*	Missing	Dead	Other Mortality	Cotton Rat Mortality	Cotton Rat Damage	Vole Mortality	Vole Damage	Rabbit Mortality	Rabbit Damage	Resprout	Survival
FP	54	4	0	0	0	0	0	0	0	0	0	50
PD	95	11	0	1	0	0	0	0	0	0	0	83
DV	6	1	0	0	0	0	0	0	0	1	0	5
MR	66	5	0	1	3	4	0	1	0	6	0	57
QN	71	10	0	0	0	3	0	3	0	6	0	61
Q spp.	46	5	0	0	7	0	3	0	3	1	0	28
PO	10	0	0	0	1	2	0	0	0	0	0	9
UNK	26	25	0	0	0	0	0	0	1	0	0	0
QNi	11	2	0	0	0	3	0	1	0	0	0	9
QP	47	4	0	0	1	3	0	2	0	1	0	42

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

A.2. Number of tree seedlings killed or damaged by mammal species at Cleveland site, summer 2006.

Species	*N*	Missing	Dead	Other Mortality	Cotton Rat		Vole		Rabbit		Resprout	Survival
					Mortality	Damage	Mortality	Damage	Mortality	Damage		
FP	54	4	0	1	0	1	0	0	0	0	0	49
PD	95	11	1	59	0	0	0	0	0	0	0	24
DV	6	0	0	0	0	0	0	0	0	0	0	6
MR	66	10	4	2	1	3	0	0	0	2	1	49
QN	71	9	0	0	1	8	0	5	0	1	0	61
Q spp.	46	15	13	12	0	0	2	0	2	0	0	2
PO	10	3	1	1	0	0	0	0	0	0	0	5
UNK	26	24	1	1	0	0	0	0	0	0	0	0
QNi	11	1	0	0	0	1	0	0	0	0	0	10
QP	47	4	1	2	0	3	0	1	0	0	0	40

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

A.3. Number of tree seedlings killed or damaged by mammal species at Cleveland site, spring 2007.

Species	*N*	Missing	Dead	Other Mortality	Cotton Rat		Vole		Rabbit		Resprout	Survival
					Mortality	Damage	Mortality	Damage	Mortality	Damage		
FP	54	6	1	1	0	1	0	0	0	0	0	46
PD	95	5	60	18	0	0	0	0	0	1	1	12
DV	6	1	0	0	0	0	0	0	0	0	0	5
MR	66	14	7	13	1	0	0	0	0	2	13	31
QN	71	8	1	1	0	0	0	0	0	4	1	61
Q spp.	46	12	29	4	1	0	0	0	0	0	0	0
PO	10	3	2	2	0	0	0	0	0	0	0	3
UNK	26	22	2	2	0	0	0	0	0	0	0	0
QNi	11	3	0	2	0	0	0	0	0	0	1	6
QP	47	8	3	0	0	0	0	0	0	2	0	36

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

A.4. Number of tree seedlings killed or damaged by mammal species at Cleveland site, summer 2007.

Species	N	Missing	Dead	Other	Cotton Rat		Vole		Rabbit		Resprout	Survival
				Mortality	Mortality	Damage	Mortality	Damage	Mortality	Damage		
FP	54	7	2	2	0	0	0	0	0	0	0	43
PD	95	5	78	0	0	0	0	0	0	0	3	12
DV	6	0	0	0	0	0	0	0	0	0	0	6
MR	66	13	21	3	0	0	0	0	0	0	2	29
QN	71	13	2	0	0	0	0	0	0	2	0	56
Q spp.	46	12	34	0	0	0	0	0	0	0	0	0
PO	10	4	4	1	0	0	0	0	0	0	0	1
UNK	26	22	4	0	0	0	0	0	0	0	0	0
QNi	11	2	2	0	0	0	0	0	0	0	0	7
QP	47	5	3	1	2	0	0	0	0	0	0	36

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO-*Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

A.5. Number of tree seedlings killed or damaged by mammal species at Cleveland site, fall 2007.

Species	*N*	Missing	Dead	Other	Cotton Rat		Vole		Rabbit		Resprout	Survival
				Mortality	Mortality	Damage	Mortality	Damage	Mortality	Damage		
FP	54	4	4	1	0	1	1	0	0	0	0	44
PD	95	6	78	1	0	0	0	0	0	1	1	10
DV	6	1	0	1	0	0	0	0	0	1	0	4
MR	66	17	24	4	1	0	1	0	0	5	0	19
QN	71	16	2	3	1	0	6	0	0	2	0	43
Q spp.	46	12	34	0	0	0	0	0	0	0	0	0
PO	10	4	5	0	0	0	0	0	0	0	0	1
UNK	26	22	4	0	0	0	0	0	0	0	0	0
QNi	11	0	2	1	0	0	0	0	0	0	0	8
QP	47	6	6	1	2	0	7	0	0	1	0	25

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO-*Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

A.6. Number of tree seedlings killed or damaged by mammal species at Cleveland, MS sites 2006-2007.

				Hispid Cotton Rat		Pine Vole		Cottontail Rabbit		White-tailed Deer		
Species	N	Missing	Other Mortality	Mortality	Damage	Mortality	Damage	Mortality	Damage	Mortality	Damage	Survival
FP	54	4	5	0	3	1	0	0	0	0	0	44
PD	95	6	79	0	0	0	0	0	2	0	0	10
DV	6	1	1	0	0	0	0	0	2	0	0	4
MR	66	17	23	6	7	1	1	0	15	0	0	19
QN	71	16	4	2	11	6	8	0	15	0	0	43
Q spp.	46	15	14	8	0	5	0	5	1	0	0	0
PO	10	4	4	1	2	0	0	0	0	0	0	1
UNK	26	19	6	0	0	0	0	1	0	0	0	0
QNi	11	0	3	0	4	0	1	0	0	0	0	8
QP	47	6	4	5	6	7	3	0	4	0	0	25

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

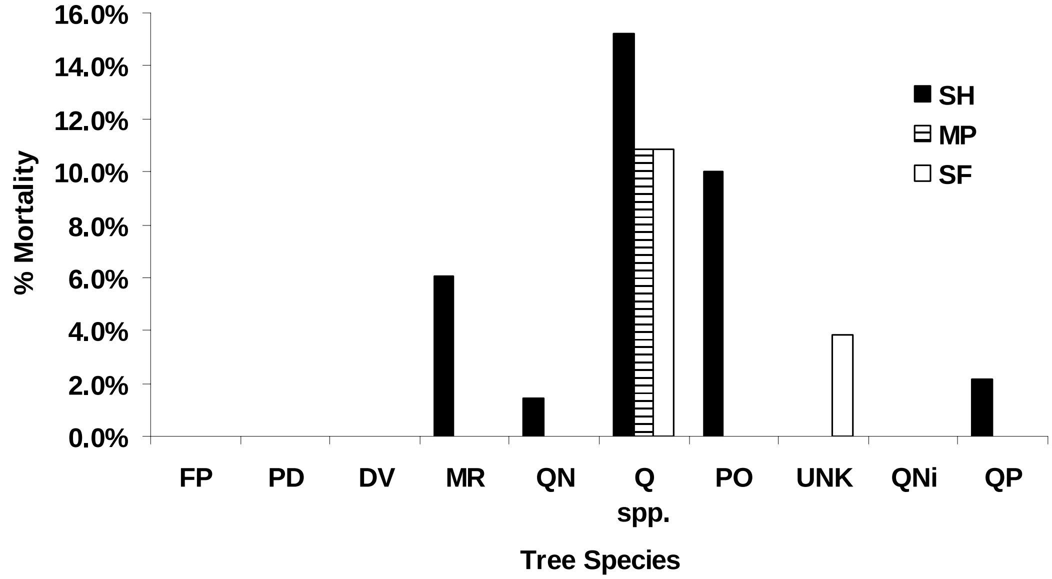
A.7. Percentages of tree seedlings killed or damaged by mammal species at Cleveland, MS site 2006-2007.

