ABUNDANCE, RICHNESS, AND HABITAT PREFERENCES OF SMALL MAMMALS ON SPRING ISLAND, SOUTH CAROLINA.

by

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DEDICATION

I would like to dedicate my thesis to my great grandmother, Jennie Dolce; I have strived my entire life to make her proud. She is the one person who supported, loved, and encouraged me throughout my life. She has passed, but I know she is in heaven looking down on me and smiling.

"Trust in the Lord with all your heart,

And lean not on your own understanding;

In all your ways acknowledge Him,

And He shall direct your paths."

Proverbs 3:5-6

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Abundance, richness, and habitat preferences of small mammals on Spring Island, South Carolina

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ABSTRACT

Rodents play significant roles in many communities acting as predators, prey, and dispersal agents for trees and plants. The distribution and abundance of rodents often reflects habitat preferences based on the quality of existing habitats. Alterations and land management practices (e.g. strip disking) can significantly affect small mammal populations.

To asses habitat quality and management practice effects, small mammal populations on Spring Island, SC were studied in the summer of 2007. Relative abundance, distance traveled, and area used by three species of small rodents were quantified in four distinct habitats: oak, pine, palmetto, and managed fields. *Peromyscus gossypinus* was the most common small terrestrial mammal on the island. Although *P. gossypinus* was found in all of the habitats, palmetto and pine habitats were preferred. Abundances of *Sigmodon hispidus* and *Oryzomys palustris* were notably lower than *P. gossypinus*. *Sigmodon hispidus* was not found in oak habitats and *O. palustris* was not found in oak or palmetto habitats; both preferred managed fields and pine habitats.

Findings confirm that *P. gossypinus* is a habitat generalist, whereas preferences of *S. hispidus* and *O. palustris* are more specific.

The distance traveled and area covered within a night by *P. gossypinus* did not differ between habitats. *Peromyscus gossypinus* is abundant in palmetto and pine habitats, but the quality of the habitats may not differ.

Within managed fields, rodents traveled greater distances in areas that were not disked relative to those areas that were disked, suggesting possible avoidance of disked areas. Findings oppose the prediction that rodents would prefer areas with greater concentration of native plants. Since disking did not influence the relative abundance of native grasses as expected, preference for un-disked areas was associated with preference for undisturbed and/or flatter topography.

Land management practices often overlook non-targeted species such as small mammals. Through this study, land managers will be able to determine the impact made on non-targeted species as well as targeted species based off of preference, abundance, and habitat quality.

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INTRODUCTION

Seventeen small mammal species have been documented in the lower Coastal Plain of South Carolina (Constantine et al 2004, Whitaker and Hamilton 1998). Except for one recent study on corridor use by small mammals in mainland experimental plantations (Constantine et al. 2004), the abundance and habitat preferences of small terrestrial mammals that occur in the lower Coastal Plain of South Carolina are poorly known. In addition, virtually no published descriptions of species on coastal islands in South Carolina exist. Nevertheless, the cotton mouse (*Peromyscus gossypinus*) is commonly trapped on the coastal islands off Georgia and Florida (Boone and Laerm 1993, Boone et al. 1993, Durden 1995, Thomas et al. 2004) and also has been collected on Spring Island in South Carolina prior to this investigation (C. Marsh, personal communication).

Peromyscus gossypinus typically occurs in bottomland hardwood forests, mesic and hydric hammocks, swamps, cleared fields, edges of salt marsh, pine savannah, palmetto thickets bordering beaches, beach dunes and mixed pine-hardwood forests (Dice 1940, Shadowen 1963, Wolfe and Linzey 1977). With several habitat types present, Spring Island is an ideal location to examine the relative value of each habitat to cotton mice and determine segregation between habitats.

Habitat selection and home range sizes of small rodents, including *Peromyscus spp.,* can vary substantially both between and within species. Within southern pine forests, *P. gossypinus* prefer a microhabitat that is high in woody biomass with high stump sizes, lower tree heights, and low distance between logs (Loeb 1999, Mengak and Guynn 2003). However, *P. gossypinus* is not limited to woody habitats (Wolfe and

Linzey 1977). The versatility in habitats used by *P. gossypinus* is, in part, associated with flexibility in refuge selection (Frank and Layne 1992).

Home range is defined as an area in which an animal travels in its normal activities of food gathering, mating, and caring for young (Burt 1943). The area that animals cover will vary with resource availability. Foraging behavior of small herbivorous mammals largely is dependent on the availability of plant material (Morris 1997). Home range sizes of *P. gossypinus* and the cotton rat (*Sigmodon hispidus*) increase in fragmented habitat, likely caused by reduced access to food and other critical resources (Mabry and Barrett 2002).

Evidence supports that home range sizes are inversely related to conspecific density for several species of small rodents, including *Peromyscus spp.* (Fortier and Tamarin 1998, Ribble et al. 2002, Wolff 1985). Male *P. gossypinus* increase range size when population density is greater than normal (Pearson 1953). Results are consistent with an increase in home range size with reduced range quality.

Land managers often modify habitats in an attempt to increase the abundance of species that are threatened or endangered (Breininger and Smith 1992, Breininger and Schmalzer 1990, Jones and Dorr 2004) or of economic importance (Baskaran et al. 2006). Population dynamics of entire communities are influenced by typical habitat modifications including burning and disking. In central Florida, prescribed burns are used to retard succession and create habitat for the Florida Scrub Jay (*Aphelocoma coerulescens coerulescens*), a federally threatened species (Breininger and Schmalzer 1990, Breininger and Smith 1992). Rotational burns do not impact the abundance of the Great Crested Flycatcher (*Myiarchus criuitus*) and the Yellow-rumped Warblers

(*Dendroica coronata*), but do decrease the number of Carolina Wrens (*Thryothorus ludovicianus*) and the White-eyed Vireos (*Vireo griseus*) (Breininger and Smith 1992). Prescribed burns also are conducted to manage habitat used by the gopher tortoise (*Gopherus polyphemus*) another federally threatened species (Jones and Dorr 2004, Baskaran et al. 2006). Burning efforts throughout the southeastern United States provide an open canopy, small amount of mid-story, and a maximum amount of herbaceous ground cover (Jones and Chamberlain 2004). Wild turkeys (*Meleagris gallopavo*), white-tailed deer (*Odocileus virginianus*), and cottontail rabbits (*Sylvilagus floridanus*) also increase in abundance in these areas (Baskaran et al. 2006, Jones and Dorr 2004). Northern bobwhite quail are managed through prescribed burning and strip disking. Burning alone can encourage the growth of invasive species that often exclude native grass species historically valuable for bobwhite. Timing of burning and disking is also critical. Land managers use both prescribed burns and strip disking in early spring to create bare soil and encourage the growth of clumped native grasses (Brown 1941, Jones and Chamberlain 2004, Greenfield et al. 2003, Beckwith 1954). Native grass seeds also can provide an important dietary resource for rodents, disking may affect small mammal populations. Yet, in many cases the impacts of land management disturbances on non-target species generally are unknown.

The primary goals of this project are: 1) to document small mammal abundance and habitat use; 2) to describe the relative quality of habitats used by *Peromyscus gossypinus* based on distances moved by individuals each night; and 3) to determine the effect of disking on field use by *P.* gossypinus and other small mammals found on Spring Island.

MATERIALS AND METHODS

Study Area.--- Study was conducted on Spring Island in Okatie, Beaufort County, South Carolina (32º19'34.82"N, 80º50'51.23"W). Spring Island is a 6,000 acre island located approximately 2 km offshore between the Colleton and Chechessee rivers, north-west of Port Royal Sound in Beaufort County, SC (Figure 1). The 6,000 acre island consists of 3,000 acres of salt marsh and 3,000 acres of upland habitat (Baldwin 1996). The island has a rich diversity of habitat and includes live-oak forest, pine savannah, mixed hardwood forests, salt marsh, palmetto scrub, and managed fields. The habitats that were chosen for this study included pine savannah, live-oak forest, palmetto scrub, and managed fields. Habitats were selected by dominant percent estimate coverage on the island and from preliminary work that showed mice and rats were abundant in these habitats.

Spring Island has a long history that has undoubtedly impacted its biodiversity. It has been estimated that Spring Island was inhabited by Native Americans as early as 10,000 B.C. Land management began more than 200 years ago when the first crop was planted in 1790 (Baldwin 1996). Because marshes and sea water between the mainland and island present a significant barrier to movement (Adler and Levins 1994), the diversity of small mammals on Spring Island is predicted to be low relative to the mainland despite the unusual diversity of habitats available on the island.

