Supplemental Information for the Sherman's Fox Squirrel

Biological Status Review Report

The following pages contain peer reviews received from selected peer reviewers, comments received during the public comment period, and the draft report that was reviewed before the final report was completed.

March 31, 2011

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Peer review #1 from William Giuliano

From: Giuliano,William M
To: Imperiled
Cc: Garrison, Elina; Giuliano,William M
Subject: Big Cypress & Sherman"s fox squirrel Draft BSR Report
Date: Wednesday, December 29, 2010 11:03:27 AM

FWC:

I have reviewed the Draft BSRs for the Big Cypress Fox Squirrel and Sherman's Fox Squirrel. Based on my review, I believe that for both subspecies, the Biological Review Groups were thorough, accurate, and complete in their use of the biological information available and data analyses, and were reasonable and justified in their assumptions, interpretations of the data, and conclusions in the respective BSRs. I concur with the recommendations made for each subspecies based on my own review of the data, and also make note that a lack of data/knowledge for both subspecies led to some uncertainty in conclusions.

Bill
William M. Giuliano
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Department of Wildlife Ecology & Conservation
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Gainesville, FL 32611-0430

Peer review #2 from Dr. Brad Bergstrom

From: Bradley J. Bergstrom
To: Imperiled
Subject: RE: Deadline reminder for peer reviews of BSR reports
Date: Friday, January 28, 2011 11:48:12 AM
Attachments: Peer review of Florida Mouse BSR.docx
Peer review of BigCypress Fox Squirrel BSR.docx
Peer review of Sherman"s Fox Squirrel.docx

Please find attached three separate Word files, which are my peer reviews of the BSRs for:

1) Florida mouse
2) Big Cypress fox squirrel
3) Sherman's fox squirrel

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Brad Bergstrom, Ph.D., Professor
Department of Biology
Valdosta State University
Valdosta, GA 31698-0015 USA

Peer review of "Biological Status Review for Sherman's fox squirrel (*Sciurus niger shermani*)"

Reviewer: Dr. Brad Bergstrom, Biology Dept., Valdosta State University, Valdosta, GA

Date of Review: 26 January 2011

Sherman's fox squirrel (*Sciurus niger shermani*) is listed as a Species of Special Concern (SSC) in Florida. As an observer of small mamals and their habitats in south Georgia and north Florida over the past 25 years, it is apparent to me that Sherman's fox squirrel has declined in overall abundance, especially in its area of occupancy (AOO), just as the AOO of fire-managed upland pine-turkey oak woodlands has declined. I have also observed that Sherman's fox squirrel, with its slow, lumbering gait, is especially vulnerable to roadkill mortality; this was not addressed in the BSR, but combined with the species' large home range and slow reproductive rate, it would seem to be a serious threat, even if habitat loss/fragmentation and fire supression were not in themselves causing declines.

The BSR acknowledges the ongoing decline and admits that we lack sufficient data to estimate its true rate. The BSR also acknowledges that we lack estimates of (sub)population sizes for Sherman's fox squirrel in Florida, and the data input into their PVA—which came from midwestern populations of fox squirrels—may not apply to the low-density, more K-selected Florida populations. Thus, we have little confidence that the relatively positive results of PVA give realistic predictions of long-term viability of Sherman's fox squirrel in Florida.

Sherman's fox squirrel is extremely sensitive to advancing succession (shrub layer encroachment) of its open woodland habitats and thus likely faces future declines without aggressive fire management of its remaining habitat. Given this, the BSR team, I think, rightly concludes that the lack of population, range, and occupancy data (and lack of confidence in other existing data) for Sherman's fox squirrel in Florida argue for maintaining SSC status until such time as studies can be completed that fill those data gaps.

I would like to see geographic distribution, density, and demographic studies completed, to include data on reproductive rates and mortality rates and causes (including roadkill). After that, we will better be able to assess the true viability or vulnerability of this species in Florida.

Finally, I believe that the biological review group (BRG) made a wise decision in this case, to urge continued SSC status, even though strict adherence to the BSR findings did not lead to the official conclusion that protected status was warranted. This is conservative, and an application of the precautionary principle (Cooney and Dickson 2005), an acknowledgment that lack of conclusive data indicating a serious threat to the population does not equate to the absence of a threat.

I am also reviewing the BSR for the eastern chipmunk in Florida; there was a similar lack of recent (or local) data allowing confidence in PVA or population and occupancy conclusions for that species, yet the BRG did not apply the precautionary principle in that case, as they should have. In fact, the eastern chipmunk was only 1 "Y" short of meeting the criteria for Threatened status, and that "Y" was missing because "Unknown, i.e. no data available to assess population change…" was interpreted to mean "no evidence of population change." I would strongly urge FWC to apply uniform standards for all species being evaluated, and I urge that standard to be the precautionary principle (Cooney and Dickson 2005). When the data are lacking, or 20 years old, or borrowed from other populations far from Florida, we should not base a conclusion to delist a species narrowly on those data. We should instead, as the Sherman's fox squirrel BRG concludes, preserve the SSC status, collect the targeted data we need, then revisit the delisting question after the data are updated and clear.

<u>Reference</u>

Cooney, R., and B. Dickson, eds. 2005. Biodiversity and the precautionary principle: Risk and uncertainty in conservation and sustainable use. Earthscan, London. 314 pp.

Peer review #3 from John Wooding

From: Wooding, John B
To: Imperiled
Cc: Garrison, Elina
Subject: RE: Deadline reminder for peer reviews of BSR reports
Date: Wednesday, January 05, 2011 11:16:15 AM

Hi Dr. Haubold, I read the Biological Status Reports for Sherman's fox squirrel and the Mangrove fox squirrel, and I am in concurrance with the findings. Ms. Garrison did an excellent job (and if possible, she should mail me a check for $20.00).

Best Regards,

John Wooding

Peer review #4 from Dr. Reed Noss

From: Reed Noss
To: Imperiled
Subject: Re: Deadline reminder for peer reviews of BSR reports
Date: Tuesday, December 28, 2010 3:34:54 PM

Dear Elisa,

After reading these two reports, I have decided not to provide a detailed review. Basically, the reports are not substantial enough at this time to warrant peer review. Much more field data (i.e., collected as part of a comprehensive status survey) and a more thorough literature review and consultation with experts, are needed before the biological status of these two subspecies (which are probably not genetically distinct, i.e., see Moncrief et al. 2010, Journal of Mammalogy 91:1112-1123) can be determined with any accuracy. Since these species have also been proposed for federal listing by the USFWS, and earlier petitions (such as the one I submitted for the Shermans's fox squirrel in 1987, where listing was found to be "warranted") are being reconsidered for these taxa, I strongly recommend that the FFWCC and USFWS jointly fund thorough status surveys for fox squirrels throughout Florida. In the meantime, the precautionary principle suggests that both taxa be listed as Threatened until or unless substantial further study finds them much more abundant and stable than existing evidence suggests.

Sincerely,

Reed
Reed F. Noss, Ph.D.
Davis-Shine Professor of Conservation Biology
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Peer review #5 from Jack Stout

From: Jack Stout
To: Imperiled
Subject: review
Date: Tuesday, January 11, 2011 1:43:35 PM
Attachments: Sherman"s fox squirrel Final Draft BSR 11 17 10.docx

I completely agree with the review of the Sherman's fox squirrel. Data are simply not available to properly evaluate this subspecies. A critical point made in the review highlights the uncertainty of GIS-based habitat assessment when ground-level surveys have not confirmed the methodology.

Jack Stout

Biological Status Review
for the
Sherman's fox squirrel
(*Sciurus niger shermani*)

EXECUTIVE SUMMARY

The Florida Fish and Wildlife Conservation Commission (FWC) directed staff to evaluate all species listed as Threatened or Species of Special Concern as of September 1, 2010. Public information on the status of the Sherman's fox squirrel was sought from September 17 to November 1, 2010. The members of the biological review group (BRG) met on November 3-4, 2010. Group members were Elina Garrison (FWC lead), Robert McCleery (University of Florida), and John Kellam (National Park Service). In accordance with rule 68A-27.0012 Florida Administrative Code (F.A.C.), the BRG was charged with evaluating the biological status of the Sherman's fox squirrel using criteria included in definitions in 68A-27.001(3), F. A. C., and following the protocols in the *Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Version 3.0)* and *Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1)*. Please visit http://myfwc.com/WILDLIFEHABITATS/imperiledSpp_listingprocess.htm to view the listing process rule and the criteria found in the definitions.

The Sherman's fox squirrel BRG concluded from the biological assessment that the Sherman's fox squirrel did not meet any of the criteria for designation as a State-threatened species. They also, however, expressed concerns about the adequacy of the data currently available for making this evaluation. FWC staff therefore recommends that the Sherman's fox squirrel be maintained as a Species of Special Concern until more data can be collected.

This work was supported by a Conserve Wildlife Tag grant from the Wildlife Foundation of Florida.

BIOLOGICAL INFORMATION

Taxonomic Classification –Sherman's fox squirrel (*Sciurus niger shermani*) is one of three subspecies of fox squirrels occurring in Florida. Sherman's fox squirrel has been defined to the subspecies *Sciurus n. s.* on the basis of size (it is only slightly larger than *S. n. niger*, but considerably larger than *S. n. avicennia*; Moore 1956; Turner and Laerm 1993 as cited in Wooding 1997).

Life History – Sherman's fox squirrel is a large (600-700mm) tree squirrel with highly variable dorsal fur color ranging from silver to all black (uncommon), with variations of silver over black and black over silver (Florida Natural Areas Inventory 2001). Ideal habitat for Sherman's fox squirrels is mature, open, fire-maintained longleaf pine (*Pinus palustrus*) - turkey oak (*Quercus laevis*) sandhills and flatwoods (Florida Natural Areas Inventory 2001; Kantola 1992, Kantola and Humphrey 1990, Moore 1957). To accommodate the large home-ranges and fluctuating food resources, suitable habitat should also include more productive lower slopes of sandhills (Kantola 1992). This species also inhabits mixed hardwood pine, mature pine forests, cypress domes, pastures, the ecotone between bayheads and pine flatwoods, and other open habitats with pines and oaks (summarized in Endries *et al*. 2009; Florida Natural Areas Inventory 2001).

Sherman's fox squirrel typically has two breeding seasons each year. The winter breeding season is from October to February and the summer breeding season is from April to August (Wooding 1997). Males expand their home ranges during the breeding season and several males will cluster around a single female while she is in estrus (Wooding 1997; see Koprowski 1994 for a summary of breeding behavior in *Sciurus niger*). Females average one litter per year with a mean of 2.3 offspring per litter (Moore 1957, Wooding 1997), compared with 2.5-3.2 young for the midwestern fox squirrel (Kantola 1992). Young are weaned at 90 days and sexual maturity is reached at about 9 months. Captive fox squirrels have lived more than 10 years (Moore 1957); however, based on an annual mortality rate of 30% for radio-collared adult squirrels and field observations, average longevity in the wild is likely considerably less than 10 years (Wooding 1997).

Longleaf pine seeds and turkey oak acorns appear to be some of the main food items utilized by Sherman's fox squirrels. Squirrels have been observed to move their home ranges into live oak forests if a mast failure of turkey oak occurs (Kantola and Humphrey 1990). The highest quality habitat for Sherman's fox squirrel may therefore be habitat that includes both longleaf pine savanna and live oak forest (Kantola and Humphrey 1990). Additional food items include other acorns, fungi, bulbs, vegetative buds, insects, nuts and staminate pine cones (Kantola 1992).

Sherman's fox squirrels use several different nests in their home ranges (Kantola and Humphrey 1990). Most nests are leaf nests made of Spanish moss, pine needles, twigs, and leaves, while a few nests are within tree cavities (Kantola and Humphrey 1990). In the Katharine Ordway Research Preserve, nests of Sherman's fox squirrels were found in six tree species: slash pine, post oak, laurel oak, live oak, turkey oak, and longleaf pine (Kantola and Humphrey 1990).

Sherman's fox squirrels in Florida occur at lower densities and have larger home ranges than estimates obtained for *Sciurus niger* elsewhere in its range (Wooding 1997). A population size of approximately 100-200 animals was estimated to inhabit the 37 km^2 area occupied by the Katharine Ordway Research Preserve, Putnam County, Florida (Kantola and Humphrey 1990). Other density estimates in Florida range from 7 to 38 individuals/ km^2 (Wooding 1997; Humphrey et al. 1985, Kantola 1986, and Moore 1957). Average home range size for Sherman's fox squirrels is 16.7 ha for females and 42.8 ha for males (Kantola and Humphrey 1990). In contrast, midwestern fox squirrel home ranges average 0.8-7.0 ha (Kantola 1992). Sherman's fox squirrel adults defend mutually exclusive core areas (Kantola and Humphrey 1990). Males have home ranges that overlap with those of females and other males, but there is very little overlap in home ranges of adult females (Wooding 1997). The relatively large home ranges of Sherman's fox squirrels may result from a food supply that varies in time and space (Kantola and Humphrey 1990).

The low carrying capacity in Florida may be explained by a lack of high quality, storable seeds, coupled with periodic failures of seed crops (Wooding 1997). Habitat that is low in productivity leads to low population densities, large home range sizes, and the low production of young per unit area (Wooding 1997).

Geographic Range and Distribution – Three surveys have assessed the distribution of fox squirrels in Florida (Brady 1977; Williams and Humphrey 1979; Wooding 1997). Based on morphological characteristics, *Sciurus niger shermani* range includes most of peninsular Florida, extending northward into central and southern Georgia, westward into Gilchrist and Levy counties, southward on the west coast probably to the vicinity of the Caloosahatchee River (at least to Highlands and Hillsborough counties), and southward on the east coast to Jupiter, Palm Beach County (Moore 1956; Wooding 1997).

Population Status and Trend – Population size of Sherman's fox squirrels is unknown. However, based on known levels of habitat loss, Sherman's fox squirrels are believed to have declined at least 85% from presettlement levels (Kantola 1992). Sherman's fox squirrels are rare because their habitat has been lost or degraded, and that which is left is highly fragmented (Kantola 1992; Wooding 1997). These trends are expected to continue due to the persistent destruction of *S. n. shermani*'s native habitat (FWC 2005; Kantola and Humphrey 1990, Wooding 1997). It is predicted that between 2010 and 2020, approximately 4% of Florida's total land area will undergo urban development. It is also predicted that 39.4% of the converted land will be native habitat (Zwick and Carr 2006). Conversely, Florida's programs for purchasing public conservation lands (e.g., Preservation 2000 and Florida Forever) have likely offset some of these losses. In addition, efforts are being made to restore degraded sandhill habitat (http://myfwc.com/wildlifelegacy/fundedprojects/GrantDetails.aspx?ID=215). These restoration projects will increase the quantity and quality of habitat for wildlife species on 6,740 ha of sandhill habitat in Florida by 2012 and may offset some of the future habitat loss and fragmentation. Approximately 50% of potential habitat is on conservation lands, the other 50% is vulnerable to degradation or conversion to other uses (Endries et al. 2009, M. Endries, FWC, unpublished data).

Quantitative Analyses – A population viability analysis was carried out on Sherman's fox squirrel using demographic information from the species as a whole (Root and Barnes 2006; Endries *et al*. 2009). The baseline model estimated a finite growth rate of 1.0034. Initial abundance was estimated at 0.025 while carrying capacity was estimated at 0.18. Results revealed that the risk of extinction in the next 100 years was zero for both managed habitat and all potential habitat. The risk of large declines was also very small (for example, the probability of a 50% decline was ~18%). The model was very sensitive to small changes in survival and fecundity so, considering what little is known about this species' demographics, the validity of the results are questionable. Regardless, changes to the finite growth rate altered the probability of a large decline in the population as a whole, but did not change the probability that the species would not go extinct over the next 100 years.

BIOLOGICAL STATUS ASSESSMENT

Threats – The biggest threat to Sherman's fox squirrels is destruction of habitat due to encroaching development (FWC 2005; Kantola and Humphrey 1990). Such habitat loss has already been significant; it is estimated that only 10-20% of original Sherman's fox squirrel native habitat is still intact, most of it having been logged, converted to pasture, ruined by lack of fire, or used for agriculture, commercial development, and residential development (Bechtold and Knight 1982 as cited in Kantola 1992). Florida's longleaf pine forests in particular were reduced by 88% between 1936 and 1986, to the extent that by 1987 only 0.38 million ha remained (Wooding 1997). Many of the other habitat types in which Sherman's fox squirrels are found are declining. Mixed hardwood-pine forest is declining; natural pineland, sandhill, and scrub are in poor condition and declining; and the condition of disturbed/transitional habitat is unknown (FWC 2008). Such habitat destruction is expected to continue as Florida's population continues to expand (FWC 2005; FWC 2008; Zwick and Carr 2006). In addition, most remaining tracts of longleaf pine savanna in Florida are not of good quality (Kantola and Humphrey 1990). Logging and the suppression of fire have led to the replacement of pine trees by turkey oak over much of *S. n. shermani*'s range (Kantola and Humphrey 1990). Yearly burns of longleaf pinelands on northern bobwhite quail (*Colinus virginianus*) plantations also prevent pine seedling growth, damaging the habitat for fox squirrels and other wildlife (Kantola and Humphrey 1990). For proper regeneration, longleaf pine savanna habitat requires a burning regime in which areas are prescribed burned every 3 to 5 years (Kantola and Humphrey 1990).

Hunting of Sherman's fox squirrels also may have been detrimental to local populations, particularly small, isolated populations that have low potential for recolonization (Kantola 1992). Presumably this threat has ceased as hunting of Sherman's fox squirrel is no longer permitted.

Sciurus niger shermani is currently listed as Lower Risk, near threatened by the IUCN Rodent Specialist Group because of "extensive loss of the habitat of *S. n. shermani*, which could be mitigated by establishment of preserves of adequate size" (Hafner *et al*. 1998).

The recommended action of the IUCN Rodent Specialist Group (Hafner *et al*. 1998) was:

"Establish large (several km^2) preserves of longleaf pine habitat for *S. n. shermani*; management should include a natural fire-cycle of burning at 3 to 5-year intervals."

Kantola (1992) recommended: (1) preserving and reclaiming large areas (at least 25 km^2) of Sherman's fox squirrel habitat with a prescribed summer burn every 2 to 3 years; (2) conduct status surveys to determine population levels throughout the fox squirrel's range; and (3) determine the effects of hunting on small or closed populations.

Statewide Population Assessment – Findings from the BRG are included in a Biological Status Review information table. Please see Appendix 1 for additional notes and clarifications.

LISTING RECOMMENDATION – The BRG found the Sherman's fox squirrel did not meet any of the criteria for designation as a State-threatened species, but they also expressed concerns about the adequacy of the data for making this evaluation. They referenced uncertainties in current estimates of extent of occurrence, area of occupancy, recent trends, and population size. Because the *Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1)* cautioned "assessors should adopt a precautionary but realistic attitude, and … resist an evidentiary attitude to uncertainty when applying the criteria." Staff recommends that the Sherman's fox squirrel be maintained as a Species of Special Concern until more data can be collected. Research is planned over the next two years to assess the taxa's range, population genetics, and habitat occupancy.

SUMMARY OF THE INDEPENDENT REVIEW
LITERATURE CITED

Bechtold, W.A. and H.A. Knight. 1982. Florida's forests. US Department of Agriculture, Forestry Service Resource Bulletin SE 62:1-84

Brady, J. R. 1977. Status of the fox squirrel in Florida. P-R Final Report, Project W-41-24, Job XV-A-1. Florida Game and Fresh Water Fish Commission, Tallahassee.

Cox, J. 2004. Commentary: Population declines and generation lengths can bias estimates of vulnerability. Wildlife Society Bulletin 32(3):1-4.

Endries, M, B. Stys, G. Mohr, G. Kratimenos, S. Langley, K. Root, and R. Kautz. 2009. Wildlife Habitat Conservation Needs in Florida. Fish and Wildlife Research Institute Technical Report TR-15. x + 178p.

Florida Natural Areas Inventory. 2001. Field guide to the rare animals of Florida. http://myfwc.com/docs/FWCG/sherman_fox_squirell.pdf

Florida Fish and Wildlife Conservation Commission (FWC). 2005. Florida's Wildlife Legacy Initiative. Florida's Comprehensive Wildlife Conservation Strategy. Tallahassee, Florida, USA.

Florida Fish and Wildlife Conservation Commission (FWC). 2008. Wildlife 2060: What's at stake for Florida. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida. 28 pp.

Hafner, D.J., E. Yensen, and G.L. Gordon, Jr. (compilers and editors). 1998. North American Rodents. Status Survey and Conservation Action Plan. IUCN/SSC Rodent Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. X + 171pp.

Humphrey, S.R., J.F. Eisenberg, and R. Franz. 1985. Possibilities for restoring wildlife of a longleaf pine savanna in an abandoned citrus grove. Wildlife Society Bulletin 13:487-496.

Kantola, A.T. 1986. Fox squirrel home range and mast crops in Florida. M.S. thesis, University of Florida, Gainesville. 68pp.

Kantola, A.T. 1992. Sherman's fox squirrel *Sciurus niger shermani*. Pages 234-241 in S.R. Humphrey (ed.), Rare and endangered biota of Florida. Vol. I. Mammals. University Press of Florida. Gainesville, Florida.

