VEGETATIVE CHARACTERISTICS OF GOPHER TORTOISE (*Gopherus polyphemus*) HABITAT ON THE LOWER SUWANNEE NATIONAL WILDLIFE REFUGE: IMPLICATIONS FOR RESTORATION AND MANAGEMENT OF PINE COMMUNITIES

By

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This document is dedicated to my father the late Douglas Alvord Barlow, Dad, mentor and friend.

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Previous land use practices on the Lower Suwannee National Wildlife Refuge altered natural fire conditions resulting in habitat degradation, especially within the high pine areas, allowing succession to begin shifting these habitats to mesic hammocks. In addition, many pine flatwoods sites exist as densely planted slash pine plantations, which have been relegated to an infrequent winter fire regime, leading to a shrub level monoculture of gallberry (*Ilex glabra*) and saw palmetto (*Serenoa repens*). Changes in vegetative structure of these prominent pine communities are thought to have lowered the quality of gopher tortoise habitat. This investigation evaluates the relationship between vegetative cover of different community strata and the density of gopher tortoise burrows.

Vegetation cover was measured on sites with high and low gopher tortoise burrow densities in high pine and pine flatwoods habitats on the refuge from April to July 2004.

The line intercept technique was used to measure canopy cover, shrub cover and ground cover. Survey compartment soil compositions were compared using Geographic Information Systems (GIS) data and the county soil surveys. It was predicted that compartments with high tortoise burrow densities would have a relatively open canopy and shrub layers, with relatively high herbaceous and bare soil ground covers.

Analysis of variance on vegetation cover data revealed that density of the canopy, shrub layer, and ground cover types were significantly different between high pine sites with different tortoise burrow densities. While the pine flatwoods sites exhibited significant differences in all categories except bare soil, due to a lack of bare soil within these habitats. Lower canopy cover, shrub cover and higher herbaceous ground cover characterized sites with high tortoise burrow densities.

Soil analysis revealed higher soil series diversity within the pine flatwoods sites. This soil series diversity is not represented vegetatively within the current slash pine plantation monoculture. The lack of relationship between soil characteristics and vegetation community composition is most likely due to past timber practices that converted all usable land to pine production with little regard for preserving small pockets of habitat. Close analysis of soil series should guide land managers' efforts in restoration of habitats in order to regain pre-European development habitat diversity.

Aggressive techniques to reverse succession on high pine sites are also recommended. Restoration of the herbaceous ground layer and a reintroduction to summer fires could then be employed. Timber thinning and a more varied fire regime emphasizing summer burning would benefit pine flatwoods sites; otherwise continued habitat succession and degradation will significantly inhibit tortoise populations.

INTRODUCTION

Once the most extensive terrestrial ecosystems in Florida, pine flatwoods and high pine communities have been heavily influenced by humans, therefore many characteristics of these communities have changed markedly since European settlement. Pine communities were extensively timbered starting during the Civil War through today (Abrahamson and Harnett 1990). Concurrently, human population growth and the concomitant fragmentation of these vast pine stands have led to a decrease in the extent and frequency of natural fires. In their natural state, these communities are characterized by their openness and frequent occurrence of fires (Laessle 1942, Ober 1954, Edmisten 1963, Platt et al. 1988). Though few natural stands closely resemble pre-settlement pine communities, the consensus is that present stands differ from pre-settlement stands by having lower fire frequencies, more even age structure, and a denser under-story with greater shrub cover and less herbaceous cover (Abrahamson and Hartnett 1990, Noel et al. 1998). In recent times many of these areas have been owned and managed by timber companies that practice intense plantation production of short rotation pine trees for the paper industry.

Thus, managers of many public lands in Florida are often faced with restoring and managing pine communities that have been severely altered. Characteristics of pine communities under timber production management and fire exclusion include densely planted even-aged stands of slash pine (*Pinus eliotti*) often planted in raised, mechanically bedded rows, with intense herbicide use. Forest stands are also often prepared using heavy machinery, they have a monotypic shrub under story, raised road beds, windrows, borrow pits, rail tramways and logging roads crisscrossing the forest. An understanding of the impacts of these former land use practices is necessary for the formulation of management strategies concerned with restoring habitats to their pre-European settlement state.

Numerous researchers have described the gradual transition high pine communities make to mesic hardwood forests and the invasion of non fire-adapted species in the absence of frequent fire (Veno 1976, Givens et al. 1984, Myers 1985, Myers and White 1987). With the exclusion of fire, fire-adapted species also decline and since they often serve as the primary fuel source for frequent fires frequency and intensity of natural, lightning-ignited fires is reduced.

Under natural conditions pine flatwoods are stable and essentially nonsuccessional due to fire (Abrahamson and Hartnett 1990). When fire is removed from pine flatwoods, or if the natural frequency or seasonality of fire is altered, flatwoods can succeed to a variety of vegetation types. Human modifications to the landscape, such as certain silvicultural practices (logging, clearing and drainage), can also stimulate successional change. It has been noted by numerous authors that disturbance of the natural fire frequency is the most common cause of successional changes in pine flatwoods (Monk 1968, Robbins and Myers 1992, Peroni and Abrahamson 1986).

Loss of pine communities along with fire exclusion and certain silvicultural practices have negatively impacted numerous wildlife species that characterize pine communities. Bird species that require open pine forests such as the red-headed woodpecker (*Melanerpes erythrocephalus*), brown-headed nuthatch (*Sitta pusilla*), loggerhead shrike (*Lanius ludovicianus*) and eastern bluebird (*Sialia sialis*) have experienced declining populations throughout the southeast (Cox 1987). Within high pine communities, population size and species richness of birds decline noticeably when these areas are converted to timber production (Repenning and Labisky 1985). Silviculture practices across the United States have been implicated in the decline or elimination of at least 26 species of salamanders including the flatwoods salamander (*Ambystoma cingulatum*) in Florida (Bury 1983, Brode and Bury 1984, Herrington and Larsen 1985, Corn and Bury 1989, Welsh 1990, Blymer and McGinnes 1977, Ash 1988, Buhlmann et al. 1988, Pentranka et al. 1993, Jordan and Mount 1975, Dodd 1991, Dodd 1993, Means et al. 1996).

Due to loss and degradation of habitat, numerous species found within pine communities are currently listed as species of special concern, threatened or endangered. One such species is the gopher tortoise (*Gopherus polyphemus*), which is a state listed species of special concern that has experienced a population reduction through loss of habitat and a lack of fire in existing habitats. Changes in fire frequency in pine communities are thought to have decreased herbaceous food plants, thereby negatively influencing gopher tortoise habitat (Landers and Speake 1980, Cox et al. 1987). Since grasses and forbs constitute the bulk of the gopher tortoise's diet, increased shading and detritus buildup associated with fire exclusion lead to reduced productivity of these plants and a decline in tortoise numbers (Garner and Landers 1979, Franz and Auffenberg 1974).

The gopher tortoise is a keystone species–one that holds a critical role in the ecosystem (Campbell and Christman 1982, Jackson and Milstrey 1988). Their burrows provide shelter for more than 300 species of obligate and facultative commensals, including arachnids, insects, reptiles, amphibians, birds, and mammals (Jackson and Milstrey 1988). Several of these species such as the southeastern indigo snake (*Drymarchon couperi*), the gopher frog (*Rana capito*) and the Florida mouse (*Podomys floridanus*) are threatened species or species of special concern. Decline of the gopher tortoise has negatively affected these secondary burrow users because there are fewer burrows available (Berish 2001).

A primary factor affecting density of gopher tortoises is habitat quality, particularly as it relates to food availability as influenced by fire and primary succession (O'Meara and Abbott 1987). However, caution should be used when comparing tortoise densities to habitat variables as dispersion of gopher tortoise burrows within available habitats is poorly understood (Cox et al. 1987). To more accurately determine the quality of habitat measures of mean reproductive success, survival and number of individuals in each age class are needed to determine quality of the habitat (Van Horne 1983). Poor habitat quality may cause tortoises to form dense colonies in small patches of suitable habitat, thus a survey which is conducted at too small of a scale, or multiple scales may over estimate tortoise densities across the habitat or flaw site comparisons (McCoy and Mushinsky 1995).

To better understand the status of tortoise populations on the Lower Suwannee National Wildlife Refuge Refuge (LSNWR) and their habitat preferences, we conducted tortoise burrow surveys in 2002 in a manner similar to that of Auffenberg and Franz

(1982) and in Cox et al. (1987). In this survey, burrows were recorded as *active*, *inactive* and *old*. Active burrows were marked using a handheld GPS unit. Marked burrows were then projected as a layer file using Arcview® 8.3 geographic information systems (GIS) software to compare burrow colony locations with habitat and soil features.

Through GIS analysis it appeared refuge tortoises were congregated in colonies within various survey compartments. This aggregating of tortoises into pockets suggests preferential habitat within the broader survey compartment possibly representing remnants of formerly large areas of habitat (McCoy and Mushinsky 1995). This clumping of tortoise burrows makes the task of density estimation across refuge habitats imperfect at best, unless additional environmental variables influencing tortoise distribution can be identified. Furthermore, tortoise burrow congregations did not appear to relate to particular GIS habitat or soil layers, thus the level of detail within the GIS data layers were lacking for discernment of these apparent site choices by tortoises.

The goal of this study was to investigate what additional environmental variables might be influencing tortoise distribution and what changes in management might be implemented to enhance tortoise habitat in pine communities on the LSNWR. Specific hypothesis to be addressed under this goal include the following:

1) To determine if differences are present between vegetation structural characteristics (ground cover, shrub cover and canopy cover) among tortoise burrow survey compartments that exhibited relatively high or low burrow densities.
2) To determine if a relationship is present between the amount of canopy and shrub cover to ground cover forms or if these variables are independent.

It was predicted that areas with low tortoise burrow density would exhibit high canopy and shrub cover with low herbaceous ground coverage, while areas with high tortoise burrow densities would contain structural characteristics of low canopy and shrub cover with higher herbaceous ground coverage. It was further predicted that the amount of ground cover forms observed would be dependent upon the amount of shrub or canopy cover present.

MATERIAL AND METHODS

Study Area

The study was conducted on the Lower Suwannee NWR, a 21,500-hectare refuge located in the heart of north Florida's Big Bend region in Dixie and Levy counties (Figure1). Situated along the Gulf of Mexico the refuge is bisected by the Suwannee River, which flows southward through the refuge for 32 kilometers before emptying into the Gulf of Mexico. Purchased by the federal government in 1979 from various timber companies, the area still bears signs from decades of timber production management.

