THE DISTRIBUTION, ABUNDANCE, AND HABITAT USE OF THE BIG CYPRESS FOX SQUIRREL (*Sciurus niger avicennia*)

by

DANIELLE A. MUNIM
B.S. University of Central Florida, 2003

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Biology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

Summer Term
2008

ABSTRACT

Human population growth and development reduce the area and quality of natural communities and lead to a reduction of populations of the species associated with them. Certain species can be useful indicators or “focal species” for determining the quality of ecosystem remnants and the required management practices. Tree squirrels are good models for studies on the effects of fragmentation because they depend on mature forests. The Big Cypress fox squirrel, (*Sciurus niger avicennia*), a state-listed Threatened subspecies endemic to south Florida, appears sensitive to habitat fragmentation and fire regime. This research aims to assess the conservation status of the Big Cypress fox squirrel. I documented the current distribution of the fox squirrel by obtaining and mapping occurrence records and through interviews with biologists and other field personnel of public land-managing agencies, and private landowners including golf course managers. Transect sampling was used to survey and sample natural areas and private lands to evaluate the distribution, abundance, and habitat use of fox squirrels. Natural areas and suburban areas appear to support Big Cypress fox squirrels, but individuals are widely distributed and only found in low numbers throughout southwest Florida. The distribution of fox squirrel populations depends on land use and understory height, but not the size of trees. Fire suppression has resulted in a dense understory in large portions of parks and preserve lands, which is unsuitable for fox squirrels.

ACKNOWLEDGMENTS

I would like to thank my co-advisors Dr. Reed Noss and Dr. Jane Waterman for all their input and guidance throughout my research project. Thanks are also due to my committee members, Dr. Martin Main and Dr. John Weishampel for their contributions to the development of my project and for editorial advice.

I would also like to thank Dr. John Fauth and Dr. Pedro Quintana-Ascencio for their statistical expertise and all the graduate students who I have worked with since entering the program. Also, I should thank the various contacts I made including park personnel, biologists, and private land managers and land owners that provided vital information for this research.

My family has also been integral in my completion of this thesis. My mother, Ellen Munim and my husband, Adam Eisenberg are due special recognition. Without their support I would never have been able to achieve my goals. Someday I hope to be able to reciprocate for all that they have done for me through these years.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

BCFS	Big Cypress Fox Squirrel
DBH	Diameter at Breast Height
GPS	Global Positioning System
UTM	Universal Transverse Mercator

INTRODUCTION

Habitat fragmentation is one of the principal causes of endangerment because it creates a mosaic of isolated patches and reduced habitat area (Koprowski, 2005). Habitat patches vary in suitability for the reproduction and survival of individuals and these differences affect the population dynamics of a species. Dramatic losses in habitat create small, isolated populations which are more susceptible to extinction (Fahrig, 1997). The state of Florida supports a host of species that evolved in relative isolation for thousands of years (Kautz & Cox, 2001). As a peninsula, Florida is particularly subject to island biogeographic phenomena, where species face higher risk of extinction with decreasing habitat area and increasing isolation of habitat patches (Krebs, 2001). With a growing human population of 17 million and tourist population of 40 million per year, native habitats are disappearing due to demands for development (Kautz & Cox, 2001). Florida was ranked as the state with the greatest degree of risk for the loss of biodiversity as compared to the rest of the United States, with at least 179 rare, threatened, and imperiled native species (Kautz & Cox, 2001). Certain species can be useful indicators or "focal species" for determining the quality of ecosystem remnants and the management practices required to preserve biodiversity (Lambeck, 1997). Tree squirrels are good models for studies of the effects of fragmentation because they depend on mature forests (Koprowski, 2005) and thus may serve as an indicator of ecosystem functioning (Kautz & Cox, 2001).

The Big Cypress fox squirrel (*Sciurus niger avicennia*) is a subspecies endemic to south Florida that was state-listed as Threatened in 1979 (Humphrey & Jodice, 1992). Fox squirrels are sensitive to fragmentation, roads, fire regime, and other aspects of the structure and function of ecosystems (Koprowski, 2005). The decline of the Big Cypress fox squirrel (BCFS) mirrors the decline in mature pine and cypress forests as south Florida has been increasingly transformed by human activities. Slash pine, (*Pinus elliottii*) declined by 79% between 1936 and 1987 (Wooding, 1997), and remaining habitat has been degraded due to fire exclusion and suppression. Periodic fires are vital for maintaining habitat quality. Pine-oak forests thrive with frequent fires that release nutrients taken up by trees and their mycorrhizal fungi, and open stands produced by fire result in better pine cone and mast production (Weigl, Steele, Sherman, Ha, & Sharpe, 1989). Fire suppression has led to the increased cover of saw palmetto (*Serenoa repens*), and other shrubs, creating a dense understory unsuitable for fox squirrels which travel and forage extensively on the ground (Jodice & Humphrey, 1992; Ditgen, Shepherd, & Humphrey, 2007).

The Big Cypress fox squirrel is found in southwestern Florida south of the Caloosahatchee River and west of the Everglades (Ditgen et al., 2007). It formerly ranged south of Lake Okeechobee across southern Florida. The Big Cypress fox squirrel was present in Dade and Broward counties until the early 1900’s, and populations were reported as rare and highly scattered in Collier, Lee, Hendry, and Monroe counties (Jodice & Humphrey, 1992). Although Big Cypress fox squirrels are generally found in pine flatwoods, their specific habitat requirements are poorly understood (Humphrey & Jodice, 1992).

A study by WilsonMiller, Inc. (2002) estimated that 949,000 acres of potential fox squirrel habitat remained, and 551,855 (58%) of those acres are within conservation lands. Even though a large amount of potential fox squirrel habitat may remain, squirrels may avoid many areas because of dense understory growth or other variables. Golf courses and rural residential lands have little to no understory, may serve as habitat corridors, and may provide more suitable habitat for fox squirrels than many remaining natural areas. Big Cypress fox squirrel populations also exist in pasture and ranch lands that were historically pine flatwoods and upland prairie (Wooding, 1997). Previous research has found higher fox squirrel abundance in suburban areas than native habitats (e.g., Jodice & Humphrey, 1992; Ditgen, 1999).

This research seeks examines the distribution, abundance, and habitat use of the Big Cypress fox squirrel in urban greenspace, private lands, and conservation lands throughout southwest Florida. If fox squirrel occurrence depends on land use (H_1), I predict that fox squirrels occur more often in urban greenspace areas than natural areas. If fox squirrel occurrence depends on understory characteristics (H_2), I predict that understory height is lower in areas where fox squirrels are found than areas where they are absent. If fox squirrel occurrence depends on tree characteristics (H_3), I predict that fox squirrels are present in areas with large, mature trees and are absent in areas where trees are small or immature.

METHODS

Biology of the Study Animal

Four *Sciurus niger* subspecies occur in Florida. While true range limits for these subspecies are unclear, the generally accepted distributions are as follows. The Carolina fox squirrel (*Sciurus niger niger*) and Bachman's fox squirrel (*Sciurus niger bachmani*) are found in the Florida panhandle and adjacent southeastern states. The Sherman's fox squirrel, (*Sciurus niger shermani)* ranges throughout central and northern Florida. The Big Cypress fox squirrel (*Sciurus niger avicennia*), is found in south Florida (Wooding, 1997). The northern boundary of Big Cypress fox squirrel range is the Caloosahatchee River (Humphrey & Jodice, 1992), which may act as a barrier to gene flow between Sherman's and Big Cypress fox squirrels (Moncrief, 1993).

Across subspecies, fox squirrels are polymorphic in pelage color, range in length from 454 – 698 mm, and have an average life span of seven years (Koprowski, 1994). Fox squirrels are large with body mass ranging from 507 – 1,361 grams (Koprowski, 1994). Variability in pelage color, habitat selection, and size differences suggest long-term isolation of Western and Eastern populations (Moncrief, 1993). The most common pelage color for southeastern fox squirrels is a grizzled gray or agouti with a buff or orange venter with white marking on the nose, ears, and feet, and black crown of the head (Koprowski, 1994). A completely melanistic morph occurs among southeastern fox squirrels and may have evolved due to inbreeding or crypsis in burned landscapes

(Kiltie, 1989). Different proportions of color morphs found between separate habitat patches suggest the importance of dispersal, inbreeding, and genetic drift in influencing dominance or fixation of traits (Weigl et al., 1989). The geographic pattern of Big Cypress fox squirrel variation may be due to local adaptations to its habitat in southwestern Florida and genetic drift is expected in a peripheral population endemic to the tip of a peninsula (Krebs, 2001).