Kantola, A.T. and S.R. Humphrey. 1990. Habitat use by Sherman's fox squirrel (*Sciurus niger shermani*) in Florida. Journal of Mammalogy 71(3):411-419

Koprowski, J.L. 1994. *Sciurus niger*. Mammalian Species 479:1-9

Moore, J.C. 1956. Variation in the Fox Squirrel in Florida. American Midland Naturalist 55(1):41-65.

Moore, J.C. 1957. The natural history of the fox squirrel *Sciurus niger shermani*. Bulletin of the American Museum of Natural History. 113:1-71

Root, K.V. and J. Barnes. 2006. Risk assessment for a focal set of rare and imperiled wildlife in Florida. Fish and Wildlife Conservation Commission.

Turner, D.A. and J. Laerm. 1993. Systematic relationships of populations of the fox squirrel (*Sciurus niger*) in the southeastern United States. Pages 21-36 in N.D. Moncrief, J.W. Edwards, and P.A. Tappe, eds. Proceedings of the second symposium on southeastern fox squirrels, *Sciurus niger*. Va. Museum of Natural History Special Publication. No. 1. 84pp.

Williams, K. S. and S. R. Humphrey. 1979. Distribution and status of the endangered Big Cypress fox squirrel (*Sciurus niger avicennia*) in Florida. Florida Scientist 42:201-205.

Wooding, J.B. 1997. Distribution and population ecology of the fox squirrel in Florida. Ph.D. dissertation. University of Florida.

Zwick, P.D. and M.H. Carr. 2006. Florida 2060: A population distribution scenario for the State of Florida. A research project prepared for 1000 Friends of Florida. Geoplan Center at the University of Florida, Gainesville, Florida, USA. 25pp

Peer review #6 from Deborah Jansen

From: Deborah_Jansen@nps.gov
To: Imperiled
Subject: Re: Deadline reminder for peer reviews of BSR reports
Date: Tuesday, January 11, 2011 3:39:51 PM
Attachments: Munim et al 2007.docx

I reviewed the Sherman's fox squirrel BSR and support their recommendation that their status remain the same until more data is obtained. I am attaching the Final Report on the Munim et al 2007 study that I referenced in my review of the Big Cypress fox squirrel BSR. I don't believe that it adds significantly to the information that had already been known about this species prior to the onset of the study.

Deborah

(See attached file: Munim et al 2007.docx)

Deborah Jansen
Wildlife Biologist
Big Cypress National Preserve
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Ochopee, FL 34141

The Status and Distribution of the Big Cypress Fox Squirrel, *Sciurus niger avicennia*

by:

Danielle Munim

Reed F. Noss

Jane M. Waterman

Final Report

Study Number: 24036024

Study Period: January 1, 2005-December 31, 2007

Department of Biology

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Table of Contents

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 of the effects of fragmentation because they are dependent on mature forests and thus may serve as a focal species for ecosystem management. The Big Cypress fox squirrel, (*Sciurus niger avicennia*), a state-listed Threatened subspecies endemic to South Florida, appears sensitive to roads, habitat fragmentation, and fire regime. This research aims to assess the conservation status of the Big Cypress fox squirrel. We documented the historic and current distribution of the Big Cypress 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. Big Cypress fox squirrels are most commonly found in urban and suburban greenspace such as golf courses, but are rarely observed in natural areas such as parks and preserves. Fire exclusion has resulted in a dense understory in many natural areas, which is unsuitable for fox squirrels. More frequent and extensive prescribed burns in parks and preserve lands are recommended for conservation management to minimize understory density and thus maintain the quality of remaining fox squirrel habitat.

Introduction

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. Fragmentation is one of the greatest threats to biodiversity and is a principal cause of endangerment (Koprowski 2005). Habitat fragmentation creates a mosaic of isolated patches with reduced habitat area. Dramatic losses in habitat create small, isolated populations which are more susceptible to extinction (Saenz et al. 2001). Individual habitat patches vary in suitability for the reproduction and survival of individuals and these differences affect the population dynamics of a species. The state of Florida supports a host a species that evolved in relative isolation for thousands of years. 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. With a growing human population of 15 million and tourist population of 40 million per year, native habitats are disappearing due to demands for development (Kautz and Cox 2001). Florida has been ranked as the state with the greatest degree of risk for the loss of biodiversity, and there are at least 179 rare, threatened, and imperiled species native to Florida (Kautz and Cox 2001). Certain species can be useful indicators or "focal species" for determining the quality of these ecosystem remnants and the management practices (Lambeck et al. 1997) required to preserve biodiversity. Tree squirrels are good models for studies of the effects of fragmentation because they are dependent on mature forests (Koprowski 2005) and thus may serve as a focal species for ecosystem management (Kautz and Cox 2001).

The Big Cypress fox squirrel (*Sciurus niger avicennia*) is a Threatened, subspecies endemic to South Florida. It appears sensitive to fragmentation, roads, fire regime, and other aspects of the structure and function of ecosystems in South Florida. Habitat destruction, hunting pressure, and environmental stochasticity (i.e. hurricanes) are implicated in the decline of this subspecies (Wooding 1997). The decline of the Big Cypress fox squirrel (BCFS) mirrors the decline in its preferred habitats as South Florida has been increasingly transformed by human activities. The logging of mature pine and cypress forests brought about the early decline of this subspecies (Wooding 1997). Remaining habitat has been degraded due to fire exclusion and suppression. Periodic fires are vital for maintaining habitat quality. Mature 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 et al. 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 extensively on the ground (Jodice and Humphrey 1992; Ditgen et al. 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 BCFS was present in Dade and Broward counties until the early 1900's, and populations are reported as rare and highly scattered in Collier, Lee, Hendry, and Monroe counties (Jodice and Humphrey 1992). The Caloosahatchee River marks the northern boundary of Big Cypress fox squirrel range (Ditgen 1999) and may act as a barrier to gene flow between Sherman's and Big Cypress fox squirrels. The BCFS and the Sherman's fox squirrel differ in pelage and cranial features (Moncrief 2001). 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.

Fox squirrels have large home ranges, appear to be long-lived, and have low adult mortality and a few, small litters each year (Koprowski 2005). These life history characteristics may explain why most populations of southeastern fox squirrels are declining and have failed to recover even after preservation of potential habitats (Conner 2001). Big Cypress fox squirrels may be present in a variety of habitat types including cypress forest, pine Flatwoods, tropical hardwood forest, oak hammocks, golf courses, and suburban areas (Williams and Humphrey 1979). While automobiles appear to be the main cause of mortality for fox squirrels, hawks, foxes, and owls are observed to prey upon them opportunistically (Weigl et al. 1989).

Although fox squirrels are generally found in pine Flatwoods, the specific habitat requirements of Big Cypress fox squirrels are poorly understood (Humphrey and Jodice 1992). A study by Wilsonville (2002) estimated that 949,000 acres of potential BCFS habitat remained, and 551,855 of those acres are within conservation lands. Even though a large amount of potential fox squirrel habitat may remain, many areas may be avoided due to understory growth or other variables. Due to fire suppression efforts, understory growth has resulted in less suitable habitat for Big Cypress fox squirrels which require an open, mature, pine-oak forest with minimal understory growth (Jodice and Humphrey 1992). Previous research has found higher fox squirrel abundance in suburban areas than in native, relatively undisturbed habitats (Jodice and Humphrey 1992, Ditgen 1999). Golf courses and other urban and suburban greenspace lands have little to no understory and may provide suitable habitat for fox squirrels. Big Cypress fox squirrel populations also exist in areas that were formerly marshland, pine Flatwoods, and upland prairie that have been drained and converted to pasture (Wooding 1997). Grazing keeps the understory to a minimum and may enhance potential fox squirrel habitat (Williams and Humphrey 1979).

Our research seeks to determine the distribution and abundance of the Big Cypress fox squirrel in urban greenspace, private lands, parks, preserves, and conservation lands throughout southwest Florida. Three hypotheses were tested to examine fox squirrel distribution and abundance and to identify preferred vs. avoided habitats. H_1: The land use of sites influences the distribution and abundance of fox squirrels. We predict that fox squirrels will be found more often in urban and suburban greenspace than natural areas. H_2: Tree characteristics influence the distribution and abundance of fox squirrels. We predict that fox squirrels will be found in areas with large, mast producing trees. H_3: Understory characteristics influence fox squirrel distribution and abundance. We predict that fox squirrels will be found in areas with minimal understory.

Methods

The current distribution of the Big Cypress fox squirrel was mapped by obtaining and mapping occurrence records from the U.S. Fish and Wildlife Service, Florida Natural Areas Inventory, Florida Museum of Natural History, and other sources, and through interviews with biologists, private land owners, and golf course managers. Through these interviews, recent and historic sightings in natural areas were documented (Appendix A). Questionnaires were mailed out to persons qualified to provide information about the historic and current trends in BCFS distribution and abundance on the lands they own or manage. Of the one thousand surveys that were distributed, only 15% were returned. Respondents were asked to indicate their personal sightings on a five-point likert 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, 2-Common) for statistical analyses. Interview participants also estimated the number of squirrels believed to live on the land they own or manage on the following scale: 1-5 squirrels, 6-10 squirrels, 11+ squirrels. Participants ranked the trends of local BCFS populations on the following scale: declining, stable, increasing. A G-test of independence was used to examine the hypothesis that the x (land use) variable has no effect on the response variables (sightings, abundance, stability).

Twenty 1-km transects were established to survey for fox squirrels and to measure habitat variables. Transect locations were selected randomly by picking twenty sites “out of a hat”. Forty accessible sites were included in the selection. Habitat characteristics were measured within 10m radius plots according to standard techniques (Avery and Burkhart 1994). The following habitat variables were assessed at each 100m interval along 1km transects: tree species, diameter at breast height (dbh), mast abundance, and understory characteristics. Understory height was measured in nested $1m^2$ subplots 5m from the center in each cardinal direction with a total of 40 measurements collected from each transect (Avery and Burkhart 1994). A 2-section collapsible pole was used to estimate understory height and percent cover (Griffith and Youtie 1988). Squirrels were counted during a 2 hr walk along each transect a total of three times. Locations of each transect were recorded using a Garmin 12 Global Positioning System (GPS). Logistic regression was used to predict a qualitative dependent variable (presence vs. absence of squirrels) from one or more independent variables (land use, tree species, dbh, understory height).

Observations were conducted at twenty golf courses to assess BCFS abundance in these habitats. These sites were identified through the questionnaires as places where fox squirrels have been seen. From 2005-2007, three, two-hour duration counts were made along golf course cart paths which served as transects.

One hundred nest boxes (40X21X21cm; 7.62cm. circular entrance) were placed at 100m intervals along ten 1km transects. The nest boxes were installed at least 6m high and were checked a minimum of two times over the course of three years. Nest boxes were also intended as a method of fox squirrel capture for collection of tissue samples and for radio-telemetry. GPS locations were recorded for each nest box.

Fox squirrels were captured in Tomahawk live traps (24X6X6" double door) baited with peanuts, walnuts, pecans, and sunflower seeds. Sixteen fox squirrels were handled in a cloth bag that restrains the body and appendages, and allows easy respiration (Koprowski 2002). Squirrels were weighed (Appendix B) and examined for sex, age, reproductive condition, and external parasites**.** The squirrels were marked for identification using PIT tags. Tissue samples were collected from a small piece of skin (5mm) from the tail tip for Nancy Moncrief, who is undertaking a rangewide genetic and phylo-geographic study of fox squirrels. All individuals were released at the site of capture. Locations of squirrels were recorded using a Garmin 12 Global Positioning System (GPS). We also attempted to trap fox squirrels to fit them with AVM 148 mhz collars for radio-telemetry analysis to track home range and movements. Squirrels were to be tracked using triangulation and by "honing-in" with a hand-held, tri-fold yagi.

Results

Survey responses from all interview questionnaires were mapped (Figure 1) to provide a visual representation of the current distribution of the Big Cypress fox squirrel. These responses were analyzed with contingency analyses to examine relationships between land use and BCFS presence, sightings, and estimated abundance and stability. Reported trends in population stability were indicated as follows: fox squirrels numbers are decreasing, stable (no change), or increasing. Several dependent variables such as sightings, presence-absence, abundance, and stability were assessed in comparison with land use, which was divided into three categories: urban/suburban greenspace, farm/grove/pasture, natural area. For analyses of abundance and stability, only golf courses and private lands were assessed due to the low number of observations in natural areas and the inability of interview participants to estimate trends in stability. G-tests indicate a significant interaction between BCFS presence/absence and land use ($G = 7.3$, $d.f. = 2$, $P = 0.03$) (Figure 2), and sightings and land use ($G = 44.95$, $d.f. = 4$, $P < 0.0001$) (Figure 3). BCFS sightings are not independent of land use. Big Cypress fox squirrels are observed most frequently in urban greenspace areas such as golf courses, but are generally rare in natural areas. The G-test revealed a significant interaction between BCFS abundance and land use (Figure 4). The abundance of Big Cypress fox squirrels is not independent of land use

(G = 16.36, *d.f.* = 2, P = 0.0003). No significant relationship was indicated by the G-test for BCFS stability and land use (Figure 5). The stability of Big Cypress fox squirrels is independent of land use (G= 4.14, d.f.= 2, P= 0.126). We accept the alternative hypothesis (H_1) that land use influences the distribution and abundance of fox squirrels in terms of sightings and abundance, albeit no relationship was found between land use and stability.

Although 120 total hours were spent surveying the twenty random sampling transects (Table 1, Figure 6) very few squirrels were observed. Fox squirrels were found at 25% of the study sites; however fox squirrels sightings were reported in 85% of the study areas within the past five years. Sightings were very rare in natural areas, and along most transects no fox squirrels were observed (Table 2). More than one squirrel was often observed in sites such as golf courses and other areas of urban greenspace. We chose to analyze the data in terms of presence-absence because the Big Cypress fox squirrel was observed at very few sites. Presence-absence methods can be used when the species of interest exists in low numbers or is difficult to detect (Joseph et al. 2006; Pollock 2006).

The following species of native trees were found along the surveyed transects: South Florida slash pine, (*Pinus elliotti var. densa*), bald cypress (*Taxodium distichum*), pond cypress (*Taxodium ascendens*), live oak (*Quercus virginianum*), laurel oak (*Quercus laurifolia*), and cabbage palm (*Sabal palmetto*). Nominal logistic regression revealed a significant relationship between the size (Figure 7) and abundance (Figure 8) of mast tree species and presence-absence of fox squirrels (full model: R^2 = 0.13; *d.f.*= 6; P= <0.0001). Sites where fox squirrels were found had larger mast trees than sites where fox squirrels were not observed. We accept the alternative hypothesis (H_2) that tree characteristics influence the distribution and abundance of fox squirrels.

Logistic regression revealed a significant relationship (full model: R^2= 0.52; *d.f.* = 2; P = 0.002) between mean understory height and mean percent cover in sites where squirrels were and were not observed (Figure 9). When land use was included in the analysis, mean understory height is a significant predictor (full model: R^2=0.37; *d.f.* = 1; P <0.0001) for the presence of fox squirrels in both natural areas and urban greenspace (Figure 10). We accept the alternative hypothesis (H_3) that understory characteristics influence the distribution and abundance of fox squirrels.

Observational studies from twenty golf courses (Figure 11) revealed higher numbers of squirrels (Table 3) than observed in natural areas and. None of the nest boxes that were installed along ten transects (Figure 12) from 2005-2007 can be confirmed as fox squirrel nests, but many other species were found with eggs or young in the nest boxes including great-crested flycatchers (*Myiarchus crinitus*), Eastern screech owls (*Megascops asio*), and gray squirrels (Table 4). Natural cavities and leaf nest were inspected along transects to identify natural nests, but only one leaf nest can be confirmed as an active BCFS nest in a Slash Pine (*Pinus elliotti var. densa*) tree on private land in northern Hendry county. One resident fox squirrel was observed on multiple occasions entering and leaving the nest at different times throughout the day. Other nests of similar size and composition were located in trees nearby this nest tree but they may have been old, inactive nests.

The months of January through July of 2005 proved to be a period of high trapping success. Sixteen squirrels were trapped on golf courses in Naples, and tissue samples were collected. These samples were sent to Ronald Van Den Bussche at the University of Oklahoma as directed by Nancy Moncrief for their research addressing the phylo-genetic relationships of *Sciurus*. Golf course superintendents and other county land managers frequently reported Big Cypress fox squirrel road-kills. Ten road-killed fox squirrels were collected from golf courses in Naples and two were collected from busy roads surrounding Lee County's Conservation 20/20 land, Pine Lake Preserve (Table 5). Two fox squirrels were found dead of unknown causes and were also collected. We salvaged a total of fourteen fox squirrel carcasses between 2005 and 2007. The frozen specimens were deposited in January 2008 at the Florida Museum of Natural History at the University of Florida to be vouchered.

From February 2007-May 2007, we attempted to trap squirrels to fit with radio-collars to track movements and home range size on private ranch land and several golf courses in the Naples area. These were locations where fox squirrels were observed consistently and where we had successfully trapped squirrels in the winter and spring seasons of 2005 and 2006 for tissue collection. Over eighty hours were dedicated to attempt to trap and to fit squirrels with radio-collars in 2007. Unfortunately, we had very low trapping success (only two squirrels were trapped and the individuals escaped before the collars were properly fitted), and we were unable to conduct the radio-telemetry aspect of the study.

Discussion

Natural areas, private lands, and urban greenspace all appear to support Big Cypress fox squirrels, but they are widely distributed and in 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 where despite intensive searches for fox squirrels in the Big Cypress National Preserve (Jodice and Humphrey 1993) and other natural areas (Ditgen 1999) very few animals were found.

The distribution and abundance of fox squirrel populations are dependent on specific habitat characteristics such as land use, tree species, tree size, and understory height. Our results found evidence to support tree and understory characteristics as important predictors of fox squirrel presence. Fire suppression has resulted in a dense understory in large portions of parks and preserve lands and suburban areas have attractive habitat cues for the BCFS such as a minimal understory and a variety of native and exotic mast-producing trees. Many of these golf courses in the Naples area were established over fifty years ago, and some old-growth stands of pines and cypress were preserved with them. Other species frequently observed at golf courses in the Naples area included gray squirrels (*Sciurus carolinensis*), bald eagles (*Haliaeetus leucocephalus*), pileated woodpeckers (*Dryocopus pileatus*), and osprey (*Pandion haliaetus*). While sightings on golf courses are common, BCFS population density is presumably low because observations are typically of a few resident individuals.

While the habitat itself in these suburban 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 due to the abundance of native and exotic mast producing trees, populations may not be prospering at such locations. Traffic is very heavy on the roads surrounding these pockets of urban greenspace, and fox squirrels are quite often hit and killed. Squirrels are struck not only by automobiles, but also by the golf carts and maintenance equipment on golf courses. Often, squirrels are hit by golf carts because they are habituated to humans and are approaching them seeking food. Fox squirrels have become a perceived nuisance on at least two golf courses in Naples and a superintendent reported that a golfer struck a BCFS with his club when it approached too close. 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.

To look at demographic performance, radio-telemetry was attempted in this project but failed due to poor trapping success. This lack of trapping success was unanticipated especially because fox squirrels in these areas were relatively easy to trap in years past. However, there was extreme drought in 2007 which may have negatively affected trapping success. At this time, fox squirrels not only appeared “fat”, but were uninterested in the bait, and not even peanut butter (previously avoided due its attractive nature to fire ants) was able to lure them into traps. We also failed to capture any Big Cypress fox squirrels for our radio-telemetry study through the use of nest boxes. Although none of the nest boxes established in areas of potential fox squirrel habitat can be confirmed as active fox squirrel nests, these boxes should be monitored in the long term, as studies show that it may take several years for fox squirrels to inhabit the boxes (Weigl et al. 1989). In fact, one fox squirrel was observed taking refuge in a nest box that has been installed on a golf course several years ago by another researcher. Continued monitoring of these nest boxes may enable assessments of preferred vs. avoided habitats for refugia and rearing of young.

Very little data exist to document current and historic fox squirrel occurrence. Big Cypress fox squirrels are observed in the natural areas by park visitors and park personnel, but in most cases, the sightings are not documented. Unfortunately, many private land owners were unwilling to report the incidence of Big Cypress fox squirrels on their property and refused participation in this study. 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 (Kautz and Cox 2001) and should be consistently monitored for fox squirrel populations. Also, most of the occurrence data reported here are based on interviews and questionnaires. These data may not always be reliable and there is a tendency for observations of rare species to be located in places most accessible to observers. However, sighting data are a valuable source of information for rare and endangered species.

Two main issues complicated our estimations of fox squirrel populations. First, 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 (Royle and Nichols 2003). However, randomness is hindered by limitations in the ability to access various sites in both natural and private lands. Second, there is the confounding factor of detectability and survey methods rarely detect all animals present in any sample unit (Royle and Nichols 2003). 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 is an artifact of differences in ease of observation. These anthropogenic habitats are not necessarily preferred over natural habitats.

While we have attempted to assess the distribution and abundance of the Big Cypress fox squirrel, a status survey is incomplete without an assessment of a species demographic performance and genetic condition within and among local populations. Such analyses are sure to provide valuable insights into which of the subspecies characteristics vary under differing ecological conditions. Under the island archipelago model, old-growth islands of habitat scattered among stands of varying habitat quality with adequate dispersal corridors may preserve genetic diversity better than a single large park or preserve (Noss et al. 1997). Dispersal is vital in maintaining viable populations in fragmented landscapes. The genetic impacts of population fragmentation depend critically upon gene flow among fragments. Fragmentation restricts gene flow and typically leads to greater inbreeding and loss of genetic diversity within fragments (Futuyma 1998**)**. Theory predicts that genetic drift and inbreeding are inevitable in small populations. Moncrief (1998) found reduced genetic diversity in isolated fox squirrel populations. The ability of a species to traverse an inhospitable matrix is important in determining the viability of populations in fragmented landscapes (Goheen et al. 2003). Species that disperse at high rates or long distances are less likely to be affected by fragmentation. The distance between habitat patches is a key predictor influencing dispersal, with lower rates of movement occurring between patches separated by large distances (Goheen et al. 2003). The extent to which habitat fragmentation has hindered the dispersal and gene flow of the Big Cypress fox squirrel is unknown and deserves investigation.