The topography of the study area is relatively flat, with dominant habitats including salt marsh, southern hydric hardwood, bottomland forest, and pine plantation (Figure 2) (Sykes et al. 1999). This diversity of habitats on the area is matched by the variety of soil orders found on the refuge. Of the seven soil orders in Florida, the refuge contains six, with Histosols being the most common (Slabaugh et al. 1996, Liudahl et al. 2003). The refuge contains 43 individual soil series, many of which are poorly drained or very poorly drained and strongly acid (pH 5.1-5.5) to extremely acid (pH 4.0-4.4) (Slabaugh et al. 1996, Liudahl et al. 2003).

Survey Compartments

Survey transects selected for this study were evenly divided between high pine habitats and pine flatwood habitats as well as by tortoise burrow density (Figure 3). Ten transects were randomly selected from high pine habitats: 5 transects in high tortoise

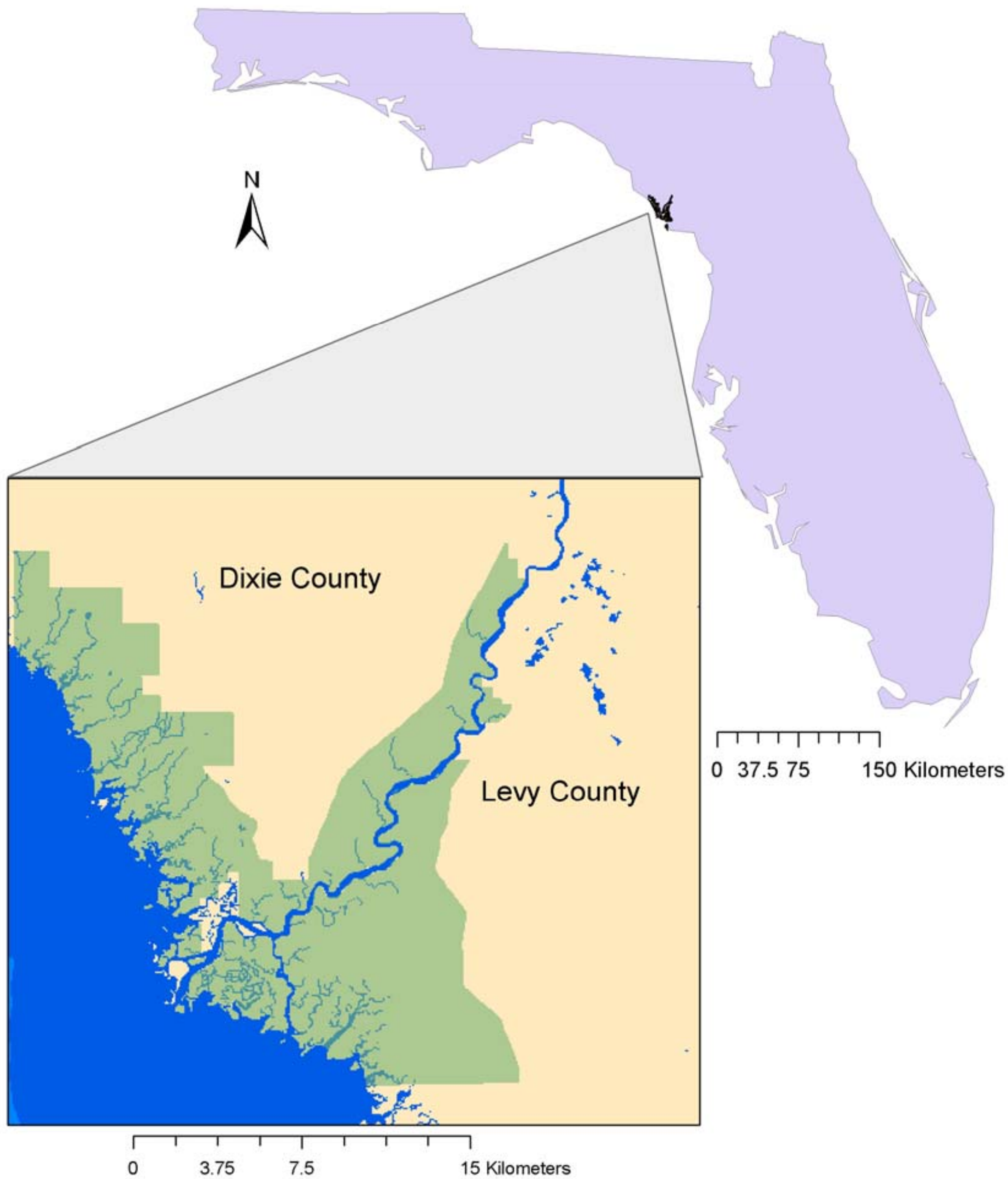


Figure 1. Location of the Lower Suwannee NWR, Florida.

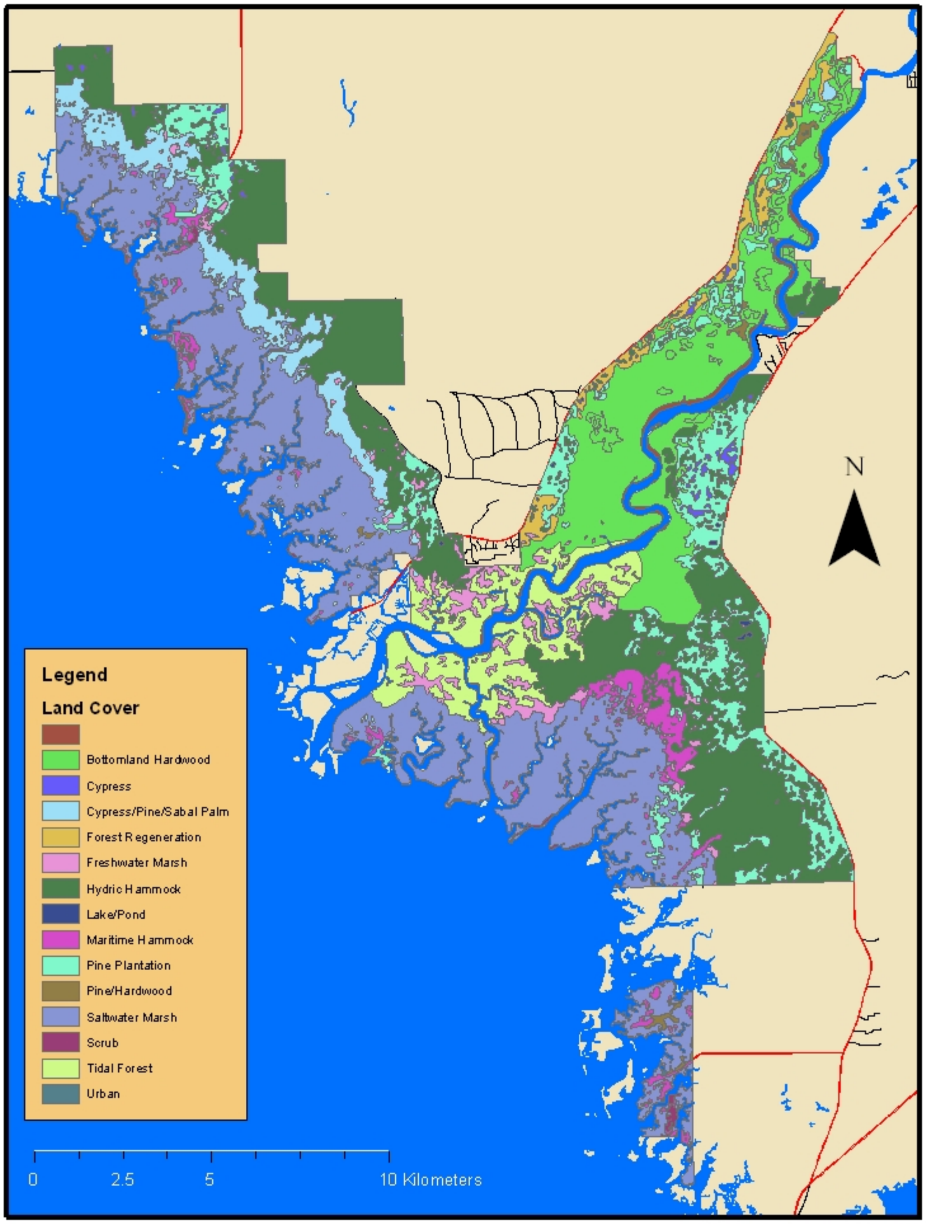


Figure 2. Land cover forms on the Lower Suwannee NWR, Florida.