Fox squirrels are primarily asocial and non-territorial and have a diurnal activity pattern (Koprowski, 1994). Southeastern fox squirrels have large home ranges (10 – 40 hectares), a polygynous mating system, and produce a few, small (2 – 5 offspring) litters each year (Weigl et al., 1989; Koprowski, 1994). Dispersal from the natal site occurs following the attainment of sexual maturity at one year of age (Koprowski, 1994). Fox squirrels nest in cavities and leaf nests in oak, cabbage palm, pine, and cypress trees (Jodice & Humphrey, 1992). Leaf nests are constructed of Spanish moss (*Tillandsia usneoides*), twigs, grass, leaves, and pine needles (Weigl et al., 1989). Big Cypress fox squirrels may be present in a variety of habitat types including cypress forest, pine flatwoods, tropical hardwood forest, oak hammocks, and suburban areas (Williams & Humphrey, 1979).

Big Cypress fox squirrels may breed both in the winter and summer seasons, but the main breeding season occurs in the winter; December and January are the primary breeding months. These breeding seasons may be correlated with the time of abundant food supply (Koprowski, 1996). In Florida, November through January is the early dry season, and February through April is the late dry season. The early wet season extends from May through July and the late wet season occurs from August through October (Ditgen et al., 2007). From August until January, fox squirrels primarily rely on native species for food such as slash pine (*Pinus elliottii var. densa*) cones, cypress (*Taxodium distichum* and *Taxodium acsendens*) cones, and acorns from oak trees (*Quercus virginianum* and *Quercus laurifolia*). From February through July, fox squirrels rely on cabbage palm (*Sabal palmetto*) fruits and food produced by exotic species that are common in south Florida's landscape including queen palm (*Cocos plumosa*), ficus (*Ficus benjamina*), and bottlebrush (*Callistemon viminalis*) trees (Ditgen et al., 2007).

<u>Surveys</u>

The current distribution of the Big Cypress fox squirrel was assessed by obtaining occurrence records and through interviews with biologists, private land owners, and golf course managers. One thousand questionnaires were mailed out to persons qualified to provide information about the historic and current trends in fox squirrel distribution and abundance on the lands they own or manage. Participants were asked to indicate their personal sightings on a five-point scale: 0 – none (no sightings in last 10 years), 1 – very rare (no sightings in last year), 2 – rare (once or twice a year), 3 – regular (monthly sightings), 4 – common (daily sightings). These scores were later aggregated into three categories: 0 – none, 1 – rare (no sightings in last year and yearly sightings), 2 – common (monthly and daily sightings) for statistical analyses. Participants also estimated the number of squirrels believed to exist on the land they own or manage on the following scale: low (one to five squirrels), high (six or more squirrels). Participants were also asked to rank the trends of local fox squirrel population growth on the following scale: declining, stable (no change), increasing. These responses were analyzed with contingency analyses to examine relationships between land use and fox squirrel presence versus absence, sighting scores, estimated abundance, and trends in population growth. For analyses of fox squirrel presence versus absence and sighting scores, land use was divided into three categories: urban greenspace, farm/ranch/grove, and park/preserve. For analyses of abundance and trends in population growth, only urban greenspace and farm/ranch/grove lands were assessed due to the low number of fox squirrel observations in park and preserve lands and the inability of interview participants to estimate fox squirrel population size and trends in population growth in these areas.

Study Sites

Twenty transects, 1-km in length, (see Figure 1) were established to census fox squirrels and to measure habitat variables. Twelve transects were established in natural areas (parks and preserves), and eight transects were established in areas of urban greenspace including five golf courses and three private ranch lands. The area studied along each transect consisted of 0.2-km^2. Transect locations were selected in a stratified random manner where areas of potential habitat were identified through a combination of geographic location, land use, and accessibility. Subsets of 20 transect study areas were randomly selected from a pool of 40 potential study sites in natural areas, private ranch lands, and urban greenspace. Orientation (N – S, E – W) was randomly assigned to each transect by the flip of a coin. Universal Transverse Mercator (UTM) coordinate locations for each transect were recorded using a Garmin 12 Global Positioning System (GPS).

Habitat characteristics were measured within 20-m diameter plots at 100-m intervals (see Figure 2) along 1-km transects (Avery & Burkhart, 1994). Habitat variables measured within these plots included: tree species, diameter at breast height (DBH), and understory height. A two meter pole was used to estimate understory height in nested one square meter subplots five meters from the center of each plot in all four cardinal directions (Griffith & Youtie, 1988) with a total of 40 measurements collected from each transect. These 40 measurements were averaged to obtain a mean understory height value for each study site. Fox squirrel counts were conducted a total of three times during a two-hour walk along each transect, and counts were averaged to estimate fox squirrel abundance at each site. Counts were conducted in both the dry and wet seasons and because of the diurnal nature of the study animal, observations could be conducted in the morning (600 – 1200) or the afternoon (1200 – 1800).

Observations were conducted at 20 golf course study sites (see Figure 3) to estimate Big Cypress fox squirrel abundance in these urban greenspace habitats. These sites were identified through interview questionnaires as places where fox squirrels are observed. Two-hour duration fox squirrel counts were conducted a total of three times between 2005 and 2007 at twenty 18-hole golf courses while riding on a golf cart throughout the entire course along cart paths which served as transects. Counts were averaged at each site to estimate fox squirrel abundance.

Statistical Analyses

Contingency analyses, G-tests of independence, were used to test the hypothesis that land use has no effect on the response variables (presence versus absence, sighting score, abundance, trends in population growth). The log-likelihood ratio, G, approximates chi-square distribution and evaluates how well the categorical model fits the data. Chi-square statistics and G often yield the same conclusions when sample sizes are large, but G is a more powerful test when sample sizes are not large (Zar, 1998).

Logistic regression was used to predict a qualitative dependent variable, presence versus absence of squirrels, from two independent variables: mean understory height and mean tree diameter at breast height (DBH). The logistic regression equation relates the proportions of a dependent variable to one or more independent variables (Sokal & Rohlff, 1995).

I analyzed data in terms of presence-absence because the Big Cypress fox squirrel was observed at very few sites. Presence-absence methods are useful when the species of interest exists in low numbers or is difficult to detect (Joseph, Field, Wilcox, & Possingham, 2006). JMP statistical software was used to perform contingency and logistic regression analyses. Alpha, α, was set at .05 for significance.

RESULTS

Of the 1,000 questionnaires I distributed to document recent and historic sightings of fox squirrels, 145 (15%) were returned. Survey responses from interview questionnaires and occurrence records were mapped (see Figure 4) to provide a visual representation of the current known distribution of the Big Cypress fox squirrel.

Contingency analyses yielded a significant interaction, $G = 10.24$, $df = 2$, $^{*}p < .01$, $N = 145$, between fox squirrel presence versus absence and land use. The presence versus absence of the Big Cypress fox squirrel in a site is not independent of land use. Fox squirrels were reported as present in 78% of sites in urban greenspace, but were only reported as present in 51% of farm/ranch/grove sites and 62.5% of park/preserve lands (see Figure 5). A significant interaction, $G = 30.89$, $df = 4$, $^{*}p < .0001$, $N = 145$, was found between fox squirrel sighting scores and land use. Big Cypress fox squirrel sighting scores were not independent of land use. Big Cypress fox squirrel sightings were reported as common in 50% of urban greenspace sites, but common sightings were only reported in 18% of farm/ranch/grove sites (see Figure 6). No (0%) fox squirrel sightings in park/preserve lands were reported as common. The G-test did not reveal a significant interaction, $G = .16$, $df = 1$, $p > .05$, $N = 59$, between Big Cypress fox squirrel abundance and land use. Fox squirrel abundance is independent of land use. Fox squirrel abundance was reported as low in 70% of urban greenspace sites and 75% of farm/ranch/grove sites (see Figure 7). A significant interaction, $G =$

7.79, df = 2, *$p < .05$, $N = 57$, was found between trends in Big Cypress fox squirrel population growth and land use. Trends in fox squirrel population growth are not independent of land use. Fox squirrel populations in urban greenspace were reported as stable (no change) in 66% of the sites surveyed, but were reported as declining in 50% of farm/ranch/grove sites (see Figure 8).

Big Cypress fox squirrel sightings were low (see Table 1) along 1-km transects in urban greenspace areas and natural areas. Fox squirrels were only observed in seven of the twenty sites, and five of those sites were urban greenspace lands. Zero fox squirrels were observed along transects in ten of the twelve sites located in natural areas. The largest average number of fox squirrels observed along the 1-km transects was 3.7 individuals.

Observations revealed Big Cypress fox squirrels occurring at most golf courses (see Table 2). Fox squirrels were observed in eighteen of the twenty golf course study sites. The largest average number of fox squirrels observed was 8.3 individuals. At four golf course sites, fox squirrel abundance was high with an average of six or more squirrels observed, but in thirteen sites fox squirrel abundance was low with an average of one to five individuals observed.

