A Species Action Plan for the Big Cypress Fox Squirrel
Sciurus niger avicennia

Final Draft
November 1, 2013

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DEDICATION

This Species Action Plan is dedicated to the memory of:

Courtney Hooker Tye

(1983-2014)

In addition to being a bright and gifted wildlife biologist studying the ecology and conservation of the Florida's fox squirrels, Courtney had an amazing affect on all those she came in contact with. She was generous and her curiosity was insatiable. She loved the natural world and all the critters she encountered in her exploration. We were fortunate that Courtney brought her energy and enthusiasm to the development of this plan. Her contributions were as big as her heart. It is to her spirit and memory that we dedicate this work.

The Big Cypress Fox Squirrel Team

Cover photograph by Ralph Arwood

Recommended citation:
Florida Fish and Wildlife Conservation Commission. 2013. A species action plan for the Big Cypress fox squirrel. Tallahassee, Florida.

EXECUTIVE SUMMARY

The Big Cypress fox squirrel (BCFS; *Sciurus niger avicennia*) was originally described in 1919 as a subspecies of the eastern fox squirrel on the basis of its coloration, smaller size, and restricted range in southwest Florida. A major threat to the conservation of BCFS is loss of suitable habitat within its range in southwest Florida. Degradation and fragmentation have also contributed to the decline of suitable habitat. Habitat has been lost through conversion to other uses in Hendry County, while rapid urbanization has fragmented available habitat at the edge of the species' range in western Lee and Collier counties. Insufficient application or exclusion of fire has reduced habitat quality in some remaining areas of natural habitat, which has contributed to declines. Sites determined to be critical for effective conservation of the BCFS should be designated as core conservation areas and prioritized for management action. Some urbanized habitats, such as golf courses and parks, may be suitable for BCFS if the understory is open and there is an abundant food supply. However, mortality can be high in urbanized areas. As a result, some urban local populations may be unsustainable without regular immigration of individuals from other local populations.

A biological assessment of the BCFS determined that the subspecies warranted listing as Threatened on the Florida Endangered and Threatened Species List because the species met 2 of the listing criteria. The goal of this plan is to improve the conservation status of the BCFS to the point that the species can be removed from the Florida Endangered and Threatened Species List and will not need to be listed again. Objectives include clarifying genetic relationships with other fox squirrel subspecies to better evaluate the distribution (extent of occurrence) and listing status of the BCFS, maintaining or increasing the area of occupancy, and increasing the survival and productivity of BCFS.

Successful conservation of BCFS will require effective coordination among local, state, and federal agencies; non-governmental organizations; private landowners; university researchers; and the public. The Florida Fish and Wildlife Conservation Commission (FWC) can provide technical and logistical support for private landowners and other groups, as well as direct involvement to implement or influence identified actions necessary to achieve the conservation goal for this species.

This plan provides the framework for the conservation and management of the BCFS. Conservation needs of the Sherman's fox squirrel are addressed in a separate Species Action Plan to clarify the differences in habitat use, necessary conservation actions, and conservation status and goals for each subspecies.

This plan, developed by FWC in collaboration with National Park Service staff members, details the actions necessary to improve the conservation status of the BCFS. A summary of this plan will be included in the Imperiled Species Management Plan (ISMP), in satisfaction of the management plan requirements in Chapter 68A-27, Florida Administrative Code, Rules Relating to Endangered or Threatened Species. The ISMP will address comprehensive management needs for 60 of Florida's imperiled species and will include an implementation plan; rule recommendations; permitting standards and exempt activities; anticipated economic, ecological, and social impacts; projected costs of implementation and identification of funding sources; and

a revision schedule. The imperiled species management planning process relies heavily on stakeholder input and partner support. This level of involvement and support is also critical to the successful implementation of the ISMP. Any significant changes to this plan will be made with the continued involvement of stakeholders.

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GLOSSARY OF TERMS AND ACRONYMS

Agouti: A pattern of pigmentation in which individual hairs have several bands of light and dark pigment with black tips.

Area of Occupancy (AOO): The area within its extent of occurrence (see Extent of Occurrence), which is occupied by a taxon, excluding cases of vagrancy. This reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats (as defined by International Union for Conservation of Nature [IUCN]).

BCFS: Big Cypress fox squirrel

BICY: Big Cypress National Preserve

BRG: Biological Review Group: A group of taxa experts convened to assess the biological status of taxa using criteria specified in Rule 68A-27.001, Florida Administrative Code (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).

BSR: Biological status review report, the summary of the biological review group's findings. Includes a Florida Fish and Wildlife Conservation Commission (FWC) staff recommendation on whether or not the species status meets the listing criteria in Rule 68A-27.001, F.A.C. These criteria, based on IUCN criteria and IUCN guidelines, are used to help decide if a species should be added or removed from the Florida Endangered and Threatened Species List. In addition, FWC staff may provide within the report a biologically justified opinion that differs from the criteria-based finding.

Core Conservation Area: A designated, managed, high-priority conservation site. Core conservation areas support biologically diverse ecological communities similar to those expected in very high-quality habitats of comparable type. The communities and habitats that occur within a core conservation area may be considered irreplaceable in that their loss could negatively impact the survival of the species or communities for which that area was designated.

DEP: Florida Department of Environmental Protection

Extent of Occurrence (EOO): The geographic area encompassing all observations of individuals of a species, including intervening areas of unoccupied habitat. Synonymous with range. See also Area of Occupancy.

EQIP: Environmental Quality Incentives Program

F.A.C.: Florida Administrative Code: The Department of State's Administrative Code, Register and Laws Section is the filing point for rules promulgated by state regulatory agencies. Agency rulemaking is governed by Chapter 120, Florida Statutes, the Administrative Procedures Act. Rules are published in the Florida Administrative Code.