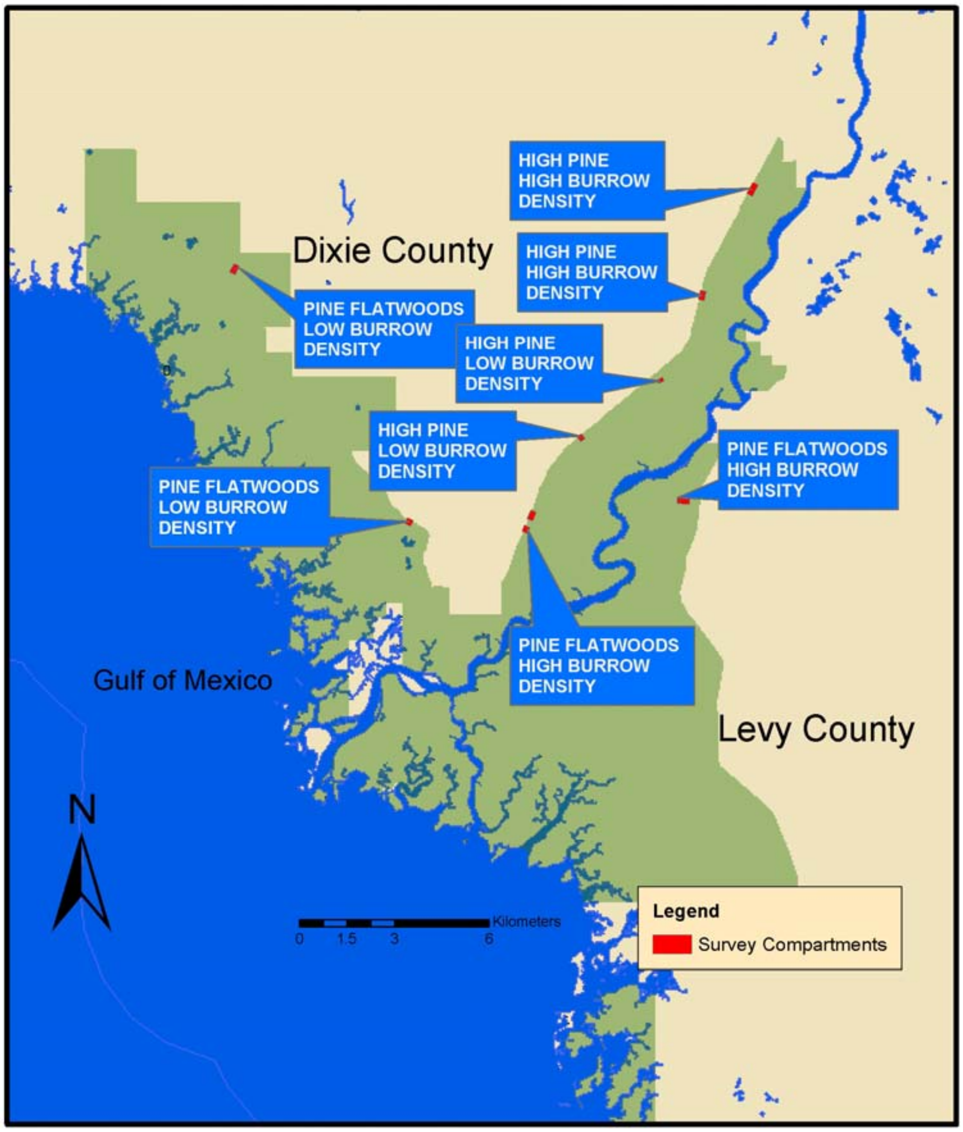
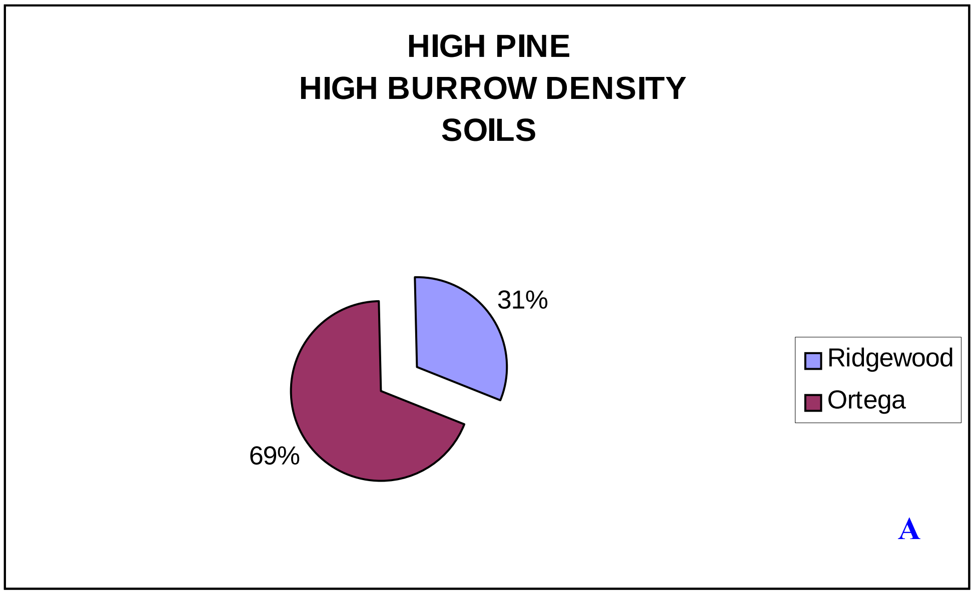


Figure 3. Location of tortoise burrow and vegetation survey compartments, Lower Suwannee NWR, Florida.

burrow density compartments and 5 transects within low tortoise burrow density compartments. Similarily10 transects were randomly selected from pine flatwoods compartments, also equally divided by tortoise burrow density.

High pine survey compartments consisted of even-aged mechanically planted long-leaf pines, planted in 1993 (Figure 6). Thus, the species, age, and basal area of the planted pine canopy component were controlled for between burrow density compartments. Interspersed within the planted long-leaf pines were turkey oak (*Quercus laevis*), live oak (*Quercus virginiana*) and a shrub layer containing immature oaks (*Quercus spp*.), sparkleberry (*Vaccinium arboreum*) and dog fennel (*Eupatorium compositifolium*). Herbaceous ground cover within the compartments contained deer's tongue (Carphephorus odoratissimus), greenbriar (*Smilax spp*.), partridge pea (*Chamaecrista pilosa*) wire grass and associated forbs and grasses.

The refuge practices an aggressive prescribed burning program, introducing fire to approximately 600 hectares annually (pers. comm., K. McCain Chiefland, FL). With the majority of these being dormant season burns, within densely planted flatwoods habitats. Though occasional attempts have been made to burn within the high pine habitats, lack of a uniformly distributed fuel source throughout has made most of theses burns "spotty" and anemic at best (pers. comm., K. McCain Chiefland, FL). Following the planting of long-leaf pines on these areas, a lack of fire for at least 10 years has led to the aforementioned encroachment of non-pyric species such as oaks. Needle cast from the planted pine component within these areas currently does not provide adequate fuels to carry fire under safe weather conditions. Also, with the current tree species composition



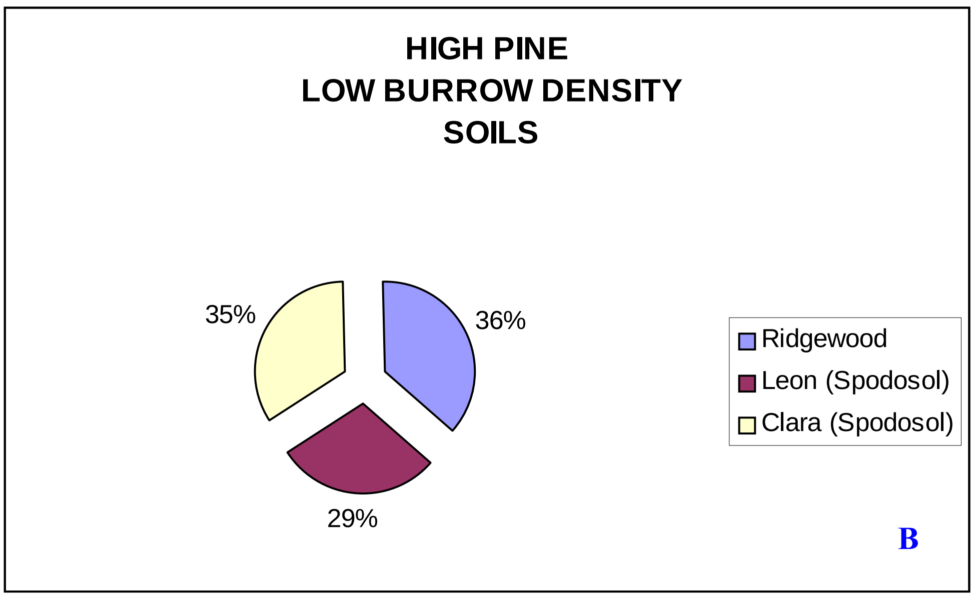
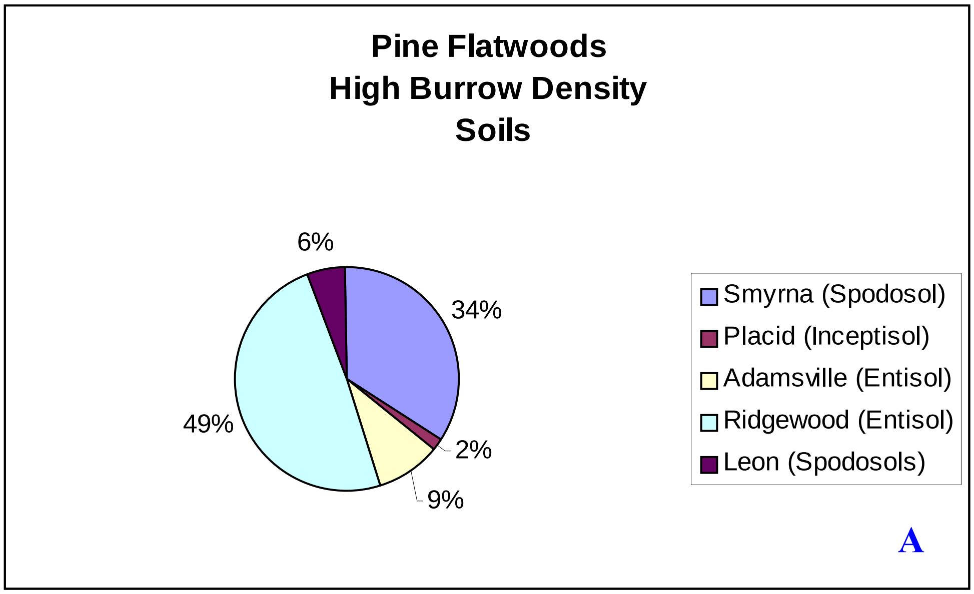


Figure 4. Soil composition of high pine survey compartment categories on the Lower Suwannee NWR, Florida. A) Soil composition of high pine compartments with high tortoise burrow densities. B) Soil composition of high pine compartments with low tortoise burrow densities.

and densities, the chances of an intense, unmanageable scrub fire killing all the trees is a serious management concern. Soils within high pine survey compartments were represented by the Clara and Leon series (Figure 4). All soils are very deep, moderately well drained soils of upland sites (Liudahl et al. 2003).

Pine flatwoods survey compartments consisted of even-aged slash pines, planted in 1978 by Buckeye Cellulose Inc., (Figure 6). Thus, the species, age, and basal area of the planted pine canopy component were controlled for between burrow density compartments. Isolated cypress (*Taxodium distichum*) wetlands are widely interspersed within these habitats but were not included within survey compartments. Years of fire exclusion followed by only dormant season fires has helped to foster the dense stands of gallberry and saw-palmetto common within refuge pine flatwoods communities, inhibiting production of herbaceous ground covers (forbs and grasses). A lack of growing season burns could facilitate the establishment of dense gallberry stands, since growing season burns appear to hinder gallberry's resprouting ability, while time since the last fire has been shown to increase the density of saw palmetto (Hughes and Knox 1964, Maliakal et al. 2000).