Species	N	(%) Missing	(%) Other Mortality	Hispid Cotton Rat (%) Mortality	Hispid Cotton Rat (%) Damage	Pine Vole (%) Mortality	Pine Vole (%) Damage	Cottontail Rabbit (%) Mortality	Cottontail Rabbit (%) Damage	White-tailed Deer (%) Mortality	White-tailed Deer (%) Damage	(%) Survival
FP	54	7.41%	9.26%	0.00%	5.56%	1.85%	0.00%	0.00%	0.00%	0.00%	0.00%	81.48%
PD	95	6.32%	83.16%	0.00%	0.00%	0.00%	0.00%	0.00%	2.11%	0.00%	0.00%	10.53%
DV	6	16.67%	16.67%	0.00%	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	66.67%
MR	66	25.76%	34.85%	9.09%	10.61%	1.52%	1.52%	0.00%	22.73%	0.00%	0.00%	28.79%
QN	71	22.54%	5.63%	2.82%	15.49%	8.45%	11.27%	0.00%	21.13%	0.00%	0.00%	60.56%
Q spp.	46	30.43%	30.43%	17.39%	0.00%	10.87%	0.00%	10.87%	2.17%	0.00%	0.00%	0.00%
PO	10	40.00%	40.00%	10.00%	20.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%
UNK	26	73.08%	23.08%	0.00%	0.00%	0.00%	0.00%	3.85%	0.00%	0.00%	0.00%	0.00%
QNi	11	0.00%	27.27%	0.00%	36.36%	0.00%	9.09%	0.00%	0.00%	0.00%	0.00%	72.73%
QP	47	12.77%	8.51%	10.64%	12.77%	14.89%	6.38%	0.00%	8.51%	0.00%	0.00%	53.19%

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp.*, PO-*Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition



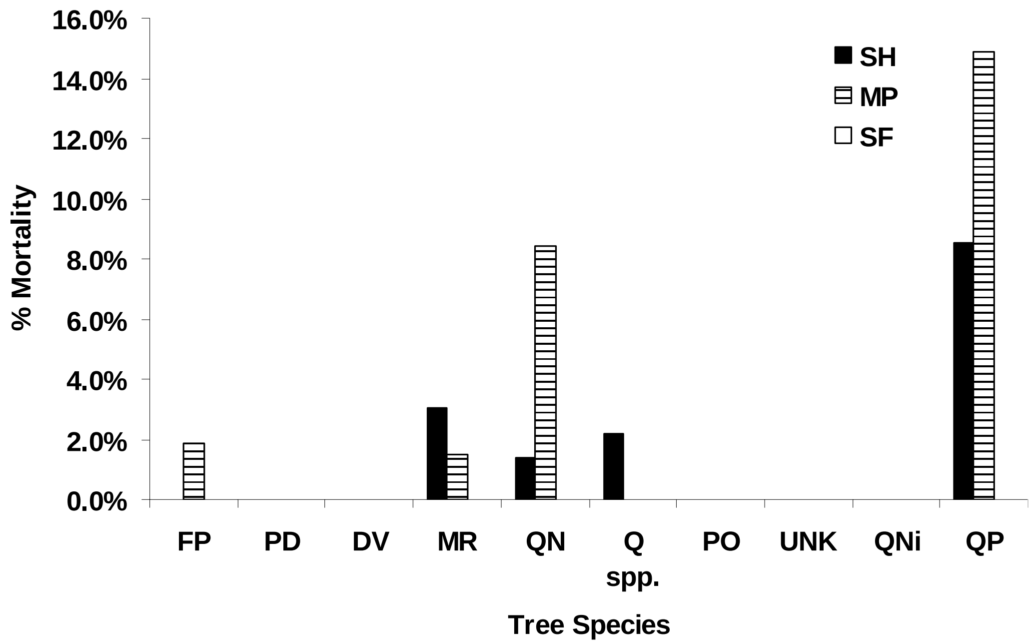
A.8. Percent mortality of trees by mammal species[4] at Cleveland, MS study site, 2006.

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

[4]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp*.



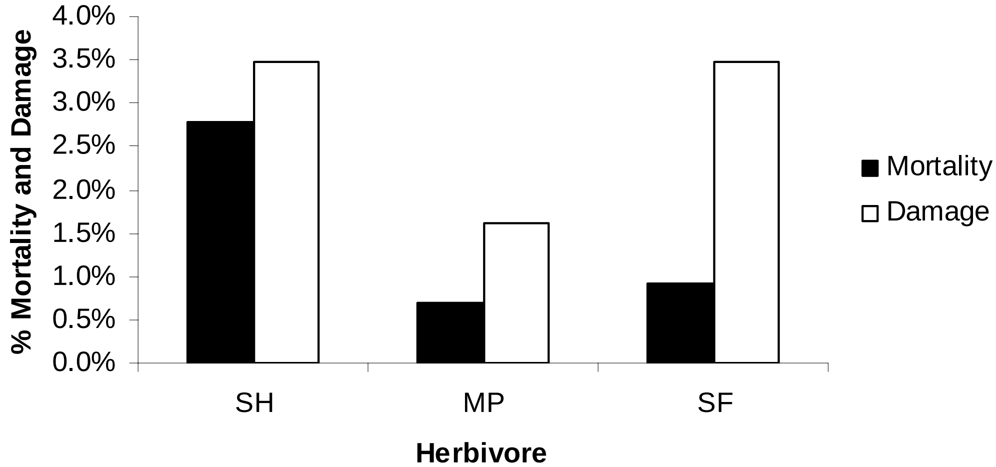
A.9. Percent mortality of trees by mammal species[4] at Cleveland, MS study site, 2007.

FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

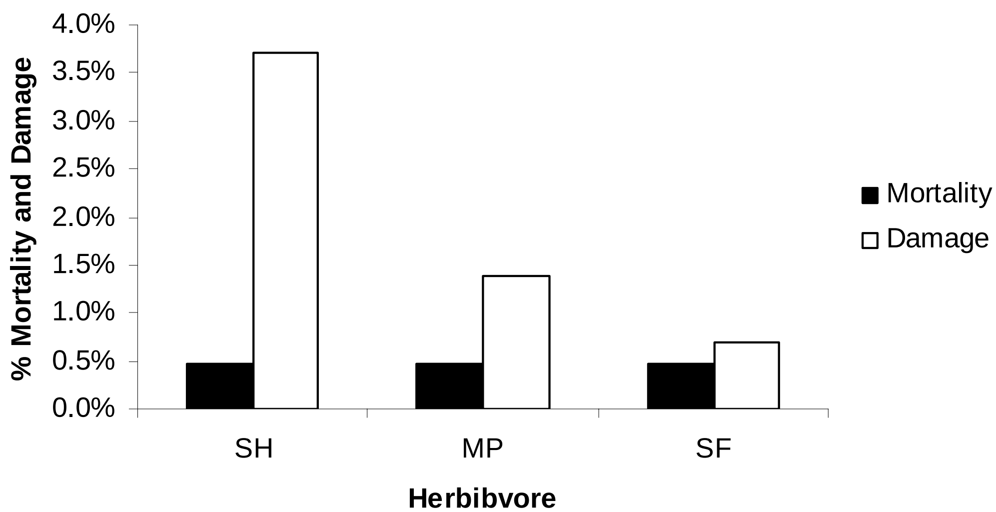
[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

[4]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp*.