FNAI: The Florida Natural Areas Inventory, a non-profit organization administered by Florida State University and dedicated to gathering, interpreting, and disseminating information critical to the conservation of Florida's biological diversity.

FWC: The Florida Fish and Wildlife Conservation Commission, the state agency constitutionally mandated to protect and manage Florida's native fish and wildlife resources.

FWCG: Florida Wildlife Conservation Guide

GIS: Geographic Information System

ISMP: Imperiled Species Management Plan

IUCN: International Union for Conservation of Nature, a professional, global, conservation network

Local Population: A group of individuals of one taxon within a prescribed area. The area may be defined geographically or otherwise.

MBW: Mexican bromeliad weevil

Metapopulation: A set of local populations of a given taxon, each of which occupies a separate, discrete patch of suitable habitat within a region. Individuals are able to move between local populations, but the rate and extent of movements is variable.

NPS: National Park Service

Phylogeography: A discipline in biology concerned with principles and processes governing the observed geographical distribution of genetic variation (genealogical lineages) within and between local populations or species. Inference of population structure, which is a reflection of divergence among populations, is at the core of phylogeographic studies.

Population: All individuals of a given taxon in Florida. This follows the specific usage of this term from the IUCN criteria for the Biological Status Review process, which is different from its common biological and ecological usage.

PVA: Population Viability Analysis

SDM: Species Distribution Model, a GIS-based approach that combines species occurrence locations and environmental parameters, such as landcover type, to determine habitat associations for that species.

SFS: Sherman's fox squirrel

Taxon: A species, subspecies, or other taxonomically defined entity. Typically used as a general term for the organism being discussed.

UF: The University of Florida

USFWS: U.S. Fish and Wildlife Service, the federal agency mandated to protect and manage the nation's native freshwater fish and wildlife resources.

WMA: Wildlife Management Area.

INTRODUCTION

Biological Background

Taxonomy

The Big Cypress fox squirrel (*Sciurus niger avicennia*) is a subspecies of the eastern fox squirrel (*Sciurus niger*). The Big Cypress fox squirrel (BCFS) was originally described by Howell (1919) on the basis of its coloration and small size. Moore (1956) confirmed the subspecies status of BCFS and expanded its range (extent of occurrence [EOO]) in southwest Florida approximately to the limits that are generally accepted today, including the standard northern limit at the Caloosahatchee River. The BCFS is 1 of 4 eastern fox squirrel subspecies that occur in Florida (Figure 1), but it is generally recognized as being smaller in size than Sherman's fox squirrel (*S. n. shermani* [SFS]), whose range is close, if not adjacent, to that of BCFS in Florida (Howell 1919, Moore 1956, Humphrey and Jodice 1992, Turner and Laerm 1993).