Logistic regression revealed a significant relationship, $R^2 = .30$, df = 1, *$p < .01$, $N = 20$ between mean understory height and the presence versus absence of fox squirrels (see Figure 9). An analysis of the relationship between mean understory height and fox squirrel presence versus absence across sites indicates a 30 cm mean understory height threshold for fox squirrel occupancy of a site (see Figure 10).

Six tree species were measured along each transect: south Florida slash pine, bald cypress, pond cypress, live oak, laurel oak, and cabbage palm. A total of 665 individual trees were measured across all transects. Logistic regression did not reveal a significant relationship, $R^2 = .01$, $df = 1$, $p > .05$, $N = 20$, between tree size (mean DBH) and the presence versus absence of fox squirrels at each of the twenty study sites (see Figure 11). The distribution of the means for each tree species across sites and the presence versus absence of Big Cypress fox squirrels is displayed in Figure 12.

DISCUSSION

Natural areas, private farm and ranch lands, and urban greenspace were all found to support Big Cypress fox squirrels, but individuals are widely distributed and only found in low numbers throughout southwestern Florida. In this study, Big Cypress fox squirrels were most commonly found in urban greenspace areas such as golf courses and residential properties, but were rarely observed in parks, preserves, and other natural areas. These results are in accordance with findings from previous studies (e.g., Jodice, 1990; Ditgen, 1999) where despite intensive searches for fox squirrels in the Big Cypress National Preserve and other natural areas very few animals were found. I accept the hypothesis (H_1) that land use influences the occurrence of fox squirrels, albeit no relationship exists between land use and abundance of fox squirrels, presumably because fox squirrels exist in low numbers throughout the region. I accept the hypothesis (H_2) that fox squirrel occurrence depends on low understory height. I reject the hypothesis (H_3) that fox squirrel occurrence depends on tree size because no significant relationship was found between fox squirrel occupancy of a site and the mean DBH (diameter at breast height) of trees. It may be that the tree composition across the study sites is relatively homogenous and that is why no clear pattern was found between fox squirrel occupancy and the size of trees. These results provide evidence to support land use and understory height as important predictors of fox squirrel presence.

Due to fire suppression efforts, understory growth has resulted in less suitable habitat for fox squirrels which require an open, mature, pine forest with minimal understory growth (Jodice & Humphrey, 1992). Loeb (1999) found that gray squirrels (*Sciurus carolinensis*) may outcompete fox squirrels in areas with dense understory growth. Fox squirrels may occur more often in urban greenspace areas than natural areas because understory vegetation in suburban areas is typically intensively managed. Fox squirrels historically existed in a landscape where natural burns maintained a clear, open forest floor. However, fire suppression policies have altered the natural fire regime and many areas in parks and preserve lands are characterized by dense understory. Although prescribed burns do occur, budgetary restrictions may reduce the ability of land managers to burn as often or extensively as needed.

The Big Cypress fox squirrel was recently denied federal listing partly due to their opportunistic use of golf courses and other suburban lands (Ditgen et al., 2007). Suburban areas may have attractive habitat cues for fox squirrels such as a minimal understory and a variety of native and exotic mast-producing trees. However, while the habitat itself in these urban greenspace areas may be suitable for fox squirrel populations, they may be ecological traps or attractive “sinks”. A species has “source-sink” dynamics if births exceed deaths in “source” habitats while in “sink” habitats deaths exceed births. Source-sink dynamics are directly related to habitat fragmentation (Krebs, 2001). While fox squirrels may be attracted to suburban areas because of an open understory and year-round food supply (Ditgen et al., 2007) populations may not be prospering at such locations. Traffic is heavy on the roads surrounding these pockets of urban greenspace, and fox squirrels are sometimes hit and killed (see Table 3). Ditgen (1999) documented Big Cypress fox squirrel population levels in a variety of golf courses, and developed a landscape evaluation index that ranked golf courses in terms of habitat suitability for fox squirrels and concluded that fewer than 5 of 48 clubs were capable of maintaining populations through the intensive development expected through 2020. Suburban areas and urban greenspace may serve as valuable wildlife corridors, but should not be considered an adequate substitute for the large tracts of natural habitat that historically existed.

Limitations to the scope of this research include the fact that very little data exist documenting current and historic fox squirrel occurrence. Big Cypress fox squirrels are observed in natural areas by park visitors and park personnel, but in many cases, the sightings are not documented. Most park personnel and biologists were unable to provide a reliable estimate of Big Cypress fox squirrel population size and trends in population growth on the lands they manage. Also, many private land owners were unwilling to report the incidence of fox squirrels on their property and refused participation in this study. Although sighting data are a valuable source of information for rare and endangered species, these data may not always be reliable because there is a tendency for observations of rare species to be located in places most accessible to observers. When large areas are involved, such as the entire range of a species, ground surveys cannot be conducted over the complete area of interest and a sample of locations needs to be randomly selected in order to make inferences about the entire area of interest, but survey methods rarely detect all animals present in any sample unit (Royle & Nichols, 2003). Also, there is the confounding variable and potential bias related to differences in detectability of fox squirrels in natural areas versus fox squirrels in suburban areas. In suburban areas, fox squirrels are much easier to observe due to the clear open landscape. In addition, these squirrels are habituated to people and do not immediately take cover in the crown of the nearest tree like non-habituated squirrels might. Thus, the appearance of higher numbers of fox squirrels in suburban areas rather than natural areas could partially be an artifact of differences in ease of observation. Consequently, these anthropogenic habitats are not necessarily preferred over natural habitats.

Habitat protection strategies should be implemented to identify critical habitats that support rare species before they are lost to development or further environmental degradation (Kautz & Cox, 2001). Exhaustive region-wide fox squirrel surveys are needed for all public lands. Annual counts in parks and preserves and other natural areas may serve as a valuable tool for identifying and monitoring fox squirrel populations. Prescribed burn experiments in parks and preserve lands should be conducted and evaluated in regard to their effects on fox squirrel demographics (survival, reproduction) and movements (dispersal). More frequent and extensive prescribed burns may be necessary to minimize understory density and thus maintain the quality of remaining fox squirrel habitat.

Recent land acquisitions and conservation easements through Florida Forever have great potential for providing habitat and corridors for the Big Cypress fox squirrel. The large tracts of ranch and pastureland that exist in Hendry and eastern Lee and Collier counties may provide valuable habitat for a variety of species (i.e. Florida panther, *Puma concolor coryi*, and red-cockaded woodpecker, *Picoides borealis*) and should be consistently monitored for fox squirrel populations. As long as enough pines, oaks, palms, or cypress trees remain, management of private lands as pasture may enhance potential fox squirrel habitat because grazing keeps the understory to a minimum (Williams & Humphrey, 1979). These large tracts of private ranch and farm lands could also serve as potential sites for fox squirrel reintroductions and translocations. A useful conservation strategy may be to provide incentives to private land owners who exercise land management practices that provide habitat favorable for fox squirrels.

Studies should be conducted to determine whether fox squirrel recruitment on golf courses is local or from dispersal to appropriately assess source-sink dynamics of these habitats. There is also a need to examine the effects of chemical applications (pesticides and herbicides) on fox squirrel populations occurring on urban and suburban lands; bioaccumulation of chemicals may have detrimental effects on long-term survival and reproduction (Grue, Gilbert, & Seeley, 1997). In the short term, fox squirrel populations occurring on golf courses should be managed appropriately to maintain the high numbers of squirrels observed on some courses. Lowering speed limits on golf course access roads and roads surrounding parks and preserve lands may decrease fox squirrel road mortalities. Golfers, visitors, and local residents should also be educated to avoid directly feeding the squirrels and thus limit habituation. In these managed landscapes, it is recommended that the trimming of cabbage palm trees should only be conducted in the non-breeding seasons of fall and spring to avoid the potential destruction of active fox squirrel nests. Although these suburban areas may be population “sinks”, they are valuable habitat reservoirs and once the genetic composition of populations is known translocations of individuals from suburban habitats to managed native habitats as conducted by Jodice (1990) may be a useful conservation strategy.

While I have attempted to assess the distribution and abundance of the Big Cypress fox squirrel, a status survey is incomplete without an assessment of species demographic performance and genetic condition within and among local populations. Future studies should attempt to collect demographic data such as reproduction, mortality, and movements of fox squirrel populations through radio-telemetry analyses to determine the extent to which fragmentation may have hindered dispersal abilities, and to provide the wealth of data needed to construct a spatially-explicit population model. Spatially-explicit models incorporate landscape structure and habitat use to predict population responses to anthropogenic alterations of ecosystems (Dunning et al., 1995; Fahrig, 1997). A spatially-explicit population model may be the most reliable means of assessing population and metapopulation viability.