Research was conducted for a 12 week time period starting on May 9, 2007 and ending on August 11, 2007. The average rainfall was 0.3 ± 0.37 cm/day, and the average

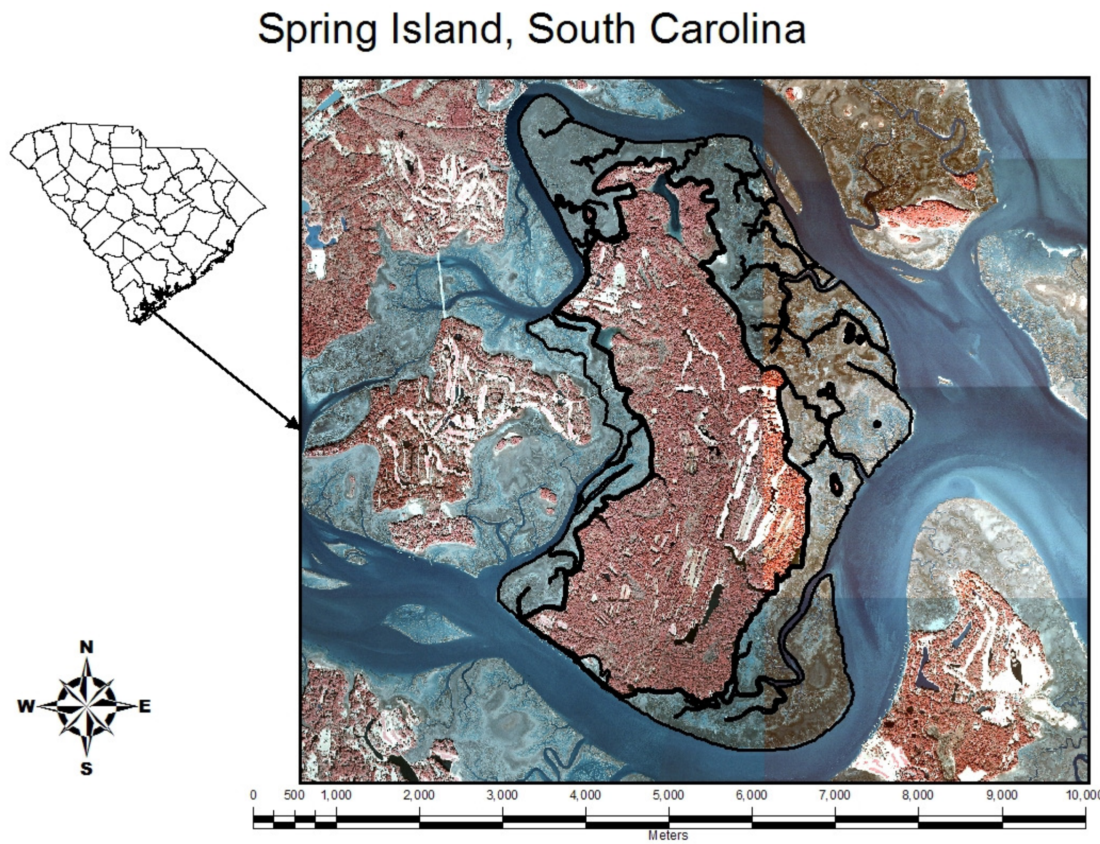


Figure 1: Digital aerial photograph (SCDNR 2006) ortho-rectified of Spring Island, South Carolina. Black and white map at left shows the position of Spring Island within the state of South Carolina. Image produced by G.A. Wood.

daily temperature was 25.67 ± 14.6 °C with an average daily humidity of 23.34 ± 12.93 °C.

Small mammal abundance and habitat use.--- Small terrestrial mammal activity was targeted in four distinct habitats, including pine savannah, live oak dominated forests, palmetto scrub, and managed fields. Within each habitat four plots were established (4 plots per habitat x 4 habitats = 16 total fields). The size of each plot varied slightly 20 m wide by 160 m long (0.32 ha), 40 m wide by 110 m long (0.44 ha), 30 m wide by 210 m long (0.63 ha), and 20 m wide by 210 m long (0.42 ha). Each plot was separated by a minimum of 150 m.

Managed fields were burned and then partially strip disked in late February to early March 2007. Field sizes varied among the four plots; the largest (tortoise yard) contained 8,859 sq. m, the second largest (duckpond) contained 6,353 sq. m, the second smallest (25c) contained 4,977 sq. m, and the smallest (bee alley) contained 4,629 sq. m. Approximately one third of each plot was disked with the percent disked ranging from 31% to 35% of the total field area. Total disked area in plots were 2,867 sq. m in tortoise yard, 2,020 sq. m in duckpond, 1,732 sq. m in 25c, and 1,428 sq. m in bee alley. Disking took place roughly 2-3 wks. after burning occurred.

A grid was established within each plot and was divided into 10 m x 10 m squares. The corners of each square were marked with a survey flag. Small terrestrial mammals were collected with Sherman (7.6 cm W x 8.9 cm H x 22.9 cm L) and pitfall traps. Sherman traps were set with two traps facing in opposite directions and running parallel to the long edges of the habitat. Pitfall traps were arranged in a Y-shaped array with 2.5 m long limbs. The center and each distal end lead to a single pitfall trap composed of a five gallon bucket set into the soil to create an open pit that was flush with the ground (adapted from Ford et al. 1999). Drift fences were placed along the arms of the array mimicking naturally occurring structural elements to improve capture success by funneling small mammals into the pitfall trap (Mengak and Guynn 1987). Half meter high drift fences were constructed of a mesh fabric supported by stakes.

The number of Sherman traps and pitfall arrays was based on the area of each plot. Sherman traps (2 ea.) were set at 3/100 m^2, and pitfall traps at 1/15,000 m^2. The 2 smaller replicates contained 2 pitfall arrays with 10 Sherman trap stations, the second to largest replicates contained 3 pitfall arrays with 15 Sherman trap stations, and the largest replicates contained 4 pitfall arrays and 20 Sherman trap stations.

To assign locations for the pitfall arrays, each 10 m x 10 m box within each habitat grid was assigned a sequential number. A random number generator was then used to select the 10 m x 10 m box that each array was centered within. Once the location was determined, the central bucket was placed and the arms of the Y were selected by location of shrubbery and tree roots. If arrays overlapped or were within 20 m of each other, a new set of coordinates were selected.

Each plot was trapped for three consecutive days. For every three day trapping period, one plot from each of two habitat types was trapped. Prior to the onset of each trapping period, Sherman traps were baited and left open for three days. During the locked open period animals were able to become accustomed to the traps before the traps were set for trapping (Daly and Behrends 1984). While opened traps were used in two plots for acclimation, two different plots were being trapped for a total of four plots being trapped per week. During this 12 week sampling period, all plots were monitored three times (Table 1). Sherman traps were moved between sampling events and lids were placed on all pitfall traps. All traps were checked for occupants after dawn and before dusk.

The grid location was recorded for each animal captured. Each animal was transferred from the trap to a rodent restraint cone that consisted of a clear disposable cake decorating bag with the tip of the cone cut open for ventilation (Figure 2). Species, sex, mass, reproductive condition of males and presence of visible ectoparasites were recorded for each individual. Adult males were described as reproductively active if testes were descended. All individuals were ear tagged, males on right and females on left, and measured (hind foot, weight) while restrained. After measuring, the animal was re-placed in the Sherman trap until dusk the following night (Lemen and Freeman 1985).

Home range typically is measured by radio-tracking animals, relocating animals numerous times and recording the coordinates of the animal. Data can then be used to create polygons around the outermost coordinates and is defined as the animal's home range (Martin et al. 2001). Likewise, trap coordinates also can be used when individuals are trapped repeatedly and traps are left in place for many months to years (Martin et al. 2001). Several potential problems are associated with trapping techniques. Trapping can be insensitive to short term changes in resource availability and fluctuations in resource demand (e.g. during reproduction). In addition, trap avoidance is common which could create difficulty generating an accurate picture of area used (Sealander and James 1958). The alternative, telemetry, is expensive and both trapping and telemetry are labor intensive (Sanderson 1966, Jike et al. 1988).

Table 1: Summary of trapping effort for one habitat on Spring Island. This design was repeated for each of the 4 habitats (pine, oak, palmetto, managed fields).

Plot	Number of Sherman traps	Number of pitfall buckets	Number of total traps	3 Consecutive nights	3 Sampling events	Total trap nights
1	10	2	12	3	3	108
2	10	2	12	3	3	108
3	15	3	18	3	3	162
4	20	4	24	3	3	216
Total	55	11	66	12	12	594

Figure 2: Example of a cake decorating bag used to restrain small mammals. Animals were maneuvered so their head was directed to the small opening of the bag. All morphological measurements were taken with the animal inside the bag.

Telemetry also can influence an animals movement (Sanderson 1966). Radio-collars reduce vole activity in the lab and may reduce normal activity for the free ranging *P. gpssypinus* (Mullican 1988, Hamley and Falls 1975, Webster and Brooks 1980). Additionally, transmitters can cause greater susceptibility to predation (Mullican 1988), severe neck irritation or hair loss (Eagle et al. 1984), and can be lost because of malfunction (Koehler et al. 1987, Eagle et al. 1984).