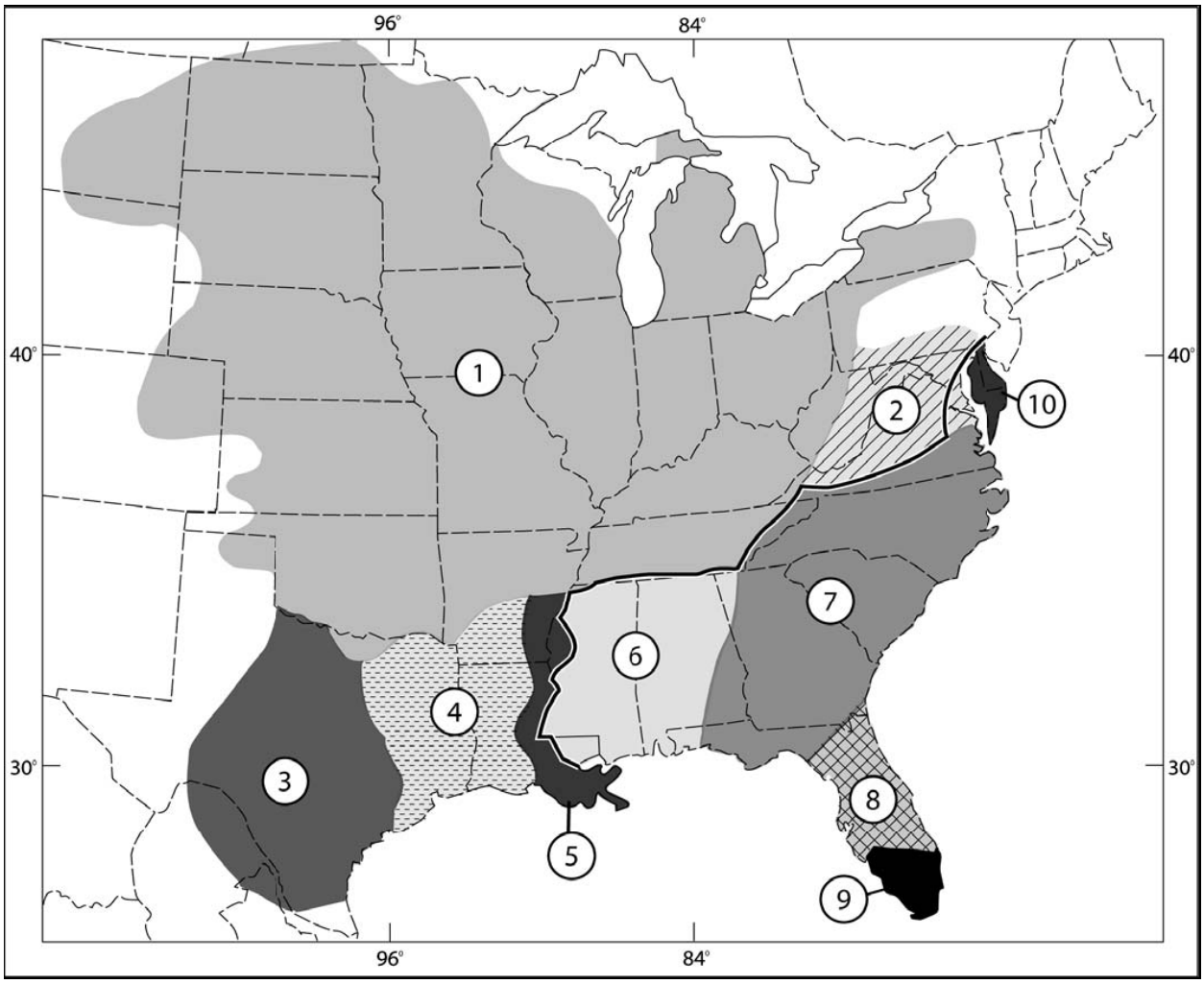

Figure 1. Geographic distribution of *Sciurus niger* subspecies in North America: 1) *S. n. rufiventer*, 2) *S. n. vulpinus*, 3) *S. n. limitis*, 4) *S. n. ludovicianus*, 5) *S. n. subauratus*, 6) *S. n. bachmani*, 7) *S. n. niger*, 8) *S. n. shermani*, 9) *S. n. avicennia*, and 10) *S. n. cinereus* (from Moncrief et al. 2010, after Koprowski 1994 and Hall 1981).

Other common names that have been used for the BCFS are the mangrove fox squirrel, Everglades fox squirrel, and south Florida fox squirrel (Hafner et al. 1998). The original common name, mangrove fox squirrel, implies an association with a singular habitat type, which is inaccurate. Therefore, *S. n. avicennia* is best referred to as the Big Cypress fox squirrel (Hafner et al. 1998, Humphrey and Jodice 1992).

Figure 2. A Big Cypress fox squirrel, from Naples, showing black head and dorsal fur, with buff and black agouti sides, buff belly, and a buff and black agouti tail. Photograph by Michael Landwehr.

Description

The BCFS is a large tree squirrel, highly variable in color and patterning (Figures 2, 3). The most common pattern includes a black head and dorsal fur, buff sides and belly, buff and black tail, and white nose and ears (Moore 1956, Florida Natural Areas Inventory [FNAI] 2001).

In a study conducted on the Big Cypress National Preserve (BICY), Kellam et al (2013) identified 3 study-specific color phases in captured BCFS (Figure 3). They described the squirrels as being: 1) buff (n = 16), where buff with black agouti was the dominant dorsal fur color and the head was black with white fur on the nose, lips, and ear tips; the belly was usually either white or buff colored; tail fur was typically buff and black agouti; 2) black (n = 6), where black was the dominant dorsal fur color and the head was black with white fur on the nose, lips, and ear tips; the belly varied, being either black, white, or buff colored; tail fur was typically black, but often with white or buff and agouti fur present; or 3) tan (n = 2), where the dorsal fur was typically tan and black agouti, and the head was black with white fur on the nose, lips, and ear tips; the belly was typically white or tan; tail fur was usually tan and black agouti.

Figure 3. Three color phases of Big Cypress fox squirrel fur identified by Kellam et al. (2013) among squirrels captured during that study. 1) Buff, the most common; 2) black (with radio transmitter); and 3) tan, the least common. Photographs by Ralph Arwood.

Life History

While considered a tree squirrel (Koprowski 1994), BCFS spends a large proportion of its time on the ground. It inhabits a range of natural, rural, and urbanized habitats (see Habitat Conservation and Management). Optimal habitat conditions for BCFS are dependent upon the availability of appropriate trees for nest sites, abundant year-round food resources, and an open understory with little or no bushes or shrub layer present (Jodice and Humphrey 1992, Eisenberg et al. 2011).

Reproductive behavior is summarized as follows, based in part on information for *Sciurus niger* overall (see Koprowski 1994 for additional references). Fox squirrels can mate at any time of the year, but most breeding occurs between November and February, with a peak in December, and between April and July, with a peak in June. On a golf course in western Collier County, observed productivity was higher in summer than in winter. This was attributed to the availability of foods from non-native plants in summer, which supplemented a limited diet of native plants (Ditgen et al. 2007). *Sciurus niger* females go into estrus for only 1 day during a breeding season, and it is typical for several males to aggregate on a female's home range during that time. Females generally mate with more than 1 male. Average litter size is typically 2 or 3 offspring. Females can become sexually mature at 8 months of age, but more commonly delay reproduction until they are over a year old. Females are able to breed for more than 12 years.

Territoriality has not been observed in *Sciurus niger* (see Koprowski 1994 and additional references cited there). While adults, especially females, often defend exclusive core areas, home ranges of individuals typically overlap. All juveniles eventually disperse from their mother's home range, but some may remain with their mother during their first winter. BCFSs translocated from Naples, Florida, to BICY exhibited inconsistent site fidelity and movements of up to 32 km (20 mi), which could be attributed to homing, post-release investigative behavior, or long-distance foraging (Jodice 1993).