CONCLUSION

The primary benefit of this study is an improved understanding of the distribution and habitat use of the Big Cypress fox squirrel. Fox squirrels are common in urban greenspace areas, but are rarely observed in natural areas. Although sightings on golf courses are common, fox squirrel population density is presumably low because observations are typically of a few resident individuals. Habitat in suburban areas may not be adequate for long-term survival because further habitat fragmentation is expected due to increasing demands for development in south Florida, thereby increasing susceptibility to extinction of populations. Understory height, rather than tree size, may be the key determinant in fox squirrel avoidance versus preference of habitats. Therefore, habitat management practices such as more extensive and frequent prescribed burning in parks, preserves, and other conservation lands may be a critical tool to enhance habitat quality in natural areas for fox squirrels.

Population viability analyses would aid future decision-making and the development of policies to best conserve habitat for the Big Cypress fox squirrel. This research helps build the empirical basis for a comprehensive assessment of the status and viability of the Big Cypress fox squirrel. Although I do not claim that these results will unequivocally answer the question of whether the subspecies requires listing under the U.S. Endangered Species Act, I hope that listing decisions and recovery planning will be aided by these findings.

APPENDIX: FIGURES AND TABLES

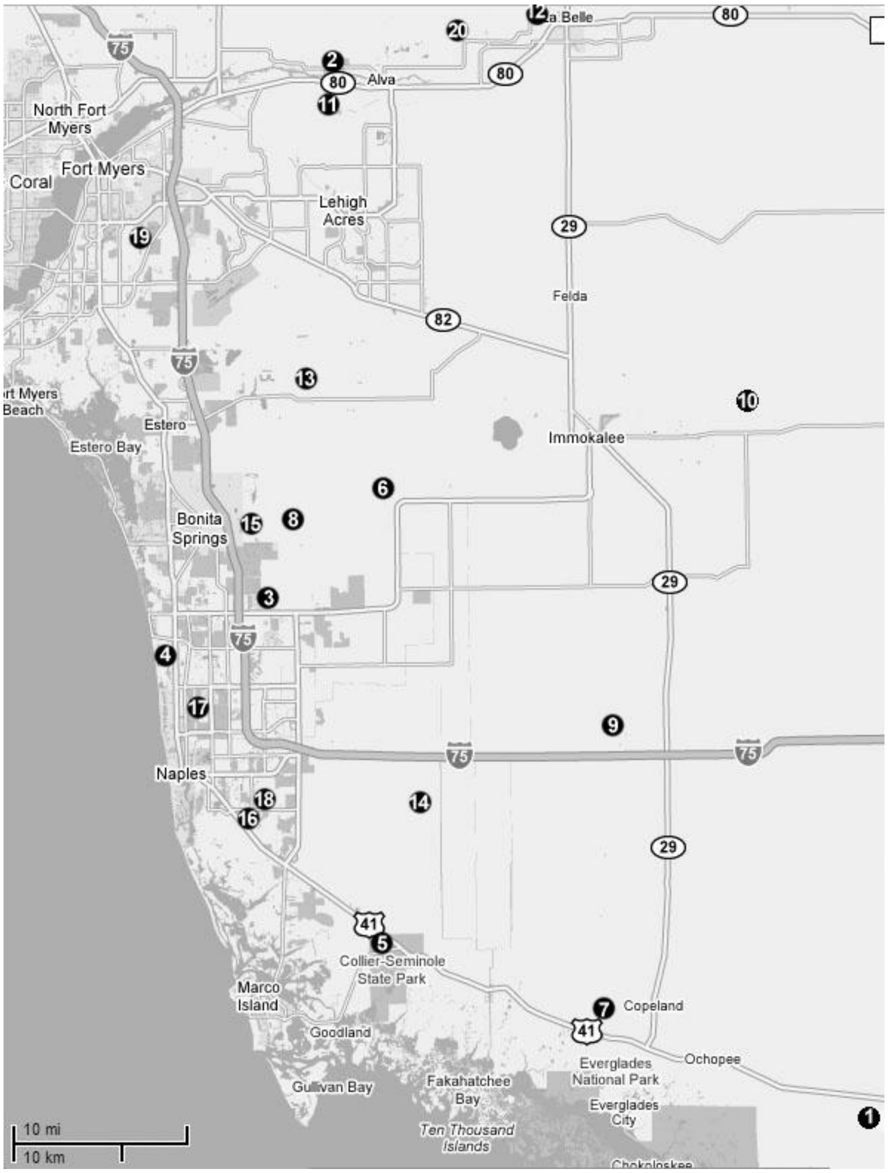

Figure 1: Locations of 1-km transect study sites.

Map Legend: **1** Big Cypress National Preserve, **2** Caloosahatchee Regional Park, **3** Club at Olde Cypress, **4** Club at Pelican Bay, **5** Collier-Seminole State Park, **6** Corkscrew Swamp Sanctuary, **7** Fakahatchee Strand State Park, **8** Flint Pen Strand, **9** Florida Panther National Wildlife Refuge,**10** Half Circle L Ranch, **11** Hickey's Creek Mitigation Park, **12** Hunters Ranch, **13** Imperial Marsh Preserve, **14** Picayune Strand State Forest, **15** Pine Lake Preserve, **16** Royal Palm Golf Club, **17** Royal Poinciana Golf Club, **18** Royal Wood Golf Club, **19** Six Mile Cypress Slough, **20** Sweet Cypress Ranch

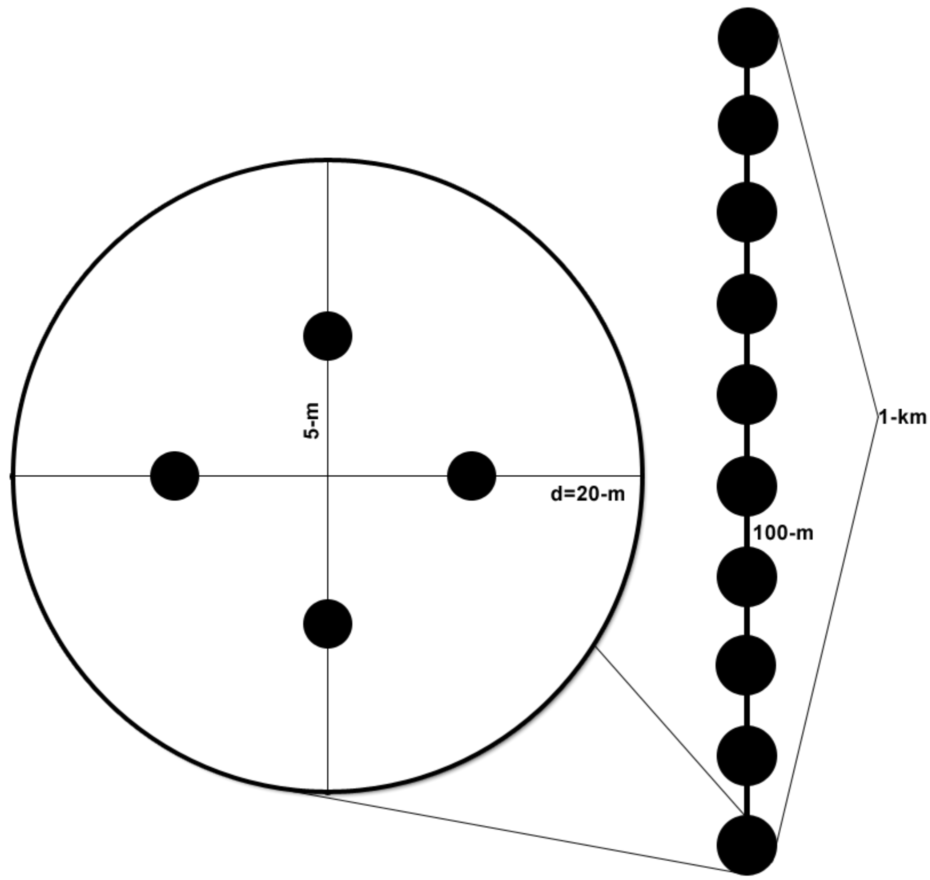

Figure 2: Diagram of one kilometer transect and habitat sampling matrix.