An alternative to telemetry involves the use of fluorescent powder (Lemen and Freeman 1985). Animals were placed into a paper bag and sprinkled with florescent powder before being released (DayGlo, Cleveland, Ohio). The bag was slightly shaken and the small mammal was released at the exact site of capture. Animals coated with fluorescent powder slowly drop powder as they move through their home range. Fluorescent powder produced a pigmented trail and a nearly continuous three dimensional record of the animal's movement for up to 900 m within a 24 hour window (Mullican 1988, Lemen and Freeman 1985). The next night a UV black light was used to trace the powder through the fields (Lemen and Freeman 1985). The trail was followed with a Trimble GPS tracking system (GeoXT Handheld) allowing the path to be measured and mapped for each rodent (Barnum et al. 1992). Comparison of two days of fluorescent powder data and three days of continuous radio-tracking (coordinates recorded at 30 minute intervals) resulted in equivalent estimates of home range (Jike et al. 1988). Since the fluorescent method was inexpensive and seems to not have an ill effect on the animals (Lemen and Freeman 1985) this method was used to compare relative home range sizes by habitat in this study.

Effect of disking on field use by small mammals.--- A combination of Sherman traps and pitfall trap arrays also were used within the managed fields to trap small mammals. The arrangement of traps mimicked that of the habitat use study, with four plots overlapping between studies. Once grids were arranged in the managed fields and the management practices were completed, flags were placed along the edges of the disked habitat every five meters to distinguish the disked verse un-disked habitat. Each managed field plot also was walked with the Trimble GPS tracking system in order to distinguish disked verse un-disked areas once the vegetation grew back in the fields. Animals were followed with the Trimble GPS tracking system. As animals entered and exited an area of disked or un-disked, a new path was developed on the tracking system. Data from walking disked versus un-disked fields were uploaded into GIS and polygons were constructed to create a map of the field. The map was used as a database to differentiate between disked and un-disked sections of tracks as animals moved between the habitats.

Weather conditions in some instances proved to be too severe to allow use of the dye. Days that had any rainfall lightened the trail of the small mammal or completely erased the trail, due to the rain washing the powder away. Animals that were recaptured within the same three day trapping period were not recorded within this study. Distance moved was calculated by uploading data from the Trimble GPS tracking system into ArcGis, which provided the path in meters that the animal moved. All measurements were based on a two dimensional measure of distance. Minimum convex polygons also were based on the two dimensional distances and were created using ArcGIS (ArcMap Version 9.2).

Vegetations analysis.--- Habitats within this study were characterized by the type of overstory tree biomass represented within each plot. Habitats were designated palmetto, pine, and oak based on the overall abundance and dominance of trees located within fields. The managed fields were characterized based on land management practices of the Low Country Institute and Spring Island.

Vegetation abundance was quantified for each plot. The relative coverage of vegetation within the managed fields was determined by surveying 5 % of the total area with a 1 m x 1 m square quadrat. The number of 1 m x 1 m quadrats necessary to cover 5 % of the total area was determined and then a random number generator was used to select coordinates for each location. Plant species were identified and relative coverage (0-100%) within each 1 m x 1 m quadrat was estimated. In palmetto, oak, and pine habitats, relative abundance of trees covering 25 % of the total area was identified using a 10 m x 10 m square quadrat. The number of 10 m x 10 m quadrats required to cover 25 % of the area was established and coordinates for each quadrat was determined using a random number generator. Tree species richness was analyzed with ANOVA and tree composition was statistically analyzed by square root transforming data using Hellinger Distance as the similarity index in PERMANOVA (Anderson 2001). Vegetation was identified in all of the fields during the month of July 2007.

Statistical analysis.--- Habitat preference was determined for *P. gossypinus* using a R x C contingency table based on a similar number of captures in each habitat (total mice captured/four habitats). An R x C contingency table also was used to determine if *S. hispidus* displayed habitat preferences, based on a similar number of captures in each habitat (total mice captured/four habitats). There were not enough captures of *O.*

palustris for statistical analysis. As a measure of habitat quality, total distance moved and area covered each night were compared between habitats (oak, pine, palmetto, and managed fields) and season (late vs. early summer) for *P.* gossypinus using analysis of variance (ANOVA, SPSS, Chicago, Illinois).

P. gossypinus, *O. palustris*, and *S. hispidus* all were captured in disked fields, but the abundance of each species was too low for individual comparison. To address the question of whether rodents preferentially use disked areas of managed fields, all species were pooled and a goodness of fit test was used. If rodents showed preference, on average 1/3 of the distance moved and area used by rodents would occur within disked areas of the field. Although, pooling species is not preferable, the chi-squared design allows the expected area within disked areas to be calculated independently for each animal, thus accounting for species specific differences in distance traveled.

RESULTS

Habitat characteristics.--- Managed fields were dominated by herbaceous plants and had no overstory or midstory. Herbs covered an average of 90 % of the total area in the managed plots. Plant classification was subdivided into grasses, flowering plants, trees, herbs, and ferns. The understory consisted of a mixture of native and non-native plants and was dominated by several species. Species included *Paspalum sp.* (bahia and vasey grass), *Heterotheca sp.* (Aster), *Clitoria mariana* (butterfly pea), *Andropogon sp.* (broomsedges), and *Sesbania sp.* (dogfennel) (Table 2).

The palmetto scrub habitat bordered the Colleton and the Chechessee rivers as well as the Great Salt Pond on the exteriors of the island. Greatest input to the area came from the surrounding marine ecosystem and was flooded with water during hard rains and high tides. In the palmetto habitat, the overstory was dominated by cabbage palmetto (*Sabal palmetto*), but in some plots loblolly or live oak also contributed to the overstory (Table 3). The midstory was very sparse but had a thick understory of vegetation. The dominant understory plants included *Serenoa repens* (saw palmetto), *Sabal minor* (dwarf palmetto), *Juncus spp*. (rush), *Paspalum spp.* (grasses), *Panicum spp.* (switchgrasses), and *Andropogon spp.* (broomsedges) (Table 4).

The live oak forest was undisturbed by management practices and had an overstory that included mature live oak and laurel oak. Young live oak, laurel oak, sweet gum (*Liquidambar styraciflua*), and wax myrtle (*Myrica cerifera*) characterized the midstory (Table 3). The understory consisted of plants such as *Rhus radicans* (poison ivy), *Ilex spp*. (holly), *Mitchella repens* (partridgeberry), *Campsis radicans* (trumpet creeper), and *Parthenocissus quinqufolia* (Virginia creeper) (Table 4).

The pine savannah was managed with prescribed burns to maintain a 2-layered forest system that lacked a midstory. In the pine habitat the overstory was dominated by loblolly (*Pinus taeda*) or slash pine (*Pinus elliottii*) (Table 3) and herbaceous vegetation in the understory was dominated by *Andropogon sp*. (Broomsedges), *Scleria sp*. (nut-rushes), *Setaria sp*. (foxtails), and *Paspalum sp*. (grasses) (Table 4). There was also a substantial amount of woody debris in the understory due to recent logging.

Table 2: Relative coverage of vegetation found in managed fields on Spring Island, including average percent cover and standard deviation. Vegetation within the managed fields is classified as grasses, flowering plants, herbs, trees, and ferns.

	Bee Alley	25C	Tortoise	Duckpond	Average % Cover	Standard Deviation
Grasses						
Digitaria spp.	34.90%	28.90%	0.00%	8.75%	18.10%	0.1644
Setaria spp.	2.00%	1.56%	0.00%	0.00%	0.89%	0.0104
Cenchrus spp.	14.50%	7.88%	0.00%	2.25%	6.15%	0.0646
Paspalum notatum	8.29%	4.84%	73.80%	43.90%	32.70%	0.3258
Paspalum urvillei	4.86%	0.00%	0.00%	1.81%	1.67%	0.0229
Andropogon spp.	2.86%	22.10%	4.08%	9.06%	9.52%	0.0879
Flowering Plants						
Clitoria ternatea	0.76%	8.80%	3.96%	0.38%	3.48%	0.0389
Cirsium spp.	0.24%	0.40%	0.00%	0.00%	0.16%	0.0019
Sesbania spp.	1.52%	1.80%	1.46%	7.31%	3.02%	0.0286
Lespedeza cuneata	0.57%	5.64%	10.30%	0.00%	4.12%	0.0481
Heterotheca spp.	2.00%	0.44%	0.76%	0.75%	0.99%	0.0069
Verbesina spp	1.05%	0.00%	0.06%	0.38%	0.37%	0.0048
Eupatorium capillifolium	14.20%	1.64%	0.00%	4.06%	4.99%	0.0639
Cnidoscolus stimulosus	0.19%	2.60%	0.19%	0.00%	0.75%	0.0123
Rubus spp.	4.81%	8.52%	0.00%	0.00%	3.33%	0.0413
Desmodium spp.	0.29%	0.00%	0.00%	5.31%	1.40%	0.0261
Rhexia spp.	0.00%	0.00%	0.00%	18.50%	4.63%	0.0925
Herb						
Chenopodium ambrosioides	6.57%	0.00%	0.00%	0.00%	1.64%	0.0328
Tree						
Prunus spp.	0.43%	0.16%	2.28%	0.00%	0.72%	0.0105
Fern						
Pteridophyta	0.00%	0.00%	0.00%	1.06%	0.27%	0.0053

Table 3: Relative abundance of trees found in pine, oak, and palmetto habitats on Spring Island including average percent cover and standard deviation.