Kellam et al (2013) reported mean home range sizes of 75.6 ha (187 ac) for male and 10.4 ha (26 ac) for female BCFS in natural habitats in BICY. This male home range size is more than 7 times greater than the female home range size and more than 70% greater than that of male SFS (42.8 ha [106 ac]) (Kantola and Humphrey 1990). The male-to-female ratio of home range size reported by Kellam et al. (2013) is much greater than the ratio reported for SFS by Kantola and Humphrey (1990), in which the male's home range was only 2 to 3 times larger than the female's home range. Although the reported female BCFS home range size is smaller than the mean reported for female SFS (16.7 ha [41.2 ac]) (Kantola and Humphrey 1990), it is within the span of reported female fox squirrel home ranges (0.85 to 17.2 ha [2.1 to 42.5 ac]) (Geeslin 1970, Adams 1976, Hilliard 1979, Benson 1980, Weigl et al. 1989, Koprowski 1994).

Crude estimates of BCFS local population densities have been calculated at 0.0009 squirrels/ha (0.00036 squirrels/ac) in typical cypress swamp habitat in Corkscrew Swamp Sanctuary and 0.0192 squirrels/ha (0.0078 squirrels/ac) in ranchland woodlots (Jodice and Humphrey 1993). However, Humphrey and Jodice (1992) stated that these estimates are probably much too low, because they included some unoccupied habitat. Density estimates for other fox squirrels in the southeastern United States average 0.05 squirrels/ha (0.02 squirrels/ac) for *S. n. niger* (as summarized in Koprowski 1994) and from 0.04 to 0.38 squirrels/ha (0.016 to 0.153 squirrels/ac)

for SFS (Moore 1957, Humphrey et al. 1985, Kantola 1986, Kantola and Humphrey 1990, Wooding 1997).

Items reported in the diet of BCFS, have included items found in both natural and developed habitats: java plums (*Syzygium cumini*), figs (*Ficus* spp.), bischofia (*Bischofia javanica*) berries, acorns (*Quercus* spp.), red maple (*Acer rubrum*) seeds, bottlebrush (*Callistemon citrinus*) and silk oak (*Grevillea robusta*) flowers, insects, fungi, bromeliad (Bromeliaceae) buds, thistle (*Cirsium* spp.) seeds, pond apple (*Annona glabra*) fruit, cabbage palm (*Sabal palmetto*) fruit, holly (*Ilex* spp.) fruit, queen palm (*Syagrus romanzoffiana*) fruit, saw palmetto (*Serenoa repens*) fruit, hog plum (*Ximenia americana*) fruit, wax myrtle (*Morella cerifera*) berries, cocoplum (*Chrysobalanus icaco*) berries, pine (*Pinus* spp.) seeds, and cypress (*Taxodium* spp.) seeds. (Jodice and Humphrey 1992, Ditgen et al. 2007, Jansen 2008, Kellam et al. 2013). Scatter hoarding of some foods such as pine cones, cypress cones, and queen palm fruits has been reported (Jodice and Humphrey 1992, Ditgen et al. 2007).

Kellam et al. (2013) reported that 98% of 403 observed BCFS nests in BICY were built in bald cypress (*Taxodium distichum*) trees. Cabbage palm and slash pine (*Pinus elliottii*) trees were only occasionally used (1% and 0.2%, respectively) as nest sites. Kellam et al. (2013) identified 6 types of nest that are built by BCFS: 1) stick platform with stripped cypress bark, 2) bromeliad (*Tillandsia fasciculata*) with stripped cypress bark, 3) cabbage palm with stripped cypress bark and palm frond fibers, 4) cypress tree defect (splintered trunk) with stripped cypress bark, 5) bromeliad with Spanish moss (*Tillandsia usneoides*), and 6) stick platform with Spanish moss. The 2 most common nest types were stick nests with stripped cypress bark and bromeliad nests with stripped cypress bark (Figure 4) (Kellam et al. 2013). Jodice (1993) reported that nests made by BCFS translocated into BICY were either stick structures or were nestled among the leaves of bromeliads in cypress trees, which is consistent with nest structures observed by Kellam et al. (2013). See Appendix 4 for further details.

Figure 4. The 2 most common Big Cypress fox squirrel nest types documented within Big Cypress National Preserve by Kellam et al. (2013) were a stick nest with stripped cypress bark (left), and a bromeliad nest with stripped cypress bark (right). Photographs by Dennis Giardina (left) and Ralph Arwood (right).

Geographic Range and Distribution

The BCFS is the only subspecies of fox squirrel endemic to Florida (Turner and Laerm 1993 as cited in Wooding 1997, Hafner et al. 1998, FNAI 2001). The extent of occurrence (Figure 5) is recognized as being limited to southwestern peninsular Florida, south of the Caloosahatchee River, in Hendry, Lee, and Collier Counties, the northern part of mainland Monroe County, and extreme western Miami-Dade County (a strip of land that occurs largely within BICY) (Moore 1956, Williams and Humphrey 1979, U.S. Fish and Wildlife Service [USFWS] 2002). Moore (1956) described the range of *Sciurus n. avicennia* as occupying "the mangrove, the pinelands, and the Big Cypress west of the Everglades and south of the Caloosahatchee River."