A spatially-explicit model population model may be the most reliable means of assessing population and metapopulation viability. Spatially-explicit models incorporate landscape structure and habitat use to predict population responses to anthropogenic alterations of ecosystems (Dunning et al. 1995). Scenario analyses which combine fox squirrel census data with habitat models may be useful in exploring impacts of changes in environmental conditions. Population viability analyses would aid future decision-making and the development of policies to best conserve habitat for the Big Cypress fox squirrel. Such models are data-hungry and must be founded on reliable empirical data and on an understanding of variability in habitat suitability for the species of concern (Scott et al. 2002). Our research helps build the empirical basis for a comprehensive assessment of the status and viability of the Big Cypress fox squirrel.

Conclusions

The primary benefit of this study is an improved understanding of the distribution, status, and conservation needs of the Big Cypress fox squirrel. Fox squirrels are commonly found on golf courses and other areas of urban greenspace, and are rarely observed in natural areas. It appears that a low understory is the key determinant in the avoidance vs. preference of habitats, but bias in observations of fox squirrels in this study is undeniable because fox squirrels are more readily detected in these open landscapes. The difficulty associated with finding Big Cypress fox squirrels in natural areas inhibits our ability to examine the population structure of these animals in their native habitat in comparison with populations in suburban habitats.

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). We feel that this denial is unwarranted because these suburban areas are likely sinks due to high road mortality (Table 5). While the Big Cypress fox squirrel occurs on conservation lands and in suburban areas, habitat in these areas may not be adequate for long-term survival. Although we do not claim that these results will unequivocally answer the question of whether the subspecies requires listing under the U.S. Endangered Species Act, we hope that listing decisions and recovery planning will be aided by these findings.

Habitat protection strategies should be implemented to identify critical habitats that support rare species before they are lost to development (Kautz and Cox 2001) or further environmental degradation. Recent land acquisitions and conservation easements through Florida Forever have great potential for providing habitat and corridors for the Big Cypress fox squirrel. Fox squirrel populations occurring on golf courses should also be managed appropriately to maintain the high numbers observed on some courses. Lowering speed limits on golf course access roads and roads surrounding other areas of urban greenspace may decrease road mortalities. Golfers, visitors, and local residents should also be educated to avoid directly feeding the squirrels and thus limit habituation. Although these suburban populations may be sinks, they are valuable habitat reservoirs and once the genetic composition of populations is known translocations of individuals from suburban habitats to managed natural habitats as conducted by Jodice (1990) may be a useful conservation strategy.

Annual counts should be implemented at the various parks, preserves, and conservation lands in southwest Florida to monitor fox squirrel populations. More frequent and extensive prescribed burns in parks and preserve lands are recommended for conservation management to minimize understory density and thus maintain the quality of remaining fox squirrel habitat. These practices will not only favor the Big Cypress fox squirrel, but also many other rare and imperiled species including the Florida panther (*Puma concolor coryi*) and the red-cockaded woodpecker (*Picoides borealis*)(Saenz et al. 2001).

Future studies should attempt to collect demographic data such as reproduction, mortality, and movements of fox squirrel populations through radio-telemetry analyses to identify source and sink populations, determine the extent to which fragmentation has hindered dispersal abilities, and to provide the wealth of data needed construct a spatially-explicit population model. There is also a need to examine the effects of chemical applications (pesticides and herbicides) on the Big Cypress fox squirrel; bioaccumulation of chemicals on urban and suburban lands may have detrimental effects on their long-term survival and reproduction. The genetic condition of Big Cypress fox squirrel populations should also be assessed to refine a population viability model and inform future listing decisions.

References

Avery, T.E. and H.E. Burkhart. 1994. Forest Measurements, 4th ed. McGraw-Hill Inc., New York.

Conner, L. Mike. 2001. Survival and cause-specific mortality of adult fox squirrels in southwestern Georgia. Journal of Wildlife Management, 65(2): 200-204.

Ditgen, Rebecca S. 1999. Population estimates, habitat requirements, and landscape design and management for urban populations of the endemic Big Cypress fox squirrel (*Sciurus niger avicennia*). Doctoral dissertation, University of Florida, Gainesville. 131pp.

Ditgen, Rebecca S., Shepherd, John D., and Stephen R. Humphrey. 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., D.J. Stewart, B.J. Danielson, B.R. Noon, T.L. Root, R. Lamberson, and E.E. Stevens. 1995. Spatially explicit population models: current forms and future uses. Ecological Applications, 5: 3-11.

Futuyma, Douglas J. 1998. *Evolutionary Biology.* Sinauer, Massachussetts.

Goheen, Jacob R., Swihart, Robert K., Gehring, Thomas N., and Michael S. Miller. 2003. Forces structuring tree squirrel communities in landscapes fragmented by agriculture: species differences in perceptions of forest connectivity and carrying capacity. OIKOS, 102: 95-103.

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

Humphrey, S. R., and P. G. R. Jodice. 1992. Big Cypress fox squirrel. Pp. 224-233 in *Rare and Endangered Biota of Florida*, vol. 1: *Mammals*, ed. S. R. Humphrey. University Press of Florida.

Jodice, Patrick G. 1990. Ecology and translocation of an urban population of Big Cypress fox squirrels (*Sciurus niger avicennia*). Thesis, University of Florida, Gainesville, FL. 89p.

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

Joseph, Liana M., Field, Scott A., Wilcox, Chris, and Hugh Possingham. 2006. Presence-absence vs. abundance data for monitoring threatened species. Conservation Biology, 20(6): 1679-1687.

Kautz, Randy S. and James A. Cox. 2001. Strategic habitats for biodiversity. Conservation in Florida. Conservation Biology, 15(1): 55-77.

Koprowski, John L. 2002. Handling tree squirrels with a safe and efficient restraint. Wildlife Society Bulletin, 30(1): 101-103.

Koprowski, John L. 2005. The response of tree squirrels to fragmentation: a review and synthesis. Animal conservation, 8: 369-376.

Krebs, Charles J. 2001. *Ecology*. 5th edition. Benjamin Cummings, San Francisco.

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

Moncrief, Nancy D. 1998. Allozymic variation in populations of fox squirrels (*Sciurus niger*) and gray squirrels (*S. carolinensis*) of the lower Mississippi River Valley. Journal of Mammalogy, 74: 547-576.

Moncrief, Nancy D. 2001. Allozymic variation in the endangered Delmarva fox squirrel (*Sciurus niger cinereus*): genetics of a translocated population. American Midland Naturalist, 146: 37-42

Noss, R.F., M.A. O'Connell, and D.D. Murphy. 1997. The science of conservation planning: habitat conservation under the Endangered Species Act. Island Press, Washington D.C.

Pollock, Jacob F. 2006. Detecting population declines over large areas with presence-absence, time-to-encounter, and count survey methods. Conservation Biology, 20(3): 882-892.

Royle, J. Andrew and James D. Nichols. 2003. Estimating abundance from Repeated presence-absence data or point counts. Ecology, 84(3): 777-790.

Saenz, Daniel, Conner, Richard N., Rudolph, D. Craig, and R. Todd Engstrom. 2001. Is a "hands off" approach appropriate for red-cockaded woodpecker conservation in twenty-first-century landscapes? Wildlife Society Bulletin, 29(3): 956-966.

Scott, J.M., P.J. Heglund, and M.L. Morrison, editors. 2002. Predicting species occurrences: issues of accuracy and scale. Island Press, Washington D.C.

Weigl, P. D., M. A. Steele, L. J. Sherman, J. C. Ha, and T. L. Sharpe. 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, Kathleen S. and Stephen R. Humphrey. 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. Comment on the petition for listing of the Big Cypress Fox squirrel (*Sciurus niger avicennia*) under the Endangered Species Act.

Wooding, John B. 1997. Distribution and population ecology of the fox squirrel in Florida. Doctoral Dissertation, University of Florida, Gainesville. 138p.

Table 1: History of BCFS sightings at 20 study sites (see Figure 2 for locations).

Transect Sites	Size (acres)	Habitat	BCFS History	Recent sightings
1 Big Cypress National Preserve	720,000	pine flatwoods, hardwood hammocks, mangroves, dominated by cypress swamps	common until the late 1970's	Sweetwater Strand, Burns Lake, Turner River Road, and hunting camps
2 Caloosa-hatchee Regional Park	765	pine flatwoods, scrub oak, cypress swamps and oak hammocks	observed over ten years ago along hiking trails	none
3 Club at Olde Cypress	140	golf course with pine and cypress stands	common sightings	common
4 Club at Pelican Bay	150	golf course with oaks and exotic ornamentals	frequently observed	rare
5 Collier Seminole State Park	6430	cypress swamp, pine flatwoods, tropical hammock, and mangrove swamp	observed once or twice every few years in mangroves or hardwood hammocks	hardwood hammocks by boat launch and picnic area
6 Corkscrew Swamp Sanctuary	11,000	cypress swamp, pine flatwoods, hardwood hammocks	common until 2000, major mortality event occurred	rare, pair observed Fall 2005
7 Fakahatchee Strand State Park	80,000	hydric pine flatwoods, cypress swamp, hardwood hammocks	rarely observed along boardwalk and Janes Scenic Drive	Big Cypress Bend Boardwalk, Janes Scenic Drive, and in the Northwest corner of the park
8 Flint Pen Strand	14,173	converted pastureland, hydric pine flatwoods and cypress domes	unknown	summer 2005 pine flatwoods
9 Florida Panther NWR	26,400	hydric pine flatwoods, hardwood hammocks	regular sightings	northwest corner, pine flatwoods
10 Half Circle L Ranch	10,500	pastureland, hydric pine flatwoods	regular sightings until 2000	none

11 Hickey's Creek Mitigation	770	scrubby flatwoods	regular sightings before land clearing began around the park in 2004	one or two sightings every few years
12 Hunter's Ranch	5	residential, pine flatwoods	regular sightings	common, two confirmed nest sites on the property
13 Imperial Marsh Preserve	7,000	hydric pine flatwoods, cypress swamp, hardwood hammocks	regular sightings	once or twice a year in pine and hardwood stands
14 Picayune Strand State Forest	57,000	hydric pine flatwoods, cabbage palms	rarely observed	summer 2005, hydric pine flatwoods off Miller Road
15 Pine Lake Preserve	140	pine flatwoods, cypress stands undergoing melaleuca removals	unknown	regularly observed since 2004
16 Royal Palm Golf Club	140	golf course with pines, palms, and oaks	common	common
17 Royal Poinciana Golf Club	150	golf course with pine and cypress stands	common	common
18 Royal Wood Golf Club	130	golf course with pines, palms, and oaks	common	common
19 Six Mile Cypress Slough	2,200	cypress swamp, hardwood hammocks	regular prior to the late 1990's	none for over 10 years
20 Sweet Cypress Ranch	33	residential, cypress dome	regularly observed	regularly observed until 2006

Table 2: Mean number of fox squirrels counted along random sampling transects.

Transect Site	mean	min	max
Big Cypress National Preserve	0.33	0	1
Caloosahatchee Regional Park	0	0	0
Club at Olde Cypress	1.7	1	3
Club at Pelican Bay	0.6	0	2
Collier Seminole State Park	0	0	0
Corkscrew Swamp Sanctuary	0	0	0
Fakahatchee Strand State Park	0	0	0
Flint Pen Strand	0	0	0
Florida Panther NWR	0	0	0
Half Circle L Ranch	0	0	0
Hickey's Creek Mitigation	0	0	0
Hunters Ranch	3.7	2	5
Imperial Marsh Preserve	0	0	0
Picayune Strand State Forest	0	0	0
Pine Lake Preserve	0.33	0	1
Royal Palm Golf Club	3.7	2	5
Royal Poinciana Golf Club	3.3	3	4
Royal Wood Golf Club	0	0	0
Six Mile Cypress Slough	0	0	0
Sweet Cypress Ranch	0	0	0

Table 3: Mean BCFS counts on golf courses (see Figure 11 for locations).

Observation Site	mean	min	max
1. Audubon	0.67	0	1
2. Club at Olde Cypress	2.33	2	3
3. Club at Pelican Bay	0.67	0	2
4. Country Club of Naples	2.33	0	4
5. Foxfire	4	3	5
6. Glen Eagle	0	0	0
7. Hibiscus	6.33	6	7
8. Imperial	3.33	1	5
9. Laplaya	0.33	0	1
10. Naples National	1.33	1	2
11. Quail Creek	7.33	5	9
12. Quail West	2.67	2	4
13. Riviera	1.67	1	3
14. Royal Palm	7	5	8
15. Royal Poinciana	8.33	6	11
16. Royal Wood	0	0	0
17. Wildcat Run	1	0	2
18. Wilderness	5.33	4	7
19. Worthington	5.33	5	6
20. Wyndemere	3.33	3	4

Table 4: Locations and activity of nest boxes along ten transects (see Figure 12 for locations).

Nest Box Locations	**UTM locations of transects**	**Dominant Habitat**	**Date established**	**Box Use**
1 Big Cypress National Preserve	5 nest boxes start: 17R 0506664 / 2848524;end: 17R 0506703 / 2848351 (**Map: 1**) last 5 boxes start: 17R 0476961 / 2863152;end: 17R 0476972 / 2862925 (not shown on map)	hydric pine and cypress	January-07	unidentified bird nests
2 Collier-Seminole State Park	start: 17R 0439997 / 2875588;end: 17R 0439007 / 2875769 (**Map:2**)	mesic pine flatwoods	October-06	unidentified bird nests
3 Fakahatchee Strand State Park	start: 17R 0456497 / 2880444; end: 17R 0457215 / 2879730 (**Map: 3**)	mixed-hardwood forest	December-05	no confirmed activity
4 Hickey's Creek Mitigation Bank	start: 17R 0434164 / 2954740; end: 17R0433949 / 2954818 (**Map: 4**)	pine flatwoods	October-06	great-crested flycatchers and gray squirrels
5 Hunter's Ranch	start: 17R 0454003 / 2961637; end: 17R 0454010 / 2961571 (**Map: 5**)	pine	March-06	probable fox squirrel use
6 Johnson Grove	start: 17R 0442759/ 2927421; end: 17R 0442792 / 2927426 (**Map: 6**)	orange grove with pines	February-07	no confirmed activity
7 Picayune Strand State Forest	start: 17R 0443230 / 2888279; end: 17R 0443262 / 2889171 (**Map: 7**)	hydric pine flatwoods	August-05	screech owls and eggs observed
8 Pine Lake Preserve	start: 17R 0425519 / 2913828; end: 17R 0425981 / 2913548 (**Map: 8**)	hydric pine and cypress	September-06	unidentified bird nests
9 Royal Wood Golf and Country Club	start: 17R 0427545 / 2888541; end: 17R 0427413 / 2889117	pine	April-06	no confirmed activity

	(**Map: 9**)			
10 Sweet Cypress Ranch	start: 17R 0446747 / 2960614; end: 17R 0446636 / 2960416 (**Map: 10**)	pine and cypress	November-06	no confirmed activity

Table 5: BCFS road-kill locations and mortality rates.

Site	Total (N)	Time Frame	Mortality Rate (per month)	Date Collected	Site UTM
Royal Poinciana Golf	3	8 months	0.4	August 15, 2006	17R 0422088 / 2897259
				December 10, 2006	17R 0421899 / 2896289
				April 2, 2007	17R 0421353 / 2897673
Imperial Golf	3	6 months	0.5	June 18, 2007	17R0 422361 / 2908397
				October 26, 2007	17R 0421366 / 2908066
				December 13, 2007	17R 0422132 / 2908523
Club at Olde Cypress	4	2 months	2	October 3, 2007	17R 0428034 / 2906379
				November 6, 2007	17R 0428114 / 2906537
				November 7, 2007	17R 0427401 / 2906068
				November 14, 2007	17R 0427004 / 2906248
Pine Lake Preserve	2	4 months	0.5	April 5, 2007	17R 0426304 / 2913462
				August 21, 2007	17R 0426078 / 2914218

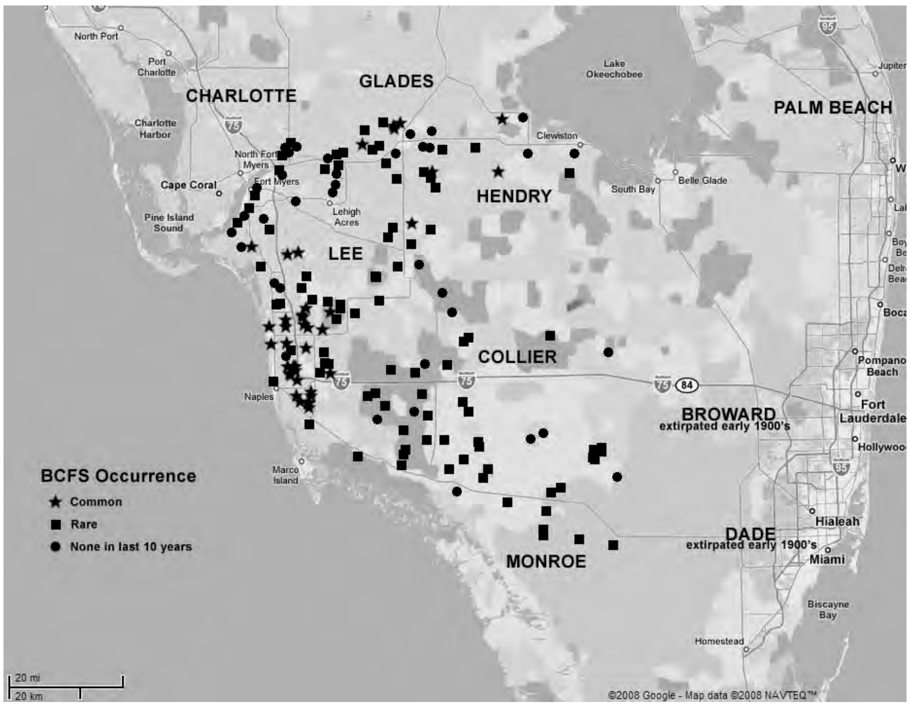

Figure 1: The current distribution of the Big Cypress fox squirrel.

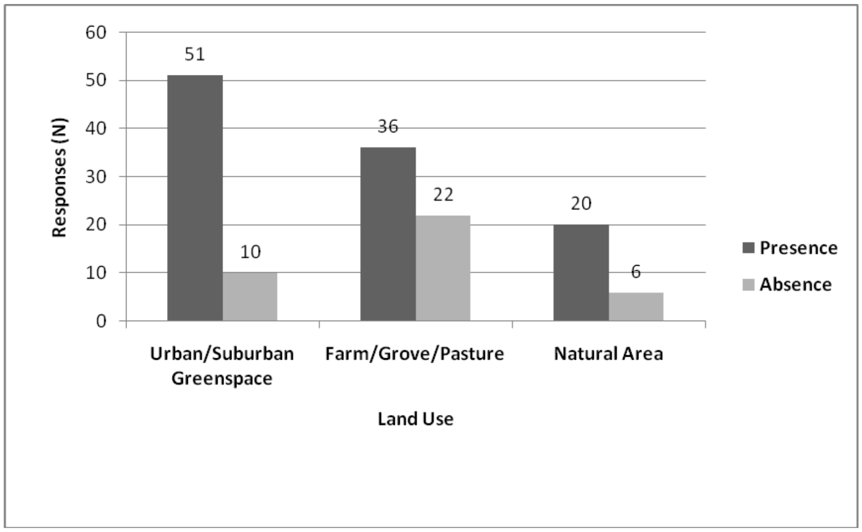

Figure 2: Presence/Absence of fox squirrels and land use (N=145).

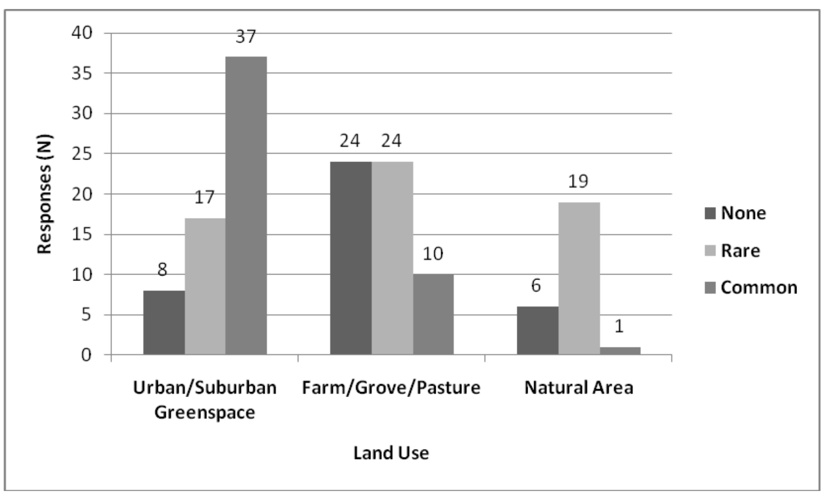

Figure 3: BCFS sightings and land use (N=145).

