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A Comparison of Eastern Gray Squirrel (Sciurus Carolinensis) Nesting Behavior among Habitats Differing in Anthropogenic Disturbance

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A Comparison of Eastern Gray Squirrel (*Sciurus carolinensis*) Nesting Behavior among Habitats Differing in Anthropogenic Disturbance

by

ELIZABETH WILLIAMS
(Under the Direction of Michelle Cawthorn)

ABSTRACT

Eastern gray squirrels inhabit a large range of heterogeneous habitats and climates, and live with various levels of anthropogenic disturbance. Previous studies have examined this species in unmodified and modified surroundings; however, a comparison of populations between these habitats has yet to be published. Their widespread occurrence coupled with their success in urban areas and the invasive nature of introduced populations, suggests this species is behaviorally flexible. The purpose of this study was to determine the effect of anthropogenic disturbance and development on gray squirrel nesting behavior by comparing variables related to nesting habitat preference among habitats of differing levels of anthropogenic disturbance. Among the habitats, food trees were preferred over non-food trees. Nests were built at a height of approximately 12 m. Tree size preferences tended toward those at least 10 cm in diameter. Trees used in developed areas were larger than trees in natural areas, due to availability; but a trend toward larger trees was observed in undeveloped areas as well. Based on nesting behavior, eastern gray squirrel populations do not appear to be adversely affected by anthropogenic modification.

INDEX WORDS: Eastern Gray Squirrel, Habitat modification, *Sciurus carolinensis*, Nesting behavior

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CHAPTER 1

INTRODUCTION

During the last 100 years, the United States population has increased by over 200 million people (Hobbs and Stoops 2002). Concurrently, Georgia saw an increase of 6 million people, with a projected growth of 34% by 2015 (Giacomini and Hadley 2005). As city populations grow, urban development overflows into suburban areas, leading to urban sprawl and increased development in rural areas. Development creates a gradient of altered habitat from urban to rural, along which differences in habitat quality and biodiversity can be found (McKinney 2002).

Habitat quality along the urban-rural gradient may be influenced by temperature and precipitation (i.e. heat island effect), soil pH and nutrient levels, and pollution levels (Whitney 1985). They also vary in levels of fragmentation and introduced species. Altered habitats may be categorized into four groups of increasing quality: built habitat (McKinney 2002), managed vegetation, ruderal vegetation, and natural remnant vegetation (Whitney 1985). Built habitat includes solid surfaces, such as roads, parking lots, and buildings; this habitat is most common in urban cores. Managed vegetation includes managed open green spaces, such as lawns and landscaped areas. While common in urban centers, managed vegetation is also found in outlying suburban areas. Ruderal vegetation is characterized by unmanaged green space, such as empty woodlots and abandoned agricultural fields. Habitats classified as natural remnant vegetation are fragments of original vegetation (McKinney 2002).

Although the overall result of development is a decrease in biodiversity (Hansen et al. 2005), individual species react differently to human impacts. Blair and Launer (1997) identified three main reactions to urbanization: “urban avoiders”, “suburban adapters” and “urban exploiters”. Urban avoiders are those species whose numbers decline in the presence of anthropogenic development, such as large mammals (Matthiae and Stearns 1981), or birds adapted to the interior of old growth forest (Beissinger and Osborne 1982). Suburban adapters can quickly adjust to the changing environment of suburban areas by taking advantage of human-supplied food sources such as ornamental plants, wildlife feeders, and garbage (McKinney 2002). These are usually species adapted to forest edges and early successional habitats (Bessinger and Osborne 1982), such as raccoons, who might take refuge in urban patches and fragments of vegetation (Dickman 1987).

Urban exploiters are synanthropic generalists (Shochat et al. 2006), meaning they are adapted to many habitats and have a long history of interacting with humans, allowing them to exploit supplemental resources humans provide. Because of the increase in resources and a decrease in patch size, urban exploiters have increased population densities in urban areas. While species in this group share a litany of traits, such as an omnivorous diet, gregarious habits, and stationary home ranges, Kark et al. (2007) also argue that urban exploiters should show increased behavioral flexibility and a variety of feeding innovations in order to adapt to the artificial environment of an urban center successfully. Urban exploiters may be native, although the most well known examples are introduced species found worldwide. These include the Pigeon (*Columbia fasciata*), European Starling (*Sturnus vulgaris*), House Sparrow (*Passer domesticus*), and Norway rat (*Rattus norvegicus*) (Mackin- Rogalska et al. 1988, Adams 1994).

Although not previously categorized as an urban exploiter, the eastern gray squirrel (*Sciurus carolinensis*) has the potential to be categorized as such. It is a widely occurring species and is common in both developed and undeveloped areas. Historically, the species ranges throughout the deciduous forest of the eastern US, north to Canada, and west to the Great Plains. Its current range extends to areas along the Pacific coast of North America as well as Europe and Africa, where it has been introduced (Koprowski 1994). Problems associated with exotic eastern gray squirrels include displacement of native tree squirrel species (Gurnell and Pepper 1993) as well as damage to park trees (Gilbert 1989) and commercial plantings (Nowak 1999). Urban populations of eastern gray squirrels often experience increased densities and intraspecific aggression along with a reduced fear of humans (Parker and Nilon 2008).

In undeveloped areas of the coastal plain, populations of eastern gray squirrels are restricted to mixed pine-hardwood uplands, bottomland hardwoods and forested wetland areas. This is due to their dependence on hard-mast tree species. Although gray squirrels consume a large variety of plant species, they rely primarily on hard-mast producing species for winter sustenance. Eastern gray squirrels implement a strategy called scatter hoarding; they collect acorns and other tree nuts and hoard them in multiple places within their home range, which may be from one-half to over five hectares. These hoards may be collections of nuts, or individual nuts buried within a small area.

Depending on their location, gray squirrels may be considered a useful habitat indicator or a pest. In a natural habitat, their dependence on hard mast makes them useful as an indicator species for old growth oak communities and other mast dependent animals, such as turkey and deer (Healy and Welsh 1992). They may also be used by natural resource managers to measure the effects of anthropogenic activity in natural areas (Hein 1997) since squirrel population density can be used as a measure of habitat quality. In developed areas, eastern gray squirrels often display pest behavior, and have been known to cause power outages (Hamilton et al. 1989), damage telephone lines, invade homes and buildings, and damage expensive ornamental plantings (Flyger 1970).

According to previous studies, tree squirrels are affected by fragmentation (Koprowski 2005). As fragments become smaller, eastern gray squirrels have smaller home ranges and population densities become larger. Higher densities may be due to decreased predation (Virgós et al. 2002) or higher quality habitat provided by increased edge. Fisher and Merriam (2000) suggest that eastern gray squirrels benefit from fragmentation. In their study, squirrel abundances increased as patch size reached 23 ha, and then decreased. The success of eastern gray squirrels in Europe has been attributed to their ability to utilize fragmented habitat (Koprowski 2005).

In a study of the relationship between population density, intraspecific aggression, and wariness, populations of eastern gray squirrels were observed in city parks across Baltimore, MD and in Lafayette Park, Washington D.C. In each case, densities were elevated above those seen in rural settings (Barkelow et al. 1970) with a range of 3 to 31.3 squirrels per hectare (rural densities range from 1-2/ha). Habitat suitability indices indicated that the parks did not provide enough natural resources to support these densities, suggesting that the squirrels relied on supplemental food sources such as active feeding by humans, trash receptacles and the availability of feeders and plantings in the surrounding neighborhoods. Resource availability within the parks increased the intraspecific aggression involved in defending territories, while high densities and frequent contact with humans led to decreased wariness (Parker & Nilon 2008). Intraspecific competition for non-food resources is also sometimes observed in high density, urban populations. Increased population density limits the habitat available for individual home ranges; because home ranges overlap, this may also limit resources such as nesting habitat.

Tree squirrels, such as the eastern gray squirrel, spend the majority of their time in the crowns of trees, where they feed and make their nests. Tree squirrels use a combination of den cavities and leaf nests (dreys) for protection from the elements and to rear young. Den cavities are most often used in winter, but natural processes that prepare a tree for use, such as wood decay and softening, can take between 8 and 30 years to occur (Koprowski 1994) and sufficient cavities are often not available. Composed of a stick base covered with leaves, dreys are more easily constructed and may be used for a long or short term (Fitzwater and Frank 1944). In the event that cavities or artificial nest boxes are not available, leaf nests will be used during the winter, when they are usually thicker than nests constructed in summer.

Nesting habits and site selection in tree squirrels have been studied across the eastern US, and in relation to many aspects of tree squirrel behavior. Salsbury et al. (2004, 2008) examined fox squirrel dreys in disturbed and undisturbed woodlots throughout Marion County, Illinois. Uhlig (1956) related leaf nest construction to seasonal life history events, such as mating and dispersal. Leaf nests have been studied in relation to other variables as well, such as habitat use (Sanderson et al. 1976), niche partitioning and ecology of sympatric populations of gray and fox squirrels (Edwards and Guynn 1995, Koprowski 1996), and estimating population densities (Don 1985). Artificial nest boxes have been used to conduct studies to determine their effect on population size (Burger 1969, Nixon et al. 1984), examine habitat use (Steele and Koprowski 2001) and estimate population density (Barkalow et al. 1970). However, only one study specifically examined nest construction and nesting habitat preferences for eastern gray squirrel leaf nests.

The primary comprehensive study describing the construction and nature of gray squirrel leaf nests examined 146 nests in a 389 ha tract of the Litchfield-Morris Wildlife Sanctuary in west-central Connecticut (Fitzwater and Frank 1944). Habitat and nest structure were evaluated in order to determine nesting habitat preference and nest building behavior. The tree species selected most often were white pine (*Pinus strobes*), red maple (*Acer rubrum*), gray birch (*Betula populifolia*), hemlock (*Tsuga canadensis*), and white oak (*Quercus alba*). Nests in white pine and hemlock were typically in isolated trees surrounded by second growth hardwoods. Several other species of hardwood were also present, but not chosen for nest sites. Nest tree size ranged from 15-35 cm in diameter and 8-17 m tall, and nests were found at an average height of 11.1m. Within the tree, nests were located either in the topmost branches of smaller trees, or near the trunk on a main branch in larger trees. Construction materials varied depending on the species of tree in which the nest was made and availability of other materials nearby.

To date, comprehensive studies on nest construction have not been conducted in the Southeast or between urban and rural habitats. Differences due to climate and forest composition are expected between the southeast and northern reaches of the gray squirrel range. Warmer climate may result in gray squirrels using fewer cavity nests and more leaf nests, or constructing leaf nests in a similar manner year round. Different forest composition should affect tree species preference and tree size preference. The predominant forest type in the Southern US is oak-pine, while the northern regions are mostly oak-hickory (Eyre 1980). In the transition from natural to more urban areas, nest habitat choice may be affected by tree size and species availability as well as the availability of other resources.

I determined the effect of anthropogenic disturbance and development on squirrel nesting behavior by comparing variables related to nesting preference among habitat classes differing in levels of anthropogenic development. Nesting behavior was documented in terms of nest and population density, and nest-site selection. My first objective was to document the habitat characteristics in each habitat class. In addition, their suitability as eastern gray squirrel habitat was determined using a Habitat Suitability Index (HSI) model (Nilon and McPherson 1987). Habitat was evaluated using tree density, hard mast relative density, average diameter at breast height, percent over-story density, and percent shrub crown cover, variables have been established as important for eastern gray squirrels (Allen 1982). I predict that if anthropogenic development decreases habitat quality, habitat classes with greater levels of development should have less suitable habitat as measured by habitat variables, including the HSI.

Second, I used leaf nest densities to calculate population densities and determined if specific habitat variables or differences in habitat quality and patch size among the habitat classes had an influence. Patch size decreases with anthropogenic development, therefore higher leaf nest and population densities should be evident in more developed areas. Although Parker and Nilon (2008) did not find a relationship between HSI and population density at one level of anthropogenic development, I predicted a relationship would be evident when habitats differing in levels of development were compared.

Third, I surveyed and characterized nest sites within areas differing in levels of anthropogenic development to determine if nest sites were selected based on preference or available resources. If nest site selection were based on specific preferences, nest sites would be restricted to oaks and other hardwoods 30-40 cm in diameter at breast height (Allen 1982), within foraging distance of a permanent water source (Steele and Koprowski 2001), and a large amount of hard mast. Nests would also be found at a consistent height. If, however, preference was not seen and nest sites were chosen from available resources, then nesting characteristics would vary significantly due to anthropogenic development. The relationships between habitat variables and nesting variables were also evaluated.