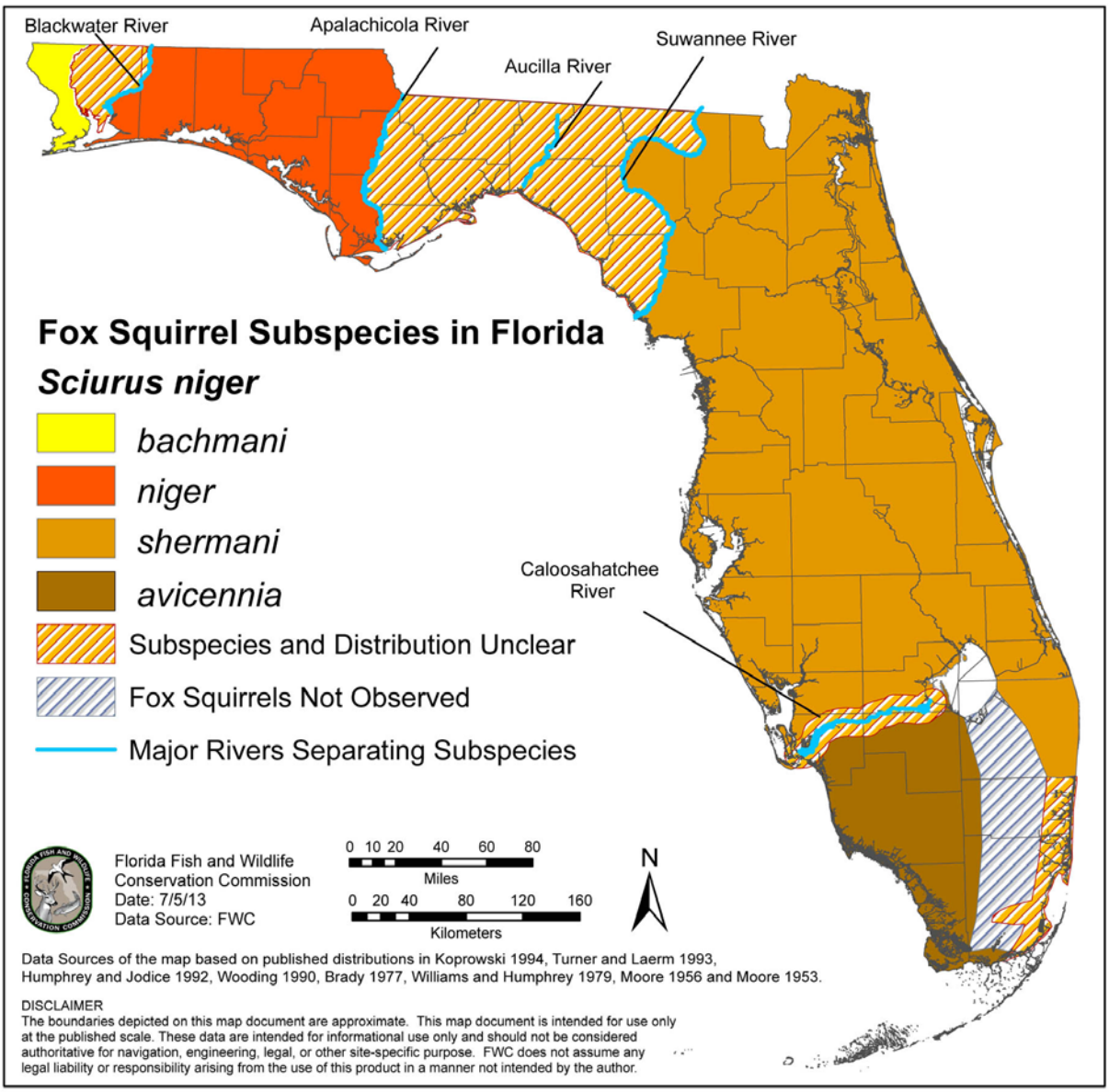

Figure 5. Range (extent of occurrence) of the Big Cypress fox squirrel in southwest Florida, shown along with ranges of the other fox squirrel subspecies in Florida.

Conservation History

In 1974, the BCFS was listed as Threatened by the Florida Game and Fresh Water Fish Commission (predecessor to the Florida Fish and Wildlife Conservation Commission [FWC]; its status was changed to Endangered from 1975 to 1978, and then returned to Threatened in 1979. The BCFS may have warranted listing by the USFWS. Beginning in 1982, however, the species was identified as one for which there was not sufficient data to determine status designation (i.e., category 2 candidate) (USFWS 1982), and so it was not listed (USFWS 2002). The Florida Committee on Rare and Endangered Plants and Animals has designated the Big Cypress fox squirrel as Threatened (Humphrey 1992) and FNAI ranked the BCFS as G5T2/S2 (G5 refers to the entire species = demonstrably secure globally; T2 refers to the specific subgroup; equivalent to the S2 ranking because BCFS is endemic to Florida. S2 = Imperiled in Florida because of rarity or because of vulnerability to extinction due to some natural or manmade factor) (FNAI 2001).

No specific, range-wide habitat conservation actions have been undertaken for the BCFS. Land acquisition by state and federal governments have provided significant areas of habitat for BCFS and other fox squirrels. Staff at BICY has been active in supporting BCFS monitoring and conservation efforts since the late 1970s.

Examples of BICY monitoring and conservation actions for BCFS include:

- Recording and maintaining records of BCFS sightings;
- Collecting and preserving road-killed specimens and tissue and hair specimens for DNA analysis;
- Actively managing pinelands to reduce understory vegetation with the use of prescribed fire;
- Funding and implementing hydrologic restoration projects in habitats occupied by BCFS, and funding BCFS research studies (e.g., Jodice 1990);

Funding other research studies (BICY BCFS study);

- Development and implementation of occupancy surveys within BICY;
- Development of effective trapping techniques;
- Identifying and documenting squirrel poxvirus present in BCFS and investigating sightings of possible squirrel poxvirus infected BCFS in BICY;
- Presenting BCFS ecology and conservation information at scientific symposiums, public, and private meetings; and
- Providing BCFS ecology swamp walks and information brochures to the public.

Within the range of BCFS, government agencies, non-governmental organizations, and private landowners actively use prescribed fire to maintain natural habitat characteristics. Habitat restoration projects are underway on some public conservation lands, which will improve habitat quality. These conservation actions benefit BCFS and other wildlife species.