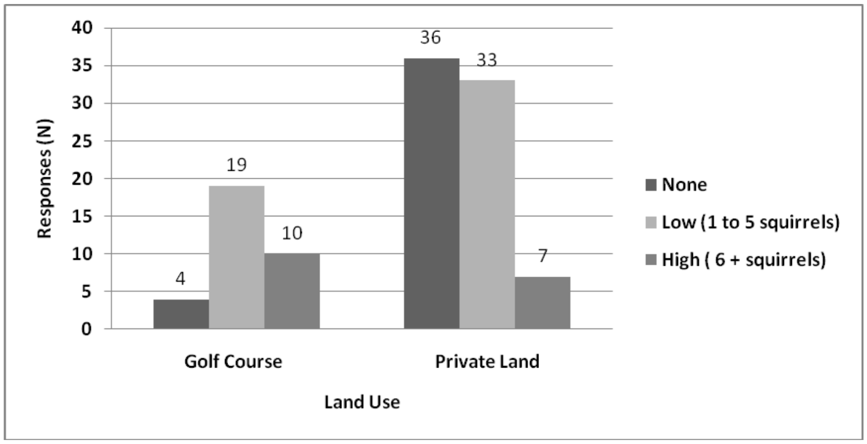

Figure 4: BCFS abundance and land use (N=109).

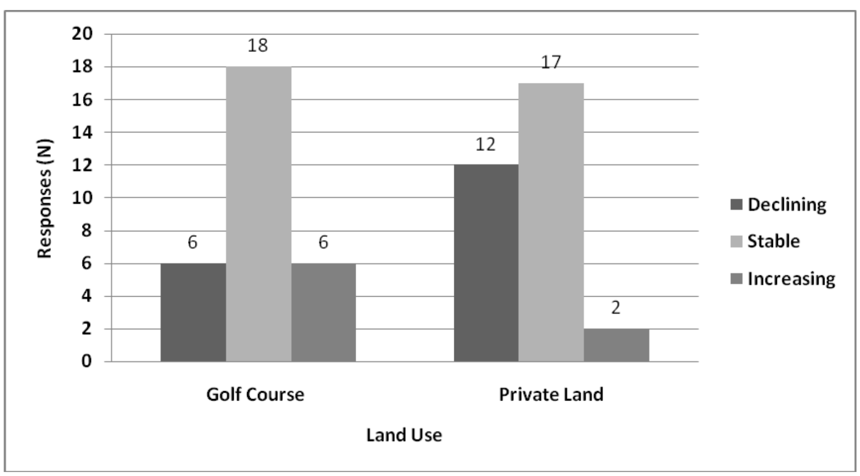

Figure 5: BCFS stability and land use (N=61).

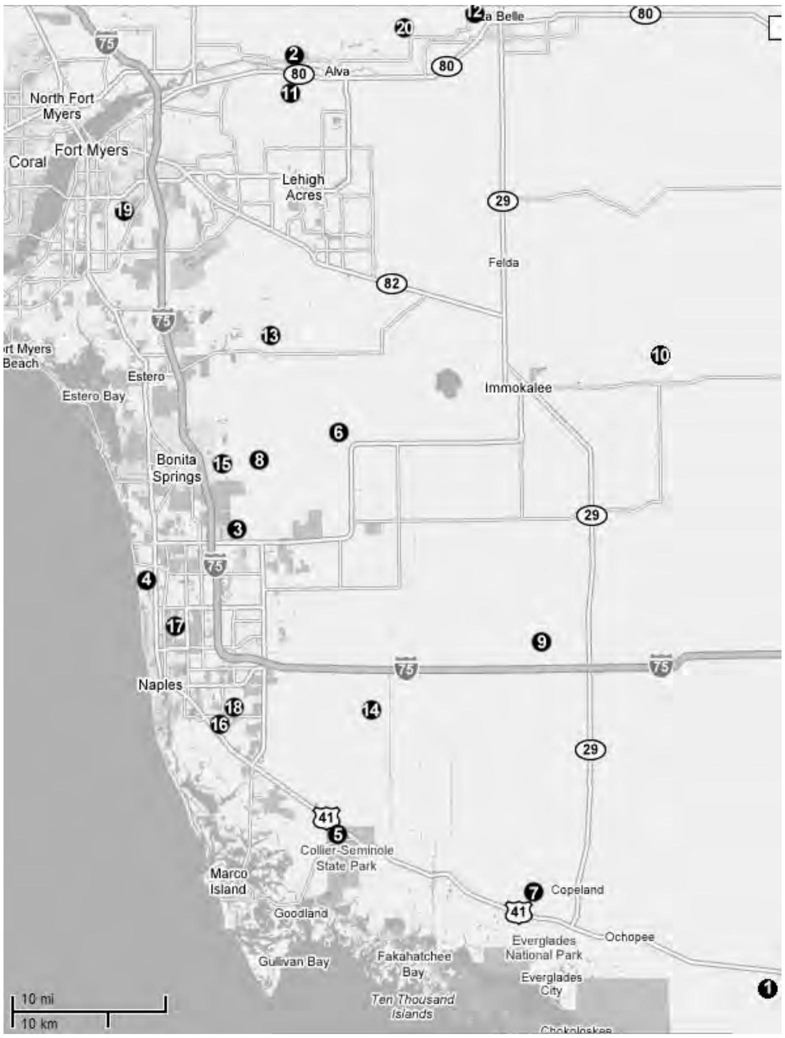

Figure 6: Locations of random transect sampling study sites (see Table 1 for legend and details).

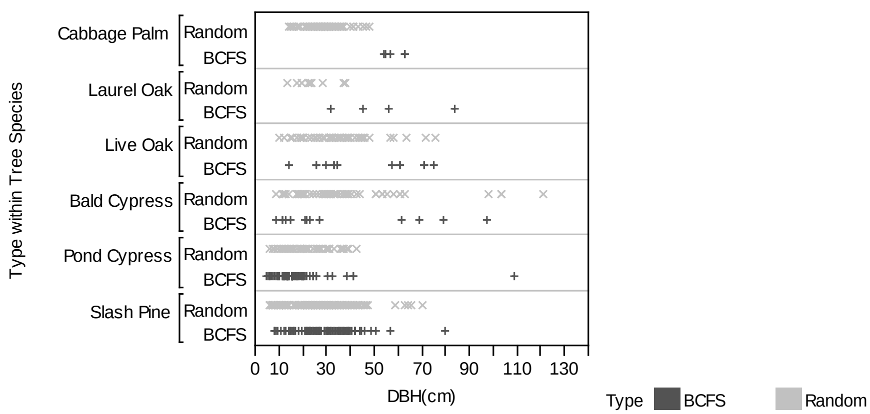

Figure 7: Comparisons of tree species and mean dbh in sites where fox squirrels were observed (BCFS) and where no squirrels (Random) were observed. (N= 665).

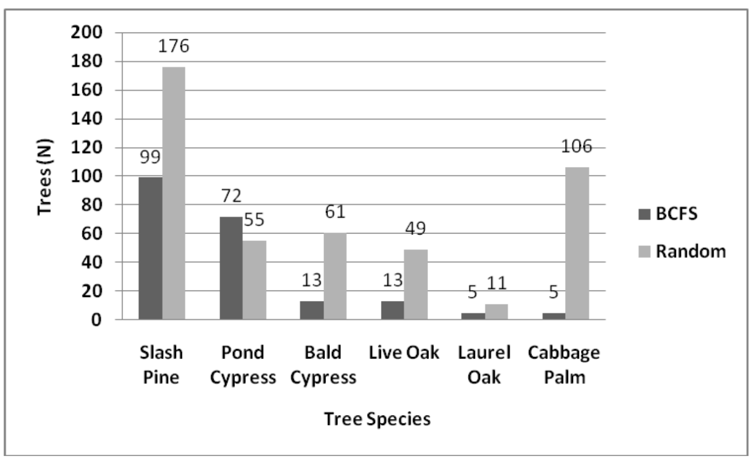

Figure 8: Comparisons of the abundance of different species of trees in sites where fox squirrels were observed (BCFS) and where no squirrels (Random) were observed (N=665).

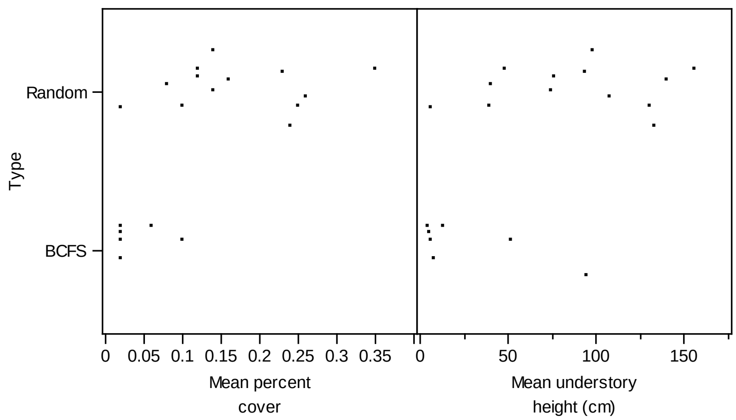

Figure 9 : Scatterplot of understory height and percent cover means in sites (BCFS) where squirrels were observed and site (Random) where no squirrels were observed (N=20).

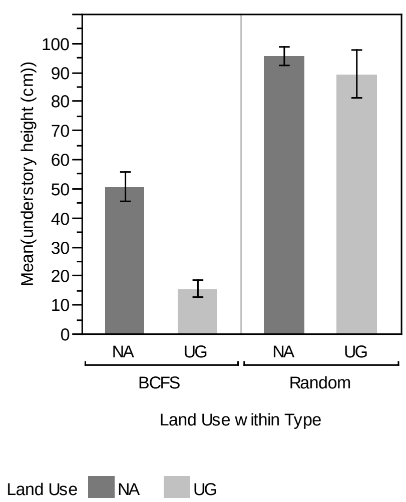

Figure 10: Mean understory height of sites in natural areas (NA) and urban greenspace (UG) where squirrels (BCFS) were observed and where no squirrels (Random) were observed (N=20).

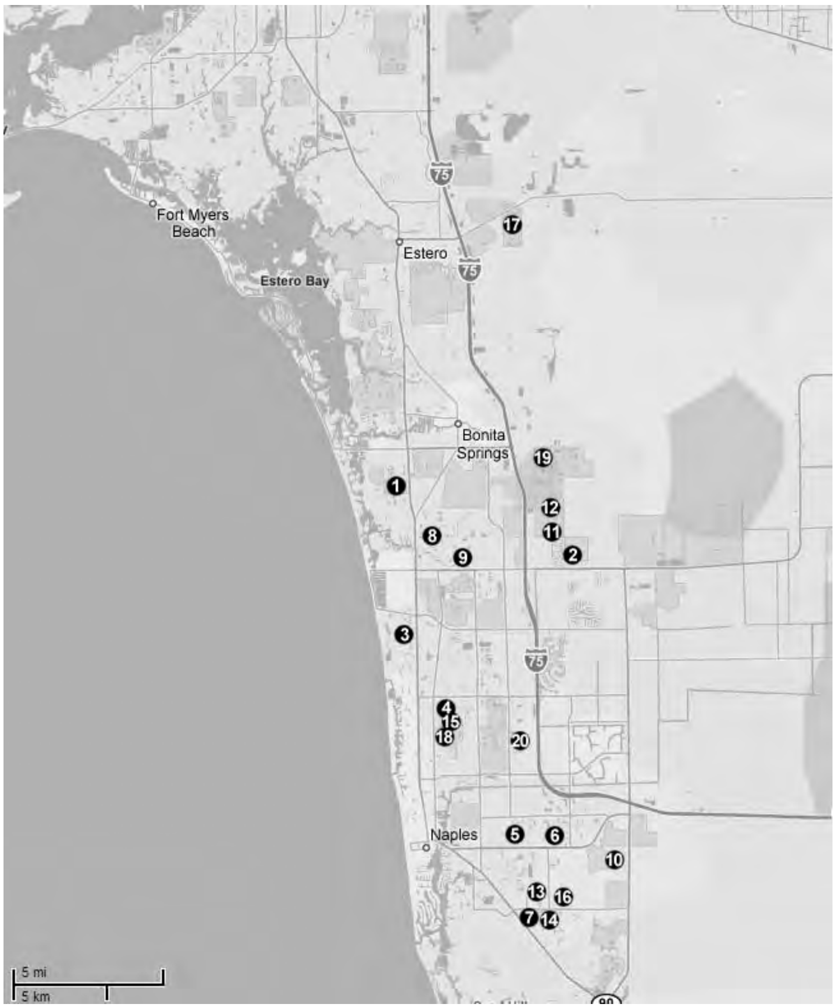

Figure 11: Locations of golf course observation sites (see Table 3 for map legend and mean BCFS counts).

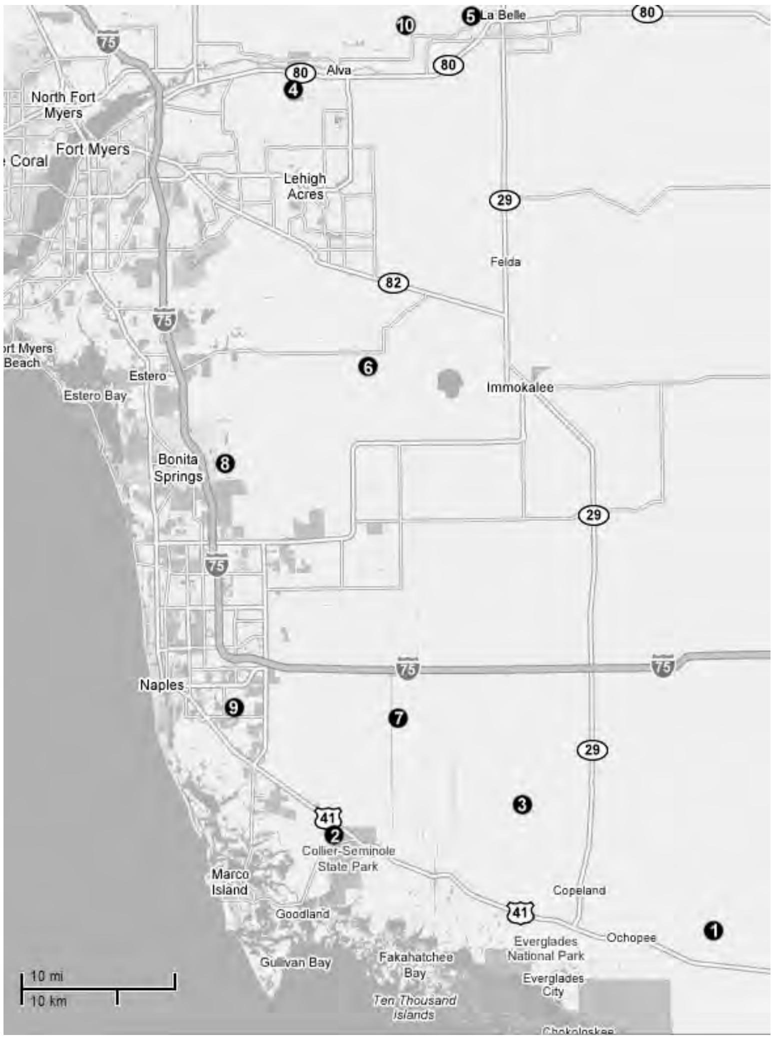

Figure 12: Locations of ten nest box transects (see Table 4 for details).

Appendix A: BCFS sighting history in natural areas.

Parks and Preserves	Contacts	BCFS Sightings	Sighting dates and coordinates (if available)
Big Cypress National Preserve	Lisa Andrews, Fred Dayhoff, Jim Bozzo	Rare	November 2004 (17R 0512051 / 2849261); January 2005 (17R 0513779 / 2849174); Summer 2005 (17R 0489988 / 2852266); March 2006 (17R 0489988 / 2852266);Spring 2006 (17R 0484858 / 2861048); November 30, 2006 (25.90747 81.09562)
Caloosahatchee Regional Park	Michelle Miller	No	last sightings over 10 years ago
Collier Seminole State Park	Kirby Wilson, Chris Kimball	Very Rare	Fall 1994; May 11, 1997; January 30, 1999; April 2004; January 31, 2005; October 4, 2006; January 2007
Corkscrew Swamp Sanctuary	Jason Lauritsen, Mike Knight, Dick Brewer	Very Rare	Census records/squirrel counts: October 1998 (42); November 1998 (31); December 1998 (13); January 1999 (7); February 1999 (71); March 1999 (77); April 1999 (10); May 1999 (3); October 1999 (4); December 1999 (7); March 2000 (6); February 2001 (4); September 2001 (4); November 2003 (3); February 2004 (3). Recent sightings: summer 2005 (17R0440048 / 2917453); January 2007
Delnor-Wiggins State Park	unidentified park ranger	No	no recorded sightings
Estero Bay State Park	unidentified park ranger	Very Rare	Summer 2003
Fakahatchee Strand State Park	Mike Owen, Dennis Giardina	Very Rare	March 9, 1984; March 8, 1986; March 23, 1991; April 21, 1996; November 11, 1996; December 30, 1998; February 14, 1998; February 24, 2001; December 30, 2004; April 28, 2006 (Township50-Range29-Section05);December 2, 2006 (17R0453180 / 2870121); February 19, 2007 (Janes Scenic Drive)
Flint Pen Strand	Paige Martin	Very Rare	Spring 2004 (17R 0427811 / 2923066); Summer 2005
Florida Panther National Wildlife Refuge	Larry Richardson, Takako Hashimoto	Very Rare	August 2004 (17R 0454302 / 2892893), December 21, 2004; June 2007 (17R 0452256 / 2893502)
Gator Hole Preserve	Lynne Boyd	No	no recorded sightings
Hickey's Creek Mitigation Park	Laura Greeno	Very Rare	April 2005; July 11, 2005 (17R 0434027 / 2954722); June 6, 2007

Imperial Marsh	Lynne Boyd	Very Rare	October 24, 2004; October 29, 2004; March 22, 2005
Koreshan	Michelle Miller	No	last sightings over 15 years ago
Okaloacoochee Slough State Forest	Kevin Podkowka	Very Rare	no recorded sightings
Picayune Strand State Forest	Amanda Peck	Very Rare	June 7, 2005 (17R 0443264 / 2888956)
Pine Lake Preserve	Lynne Boyd, Cathy Olson	Rare	March 8, 2005 (17R 0426188 / 2913832); March 25, 2005 (17R 0426143 / 2913506); March 30, 2005 (17R 0426079 / 2914107); May 6, 2005 (17R 0425978 / 2913697)
Six Mile Cypress Slough Preserve	unidentified park ranger	No	last sightings over 10 years ago
Wild Turkey Strand Preserve	Lynne Boyd	No	no recorded sightings

Appendix B: Trapping data

BCFS ID	Weight (g)	Sex	Capture Site
1	840	M	Royal Palm Golf
2	820	M	Royal Palm Golf
3	620	M	Royal Palm Golf
4	780	M	Royal Palm Golf
5	700	M	Royal Palm Golf
6	720	F	Royal Palm Golf
7	840	F	Royal Palm Golf
8	760	F	Club at Pelican Bay
9	485	M	Country Club of Naples
10	965	F	Royal Poinciana Golf
11	985	M	Royal Poinciana Golf
12	440	M	Wilderness Country Club
13	720	M	Foxfire Golf Club
14	780	F	Hibiscus Golf Club
15	740	M	Hibiscus Golf Club
16	880	M	Hunters Ranch
17	1010	M	Hunters Ranch

mean weight all squirrels	770 grams
mean weight males	752 grams
mean weight females	813 grams

Letters and emails received during the solicitation of information from the public period of September 17, 2010 through November 1, 2010

Email from Paula Halupa

From: Paula_Halupa@fws.gov
To: Imperiled; Garrison, Elina
Cc: Dana_Hartley@fws.gov
Subject: Re: Sherman"s fox squirrel - threats
Date: Tuesday, November 02, 2010 2:42:11 PM
Attachments: 19890328 phone call Humphrey with Service.pdf
Importance: High

Hi Elina,

During a quick search, I found this old telephone conversation record in our electronic files. I will try to search a few other files today to see if I can locate any additional information.

Thanks,

-Paula
(See attached file: 19890328 phone call Humphrey with Service.pdf)
^^^
Paula J. Halupa
Fish and Wildlife Biologist
Listing, Candidate Conservation, and Recovery
U.S. Fish and Wildlife Service
South Florida Ecological Services Office
1339 20th Street
Vero Beach, FL 32960-3559

March 28, 1989 telephone conversation with Dr. Steve Humphrey,
Florida Museum of Natural History

We discussed four species:

1. Steve has been working on the taxonomy of the Homossassa shrew, and believes that it represents a distinct species, with a range extending from Leon County (Tallahassee) to Polk County (Tiger Creek). It appears, therefore, to be a fairly wide-ranging species found in riparian areas and extending into hydric hammocks.

2. Pat Jodice is working with Steve on the Big Cypress fox squirrel. The animal is now very rare in the Big Cypress Preserve, with only a few animals having been seen in about a month and a half of looking. There are more animals around some of the golf course areas outside the Preserve. No one is sure why they have declined so much in the Preserve; poaching has been suggested as a cause but this has not been proven.