The sites were bedded for planting, but other management techniques conducted on these sites by the timber company is unknown. The U.S. Fish and Wildlife Service assumed management of the stands in 1985, since refuge acquisition the sites have received several dormant season prescribed burns. The plantations also received third row thinnings in 1997-98.



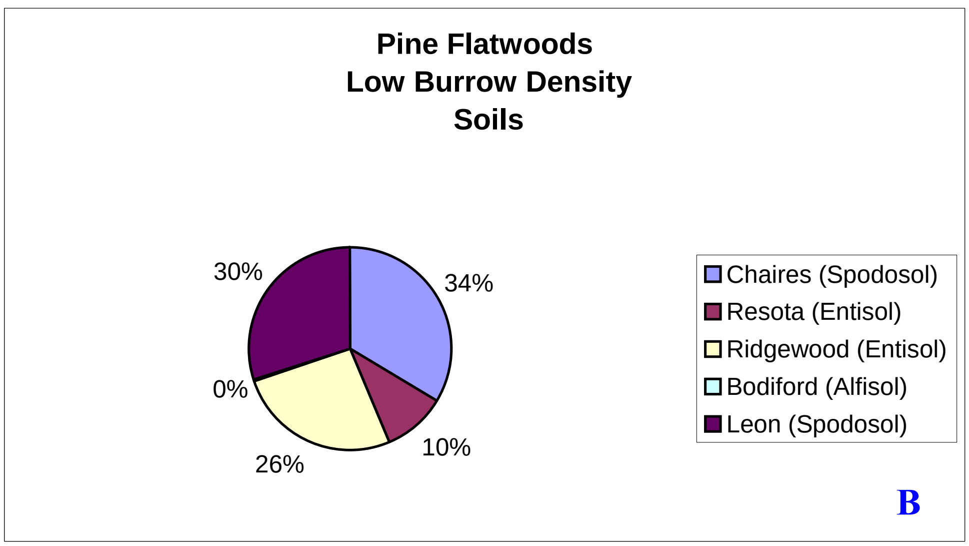


Figure 5. Soil composition of pine flatwoods survey compartment categories on the Lower Suwannee NWR, Florida. A) Soil composition of pine flatwoods compartments with high tortoise burrow densities. B) Soil composition of pine flatwoods compartments with low tortoise burrow densities.

Soil composition of pine flatwoods survey compartments contained primarily Spodosols, though Entisols, Inceptisols, and Alfisols were also present (Figure 5). The soils of flatwoods survey compartments were less uniform and more interspersed than high pine compartments. Spodosol's were represented by Smyrna, Chaires and Leon series, which have similar characteristics of being deep to very deep and poorly drained. While Entisol's were represented by Adamsville, Ridgewood and Resota series which are very deep, moderately drained psamments. Inceptisols and Alfisols occupied only 0.33 hectares within the flatwoods compartments and were represented by Bodiford and Placid soil series (Slabaugh et al. 1996, Liudahl et al. 2003).

Vegetation Surveys

Vegetation surveys were conducted from April through July 2004. Canopy cover, shrub cover and ground cover were determined within survey compartments that had exhibited relatively high or low tortoise burrow densities during the 2002 tortoise burrow surveys. A line-intercept technique was used to estimate percent canopy cover and shrub cover along each transect (Higgins et al. 1994). A 10-meter line was stretched between two stakes at a height of 1-meter. Percent canopy cover was measured by observing the total length of line intercepted by vertical projections of the canopy. Percent shrub cover was measured by observing the total length of line intercepted by plants touching the line. Only shrubs touching the nylon line were included, whereas the entire plant intercepting the vertical line was counted as percent cover. Percent ground cover was obtained using the pen-drop technique, where a pen was dropped at 1-meter increments along the line and the dominant ground cover touching the pen was recorded. Ground cover forms were grouped at each sampling location into the following 4 categories: (1) Woody (i.e., woody shrubs, tree seedlings), (2) Herbaceous (i.e., non-woody plants, legumes, forbs

Figure 6. Representative pictures of each survey compartment category: A) High pine with high tortoise burrow density, B) High pine with low tortoise burrow density, C) Pine flatwoods with high tortoise burrow density and D) Pine flatwoods with low tortoise burrow density.

and grasses), (3) Detritus (i.e., non-living plant material, leaves, needles) and (4)Bare(i.e., mineral soil). Vegetation surveys were conducted along the same transects used during the 2002 tortoise burrow surveys. Tortoise burrow survey transects were 200-meters long by 20-meters wide, covering approximately .4 hectares. Survey transects were grouped in compartments, which were placed within suitable tortoise habitats using the refuge's GIS habitat and soils layers (Cox et al. 1987, Breininger et al. 1988). Following the 2002 tortoise burrow survey, compartments were labeled either *high burrow density* or *low burrow density*; compartments were also arranged within 2 habitat categories- *pine flatwoods* or *high pine*, see Table 1 (Abrahamson and Hartnett 1990, Myers 1990).

Burrow densities for each compartment were determined by dividing the compartment area by the total number of both active and inactive burrows observed, burrow densities >1burrow/hectare were designated as high density while those compartments with ≤1burrow/hectare were identified as low density compartments. Using a random numbers table, survey transects within 8 distinct compartments were randomly selected for vegetation cover surveys (Ott 1983).

Five survey transects were selected from each habitat and burrow density category, (i.e., 5 transects taken from high pine/high burrow density compartments were compared with 5 transects taken from high pine/low burrow density compartments, while 5 transects were taken from flatwoods pine/high burrow density compartments were compared with 5 transects taken from flatwoods pine/low burrow density compartments). Since all survey compartments had been mechanically planted as even-aged stands, I was able to control for timber basal area, age class and species. Compartments also contained

Table 1. Habitats and relative burrow densities within burrow survey compartments on the Lower Suwannee NWR, Florida as determined during the 2002 survey.

Compartment/Transects	Habitat	Burrows/Hectare	Burrow Density
1/1-20*	Pine Flatwoods	1.13	High
1/21-30	Pine Flatwoods	1.00	Low
1/31-40	Pine Flatwoods	0.50	Low
1/41-50	Pine Flatwoods	1.25	High
1/51-60	Pine Flatwoods	0.25	Low
1/61-70	Pine Flatwoods	0.00	Low
2/1-10	Pine Flatwoods	1.00	Low
2/11-17	Pine Flatwoods	0.00	Low
3/1-6	Pine Flatwoods	0.00	Low
4/1-16	Pine Flatwoods	0.94	Low
4/17-36	Pine Flatwoods	0.88	Low
4/37-53	Pine Flatwoods	0.74	Low
6/1-15	Pine Flatwoods	0.00	Low
6/16-25	Pine Flatwoods	0.00	Low
7/1-10*	Pine Flatwoods	0.00	Low
7/11-16*	Pine Flatwoods	0.00	Low
8/1-15*	Pine Flatwoods	3.50	High
8/16-25*	Pine Flatwoods	3.50	High
9/1-20*	High Pine	4.25	High
9/21-35*	High Pine	5.17	High
9/36-45	High Pine	1.00	Low
9/46-55	High Pine	2.50	High
9/56-61*	High Pine	0.83	Low
9/62-70 *	High Pine	0.83	Low

*Compartments containing randomly selected vegetation surveys.

very similar burn histories; with no compartments receiving a growing season burn prior to this study. Vegetation cover percentages were recorded at 20-meter intervals along the 200-meter burrow survey transects. At 20-meter intervals a 10-meter vegetation cover transect was surveyed perpendicular to and on both sides of the burrow survey transect. This provided 20, 10-meter vegetation cover transects spaced throughout each burrow survey transect.

Statistical Analysis

Microsoft Excel® 2000 was used for statistical analysis. I arcsine transformed percentages (i.e., percent canopy cover, shrub cover and ground cover) prior to analysis so they would better meet the normality assumption of analysis of variance (Ott 1983). The assumption of homogeneity of population variances was not considered critical since the sample sizes were equal. I considered a 0.05 probability level statistically significant for all tests. A chi-square test of independence was used to determine if the amount of the 4 ground cover forms were independent of the amount of shrub or canopy cover observed. For the chi-square test of independence canopy, shrub and the 4 ground cover forms data was grouped into 2 categories: High for values ≥ 0.5, and Low for values < 0.5. Data represented in descriptive statistics or used for the chi-square test was not transformed.

RESULTS

Vegetation Surveys

Analysis of canopy closure data indicates significant differences when comparing between burrow densities within each of the pine community types (Figure 6). Canopy cover differed significantly between high pine burrow density category sites (P=0.000). Canopy cover also differed between pine flatwoods high and low tortoise burrow density sites (P=0.000). Within both habitat categories, low tortoise burrow density sites had greater canopy closure than respective high tortoise burrow density sites. The mean values prior to transformation, for each habitat and tortoise burrow density category can be found in table 2.

Shrub cover within the two pine communities also differed significantly between high pine tortoise burrow density category sites (P=0.000). Shrub cover also differed between pine flatwoods high and low tortoise burrow density sites (P=0.000). Within both habitat categories, low tortoise burrow density sites had greater shrub cover densities than respective high tortoise burrow density sites (Figure 7).

Herbaceous ground cover differed significantly between high pine tortoise burrow density category sites (P=0.000). Herbaceous ground cover also differed between pine flatwoods high and low tortoise burrow density sites (P=0.000). Within both habitat categories high tortoise burrow density sites had greater herbaceous ground cover densities than respective low tortoise burrow density sites (Figure 8).

Table 2. Descriptive statistics of vegetation cover for each habitat and burrow density category on the Lower Suwannee NWR, Florida.