CHAPTER 2

METHODS

Study Sites

Based on land use studies, forest cover in the southern coastal plain has changed over the last 50 years. Between 1974 and 1998, urban land development and fallow/low-vegetation cover increased, while forested wetland cover and agricultural usage decreased (GADNR 2005). Primarily, forest cover is made up of plantations of loblolly and slash pine. Naturally occurring forest cover types include longleaf pine-turkey oak and mixed pine-hardwood uplands, and cypress-gum, bay-swamp and bottomland hardwoods.

Observations of squirrel nesting behavior were conducted across varying habitats in six locations throughout southeast Georgia. Study sites included the Georgia Southern University (GSU) campus in Statesboro, GA, Magnolia Springs State Park (MSSP) near Millen, GA, George L. Smith State Park (GLSSP) near Twin City, GA, the cities of Metter, Georgia (MGA) and Savannah, Georgia (SGA), as well as two private woodlots near Metter, GA (Fig.1).

GSU is a 283-hectare suburban campus in Statesboro, Georgia. Study plots were established within two areas of the campus, Sweetheart Circle and Herty Pines. Sweetheart Circle, a park-like area in the center of the historic area of the campus is approximately 2.5 ha with large, planted live oak (*Quercus virginiana*), pecan (*Carya illinoisensis*), common crepe myrtle (*Lagerstroemia indica*), dogwood (*Cornus florida*), magnolia (*Magnolia grandiflora*), American holly (*Ilex opaca*), and red cedar (*Juniperus virginiana*). Herty Pines Nature Preserve is a five-hectare woodlot comprised primarily of loblolly pine (*Pinus taeda*) and slash pine (*Pinus eliottii*). The area includes low, wetland areas as well as upland hillsides. Upland areas are mixed pines and hardwoods, with occurrences of live oak, laurel oak (*Quercus laurifolia*), American holly, magnolia and dogwood. Over the past two years, a project has been underway to restore Herty Preserve to longleaf pine (*Pinus palustris*).This has included controlled burns and clearing out shrub. Although the project will remove the majority of the hardwoods within the preserve, large, mature oaks border the area and these trees will continue to provide shelter and food resources for the squirrels within Herty Pines.

George L. Smith State Park is 38.6 km northwest of Statesboro near Twin City, Georgia. It has an area of 653 ha including a 165 ha cypress pond, and features sandhill habitat as well as river-bottom. The sandhill consist primarily of longleaf pine (*Pinus palustris)* and turkey oak (*Quercus laevis)* with minimal understory, while the river bottom incorporates a mixture of hardwood and pine species as well as areas of thick, shrubby understory.

Magnolia Springs State Park (433 ha), located 56.2 km north of Statesboro, is a combination of upland and lowland habitat surrounding an 11 ha lake. Dominant tree species include buckeye (*Aesculus sylvatica*), sparkleberry (*Vaccinium arboretum*), dogwood (*Cornus florida*), longleaf pine (*Pinus palustris*), hickory (*Carya spp.*), red oak (*Quercus rubra*), white oak (*Quercus alba*) and red cedar (*Juniperus virginiana*) (GADNR). Both Magnolia Springs and George L. Smith have campgrounds, picnic areas, administrative buildings and other structures as well as hiking trails and natural areas.

Metter, Georgia is a small town 32.2 km west of Statesboro. The downtown area has a small city park of approximately 1 ha containing live oak and dogwood with a centrally located decorative fountain.

The 240 ha private property north of Metter, Georgia is comprised of mixed pine-hardwood stands and pine plantations. Study plots were established in a bottomland area between two ponds and an old growth hardwood stand. The bottomland contains oaks (*Quercus spp.*), dogwood, maple, holly, and magnolia. The old growth stand is mostly hardwood, with some pines present and is wet most of the year with as much as 15 cm of standing water in some places. Sweet gum (*Liquidambar styraciflua*) and oak are present along with elm (*Ulmus spp.*), maple (*Acer spp.*), dogwood (*Cornus florida*), and magnolia (*Magnolia grandiflora*). Red bay (*Persea borbonia*) is also plentiful.

Savannah, Georgia is well known for its historic parks. The largest of these, Forsyth Park, is also the southernmost in the historic district. A large fountain, mock forts and monuments dot the landscape. The northern end of the park is home to an arboretum of 52 ornamental species, both local and exotic. Live oak is the most common, however, and lines the perimeter and interior walkways. The southern two-thirds of the park are lawn bordered by live oak and crepe myrtle, and contain tennis and basketball courts. Colonial Park Cemetery is a historic cemetery now designated as a park and historic site. A number of native and non-native species are present, including live oak, elm, and crepe myrtle. Many of the trees in Colonial Park Cemetery are mature; however, recent plantings of immature trees are also present.

Habitat Assessment

At each location, 1 ha (10,000 m^2) study plots were established. Three 100 m transects placed 50 m apart were measured and marked with orange survey flags at 0, 25, 50, 75 and 100 m points. Tree density and over-story density, and shrub crown cover were measured along the central transect using ten points a minimum of 5 meters apart. They were randomly selected using a random number generator: 1 m, 24 m, 29 m, 34 m, 43 m, 59 m, 69 m, 79 m, 89 m and 95 m (Mitchell 2007). Thirty-three transects across six locations were surveyed.

Tree density was determined using the point-centered quarter method (PCQM). At each random point along the center transect, the four closest trees were identified and the circumference at chest height (CCH, 1.5 m) and the distance from the transect were measured. A minimum CCH of 12.5 cm was necessary in order to include the tree in the PCQM survey. The diameter at breast height (DBH) was calculated from CCH (a), and the total density (b) and relative densities (c) for all hard mast producing genera were then estimated using equations from Mitchell (2007).

(a)

$$\text{Diameter} = \frac{CCH}{\pi}$$

(b)

$$\frac{16n^2}{(\sum_{i=1}^{n} \quad \sum_{j=1}^{4} \quad R_{ij}}$$

(c)

$$\frac{\text{Quarters with species } k}{4n} \times 100$$

Over-story density was measured using a spherical densiometer. A measurement was taken at each random point along the transect in each of the cardinal directions; the numbers for each point were multiplied by 1.04, to create a percent, and averaged, then averaged across the entire data set and subtracted from 100 to give percent over-story density (Lemon 1956).

Shrub crown cover was measured by running a meter tape through the study area and recording the distance at the beginning and end of shrub crowns. The distance between these two points was calculated, and measurements for each shrub patch were summed and expressed as a percentage of the total distance measured.

Four qualitative categories were established to describe the level of anthropogenic development for each transect (Tables 1 and 2). Habitat class 1 included all unmanaged transects, or those with natural management goals, surrounded by a minimum buffer of 100 m of unmodified habitat. Transects developed for rural recreational purposes (camping and picnicking), and having unmodified habitat within a maximum distance of 100 m, were categorized as habitat class 2. Habitat class 3 included transects containing undeveloped woodlots separated from either agriculture or urban development by less than 100 m of unmodified habitat. Transects surveyed in spaces developed for urban recreation surrounded by at least 75% urban/suburban matrix, such as city parks, were placed in habitat class 4.

Food Availability Profile

A Food Availability Profile (FAP) was constructed to get a more detailed estimate of resource availability within the study plots and habitat classes. A list of trees encountered during PCQM and nest surveys was compiled for each transect, then evaluated as food resources (Chapman and Feldhamer 1982, Wenger 1984, Koprowski 1994, Feldhamer et al. 2003). The species were scored based on preferences determined by a previous study (Davison 1964), then categorized based on when they are available throughout the year. This provided a list of food sources available during each season of the year within each transect and data necessary for calculating the habitat suitability indices for each transect (for FAP by transect see Appendix I).

Habitat Suitability Index

To evaluate the affects of all habitat variables on nesting density, a habitat suitability index (HSI) was calculated for each transect after Nilon and McPherson (1987). This index model was developed for an urban cemetery, and was chosen for its ease of use and the spectrum of habitats used in the current study. The HSI model combined average food tree DBH, average over-story density, number of primary and secondary food sources, and overall average DBH to calculate a single number representing the suitability of that area as gray squirrel habitat. Individual components were scored and then the scores were averaged and divided by total possible points to create the HSI (Table 3). HSI is scored out of 100; a higher score indicates a more suitable habitat. Food tree DBH and average over-story density give a measure of the amount of food produced in the site, while the number of primary and secondary food sources gives a measure of species richness. The more species available, the more successful a squirrel population may be. Overall tree DBH represents the site as a whole; a larger average DBH means the area has more mature trees more likely to have cavities for winter dens.

Nest and Population Density

Nest densities were calculated as the total number of nests per 1 hectare transect. Population density was calculated using Don (1985). His study found a strong correlation between leaf nest density and population density ($R^2 = 0.84$). The regression equation allowed for a calculation of population density from the log of leaf nest density (d).

(d)

$$y = 0.982x - 0.146$$

Nest Site Selection

Within each study plot, surveys were conducted to locate squirrel leaf nests. Nests which appeared to be derelict (sunlight seen through the nest) were not included in the study. The GPS coordinates, genus, and circumference at chest height (CCH) (1.5 m) were recorded for each nest bearing tree; diameter (DBH) was later calculated for statistical analysis (equation a). Nest height was determined using a clinometer, the distance to water was measured using a meter tape or Google Earth, and GPS coordinates, depending on the distance. The primary food source of the gray squirrel is hard mast (acorns, nuts, etc.) therefore, the distance from each nest to the nearest hard mast producing tree was also measured using a meter tape.

Analysis

To determine differences in habitat characteristics, nest and population density, and nest site selection among habitats, I used nested ANOVA. To determine relationships between habitat variables and nesting variables, Spearman Rank Correlations were performed. Due to the large number of correlations, a Bonferroni correction was applied ($\propto$=0.0125) to the Spearman Rank Correlations. The computer program JMP ® 8.0/9.0 was used for all statistical analyses.

CHAPTER 3

RESULTS

Across 33 transects, 57 genera of trees were identified and data on 236 nests were collected. Squirrels were seen to nest in a variety of species (Table 4) and locations within a tree. Nests could be found both abutting the trunk as well as on the outer edges of limbs. Nest materials varied from site to site; Spanish moss (*Tillandsia usneoides*) was seen in some nests, but all contained combinations of leaves and/or pine needles. While most trees hosted only one or two nests, some trees contained as many as five nests. Nest density averaged 9.8 nests/ha and population density averaged 6.71 squirrels/ha. Nests were found in trees with a mean diameter of 59.9 cm and a mean height of 12.04 m.

Habitat Assessment

The habitat assessed was classified based on levels of development (Table 1). Habitat class 1 was undeveloped, naturally managed habitat. Class 2 included land developed and managed for rural recreation. Habitat class 3 was unmanaged, undeveloped woodlots surrounded by an agricultural or urban matrix. Habitat class 4 was comprised of areas developed for urban recreation surrounded by an urban matrix. Habitat features were compared within each habitat class, and then compared among the four classes.

Habitat class 1 (undeveloped) and habitat class 4 (most developed) represented extremes. For the variables exhibiting differences among habitat classes, 1 and 4 were consistently significant from each other (Figs. 2-9). The intermediate habitat classes, 2 and 3, were inconsistent in the differences they exhibited. Neither hard mast relative density, nor percent over-story density were different among habitat classes (nested ANOVA; hard mast relative density: $F_{(3, 11)} = 1.4701$, $F_{(11, 18)} = 2.2647$, NS, percent over-story: $F_{(3, 11)} = 2.6875$, NS), although percent over-story density was significant among sites within habitat classes ($F_{(11, 18)} = 4.2776$, $P = 0.0032$). Tree density, percent shrub crown cover and mean DBH was greatest in habitat class 1 but least in class 4 (Fig.

2, 3 and 4). Tree density was 1.5 times greater and percent over-story density was 24% greater in habitat 3 when compared to habitat class 2. Tree density was significant for sites with habitat classes as well (nested ANOVA, $F_{(11, 18)}$ = 2.7462, P= 0.0277).There were no significant differences in percent shrub crown cover between classes 2 and 3 (Fig. 3).

Food Availability Profile

Habitat class was found to be an added source of variation in the absolute density of primary food sources (number of individuals of food tree species/ha) during the seasons surveyed (spring and summer) (nested ANOVA, $F_{(3, 11)}$ =7.7183, P=0.0003). Habitat class 1 had 1.5 times as many individual food trees as habitat class 4, and class 3 had 1.3 times as many individual food trees as habitat class 2 (Fig. 5).