3. Sherman's fox squirrel - Steve says that forestry statistics show that longleaf pine stands have declined 90 percent from 1936 to 1986. Since this was the primary habitat of Sherman's fox squirrel, he feels that the species may soon need to be listed as threatened or endangered at the State (and presumably Federal) level.

4. Anastasia Island beach mouse - Steve has been working with Phil Frank on this subspecies on a State Nongame grant for several months. At the State Park, they have not found as many house mice as they expected (though populations may increase in the warmer months) but they have found large numbers of feral cats. This suggests that predation may be a more severe problem for beach mice at the State Park than competition from house mice. Cats and house mice are uncommomn at Fort Matanzas National Monument, which has more beach mouse habitat and a much denser beach mouse population.

Michael M. Bentzien
March 29, 1989

Email from Mark Fredlake

From: Fredlake Mark J Civ 23 WG DET 1 OL A/CEVN
To: Imperiled
Subject: Surveys of Sensitive Species on Avon Park Air Force Range: Sherman"s fox squirrel, gopher frog, Florida
mouse, Florida pine snake, Burrowi ng owl, etc.
Date: Monday, November 01, 2010 3:35:56 PM
Attachments: CHAP_7_APAFR_TortReport_2009.docx
Wetland Assessment 2002-2003.pdf
BUOW data.xlsx
BO observations.jpg

I am currently reviewing our files to determine if we have any information regarding the 61 species under review. I currently have found several reports of interest:

AVON PARK AIR FORCE RANGE PROJECT: DISTRIBUTION AND ABUNDANCE OF SENSITIVE WILDLIFE SPECIES AT AVON PARK AIR FORCE RANGE FINAL REPORT PROJECT RWO-169 DECEMBER 1998 authors: Richard Franz , David Maehr, Alton Kinlaw, Christopher O'Brien, and Richard D. Owen
This report contains information regarding population levels of the following species: Florida mouse: found commonly in well-drained soils through APAFR, in oak scrub and scrubby flatwoods. Live trapping effort yielded 274 captures of Florida mouse in 8160 trap nights, spread over a 16 month period.

Sherman's fox squirrel: Found in both native and planted pine stands, Sherman's fox squirrels prefer slash pine plantations over native long-leaf stands in APAFR. Population of fox squirrel for plantations in APAFR (7948 hectares) was estimated in the range of 433 to 867.

Florida gopher frog: documented in eleven breeding sites in APAFR mostly in the southern portion of the Bombing Range scrub ridge. Six to ten dry ponds were identified as potential breeding sites during wet seasons.

The report also documents the occurrence on APAFR of Florida pine snake based on one record along old Bravo Road, APAFR.

I suspect you probably have a copy of this report in your files. Nevertheless it can be downloaded from: http://aquacomm.fcla.edu/1072/1/OCRFranz%2C_R._1998.pdf

A second report (**BASELINE AQUATIC FAUNAL SURVEY OF AVON PARK AIR FORCE RANGE, FLORIDA: Fishes, Mollusks, and Crayfishes** PROJECT RWO-157. July 2000, Authors: Leo G. Nico, James D. Williams, and Holly N. Blalock-Herod) contains no information relevant to the special status species under review.
It can be downloaded from:
http://aquacomm.fcla.edu/1288/1/OCRNico%2C_L._2000.pdf

The third report: (**Population Survey and Monitoring of the Gopher Tortoise (*Gopherus polyphemus*) at Avon Park Air Force Range.** ANNUAL REPORT. October 2008 - September 2009 Authors: Betsie Rothermel, Ph.D. Traci Castellón, Ph.D. February 2010 Archbold Biological Station) contains some locations of Gopher Frog and Florida Pine

CHAPTER SEVEN (COMMENSUAL SPECIES) EXCERPT FROM: POPULATION SURVEY AND MONITORING OF THE GOPHER TORTOISE (*GOPHERUS POLYPHEMUS*) AT AVON PARK AIR FORCE RANGE. ANNUAL REPORT. October 2008 - September 2009

Authors:
Betsie Rothermel, Ph.D.
Principal Investigator

Traci Castellón, Ph.D.
Post-doctoral Research Fellow
February 2010

Archbold Biological Station
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brothermel@archbold-station.org

CHAPTER 7
COMMENSAL, MORTALITY, AND DISEASE MONITORING

Observations of Commensal Species

An additional objective of our research at APAFR was to document and gather data on Gopher Tortoise burrow commensals, especially for species of conservation concern (e.g., the Eastern Indigo Snake, *Drymarchon couperi*). In total, we encountered at least 11 species of vertebrate commensals since fieldwork began in March 2009 (Table 7). Observations were derived from examination of tortoise burrows using the video scope, records from field cameras with motion sensors located outside burrow entrances, and other opportunistic encounters. Commensals were observed inside tortoise burrows at 30 sites, and included 26 anurans (12 Gopher Frogs, one unidentified treefrog, and 13 unidentified anurans), six snakes (one Eastern Coachwhip, three Eastern Diamondback Rattlesnakes, one Pine Snake, and one Eastern Indigo Snake), and one unidentified mouse (possibly a Florida Mouse, *Podomys floridanus*).

Other vertebrates that were observed entering or exiting burrows included Eastern Cottontails at eight sites, Eastern Spotted Skunks at six sites, Nine-banded Armadillos at five sites, unidentified mice (Family Cricetidae, possibly the Florida Mouse) at nine sites, and a Hispid Cotton Rat at one site (Table 7). Two bird species (Bachman's Sparrow and Eastern Towhee) were also observed foraging in front of, entering, and leaving three different burrows. One Eastern Indigo Snake was also observed while driving along Frostproof Road.

Table 7. Observations of commensal species obtained from burrow scoping activities, motion-sensor field cameras and opportunistic sightings. Species, habitat type and UTM locations are provided. Habitats include the scrub stratum (Scrub) and the flatwoods and pine plantation strata (FW & PL).

Species	Habitat	GPS Northing	GPS Easting
Frogs and Toads	FW&PL	3066118	463999
Order Anura	FW&PL	3056124	476147
	FW&PL	3063795	462598
	FW&PL	3055430	484694
	FW&PL	3048967	467312
	Scrub	3064155	461833
	Scrub	3063997	471771
	FW&PL	3046819	468667
	Scrub	3064217	461853
	FW&PL	3046812	468546
	Scrub	3063968	471957
	Scrub	3064181	472290
	Scrub	3048791	474287
Treefrog	Scrub	3049025	474458
Family Hylidae			
Gopher Frog	Scrub	3060890	472404
Rana capito	Scrub	3054510	474003
	Scrub	3048157	474347
	Scrub	3059387	472678
	Scrub	3053088	474309
	FW&PL	3055451	484575
	Scrub	3054760	475692
	Scrub	3048278	474332
	Scrub	3048274	474490
	Scrub	3046769	474355
	Scrub	3049130	474690
	Scrub	3047054	474238
Eastern Coachwhip	Scrub	3064573	472035
Coluber (formerly *Masticophis*)			
flagellum			
Eastern Indigo Snake	Scrub	3060890	472404
Drymarchon couperi	FW&PL	3067011	459803

Pine Snake	Scrub	3056513	474555
Pituophis melanoleucus			
Eastern Diamondback Rattlesnake	Scrub	3057414	474260
Crotalus adamanteus	Scrub	3057484	474413
	FW&PL	3057080	473331
Eastern Towhees	Scrub	3060683	472265
Pipilo erythrophthalmus	Scrub	3060744	472560
Bachman's Sparrow	Scrub	3064570	472159
Aimophila aestivalis			
Nine-banded Armadillo	Scrub	3061106	472168
Dasypus novemcinctus	Scrub	3060890	472404
	Scrub	3060683	472265
	Scrub	3064574	472035
	Scrub	3060744	472560
Mouse	Scrub	3064261	472038
Family Cricetidae	Scrub	3061106	472168
	Scrub	3060486	472518
	Scrub	3060890	472404
	Scrub	3060824	472382
	Scrub	3060683	472265
	Scrub	3060744	472560
	Scrub	3064570	472159
	Scrub	3064574	472035
	Scrub	3060792	472092
Hispid Cotton Rat	Scrub	3061106	472168
Sigmodon hispidus			
Eastern Cottontail	Scrub	3061106	472168
Sylvilagus floridanus	Scrub	3060486	472518
	Scrub	3060890	472404
	Scrub	3060824	472382
	Scrub	3060683	472265
	Scrub	3064570	472159
	Scrub	3064574	472035
	Scrub	3060792	472092

Eastern Spotted Skunk	Scrub	3061106	472168
Spilogale putorius	Scrub	3060486	472518
	Scrub	3060890	472404
	Scrub	3060824	472382
	Scrub	3064570	472159
	Scrub	3064574	472035

Project Title: Wetland Assessment in a Landscape Context on Avon Park Air Force Range: Surveys for Wading Birds and Round-tailed Muskrats (*Neofiber alleni*)

Annual Report

Report Period: 1 July 2002 - 30 June 2003

Contract Number: UPN 01013122

Authors: Robert L. Schooley and Lyn Branch, Department of Wildlife Ecology & Conservation, University of Florida, Gainesville, FL 32611

Submitted: 30 June 2003

Background

Extensive loss and degradation of wetlands are among the most pervasive impacts by humans on the environment in Florida (Frayer and Hefner 1991). Diverse taxa depend on these declining habitats, and wetlands are the most highly ranked ecological communities in Florida, after coastal strands, for importance in supporting wildlife of conservation concern (Millsap et al. 1990). The most obvious effects of wetland loss and degradation are reductions in habitat amount and quality. Furthermore, wetland species may exhibit a metapopulation structure (Sjögren-Gulve and Ray 1996, Joly et al. 2001, Fedriani et al. 2001) in which subpopulations occur in relatively discrete patches of suitable habitat, experience repeated extinction and colonization events, and are connected by inter-patch dispersal (Hanski 1999). Hence, wetland loss further fragments already naturally patchy wetland systems, increases wetland isolation, and may affect dispersal success and regional persistence of metapopulations. Moreover, the functional connectivity (Wiens 1996) of wetlands may be decreased due to modifications of the terrestrial habitat matrix that hinder movements of organisms among wetlands. Understanding how landscape context affects wetland quality is a key step in assessing their value as wildlife habitat.

There also is a conspicuous lack of knowledge regarding the importance of small, isolated wetlands for wetland-associated species. Small wetlands (<4 ha) may be critical for maintaining adequate landscape connectivity for species with a metapopulation spatial structure (Gibbs 1993, Semlitsch and Bodie 1998), but empirical data for evaluating this proposition are sparse. For most wetland species, we also are uninformed whether there is a minimum critical patch size required for occupancy, and how such a size might correspond to existing wetland regulations (Kaiser 1998, Semlitsch and Bodie 1998).

The Avon Park Air Force Range (APAFR) contains >24,000 acres of wetlands. The relative use of these wetlands by different vertebrate species is unknown. APAFR has diverse upland plant communities (Bridges 2000) and assorted land uses, including military training, forestry, cattle grazing, and recreation. APAFR is one of the largest tracts of federal land in south-central Florida, and thus it is a key conservation area. Overall, APAFR is an ideal location for investigating the effects of natural landscape heterogeneity and land management on the distribution of wetland species.

This project is focusing on the use of wetlands by wading birds and round-tailed muskrats (*Neofiber alleni*). These species were selected because they use the landscape at different spatial scales (Birkenholz 1963, Haig et al. 1998) and should provide complementary perspectives regarding landscape effects on APAFR wetlands. Moreover, wading birds are state and federally listed in categories ranging from 'Species of Special Concern' to 'Endangered' and *Neofiber* is listed as a Species of Special Concern (Humphrey 1992) because of presumed statewide population declines due to wetland losses (Lefebvre and Tilmant 1992).

Project Objectives

1) Obtain baseline data for assessing the potential impacts of military operations on wetland conditions and connectivity as indicated by the focal species.

2) Provide information on the distribution and abundance of wading birds and round-tailed muskrats and the characteristics of their wetland habitats at APAFR.

3) Develop and test a predictive habitat model for round-tailed muskrats.

4) Provide recommendations concerning management and future research directions for wetlands at APAFR.

Main activities during this year

1) Designed a sampling protocol for aerial surveys of wading birds at APAFR.

2) Conducted three aerial surveys of wading birds.

3) Completed ground surveys of 459 wetlands for habitat characteristic and occupancy by wading birds, round-tailed muskrats, and marsh rice rats (*Oryzomys palustris*).

4) Initiated livetrapping and movement studies of round-tailed muskrats and marsh rice rats.

5) Created a spatially accurate GIS map layer for all of the wetlands for which we conducted ground surveys.

Methods

Aerial surveys of wading birds: distribution patterns and habitat correlates

We designed our aerial surveys after the Systematic Reconnaissance Flights (SRF) that are used for monitoring wading birds in the Florida Everglades. The SRF approach has been effective in relating the distribution and abundance of wading birds to hydrological patterns (Russell et al. 2002) and to nutrient enrichment (Crozier and Gawlik 2002). In general, evenly spaced transects following lines of latitude are flown at a low altitude in a fixed-wing aircraft, and two observers on opposite sides of the airplane count all birds observed within a predetermined strip width. We established 15 transects across the entire APAFR that were separated by 1.5 km and flown in a Cessna 172 in alternating directions (west-to-east and east-to-west) at an altitude of 250 feet (76 m). Each of the two back-seat observers counted birds in a 150-m strip. Hence, for each transect we sampled a 300-m combined strip, which resulted in a 20% sample of the total area (300 m out of 1500 m). For comparison, the Everglades SRF are flown on transects separated by 2 km at an altitude of 200 ft. (60 m) using 150-m strips for a 15% sample of the area (Crozier and Gawlik 2002, Russell et al. 2002).

Each observer recorded the number of individuals of each species seen within the viewing strip into a microcassette recorder. The potential species included wood storks (*Mycteria americana*), great egrets (*Ardea alba*), white ibis (*Eudocimus albus*), great blue herons (*Ardea herodias*), sandhill cranes (*Grus canadensis*), and 'small white herons'. This last group mainly consisted of cattle egrets (*Bubulcus ibis*) and perhaps an occasional snowy egret (*Egretta thula*). For each observation, we also recorded the longitude along the transect using an onboard GPS system. Thus, we have spatial locations for all observed wading bird individuals or groups.

For analysis, we will divide the study area into 2.25-km^2 cells. The flight transects pass through the center of the cells. Various predictor variables will be measured for each cell and correlated with the number of individuals of each species per cell and the total number of individuals per cell (Crozier and Gawlik 2002, Russell et al. 2002). The explanatory variables will include the total area of wetland habitat, diversity of wetland types, density and median size of wetlands, perimeter-to-area ratios for wetlands, cover of matrix habitat, distance to major rivers and lakes, and land use (including percent of each cell within an active bombing range). We will also aggregate the cells into larger cell sizes (e.g., 4.5-km^2, 9-km^2) and repeat the analyses. This multi-scale approach should help to identify particular spatial scales at which wading birds are responding most strongly to their environment. Insights from this type of analysis should be valuable for designing future monitoring programs for wading birds at APAFR.

We flew a practice flight on 14 February 2003 (2.7 hours total flight time) and conducted our first regular survey on 28 February 2003 (2.8 hours). Unfortunately, we were not given final clearance for the survey flight from the Air Force until <24 hours before takeoff. This late notification caused us to lose our regular pilot (that we used for the practice flight), and forced us to use a substitute pilot. Due to some miscommunication with the new pilot, our survey transects were not flown on the correct latitudes. Hence, the flight on 28 February must be considered a preliminary survey, and we will only report some summary statistics for counts of wading birds. We conducted another survey on 31 May 2003 (2.8 hours) following the correct flight path. The May survey was completed toward the end of the period when shallow wetlands dry out, and thus it provides a useful contrast with the February survey when most wetlands still held water.

Statistical analyses of the wading bird counts will be performed after we finish creating a spatially referenced GIS map layer of wetlands for the entire APAFR. We currently have one for the southern half of the study area only (see below).

Ground surveys of wetlands

We focused our sampling of wetlands on the southern half of APAFR because it contains most of the landscape-scale variation in plant communities and land use found within APAFR. Moreover, we detected a higher occupancy rate for *Neofiber* in the southern half of the APAFR during our preliminary surveys in the spring-summer of 2002.

Wetland-level variables

We recorded habitat characteristics of each wetland during our surveys. Our methodology is designed to allow for rapid assessment without detailed vegetation measurement. Such procedures allowed us to sample a large number of wetlands, and they should be useful for future monitoring of wetland conditions.

We visually estimated the percent of each marsh covered by different plant zones (≤4) and measured traits of those zones: dominant species, cover, height of emerged plants, and water depth. For each marsh, we also recorded the substrate type, percent of marsh with water, presence of trees and shrubs, and the upland plant communities in the immediate neighborhood.

Wetland mammals and wading birds

We surveyed marshes for round-tailed muskrats and for marsh rice rats by searching for their lodges, feeding platforms, and feces. Because rice rats are more of a generalist species with an omnivorous diet (Wolfe 1982) compared to the relatively specialized and herbivorous muskrats, we expected that rice rats would have a higher occupancy rate than that of muskrats. This wider distribution might enable us to detect impacts on rice rats from military operations or other management that are not revealed for the more sparsely distributed muskrat.

Initially, we surveyed the entire marsh for sign of the two mammal species. We always began the searches in the plant zones where we were most likely to find muskrat or rice rat lodges. To facilitate a more rapid survey method, we recorded how much time it took until positive sign (a lodge) was first encountered in occupied marshes. We used these data to set a standardized maximum search time for marshes.

Based on conditions of lodges, we classified muskrat and rice rat sign within wetlands as either current use (Y) or past use (P). For this report, we calculated occupancy rates using all sign (i.e., marshes classified as Y or P). We present occupancy patterns for all surveys conducted between 1 July 2002 and 15 February 2003.

We also recorded the species and number of wading birds observed in wetlands during our ground surveys. Most species were seen during our initial approach to the marshes. One exception was the American bittern (*Botaurus lentigenosus*), which is a secretive bird that prefers wetlands with thick vegetation (Riffell et al. 2001). Bitterns typically were seen only when they were flushed from dense plant cover at a short distance (<20 m) during our walking surveys.

Landscape context

We obtained UTM coordinates for the center of each surveyed wetland using a hand-held global positioning system (Garmin GPS 76). These units had WAAS (Wide Area Augmentation System) correction and typically provided estimated accuracies of <5 m. We will use these spatial coordinates in preliminary analyses of wetland connectivity.

A more complete analysis of landscape context and connectivity will incorporate information on plant communities and land use from GIS layers for the APAFR. Because the current GIS map layer for plant communities (and wetlands) is not geo-rectified, and the project for updating the plant layer is substantially behind schedule, it is necessary that we piece together the spatial data layers required for our analysis of landscape context effects. We plan to use the new landscape association map based on Bridges (2000) as a base vegetation map. To this layer, we will add our surveyed marshes and other wetland types (e.g., cypress stands, sawgrass, hardwood swamps). We created a spatially accurate map layer of these wetlands by using low-altitude aerial photographs from 1999 to move wetlands from the current GIS plant community map to their correct positions. In addition, we identified a number of marshes that were not on the current GIS plant community map. We added these to our map layer by digitizing in ArcView (using the aerial photographs) or by delineating the marsh boundaries in the field with a GPS unit. We will add additional map features in the future, including pine plantations that are currently being digitized by Peg Margosian, and any spatially referenced data available on cattle grazing, fire history, and military activities.

Preliminary analyses

Spatial autocorrelation in ecological data can lead to false conclusions about relationships (Lichstein et al. 2002). We calculated correlograms based on Moran's *I* to evaluate potential autocorrelation in the occupancy patterns of *Neofiber* and *Oryzomys*. Correlograms display the degree of correlation in variables in space across a range of scales. We used indicator correlograms, which are simply correlograms based on binary data (presence and absence).

We examined the relationship between wetland area and the probability of occupancy by round-tailed muskrats, rice rats, and American bitterns using logistic regression. We $\log_{10}$-transformed wetland area prior to analyses. We present incidence curves that include the predicted probabilities of occupancy and 95% confidence envelopes on these estimates.

We used multiple logistic regression models to evaluate the ability of several wetland-level traits to predict occupancy of wetlands by *Neofiber* and *Oryzomys*. In the models, we included wetland area, wetland perimeter, substrate type, and some measure of habitat quality as explanatory variables. For *Neofiber*, we used a single variable for quality that was a ranking based on the coverage of plant zones with maidencane (*Panicum hemitomon*) as a dominant or codominant species. The presence of a plant zone with dense, emergent maidencane may be an important variable for predicting wetland occupancy by muskrats because it is a preferred species for food and lodges (Birkenholz 1963, Franz et al. 1998). *Oryzomys* seems to prefer several plant species for lodge building, including pickerelweed (*Pontederia cordata*), sand cord grass (*Spartina bakeri*), and soft rush (*Juncus effusus*). We included these three variables in models as binary variables (presence or absence of zone dominated by the species).

Livetrapping of muskrats and rice rats

We initiated livetrapping efforts aimed at *Neofiber* to determine whether future work on movement behavior would be feasible. *Neofiber* is considered a difficult species to capture. For instance, Bergstrom et al. (2000) reported only one capture in >800 trap nights.

We designed a small platform (30.5 x 61 cm) made of plywood with three adjustable legs made of PVC pipes to use in the shallow marshes where the muskrats occur. The adjustable legs allowed us to quickly change the height of the platforms when water levels changed. We attempted to keep the platforms level with the water surface. On each platform, we placed one Tomahawk live trap (15 x 15 x 40 cm) baited with apple slices. The trap was placed near the back of the platform so that there was a small platform area in front of the trap opening where a muskrat could sit and feed on additional apple bait. We placed platforms and traps near active lodges or natural platforms when possible. Our trap design was also suitable for capturing rice rats.