Burrow Density	Canopy Cover Mean	SD	Shrub Cover Mean	SD	Herb Cover Mean	SD	Woody Cover Mean	SD	Bare Soil Mean	SD	Detritus Cover Mean	SD
HIGH PINE												
High(n=100)	0.12	0.13	0.10	0.12	0.43	0.23	0.13	0.14	0.26	0.19	0.17	0.21
95% CI	0.03		0.02		0.05		0.03		0.04		0.04	
Low(n=100)	0.43	0.03	0.72	0.22	0.14	0.14	0.43	0.20	0.07	0.11	0.36	0.22
95% CI	0.05		0.04		0.03		0.04		0.02		0.04	
PINE FLATWOODS												
High(n=100)	0.28	0.28	0.11	0.15	0.53	0.30	0.23	0.18	0.00	0.02	0.20	0.21
95% CI	0.05		0.03		0.06		0.03		0.00		0.04	
Low (n=100)	0.52	0.30	0.81	0.12	0.19	0.16	0.51	0.22	0.00	0.00	0.30	0.22
95% CI	0.06		0.02		0.03		0.04		0.00		0.04	

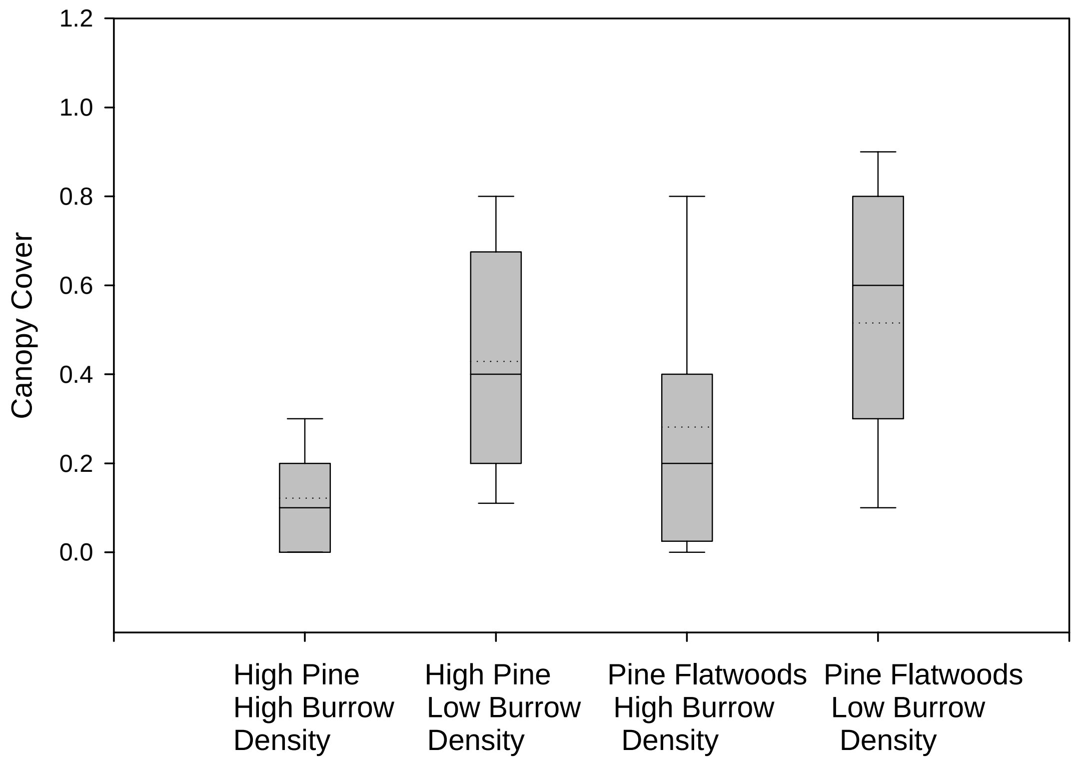


Figure 7. Comparisons of canopy cover between burrow densities within each of the pine community types on the Lower Suwannee NWR, Florida. Box contains upper and lower quartiles, dotted line indicates mean, dash indicates median, whiskers connect box to largest and smallest values. Data was not transformed.

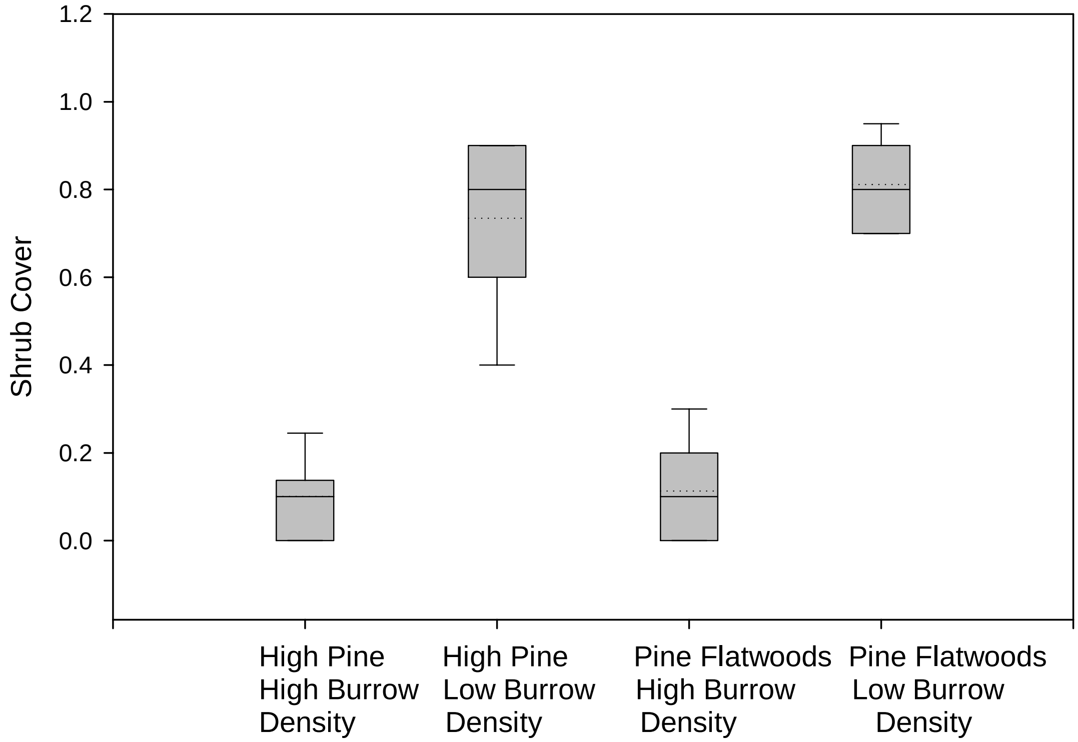


Figure 8. Comparisons of shrub cover between burrow densities within each of the pine community types on the Lower Suwannee NWR, Florida. Box contains upper and lower quartiles, dotted line indicates mean, dash indicates median, whiskers connect box to largest and smallest values. Data was not transformed.

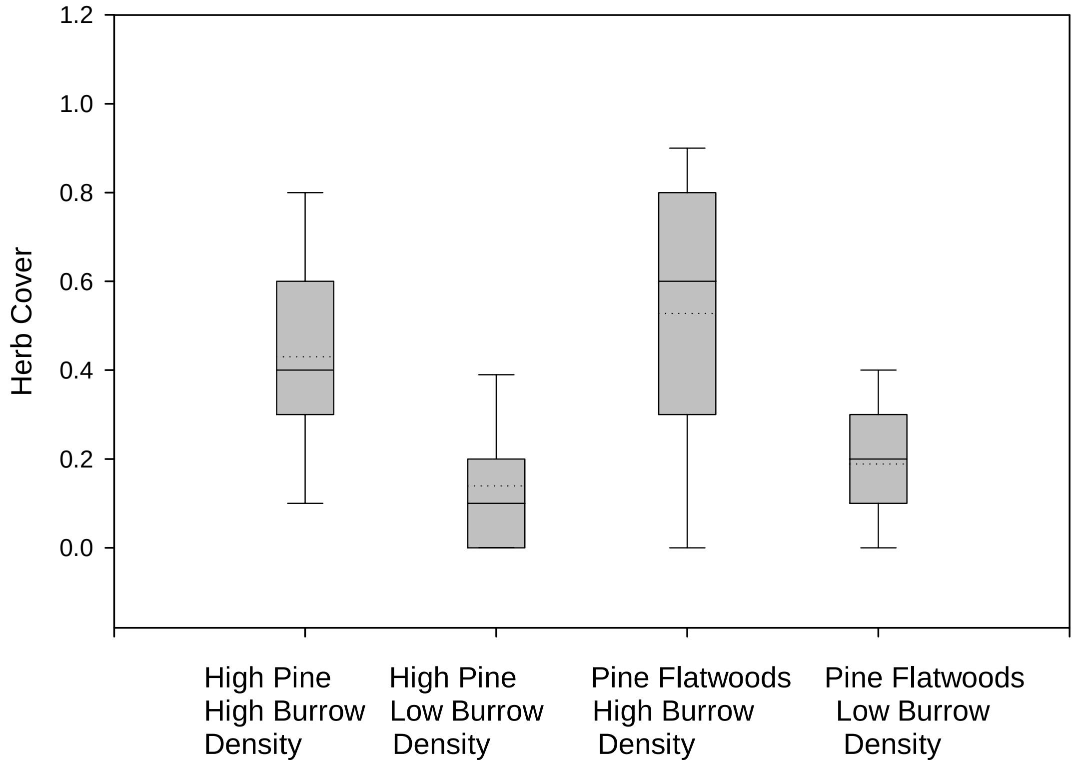


Figure 9. Comparisons of herbaceous ground cover between burrow densities within each of the pine community types on the Lower Suwannee NWR, Florida. Box contains upper and lower quartiles, dotted line indicates mean, dash indicates median, whiskers connect box to largest and smallest values. Data was not transformed.

Woody ground cover differed between high pine tortoise burrow density category sites (P=0.000). Woody ground cover also differed between pine flatwoods high and low tortoise burrow density sites (0 P=0.000). Within both habitat categories, low tortoise burrow density sites had greater woody ground cover densities than respective high burrow density sites (Figure 9).

Amount of exposed bare mineral soil differed between high pine tortoise burrow density category sites (P=0.000), as illustrated in Figure 10. However, amount of exposed bare mineral soil did not differ between pine flatwoods high and low tortoise burrow density sites (P=0.320). Within high pine habitat, sites with high tortoise burrow densities had more exposed bare mineral soil than respective low burrow density sites. Within pine flatwoods sites, areas of bare mineral soil were infrequent, thus accounting for the lack of difference between sites.

The amount of detritus ground cover differed between high pine tortoise burrow density category sites (P=0.000). The amount of detritus ground cover also differed between pine flatwoods high and low tortoise burrow density sites (P=0.004). Within both habitat categories low tortoise burrow density sites had more detritus ground cover than respective high burrow density sites (Figure 11).

Chi-Square Analysis

Chi-square tests of independence results for the association of canopy cover to shrub cover within both habitat categories are shown in table 3. Shrub cover was dependent upon canopy cover in both high pine and pine flatwoods categories respectively (χ^2=40.7, 24.7).