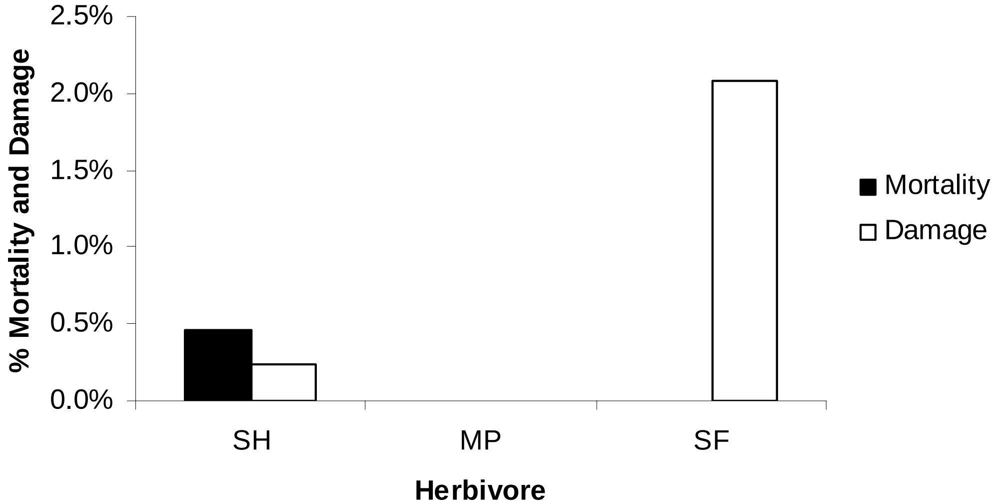
A.10. Percent mortality and damage on all trees by mammal species[1] at Cleveland study site, spring 2006.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp*.



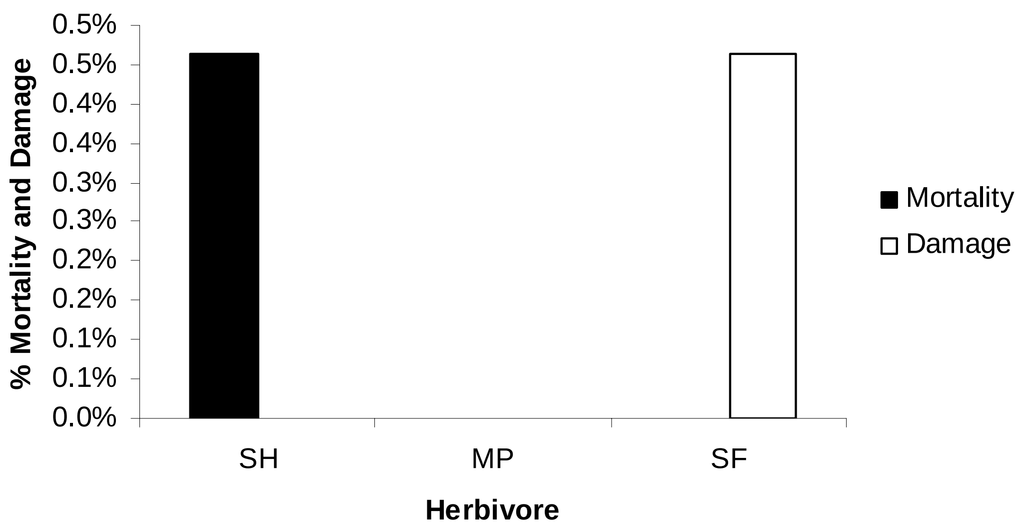
A.11. Percent mortality and damage on all trees by mammal species[1] at Cleveland study site, summer 2006.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp*.



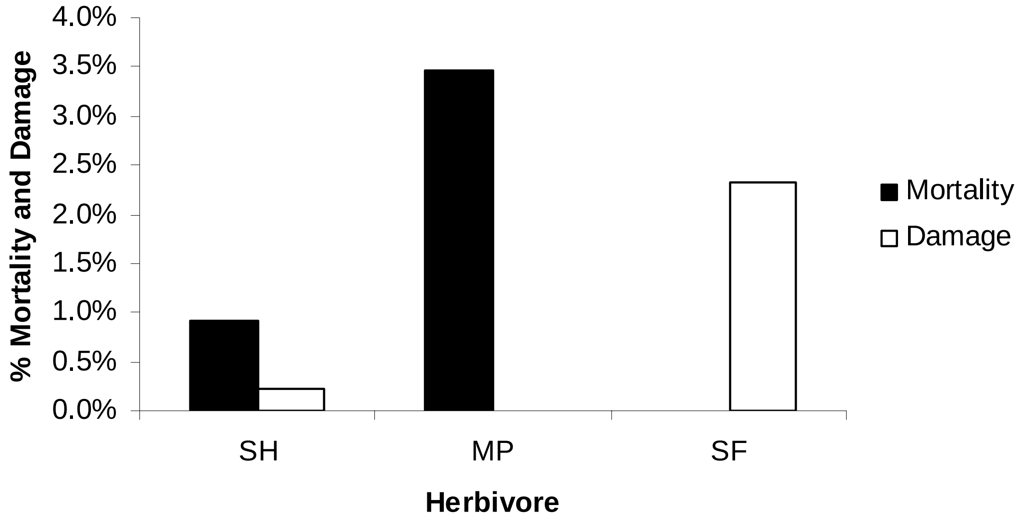
A.12. Percent mortality and damage on all trees by mammal species[1] at Cleveland study site, spring 2007.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp*.



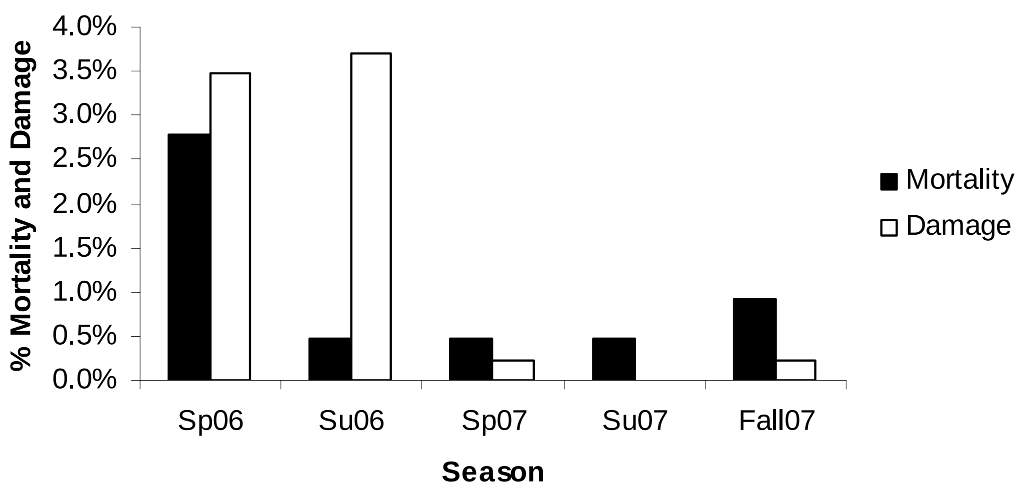
A.13. Percent mortality and damage on all trees by mammal species[1] at Cleveland study site, summer 2007.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp*.

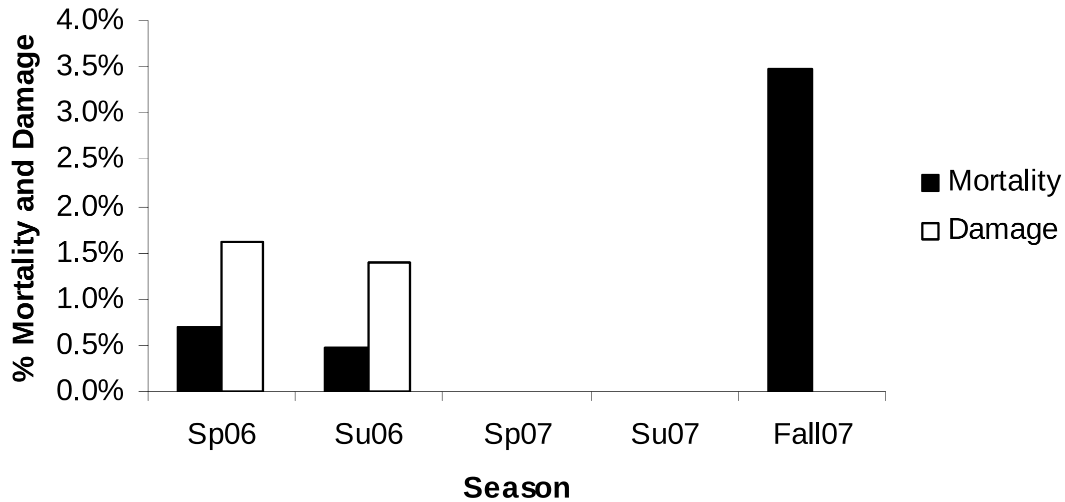


A.14. Percent mortality and damage on all trees by mammal species[1] at Cleveland study site, fall 2007.