For all captured animals, we recorded their age, sex, and reproductive status. Beginning in June, we marked muskrats with PIT tags (Schooley et al. 1993) and rice rats with ear tags.

Results and Discussion

Wading birds

Aerial Surveys

We counted a total of 410 wading bird individuals during our survey on 28 February 2003 and 230 on 31 May 2003 (Table 1). Hence, we expect there will be substantial seasonal variation in the number of wading birds foraging at APAFR. For comparison, Crozier and Gawlik (2002) counted an average of 323 individuals in a wet year, and 804 in a dry year, on a similar-sized study area (WCA 2A in the northern Everglades; 42,206 ha).

During both of our surveys, white ibis were the most numerous species (Table 1). This result is not surprising because white ibis typically occurred in relatively large groups (15 – 80 individuals). We counted more wood storks in May compared to February, even though fewer wading birds were observed overall (Table 1). The wood storks might have been attracted to wetlands that still had water, but in which some drying had occurred, because foraging wood storks require receding water levels that concentrate prey (Bancroft et al. 1992).

The total number of individuals varied considerably among transects (Fig. 1). In both surveys, there was a peak between transects 8 and 11. There was a striking absence of wading birds on the four most southern transects during the May survey (Fig. 1). Overall, there was much spatial variation in the counts (Appendix 1), which we will be able to correlate to landscape characteristics.

Ground surveys

We observed wading birds in 121 of 459 (0.26) marshes. The number of species in any one marsh ranged from 0-6 (Fig. 2). The 12 species detected in decreasing incidence were the

American bittern (n = 70 marshes), great egret (n = 39), great blue heron (n = 29), sandhill crane (n = 15), cattle egret (n = 12), white ibis (n = 8), wood stork (n = 5), little blue heron (*Egretta caerulea*, n = 5), green heron (*Butorides virescens*, n = 2), tricolored heron (*Egretta tricolor*, n = 2), snowy egret (n = 1), and rail (*Rallus* sp., n = 1). The species richness of wading birds was positively related to wetland size (X^2 = 29.31, P = 0.0001, R^2 = 0.19) but not to wetland perimeter (X^2 = 0.02, P = 0.8966).

Other water birds that we observed included the mottled duck (*Anas fulvigula*), hooded merganser (*Lophodytes cucullatus*), double-crested cormorant (*Phalacrocorax auritus*), anhinga (*Anhinga anhinga*), pied-billed grebe (*Podilymbus podiceps*), and greater yellowlegs (*Tringa melanoleuca*).

American bitterns are difficult to survey due to their preference for dense cover and ability to stay well hidden. Surveys of bitterns during the breeding season rely on broadcasting recorded vocalizations to elicit responses (Riffell et al. 2001). Our sightings of flushed birds during walking surveys also should provide useful data on incidence because we typically search all of the dense plant zones. American bitterns are migratory and we first observed an individual during surveys on 7 October 2002. Hence, we calculated an estimate of patch occupancy restricted to the 394 marshes surveyed after the 'arrival date'. American bitterns occurred in 70 (0.18) marshes, had a patchy distribution (Fig. 3), and their probability of occupancy was related to wetland area (Fig. 4). Wetland area and vegetation density were the most important explanatory variables for bitterns on their breeding range (Riffell et al. 2001).

Wetland mammals

Wetland traits

Many of the shallow depression marshes at APAFR are small (median = 0.92 ha), but there is a large amount of variation in wetland size (Table 2). The distribution of wetland area was skewed with a long right tail. Most of the wetlands were filled with water (Table 2) during our ground surveys, although many of these dried out completely in late March to May 2003. Water depths are typically only 20 – 40 cm in most plant zones (Table 2), but water levels fluctuate widely on short time scales in response to rain events. Wetland organisms must be adapted to this sort of environmental variability. Most of the surveyed wetlands had a mucky substrate, contained trees, had trees along their edges (including escaped slash pines from nearby plantations), and about half had shrubs along their edges (Table 3).

Sampling effort and search time

For round-tailed muskrats, we surveyed 106 marshes from 7 August to 12 November 2002 in which we recorded the amount of time required to find positive sign in occupied marshes (n = 27). Two observers were present for most (87%) of these surveys; 3-5 observers were present for the remainder. In most of the marshes (96%), the first sign was encountered in <15 min (Fig. 5). The one marsh that required 32 min was 3.2 ha and had a thick coverage of maidencane and pickerelweed. For marsh rice rats, we surveyed 98 marshes from 4 September to 12 November 2002 in which we recorded the amount of time required to find positive sign in occupied marshes (n = 42). Again, two observers were present for most (86%) of the surveys, and 3-5 observers were present for the rest. In most of the marshes (95%), the first sign was encountered in <30 min (Fig. 5). The two marshes that required >30 min were >1 ha and had thick plant cover. We concluded that a 30-min search was adequate to determine whether these two mammal species were present in most marshes. Hence, we restricted most additional surveys to 30 min, but extended the search time up to 60 min for large marshes with exceptionally dense plant cover.

From 1 July 2002 to 15 February 2003, we conducted surveys of 459 marshes for the presence of muskrats and rice rats. This sampling effort not only exceeds our proposed effort for this project (225 patches), it also greatly surpasses the sample sizes for most previous studies of patch occupancy by mammals (e.g., Franz et al. 1998, Forys and Humphrey 1999, Hanski 1999, Fedriani et al. 2002). Overall, at least two observers searched most wetlands (97.6%), and often there were 3-4 observers (54.1%). We generally used ≥4 observers for larger marshes (>2.5 ha).

Wetland occupancy: round-tailed muskrats and marsh rice rats

As expected, the occupancy rate of marshes (n = 459) was substantially lower for round-tailed muskrats (0.26) than for marsh rice rats (0.55). Muskrats not only occurred in fewer wetlands, they also had a more patchy distribution on a broad scale (Appendices 2 and 3). In particular, muskrats were nearly absent from the southwest portion of the study area south of Arbuckle Marsh and west of Van Eeghen Road.

The xeric scrub ridge in the center of the study area contained only a few, isolated marshes. Round-tailed muskrats occupied none of these wetlands (Appendix 2). Hence, the scrub ridge might separate our study area into two relatively independent patch networks for *Neofiber*. In contrast, marsh rice rats occurred in several of the wetlands imbedded in the scrubby area (Appendix 3).

The distribution of both muskrats and rice rats exhibited positive spatial autocorrelation at fine scales (<1.5 km), but the pattern was stronger for the muskrats (Fig. 6). Such results can be due to autocorrelation of environmental variables related to occupancy, or to spatial dynamics of the species independent of measured variables. In either case, our logistic regression results must be considered preliminary. Our final analyses will include an evaluation of whether we need to statistically control for broad-scale spatial trend (with trend surface analysis) and for fine-scale autocorrelation (with autoregressive models).

The occupancy of wetlands was positively related to wetland size for round-tailed muskrats and for marsh rice rats (Fig. 7). Because of differences in overall occupancy rates and the shapes of the incidence curves, the point where the probability of occupancy was ≥50% differed substantially for the two species (muskrats = 6.2 ha, rice rats = 0.7 ha). Interestingly, wetland area did not explain a large amount of the variance for either mammal species (Fig. 7).

Of the four wetland-level variables that we evaluated for predicting occupancy of *Neofiber*, habitat quality was the most important (Table 4, Figure 8). In fact, the importance of wetland area was marginal when included in the model with habitat quality. The model with only quality explained 29% of the overall variation, whereas a model with area and quality explained 32%. This outcome is at odds with current ideas on spatially structured metapopulations, in which patch area is assumed to be a key determinant of occupancy (Hanski 1999).

For *Oryzomys*, wetland area was an important predictor variable (Table 5). Habitat quality, as indexed by the presence of *Juncus*, *Spartina*, and *Pontederia*, was also related to occupancy (Table 5). The logistic regression model that included wetland area and the three indicator species explained 20% of the overall variation in occupancy.

For both mammal species, there was a fair amount of unexplained variance that may be related to variables not used in our preliminary models, including other wetland traits, isolation, land use, and landscape context. Moreover, we should be able to refine our measures of habitat quality for future analyses.

Livetrapping of muskrats and rice rats

In March 2003, the capture success of *Neofiber* was 6.9% (19 captures/276 trapnights), and the capture success of *Oryzomys* was 5.8% (16/276). In June 2003, the capture success of *Neofiber* was only 1.6% (8 captures/513 trapnights), and all of the captures were of the same individual. The seasonal decline in capture success for *Neofiber* coincided to a general lack of activity in the shallow depression marshes; we found no fresh muskrat lodges during May or June. *Neofiber* must burrow in other areas during the periods when wetlands are dry and when early summer rains refill the wetlands. The capture success of *Oryzomys* in June was 6.2% (32/515), so we initiated movement experiments with them aimed at determining their ability to locate and orientate toward wetlands while dispersing (Zollner 2000).

Potential effects of land use

We will evaluate the potential influences of military activities and other land uses on wetland quality, landscape connectivity, and vertebrate distribution patterns at APAFR. Our general analytical approach will be to develop correlative habitat models using environmental variables (e.g., wetland size, wetland quality, isolation, matrix habitat), and then to ask whether additional variation in patterns of distribution and abundance can be explained by land use. The degree that we can incorporate different types of land use as predictor variables in our statistical models for wading birds and marsh mammals will depend on the availability of spatially referenced data. Ideally, we plan to examine levels of military activity, current and past grazing pressures, fire histories, and planting of pine plantations. Moreover, we will evaluate whether roadside ditches might serve as movement corridors for *Neofiber* and *Oryzomys* indirectly by comparing models of landscape connectivity that either include or exclude these linear elements in the calculation of wetland isolation.

The most significant finding of our preliminary analysis is the importance of habitat quality of wetlands in determining distribution patterns of *Neofiber*. Wetland size may matter, but quality matters more. Therefore, land use could influence wetland occupancy not only by affecting the nature of matrix habitat and wetland connectivity, but also by directly affecting the habitat quality of the wetlands. For instance, cattle grazing could influence the cover of maidencane in marshes via herbivory and trampling, or road building and pine planting could alter hydrological patterns and the vegetation of wetlands. Finally, the round-tailed muskrat currently occurs in marshes throughout much of Echo, Charlie, and OQ ranges at APAFR. Therefore, any substantial changes in activities and land use within these areas could potentially influence the distribution and network-level persistence of this patchily distributed mammal.

Main activities for next year

1) Conduct six additional aerial surveys of habitat use by foraging wading birds at APAFR.

2) Resurvey 459 wetlands for habitat characteristics and for the presence of wading birds, round-tailed muskrats, and marsh rice rats.

3) Continue livetrapping of round-tailed muskrats and marsh rice rats and conduct studies to obtain data on movement behavior, space use, and inter-wetland dispersal.

4) Conduct statistical analysis for (a) distribution patterns of wading birds, and (b) predictive models of patch occupancy for muskrats, rice rats, and American bitterns.

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Literature Cited

Bancroft, G. T., W. Hoffman, R. J. Sawicki, and J. C. Ogden. 1992. The importance of the water conservation areas in the Everglades to the Endangered wood stork (*Mycteria americana*). Conservation Biology 6:392-398.

Bergstrom, B. J., T. Farley, H. L. Hill, Jr., and T. Hon. 2000. Ecology and conservation of a frontier population of the round-tailed muskrat (*Neofiber alleni*). Occasional Papers North Carolina Museum Natural Science 12:74-82.

Birkenholz, D. E. 1963. A study of the life history and ecology of the round-tailed muskrat (*Neofiber alleni* True) in north-central Florida. Ecological Monographs 33:255-280.

Bridges, E. L. 2000. Vegetation/landscape mapping for Avon Park Air Force Range, Florida: an ecological landscape association classification system. Final Report to Department of Defense, DAC01-96-D-0009.

Crozier, G. E., and D. E. Gawlik. 2002. Avian response to nutrient enrichment in an oligotrophic wetland, the Florida Everglades. The Condor 104:631-642.

Fedriani, J. M., M. Delibes, P. Ferreras, and J. Roman. 2002. Local and landscape habitat determinants of water vole distribution in a patchy Mediterranean environment. Ecoscience 9:12-19.

Forys, E., and S. R. Humphrey. 1999. The importance of patch attributes and context to the management and recovery of an endangered lagomorph. Landscape Ecology 14:177-185.

Franz, R., D. Maehr, A. Kinlaw, C. O'Brien, and R. D. Owen. 1998. Distribution and abundance of sensitive wildlife species at Avon Park Air Force Range. Final Report to Department of Defense, RWO-169.

Frayer, W.E., and J.M. Hefner. 1991. Florida wetlands: Status and trends, 1970's to 1980's. U.S. Fish and Wildlife Service, Atlanta, Ga. 32 pp.

Gibbs, J. P. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands 13:25-31.

Haig, S. M., D. W. Mehlman, and L. W. Oring. 1998. Avian movements and wetland connectivity in landscape conservation. Conservation Biology 12:749-758.

Hanski, I. 1999. Metapopulation ecology. Oxford University Press.

Humphrey, S. R. (ed.). 1992. Rare and endangered biota of Florida. Volume I. Mammals, University Press of Florida.

Joly, P., C. Miaud, A. Lehmann, and O. Grolet. 2001. Habitat matrix effects on pond occupancy in newts. Conservation Biology 15:239-248.

Kaiser, J. 1998. New wetlands proposal draws flak. Science 279:980.

Lefebvre, L. W., and J. T. Tilmant. 1992. Round-tailed muskrat (*Neofiber alleni*). Pages 276-286 *in* Humphrey, S. R. (ed.), Rare and endangered biota of Florida. Volume I. Mammals. University Press of Florida.

Lichstein, J. W., T. R. Simons, S. A. Shriner, and K. E. Franzreb. 2002. Spatial autocorrelation and autoregressive models in ecology. Ecological Monographs 72:445-463.

Millsap, B. J. Gore, D. Runde, and S. Cerulean. 1990. Setting priorities for the conservation of fish and wildlife species in Florida. Wildlife Monograph 111.

Riffell, S. K., B. E. Keas, and T. M. Burton. 2001. Area and habitat relationships of birds in Great Lakes coastal wet meadows. Wetlands 21:492-507.

Russell, G. J., O. L. Bass, Jr., and S. L. Pimm. 2002. The effect of hydrological patterns and breeding-season flooding on the numbers and distribution of wading birds in Everglades National Park. Animal Conservation 5:185-199.

Semlitsch, R. D., and J. R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Schooley, R. L., B. Van Horne, and K. P. Burnham. 1993. Passive integrated transponders for marking free-ranging Townsend's ground squirrels. Journal of Mammalogy 74:480-484.

Sjögren-Gulve, P., and C. Ray. 1996. Using logistic regression to model metapopulation dynamics: large-scale forestry extirpates the pool frog. Pages 111-137 *in* McCullough, D. R. (ed.), Metapopulations and Wildlife Conservation, Island Press. Washington, D. C., USA.
Wiens, J. A. 1996. Wildlife in patchy environments: metapopulations, mosaics, and management. Pages 53-84 *in* McCullough, D. R. (ed.), Metapopulations and Wildlife Conservation, Island Press. Washington, D. C., USA.
Wolfe, J. L. 1982. *Oryzomys palustris*. Mammalian Species 176:1-5.
Zollner, P. A. 2000. Comparing the landscape level perceptual abilities of forest sciurids in fragmented agricultural landscapes. Landscape Ecology 15:523-533.

Table 1. Aerial counts of wading birds on 15 transects at APAFR. We sampled 20% of the study area during the surveys. 'Small white herons' are primarily cattle egrets.

Species	28 February 2003		31 May 2003	
	Count	%	Count	%
Wood stork	8	1.95	21	9.13
White ibis	276	67.32	167	72.61
Great egret	51	12.44	31	13.48
Great blue heron	17	4.16	8	3.48
'Small white heron'	56	13.66	3	1.30
Sandhill crane	2	0.49	0	0.00
TOTAL	410		230	

Table 2. Continuous environmental variables measured at 459 wetlands surveyed from 3 July 2002 – 15 February 2003. The traits are potential explanatory variables for predictive habitat models.

Variable	Mean	SE	Median	Minimum - Maximum
Area (ha)	1.92	0.22	0.92	0.04 – 73.79
Perimeter (m)	535.4	27.1	376.0	94.0 – 6832.0
Water cover (%)	88.57	1.07	100	0 – 100
Mean water depth (cm)	22.3	0.62	22.8	0 - 80.8
Water depth of deepest zone (cm)	36.8	0.91	35	0 - 115

Table 3. Categorical environmental variables measured at wetlands surveyed from 3 July 2002 – 15 February 2003 at APAFR.

Variable	No. of wetlands	%
Substrate		
Mucky	387	84.3
Sediment	69	15.0
Other	3	0.6
Trees in wetland		
Present	275	60.0
Absent	183	40.0
Trees along wetland edge		
Present	337	73.6
Absent	121	26.4
Shrubs along wetland edge		
Present	215	46.9
Absent	241	53.1

Table 4. Logistic regression analysis of occupancy of shallow marsh wetlands ($n = 459$) by round-tailed muskrats (*Neofiber alleni*). The model includes four patch-level variables. Wetland area was log-transformed. Significance was based on a Type III analysis.

Source of variation	d.f.	X^2	*P*
Wetland area	1	2.42	0.1194
Wetland perimeter	1	0.97	0.3253
Habitat quality	1	82.16	**0.0001**
Substrate	1	0.79	0.3745

Table 5. Logistic regression analysis of occupancy of shallow marsh wetlands ($n = 459$) by marsh rice rats (*Oryzomys palustris*). The model includes six patch-level variables. Wetland area was log-transformed. Significance was based on a Type III analysis.

Source of variation	d.f.	X^2	*P*
Wetland area	1	19.96	**0.0001**
Wetland perimeter	1	1.07	0.2998
Juncus	1	9.37	**0.0022**
Spartina	1	26.96	**0.0001**
Pontederia	1	5.25	**0.0220**
Substrate	1	0.51	0.4742

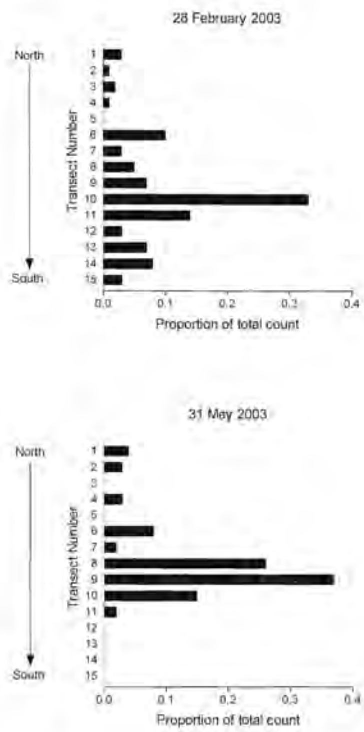


Figure 1. Distribution of wading birds counted along 15 transects during aerial surveys at Avon Park Air Force Range.

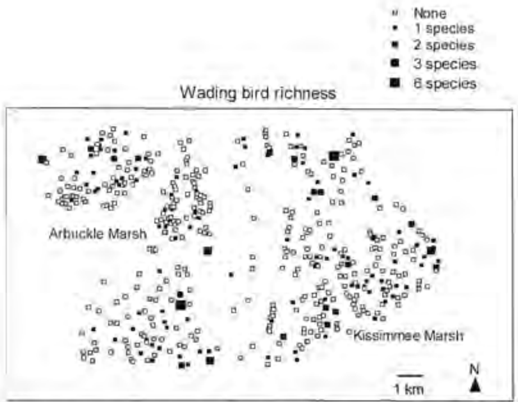


Figure 2. Species richness of wading birds in depression marshes (n = 459) at Avon Park Air Force Range, July 2002-February 2003 based on ground surveys of wetlands.

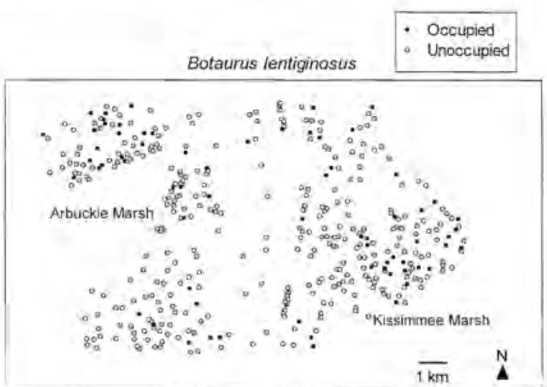


Figure 3. Patterns of patch occupancy for American bitterns (*Botaurus lentiginosus*) at Avon Park Air Force Range, October 2002-February 2003. Each circle indicates the location of a depression marsh (n = 394).

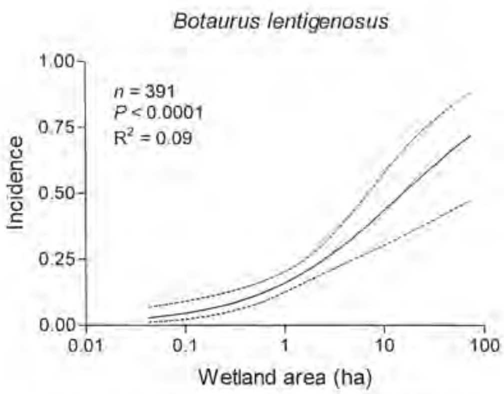


Figure 4. Relationship between wetland size and the probability of wetland occupancy by American bitterns (*Botaurus lentigenosus*). The incidence curve is based on predicted probabilities from a logistic regression model. Dotted lines indicate a 95% confidence envelope for the predicted values. The X-axis is on a $\log_{10}$ scale.