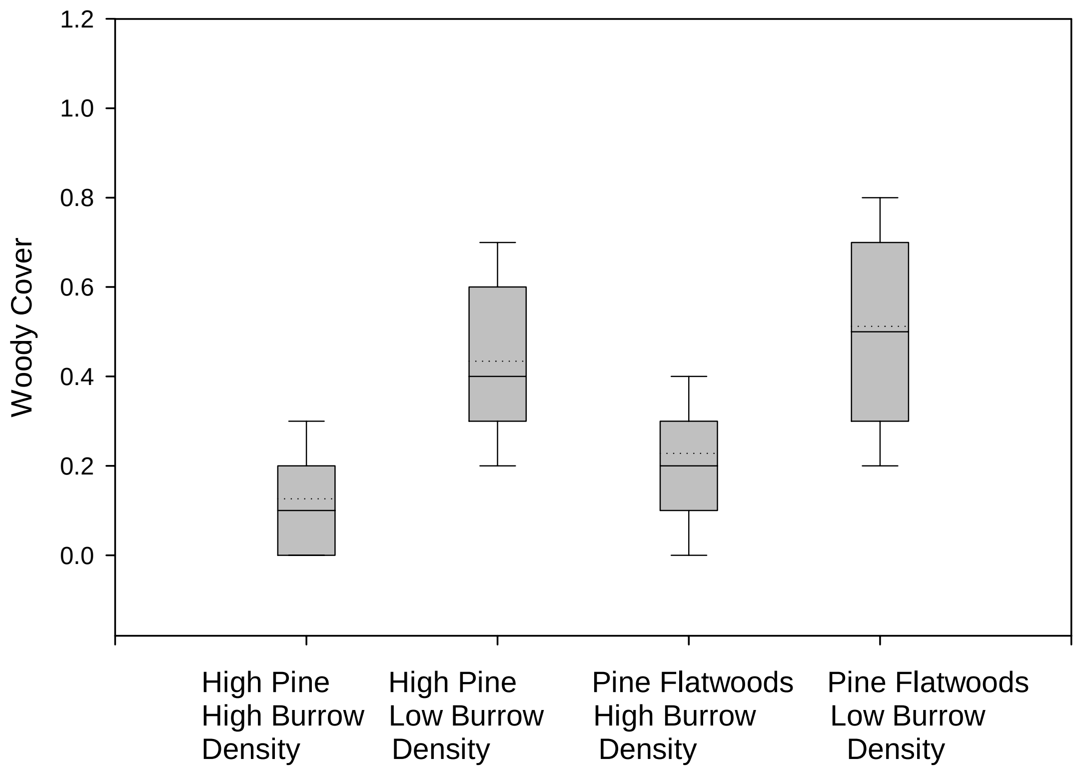


Figure 10. Comparisons of woody ground cover between burrow densities within each of the pine community types on the Lower Suwannee NWR, Florida. Box contains upper and lower quartiles, dotted line indicates mean, dash indicates median, whiskers connect box to largest and smallest values. Data was not transformed.

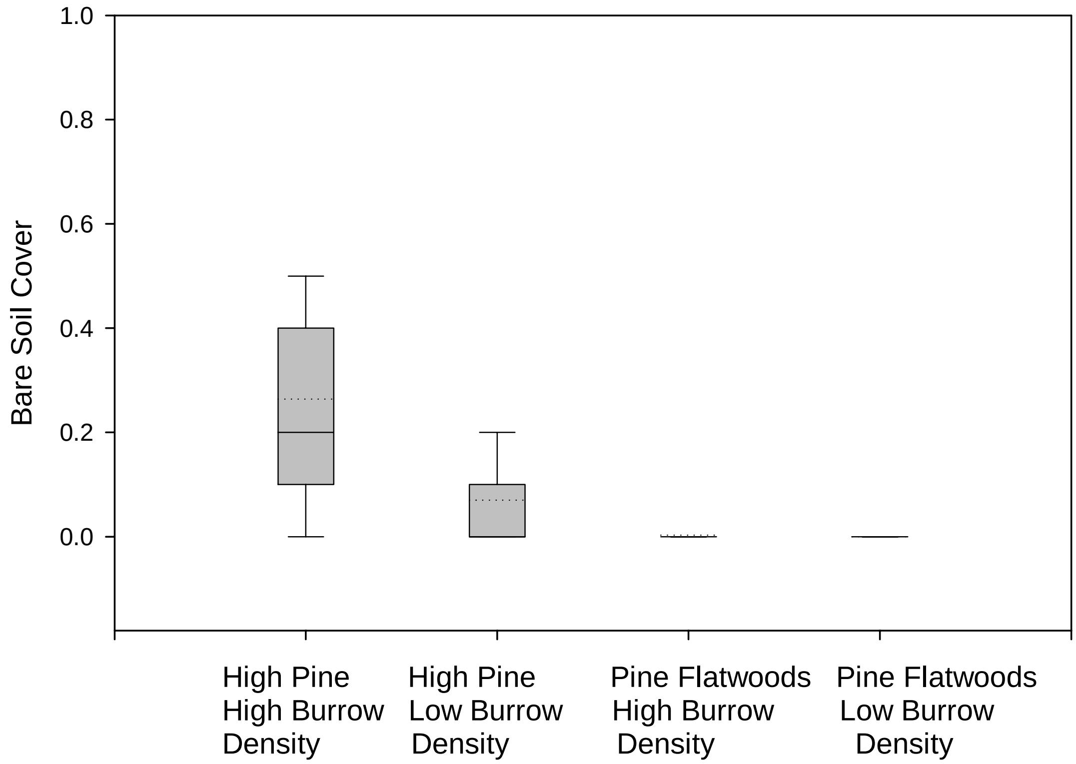


Figure 11. Comparisons of bare soil ground cover between burrow densities within each of the pine community types on the Lower Suwannee NWR, Florida. Box contains upper and lower quartiles, dotted line indicates mean, dash indicates median, whiskers connect box to largest and smallest values. Data was not transformed.

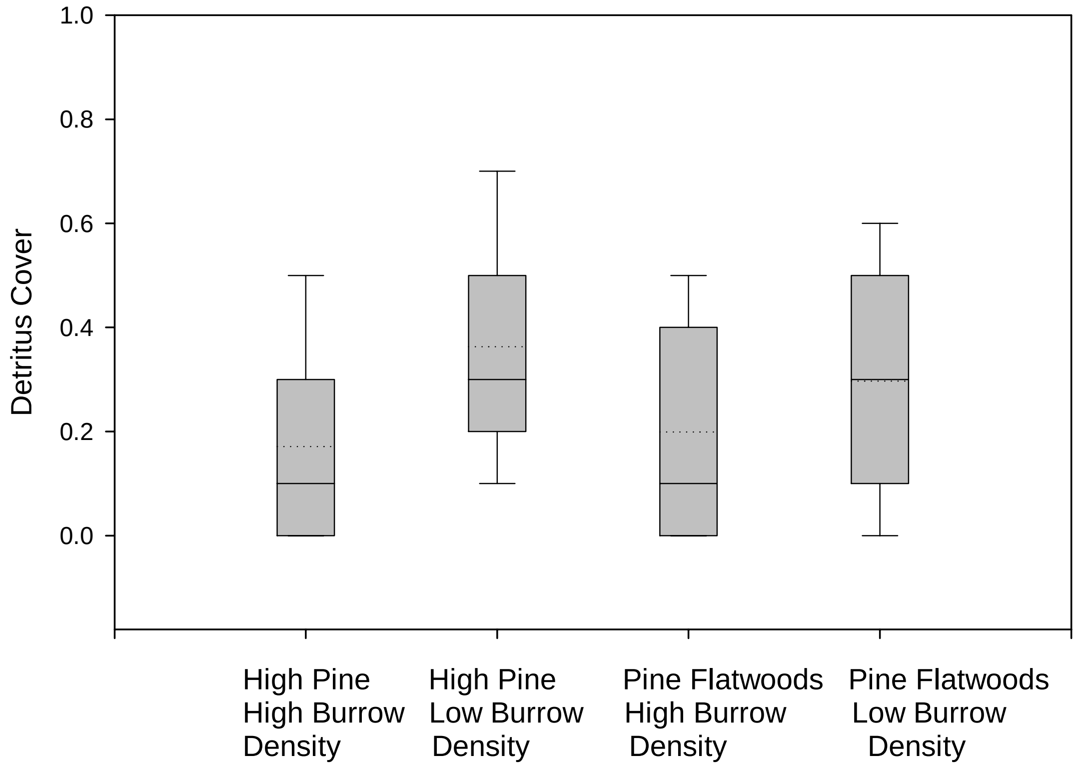


Figure 12. Comparisons of detritus ground cover between burrow densities within each of the pine community types on the Lower Suwannee NWR, Florida. Box contains upper and lower quartiles, dotted line indicates mean, dash indicates median, whiskers connect box to largest and smallest values. Data was not transformed.

Chi-square tests of independence results for the association of canopy cover to herbaceous ground cover, within both habitat categories are shown in table 4. Notice within the pine flatwoods habitat category canopy cover and herbaceous ground cover are independent (χ^2=2). While herbaceous ground cover was not independent of canopy cover within the high pine category (χ^2=8.9).

Chi-square tests of independence results for the association of canopy cover to woody ground cover, within both habitat categories are shown in table 5. High chi-square values for both high pine and pine flatwoods categories respectively (χ^2= 17.4, 17.8) indicate the amount of woody ground cover was not independent of the accompanying canopy cover. Chi-square tests of independence results for the association of canopy cover to bare ground cover, within both habitat categories are shown in table 6. The chi-square values suggest bare ground cover is not independent within the high pine habitats (χ^2= 5.6), however within the pine flatwoods category bare ground cover is independent of canopy cover (χ^2= 0.01). Chi-square tests of independence results for the association of canopy cover to detritus ground cover are shown in table 7. Within both habitat categories detritus ground cover was dependent upon the amount of canopy cover, with a high pine χ^2 value of 7 and a pine flatwoods of 4.9.