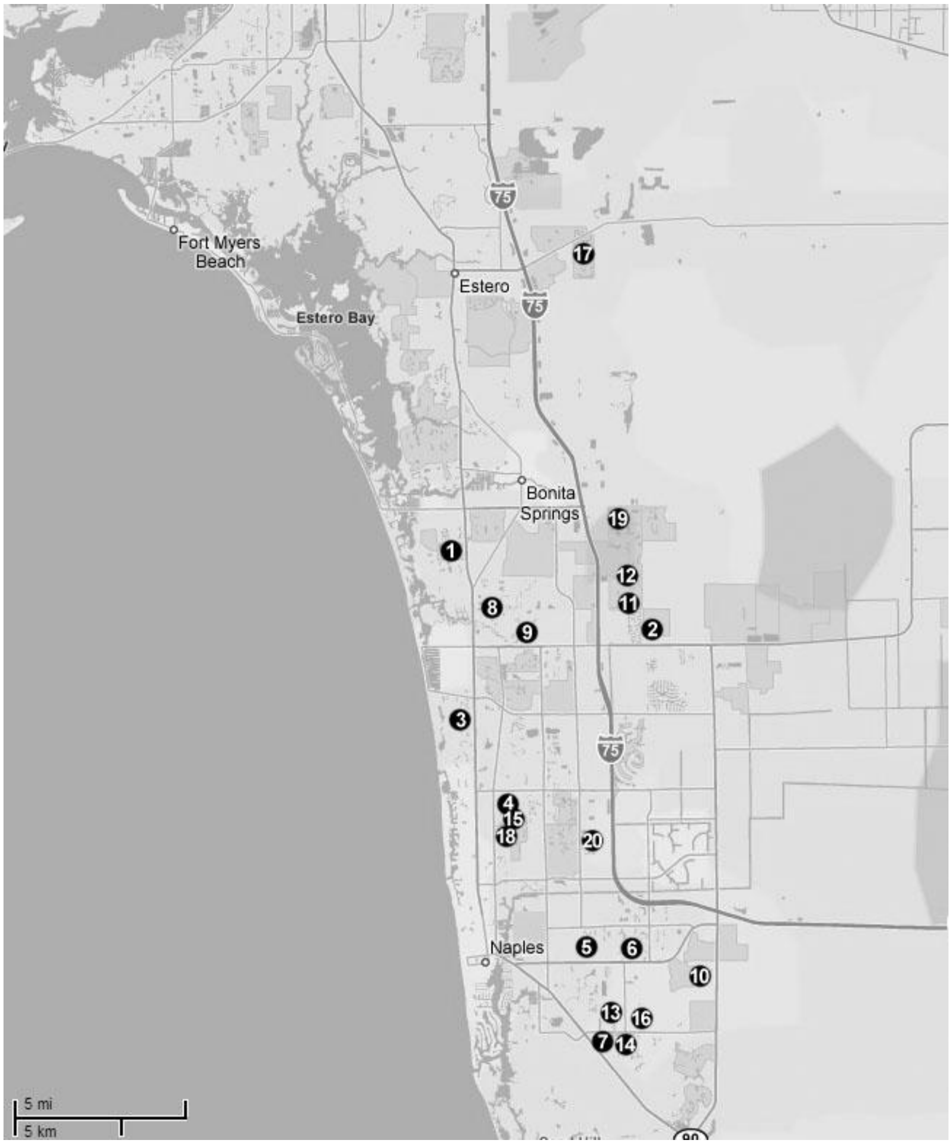

Figure 3: Locations of golf course observation study sites.

Map Legend: **1** Audubon Golf Club, **2** Club at Olde Cypress, **3** Club at Pelican Bay, **4** Country Club of Naples, **5** Foxfire Golf Club, **6** Glen Eagle Golf Club, **7** Hibiscus Golf Club, **8** Imperial Golf Club, **9** LaPlaya Golf Club,**10** Naples National Golf Club, **11** Quail Creek Golf Club, **12** Quail West Golf Club, **13** Riviera Golf Club, **14** Royal Palm Golf Club, **15** Royal Poinciana Golf Club, **16** Royal Wood Golf Club, **17** Wildcat Run Golf Club, **18** Wilderness Country Club, **19** Worthington Golf Club, **20** Wyndemere Golf Club

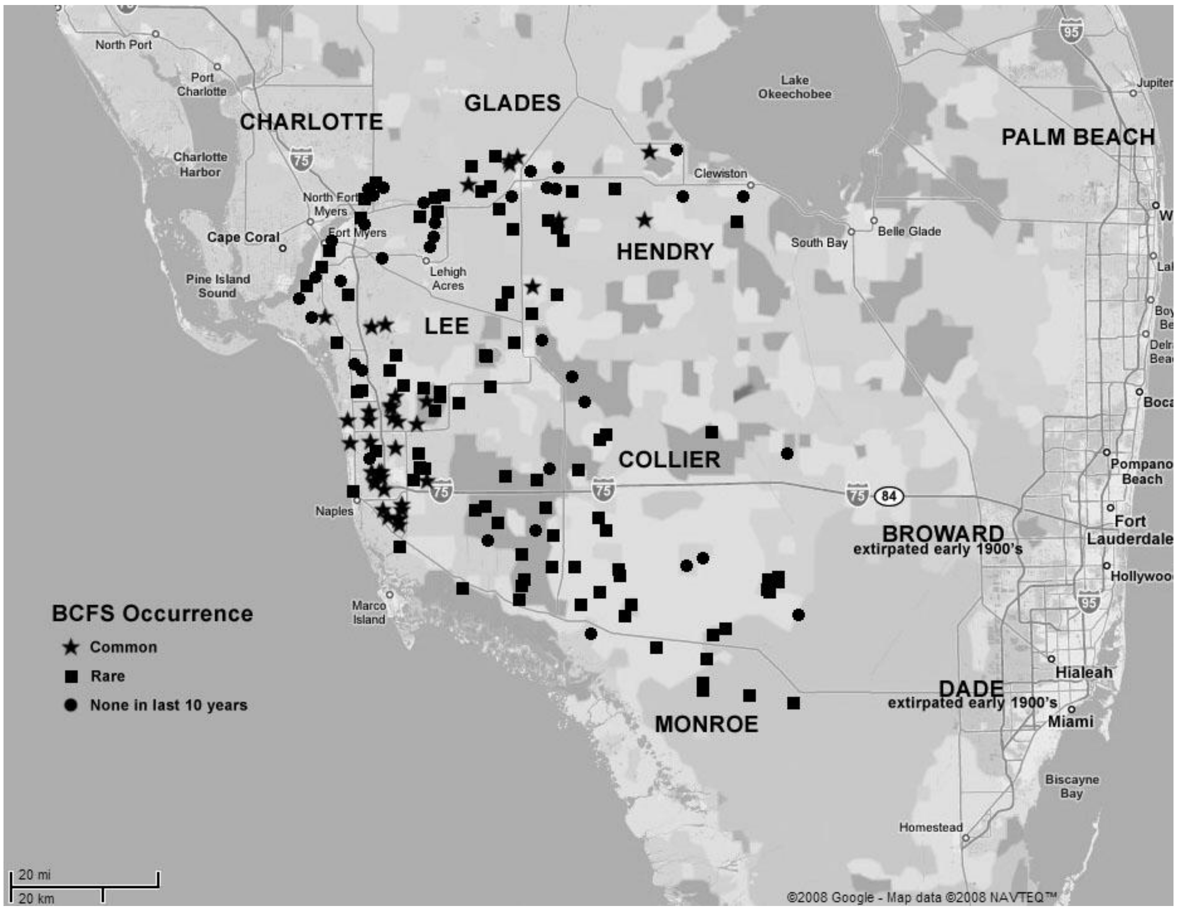

Figure 4: The current known distribution of the Big Cypress fox squirrel.

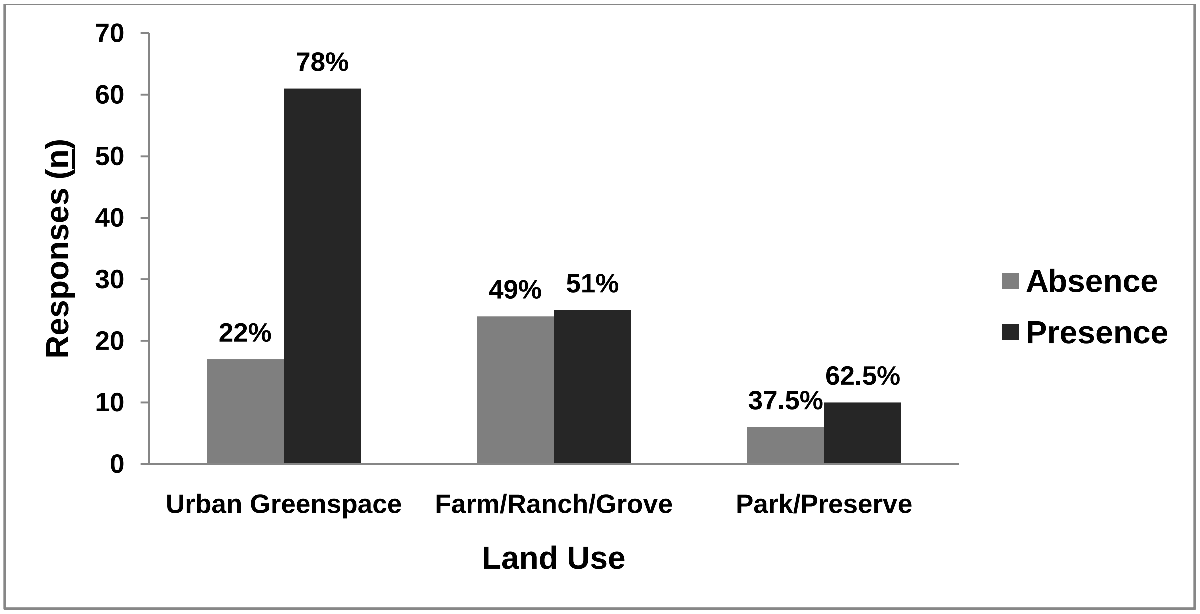

Figure 5: Percentages of responses for land use types characterized by the absence and presence of Big Cypress fox squirrels (N = 145).