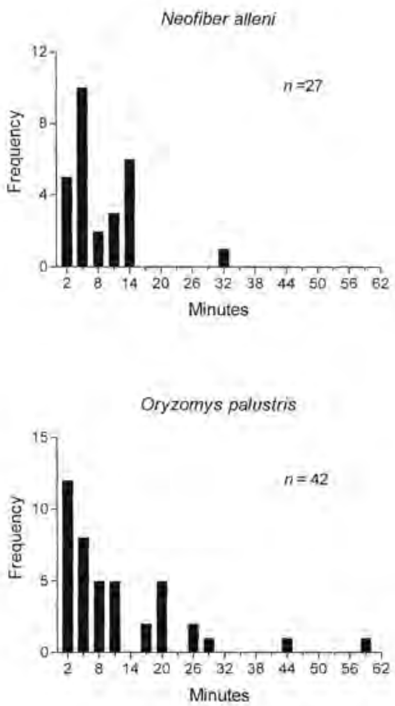


Figure 5. The amount of time until the first sign of occupancy was encountered for round-tailed muskrats (*Neofiber alleni*) and marsh rice rats (*Oryzomys palustris*) during wetland surveys. The sample size refers to the number of depression marshes with sign of occupancy.

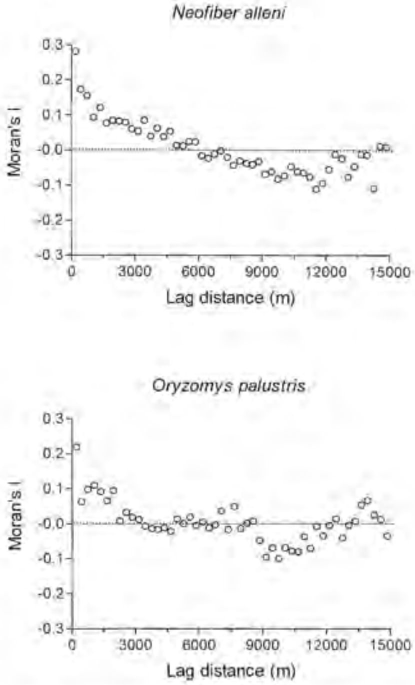


Figure 6. Isotropic indicator correlograms for wetland occupancy by round-tailed muskrats and marsh rice rats. The correlograms indicate the degree of spatial autocorrelation in occupancy patterns across a range of spatial scales. Positive values at small lag distances indicate that nearby wetlands have similar values (if a marsh is occupied then the neighboring marshes tend to be occupied).

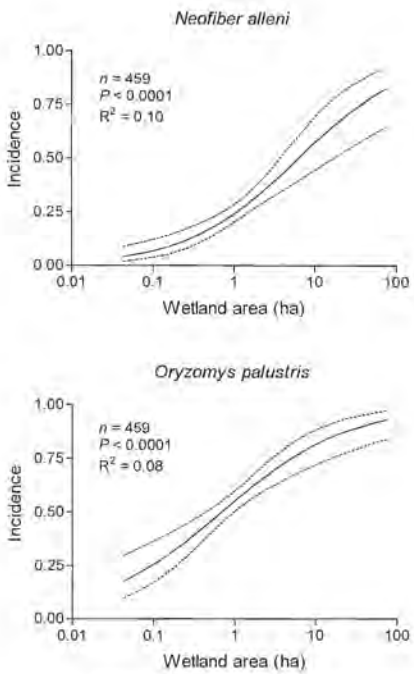


Figure 7. Relationship between wetland size and the probability of wetland occupancy by round-tailed muskrats (*Neofiber alleni*) and by marsh rice rats (*Oryzomys palustris*). The incidence curves are based on predicted probabilities from logistic regression models. Dotted lines indicate 95% confidence envelopes for the predicted values. The X-axes are on a $\log_{10}$ scale.

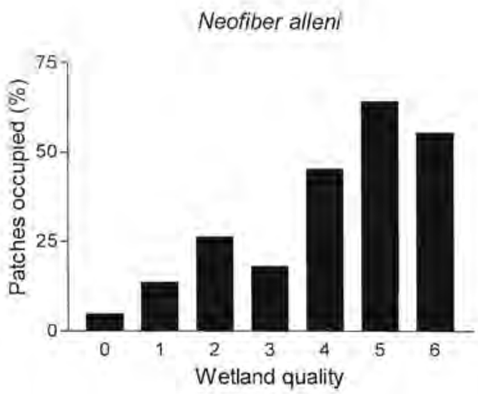
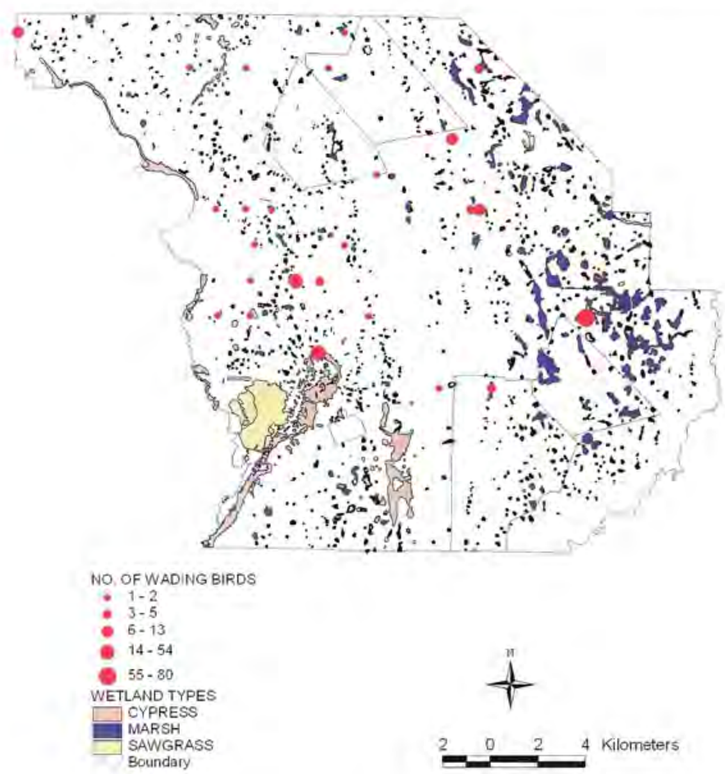
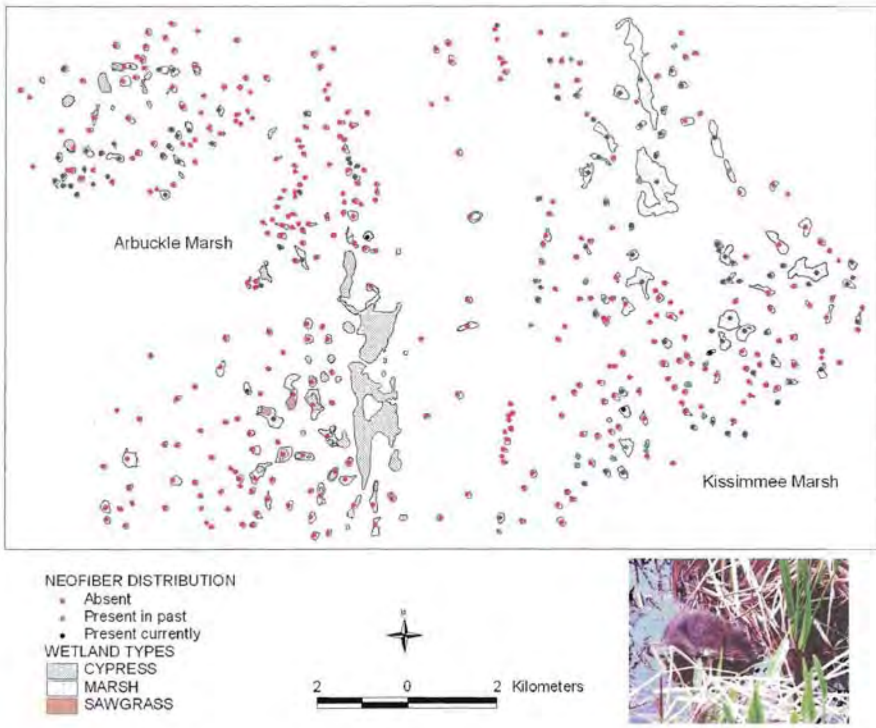


Figure 8. Relationship between habitat quality and occupancy of wetlands by round-tailed muskrats. Quality is a rank based on the coverage of plant zones in which maidencane is a dominant or codominant species.

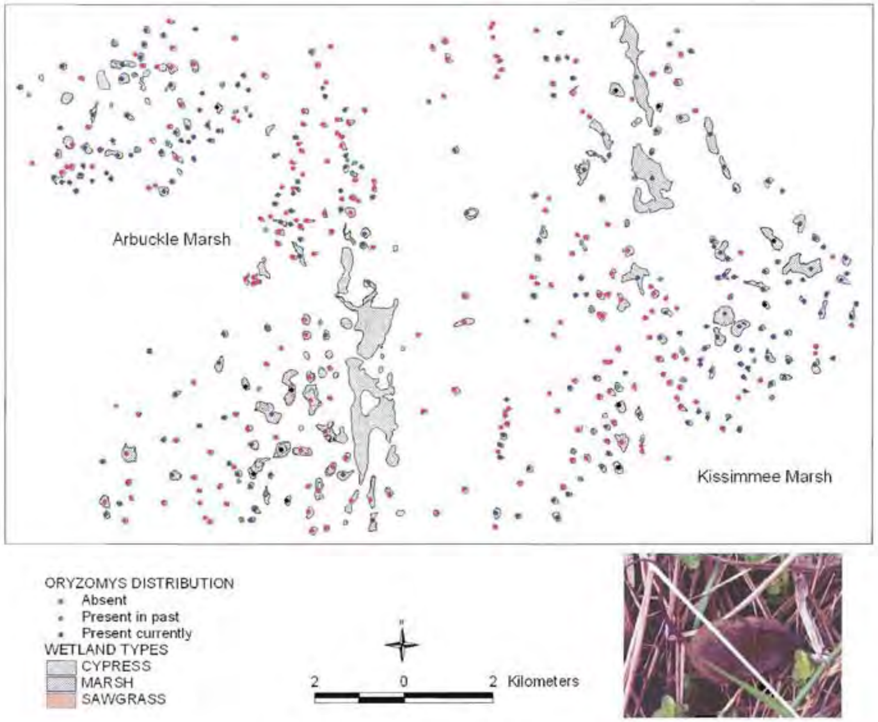
Appendix 1. Spatial distribution of wading birds from aerial survey at APAFR on 31 May 2003.



Appendix 2. Distribution patterns of round-tailed muskrats at Avon Park Air Force Range, 2002-2003.

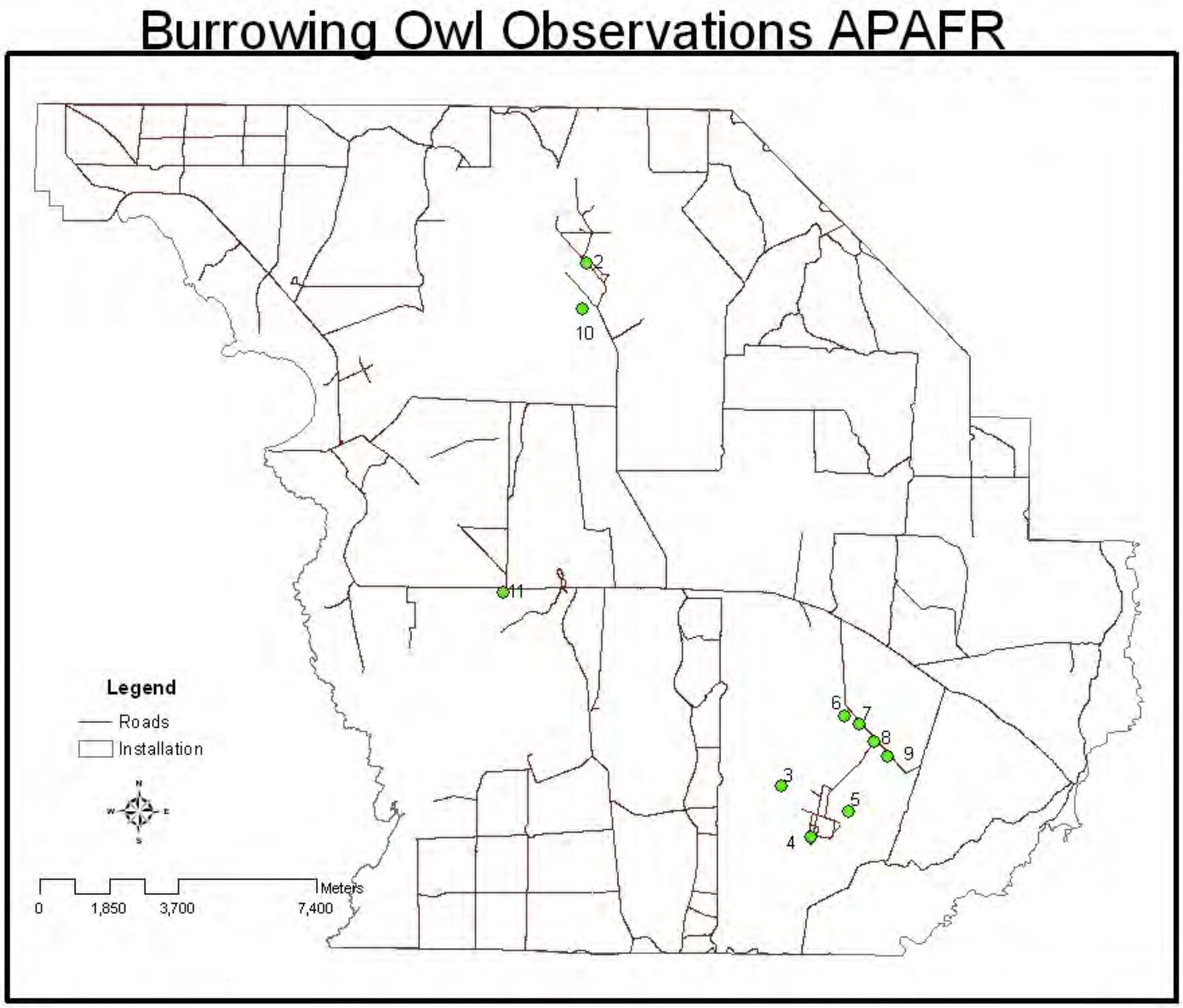


Appendix 3. Distribution patterns of marsh rice rats at Avon Park Air Force Range, 2002-2003.



Date	Location	Notes
6/5/2009	Foxtrot, near point 214	pair with burrow in bomb crater, near targets.
late march, not seen upon return a month later	Echo, near point 61	Single bird flushed from recent burn, digging burrow. Inactive as of 6/18
5/15/2009	Echo, south of point 53	Single bird flushed from active burrow. Inactive as of 6/1
5/14/2009	Echo, near point 149	Single bird seen, no burrow. Seen again in the same area 5/25, being mobbed by red-winged blackbirds
late march, seen almost every time we drove by	Charlie-Echo road, just south of North Tower	pair with burrow along road
late march, seen almost every time we drove by	Charlie-Echo road, between Middle and North Towers	Pair with burrow along road, at least 1 chick by mid June
6/5/2009	Charlie-Echo road, just south of Middle Tower	Single bird at burrow along road. Re-sighted twice in June
6/7/2009	Charlie-Echo road, Between Middle and South Towers	1 adult and at least 2 fledglings near burrow along road. Re-sighted a few more times throughout June and July
7/3/2009	bravo range,	1 adult, perched in

	about 400m west of OP1, along the range that goes through bravo range	burnt shrub, being mobbed by nighthawks										
7/11/2009	OQ range, along Kissimmee road	1 adult, flew in front of car and landed on fence post. 7/24 and 7/26 2, possibly 3 birds were seen flying back and forth across the road between OQ and Delta										



Burrowing Owl Observations APAFR
Legend
Roads
Installation
0
1,850
3,700
7,400
Meters
2
10
11
3
4
5
6
7
8
9

Copy of the Sherman's fox squirrel BSR draft report that was sent out for peer review

Biological Status Review for the Sherman's fox squirrel (*Sciurus niger shermani*)

EXECUTIVE SUMMARY

The Florida Fish and Wildlife Conservation Commission (FWC) directed staff to evaluate all species listed as Threatened or Species of Special Concern as of September 1, 2010. Public information on the status of the Sherman's fox squirrel was sought from September 17 to November 1, 2010. The members of the biological review group (BRG) met on November 3-4, 2010. Group members were Elina Garrison (FWC lead), Robert McCleery (University of Florida), and John Kellam (National Park Service). In accordance with rule 68A-27.0012 Florida Administrative Code (F.A.C.), the BRG was charged with evaluating the biological status of the Sherman's fox squirrel using criteria included in definitions in 68A-27.001(3), F. A. C., and following the protocols in the *Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Version 3.0)* and *Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1)*. Please visit http://www.myfwc.com/WILDLIFEHABITATS/imperiledSpp_listingprocess.htm to view the listing process rule and the criteria found in the definitions.

The Sherman's fox squirrel BRG concluded from the biological assessment that the Sherman's fox squirrel did not meet any of the criteria for designation as a State-threatened species. They also, however, expressed concerns about the adequacy of the data currently available for making this evaluation. FWC staff therefore recommends that the Sherman's fox squirrel be maintained as a Species of Special Concern with the associated protections until more data can be collected.

This work was supported by a Conserve Wildlife Tag grant from the Wildlife Foundation of Florida.

BIOLOGICAL INFORMATION

Taxonomic Classification –Sherman's fox squirrel (*Sciurus niger shermani*) is one of three subspecies of fox squirrels occurring in Florida. Sherman's fox squirrel has been defined to the subspecies *Sciurus n. s.* on the basis of size (it is only slightly larger than *S. n. niger*, but considerably larger than *S. n. avicennia*; Moore 1956; Turner and Laerm 1993 as cited in Wooding 1997).

Life History – Sherman's fox squirrel is a large (600-700mm) tree squirrel with highly variable dorsal fur color ranging from silver to all black (uncommon), with variations of silver over black and black over silver (Florida Natural Areas Inventory 2001). Ideal habitat for

Sherman's fox squirrels is mature, open, fire-maintained longleaf pine (*Pinus palustrus*) - turkey oak (*Quercus laevis*) sandhills and flatwooods (Florida Natural Areas Inventory 2001; Kantola 1992, Kantola and Humphrey 1990, Moore 1957). To accommodate the large home-ranges and fluctuating food resources, suitable habitat should also include more productive lower slopes of sandhills (Kantola 1992). This species also inhabits mixed hardwood pine, mature pine forests, cypress domes, pastures, the ecotone between bayheads and pine flatwoods, and other open habitats with pines and oaks (summarized in Endries *et al*. 2009; Florida Natural Areas Inventory 2001).

Sherman's fox squirrel typically has two breeding seasons each year. The winter breeding season is from October to February and the summer breeding season is from April to August (Wooding 1997). Males expand their home ranges during the breeding season and several males will cluster around a single female while she is in estrus (Wooding 1997; see Koprowski 1994 for a summary of breeding behavior in *Sciurus niger*). Females average one litter per year with a mean of 2.3 offspring per litter (Moore 1957, Wooding 1997), compared with 2.5-3.2 young for the midwestern fox squirrel (Kantola 1992). Young are weaned at 90 days and sexual maturity is reached at about 9 months. Captive fox squirrels have lived more than 10 years (Moore 1957); however, based on an annual mortality rate of 30% for radio-collared adult squirrels and field observations, average longevity in the wild is likely considerably less than 10 years (Wooding 1997).

Longleaf pine seeds and turkey oak acorns appear to be some of the main food items utilized by Sherman's fox squirrels. Squirrels have been observed to move their home ranges into live oak forests if a mast failure of turkey oak occurs (Kantola and Humphrey 1990). The highest quality habitat for Sherman's fox squirrel may therefore be habitat that includes both longleaf pine savanna and live oak forest (Kantola and Humphrey 1990). Additional food items include other acorns, fungi, bulbs, vegetative buds, insects, nuts and staminate pine cones (Kantola 1992).

Sherman's fox squirrels use several different nests in their home ranges (Kantola and Humphrey 1990). Most nests are leaf nests made of Spanish moss, pine needles, twigs, and leaves, while a few nests are within tree cavities (Kantola and Humphrey 1990). In the Katharine Ordway Research Preserve, nests of Sherman's fox squirrels were found in six tree species: slash pine, post oak, laurel oak, live oak, turkey oak, and longleaf pine (Kantola and Humphrey 1990).