Chi-square tests of independence results for the association of shrub cover to herbaceous ground cover, within both habitat categories are shown in table 8. Within both habitat categories herbaceous ground cover was not independent of shrub cover (high pine χ^2= 37.9, pine flatwoods χ^2= 60.3). Chi-square tests of independence results for the association of shrub cover to woody ground cover, within both habitat categories are shown in table 9. Indicating the amount of woody ground cover was not independent

Table 3. Chi-square tests of independence between canopy cover and shrub cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Shrub Observed (expected)	<50% Shrub Observed (expected)	Totals
≥50% Canopy	39(20.7)	6(25.8)	45
<50% Canopy	50(70.2)	105(87.4)	155
Totals	89	111	200

χ^2= 40.7

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Shrub Observed (expected)	<50% Shrub Observed (expected)	Totals
≥50% Canopy	58(41.6)	21(39.2)	79
<50% Canopy	45(63.4)	76(59.8)	121
Totals	103	97	200

χ^2= 24.7

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Table 4. Chi-square tests of independence between canopy cover and herbaceous ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Herb Observed (expected)	<50% Herb Observed (expected)	Totals
≥50% Canopy	3(11)	42(35.4)	45
<50% Canopy	44(37.4)	111(120.1)	155
Totals	47	153	200

χ^2= 8.9

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Herb Observed (expected)	<50% Herb Observed (expected)	Totals
≥50% Canopy	21(26.4)	58(54.4)	79
<50% Canopy	44(40.3)	77(83)	121
Totals	65	135	200

χ^2= 2

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Table 5. Chi-square tests of independence between canopy cover and woody ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Woody Observed (expected)	<50% Woody Observed (expected)	Totals
≥50% Canopy	22(11.5)	23(34.5)	45
<50% Canopy	28(39)	127(117)	155
Totals	50	150	200

χ^2= 17.4

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Woody Observed (expected)	<50% Woody Observed (expected)	Totals
≥50% Canopy	39(25.6)	40(54.4)	79
<50% Canopy	25(39)	96(83)	121
Totals	64	136	200

χ^2= 17.8

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Table 6. Chi-square tests of independence between canopy cover and bare ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Bare Observed (expected)	<50% Bare Observed (expected)	Totals
≥50% Canopy	0(4.1)	45(41.9)	45
<50% Canopy	18(14)	137(142)	155
Totals	18	182	200

χ^2= 5.6

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Bare Observed (expected)	<50% Bare Observed (expected)	Totals
≥50% Canopy	0(0)	79(80)	79
<50% Canopy	0(0)	121(122)	121
Totals	0	200	200

χ^2= 0.01

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Table 7. Chi-square tests of independence between canopy cover and detritus ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Detritus Observed (expected)	<50% Detritus Observed (expected)	Totals
≥50% Canopy	17(10.6)	28(35.4)	45
<50% Canopy	29(35.9)	126(120)	155
Totals	46	154	200

$\chi^2 = 7$

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Detritus Observed (expected)	<50% Detritus Observed (expected)	Totals
≥50% Canopy	11(17.6)	68(62.4)	79
<50% Canopy	33(26.8)	88(95.2)	121
Totals	44	156	200

$\chi^2 = 4.9$

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Table 8. Chi-square tests of independence between shrub cover and herbaceous ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Herb Observed (expected)	<50% Herb Observed (expected)	Totals
≥50% Shrub	2(23.4)	87(66.6)	89
<50% Shrub	45(29.1)	66(82.9)	111
Totals	47	153	200

χ^2= 37.9

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Herb Observed (expected)	<50% Herb Observed (expected)	Totals
≥50% Shrub	5(30.7)	98(73.3)	103
<50% Shrub	54(29.4)	43(69.1)	97
Totals	59	141	200

χ^2= 60.3

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

the amount of shrub cover. With high chi-square values reached within both habitat categories (high pine χ^2= 60.3, pine flatwoods χ^2= 50.5). Chi-square tests of independence results for the association of shrub cover to bare ground cover, within both habitat categories are shown in table 10. Within the high pine habitats bare ground cover was not independent of shrub cover (χ^2= 15.9), while the pine flatwoods category was unable to show independence (χ^2= 0), most probably due to a lack of bare ground within this habitat.

Chi-square tests of independence results for the association of shrub cover to detritus ground cover, within both habitat categories are shown in table 11. Within both high pine and pine flatwoods categories, respectively the amount of detritus ground cover was not independent from the amount of accompanying shrub cover (χ^2= 16.4 and 4.6).

Table 9. Chi-square tests of independence between shrub cover and woody ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Woody Observed (expected)	<50% Woody Observed (expected)	Totals
≥50% Shrub	46(22.5)	43(67.5)	89
<50% Shrub	4(28)	107(84)	111
Totals	50	150	200

χ^2= 60.3

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Woody Observed (expected)	<50% Woody Observed (expected)	Totals
≥50% Shrub	56(33.3)	47(71.8)	103
<50% Shrub	7(31.4)	90(67.6)	97
Totals	63	137	200

χ^2= 50.5

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Table 10. Chi-square tests of independence between shrub cover and bare ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Bare Observed (expected)	<50% Bare Observed (expected)	Totals
≥50% Shrub	0(8.1)	89(81.9)	89
<50% Shrub	18(10)	93(101.9)	111
Totals	18	182	200

χ^2= 15.9

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Bare Observed (expected)	<50% Bare Observed (expected)	Totals
≥50% Shrub	0(0)	103(103)	103
<50% Shrub	0(0)	97(97)	97
Totals	0	200	200

χ^2= 0

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Table 11. Chi-square tests of independence between shrub cover and detritus ground cover within the 2 habitat categories on the Lower Suwannee NWR, Florida.

High Pine Vegetation Cover	≥50% Detritus Observed (expected)	<50% Detritus Observed (expected)	Totals
≥50% Shrub	32(20.7)	57(70.2)	89
<50% Shrub	13(25.8)	98(87.4)	111
Totals	45	155	200

χ^2= 16.4

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

Pine Flatwoods Vegetation Cover	≥50% Detritus Observed (expected)	<50% Detritus Observed (expected)	Totals
≥50% Shrub	29(22.9)	74(81.1)	103
<50% Shrub	15(21.6)	82(76.4)	97
Totals	0	200	200

χ^2= 4.6

df= (2-1)(2-1)= 1

P (α=.05) = 3.84

DISCUSSION

Vegetation cover survey results showed significant differences in all vegetation categories except the bare soil ground cover form, since bare soil was uncommon within the pine flatwoods compartments. These results supported the hypothesis that compartments with high herbaceous ground cover and low shrub/canopy covers supported higher densities of gopher tortoise burrows. While areas with low burrow densities had higher shrub and canopy covers with lower herbaceous ground cover. Chi-square results allowed the rejection of the null hypothesis that ground cover densities were independent of canopy and shrub cover densities in almost all categories. Though within the flatwoods habitats herbaceous and bare ground covers were not dependent upon canopy cover. Also, within the flatwoods habitats bare ground cover was not dependent upon the amount of shrub cover. The following discussion describes these findings in the context of the respective habitat categories.

High Pine Habitats

In high pine habitats on the Lower Suwannee NWR, tortoise burrow densities were higher within survey compartments with the most open shrub layers. A lack of burrows within a survey compartment was associated with both shrub and canopy closure. The shrub and canopy layers within low tortoise burrow density compartments were characterized by a dense covering of young oaks. These successional changes within the shrub and canopy layers appear to have led to lower herbaceous ground cover, less areas of exposed bare soil with higher woody and detritus ground covers observed. Within high pine habitat compartments paired comparisons indicate the strongest association between tortoise burrow density and vegetation cover was at the shrub layer, this is likely because of the rather young age of the planted pine component (11 years) where light limitation to understory vegetation due to canopy closure has not yet occurred.

The vegetation cover differences, and therefore tortoise burrow density differences, between survey compartments cannot be fully explained by past management practices. The U. S. Fish and Wildlife Service assumed management of the lands containing the high pine survey compartments in 1990, from the Georgia Pacific timber company. Soon after refuge acquisition the area was completely clear-cut of planted slash pines by Georgia Pacific in accordance with a deed agreement. After clear cutting, refuge personnel began mechanical, V-blade planting of the sites to long leaf pine in 1993. Intensive site prepping was not conducted prior to the 1993 plantings. A detailed management history, including methods of site prep, vegetation control and planting techniques on these sites prior to 1990 is unknown. Though some site prep techniques could entomb tortoises, such as the piling of large windrows directly on a burrow, gopher tortoises are able to dig out of impacted burrows following certain types of site preparation on sandy soils (Landers and Buckner 1981, Diemer and Moler 1982). Thus, it is unlikely tortoises entombment can explain differences in tortoise density noted in the 2002 survey.

One explanation for the observed vegetation cover differences between survey compartments is available soil moisture. The GIS soil analysis revealed that 29% of the two low tortoise burrow density compartments occurred in a Leon soil series. This soil series has a higher moisture content than other soils series present in this survey compartment. However this particular Spodosol soil is very deep and has high permeability in the A and E horizon with moderate permeability in the Bh horizon. Also, plant community composition observed did not reflect an extreme difference in available moisture compared to other high pine sites, as more mesic or flatwoods type vegetation such as gallberry (*Ilex glabra*) or ericaceous shrubs were not observed to dominate any of the high pine sites. A working hypothesis to be tested in the future is that higher soil moisture contents may have increased the rate of shrub and canopy closure within these sites, but that soil moisture differences were not dramatic enough to shift community composition towards flatwoods type plants.

Pine Flatwoods Habitats

Within pine flatwoods compartments surveyed, differences in vegetation cover and gopher tortoise burrow densities were most strongly associated with the amount of shrub cover. Observed shrub cover was very low in compartments characterized as high tortoise burrow density, while the opposite was observed in low tortoise burrow density compartments. Since all compartments contained planted slash pines of very similar ages and basal areas, canopy differences observed were related to canopy closure by plants within the shrub layer. This successional closure of the shrub and canopy layers presumably caused lower herbaceous ground cover along with higher woody and detritus ground covers observed within the low tortoise density compartments.

The shrub cover observed in low tortoise burrow density compartments is characterized by dense stands of gallberry and saw-palmetto with intermixed oaks. Shifting to growing season burns may reduce the density of saw-palmetto and gallberry stands. It has been theorized that top kill of many species early in the growing season can halt carbohydrate production when carbohydrate reserves normally in the root system are at their lowest level, thereby increasing kill (Waldrop et al. 1987). However, other studies suggest that even after repeated, early growing season burns these very fire resilient species will not be eradicated (Hough 1968, Hughes and Knox 1964). Though growing season burns should decrease their densities due to the stress placed on carbohydrate reserves.

Carbohydrate reserves in the rhizomes of gallberry and saw-palmetto have been found at their lowest in August (Hough 1968, Hughes and Knox 1964). Therefore, if the management goal is to decrease the densities of these two species late growing season burns may be most effective.