Hydrologic restoration and management efforts within and adjacent to conservation lands are also essential. Appropriate hydrology is indispensable, providing adequate and timely water for healthy cypress and mangrove swamp ecosystems, which sustain robust BCFS local populations.

Threats and Recommended Listing Status

Threats

The main threats to the BCFS are loss, degradation, and fragmentation of suitable habitat that have resulted mostly from development and conversion to other uses, especially on the western periphery of the species' range (Jodice and Humphrey 1992, Koprowski 1994, FWC 2005, Zwick and Carr 2006, FWC 2008, Jansen 2008, Munim 2008). Rapid urbanization has isolated BCFS local populations within fragmented habitat patches in western Lee and Collier counties (Ditgen et al. 2007). Similarly, grazed slash pine rangeland that has been converted to citrus groves has caused habitat loss in Hendry County (Ditgen et al. 2007).

Problems that are produced by loss of habitat are increased by degradation of conservation lands. Insufficient management may be causing declines in habitat quality for BCFS across large segments of the remaining natural pineland or slash pine forest communities within its range or EOO (FWC 2005). Fire exclusion or insufficient prescribed fire (in which fire return intervals are longer than appropriate to optimize habitat quality) have led to is believed to have caused declines in BCFS numbers in some habitats (Ditgen et al. 2007). However, most available information on the relationship between fire frequency and habitat quality comes from studies of the BCFS local population at a single site in BICY (Jansen 2008, Kellam and Jansen 2010, Kellam et al. 2013).

Figure 6. Urban Big Cypress fox squirrel crossing a street in Naples. Photograph by Jennifer Fiorenza.

The threat of insufficient fire to the viability of BCFS local populations across habitats is not fully understood. Kellam et al. (2013) have shown clearly that fire can be important for maintaining or increasing the quality of natural habitats for BCFS, but their analyses have not been replicated at multiple sites and they only studied 1 habitat type. These constraints make it difficult to draw broad conclusions regarding fire and habitat use by BCFS.

The loss of large trees for nest sites and cover in urban and rural developed lands could be a significant threat to maintaining the quality of those areas for BCFS (Eisenberg et al. 2011). Developed lands typically have a reduced understory and may provide suitable habitat for BCFS as long as large trees remain available in those areas to provide food and nest sites. Unfortunately, it appears that in many urbanized and agricultural areas, which could otherwise provide suitable habitat, large trees are often not being replaced when they die.

Another threat to habitat quality for BCFS is potentially large reductions of native bromeliads (e.g., *Tillandsia fasciculata*). The Mexican bromeliad weevil (*Metamasius callizona*), an invasive non-native species, was first reported in Florida in 1989 (O'Brien et al. 1990), and has spread to the urban and natural areas of Collier, Lee, and Hendry counties (Frank 1999). Mexican bromeliad weevil (MBW) larvae eat into bromeliads, killing them. Where it occurs in

Florida, the MBW has had a devastating effect on Florida's native bromeliad populations (Frank and Thomas 1994). Big Cypress fox squirrels utilize *T. fasciculata* for nest substrate, a non-nesting refuge, and as an important seasonal food item in urban green spaces (Ditgen et al. 2007) and natural habitats (Kellam et al. 2013). The recent study of BCFS at BICY (Kellam et al. 2013) revealed that *T. fasciculata* was the primary substrate component in 44.9% of all observed BCFS nests (n = 403) and the principal documented food item from March to May.

Diseases may pose significant threats to the stability and viability of BCFS local populations. A skin fungus is known to cause mortality of Big Cypress fox squirrels in urban areas, although researchers have not indicated the fungus is a major threat to the viability of local populations (USFWS 2002). Mange also is known to cause mortality in BCFS, but rates of mortality and potential impacts on local populations are not well understood (see Appendix 2 for additional details). Squirrel poxvirus is an infectious disease (Robinson and Kerr 2001) that can cause high rates of mortality in infected squirrels (Terrell et al. 2002). In 2010, squirrel poxvirus was reported at BICY in a single BCFS (Kellam 2010).

Historically, the BCFS was a game species (Williams and Humphrey 1979). As a result of the general decline in the BCFS population, legal hunting ended in 1972 (Duever et al. 1986, Wooding 1997). However, many authors believed that illegal killing (poaching) of BCFS continued after the closure and that the rate of mortality due to poaching was significant (Williams and Humphrey 1979, Duever et al. 1986, Humphrey and Jodice 1992). However, USFWS stated that it did not have evidence to support the claim of significant illegal hunting mortality (USFWS 2002). The current rates of mortality to BCFS from poaching is unknown. Very few poaching violations are reported to FWC law enforcement on an annual basis (D. Sims, FWC, personal communication).

While BCFS local populations do occur in urbanized habitats on sites such as golf courses (Jodice and Humphrey 1992, USFWS 2002, FWC 2005, Ditgen et al. 2007), these sites are able to support fox squirrels only when the habitat provides sufficient food, other needed resources (e.g., nest sites) are available, and predation or other causes of mortality are sufficiently low. However, Meehan and Jodice (2010) found that the ability of individual fox squirrels to move among patches of suitable habitat in urbanized areas may have been important in determining whether local populations remained present on selected sites. Unfortunately, vehicle-caused mortality can be especially high in urbanized areas (Figure 6 and Figure 7). Where mortality rates are unsustainably high, urbanized habitats can be population sinks for BCFS (Ditgen et al. 2007, Munim 2008, Eisenberg et al. 2011).

Figure 7. Road mortality can have a significant impact on fox squirrel populations, especially in urban areas. Photograph by Jeff Gore, FWC, near Reddick, FL.