Habitat Suitability Index

Habitat class was not a significant source of added variation in HSI (nested ANOVA, $F_{(3, 11)}$ =1.94, NS), however site within habitat class was ($F_{(11, 18)}$ = 5.5241, P= 0.0007). HSI ranged from 40 – 80 across all transects. Nilon and Macpherson's (1987) habitat suitability indices and limiting factors for all transects are in Table 5.

Nest and Population Density

Population densities were calculated from leaf nest densities (Fig. 6); a 0.82:1 relationship exists between the variables. Densities ranged from 1 to 28 with a mean of 8.6 nests/ha. Nest densities were not different among habitat classes (nested ANOVA, $F_{(3, 11)}$ =1.3194, NS), neither were population densities (nest ANOVA, $F_{(3, 11)}$ = 1.3128, NS). Nest and population densities were different among sites within habitat classes, however (nested ANOVA; nest density: $F_{(11, 18)}$ = 4.083, P= 0.0041, population density: $F_{(11, 18)}$ = 4.0697, P= 0.0042). Densities were not affected by the habitat variables measured in this study**.** Habitat classes 1 and 4 again exhibited extremes; class 4 had 42% more nests than class 1. Classes 2 and 3 were both intermediate.

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Nest Site Selection

Oak species were selected more than expected based on availability in three out of four habitat classes (Fig. 7). Neither distance to water, nor nest height showed a difference among habitat classes (nested ANOVA; water (m): $F_{(3, 11)} = 0.1.4092$, NS, nest height: $F_{(3, 11)} = 0.2387$, NS), although sites within habitat classes were sources of variation for both (water (m): $F_{(11, 221)} = 47.0813$, P<0.0001, nest height: $F_{(11, 221)} = 4.7904$, P<0.0001). Large nest tree size and close proximity to food were associated with low tree density, high hard mast relative density, low percent over-story density, and low percent shrub crown cover within a transect. The number of nests found in each tree was influenced by tree density and tree DBH (spearman's rank correlation, Table 6). Areas with lower tree density, and large tree DBH had a greater number of nests within each tree and those nests were closer to food.

Cliftonia monophylla (Titi) was selected as a nest tree in habitat class 1 more than expected based on availability (χ^2=25.95, df=4, P<0.0001). *Nyssa sylvativa* (Black Tupelo) was a second choice, comprising 24% of nest trees, although this was consistent with availability. *Quercus* spp., *Acer rubrum*, and *Pinus* spp. were also used as nest trees in habitat class 1, but in fewer numbers and less than expected based on availability. Nest trees in habitat class 1 were 1.5 times further from food than those in the other classes (Fig 8). Nests/tree and nest tree DBH were not significantly different among habitat classes 1, 2 and 3.

Quercus spp. was the primary nest tree species in habitat class 2 (70%), followed by *N. sylvatica* (16%). Other species utilized in class 2 were *Pinus* spp., *Prunus serotina*, and *Carya* spp. Oaks were used more than expected based on availability (χ^2= 53.09, df=4, P<0.0001). Nests were primarily located in *Quercus* spp. and *Pinus* spp. in class 3 (78%). *Acer rubrum* comprised another 10% of nest trees in habitat class 3. Oak was selected more often than expected based on availability (χ^2=26.48, df=7, P=0.0004).

Quercus spp. and *Carya illinoisensis* were the preferred species in habitat class 4, making up 81% of nest tree species. Oaks were selected more often than expected based on availability (χ^2=81.24, df =10, P<0.0001). Nest tree DBH was 95% larger in class 4 compared to classes 1 through 3. In addition, mean nest tree DBH was 44% greater than mean transect DBH (Wilcoxen sign rank, S= -52.5, df =13, P=0.0001, Fig. 4). Habitat class 4 also had 1.2 times as many nests per tree (Fig.9).

CHAPTER 4

DISCUSSION

Habitat Assessment

The relationship between habitat classes 1 and 4 demonstrates the extreme changes produced by anthropogenic activity. The unmodified areas belonging to habitat class 1 were dense tree stands with dense canopies. Snags and downed trees provided gaps in the canopy, which allowed for the growth of thick shrub crown cover in some transects. Transects in habitat class 4 were the most modified and had a sparse growth of mature hard mast producing trees. The canopy these provided was meager when compared to the other three classes, but landscaping limited the shrub layer. Class 2 looked similar to habitat class 4. Although the habitat in class 2 was modified for a different purpose than those in class 4, management goals were similar between the classes. Likewise, the characteristics of transects in class 3 were similar to those of class 1 due to the unmanaged nature of the habitats categorized as class 3.

Several variables measured in this study showed significant variation at sites within habitat classes. Microhabitats at each site may have been the source for this variation. Increasing the number of sites sampled within each habitat class, and insuring a more random sampling of transects within sites may help reduces this effect in future studies. More surveys of undeveloped habitat, in particular, would be beneficial.

Food Availability Profile

Food resources within the habitat classes were affected by a combination of tree species composition and tree density. Although habitat class 4 had 33.5% more hard mast than the other classes, the higher tree density found in habitat class 1 resulted in its having 1.5 times the number of hard mast trees as class 4.

Because the majority of this study took place during spring and summer months, foods available during these seasons were of primary concern. For the gray squirrel, hard mast is most often evaluated due to its importance as a winter food source. However, hard mast species are used throughout the year (Wenger 1984). Besides acorns and nuts, fruits, buds, and leaves may also be consumed. *Quercus* and *Carya* spp. were some of the most common hard mast trees, found in 94% of transects. Pines and magnolia also make excellent year-round sources of food and these were present in over half of the sites surveyed. Secondary food sources available during spring and summer, such as dogwood and sweetgum, were also common throughout the study sites.

Habitat suitability index

Habitat characteristics did not indicate that quality necessarily decreased with modification. Based on variables deemed important to gray squirrels by the HSI model, the large, mature hard mast trees found in the most modified transects are characteristic of prime habitat for Eastern Gray Squirrels. I predicted HSI would decrease with modification, but results suggest the habitats studied were similarly suited regardless of modification. However, sites within habitat classes varied significantly, indicating the need for a finer measurement than that used in this study. When comparing mean scores among habitat classes, all of the classes score above 50 points, but habitat class 4 has the highest score at 71 points, suggesting that habitat class 4 has marginally better gray squirrel habitat.

HSI models are considered a useful tool for wildlife management, but their scientific applicability is debatable. Schamberger and O'Neil (1984) suggest that HSI models may not be suitable for experimental use because they are difficult to test and validate. They are also of limited value in that they only evaluate response to habitat and ignore other impacts on population such as predation and competition. Thus, HSI models are, by their nature, neither research models nor population predictors. However, they may be useful indicators of potential carrying capacity. An HSI model was used in this study in the hopes of showing a relationship between a combination of habitat variables and squirrel population density. The HSI model was the simplest way to combine multiple variables into a single value for univariate statistical analysis.

Nest and Population Density

Nest and population density do not appear to be influenced by habitat suitability or any single habitat variable. Fragmentation was expected to impact nest and population densities as evidenced by increased densities in modified habitats. Koprowski (2005) found evidence of an inverse relationship between patch size and population density. Although density did not vary significantly among habitat classes, a trend toward higher densities in more modified areas was present. My results are consistent with Parker and Nilon's (2008) findings in urban parks of Washington, D.C. and Baltimore, MD. They suggested bottom up effects do not control population densities in urban areas due to supplemental food from human sources. One would expect bottom up effects to control natural populations, where little to no supplemental food is available, but that was not observed in this study. A future study should evaluate a different suite of variables to examine the relationship between habitat characteristics and population densities within unmodified habitats to identify a variable more important to controlling population density.

Nest Site Selection

A preference for food tree species over non-food tree species is present in nest tree selection. In this study, approximately seventy-six percent of the nests surveyed were found in either a hard mast or other food tree, with a majority located in species of oak. Other studies found similar results (Fitzwater and Frank 1944, Sanderson et al. 1976, Edwards and Guynn 1995). However, availability does influence species choice. Habitat class 1 consisted of transects along an ecotone between river-bottom and upland sand hill. Hard mast relative density was very low in habitat class 1. The few hard-mast species present were laurel oak and turkey oak. Few nests were found in laurel oak, but none was located in turkey oak, which is characterized as a small species with a broad, open crown (Burns and Honkala 1990). Instead, the majority of nests in these areas were constructed in Titi, which was more abundant. Titi is found in the river-bottom and has wide spread branches with an open, rounded crown. This architecture may be preferred due to the added support and ease of access provided by broadly arching branches.

Nest tree size appears to be largely based on availability, although a trend towards larger trees does exist. Nest trees selected in classes 1, 2 and 3 were all of a similar size, but these were also similar to the size of trees available in each class (mean nest tree DBH was 33 cm, mean transect DBH was approximately 28 cm). A slight preference for larger trees was seen in classes 1, 2 and 3, but squirrels in transects in class 4, showed a marked preference for larger trees. Trees in habitat class 4 were larger than the trees found in the other classes due to the low tree density and maintenance by park managers. A preference in size may be due to food production and availability. For oak species, there is a relationship between trunk diameter and seed yield (Goodrum et al. 1971); seed production often does not start until after 20 or more years of age (Burns and Honkala 1990).

An average nest height of 12 meters was consistent across all habitat classes. This is comparable to nest heights observed in previous studies (Fitzwater and Frank 1944, Edwards and Guynn 1995) and may describe an optimum height, possibly for predator evasion. As small mammals, eastern gray squirrels have many predators including snakes, birds of prey, and other mammals (Koprowski 1994, Feldhamer et al. 2003). For birds, the "mid-height" hypothesis states that placing a nest at mid-height provides protection from both aerial and terrestrial predators (Filliater et al. 1994). It has also been suggested that there is a trade-off in nest site selection between hiding from predators yet maintaining a line of site to conspecifics and competitors (Götmark et al. 1995). These hypotheses may also be applicable to tree squirrels.

Steele and Koprowski (2001) concluded that optimal nest sites have a certain proximity to a reliable water source. Although eastern gray squirrels obtain water from food and temporary sources, lactating mothers require a constant and reliable source of water. A preference for proximity to water seems to exist, as this variable was consistent among the habitat classes. Water was a mean distance of 109.5 m from nest trees, well within the foraging distance of a gray squirrel. Although Steele and Koprowski did not report the distances to water they observed, the results of this study seems to support their finding.

Proximity to food is an important variable in nest site selection, and a preference seems to exist for nearness to hard mast resources. Seventy-nine percent of nests were located within 10 m of a hard mast tree and mean distance to hard mast across all habitat classes was 11 m. It appears that characteristics associated with modification- low tree density, low percent over-story density, and low percent shrub crown cover- are also associated with a nearness to hard mast for squirrel nests. Although, this is most likely due to the size trees are allowed to gain in these habitats. Nests in habitat class 1 were, on average, further from food, but the mean distance of 31.7 m was well within the reported home ranges for the gray squirrel (Koprowski 1994). In addition, seasonal foods not taken into account by this study were observed within a closer proximity to nests in habitat class 1.

Nest densities within nest trees were also evaluated and, in many transects, multiple nests were observed in a single tree, although Fitzwater and Frank (1944) consistently found only one active nest per tree. While most of the nest trees surveyed contained one active nest, 22% of nest trees contained two or more active nests; as many as five were observed in a single tree. Tree size is positively correlated with the number of nests per tree and is a major variable in the HSI scoring used in this study. Larger trees may support more nests simply due to architecture, but larger hard mast trees probably attract more squirrels due to their higher mast production.

Conclusions

Eastern gray squirrels showed preferential nest site selection in the southeastern coastal plain of Georgia. Food trees were selected over non-food trees. Although a preference in nest tree size was not supported statistically, a trend in selection for larger trees was noted. Nest trees were a minimum of 7.5 cm DBH, but were 48 cm DBH on average (published preference is 30 – 40 cm DBH). Nests were built, on average, at a height of 12 m, which is comparable to published reports and possibly serves as a defense mechanism. Nest trees were within a mean distance of 11 m from hard mast trees, and 109 m from permanent water sources, which is well within the reported home range for the Eastern Gray Squirrel.

Evidence from this study suggests as long as adequate habitat is available, the extent or lack of urbanization has a weak influence on squirrel nesting behavior. In all habitats, nesting behavior is similar to that reported from other parts of the gray squirrel's range (Fitzwater and Frank 1944, Edwards and Guynn 1995, Steel and Koprowski 2001). Densities were elevated in optimal habitat, which in the coastal plain of Georgia, o tended to be areas in urban parks, which were maintained with relatively high densities of hard mast trees, moderately dense over-story, and open under-story.