As with the high pine survey compartments the observed differences in vegetation cover can not be fully explained by past management practices; most probably, slight differences in soil moisture may have accelerated succession within certain compartments.

MANAGEMENT IMPLICATIONS

Gopher tortoise burrow densities were highest in high pine and pine flatwoods communities on the Lower Suwannee NWR when shrub and canopy cover was relatively low and herbaceous ground cover, as well as areas of bare soil, were relatively high. Gopher tortoise densities are higher in open areas with herbaceous ground cover than in brushy, shaded sites; the former have patches of bare ground needed for nest excavation and also provide abundant herbaceous vegetation for feeding (Cox et al. 1987). This type of habitat can be promoted by growing season fires (Robbins and Meyers 1992). Furthermore, it has been suggested that growing season fires might increase the amount of food available in late summer when food quality is declining and would provide food conditions for new hatchlings, which emerge in late summer and early fall (Cox et al. 1987).

Under current conditions burning is problematic, if not impossible within high pine areas on the refuge due to years of habitat degradation from a lack of fire. Fire suppression has allowed these areas to begin succession to a mesic hardwood forest. This process of succession has concentrated gopher tortoise populations to the higher, drier sites, where inevitable succession is lagging behind more moist sites. Mesic hardwood forest conditions are characterized by higher shading, greater detritus accumulation, and less herbaceous ground cover than natural high pine forests. Since these areas have been excluded from fire for at least 15 years, a lack of ground fuel greatly restricts a fire's intensity and its ability to spread thereby rendering fire alone somewhat ineffective as a management tool for restoration of these habitats.

Two alternate methods for restoring high pine habitats on the refuge include use of a selective herbicide to remove hardwoods and restoration plantings. The utility of a selective herbicide such as hexazinone, has been demonstrated for restoration of longleaf pine communities (Hay-Smith and Tanner 1994). Hexazinone can facilitate the release of wiregrass and aid in the reduction of scrub oak populations without damage to other woody and herbaceous vegetation. Current research calls for forest managers to use hexazinone rates ranging from 0.84 to 1.68Kg/ha, in liquid form applied in a grid pattern to the soil surface. Applications should be made prior to rainfall, as rain is required to distribute the herbicide through the root column. Broadcast applications of granular hexazinone are discouraged as this may damage the herbaceous plant layer. It should also be noted, the use of an herbicide is an important precursor to facilitate future prescribed fire, not to replace fire.

After herbicide use restoration plantings of wiregrass should be pursued as aggressively as possible. Restoration plantings of wiregrass will reintroduce this fire-dependant species to these sites and further provide an ignition source to carry future prescribed fires. These plantings will also provide forage for resident gopher tortoises and other fauna. Depending upon the amount of site preparation needed on individual sites and costs, refuge management can choose between sowing wiregrass seeds or planting plugs. Wiregrass seeds do best when sown upon bare soil, while plugs, despite their higher costs are better suited for a wider array of planting sites.

Following herbicide application and the establishment of wiregrass, prescribed fire should be returned to these sites. Initially emphasis should be placed on growing season burns to facilitate the further propagation of wiregrass. Subsequently, burning at various times of the year under varying conditions will encourage plant diversity without completely eliminating individual species. A fire frequency of 2 to 4 years would mimic the natural burning frequency, maintain pine dominance and promote reproduction in wiregrasses (Tanner et al. 1991).

Pine flatwoods habitats on the refuge exist as slash pine plantations established for pulpwood production, therefore, these habitats differ markedly from natural flatwoods habitats. To bolster pulpwood production, timber companies established dense plantations of slash pine across landscapes. Currently slash pine plantations on the refuge are planted too densely and should be thinned. Timber thinning opens the canopy, which promotes herbaceous growth on the forest floor and aids in prescribed burning by allowing the upward release of heat, the latter especially important for the safe implementation of growing season burns. As with the high pine habitats, a return to growing season burns and a varied burn cycle with burns occurring every 2 to 4 years should be a management goal.

Compartments surveyed for this study contained slash pine basal areas of approximately 21.75 sq. meters/hectare (94 sq. feet/acre) (pers. comm., D. Barrand, Chiefland, FL). The refuge's habitat management plan appropriately calls for thinning of these stands down to 11.5-15 sq. meters/hectare (50-65 sq. feet/acre) during second entry thinnings (unpubl. Data, USFWS, LSNWR). This study highlights the importance of timber thinning and the need to restore diversity to areas indiscriminately planted to slash pine monocultures. Upon thinning, restoration plantings of longleaf pine and wiregrass should take place.

Within the habitat management plan the refuge is divided into 9 compartments to facilitate habitat management actions and aid record keeping. Management compartment boundaries were established along major physiographical and legal features such as roads, streams and landowner boundaries. Some of these compartments are further compartmentalized into sub-compartments for more precise land management work.

The current system of compartmentalization should be further delineated since the current compartments ignore or leave out habitats that were converted to slash pine stands by the previous timber company management. For example, areas within the compartments I sampled contained ridges of sandy, Entisol soils which would have supported either high pine or scrub habitats prior to timber management. Also, within these compartments, areas of wetter, Aquent soils were bedded and planted through.

Spodosols would be the primary soils dominated by pine flatwoods, as they form under coniferous trees whose needles are low in base-forming cations and high in acid resins. These acids bind with iron and aluminum and are carried downward until they precipitate forming the characteristic spodic horizon (Brady and Weil 2002). A closer look at each management unit, noting these areas of soil diversity could benefit future habitat management activities on the refuge. For example, depending on area, higher ridges could be clear cut of planted slash pine, then restored to high pine or scrub habitats, while areas of spodosol soils could be maintained as pine flatwoods. Instead of looking at one block of slash pine timber, this shift in management approach would focus on restoring the natural interspersion of habitats that existed on the area prior to timber company acquisition, thereby greatly increasing habitat diversity on the refuge.

APPENDIX
ANALYSIS OF VARIANCE TABLES

Table 12. Analysis of variance results for high pine canopy cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	29.53	0.295	0.047
Low Burrow Density	100	70.42	0.704	0.088

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.359	1	8.359	122.700	1.675E-22	3.888
Within Groups	13.490	198	0.068			
Total	21.850	199				

Table 13. Analysis of variance results for high pine shrub cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	26.01	0.260	0.042
Low Burrow Density	100	106.15	1.061	0.068

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.112	1	32.112	575.799	1.629E-60	3.888
Within Groups	11.042	198	0.055			
Total	43.154	199				

Table 14. Analysis of variance results for high pine woody ground cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	29.01	0.290	0.057
Low Burrow Density	100	70.77	0.707	0.057

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.719	1	8.719	152.52	2.370E-26	3.888
Within Groups	11.319	198	0.057			
Total	20.039	199				

Table 15. Analysis of variance results for high pine bare mineral soil cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	49.32	0.493	0.070
Low Burrow Density	100	18.2	0.182	0.043

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.842	1	4.842	84.635	5.109E-17	3.888
Within Groups	11.328	198	0.057			
Total	16.170	199				

Table 16. Analysis of variance results for high pine detritus ground cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	33.52	0.335	0.095
Low Burrow Density	100	53.3	0.533	0.107

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.956	1	1.956	19.259	1.854E-05	3.888
Within Groups	20.111	198	0.101			
Total	22.067	199				

Table 17. Analysis of variance results for high pine herbaceous ground cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	71.27	0.712	0.080
Low Burrow Density	100	31.31	0.313	0.056

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.984	1	7.984	116.741	1.089E-21	3.888
Within Groups	13.541	198	0.068			
Total	21.525	199				

Table 18. Analysis of variance results for pine flatwoods canopy cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	49.39	0.493	0.135
Low Burrow Density	100	79.48	0.794	0.133

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.527	1	4.527	33.646	2.583E-08	3.888
Within Groups	26.640	198	0.134			
Total	31.167	199				

Table 19. Analysis of variance results for pine flatwoods shrub cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	26.36	0.263	0.061
Low Burrow Density	100	113.48	1.134	0.033

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.949	1	37.949	801.44	1.564E-71	3.888
Within Groups	9.375	198	0.047			
Total	47.325	199				

Table 20. Analysis of variance results for pine flatwoods woody ground cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	45.52	0.455	0.068
Low Burrow Density	100	80.15	0.801	0.062

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.996	1	5.996	91.798	4.173E-18	3.888
Within Groups	12.933	98	0.065			
Total	18.929	199				

Table 21. Analysis of variance results for pine flatwoods bare mineral soil cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	3.29	0.032	0.000841
Low Burrow Density	100	3	0.03	1.822E-18

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00042	1	0.000420	1	0.318	3.888
Within Groups	0.083	198	0.0004205			
Total	0.083	199				

Table 22. Analysis of variance results for pine flatwoods detritus ground cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	37.86	0.378	0.095
Low Burrow Density	100	53.23	0.532	0.084

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.181	1	1.181	13.147	0.00036624	3.888
Within Groups	17.789	198	0.089			
Total	18.970	199				

Table 23. Analysis of variance results for pine flatwoods herbaceous ground cover comparisons.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High Burrow Density	100	81.06	0.810	0.165
Low Burrow Density	100	40.45	0.404	0.053

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.245	1	8.245	75.187	1.541E-15	3.888
Within Groups	21.714	198	0.109			
Total	29.960	199				

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BIOGRAPHICAL SKETCH

Stephen E. Barlow was born on 25 July 1969 in Plant City, Florida. Soon after, his family moved to Chiefland, Florida, where he was raised; he graduated from Chiefland High School in May 1987. After serving five years in the U. S. Army and three years in the U.S. Army Reserve he attended Pittsburg State University in Pittsburg, Kansas, from which he received his Bachelor of Science degree in biology in December 1997. He enrolled at the University of Florida in January 1998, majoring in environmental science with a minor in wildlife ecology, and graduated with the Master of Science degree in December 2004. During graduate school he began his professional career as a wildlife technician with the Florida Fish and Wildlife Conservation Commission in January 1999. He was soon promoted to biological scientist and after 3 years of service with the state of Florida, he accepted his current position with the U.S. Fish and Wildlife Service as the wildlife biologist on the Lower Suwannee National Wildlife Refuge. He and Elizabeth Jane Works, of Humboldt, Kansas, were married on 21 December 1992. They have one son, Seth Douglas Barlow, born in Gainesville, Florida, on 21 August 2001.