Impacts from climate change may produce further challenges for conservation of the BCFS. However, adaptation to those changes will require an understanding of projected impacts to the habitats and ecological systems on which the BCFS is dependent. Potential impacts from climate change are not well understood; therefore, identification of appropriate management strategies is

not readily possible (Dubois et al. 2011). The vulnerability of BCFS local populations to climate change will depend on the degree to which the BCFS is likely to experience harm from stressors produced by changes in large-scale climatic drivers (Intergovernmental Panel on Climate Change [IPCC] 2007, Dubois et al. 2011). BCFS vulnerability will be a result of multiple variables including the intensity and duration of the climate changes, innate sensitivities of the BCFS to those changes, and, ultimately, the capacity of the BCFS to adapt to changes that occur (IPCC 2007, Dubois et al. 2011). A vulnerability assessment could be conducted to help identify the potential effects to the BCFS from projected climatic changes. Such an assessment could better inform conservation strategies for the BCFS (Dubois et al. 2011, Glick et al. 2011).

The USFWS reviewed the status of the BCFS and concluded that this subspecies did not qualify for federal listing as Endangered or Threatened, in large part due to a lack of data on BCFS ecology and the large number of acres of potential BCFS habitat found on state and federal conservation lands (USFWS 2002). S*ciurus niger avicennia* is currently listed as being at lower risk, but conservation-dependent, by the International Union for Conservation of Nature (IUCN) Rodent Specialist Group, "based on the historical loss of habitat and restricted number and distribution of populations of *S. n. avicennia*, probably including [BICY]" (Hafner et al. 1998).

Recommended Listing Status

In 2010, the FWC directed staff to evaluate the status of all species listed as Threatened or Species of Special Concern that had not undergone a status review in the past decade. To address this charge, staff conducted a literature review and solicited information from the public on the status of the BCFS. The FWC convened a biological review group (BRG) of experts on the BCFS to assess the biological status of the subspecies using criteria in Rule 68A-27.001, Florida Administrative Code (F.A.C.). This rule includes a requirement for BRGs to follow 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). FWC staff developed a draft Biological Status Review Report (BSR) that included the BRG's findings and preliminary listing recommendation from staff. FWC distributed the draft for peer review, and the reviewers' input was incorporated in a final report.

The BRG concluded from the biological assessment of the Big Cypress fox squirrel that the species met the following 2 listing criteria:

- The BCFS has a limited geographic range, meeting criterion B related to geographic range. Specifically BCFS has a restricted area of occupancy of less than 2,000 km^2 (772 mi^2) and an extent of occurrence of less than 20,000 km^2 (7,772 mi^2), meeting IUCN criteria for (b)1 and (b)2. Further, both of these parameters are projected to have ongoing declines and fluctuations, meeting the subcriterion b for projected declines in area of occupancy, habitat quality, number of locations, and number of mature individuals and subcriterion c for extreme fluctuations in occupancy and number of locations.
- The population size was estimated as below 10,000 individuals, meeting criterion C related to population size and trend. A projected continued decline and observed extreme fluctuations in number of mature individuals met subcriteria (c)2 and b.

Reviewers of the BRG findings in the BSR concurred with the BRG recommendation that the BCFS should be listed as Threatened on the Florida Endangered and Threatened Species List.

CONSERVATION GOALS AND OBJECTIVES

Goal

Conservation status of the Big Cypress fox squirrel is improved to the point that the species is secure within its historical range.

Objectives

I. Determine the level of genetic variation among the different subspecies of fox squirrels potentially occurring in Florida (*Sciurus niger shermani*, *S. n. niger*, *S. n. avicennia*, *S. n. bachmani*) within 5 years of plan implementation.

Rationale

The BCFS is 1 of 4 subspecies of the eastern fox squirrel occurring in Florida. However, the ranges of those subspecies and their relationships to each other are not fully understood. A clear delineation of the range of BCFS and the other subspecies is needed, in part because of declining populations and the precarious status of several subspecies (Turner and Laerm 1993). To best evaluate phylogeographic structure (genetic structure within and among local populations at a landscape or regional scale), genetic studies should be implemented to analyze local populations of fox squirrels across the ranges of the currently recognized subspecies. These analyses will make it possible to develop better protections for BCFS local populations in southwest Florida.

Moncrief et al. (2010) found "…no phylogeographic structure in the cytochrome-b sequences [of mitochondrial DNA] of *S. niger*…", which meant their results could not delineate subspecies or unique groups within subspecies. Therefore, future genetic studies could be based on the results of mitochondrial DNA analyses (e.g., Bryant 2007, Moncrief et al. 2010), but should examine segments of DNA that evolve more rapidly to reveal patterns of divergence and phylogeographic structure such as microsatellites, amplified fragment length polymorphisms, and single nucleotide polymorphisms (Manel et al. 2003, Moncrief et al. 2010). For example, Fike and Rhodes (2009) have developed 26 polymorphic microsatellite markers for the fox squirrel. Further, select statistical procedures that can be employed to analyze genetic data spatially, across a landscape, may offer opportunities for robust analyses to better identify patterns or structure (Manel et al. 2003).

II. Determine EOO and Area of Occupancy (AOO) within 5 years of plan implementation.

Rationale

The current EOO is estimated to be 16,679 km^2 (6,440 mi^2) based on the total area of the counties where BCFS is known to occur. The estimated AOO is 1,677 km^2 to 3,840 km^2 (647 mi^2 to 1,483 mi^2) based on an analysis of potential habitat. Unfortunately, these estimates are believed to be much greater than the actual EOO and AOO for BCFS. Habitat loss, degradation, and fragmentation are major threats to BCFS, particularly in urbanized areas. The subspecies is likely to continue to lose habitat to urbanization, agriculture, and mining. Additional threats include disease (squirrel poxvirus and mange), predation, road mortality, and hurricanes.