Pine Habitats	Marker 44	Campsite 2	Campsite 4	Marker 43	Average % Cover	Standard Error
Loblolly	91.70%	0.00%	0.00%	80.00%	42.90%	0.2145
Slash Pine	0.00%	89.00%	81.00%	0.00%	42.50%	0.2125
Live Oak	8.33%	0.00%	6.00%	0.00%	3.58%	0.0179
Laurel Oak	0.00%	0.00%	0.00%	0.00%	0.00%	0
Cabbage Palmetto	0.00%	11.00%	13.00%	20.00%	11.00%	0.055

Oak Habitats	Goosepond	Oak Rd 2	Marker 9	Oak Rd 3	Average % Cover	Standard Error
Loblolly	0.00%	0.00%	0.00%	0.00%	0.00%	0
Slash Pine	0.00%	0.00%	0.00%	0.00%	0.00%	0
Live Oak	72.00%	23.00%	50.00%	39.00%	46.00%	0.23
Laurel Oak	28.00%	77.00%	50.00%	61.00%	54.00%	0.27
Cabbage Palmetto	0.00%	0.00%	0.00%	0.00%	0.00%	0

Palmetto Habitats	Saltpond 2	Saltpond 3	Saltpond 4	Sandpit	Average % Cover	Standard Error
Loblolly	0.00%	0.00%	0.00%	0.00%	0.00%	0
Slash Pine	12.00%	36.00%	40.00%	28.00%	29.00%	0.145
Live Oak	5.00%	0.00%	0.00%	7.00%	3.00%	0.015
Laurel Oak	0.00%	0.00%	0.00%	0.00%	0.00%	0
Cabbage Palmetto	83.00%	64.00%	60.00%	65.00%	68.00%	0.34

Table 4: Abundant vegetation in the pine, oak, palmetto habitats located on Spring Island.

Palmetto Habitats		**Oak Habitat**		**Pine Habitats**	
Saw Palmetto	*Serenoa repens*	Laurel Oak	*Quercus laurifolia*	Bracken Fern	*Pteridium aquilinum*
Dwarf Palmetto	*Sabal minor*	Wax Myrtle	*Myrica cerifera*	Nutrush	*Scleria sp.*
Stagger Bush	*Lyonia ferruginea*	Red Bay	*Persea borbonia*	Fox Tails	*Setaria sp.*
Broomsedges	*Andropogon sp.*	Cabbage Palmetto	*Sabal palmetto*	Sugar Cane	*Saccharum giganteum*
Deer Tongue	*Trilisa paniculata*	Ground Seltree	*Baccharis sp.*	Crab Grass	*Digitaria sp.*
Switchcane	*Arundinaria gigantea*	Bullnettle	*Cnidolscolus stimulosus*	Vasey/Bahia Grass	*Paspalum sp.*
Vasey/Bahia	*Paspalum sp.*	Partridgeberry	*Mitchella repens*	Panic Grass	*Panicum sp.*
Switchcane	*Arundinaria gigantea*	Holly	*Ilex sp.*	Sedges	*Carey sp.*
Rush	*Juncus sp.*	Virginia Creeper	*Parthenocissus quinquefolia*	Beaksedges	*Rhynchaspora*
Crab Grasses	*Digitaria sp.*	Trumpet Creeper	*Campsis radicans*	Broomsedges	*Andropogon sp.*
Switchgrass	*Panicum sp.*	Poison Ivy	*Rhus radicans*	Trumpet Creeper	*Campsis radicans*
Sarsparilla Vines	*Smilax pumila*	Bahia Grass	*Paspalum notatum*	Virgina Creeper	*Parthenocissus quinquefolia*
Trumpet Creeper	*Campsis radicans*	Wood Oats	*Chasmanthium sp.*	Wax Myrtle	*Myrica cerifera*
Virginia Creeper	*Parthenocissus quinquefolia*			Elderberry	*Sambucus canadensis*
Butterfly Pea	*Clitoria mariana*			Deerberry	*Vaccimium sp.*
				Thistles	*Cirsium sp.*
				Butterfly pea	*Clitoria mariana*
				Golden Rod	*Solidago sp.*
				Drop Seed	*Sporobulus sp.*
				Beauty Berry	*Callicarpa americana*
				Blazing Star	*Liatris sp.*

Species richness was analyzed for tree structure within the pine, palmetto, and oak habitats. Tree species richness was not significantly different among the 3 habitats (ANOVA, $F_{2,9} = 1.29$, $P > 0.3$) (Figure 3). Species composition was significantly different among pine, oak, and palmetto habitats (PERMANOVA, $F_{2,9} = 9.56$, $P < 0.001$). Pairwise comparison shows that pine and oak habitats ($t = 2.83$, $P < 0.007$) and oak and palmetto habitats ($t = 9.28$, $P < 0.001$) are significantly different, while pine and palmetto habitats are not ($t = 1.43$, $P > 0.05$). Although tree composition between pine and palmetto habitats was not significant, looking at the abundance data, (Table 3) pine and palmetto habitats were determined to be different by the percent estimate coverage data of tree species.

Small mammal abundance and habitat use.--- Over the 12 week study, 84 rodents were captured belonging to 3 species with 19 animals being recaptured during this study. The 19 animals were treated as a new capture because of the time period between recaptures. All recaptures at least four weeks apart were considered independent. *Peromyscus gossypinus* was trapped most frequently (75% of all captures) and was found in all habitat types. *Peromyscus gossypinus* was trapped within the palmetto and pine habitats greater than expected by chance ($X^2 = 20.13$, df = 3, $p < 0.005$) suggesting preferential use of habitats (Figure 4). In addition, 15 cotton rats, *Sigmodon hispidus* and 6 marsh rats, *Oryzomys palustris* also were collected. Both *S. hispidus* ($X^2 = 4.25$, df = 3, $p < 0.5$) (Figure 5) and *O. palustris* (Figure 6) were trapped more frequently in managed fields and pine habitats, but neither was collected in the oak habitat.

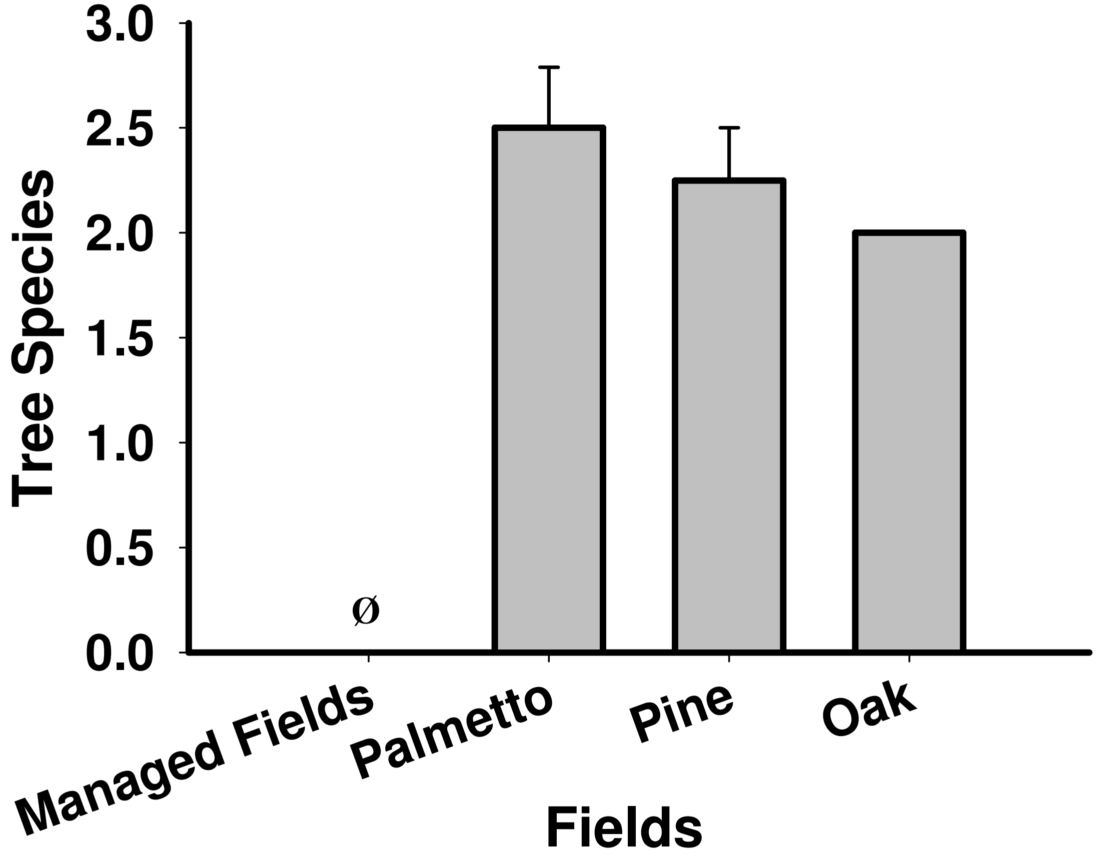


Figure 3: Tree species richness among the four habitats on Spring Island. No trees where present in the managed fields.