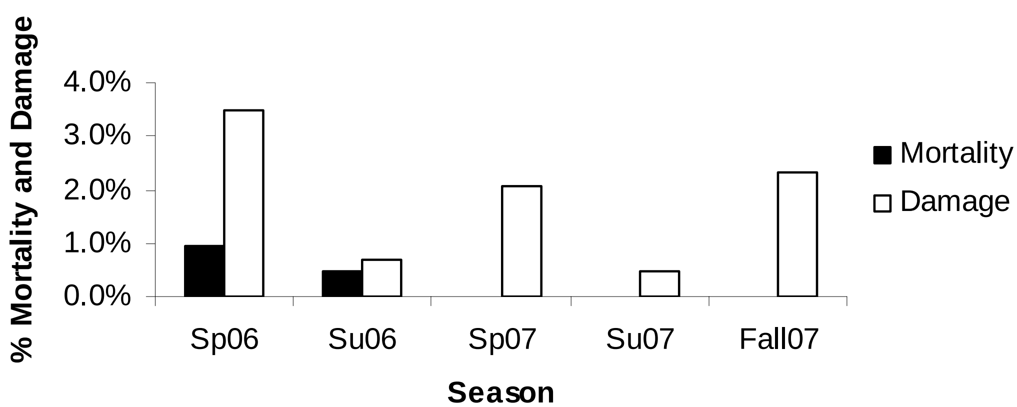
[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus floridanus*.



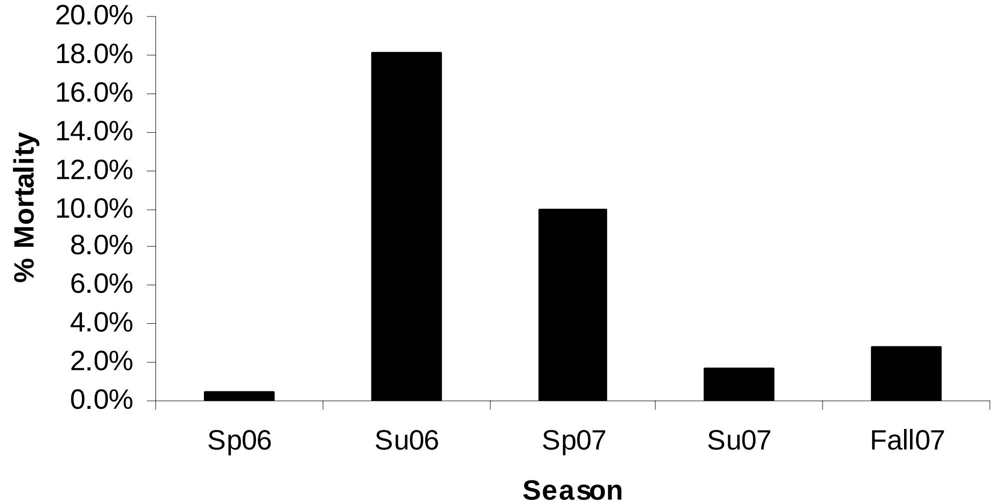
A.15. Percent mortality and damage for all trees from hispid cotton rat herbivory on Cleveland study site, 2006- 2007.



A.16. Percent mortality and damage for all trees from pine vole herbivory on Cleveland study site 2006- 2007.



A.17. Percent mortality and damage for all trees from rabbits on Cleveland study site 2006- 2007.



A.18. Percent mortality not attributed to mammalian herbivory on Cleveland study site, 2006- 2007.

A.19. Cotton rat captures (*Sigmodon hispidus*) on Cleveland, MS, study site, 2006-2007.

Month Year	Total # Caught	Total Adults	Total Juveniles	Adult Females	Adult Males	Juvenile Females	Juvenile Males	Weight Range			
								Adult Female	Adult Male	Juvenile Female	Juvenile Male
March 2006	2	1	1	0	1	1	0	0-0	120	30	0-0
Nov. 2006	31	3	28	2	1	18	10	130-140	122	41-113	51-100
Dec. 2006	15	1	14	0	1	7	7	0-0	149	50-80	45-100
Jan. 2007	6	1	5	0	1	4	1	0-0	128	48-74	72
Feb 2007	0	0	0	0	0	0	0	0-0	0-0	0-0	0-0
March 2007	2	1	1	1	0	1	0	121	0-0	100	0-0
Nov. 2007	90	16	74	5	11	35	39	115-150	115-172	53-112	38-110
Dec. 2007	100	41	59	20	21	30	29	115-162	115-163	50-112	10-115

APPENDIX B

SUMMARY OF HERBIVORY-RELATED MORTALITY AND DAMAGE TO TREE SEEDLINGS AT GREENVILLE, MS FIELD SITE

B.1. Number of tree seedlings killed or damaged by mammal species at Greenville site, spring 2006.

				Other	Hispid Cotton Rat		Pine Vole		Eastern Cottontail		White-tail Deer			
Species	*N*	Missing	Dead	Mortality	Mortality	Damage	Mortality	Damage	Mortality	Damage	Mortality	Damage	Resprout	Survival
FP	47	0	0	0	0	0	0	0	0	0	0	0	0	47
PD	96	6	0	1	0	0	0	0	0	1	0	0	0	89
DV	2	0	0	0	0	0	0	0	0	0	0	0	0	2
MR	64	2	0	1	1	4	0	0	0	1	0	0	0	60
QN	57	8	0	0	0	3	0	6	0	1	0	0	0	49
Qspp	88	11	0	9	3	6	2	4	0	0	0	0	0	63
QA	7	0	0	0	0	0	0	0	0	1	0	0	0	7
PO	3	0	0	0	0	0	0	0	0	0	0	0	0	3
Unk	19	16	0	0	0	0	0	0	0	0	0	0	0	3
QNi	14	1	0	0	0	2	0	0	0	0	0	0	0	13
QP	39	8	0	0	0	1	1	2	0	0	0	0	0	30

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition

B.2. Number of tree seedlings killed or damaged by mammal species at Greenville site, summer 2006.

					Hispid Cotton Rat		Pine Vole		Eastern Cottontail		White-tail Deer			
Species	*N*	Missing	Dead	Other Mortality	Mortality	Damage	Mortality	Damage	Mortality	Damage	Mortality	Damage	Resprout	Survival
FP	47	4	0	0	0	0	0	0	0	0	0	1	0	43
PD	96	16	1	66	0	0	0	0	0	0	0	0	0	13
DV	2	0	0	0	0	0	0	0	0	0	0	0	0	2
MR	64	8	2	2	5	6	0	0	0	0	0	0	0	47
QN	57	3	0	1	3	0	1	0	1	2	0	0	0	48
Qspp	88	33	14	19	8	1	2	0	1	0	0	0	0	11
QA	7	0	0	1	3	1	0	0	0	1	0	0	0	3
PO	3	0	0	0	0	0	0	0	0	0	0	0	0	3
Unk	19	18	0	1	0	0	0	0	0	0	0	0	0	0
QNi	14	1	0	0	1	1	0	0	0	0	0	1	0	12
QP	39	5	1	2	3	8	0	1	0	0	0	0	0	28

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition

B.3. Number of tree seedlings killed or damaged by mammal species at Greenville site, spring 2007.