The Eastern Gray Squirrel may lack the behavioral flexibility to succeed as an urban exploiter, however. True urban exploiters are able to rely solely on resources provided by humans. Although gray squirrels in urban areas take advantage of human supplemented resources, they primarily rely on the managed habitats we maintain in our recreational areas. Without these urban park oases, I hypothesize that urban squirrel populations would diminish. A better categorization for gray squirrels may be that of urban adapter, an animal that may take advantage of anthropogenic resources, but maintains a lifestyle more similar to its counterparts in unmodified areas.

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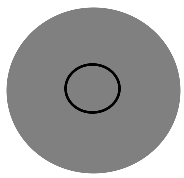
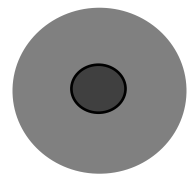
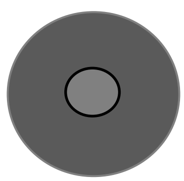
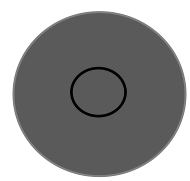
Tables

Table 1 Habitat classes used to describe levels of anthropogenic activity within transects. The inner circle in each diagram represents the habitat sampled, while the outer circles represent surrounding areas.

Habitat Class 1 Unmodified areas surrounded by a minimum buffer of 100 m of unmodified habitat 	**Habitat Class 2** Modified for rural recreational (camping and picnicking), maximum of 100 m, between modified and unmodified habitat 
Habitat Class 3 Undeveloped woodlots separated from either agriculture or urban development by less than 100 m of unmodified habitat 	**Habitat Class 4** Spaces developed for urban recreation surrounded by at least 75% urban/suburban matrix 

Undeveloped Developed

Table 2 Study sites by habitat class with transect descriptions. Sites: GLSSP (George L. Smith State Park), MSSP (Magnolia Springs State Park), CF (Chandler Farm), GSU (Georgia Southern University), SGA (Savannah, GA), MGA (Metter, GA)

Habitat Class	Site	Transect Description
1	GLSSP	River bottom
	GLSSP	River bottom
	GLSSP	River bottom
	GLSSP	River bottom
	GLSSP	Sand Hill
2	GLSSP	Group Shelter
	GLSSP	Campground
	GLSSP	Campground
	GLSSP	Picnic Area
	GLSSP	Picnic Area
	MSSP	Campground
	MSSP	Campground
	MSSP	Picnic Area
3	CF	Bottomland
	GSU	Herty Pines
	GSU	Herty Pines
	CF	Old Growth
	CF	Bottomland
	CF	Old Growth
4	GSU	Sweetheart Circle
	GSU	Sweetheart Circle
	SGA	Forsyth Park-Arboretum
	SGA	Forsyth Park-Arboretum
	MGA	City Park
	SGA	Forsyth Park-Lawn
	SGA	Forsyth Park-Arboretum
	SGA	Forsyth Park-Lawn
	SGA	Forsyth Park-Arboretum
	SGA	Forsyth Park-Lawn
	SGA	Forsyth Park-Lawn
	SGA	Forsyth Park-Lawn
	SGA	Forsyth Park-Lawn
	SGA	Colonial Park Cemetery

Table 3 Gray squirrel Habitat Suitability Index (HSI) model, adapted from Nilon and McPherson (1987). Measurements and possible scores were expanded for more precise scoring.

		Winter Food	
Characteristic		*Measurements*	*Possible Score*
A	Average tree diameter of preferred food species (cm DBH)	> 25.0	10
		21.6- 25.0	9
		18.4-21.60	8
		15.1-18.4	7
		13.2-15.1	6
		11.4-13.24	5
		9.55-11.40	4
		7.8-9.55	3
		7.7	2
		< 7.6	1
B	Percentage of Canopy Closure	<30.0	1
		30.0 - 30.3	2
		30.3 – 36.6	3
		36.6 – 40.0	4
		40.0 – 60.0	5
		60.0 - 63.3	4
		63.3 – 66.6	3
		66.6 – 70.0	2
		>70.0	1
C	Number of preferred food plant species	>10.0	5
		7.5 – 9.0	4
		6.0 – 7.5	3
		5.0	2
		<5	1
D	Number of supplemental food species	> 5	5
		4-5	4
		3-4	3
		2	2
		<2	1
		Cover/ Reproduction	
Characteristic		*Measurements*	*Possible Score*
E	Average tree diameter (cm DBH)	> 45.7	10
		41.9 – 45.7	9
		38.1 – 41.9	8
		31.7 – 38.0	7
		25.4 – 31.7	6
		22.58 – 25.3	5
		20.15 – 25.8	4
		17.6 – 20.15	3
		15.0- 17.6	2
		<15.0	1

Table 3b Calculations for HSI score and limiting factors.

HSI Calculations
HSI Score
A + B + C + D + E
HSI
(HSI Score/35) x 100
Limiting Factors
Winter Food
((A + B + C + D)/25) x 100
Cover/ Reproduction
(E/10) x 100

Table 4 Tree species identified during PCQM and nest surveys. * indicates use as a nest tree. ж indicates primary food species, § indicates secondary food source.

Common Name	Scientific Name	Common Name	Scientific Name
Florida Maple ж	*Acer barbatum*	Magnolia* ж	*Magnolia grandiflora*
Red Maple *ж	*Acer rubrum* ж	Sweetbay	*Magnolia virginana*
Shantung Maple ж	*Acer truncatum*ж	Chinaberry	*Melia azedarach*
Pignut Hickory ж	*Carya globra* ж	Black Tupelo*	*Nyssa sylvatica*
Pecan* ж	*Carya illinoisensis* ж	Redbay	*Persea borbonia*
Hickory* ж	*Caryra spp.* ж	Pine* ж	*Pinus spp.*
Hackberry*	*Celtis occidentalis*	Sycamore	*Platanus occidentalis*
Eastern Redbud	*Cercis canadensis*	Black Cherry* ж	*Prunus serotina*
Chinese Fringetree	*Chionanthus retusus*	(Bradford) Callary Pear	*Pyrus calleriana*
Fringetree	*Chionanthus virginicus*	Sawtooth Oak* ж	*Quercus acutissima*
Titi*	*Cliftonia monophylla*	Laurel Oak* ж	*Quercus hemisphaerica*
Flowering Dogwood§	*Cornus florida*	Turkey Oak ж	*Quercus laevis*
China Fir ж	*Cunninghamie lanceolata*	Overcup Oak* ж	*Quercus lyrata*
Carolina Ash	*Fraxinus carolinana*	Bur Oak *ж	*Quercus macrocarpa*
Ginkgo§	*Ginkgo biloba*	Swamp Chestnut Oak *ж	*Quercus michauxii*
Holly*	*Ilex opaca*	Nuttall Oak* ж	*Quercus nuttalli*
Southern Redcedar	*Juniperus silicicola*	Willow Oak* ж	*Quercus phellos*
Eastern Redcedar*	*Juniperus virginiana*	Northern Red Oak* ж	*Quercus rubra*
Chinese Flametree	*Koelreuteria bipinnata*	Live Oak* ж	*Quercus spp.*
Crepe Myrtle	*Lagerstroemia indica*	Cabbage Palm	*Sabal palmetto*
Tulip Poplar*	*Liriodendron tulipifera*	Baldcypress	*Taxodium distichum*
Sweetgum*§	*Liquidambar styraciflua*	Elm* ж	*Ulmus americana*

Table 5 Habitat suitability indices and limiting factor scores for all transects. Scores are out of 100, a higher HSI indicates more suitable habitat. * indicates limiting factor in a transect. GSU: Georgia Southern University, CF: Chandler Farms, SGA: Savannah, Georgia, MGA: Metter, Georgia, GLSSP: George L. Smith State Park, MSSP: Magnolia Springs State Park, SC: Sweetheart Circle, BL: Bottomland, HP: Herty Pines Nature Preserve, FP-AR: Forsyth Park Arboretum, FP-LN: Forsyth Park Lawn, CP: City Park, RB: River Bottom, SH: Sandhill, GS: Group Shelter, CG: Campground, PA: Picnic Area, CPC: Colonial Park Cemetery

Site & Description		HSI	Liming Factors	
			Winter Food	Cover
GSU	SC	71.43	60*	100
GSU	SC	77.14	68*	100
CF	BL	51.43	52	50*
GSU	HP	54.29	52*	60
GSU	HP	57.14	56*	60
SGA	FP-AR	68.57	56*	100
CF	OG	57.14	56*	60
SGA	FP-AR	65.71	52*	100
MGA	CP	65.71	52*	100
SGA	FP-LN	65.71	52*	100
CF	BL	42.86	48	30*
CF	OG	51.43	52	50*
GLSSP	RB	42.86	40*	50
GLSSP	RB	45.71	52	30*
GLSSP	RB	42.86	48	30*
GLSSP	RB	45.71	52	30*
GLSSP	SH	40.00	44	30*
GLSSP	GS	74.29	64*	100
GLSSP	CG	68.57	64*	80
GLSSP	CG	71.43	68*	80
GLSSP	PA	57.14	52*	70
GLSSP	PA	54.29	56	50*
MSSP	CG	68.57	68*	70
MSSP	CG	77.14	68*	100
MSSP	PA	80.00	72*	100
SGA	FP-AR	71.43	60*	100
SGA	FP-LN	77.14	68*	100
SGA	FP-AR	80.00	72*	100
SGA	FP-LN	65.71	52*	100
SGA	FP-LN	65.71	52*	100
SGA	FP-LN	65.71	52*	100
SGA	FP-LN	57.14	52*	70
SGA	CPC	68.57	68*	70

Table 6 Spearman rank correlations between nest and habitat variables. Bonferroni correction: ∝=0.0125, * denotes significance.

Variable	Tree Density		% Over-story Density		Hard mast Relative Density		% Shrub Crown Cover		PCQM DBH	
	Sρ	P>ρ	Sρ	P > ρ	Sρ	P > ρ	Sρ	P > ρ	Sρ	P > ρ
Nest Tree DBH	-0.8498	<0.0001*	-0.6795	<0.0001*	0.4678	0.0060*	-0.6880	<0.0001*	0.8613	<0.0001*
Food (m)	0.7311	<0.0001*	0.5533	<0.0001*	-0.6600	<0.0001*	0.5757	0.0005*	-0.5828	0.0004*
Nests/Tree	-0.5669	0.0006*	-0.3763	0.0309	0.3494	0.0462	-0.4717	0.0056*	0.5148	0.0022*

Figures

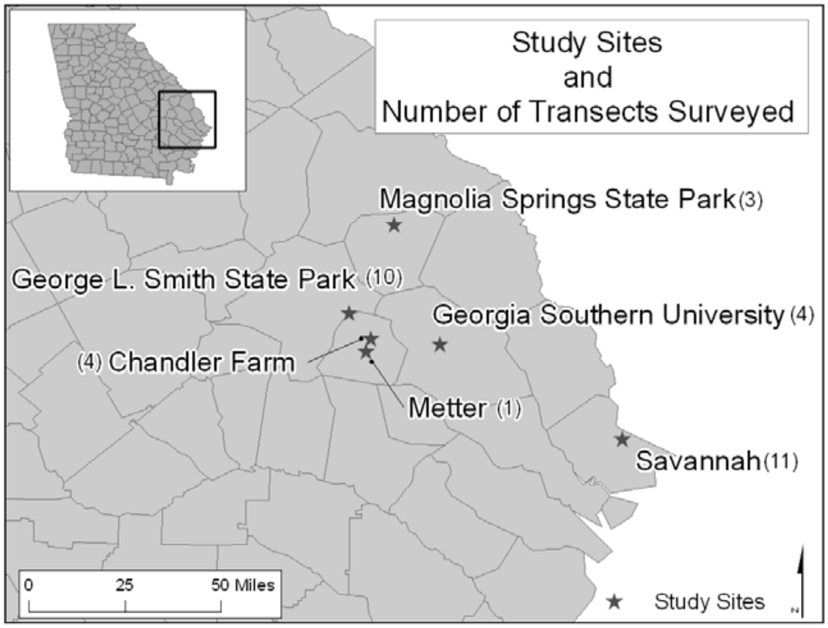


Figure 1 Study sites and number of transects at each location. Thirty-three transects were sampled across the six sites.