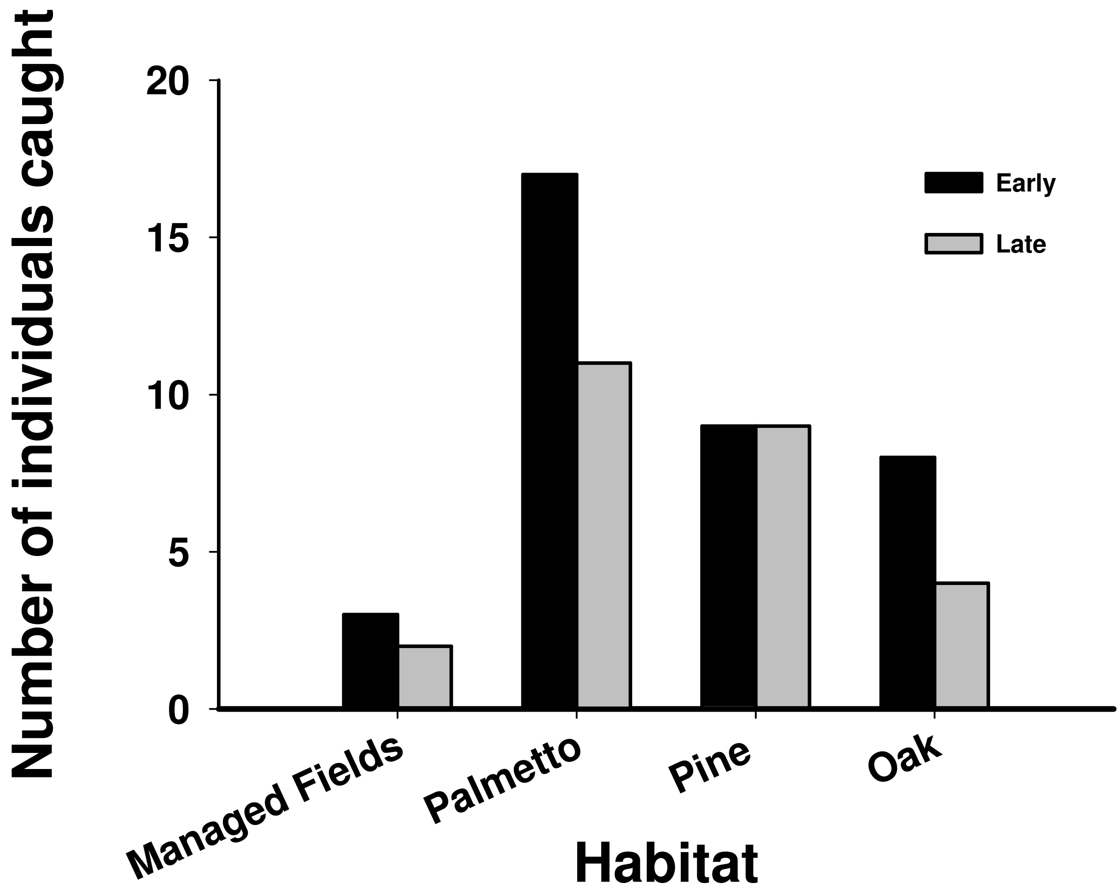


Figure 4: The total number of *Peromyscus gossypinus* captured on Spring Island, South Carolina by habitat and season (early and late summer).

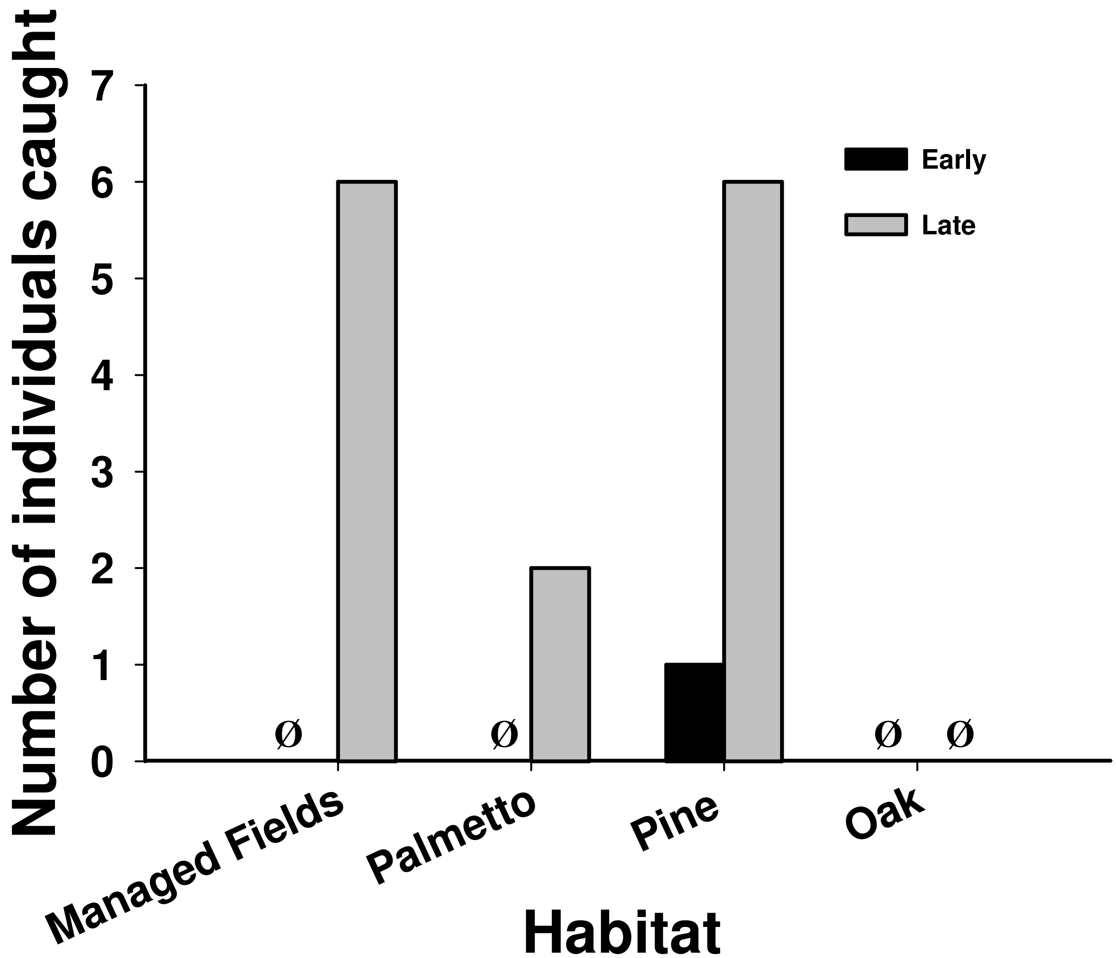


Figure 5: The total number of *Sigmodon hispidus* captured on Spring Island, South Carolina by habitat and season (early and late summer).