Species	*N*	Missing	Dead	Other Mortality	Hispid Cotton Rat		Pine Vole		Eastern Cottontail		White-tail Deer		Resprout	Survival
					Mortality	Damage	Mortality	Damage	Mortality	Damage	Mortality	Damage		
FP	47	4	0	0	0	0	0	0	0	1	0	0	0	43
PD	96	15	67	6	0	0	0	0	0	0	0	0	0	8
DV	2	1	0	0	0	0	0	0	0	0	0	0	0	1
MR	64	15	9	0	0	0	0	0	0	2	0	1	9	40
QN	57	5	6	0	0	1	0	0	0	2	0	0	1	46
Qspp	88	44	44	1	0	0	0	0	0	0	0	0	0	0
QA	7	3	4	0	0	0	0	0	0	1	0	0	0	0
PO	3	0	0	0	0	0	0	0	0	0	0	0	0	3
Unk	19	19	1	0	0	0	0	0	0	0	0	0	0	0
QNi	14	1	1	1	0	0	0	0	0	0	0	0	0	11
QP	39	9	6	0	0	0	0	0	0	2	0	0	1	24

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.
[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.
[3]UNK- Seedlings were unidentifiable due to mortality and decomposition

B.4. Number of tree seedlings killed or damaged by mammal species at Greenville site, summer 2007.

Species	*N*	Missing	Dead	Other	Hispid Cotton Rat		Pine Vole		Eastern Cottontail		White-tail Deer		Resprout	Survival
				Mortality	Mortality	Damage	Mortality	Damage	Mortality	Damage	Mortality	Damage		
FP	47	4	0	0	0	0	0	0	0	0	0	3	0	43
PD	96	15	73	1	0	0	0	0	0	0	0	1	0	7
DV	2	1	0	0	0	0	0	0	0	0	0	0	0	1
MR	64	12	9	0	0	2	0	0	1	0	0	2	7	22
QN	57	4	6	0	1	0	0	0	2	0	0	8	0	44
Qspp	88	45	45	0	0	0	0	0	0	0	0	0	0	0
QA	7	3	4	0	0	0	0	0	0	0	0	0	0	0
PO	3	0	0	0	0	0	0	0	1	0	0	0	0	2
Unk	19	18	1	1	0	0	0	0	0	0	0	0	0	0
QNi	14	1	2	0	0	3	0	0	0	0	0	1	1	11
QP	39	5	6	1	0	3	0	0	2	1	0	5	0	25

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition

B.5. Number of tree seedlings killed or damaged by mammal species at Greenville site, fall 2007.

				Other	Hispid Cotton Rat		Pine Vole		Eastern Cottontail		White-tail Deer			
Species	*N*	Missing	Dead	Mortality	Mortality	Damage	Mortality	Damage	Mortality	Damage	Mortality	Damage	Resprout	Survival
FP	47	5	4	2	0	1	0	0	0	2	2	0	0	38
PD	96	16	74	2	0	0	0	0	0	0	1	2	0	6
DV	2	1	0	1	0	0	0	0	0	0	0	0	0	1
MR	64	16	10	0	2	12	0	0	2	5	0	7	8	34
QN	57	3	9	0	1	2	0	0	1	4	1	18	0	45
Qspp	88	43	45	0	0	0	0	0	0	0	0	0	0	0
QA	7	3	4	0	0	0	0	0	0	0	0	0	0	0
PO	3	0	1	0	0	1	0	0	0	0	0	0	0	2
Unk	19	16	2	0	0	0	0	0	0	0	0	0	0	1
QNi	14	2	2	0	1	0	0	0	0	2	1	6	0	10
QP	39	5	9	0	2	3	0	0	0	2	1	5	0	25

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition

B.6. Number of tree seedlings killed of damaged by mammal species at Greenville, MS sites 2006-2007.

Species	N	Missing	Other Mortality	Hispid Cotton Rat Mortality	Hispid Cotton Rat Damage	Pine Vole Mortality	Pine Vole Damage	Cotton tail rabbit Mortality	Cotton tail rabbit Damage	White-tailed deer Mortality	White-tailed deer Damage	Survival
FP	47	5	2	0	1	0	0	0	3	2	4	38
PD	96	16	76	0	0	0	0	0	1	1	3	6
DV	2	1	1	0	0	0	0	0	0	0	0	1
MR	64	16	3	8	24	0	0	3	8	0	10	34
QN	57	3	1	5	6	1	6	4	9	1	26	45
Q spp.	88	43	29	11	7	4	4	1	0	0	0	0
PO	3	0	0	0	1	0	0	1	0	0	0	2
UNK	19	16	2	0	0	0	0	0	0	0	0	1
QNi	14	2	1	2	6	0	0	0	2	1	8	10
QP	39	5	3	5	15	1	3	2	5	1	10	25
QA	7	3	1	3	1	0	0	0	3	0	0	0

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition

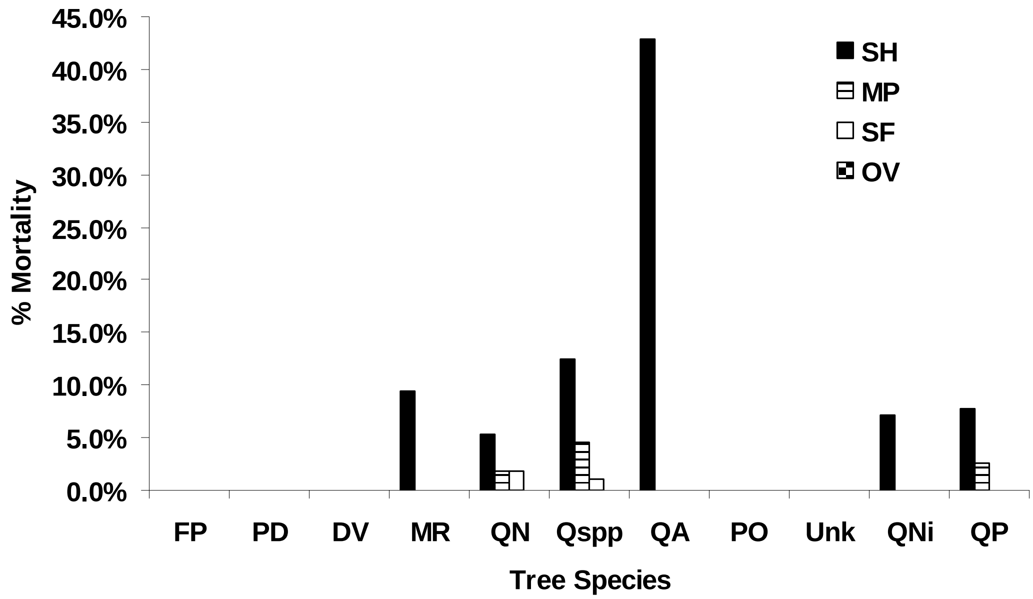
B.7. Percentages of tree seedlings killed or damaged by mammal species at Greenville, MS site 2006-2007.

Species	N	% Missing	% Other Mortality	Hispid Cotton Rat % Mortality	Hispid Cotton Rat % Damage	Pine Vole % Mortality	Pine Vole % Damage	Cotton tail rabbit % Mortality	Cotton tail rabbit % Damage	White-tailed deer % Mortality	White-tailed deer % Damage	% Survival
FP	47	10.64	4.26	0.00	2.13	0.00	0.00	0.00	6.38	4.26	8.51	80.85
PD	96	16.67	79.17	0.00	0.00	0.00	0.00	0.00	1.04	1.04	3.13	6.25
DV	2	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
MR	64	25.00	4.69	12.50	37.50	0.00	0.00	4.69	12.50	0.00	15.63	53.13
QN	57	5.26	1.75	8.77	10.53	1.75	10.53	7.02	15.79	1.75	45.61	78.95
Q spp.	88	48.86	32.95	12.50	7.95	4.55	4.55	1.14	0.00	0.00	0.00	0.00
PO	3	0.00	0.00	0.00	33.33	0.00	0.00	33.33	0.00	0.00	0.00	66.67
UNK	19	84.21	10.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.26
QNi	14	14.29	7.14	14.29	42.86	0.00	0.00	0.00	14.29	7.14	57.14	71.43
QP	39	12.82	7.69	12.82	38.46	2.56	7.69	5.13	12.82	2.56	25.64	64.10
QA	7	42.86	14.29	42.86	14.29	0.00	0.00	0.00	42.86	0.00	0.00	0.00

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., QA- *Quercus acutissima*, PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos*.