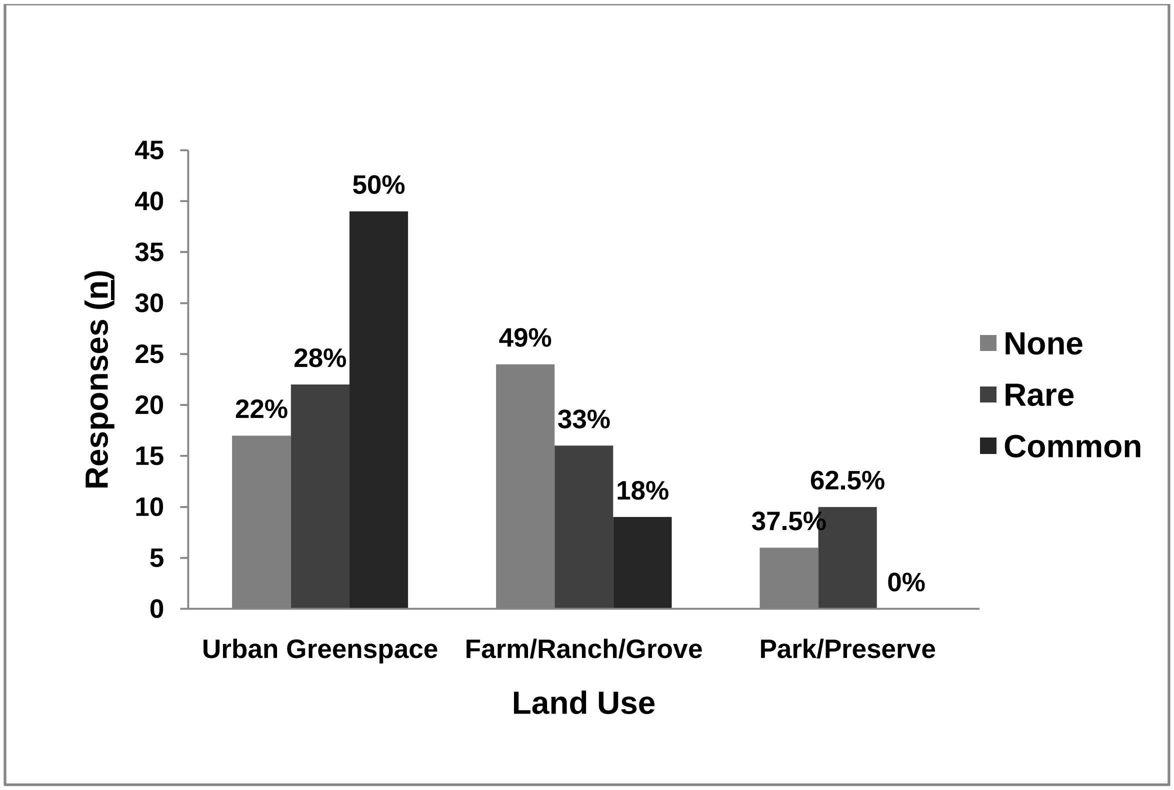

Figure 6: Percentages of responses for land use types characterized by Big Cypress fox squirrel sighting scores of none, rare, and common (N = 145).

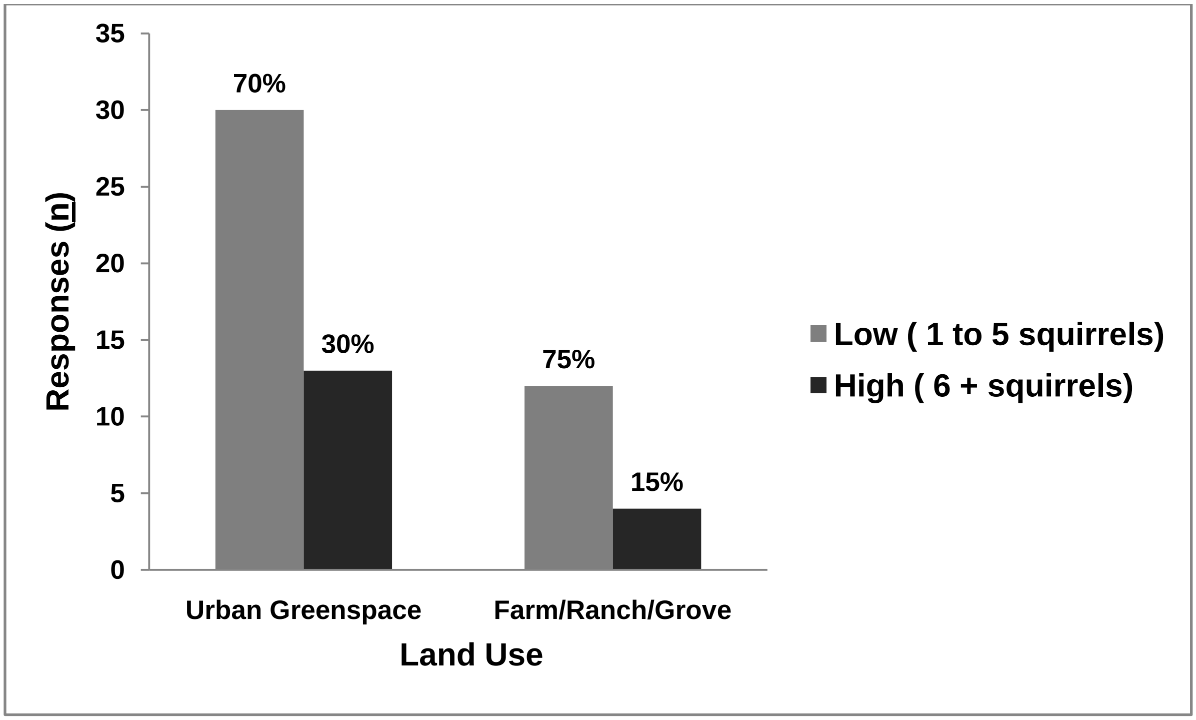

Figure 7: Percentages of responses for land use types characterized by low and high abundance of Big Cypress fox squirrels (N = 59).

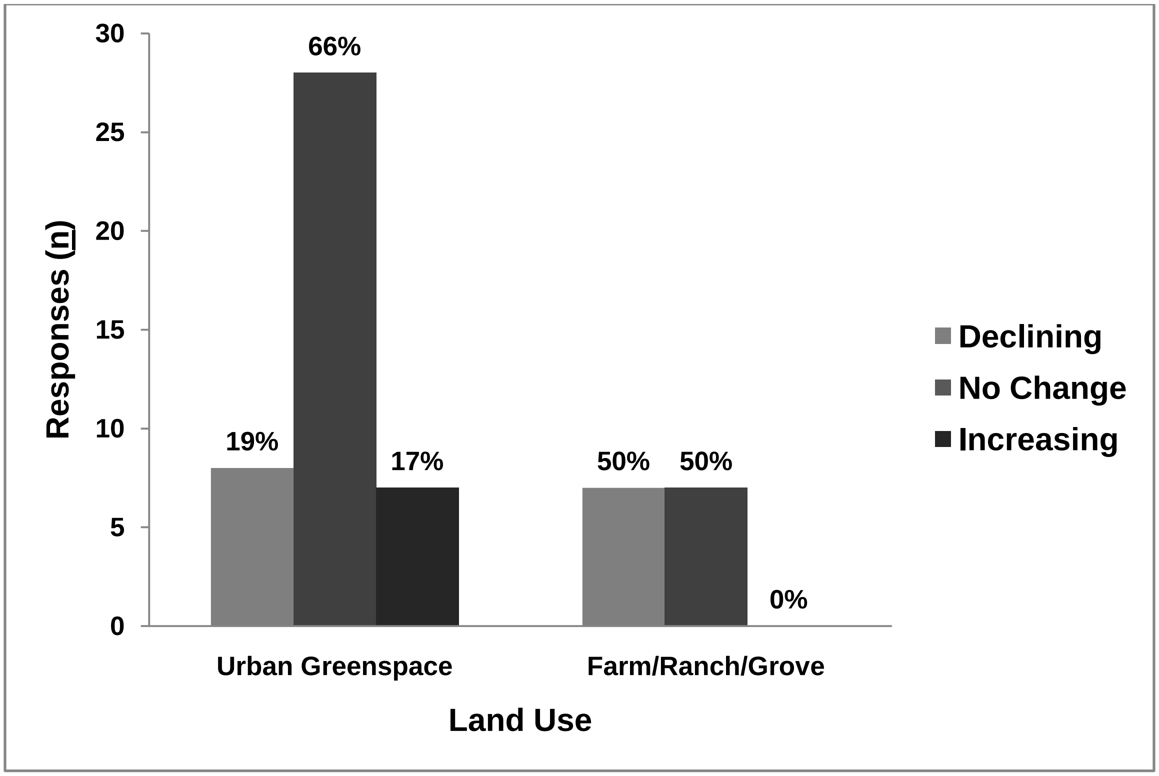

Figure 8: Percentages of responses for land use types characterized by declining, no change, and increasing trends in Big Cypress fox squirrel population growth (N = 57).