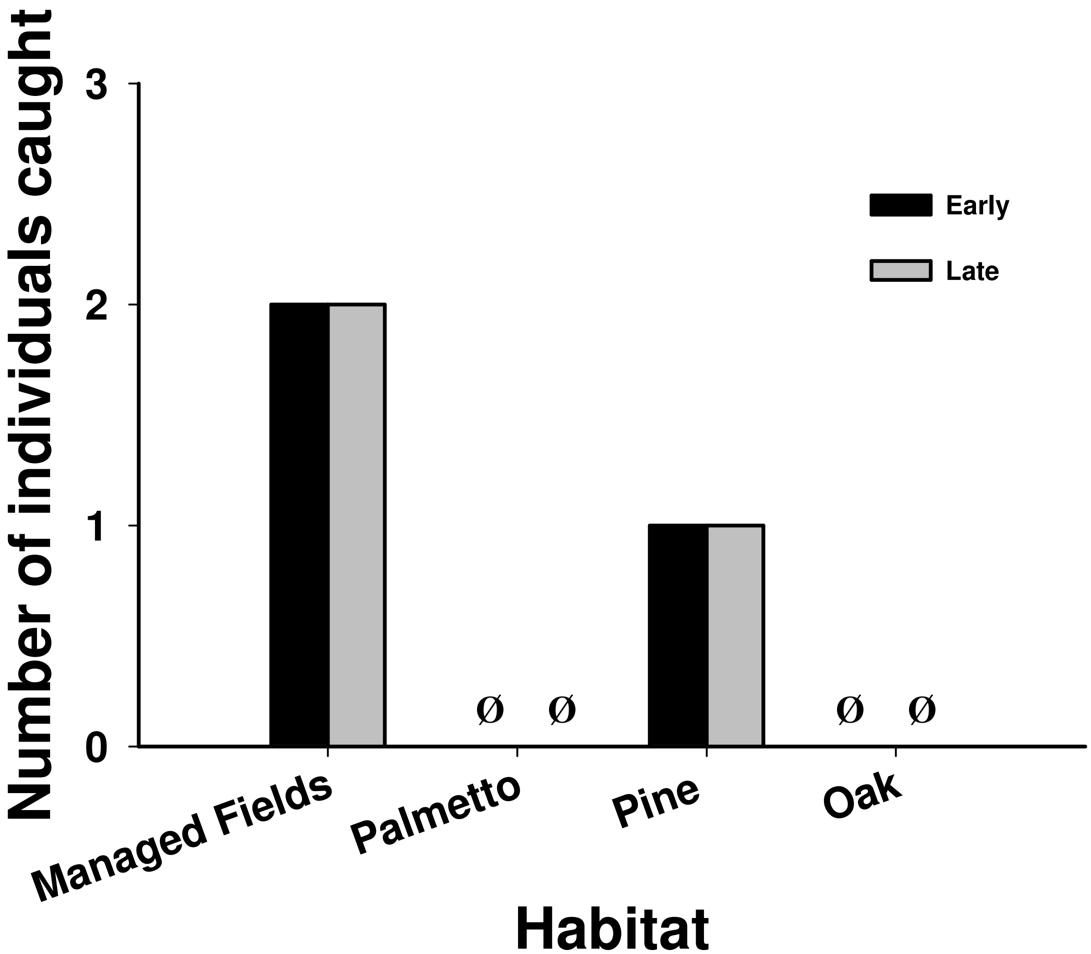


Figure 6: The total number of *Oryzomys palustris* captured on Spring Island, South Carolina by habitat and season, early and late summer.

The trapping rate of *O. palustris* was similar in early and late summer but only one *S. hispidus* was trapped in early summer while all remaining individuals were trapped in late summer.

When releasing animals from traps, animals would immediately run for cover. During this study, fluorescent pigment facilitated observations of *P. gossypinus* climbing and taking cover within several shrubs and trees of different heights including cabbage palmettos. The animals would hide under the palm fronds in the palmetto and in the pine habitats (Figure 7). The trees' height averaged approximately seven meters. Mice appeared to be taking cover under the palm fronds. In habitats without cabbage palmetto, mice would use cavities within live oak trees. Whether these animals were nesting in these trees or using them as daytime refugia is not known.

Distance traveled as an indicator of habitat quality in the cotton mouse.--- Rain events prevented the distance traveled from being collected for 14 rodents. Therefore, after excluding recaptures, distance traveled and area covered were collected for 49 *P. gossypinus*.

No interaction was found between habitat x season (ANOVA, $F_{3,41} = 0.966$, $P > 0.418$). There was no difference in total distance moved by *P. gossypinus* between habitats (ANOVA, $F_{3,41} = 0.713$, $P > 0.05$) (Figure 8) or between early and later summer (ANOVA, $F_{1,41} = 0.021$, $P > 0.887$). Minimum convex polygons used to quantify area covered in *P. gossypinus* (Figure 9) had no interaction between area and habitat x season (ANOVA, $F_{3,41} = 0.286$, $P > 0.835$). No difference between habitats (ANOVA,

Figure 7: *Peromyscus gossypinus* covered in orange fluorescent powder in a cabbage palmetto tree. Animal is approximately 7 meters above the ground. Photo was taken at dusk.

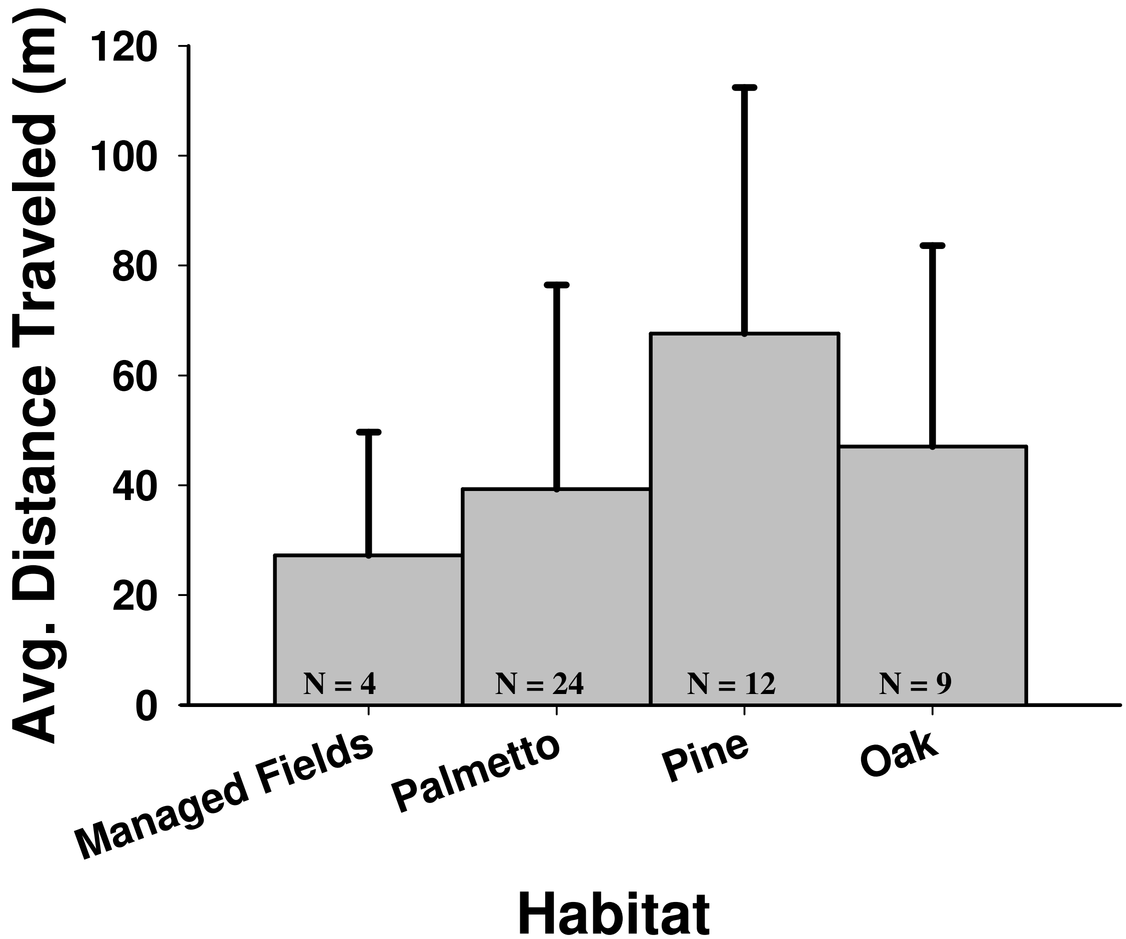
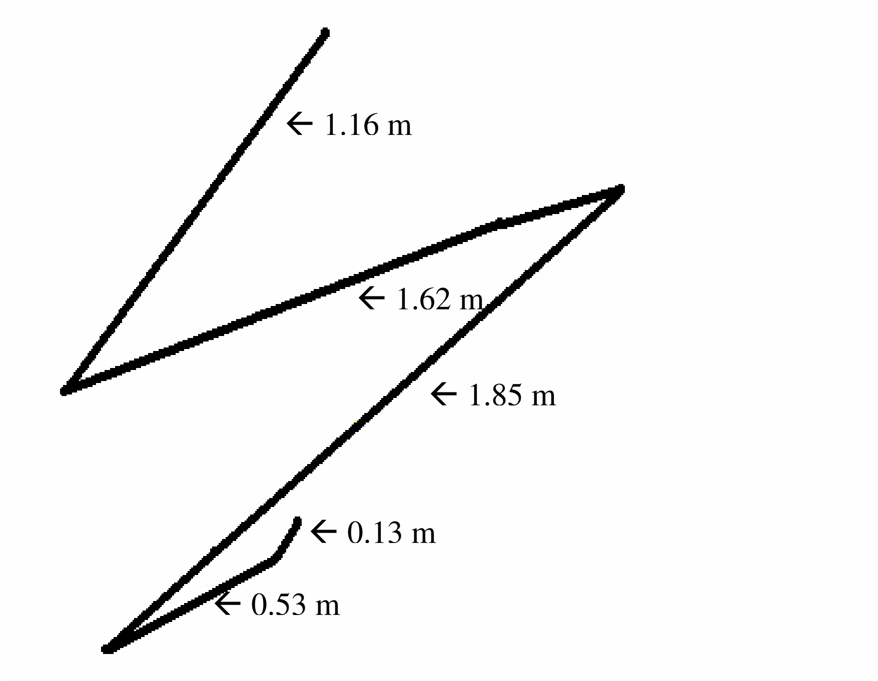
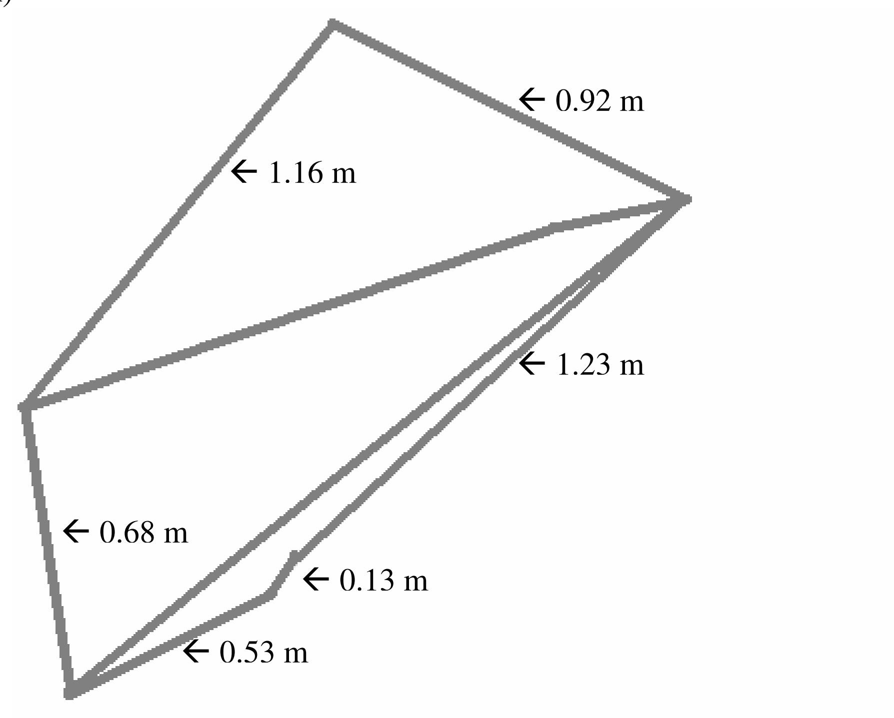