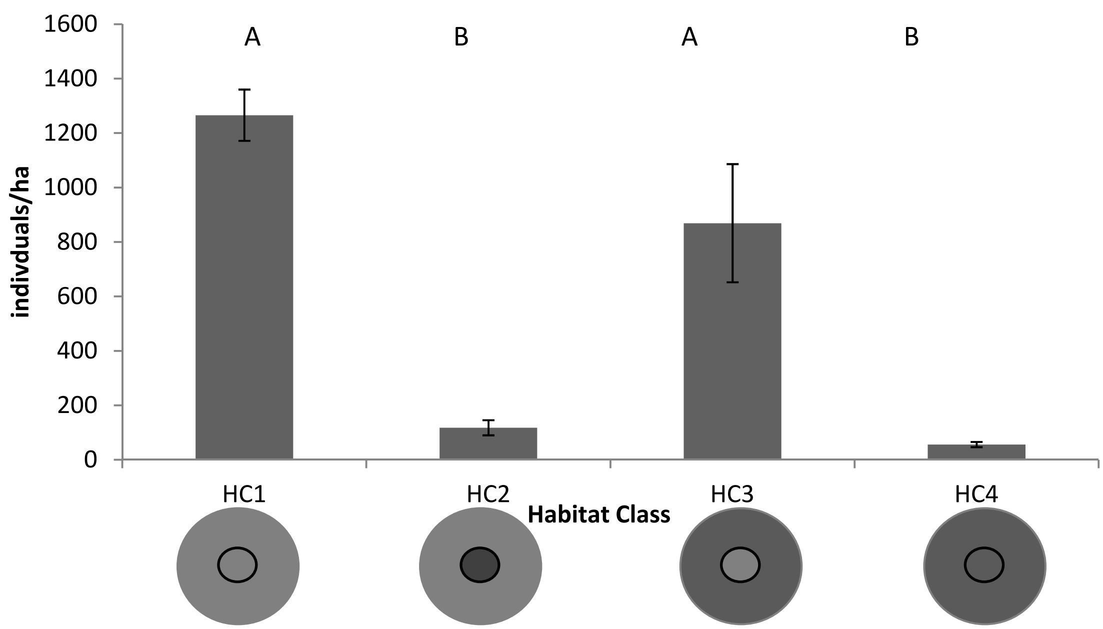


Figure 2 A comparison of mean tree density among habitat classes. Groups with different letters are significantly different based on Tukey-Kramer *a posteriori* analysis. HC 1 n=5, HC 2 n=8, HC 3 n=6, HC 4 n=14. nested ANOVA, $F_{(3, 11)} = 21.5450$, $P<0.0001$

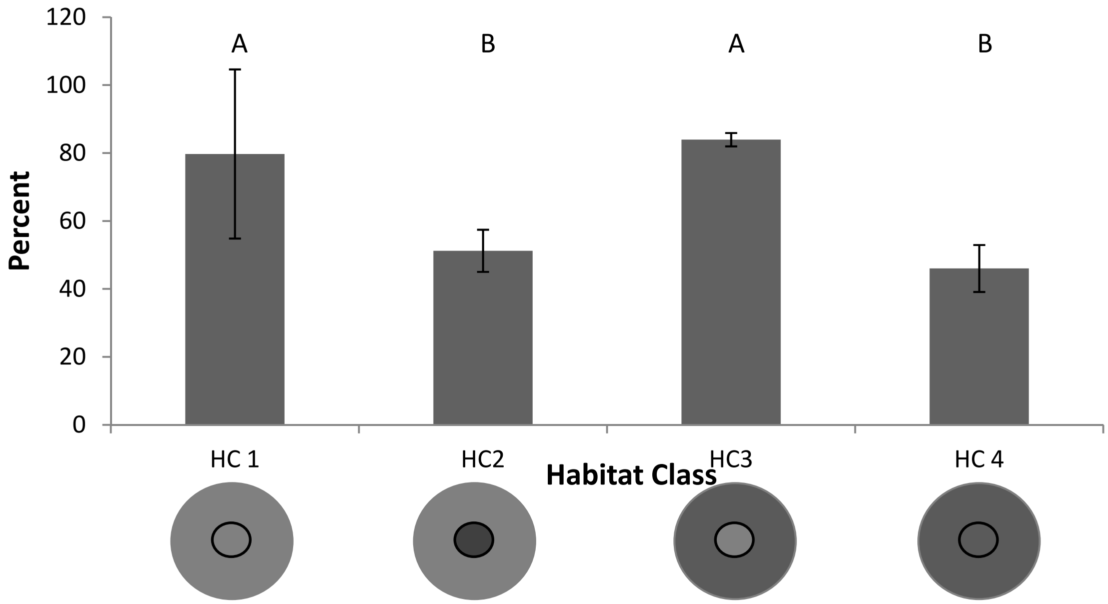


Figure 3 A comparison of percent shrub crown cover among habitat classes. Groups with different letters are significantly different based on Tukey HSD *aposteriori* analysis. HC 1 n=5, HC 2 n=8, HC 3 n=6, HC 4 n=14, nested ANOVA: $F_{(3,11)}$= 9.6244, P=0.0009**;** $F_{(11, 18)}$= 0.9976, NS

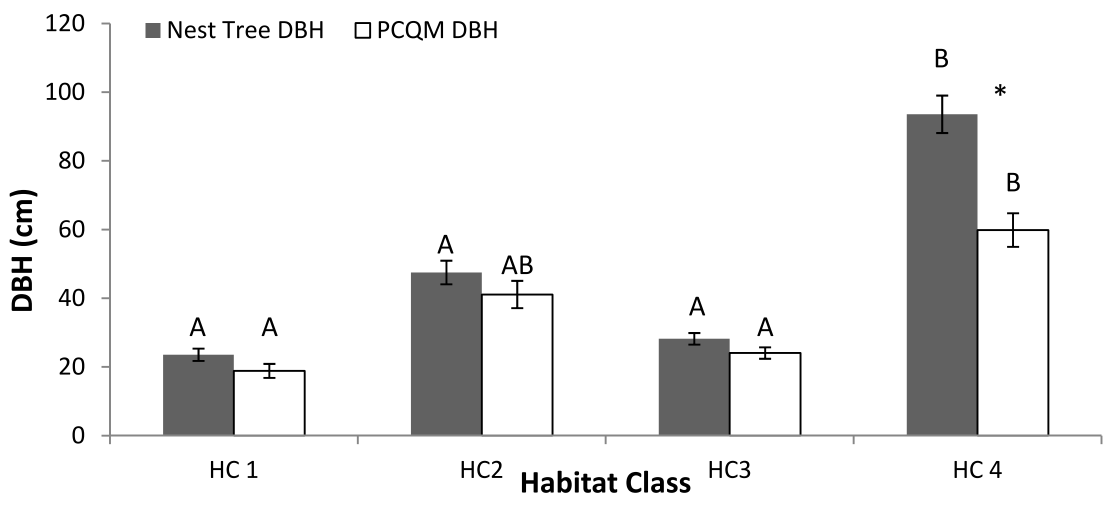


Figure 4 Tree size use versus availability. * denotes significant difference. Nested ANOVA; Mean PCQM DBH: $F_{(3,11)}$= 5.9412, P=0.0076, $F_{(11, 18)}$= 1.1758, NS (HC 1 n=5, HC 2 n=8, HC 3 n=6, HC 4 n=14); Nest Tree DBH: $F_{(3,11)}$= 22.3689, P<0.0001, $F_{(11, 221)}$ = 5.3205, P<0.0001(HC 1 n= 37, HC 2 n= 67, HC 3 n= 60, HC 4 n= 72)

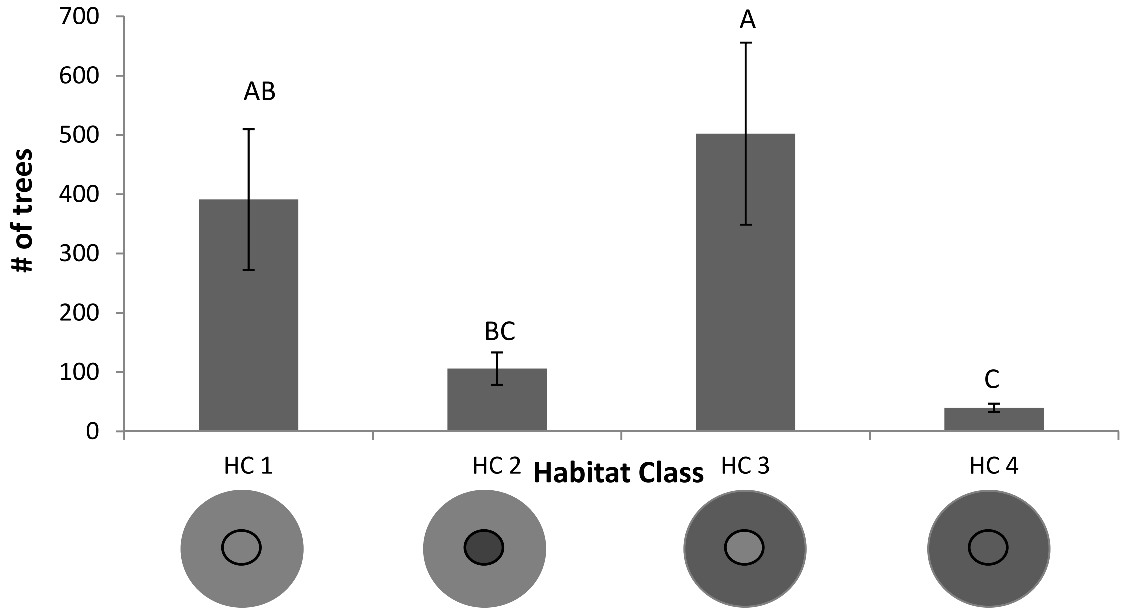


Figure 5 A comparison of absolute density of primary food tree species among habitat classes. Groups with different letters are significantly different based on Tukey HSD *a posteriori* analysis. HC 1 n= 37, HC 2 n= 67, HC 3 n= 60, HC 4 n= 72. Nested ANOVA; $F_{(3, 11)} = 7.7183$, P= 0.0003, $F_{(11, 18)} = 2.0267$, NS

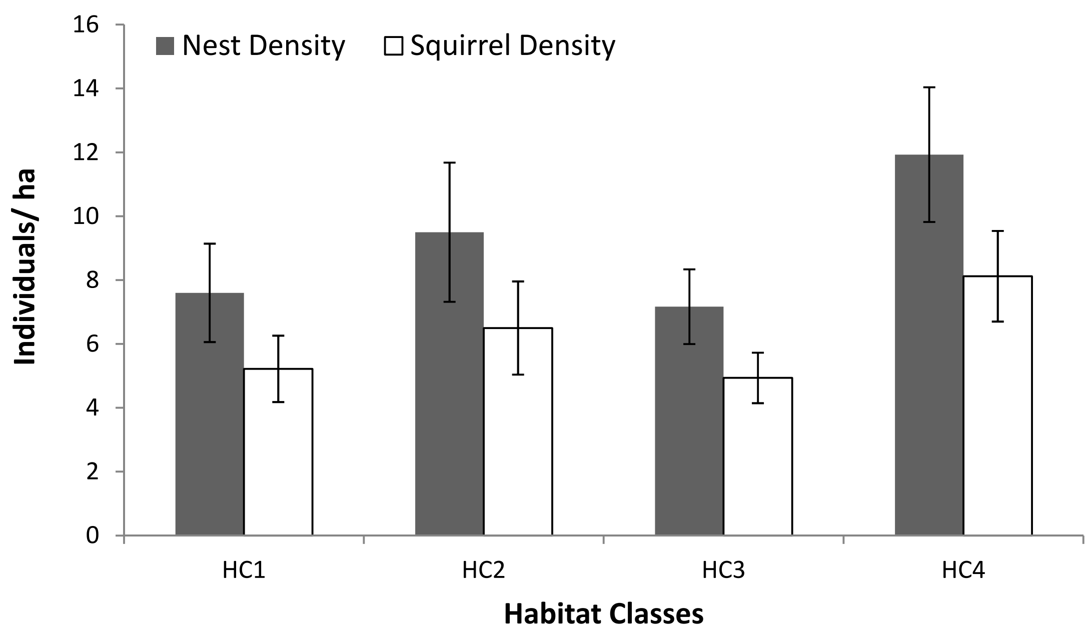


Figure 6 Mean leaf nest density and mean population density. Squirrel density is calculated from leaf nest density. Means are not significant among habitat classes.