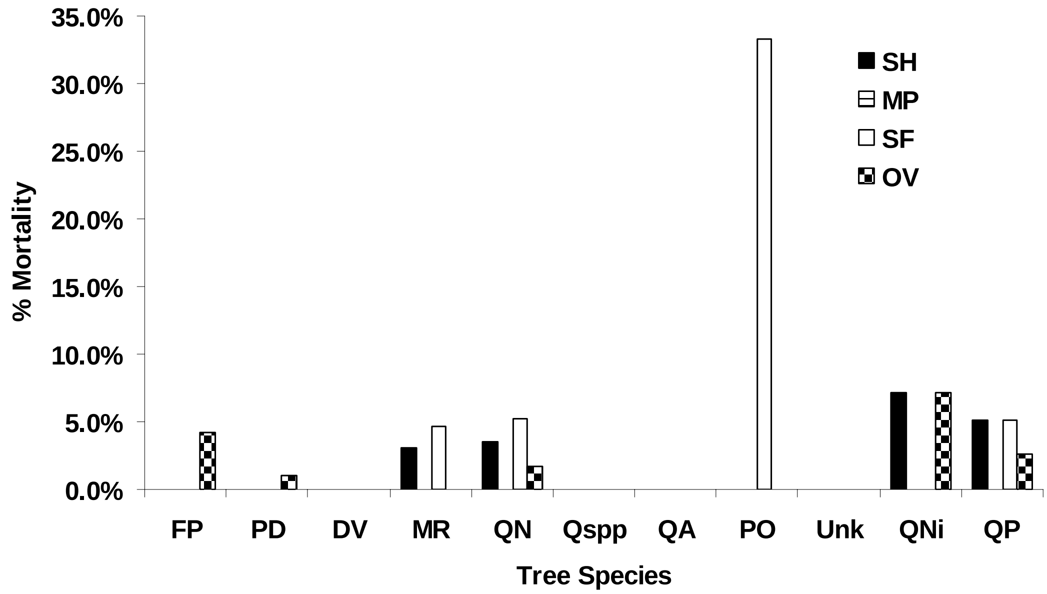
[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

[3]UNK- Seedlings were unidentifiable due to mortality and decomposition



B.8. Percent mortality of trees[1] by mammal species[4] at Greenville, MS study sites, 2006.

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos,* QA- *Quercus acutissima*.
[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.
[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.
[4]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp*.. *Odocoileus virginicus*



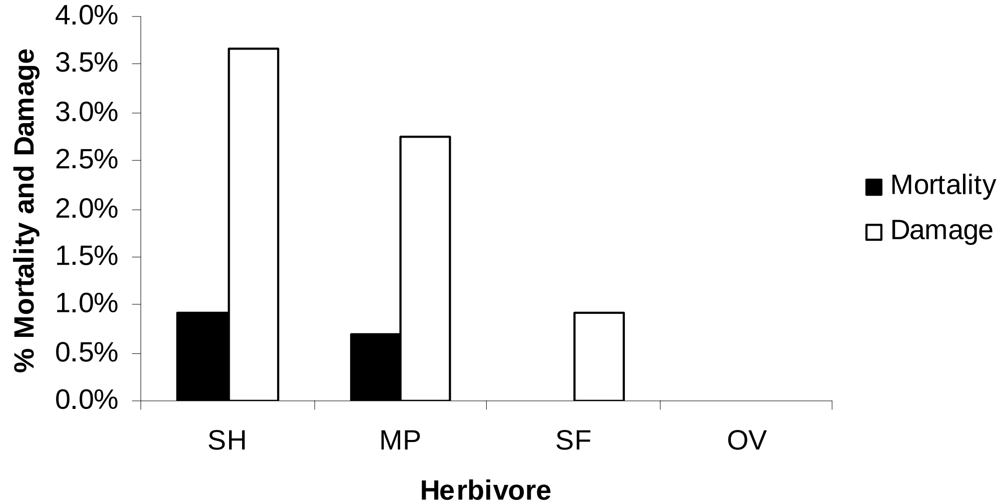
B.9. Percent mortality of trees[1] by mammal species[4] at Greenville, MS study sites, 2007.

[1] FP-*Fraxinus pennsylvanicus*, PD- *Populus deltoids*, DV- *Diospyros virginiana*, MR- *Morus rubra*, QN- *Quercus nuttallii*, Qspp[2]- *Quercus spp*., PO- *Platanus occidentalis*, UNK[3]- unknown, QNi- *Quercus nigra*, QP- *Quercus phellos,* QA- *Quercus acutissima*.

[2]Qspp- Seedlings known to be oak but could not be identified to species due to lack of identifiable characteristics, mortality, or decomposition.

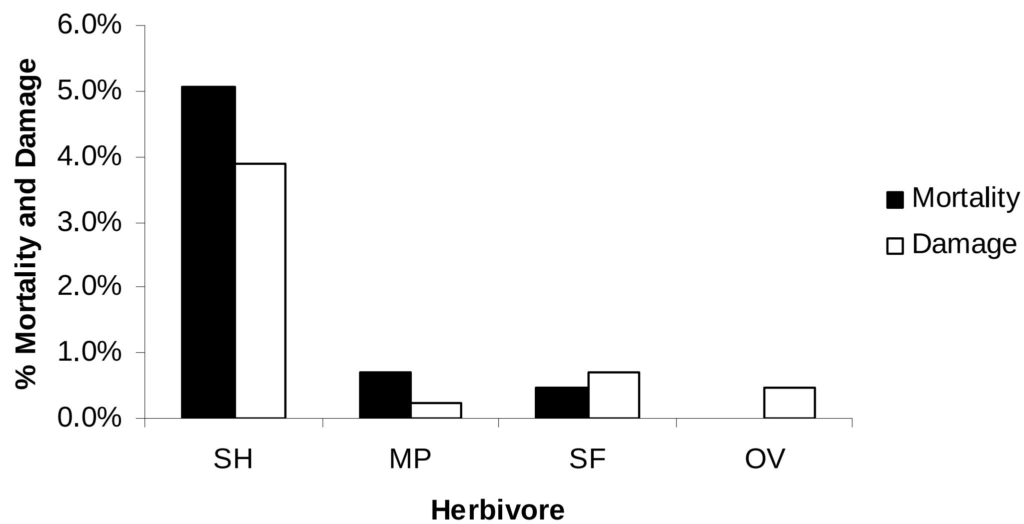
[3]UNK- Seedlings were unidentifiable due to mortality and decomposition.