Figure 8: The average distance traveled (+ SE) per night by habitat for *Peromyscus gossypinus*.



(A)



(B)

Figure 9: Example of trail created by *P. gossypinus* using florescent powder. A) Distance moved by mouse 005 on 5/25/07 and B) Area covered by the same mouse based on minimum convex polygon created from the trail above.

$F_{3,41} = 0.953$, $P > 0.424$) (Figure 10) or seasons (ANOVA, $F_{1,41} = 0.121$, $P > 0.73$), were detected.

Disking effects on field use by small mammals.--- All small mammals were used to determine if areas of disking were preferred over areas that were not disked because of the low capture rates of *P. gossypinus* within the managed fields. Numbers for the 3 species include 14 total animals caught within the managed fields including 4 *P. gossypinus*, 4 *O. palustris*, and 6 *S. hispidus*. Rodents were shown to travel in un-disked areas more than expected ($X^2 = 170.3$, df = 1, $p < 0.005$) and indicated that rodents have a preference for un-disked sections of managed fields (Figure 11).

DISCUSSION

Small mammal abundance and habitat use.--- Overall abundance and number of species on Spring Island was less than other studies located within the lower coastal plain of South Carolina (Constantine et al. 2005, Golley et al. 1965). At a Savannah River Site, ca. 175 km from Spring Island, *P. gossypinus* and *S. hispidus* were most abundant in managed pine fields (Loeb 1999). However, *Neotoma floridana* (eastern woodrat), *Ochrotomys nuttalli* (golden mouse), *Peromyscus polionotus* (oldfield mouse) also were trapped at the Savannah River Site but not on Spring Island. Within harvested loblolly pine stands ca. 50 km from Spring Island, *P. gossypinus* and *S. hispidus* also were most abundant. *Reithrodontomys humulis* (eastern harvest mouse) and *O. nuttalli* were also trapped but were not found on Spring Island (Constantine et al. 2005).

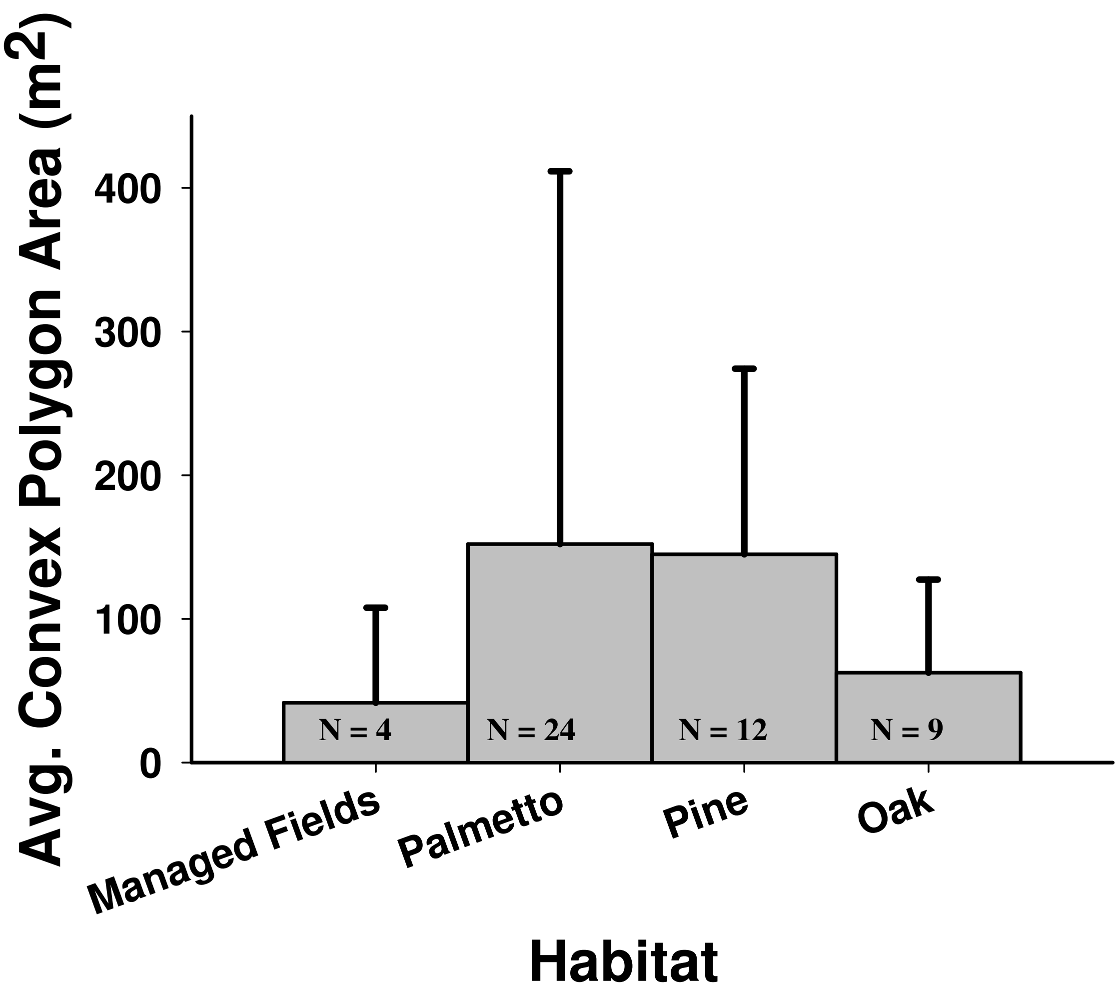


Figure 10: The average area covered (+ SE) per night by habitat for *Permyscus gossypinus*.