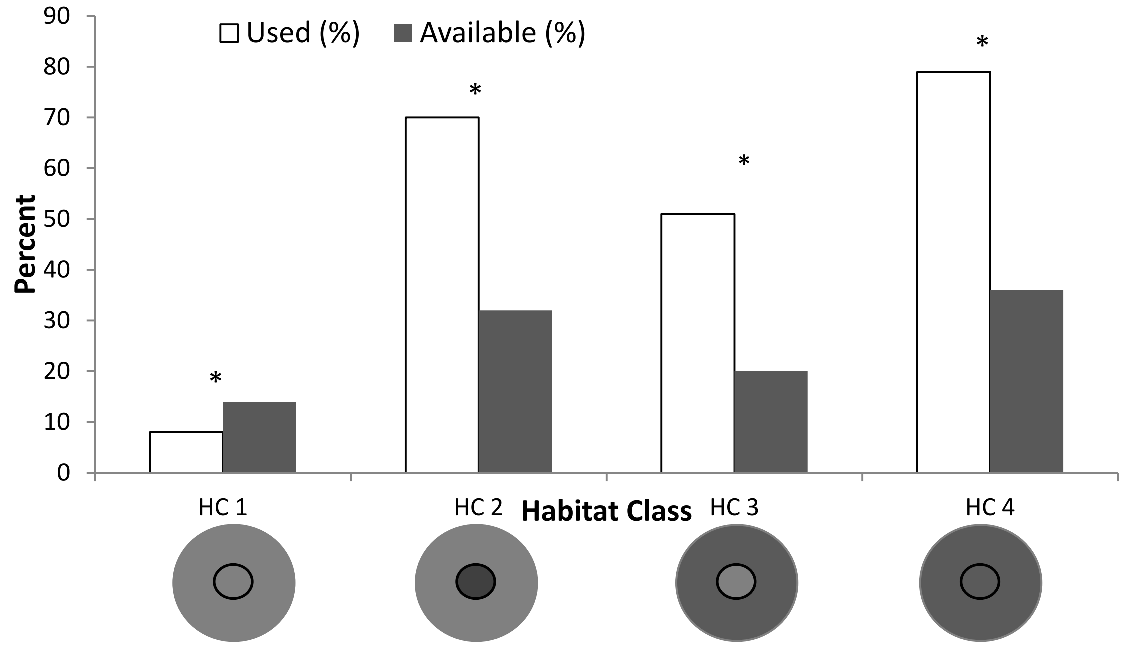


Figure 7 Comparisons of oak species use and availability. * denotes a significant difference based on chi square tests.

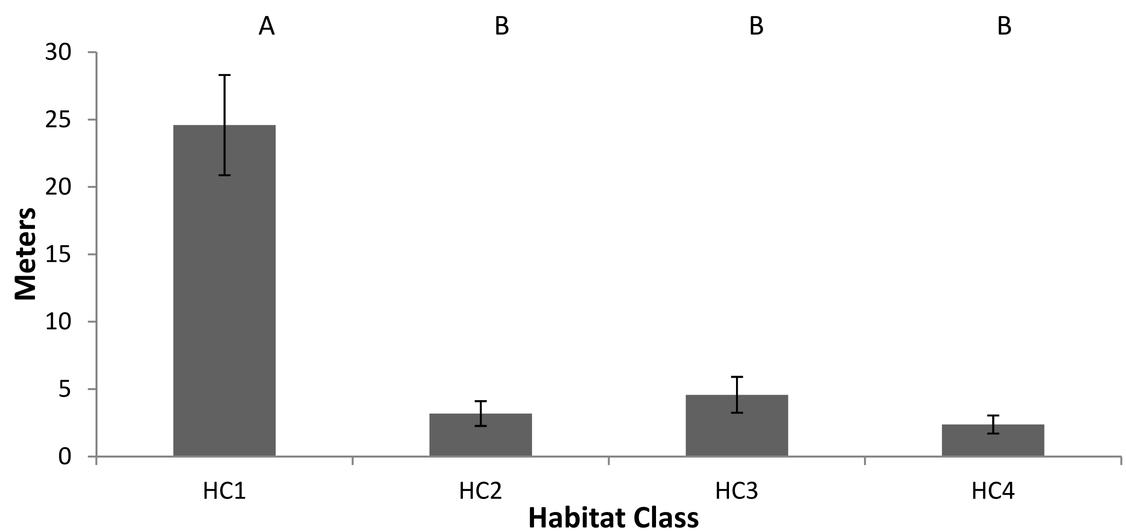


Figure 8 Distance to nearest food tree by habitat class based on nest tree data. Groups with different letters have significantly different means based on Tukey HSD *a posteriori* analysis. HC 1 n= 37, HC 2 n= 67, HC 3 n= 60, HC 4 n= 72. Nested ANOVA, $F_{(3, 11)} = 9.2840$, P=0.0010; $F_{(11, 221)} = 1.7033$, P= 0.0739, NS

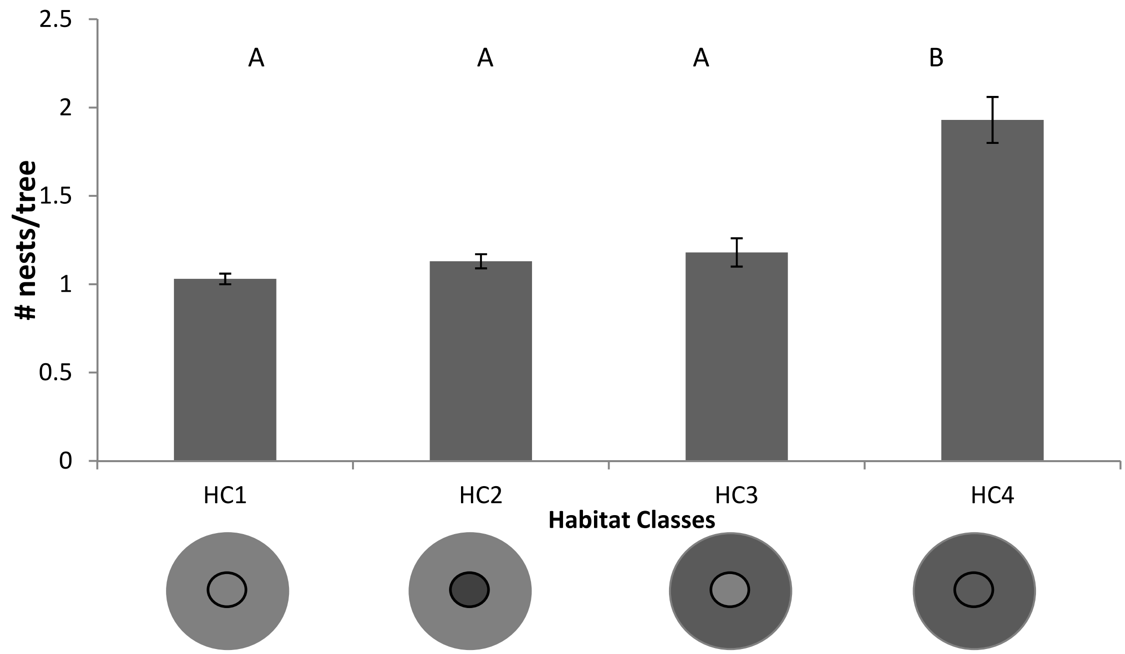


Figure 9 Mean number of nests per tree based on nest tree means. Letters denote similarity. Groups with different letters have significantly different means based on Tukey-Kramer analysis. HC 1 n= 37, HC 2 n=67, HC 3 n= 60, HC 4 n= 72. Nested ANOVA, $F_{(3, 11)} = 19.0512$, $P<0.0001$; $F_{(11, 221)} = 0.5812$, NS

APPENDIX A

FOOD AVAILABILITY PROFILE

Food trees available within each transect by season. * denotes primary food species.
GSU: Georgia Southern University, CF: Chandler Farms, SGA: Savannah, Georgia, MGA: Metter, Georgia, GLSSP: George L. Smith State Park, MSSP: Magnolia Springs State Park, SC: Sweetheart Circle, BL: Bottomland, HP: Herty Pines Nature Preserve, FP-AR: Forsyth Park Arboretum, FP-LN: Forsyth Park Lawn, CP: City Park, RB: River Bottom, SH: Sandhill, GS: Group Shelter, CG: Campground, PA: Picnic Area, CPC: Colonial Park Cemetery

Site & Description	Season: Spring	Summer	Fall	Winter
GSU-SC	Magnolia Oak*	Oak*	Oak* Pecan*	Magnolia Oak* Pecan*
GSU-SC	Magnolia	Dogwood	Dogwood Oak*	Magnolia
CF-BL	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine* Sweetgum	Maple Oak* Pine* Sweetgum
GSU-HP	Oak* Pine*	Oak* Pine* Dogwood	Dogwood Oak* Pine*	Oak* Pine*
GSU-HP	Cherry Magnolia Oak* Pine*	Dogwood Oak* Pine*	Dogwood Oak* Pine* Sweetgum	Magnolia Oak* Pine* Sweetgum
SGA-FPAR	Elm Magnolia Oak*	Ginkgo Oak*	Ginkgo Oak* Sweetgum	Elm Magnolia Oak* Sweetgum
CF-OG	Elm Magnolia Maple Oak* Pine* Sweetgum	Maple Oak* Pine*	Elm Maple Oak* Pine*	Elm Magnolia Maple Oak* Pine* Sweetgum
SGA-FPAR	Hickory Magnolia Oak*	Hickory Oak*	Hickory Oak*	Hickory Magnolia Oak*
MGA-CP	Oak*	Dogwood Oak*	Dogwood Oak*	Oak*

Site	Spring	Summer	Fall	Winter
SGA-FPLN	Oak*	Oak*	Elm Magnolia Oak*	Elm Magnolia Oak*
CF-BL	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine* Sweetgum	Maple Oak* Pine* Sweetgum
CF-OG	Magnolia Maple Oak* Pine*	Dogwood Maple Oak* Pine*	Dogwood Maple Oak* Pine* Sweetgum	Dogwood Maple Oak* Pine* Sweetgum
GLSSP-RB	Maple Pine*	Maple Pine*	Maple Pine*	Maple Pine*
GLSSP-RB	Maple Pine*	Maple Pine*	Maple Pine*	Maple Pine*
GLSSP-RB	Maple Pine*	Maple Pine*	Maple Pine*	Maple Pine*
GLSSP-RB	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*
GLSSP-SH	Cherry Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*
GLSSP-GS	Cherry Maple Oak* Pine*	Maple Mulberry Oak* Pine*	Maple Oak* Pine* Sweetgum	Maple Oak* Pine* Sweetgum
GLSSP-CG	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*
GLSSP-CG	Cherry maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*	Maple Oak* Pine*
GLSSP-PA	Cherry Oak* Pine*	Oak* Pine*	Oak* Pine*	Oak* Pine*

Site	Spring	Summer	Fall	Winter
GLSSP-PA	Oak* Pine*	Oak* Pine*	Oak* Pine*	Oak* Pine*
MSSP-CG	Cherry Oak* Pine*	Oak* Pine*	Oak* Pine*	Oak* Pine*
MSSP-CG	Oak* Pine*	Dogwood Oak* Pine*	Dogwood Oak* Pine*	Oak* Pine*
MSSP-PA	Hickory Oak* Pine*	Dogwood Hickory Oak* Pine*	Dogwood Hickory Oak* Pine* Sweetgum	Hickory Oak* Pine* Sweetgum
SGA-FPAR	Maple Oak*	Maple Oak*	Maple Oak* Sweetgum	Maple Oak* Sweetgum
SGA-FPLN	Elm Oak*	Oak*	Oak*	Elm Oak*
SGA-FPAR	Elm Maple Oak*	Magnolia Maple Oak*	Fir Magnolia Maple Oak* Sweetgum Sycamore	Elm Fir Maple Oak* Sweetgum Sycamore
SGA-FPLN	Oak*	Oak*	Oak* Sycamore	Oak* Sycamore
SGA-FPLN	Oak*	Oak*	Oak*	Oak*
SGA-FPLN	Oak*	Oak*	Oak* Sycamore	Oak* Sycamore
SGA-FPLN	Oak*	Oak*	Oak*	Oak*
SGA-CPC	Cherry Elm Magnolia Oak* Pecan*	Oak* Pecan*	Oak* Pecan* Hackberry	Elm Magnolia Oak* Pecan*