[4]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp.. Odocoileus virginicus*



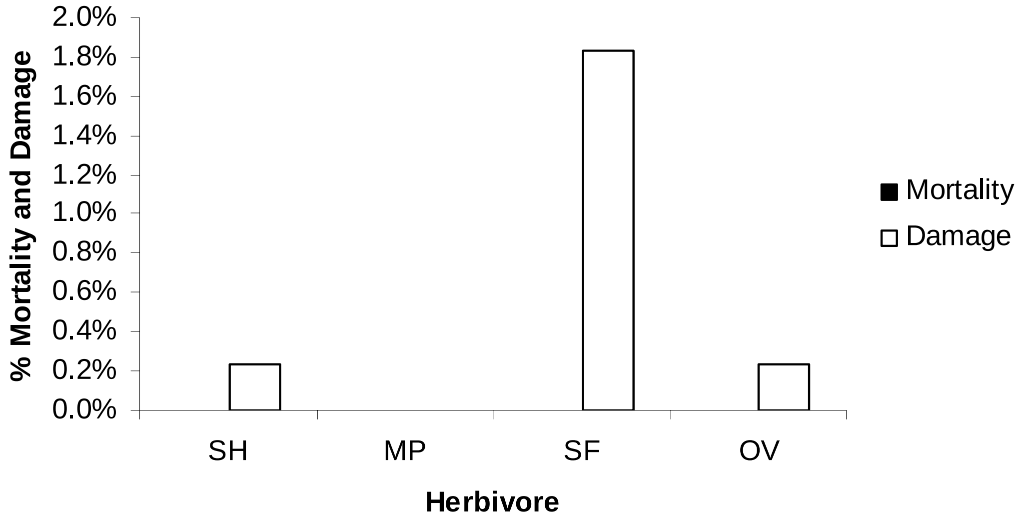
B.10. Percent mortality and damage on all trees by mammal species[1] at Greenville study site, spring 2006.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp.. Odocoileus virginicus*



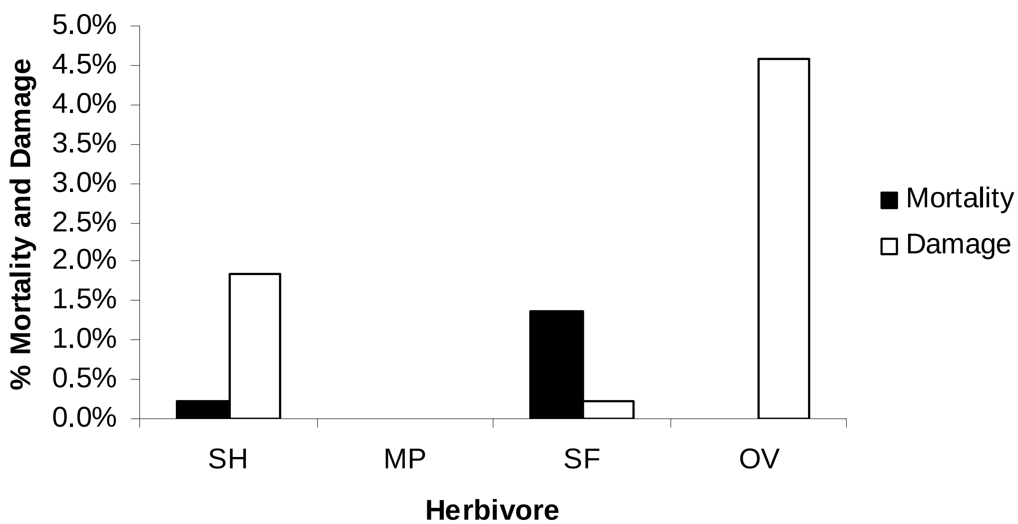
B.11. Percent mortality and damage on all trees by mammal species[1] at Greenville study site, summer 2006.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp.*, OV- *Odocoileus virginianus*.



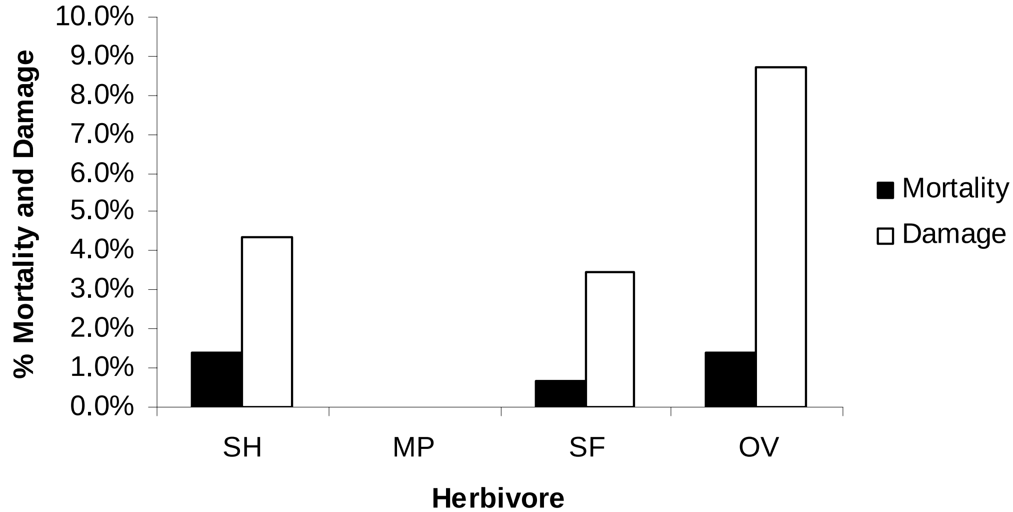
B.12. Percent mortality and damage on all trees by mammal species[1] at Greenville study site, spring 2007.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp.. Odocoileus virginicus*



B.13. Percent mortality and damage on all trees by mammal species[1] at Greenville study site, summer 2007.

[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp.*, OV- *Odocoileus virginianus*.



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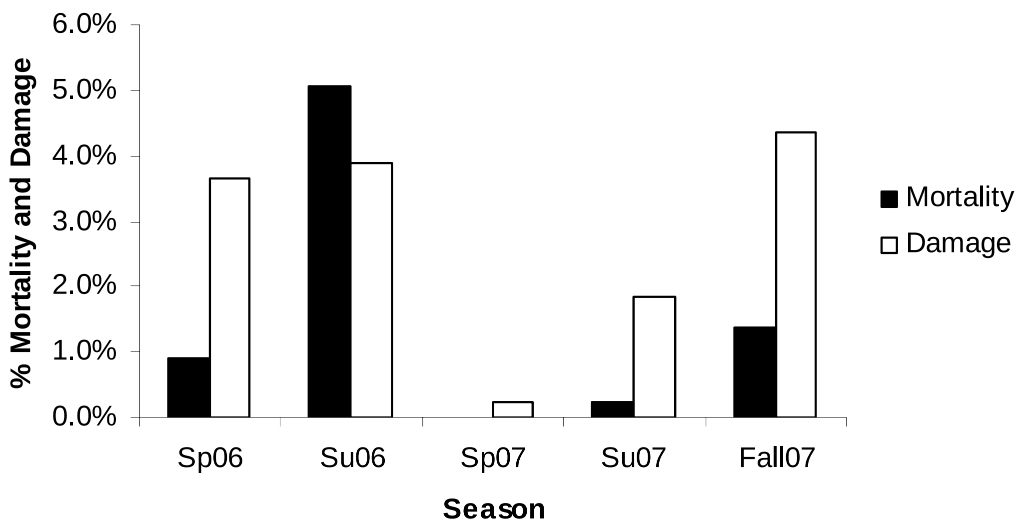
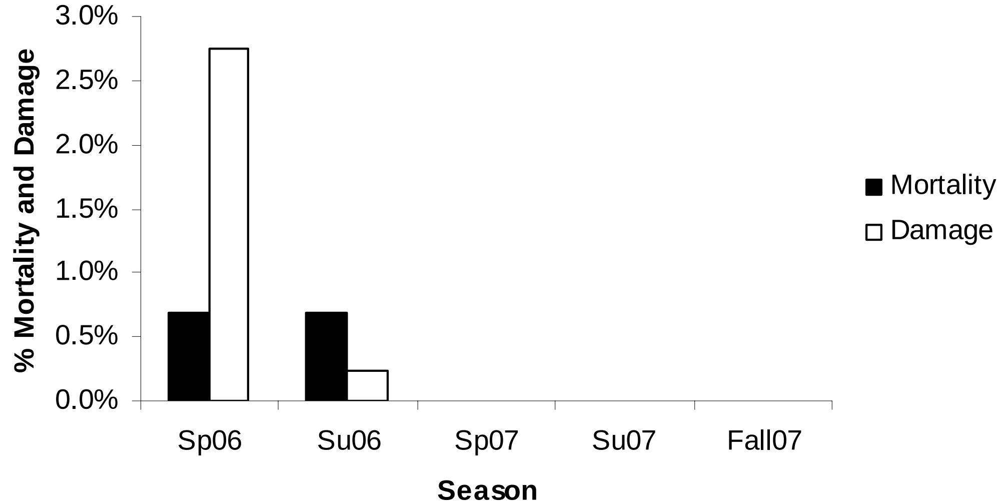
B.14. Percent mortality and damage on all trees by mammal species[1] at Greenville study site, fall 2007.