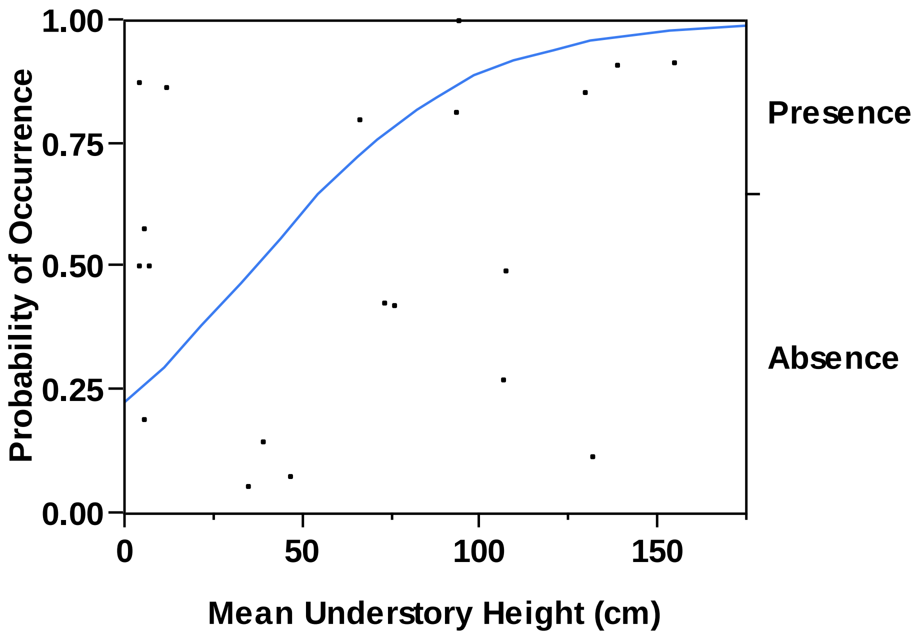

Figure 9: Logistic plot for probability of occurrence of Big Cypress fox squirrels and mean understory height (N = 20).

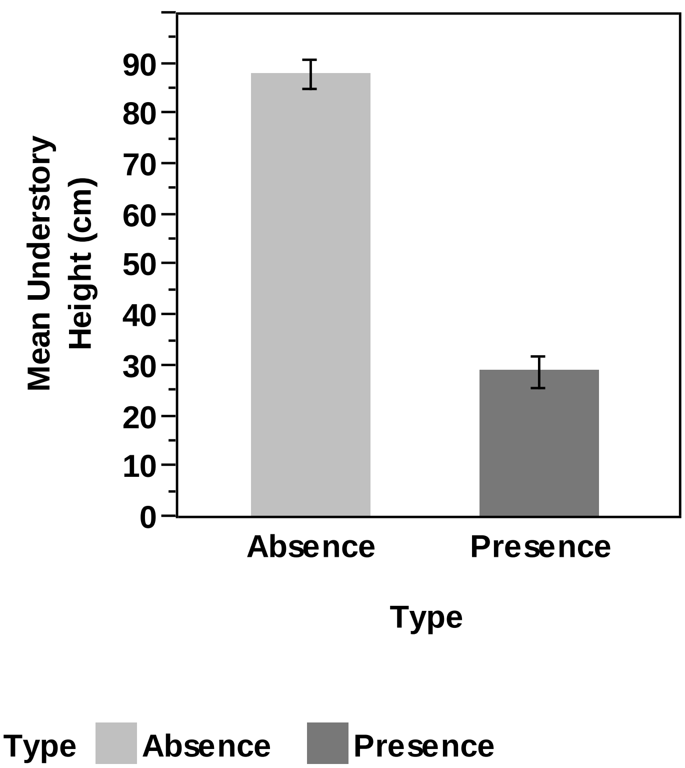

Figure 10: Mean understory height (+SE) across all sites characterized by the absence and presence of Big Cypress fox squirrels (N = 20).

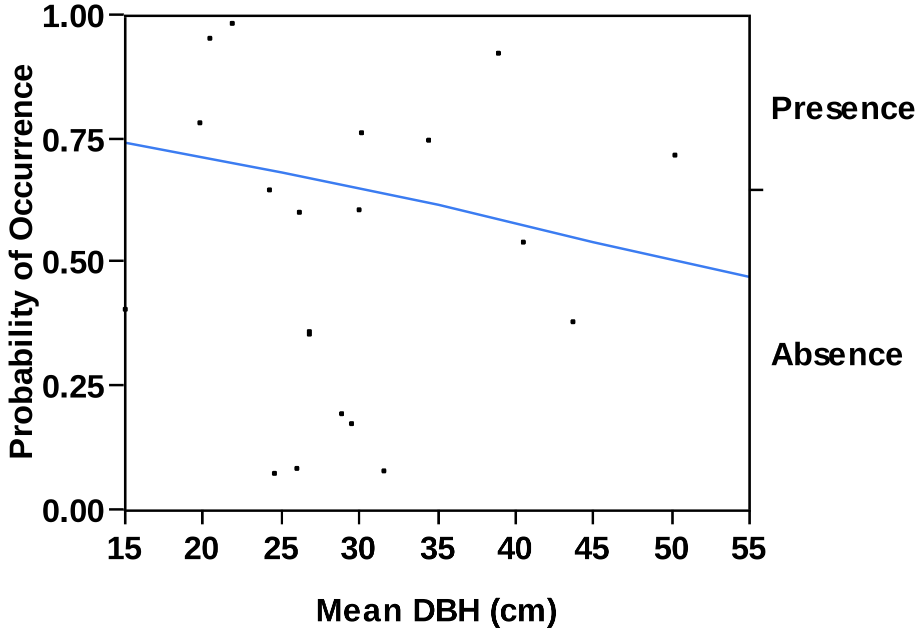

Figure 11: Logistic plot for the probability of occurrence of Big Cypress fox squirrels and mean diameter at breast height (DBH) of trees (N = 20).

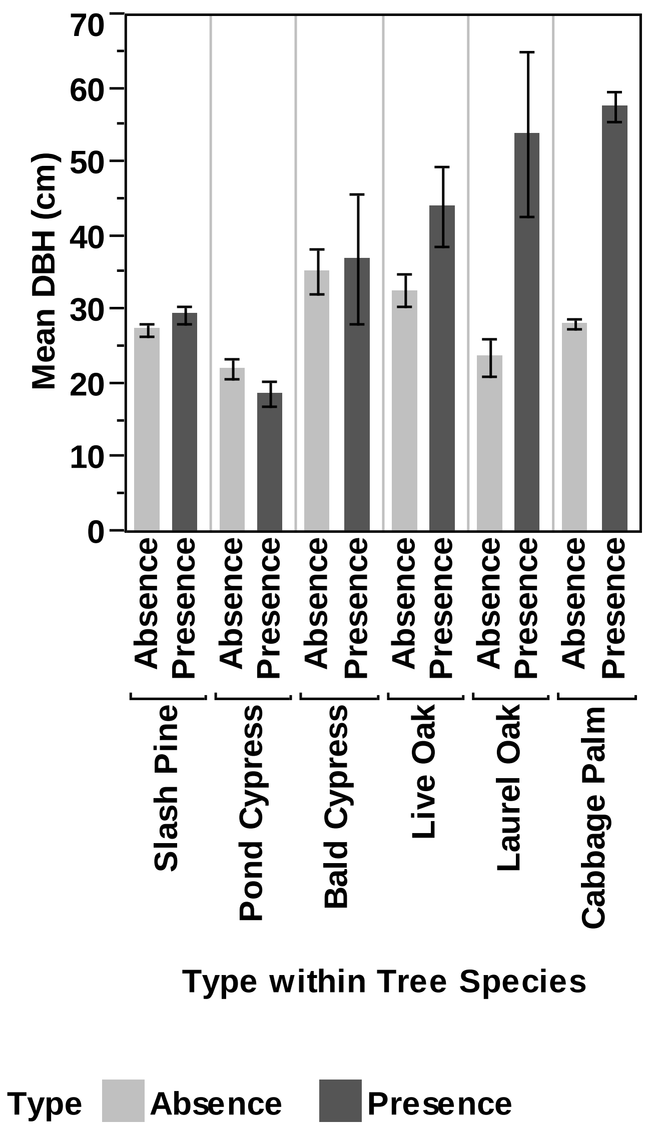

Figure 12: Mean diameter at breast height (DBH) (+SE) for six tree species in sites characterized by the absence and presence of Big Cypress fox squirrels (N = 665).