APPENDIX B
PCQM IMPORTANCE VALUES

Site	Mean Distance	Density (#/ha)	Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
GSU-SC	11.52	75	21.9	Oak	127.3	2	2.5	8.3	0.1	10.9
				Pecan	2976.3	69	92.5	83.3	93.6	269.4
				Magnolia	3460.4	4	5	8.3	6.3	19.6
GSU-SC	13.21	57	19.8	Crepe Myrtle	75.2	3	5	0.1	8.7	13.8
				Dogwood	1230.3	20	35	12.6	34.8	82.4
				Holly	305.9	1	2.5	0.2	4.3	7
				Magnolia	3610.4	3	5	5.5	8.7	19.2
				Oak	5323.7	30	52.5	81.6	43.5	177.6
CF-BL	2.89	1197	67.7	Tupelo	877.3	30	2.5	3.7	3.9	10.01
				Sweetgum	115.5	299	25	25.9	5.1	56
				Redbay	46.3	60	5	7.4	0.4	12.8
				Pine	1719.6	30	2.5	3.7	7.6	13.8
				Oak	1061.6	449	37.5	29.6	70.4	137.5
				Maple	257.6	329	27.5	29.6	12.5	69.6
GSU-HP	6.03	275	21.8	Pine	1342.9	138	50	40	85.1	175.1
				Oak	280.3	89	32.5	30	11.5	74
				Dogwood	153.8	48	17.5	30	3.4	50.9

Site	Mean Distance	Absolute Density (#/ha)	Total Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
GSU-HP	5.37	347	28.8	Cherry	412.5	9	2.5	4.3	1.3	8.1
				Dogwood	117.4	26	7.5	13	1.1	21.6
				Magnolia	139.3	17	5	8.7	0.8	14.5
				Oak	128.2	69	20	21.7	3.1	44.8
				Pine	1285.1	208	60	43.5	92.9	196.4
				Sweetgum	147.1	17	5	8.7	0.9	14.6
SGA-FPAR	5.37	347	28.8	Cherry	412.5	9	2.5	4.3	1.3	8.1
				Dogwood	117.4	26	7.5	13	1.1	21.6
				Magnolia	139.3	17	5	8.7	0.8	14.5
				Oak	128.2	69	20	21.7	3.1	44.8
				Pine	1285.1	208	60	43.5	92.9	196.4
				Sweetgum	147.1	17	5	8.7	0.9	14.6
CF-OG	3.95	641	61.1	Elm	820.3	112	17.5	18.2	15	50.7
				Magnolia	950.8	112	17.5	18.2	17.4	53.1
				Maple	69.8	32	5	6.1	0.4	11.5
				Oak	1118.1	96	15	12.1	17.6	44.7
				Pine	637.6	32	5	6.1	3.3	14.4
				Poplar	1790.1	112	17.5	18.2	32.8	68.5
				Redbay	853.9	80	12.5	12.1	11.2	35.8
				Sweetgum	209.5	64	10	9.1	2.2	21.3

Site	Mean Distance	Absolute Density (#/ha)	Total Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
SGA-FPAR	12.12	68	30.7	Callary Pear	2083.2	5	7.5	7.7	3.4	18.6
				Hickory	7305.9	3	5	7.7	7.1	19.8
				Magnolia	30265	32	47.5	38.5	31.5	117.5
				Oak	8157.2	19	27.5	26.9	50.5	104.9
				Poplar	3781.8	2	2.5	3.8	2.5	8.8
				Sugarberry	2192.8	7	10	15.4	5	30.4
MGA-CP	9.64	108	29.1	Oak	3259	84	77.5	94.1	71.4	243
				Crepe Myrtle	1540.4	5	5	2.6	7.1	14.7
				Dogwood	492.9	19	17.5	3.2	21.4	42.1
SGA-FPLN	N/A	17	13.86	Oak	7652.3	9	52.94	52.94	68.57	174.46
				Elm	4548.5	2	11.76	11.76	9.06	32.59
				Magnolia	6667.3	3	17.65	17.65	19.92	55.21
				Palm	110.00	2	11.76	11.76	1.92	25.45
				Juniper	535.35	1	5.88	5.88	0.53	12.30
CF-BL	2.49	1613	52.9	Maple	284.6	686	42.5	36	36.9	115.4
				Oak	604.6	484	30	32	55.4	117.4
				Pine	277.1	81	5	8	4.2	17.2
				Poplar	71.7	202	12.25	12	2.7	27.2
				Redbay	27.3	121	7.5	8	0.6	16.1
				Sweetgum	11.5	40	2.5	4	0.1	6.6

Site	Mean Distance	Absolute Density (#/ha)	Total Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
CF-OG	2.96	1141	97	Dogwood	52.3	86	7.5	7.7	0.5	15.7
				Magnolia	127.3	57	5	7.7	0.7	13.4
				Maple	240.7	29	2.5	3.8	0.7	7
				Oak	263	57	5	7.7	1.5	14.2
				Pine	2926.4	257	22.5	26.9	77.5	126.9
				Poplar	336.2	29	2.5	3.8	1	7.3
				Redbay	35.8	57	5	7.7	0.2	12.9
				Sweetgum	301.9	571	50	34.6	17.8	102.4
GLSSP-RB	3.6	772	44.6	Maple	235.1	135	17.5	7.1	20	44.6
				Pine	1077.4	58	7.5	14	12	33.5
				Titi	503.6	212	27.5	24	28	79.5
				Tupelo	666.3	367	47.5	54.9	40	142.4
GLSSP-RB	2.81	1266	57.8	Maple	260	127	10	5.7	12.5	28.2
				Pine	1559.7	32	2.5	8.6	6.3	17.4
				Titi	173.1	127	10	3.8	18.8	32.6
				Tupelo	482.2	981	77.5	81.8	62.5	221.8
GLSSP-RB	2.6	1479	64.9	Oak	115.1	481	32.5	8.5	23.8	64.8
				Pine	2437.1	111	7.5	41.7	14.3	63.5
				Titi	187.5	222	15	6.4	23.8	45.2
				Tupelo	422.3	666	45	43.4	38.1	126.5

Site	Mean Distance	Absolute Density (#/ha)	Total Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
GLSSP-RB	2.4	1736	64.5	Maple	229.5	87	5	3.1	9.1	17.2
				Pine	1306.9	174	10	35.2	9.1	54.3
				Redbay	15.6	43	2.5	0.1	4.5	7.1
				Sweetbay	28.7	43	2.5	0.2	4.5	7.2
				Titi	251.9	1042	60	40.7	45.5	146.2
				Tupelo	385	347	20	20.7	27.3	68
GLSSP-SH	3.05	1075	41	cherry	357.2	27	2.5	2.4	5	9.9
				maple	125	54	5	1.6	10	16.6
				oak	243.2	403	37.5	23.9	25	86.4
				Pine	771.3	269	25	50.7	25	100.7
				Titi	108.9	27	2.5	0.7	5	8.2
				Tupelo	286.1	296	27.5	20.7	30	78.2
GLSSP-GS	9.7	106	33.5	Cherry	703.1	3	2.5	0.6	3.7	6.8
				Chinaberry	132.1	5	5	0.2	3.7	8.9
				Cypress	761.7	8	7.5	1.8	7.4	16.7
				Juniper	630.3	5	5	0.9	7.4	13.3
				Maple	1347.3	37	35	14.9	25.9	75.8
				Mulberry	296.1	3	2.5	0.3	3.7	6.5
				Oak	12280	16	15	58.7	18.5	92.2
				Pine	3524.4	21	20	22.1	18.5	60.6
				Sweetgum	92.1	5	5	0.1	7.4	12.5
				Tupelo	357.2	3	2.5	0.3	3.7	6.5

Site	Mean Distance	Absolute Density (#/ha)	Total Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
GLSSP-CG	7.83	163	22.9	Oak	1009.2	20	12.5	8.8	19	40.3
				Ash	787.4	29	17.5	10	28.6	56.1
				Maple	1034.2	4	2.5	1.8	4.8	9.1
				Pine	1654.3	110	67.5	79.4	47.6	194.5
GLSSP-CG	9.95	101	13.8	Ash	240.7	5	5	0.9	7.1	13
				Cherry	738	20	20	10.7	21.4	52.1
				Juniper	733.4	3	2.5	1.6	3.6	7.7
				Maple	810.9	23	22.5	13.5	25	61
				Oak	2232.6	38	37.5	61.5	25	124
				Pine	1537.3	10	10	11.2	14.3	35.5
				Tupelo	277	3	2.5	0.6	3.6	6.7
GLSSP-PA	34.92	8	1	Cherry	172.3	0	5	0	3.8	8.8
				Juniper	1310.8	1	10	12.8	15.4	38.2
				Oak	876.5	4	55	34.3	38.5	127.8
				Pine	2655.9	2	22.5	52	30.8	105.3
				Titi	86.7	1	7.5	0.8	11.5	19.8
GLSSP-PA	6.18	262	17.4	Oak	422.1	164	62.5	39.7	50	152.2
				Pine	1135.8	92	35	60	45	140
				Tupelo	62.4	7	2.5	0.3	5	7.8
MSSP-CG	7.82	164	21.5	Ash	827.9	4	2.5	1.5	5	9
				Oak	1385.2	94	57.5	60.6	45	163.1
				Pine	1234.5	66	40	37.9	50	127.9

Site	Mean Distance	Absolute Density (#/ha)	Total Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
MSSP-CG	10.59	89	16.7	Oak	1271.5	7	7.5	5.3	17.6	30.4
				Dogwood	554.2	9	10	3	23.5	36.5
				Pine	2096.8	73	82.5	91.7	58.8	233
MSSP-PA	14.39	48	13.8	Cedar	133.8	1	2.5	0.1	3.6	6.2
				Dogwood	522.1	2	5	0.8	7.1	12.9
				Hickory	557.4	6	12.5	2.4	14.3	29.2
				Oak	2642.7	23	47.5	44.2	35.7	127.4
				Pine	4877.6	14	30	49.6	35.7	115.3
				Sweetgum	3957.3	1	2.5	2.9	3.6	9
SGA-FPAR	9.7	106	41.4	Cedar	1365.6	3	2.5	1	3.6	7.1
				Flametree	844.2	8	7.5	1.6	10.7	19.8
				Fringetree	272.8	5	5	0.3	7.1	12.4
				Magnolia	5221.2	27	25	34	21.4	80.4
				Maple	134.4	24	22.5	0.8	21.4	44.7
				Oak	5844.4	29	27.5	40.9	25	93.4
				Sweetgum	8015.3	11	10	21.3	10.7	42

Site	Mean Distance	Absolute Density (#/ha)	Total Cover (m^2/ha)	Species	Mean BA	#/ha	Relative Density	Relative Frequency	Relative Cover	Importance
SGA-FPAR	10.4	92	28.4	Sycamore	4028.6	2	2.5	2.8	2.9	8.2
				Sweetgum	1743.1	7	7.5	4.3	8.6	20.4
				Palm	746.4	7	7.5	1.8	8.6	17.4
				Oak	7130.8	28	30	70.2	25.7	125.9
				Maple	207	5	5	0.4	5.7	11.1
				Magnolia	2335.5	16	17.5	13.1	17.1	47.7
				Flametree	811.8	7	7.5	2	8.6	18.1
				Fir	812.6	14	15	4	14.3	33.3
				Elm	523.4	7	7.5	1.3	8.6	17.4
SGA-CPC	11.2	81	17.9	C. myrtle	651.9	4	5	1.5	7.1	13.6
				Elm	53.2	32	40	1	25	66
				Fringetree	23	2	2.5	0	3.6	6.1
				Magnolia	8047.2	6	7.5	27	10.7	45.2
				Oak	4798	22	27.5	59.1	28.6	115.2
				Pecan	45.8	2	2.5	0.1	3.6	6.2
				Poplar	435.8	2	2.5	0.5	3.6	6.6
				Redbud	161.1	2	2.5	0.2	3.6	6.3
				Hackberry	3476	4	5	78	7.1	19.9
				Unknown	1303.8	4	5	29	7.1	15

APPENDIX C
HABITAT VARIABLE DESCRIPTIVE STATISTICS

Mean measurements for all variables used to characterize habitat within transects.