Sherman's fox squirrels in Florida occur at lower densities and have larger home ranges than estimates obtained for *Sciurus niger* elsewhere in its range (Wooding 1997). A population size of approximately 100-200 animals was estimated to inhabit the 37 km^2 area occupied by the Katharine Ordway Research Preserve, Putnam County, Florida (Kantola and Humphrey 1990). Other density estimates in Florida range from 7 to 38 individuals/ km^2 (Wooding 1997; Humphrey et al. 1985, Kantola 1986, and Moore 1957). Average home range size for Sherman's fox squirrels is 16.7 ha for females and 42.8 ha for males (Kantola and Humphrey 1990). In contrast, midwestern fox squirrel home ranges average 0.8-7.0 ha (Kantola 1992). Sherman's fox squirrel adults defend mutually exclusive core areas (Kantola and Humphrey 1990). Males have home ranges that overlap with those of females and other males, but there is very little overlap in home ranges of adult females (Wooding 1997). The relatively large home ranges of

Sherman's fox squirrels may result from a food supply that varies in time and space (Kantola and Humphrey 1990).

The low carrying capacity in Florida may be explained by a lack of high quality, storable seeds, coupled with periodic failures of seed crops (Wooding 1997). Habitat that is low in productivity leads to low population densities, large home range sizes, and the low production of young per unit area (Wooding 1997).

Geographic Range and Distribution – Three surveys have assessed the distribution of fox squirrels in Florida (Brady 1977; Williams and Humphrey 1979; Wooding 1997). Based on morphological characteristics, *Sciurus niger shermani* range includes most of peninsular Florida, extending northward into central and southern Georgia, westward into Gilchrist and Levy counties, southward on the west coast probably to the vicinity of the Caloosahatchee River (at least to Highlands and Hillsborough counties), and southward on the east coast to Jupiter, Palm Beach County (Moore 1956; Wooding 1997).

Population Status and Trend – Population size of Sherman's fox squirrels is unknown. However, based on known levels of habitat loss, Sherman's fox squirrels are believed to have declined at least 85% from presettlement levels (Kantola 1992). Sherman's fox squirrels are rare because their habitat has been lost or degraded, and that which is left is highly fragmented (Kantola 1992; Wooding 1997). These trends are expected to continue due to the persistent destruction of *S. n. shermani*'s native habitat (FWC 2005; Kantola and Humphrey 1990, Wooding 1997). It is predicted that between 2010 and 2020, approximately 4% of Florida's total land area will undergo urban development. It is also predicted that 39.4% of the converted land will be native habitat (Zwick and Carr 2006). Conversely, Florida's programs for purchasing public conservation lands (e.g., Preservation 2000 and Florida Forever) have likely offset some of these losses. In addition, efforts are being made to restore degraded sandhill habitat (http://myfwc.com/wildlifelegacy/fundedprojects/GrantDetails.aspx?ID=215) These restoration projects will increase the quantity and quality of habitat for wildlife species on 6,740 ha of sandhill habitat in Florida by 2012 and may offset some of the future habitat loss and fragmentation. Approximately 50% of potential habitat is on conservation lands, the other 50% is vulnerable to degradation or conversion to other uses (Endries et al. 2009, M. Endries, FWC, unpublished data).

Quantitative Analyses – A population viability analysis was carried out on Sherman's fox squirrel using demographic information from the species as a whole (Root and Barnes 2006; Endries *et al*. 2009). The baseline model estimated a finite growth rate of 1.0034. Initial abundance was estimated at 0.025 while carrying capacity was estimated at 0.18. Results revealed that the risk of extinction in the next 100 years was zero for both managed habitat and all potential habitat. The risk of large declines was also very small (for example, the probability of a 50% decline was ~18%). The model was very sensitive to small changes in survival and fecundity so, considering what little is known about this species' demographics, the validity of the results are questionable. Regardless, changes to the finite growth rate altered the probability of a large decline in the population as a whole, but did not change the probability that the species would not go extinct over the next 100 years.

BIOLOGICAL STATUS ASSESSMENT

Threats – The biggest threat to Sherman's fox squirrels is destruction of habitat due to encroaching development (FWC 2005; Kantola and Humphrey 1990). Such habitat loss has already been significant; it is estimated that only 10-20% of original Sherman's fox squirrel native habitat is still intact, most of it having been logged, converted to pasture, ruined by lack of fire, or used for agriculture, commercial development, and residential development (Bechtold and Knight 1982 as cited in Kantola 1992). Florida's longleaf pine forests in particular were reduced by 88% between 1936 and 1986, to the extent that by 1987 only 0.38 million ha remained (Wooding 1997). Many of the other habitat types in which Sherman's fox squirrels are found are declining. Mixed hardwood-pine forest is declining; natural pineland, sandhill, and scrub are in poor condition and declining; and the condition of disturbed/transitional habitat is unknown (FWC 2008). Such habitat destruction is expected to continue as Florida's population continues to expand (FWC 2005; FWC 2008; Zwick and Carr 2006). In addition, most remaining tracts of longleaf pine savanna in Florida are not of good quality (Kantola and Humphrey 1990). Logging and the suppression of fire have led to the replacement of pine trees by turkey oak over much of *S. n. shermani*'s range (Kantola and Humphrey 1990). Yearly burns of longleaf pinelands on northern bobwhite quail (*Colinus virginianus*) plantations also prevent pine seedling growth, damaging the habitat for fox squirrels and other wildlife (Kantola and Humphrey 1990). For proper regeneration, longleaf pine savanna habitat requires a burning regime in which areas are prescribed burned every 3 to 5 years (Kantola and Humphrey 1990).

Hunting of Sherman's fox squirrels also may have been detrimental to local populations, particularly small, isolated populations that have low potential for recolonization (Kantola 1992). Presumably this threat has ceased as hunting of Sherman's fox squirrel is no longer permitted.

Sciurus niger shermani is currently listed as Lower Risk, near threatened by the IUCN Rodent Specialist Group because of "extensive loss of the habitat of *S. n. shermani*, which could be mitigated by establishment of preserves of adequate size" (Hafner *et al*. 1998).

The recommended action of the IUCN Rodent Specialist Group (Hafner *et al*. 1998) was:

"Establish large (several km^2) preserves of longleaf pine habitat for *S. n. shermani*; management should include a natural fire-cycle of burning at 3 to 5-year intervals."

Kantola (1992) recommended: (1) preserving and reclaiming large areas (at least 25 km^2) of Sherman's fox squirrel habitat with a prescribed summer burn every 2 to 3 years; (2) conduct status surveys to determine population levels throughout the fox squirrel's range; and (3) determine the effects of hunting on small or closed populations.

Statewide Population Assessment – Findings from the BRG are included in a Biological Status Review information table. Please see Appendix 1 for additional notes and clarifications.

LISTING RECOMMENDATION – The BRG found the Sherman's fox squirrel did not meet any of the criteria for designation as a State-threatened species, but they also expressed concerns about the adequacy of the data for making this evaluation. They referenced uncertainties in current estimates of extent of occurrence, area of occupancy, recent trends, and population size. Because the *Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1)* cautioned “assessors should adopt a precautionary but realistic attitude, and … resist an evidentiary attitude to uncertainty when applying the criteria,” Staff recommends that the Sherman’s fox squirrel be maintained as a Species of Special Concern until more data can be collected. Research is planned over the next 2 years to assess the taxa’s range, population genetics, and habitat occupancy.

SUMMARY OF THE INDEPENDENT REVIEW

LITERATURE CITED

Bechtold, W.A. and H.A. Knight. 1982. Florida’s forests. US Department of Agriculture, Forestry Service Resource Bulletin SE 62:1-84

Brady, J. R. 1977. Status of the fox squirrel in Florida. P-R Final Report, Project W-41-24, Job XV-A-1. Florida Game and Fresh Water Fish Commission, Tallahassee.

Cox, J. 2004. Commentary: Population declines and generation lengths can bias estimates of vulnerability. Wildlife Society Bulletin 32(3):1-4.

Endries, M, B. Stys, G. Mohr, G. Kratimenos, S. Langley, K. Root, and R. Kautz. 2009. Wildlife Habitat Conservation Needs in Florida. Fish and Wildlife Research Institute Technical Report TR-15. x + 178p.

Florida Natural Areas Inventory. 2001. Field guide to the rare animals of Florida. http://myfwc.com/docs/FWCG/sherman_fox_squirell.pdf

Florida Fish and Wildlife Conservation Commission (FWC). 2005. Florida’s Wildlife Legacy Initiative. Florida’s Comprehensive Wildlife Conservation Strategy. Tallahassee, Florida, USA.

Florida Fish and Wildlife Conservation Commission (FWC). 2008. Wildlife 2060: What's at stake for Florida. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida. 28 pp.

Hafner, D.J., E. Yensen, and G.L. Gordon, Jr. (compilers and editors). 1998. North American Rodents. Status Survey and Conservation Action Plan. IUCN/SSC Rodent Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. X + 171pp.

Humphrey, S.R., J.F. Eisenberg, and R. Franz. 1985. Possibilities for restoring wildlife of a longleaf pine savanna in an abandoned citrus grove. Wildlife Society Bulletin 13:487-496.

Kantola, A.T. 1986. Fox squirrel home range and mast crops in Florida. M.S. thesis, University of Florida, Gainesville. 68pp.

Kantola, A.T. 1992. Sherman's fox squirrel *Sciurus niger shermani*. Pages 234-241 in S.R. Humphrey (ed.), Rare and endangered biota of Florida. Vol. I. Mammals. University Press of Florida. Gainesville, Florida.

Kantola, A.T. and S.R. Humphrey. 1990. Habitat use by Sherman's fox squirrel (*Sciurus niger shermani*) in Florida. Journal of Mammalogy 71(3):411-419

Koprowski, J.L. 1994. *Sciurus niger*. Mammalian Species 479:1-9

Moore, J.C. 1956. Variation in the Fox Squirrel in Florida. American Midland Naturalist 55(1):41-65.

Moore, J.C. 1957. The natural history of the fox squirrel *Sciurus niger shermani*. Bulletin of the American Museum of Natural History. 113:1-71

Root, K.V. and J. Barnes. 2006. Risk assessment for a focal set of rare and imperiled wildlife in Florida. Fish and Wildlife Conservation Commission.

Turner, D.A. and J. Laerm. 1993. Systematic relationships of populations of the fox squirrel (*Sciurus niger*) in the southeastern United States. Pages 21-36 in N.D. Moncrief, J.W. Edwards, and P.A. Tappe, eds. Proceedings of the second symposium on southeastern fox squirrels, *Sciurus niger*. Va. Museum of Natural History Special Publication. No. 1. 84pp.

Williams, K. S. and S. R. Humphrey. 1979. Distribution and status of the endangered Big Cypress fox squirrel (*Sciurus niger avicennia*) in Florida. Florida Scientist 42:201-205.

Wooding, J.B. 1997. Distribution and population ecology of the fox squirrel in Florida. Ph.D. dissertation. University of Florida.

Zwick, P.D. and M.H. Carr. 2006. Florida 2060: A population distribution scenario for the State of Florida. A research project prepared for 1000 Friends of Florida. Geoplan Center at the University of Florida, Gainesville, Florida, USA. 25pp

Biological Status Review Information
Findings

Species/taxon: Sherman's Fox Squirrel (*Sciurus niger shermani*)
Date: 11/04/10
Assessors: Elina Garrison, John Kellam, Robert McCleery

Generation length: Generation length = 3 years; used 10 years as the time frame (Please see Appendix 1).

Criterion/Listing Measure	Data/Information	Data Type*	Criterion Met?	References
*Data Types - observed (O), estimated (E), inferred (I), suspected (S), or projected (P). Criterion met - yes (Y) or no (N).				
(A) Population Size Reduction, ANY of				
(a)1. An observed, estimated, inferred or suspected population size reduction of at least 50% over the last 10 years or 3 generations, whichever is longer, where the causes of the reduction are clearly reversible and understood and ceased[1]	Population reduction due to hunting (d) has ceased.	I	N	Kantola 1992
(a)2. An observed, estimated, inferred or suspected population size reduction of at least 30% over the last 10 years or 3 generations, whichever is longer, where the reduction or its causes may not have ceased or may not be understood or may not be reversible[1]	Population reduction due to habitat loss and fragmentation is suspected. Extent of decline in last 10 years is unknown.	I	N	FWC 2005, Wooding 1997, Kantola and Humphrey 1990.
(a)3. A population size reduction of at least 30% projected or suspected to be met within the next 10 years or 3 generations, whichever is longer (up to a maximum of 100 years) [1]	Population reduction projected in future based on area of occupancy and quality of habitat. Extent of the decline unknown.	I	N	Zwick and Carr 2006, FWC 2005
(a)4. An observed, estimated, inferred, projected or suspected population size reduction of at least 30% over any 10 year or 3 generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased or may not be understood or may not be reversible.[1]	Please see notes on A2 and A3.	I	N	Zwick and Carr 2006, FWC 2005
[1] based on (and specifying) any of the following: (a) direct observation; (b) an index of abundance appropriate to the taxon; (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat; (d) actual or potential levels of exploitation; (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.				
(B) Geographic Range, EITHER				

(b)1. Extent of occurrence < 20,000 km^2 (7,722 mi^2) OR	Based on available range estimates, extent of occurrence is greater than 20,000 km^2.	I, E	N	Wooding 1997, Moore 1956, Kantola 1992
(b)2. Area of occupancy < 2,000 km^2 (772 mi^2)	Based on GIS-based model of available habitat, AOO is estimated at 14,222 km^2. The habitat model has not ground proofed for actual occupancy and likely overestimates the AOO, however, it is unlikely that the overestimate exceeds 80%.	I, E	N	Endries et al. 2009
AND at least 2 of the following:				
a. Severely fragmented or exist in ≤ 10 locations	Occurs in more than 10 locations.	I	N	Wooding 1997
b. Continuing decline, observed, inferred or projected in any of the following: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent, and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals	See notes from A3.	I	N	
c. Extreme fluctuations in any of the following: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals	No data to indicate extreme fluctuations.	I	N	
(C) Population Size and Trend				
Population size estimate to number fewer than 10,000 mature individuals AND EITHER	Statewide population size is unknown, however, previous density estimates in Florida range from 2.7 - 38 squirrels/km2. Using Endries et al. 2007 estimated area of occupancy (14,222 km2) and the lowest density estimate, the number of individuals equals 38,381. Even if we assume only 50% of the estimated available habitat is occupied, the population size estimate is above the 10,000 threshold.	E, I	N	Kantola and Humphrey 1990; Wooding 1997; Humphrey et al. 1985, Kantola 1986 and Moore 1957
(c)1. An estimated continuing decline of at least 10% in 10 years or 3 generations, whichever is longer (up to a maximum of 100 years in the future) OR	We do not have estimates of decline.		N	
(c)2. A continuing decline, observed, projected, or inferred in numbers of mature individuals AND at least one of the following:	As human population continues to increase, we suspect populations will continue to decline based on habitat loss and fragmentation.	I, P	Y	Zwick and Carr 2006, FWC 2005
a. Population structure in the form of EITHER				
(i) No subpopulation estimated to contain more than 1000 mature individuals; OR	Population size estimates not available.		N	
(ii) All mature individuals are in one subpopulation	All mature individuals are not believed to be in one subpopulation.		N	Wooding 1997, Moore 1956, Kantola 1992
b. Extreme fluctuations in number of mature individuals	There is no data suggesting extreme fluctuations in the number of mature individuals.		N	

(D) Population Very Small or Restricted, EITHER				
(d)1. Population estimated to number fewer than 1,000 mature individuals; OR	Does not apply.		N	
(d)2. Population with a very restricted area of occupancy (typically less than 20 km^2 [8 mi^2]) or number of locations (typically 5 or fewer) such that it is prone to the effects of human activities or stochastic events within a short time period in an uncertain future	Does not apply.		N	
(E) Quantitative Analyses				
e1. Showing the probability of extinction in the wild is at least 10% within 100 years	PVA analysis did not show probability of extinction in wild of at least 10%. The population parameters for the PVA were generated from populations from the midwest, and most research shows that demographic data from the midwest does not apply to Florida fox squirrels, e.g., Florida fox squirrels are more K-selected, reproductive rates are lower, and ranges in the southeast are larger, resulting in lower population densities.	P	N	Root and Barnes 2006

Initial Finding (Meets at least one of the criteria OR Does not meet any of the criteria)	Reason (which criteria are met)
Does not meet any of the criteria	
Is species/taxon endemic to Florida? (Y/N)	N

If Yes, your initial finding is your final finding. Copy the initial finding and reason to the final finding space below. If No, complete the regional assessment sheet and copy the final finding from that sheet to the space below.

Final Finding (Meets at least one of the criteria OR Does not meet any of the criteria)	Reason (which criteria are met)
Does not meet any of the criteria	

1	Biological Status Review Information Regional Assessment Species/taxon:	Sherman's fox squirrels
2	Date:	11/3-4/10
3	Assessors:	Elina Garrison, John Kellam, Robert McCleery
4		
5		
6		
7		
8	Initial finding	Supporting Information
9		
10	2a. Is the species/taxon a non-breeding visitor? (Y/N/DK). If 2a is YES, go to line 18. If 2a is NO or DO NOT KNOW, go to line 11.	N
11	2b. Does the Florida population experience any significant immigration of propagules capable of reproducing in Florida? (Y/N/DK). If 2b is YES, go to line 12. If 2b is NO or DO NOT KNOW, go to line 17.	N
12	2c. Is the immigration expected to decrease? (Y/N/DK). If 2c is YES or DO NOT KNOW, go to line 13. If 2c is NO go to line 16.	
13	2d. Is the Florida population a sink? (Y/N/DK). If 2d is YES, go to line 14. If 2d is NO or DO NOT KNOW, go to line 15.	
14	If 2d is YES - Upgrade from initial finding (more imperiled)	
15	If 2d is NO or DO NOT KNOW - No change from initial finding	
16	If 2c is NO or DO NOT KNOW- Downgrade from initial finding (less imperiled)	
17	If 2b is NO or DO NOT KNOW - No change from initial finding	
18	2e. Are the conditions outside Florida deteriorating? (Y/N/DK). If 2e is YES or DO NOT KNOW, go to line 24. If 2e is NO go to line 19.	
19	2f. Are the conditions within Florida deteriorating? (Y/N/DK). If 2f is YES or DO NOT KNOW, go to line 23. If 2f is NO, go to line 20.	
20	2g. Can the breeding population rescue the Florida population should it decline? (Y/N/DK). If 2g is YES, go to line 21. If 2g is NO or DO NOT KNOW, go to line 22.	
21	If 2g is YES - Downgrade from initial finding (less imperiled)	
22	If 2g is NO or DO NOT KNOW - No change from initial finding	
23	If 2f is YES or DO NOT KNOW - No change from initial finding	
24	If 2e is YES or DO NOT KNOW - No change from initial finding	
25		
26	Final finding	No change

Appendix 1.

Generation length is defined by IUCN as the average age of adults in the population. Sherman's fox squirrels become sexually mature at 8-9 months, however, they generally do not reproduce until they are over a year old. Using adult mortality of 30% (Wooding 1997) and field observations (J. Kellam, and R. McCleery, personal communication), we estimated the generation length as 3 years. Since three generations is less than 10 years, we used 10 years as the evaluation time frame.

Regional assessment - Although the range of Sherman's fox squirrels extends into Georgia (different authors diverge on how far into Georgia Sherman's fox squirrel range extends; Kantola 1992), based on estimated dispersal distances and densities (Wooding 1997), we concluded that the number of individual fox squirrels that could contribute to reproduction in Florida is minimal.

Final thoughts - It is important to note that the Sherman's fox squirrel Biological Review Group recognized that, similar to other species with short generation length (Cox 2004), the short time frame (10 years) used to assess population trends for Sherman's fox squirrel does not take into account historic losses. Sherman's fox squirrels, with large home-range, low densities, low reproductive rates and preferred habitat that includes open, fire-maintained upland habitat are very vulnerable to habitat loss and fragmentation. However, their short generation length obligated us to limit our past and future evaluation of population trends to 10 years, therefore missing the "big picture" of extensive historical losses. In addition, without current data on geographic range, we based our evaluation of area of occupancy and subsequent calculations of population size on a habitat model that has not been ground truthed for accuracy and may overestimate the area of use. Furthermore, density estimates were obtained from areas where Sherman's fox squirrels are known to be common and may therefore overestimate the density of squirrels in other, less ideal habitats.

Our conclusion is that during the development of the management plan, research that evaluates current status, range and occupancy of Sherman's fox squirrels is critical and that as new data becomes available, it is crucial that Sherman's fox squirrels are re-evaluated prior to removing them from the state list.

Appendix 2. Biological Review Group Members Biographies

Elina Garrison has a M.S. in Wildlife Ecology and Conservation from the University of Florida. She has worked as a biologist in FWC's Terrestrial Mammal Research Subsection since 2004. Ms. Garrison has experience with a variety of Florida mammals, including black bears, white-tailed deer, and fox squirrels, and she has assisted with fox squirrel risk assessments and compiling statewide range maps.

Robert McCleery has a Ph.D. in Wildlife Science from Texas A & M University. He currently serves as an assistant professor in the Department of Wildlife Ecology and Conservation at the University of Florida. Dr. McCleery has over 15 years experience in research and conservation of wildlife and has worked extensively on the ecology of fox squirrels, Key Largo woodrats, Keys marsh rabbits, Florida Key deer and Indiana bats.

John Kellam has a BS in Biology from Humboldt State. John has been the lead biologist on a field study of Sherman's fox squirrels in Big Cypress National Preserve since 2007. To date, 20 radio-collared individuals have been monitored 3 times per week to determine movements, habitat use, food preferences, and nest tree selection.

Appendix 3. Summary of letters and emails received during the solicitation of information from the public.

No letters or emails were received from the public during the solicitation period.

Appendix 4. Information and comments received from the independent reviewers.