Table 1: Means (M) and standard deviations (SD) for Big Cypress fox squirrel counts at main transect study sites.

Land Use	**Transect Site**	**M**	**SD**
Park/Preserve	Big Cypress National Preserve	0.3	0.6
Park/Preserve	Caloosahatchee Regional Park	0	0
Park/Preserve	Collier Seminole State Park	0	0
Park/Preserve	Corkscrew Swamp Sanctuary	0	0
Park/Preserve	Fakahatchee Strand State Park	0	0
Park/Preserve	Flint Pen Strand	0	0
Park/Preserve	Florida Panther National Wildlife Refuge	0	0
Park/Preserve	Hickey's Creek Mitigation	0	0
Park/Preserve	Imperial Marsh Preserve	0	0
Park/Preserve	Picayune Strand State Forest	0	0
Park/Preserve	Pine Lake Preserve	0.3	0.6
Park/Preserve	Six Mile Cypress Slough	0	0
Ranch	Half Circle L Ranch	0	0
Ranch	Hunters Ranch	3.7	1.5
Ranch	Sweet Cypress Ranch	0	0
Golf Course	Club at Olde Cypress	1.7	1.2
Golf Course	Club at Pelican Bay	0.3	1.2
Golf Course	Royal Palm Golf Club	3.7	1.5
Golf Course	Royal Poinciana Golf Club	3.3	0.6
Golf Course	Royal Wood Golf Club	0	0

Table 2: Means (M) and standard deviations (SD) for Big Cypress fox squirrel counts at golf course study sites.

Golf Course Site	**M**	**SD**
Audubon Golf Club	0.7	0.6
Club at Olde Cypress	2.3	0.6
Club at Pelican Bay	0.7	1.2
Country Club of Naples	2.3	2.1
Foxfire Golf Club	4	1
Glen Eagle Golf Club	0	0
Hibiscus Golf Club	6.3	0.6
Imperial Golf Club	3.3	2.1
LaPlaya Golf Club	0.3	0.6
Naples National Golf Club	1.3	0.6
Quail Creek Golf Club	7.3	2.1
Quail West Golf Club	2.7	1.2
Riviera Golf Club	1.7	1.2
Royal Palm Golf Club	7	1.7
Royal Poinciana Golf Club	8.3	2.5
Royal Wood Golf Club	0	0
Wildcat Run Golf Club	1	1
Wilderness Country Club	5.3	1.5
Worthington Golf Club	5.3	0.6
Wyndemere Golf Club	3.3	0.6

Table 3: Big Cypress fox squirrel road-kill dates and locations in suburban areas.

Site	Total (N)	Date Collected	Site UTM
Royal Poinciana Golf Club	3	August 15, 2006	17R 0422088 / 2897259
		December 10, 2006	17R 0421899 / 2896289
		April 2, 2007	17R 0421353 / 2897673
Imperial Golf Club	3	June 18, 2007	17R0 422361 / 2908397
		October 26, 2007	17R 0421366 / 2908066
		December 13, 2007	17R 0422132 / 2908523
Club at Olde Cypress	4	October 3, 2007	17R 0428034 / 2906379
		November 6, 2007	17R 0428114 / 2906537
		November 7, 2007	17R 0427401 / 2906068
		November 14, 2007	17R 0427004 / 2906248

REFERENCES

Avery, T. E., & Burkhart, H. E. (1994). Forest Measurements, (4th ed.). New York: McGraw-Hill.

Ditgen, R. S. (1999). Population estimates, habitat requirements, and landscape design and management for urban populations of the endemic Big Cypress fox squirrel (*Sciurus niger avicennia*). Unpublished doctoral dissertation, University of Florida, Gainesville.

Ditgen, R. S., Shepherd, J. D., & Humphrey, S. R. (2007). Big Cypress fox squirrel (*Sciurus niger avicennia*) diet, activity and habitat use on a golf course in southwest Florida. American Midland Naturalist, 158 (8), 403-414.

Dunning, J. B., Jr., Stewart, D. J., Danielson, B. J., Noon, B. R., Root, T. L., Lamberson, R., & Stevens, E. E. (1995). Spatially explicit population models: current forms and future uses. Ecological Applications, 5, 3-11.

Fahrig, L. (1997). Relative effects of habitat loss and fragmentation on population extinction. Journal of Wildlife Management, 61 (3), 603-610.

Griffith, B. & Youtie, B. A. (1988). Two devices for estimating foliage density and deer hiding cover. Wildlife Society Bulletin, 16 (2), 206-210.

Grue, C. E., Gilbert, P. L., & Seeley, M. E. (1997). Neurophysiological and behavioral changes in non-target wildlife exposed to organophosphate and carbamate pesticides: thermoregulation, food consumption, and reproduction. American Zoologist, 37 (4), 369-388.

Humphrey, S. R. & Jodice, P. G. R. (1992). Big Cypress fox squirrel. In S. R. Humphrey (Vol. Ed.), Rare and Endangered Biota of Florida: Vol. 1: Mammals. (pp. 224-233). Gainesville: University Press of Florida.

Jodice, P. G. (1990). Ecology and translocation of an urban population of Big Cypress fox squirrels (*Sciurus niger avicennia*). Unpublished master's thesis, University of Florida, Gainesville.

Jodice, P. G., & Humphrey, S. R. (1992). Activity and diet of an urban population of Big Cypress fox squirrels. Journal of Wildlife Management, 56 (4), 685-692.

Joseph, L. M., Field, S. A., Wilcox, C., & Possingham, H. (2006). Presence-absence vs. abundance data for monitoring threatened species. Conservation Biology, 20 (6), 1679-1687.

Kautz, R. S. and Cox, J. A. (2001). Strategic habitats for biodiversity conservation in Florida. Conservation Biology, 15 (1), 55-77.

Kiltie, R. A. (1989). Wildfire and the evolution of dorsal melanism in fox squirrels, *Sciurus niger*. Journal of Mammalogy, 70 (4), 726-739.

Koprowski, J. L. (1994). *Sciurus niger*. Mammalian Species, (No. 479). New York: American Society of Mammalogists.

Koprowski, J. L. (1996). Natal philopatry, communal nesting, and kinship in fox squirrels and gray squirrels. Journal of Mammalogy, 77 (4), 1006-1016.

Koprowski, J. L. (2005). The response of tree squirrels to fragmentation: a review and synthesis. Animal Conservation, 8, 369-376.

Krebs, C. J. (2001). Ecology. (5th ed.). San Francisco: Benjamin-Cummings.

Lambeck, R. J. (1997). Focal species: a multi-species umbrella for nature conservation. Conservation Biology, 11, 849-856.

Loeb, S. C. (1999). Responses of small mammals to coarse woody debris in a southeastern pine forest. Journal of Mammalogy, 80 (2), 460-471.

Moncrief, N. D. (1993). Geographic variation in fox squirrels (*Sciurus niger*) and gray squirrels (*S. carolinensis*) of the lower Mississippi river valley Journal of Mammalogy, 74 (3), 547-576.

Royle, J. A. & Nichols, J. D. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology, 84 (3), 777-790.

Sokal, R. K. and Rohlff, F. J. (1995). Biometry. (3rd ed.). New York: W. H. Freeman.

Weigl, P. D., Steele, M. A., Sherman, L. J., Ha, J. C. & Sharpe, T. L. (1989). The ecology of the fox squirrel (*Sciurus niger*) in North Carolina: implications for survival in the southeast. Bulletin of Tall Timbers Research Station, 24, 1-93.

Williams, K. S. & Humphrey, S. R. (1979). Distribution and status of the endangered Big Cypress fox squirrel (*Sciurus niger avicennia*) in Florida. Florida Scientist, 42 (4), 196-200.

WilsonMiller, Inc. (2002, January). Comment on the petition for listing of the Big Cypress fox squirrel (*Sciurus niger avicennia*) under the Endangered Species Act. (Available from the U. S. Fish and Wildlife Service, South Florida Ecological Services Office, 1339 20th Street, Vero Beach, FL 32960)

Wooding, J. B. (1997). Distribution and population ecology of the fox squirrel in Florida. Unpublished doctoral dissertation, University of Florida, Gainesville.

Zar, J. H. (1998). Biostatistical Analysis, (4th ed.). New Jersey: Prentice Hall.