Habitat class 1: Unmodified areas surrounded by a minimum buffer of 100 m of unmodified habitat. n = 5

Variable	Mean	Variance	Minimum	Median	Maximum	Inter-quartile Range	CV
Tree Density	1265.6	136696.3	772	1266	1736	684	29.21
% Overstory Density	79.74	11.451	76.704	78.9	85.336	5.564	4.24
% Shrub Crown	67.16	603.09	36.3	68.9	94.8	47.85	36.57
Nests/ Tree	1.03	0.0034	1	1	1.13	0.065	5.67
PCQM Tree DBH	18.85	15.95	13.69	19.43	24.52	6.85	21.19
HSI	52.14	200	40	45.71	77.14	23.29	27.12
HM Relative Density	14	370.63	0	0	37.5	35	137.51
Nest Density	7.6	11.8	5	6	13	6	45.2
Squirrel Density	5.22	5.38	3.47	4.15	8.87	4	44.35
Nest Height	11.06	3.46	9.67	11.33	14.6	3.08	16.033

Habitat class 2: Modified for rural recreational (camping and picnicking), maximum of 100 m, between modified and unmodified habitat. n = 8

Variable	Mean	Variance	Minimum	Median	Maximum	Inter-quartile Range	CV
Tree Density	117.625	6164.26	8	103.5	262	105.5	66.75
% Overstory Density	51.237	309.52	11.6	55.122	67.136	17.09	34.37
% Shrub Crown	5.13	86.95	0	1.2	27.07	7.075	181.91
Nests/ Tree	1.22	0.14	1	1.13	2.14	0.22	31.12
PCQM Tree DBH	41.09	94.81	25.16	39.02	56.69	13.06	23.7
HSI	68.9	82.7	54.3	70	80	16.43	13.2
HM Relative Density	38.43	551.67	7.5	46.25	62.5	46.25	61.11
Nest Density	9.5	38	3	7.5	20	10.5	64.89
Squirrel Density	6.49	17.15	2.102	5.168	13.54	7.06	63.73

Habitat class 3: Undeveloped woodlots separated from either agriculture or urban development by less than 100 m of unmodified habitat. n=6

Variable	Mean	Variance	Minimum	Median	Maximum	Inter-quartile Range	CV
Tree Density	869	282481.6	275	891	1613	972	61.16
% Overstory Density	83.93	18.90	78.42	83.51	90.43	7.202	5.18
% Shrub Crown	35.13	790.02	0.00	36.5	71	57.65	80.00
PCQM Tree DBH	24.05	17.16	17.83	24.50	28.34	7.90	17.23
HSI	52.4	28.3	42.9	52.9	57.1	7.8	10.2
HM Relative Density	30.25	588.375	5.00	25.00	74.00	34.125	80.18
Nest Density	7.16	8.16	4.00	7.00	11.00	4.75	39.87
Squirrel Density	4.93	3.74	2.788	4.82	7.527	3.218	39.20

Habitat class 4: Spaces developed for urban recreation surrounded by at least 75% urban/suburban matrix. n = 14

Variable	Mean	Variance	Minimum	Median	Maximum	Inter-quartile Range	CV
Tree Density	55.93	1251.76	13	62.5	108	64.75	63.25
% Overstory Density	46.03	669.71	0	50.704	83.15	42.952	56.21
% Shrub Crown	5.29	244.55	0	0	57.4	0	295.85
PCQM Tree DBH	59.85	416.78	27.39	57.48	97.71	29.55	34.11
HSI	71.07	26.7	65.7	70	80	9.27	7.3
HM Relative Density	55.36	644.62	27.5	47.58	95	50	45.85
Nest Density	11.93	62.38	1	10	28	12.5	66.21
Squirrel Density	8.12	28.04	0.714	6.855	18.841	8.395	65.21

APPENDIX D

NEST CLASS DESCRIPTIVE STATISTICS

Habitat class 1: Unmodified areas surrounded by a minimum buffer of 100 m of unmodified habitat. n = 37

Variable	Mean	Variance	Minimum	Median	Maximum	Inter-quartile Range	CV
Nests / Tree	1.027	0.027	1	1	2	0	16.01
Nest Tree DBH	23.6	20.72	7.64	21.02	49.7	12.42	
Distance to Food	24.59	511.94	0	18.44	101.75	21.01	92.02
Distance to Water	107.61	1042.23	34.42	111.3	159.73	52.25	30
Nest Height	11.15	13.6	6	10.5	22	4.5	33.07

Habitat class 2: Modified for rural recreational (camping and picnicking), maximum of 100 m, between modified and unmodified habitat. n = 67

Variable	Mean	Variance	Minimum	Median	Maximum	Inter-quartile Range	CV
Nests / Tree	1.13	0.118	1	1	2	0	30.3
Nest Tree DBH	47.59	429.36	15.61	45.54	134.08	29.3	43.55
Distance to Food	3.19	56.67	0	0	48.4	2.38	236.1
Distance to Water	69.3	3896.88	0	51.3	241.54	108.66	90.08
Nest Height	11.82	18.81	5	12	26	5	36.69

Habitat class 3: Undeveloped woodlots separated from either agriculture or urban development by less than 100 m of unmodified habitat. n=60

Variable	Mean	Variance	Minimum	Median	Maximum	Interquartile Range	CV
Nests / Tree	1.183	0.389	1	1	4	0	52.74
Tree DBH	42	777.51	10.19	31.85	119.11	43.63	66.39
Distance to Food	4.58	106.67	0	0	50	5.25	225.47
Distance to Water	93.65	4446.192	7.65	85.01	238.11	116.35	71.2
Nest Height	12.875	28.99	5	11	28	7	41.82

Habitat class 4: Spaces developed for urban recreation surrounded by at least 75% urban/suburban matrix. n = 72

Variable	Mean	Variance	Minimum	Median	Maximum	Interquartile Range	CV
Nests / Tree	1.93	1.25	1	2	5	2	57.88
Tree DBH	89.77	583.01	36.62	90.13	140.13	37.1	26.99
Distance to Food	2.38	32.22	0	0	31.6	0	238
Distance to Water	153.1	10243.8	18.85	115.43	353.39	168.19	64.84
Nest Height	12.48	13.93	5	12.125	24.33	5	29.9

APPENDIX E
HABITAT VARIABLES BY TRANSECT

Measurements for habitat variables for each transect. HM= hard mast

GSU: Georgia Southern University, CF: Chandler Farms, SGA: Savannah, Georgia, MGA: Metter, Georgia, GLSSP: George L. Smith State Park, MSSP: Magnolia Springs State Park, SC: Sweetheart Circle, BL: Bottomland, HP: Herty Pines Nature Preserve, FP-AR: Forsyth Park Arboretum, FP-LN: Forsyth Park Lawn, CP: City Park, RB: River Bottom, SH: Sandhill, GS: Group Shelter, CG: Campground, PA: Picnic Area, CPC: Colonial Park Cemetery

Site & Description		Tree Density	HM Relative Density	PCQM DBH	% Overstory Density	% Shrub Crown Cover
GSU	SC	75	95	60.51	65.06	0
GSU	SC	57	50	27.39	59.23	0
CF	BL	1197	37.5	23.25	90.43	38
GSU	HP	275	74	21.02	81.8	71
GSU	HP	347	20	28.03	81.07	60
SGA	FP-AR	78	32.5	57.32	72.44	0
CF	OG	641	15	28.34	86.67	35.00
SGA	FP-AR	68	27.5	72.61	83.15	0
MGA	CP	108	77.5	48.73	75.04	16.6
SGA	FP-LN	24	70.83	79.07	0	57.4
CF	BL	1613	30	17.83	85.23	0
CF	OG	1141	5	25.80	78.42	6.8
GLSSP	RB	772	0	24.52	85.34	94.8
GLSSP	RB	1266	0	16.88	80.14	86.5
GLSSP	RB	1479	32.5	19.43	78.9	36.3
GLSSP	RB	1736	0	13.69	76.70	68.9
GLSSP	SH	1075	37.5	19.75	77.64	49.3
GLSSP	GS	106	15	50.00	63.91	8.4
GLSSP	CG	163	12.5	39.49	61.21	0
GLSSP	CG	101	37.5	38.54	53.30	27.07
GLSSP	PA	8	55	36.31	11.6	3.1
GLSSP	PA	262	62.5	25.16	67.13	2.44
MSSP	CG	164	57.5	35.99	56.94	0
MSSP	CG	89	7.5	46.50	44.46	0
MSSP	PA	48	60	56.69	51.32	0
SGA	FP-AR	106	27.5	57.64	65.57	0
SGA	FP-LN	14	64.29	74.16	42.17	0
SGA	FP-AR	92	30	51.59	60.06	0
SGA	FP-LN	13	92.31	87.85	25.12	0
SGA	FP-LN	31	45.16	51.1	22	0
SGA	FP-LN	16	87.50	97.71	27.72	0
SGA	FP-LN	20	45.00	37.18	14.2	0
SGA	CPC	81	30	35.03	32.71	0

APPENDIX F

NEST VARIABLES BY TRANSECT

Mean calculations for nest trees within transects. GSU: Georgia Southern University, CF: Chandler Farms, SGA: Savannah, Georgia, MGA: Metter, Georgia, GLSSP: George L. Smith State Park, MSSP: Magnolia Springs State Park, SC: Sweetheart Circle, BL: Bottomland, HP: Herty Pines Nature Preserve, FP-AR: Forsyth Park Arboretum, FP-LN: Forsyth Park Lawn, CP: City Park, RB: River Bottom, SH: Sandhill, GS: Group Shelter, CG: Campground, PA: Picnic Area, CPC: Colonial Park Cemetery

Site &	Description	Nests/ Tree	Nest Density	Pop. density	DBH	$\bar{x}$ Food(m)	$\bar{x}$ Water (m)	Height (m)	HSI
GSU	SC	1.29	10	6.86	61.54	3.68	236.48	9.67	71.43
GSU	SC	2.5	18	12.21	93.77	0	330.25	12.15	77.14
CF	BL	2.74	9	6.18	30.1	6.78	48.38	11.67	51.43
GSU	HP	1	11	7.53	25.16	0	112.45	10.73	54.29
GSU	HP	1	4	2.79	24.78	6.53	156.22	9.2	57.14
SGA	FP-AR	1.64	23	15.53	83.12	6.01	75.47	14.73	68.57
CF	OG	1	5	3.47	30.83	25.2	52.04	19	57.14
SGA	FP-AR	2.38	19	12.88	97.01	0	74.73	12.47	65.71
MGA	CP	1.65	28	18.84	78.98	0	31.05	13.76	65.71
SGA	FP-LN	1.67	5	3.47	93.84	2.92	40.42	12.6	65.71
CF	BL	1	9	6.18	23.99	4.16	194.66	10.44	42.86
CF	OG	1	5	3.47	34.14	4.87	156.42	17	51.43
GLSSP	RB	1.13	9	6.18	18.31	31.57	104.96	11.33	42.86
GLSSP	RB	1	6	4.15	27.65	79.93	66.8	11.83	45.71
GLSSP	RB	1	13	8.87	21.36	15.25	130.95	9.67	42.86
GLSSP	RB	1	5	3.47	21.46	13.66	131.7	10.6	45.71
GLSSP	SH	1	5	3.47	28.98	18.21	76	14.6	40
GLSSP	GS	1	6	4.15	60.72	12.8	56.21	12.67	74.29
GLSSP	CG	1	7	4.83	43.36	6.97	26.76	12	68.57
GLSSP	CG	1.13	18	12.21	51.65	3.48	14.73	10.44	71.43
GLSSP	PA	1.14	8	5.506	40.22	0.19	19.41	9.38	57.14
GLSSP	PA	1	3	2.102	28.56	5.16	19.89	12	54.29
MSSP	CG	1.25	20	13.540	40.74	0.36	112.53	12.25	68.57
MSSP	CG	1.13	9	6.181	53.98	1.22	183.9	11.78	77.14
MSSP	PA	2.14	5	3.470	60.75	0	103.89	16.4	80
SGA	FP-AR	2.4	12	8.199	89.3	2.53	80.63	17.92	71.43
SGA	FP-LN	1	1	0.714	107.64	0	43.18	11	77.14
SGA	FP-AR	2.13	17	11.543	101.31	0.53	79.82	13.53	80
SGA	FP-LN	1.5	6	4.151	105.65	0	140.48	14.33	65.71
SGA	FP-LN	1.67	5	3.470	105.41	0	258.01	11.2	65.71
SGA	FP-LN	2	6	4.151	122.6	0	159.5	14.17	65.71
SGA	FP-LN	3.33	10	6.855	111.68	0	235.41	10	57.14
SGA	CPC	1.4	7	4.829	58.03	6.5	306.4	8.71	68.57