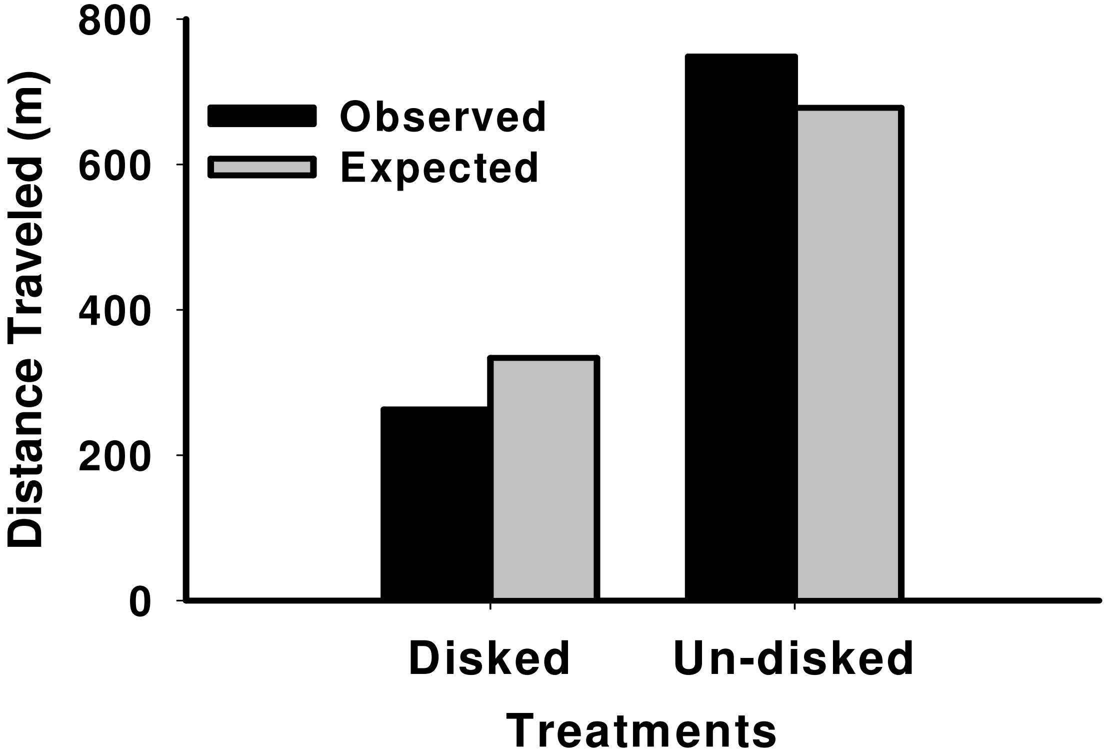


Figure 11: The observed and expected distance traveled within the disked and un-disked treatment levels.

Low abundance and number of species found on Spring Island could be attributed to an island effect (Lomolino 2005), in which the distance from the mainland and island size contributes to species diversity (MacArthur and Wilson 1963). However, the rivers surrounding Spring Island are tidal causing the island during low tide to be separated from the mainland by only a few meters of water. A bridge has existed between Spring Island and Callawassie Island for approximately 16 years and a bridge between Callawassie Island and the mainland for approximately 23 years. Swimming ability has been demonstrated in the three terrestrial small mammals observed on Spring Island (Pournelle 1950, Esher et al. 1978, Cameron and Spencer 1981) suggesting that the swimming ability may have been an important determinate for which species became prominent on the island.

Peromyscus gossypinus usually is referred to as a habitat generalist (Wolfe and Linzey 1977), however, *P. gossypinus* can preferentially select one habitat over another. Results suggest that *P. gossypinus* displays a greater preference for palmetto habitat followed by pine habitat than expected. *Peromyscus gossypinus* was also present in managed fields and oak habitats but overall abundance was much lower. Palmetto and pine habitats can be classified as riparian based on the proximity to water. Palmetto plots bordered either the Great Salt Pond or the Colleton and the Chechessee River and pine plots also were located near water bodies including the Great Salt Pond and smaller freshwater ponds. Herbs, flowering plants, and deciduous shrubs were abundant in each location, which may have provided more optimal access to food, water, and shelter than other locations. Access to water often is associated with greater insect abundance (Doyle 1990).

During the months of January, February, and March, selective logging took place within palmetto and pine habitats (D. Bishop, personal communication). Logging created an abundant amount of woody debris within these habitats (personal observation). Woody debris can be used by small mammals as daytime and even nighttime refugia (Doyle 1990). After periods of logging (i.e. increase in fragmented habitat), an increase in trapping abundance occurs due to the reduced access to food and other critical resources. Once animals migrate through or become to weak to continue, the abundance decreases back to a stable population (Kirkland 1977). These results are also seen in other species, such as ovenbirds (*Seiurus aurocapillus*), in which logging has negative impacts on success (King et al. 1996).

Throughout the period of this study drought conditions were persistant which made the managed fields particularly dry. The low rainfall may have a significant impact on small mammal abundance in the managed fields by having a lack of food, lack of drinking water, and reduced shelter associated with reduced plant growth (Kaufman and Fleharty 1974). Previous work on *Peromyscus spp.* suggests that crop failure reduces mouse abundance (Jameson 1955). Drought possibly contributed to low seed production by grasses in the managed fields. *Peromyscus spp.* have been noted to prefer habitats in which there is a diversity in foliage height (M'Closkey 1975), *Peromyscus* abundance may have been low in fields associated to slow annual plant growth, whereas perennials in the pine and palmetto habitats were a better source of necessary habitat structure.

Distance moved as an indicator of habitat quality in the cotton mouse.---
Although *P. gossypinus* displayed clear habitat preferences, quality did not appear to differ between habitats based on the distance traveled and area covered within each

habitat. Possible other measures of habitat quality may be used to compare between habitats, including survival and reproductive success (Horne 1983, Hobbs and Hanley 1990, Wheatley et al. 2002). Unfortunately, the short duration of this study prevented any measures of either value. Although numbers are too small to be statistically meaningful, reproductive male mice were distributed evenly across habitats suggesting that habitat quality likely is similar across habitats. A single measurement of distance moved and area used also may be insufficient to characterize home range and habitat quality. Habitat quality could be experimentally manipulated, as with food supplementation, to confirm the effect of food availability on total area covered and distance moved within any given night.

Disking effects on field use by small mammals.--- In this study, managed fields were associated with high diversity of small mammals, with all three species described on Spring Island occurring within managed fields, but in low total abundance. Results were surprising given that small mammal abundance typically is greater in burned fields (Baskaran et al. 2006, Jones and Dorr 2004, Jones and Chamberlain 2004) and all managed fields were burned completely prior to disking. Reasons for the low numbers of rodents could include human activities, drought, and animal interactions. Human activities, such as agricultural management practices, can negatively impact the density, diversity, and species evenness of the small mammals (Kaufman and Kaufman 1989). Drought may have negatively impacted food availability including the production of all seeds, and reduced insect abundance. Drought also may have made any activities associated with disturbing the soil, such as digging refugia, runways, or digging up invertebrate prey more difficult. Although burning has been associated with increased rodent abundance (Baskaran et al. 2006, Jones and Dorr 2004, Jones and Chamberlain 2004), few studies on the effect of burning are conducted in locations where multiple habitats are available. Further research into use of managed fields by *P. gossypinus* and other rodents likely should focus on a greater diversity of fields and/or multiyear studies that can better access environmental factors contributing to abundance.

Within the managed fields, small mammals preferentially traveled in un-disked areas, which may suggest an edge effect and that rodents may have been avoiding open spaces. Although disking was historically used to manage for bobwhite quail on Spring Island, bobwhites are few to none on the island. It is likely that rodent activity in fields would differ dramatically if nesting bobwhite were more abundant, with bobwhite eggs providing a valuable source of nourishment for rodents.

Significance and Possible Future Research.--- On Spring Island, *P. gossypinus* was the most common species caught with *Sigmodon hispidus* and *Oryzomys palustris* being caught in lower numbers. *Peromyscus gossypinus* was most abundant in palmetto and pine habitats suggesting a preference, but given that *Peromyscus gossypinus* was trapped in all locations *P. gossypinus* should still be considered a habitat generalist. Measurements of habitat quality, including distance traveled and area covered did not differ between habitats, suggesting that quality did not differ between habitats or a single measurement of distance traveled and area used per individual was insufficient to detect differences in habitat use. Data on differential survival and reproductive success by habitat may be valuable in discerning distribution patterns. In addition, food supplement experiments should be used to confirm that home range size is reduced in *P. gossypinus* with greater food availability. A greater number of plots and longer duration is likely necessary to discern preferences.

Disking is a management practice used to increase the abundance of quail and native grasses. Rodents displayed a low abundance in fields and were more likely to travel in un-disked regions of managed fields than disked areas which suggest that disking may leave these habitats less desirable for rodents. Nevertheless, a true test of the effect of disking on field use by rodents would require disked fields to be compared to similar fields that have been left undisturbed. Unfortunately, there were not enough fields on Spring Island to complete this test and the quail populations on Spring Island are few to none. Re-introduction and establishment of quail may create a rich source of food for rodents in fields and may result in rodents responding differently for disking practices.

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