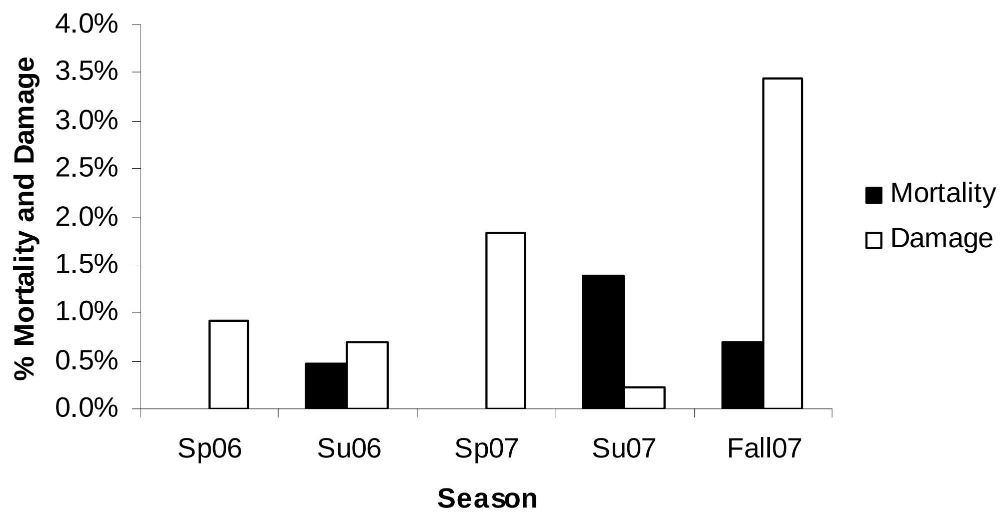
[1]SH- *Sigmodon hispidus*, MP- *Microtus pinetorum*, SF- *Sylvilagus spp.*, *OV- Odocoileus virginicus*



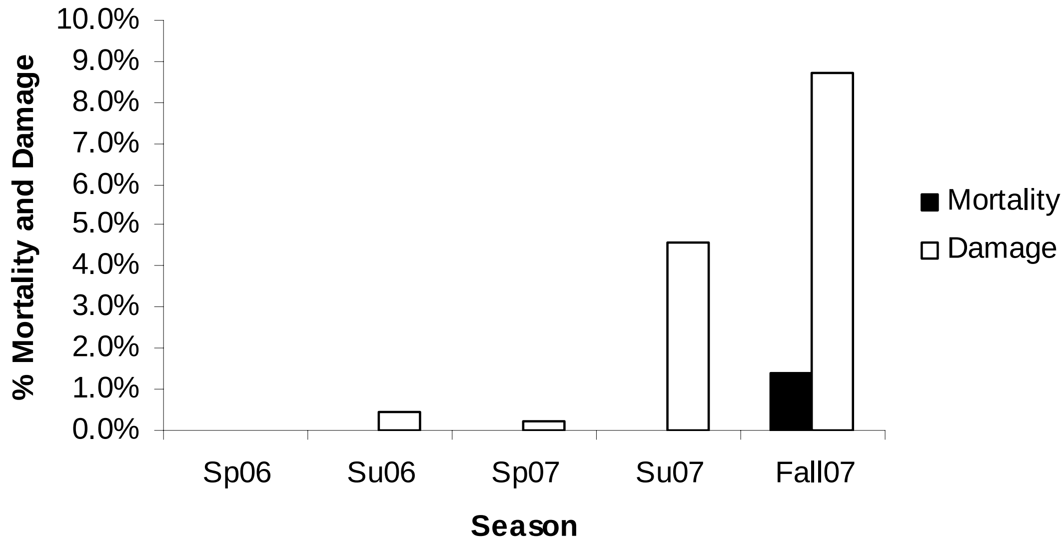
B.15. Percent mortality and damage for all trees from hispid cotton rat herbivory on Greenville study site 2006- 2007.



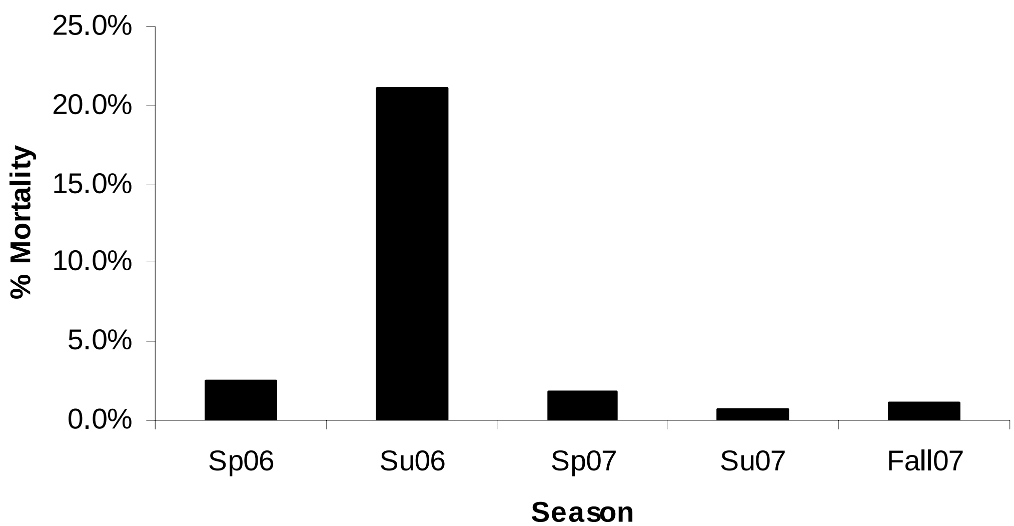
B.16. Percent mortality and damage for all trees from pine vole herbivory on Greenville study site 2006- 2007.



B.17. Percent mortality and damage for all trees from rabbits on Greenville study site spring 2006-fall 2007.



B.18. Percent mortality and damage for all trees from white-tailed deer on Greenville study site 2006- 2007.



B.19. Percent mortality not attributed to mammalian herbivory on Greenville study site 2006- 2007.

B.20. Cotton rat captures (*Sigmodon hispidus*) on Greenville, MS, study site, 2006-2007.

Month Year	Total # Caught	Total Adults	Total Juveniles	Adult Females	Adult Males	Juvenile Females	Juvenile Males	Weight Range			
								Adult Female	Adult Male	Juvenile Female	Juvenile Male
March 2006	66	32	34	2	30	26	8	123-140	119-132	30-105	30-113
Nov. 2006	109	8	101	5	3	45	56	120-140	120-130	19-110	31-114
Dec. 2006	160	18	142	7	11	62	80	120-183	120-150	40-113	40-112
Jan. 2007	63	0	17	0	0	17	46	0-0	0-0	46-97	36-96
Feb 2007	37	3	34	0	3	4	30	0-0	120-140	69-92	53-110
March 2007	28	2	26	0	2	9	17	0-0	115-120	68-96	60-110
Nov. 2007	143	34	109	18	16	50	59	115-162	115-163	45-112	11-112
Dec. 2007	125	44	81	13	31	54	27	115-163	115-180	60-111	10-113