III. Maintain or increase the EOO and AOO.

Rationale

The BCFS is mainly relegated to public conservation lands (i.e., natural habitat), small patches of urbanized habitat in golf courses and parks, and residential and agricultural lands in rural areas. Local populations are severely fragmented in western Lee and Collier counties and that is also likely in other urbanized areas where isolated habitat patches exist. More effective habitat management methods would increase habitat occupancy by BCFS. Development of improved monitoring protocols that account for differences in detectability in different habitats will allow for more reliable measurement of the EOO and AOO.

IV. Maintain or improve habitat management efforts on public and private conservation lands to maximize the size and productivity of BCFS local populations while determining the species' conservation status.

Rationale

Experts concurred during the BSR process that the size of the overall *S. n. avicennia* population was unknown, but was less than 10,000 individuals (FWC 2011). Improving the conservation status of BCFS will require effective habitat management to ensure long-term population viability. Habitat loss and degradation are major threats to BCFS. High-quality, well-managed habitat, particularly on conservation lands, will be key to reversing some of the apparent declines in BCFS survivorship and productivity.

Publicly owned conservation lands are uniquely suited to provide core areas of habitat to enhance the security of the species. However, habitat quality for BCFS on many of these conservation lands is not optimal and can be improved. Habitat management will be an ongoing emphasis for effective conservation. Efforts to improve habitat quality on existing conservation lands can begin now. Efforts on conservation lands should be augmented by efforts to encourage private landowners to improve habitat quality for BCFS in urban and rural areas. Private lands that provide suitable habitat for BCFS local populations are important to maintaining corridors between local populations.

CONSERVATION ACTIONS

The following sections describe the conservation actions that will make the greatest contribution toward achieving the conservation objectives. Actions are grouped by category (e.g., Habitat Conservation and Management, Population Management). The Conservation Action Table (Table 1) provides information on action priority, urgency, potential funding sources, likely effectiveness, identified partners, and leads for implementation.

Habitat Conservation and Management

The Big Cypress fox squirrel inhabits both natural and developed habitats. Natural habitats for BCFS include south Florida slash pine (*Pinus elliottii* var. *densa*) forests (Figure 8), pond-cypress (*Taxodium ascendens*) (Figure 9 and Figure 10), and bald cypress swamp forests, Virginia live oak (*Quercus virginiana*) woods, tropical hardwood forests, coastal broadleaf evergreen hammocks, and mangrove swamps. Developed habitats occupied by BCFS include urbanized lands such as golf courses, city parks, and residential areas, as well as on residential and agricultural lands (e.g., improved pasture or rangeland) (Howell 1919, Moore 1956, Williams and Humphrey 1979, Duever et. al 1986, Jodice and Humphrey 1992, Ditgen et al. 2007, Eisenberg et al. 2011). Habitat quality for BCFS is greater when the understory is open, with little or no shrub layer present (Munim 2008, Eisenberg et al. 2011). Understory density and height may be critical determinants of habitat quality for BCFS (Munim 2008, Eisenberg et al. 2011).

The BCFS local population studied by Kellam et al. (2013) at BICY occupied cypress dome swamp–pine forest mosaic habitats. That study documented that BCFS require cypress forest for nest sites, adjacent to good foraging habitat, typically slash pine flatwoods. That study also provided evidence that frequent prescribed fire is necessary to maintain high-quality habitat (Kellam et al. 2013).

On some developed lands (both urbanized sites such as golf courses and agricultural areas), sightings of BCFS can be relatively common, which could be indicative of high-quality habitat. However, that may simply be the result of resident squirrels being more acclimated to people and therefore being readily observable. Isolated patches of habitat on developed lands can retain some conditions preferred by BCFS, such as an open understory, but those areas likely cannot support viable BCFS local populations over long-term periods without active management to overcome limiting resources (e.g., food and cover), isolation and road mortality (Eisenberg et al. 2011).

Little is known about conditions that increase habitat quality for BCFS in other habitats such as mangrove swamps, where these squirrels are known to occur. Data on habitat use and occupancy by BCFS in these other habitats are needed to guide management of those areas.

Habitat Conservation

Action 1 Identify priority conservation areas throughout the range of the BCFS to ensure habitats with the greatest potential to benefit the species are protected, connected, and improved.

Action 2 Maintain, enhance, and encourage the creation of habitat corridors on public and private lands through existing habitat conservation programs and incentive programs.

Habitat loss and fragmentation was identified in the BSR as the primary threat to the BCFS. To counteract this threat, high priority areas should be designated as BCFS core conservation areas to clearly identify sites essential for effective conservation of BCFS (Action 1). Initial suggestions for public and private conservation lands to include in core conservation areas are listed in Appendix 9. Designation of a site, or group of sites, as a core conservation area should be done in cooperation with landowners and land managers. Our expectation is that the initial recommendations in Appendix 9 will be vetted through a process involving partners and stakeholders. Within core conservation areas and other priority conservation areas, habitat management plans should account for resource requirements of BCFS and include strategies to maximize habitat quality for BCFS in appropriate habitats.

Maintaining sufficient suitable habitat to effectively conserve the BCFS across its range or EOO will require the application of multiple management tools. Habitat acquisition is one tool that should be pursued as necessary to achieve plan objectives (Action 1). Targeted acquisitions can be pursued through both fee-simple and less-than-fee simple methods.

Habitat conservation efforts also should be encouraged through the use of incentives (Action 1 and Action 2). Incentives encourage private landowners to implement beneficial habitat management activities (Action 20) (e.g., maintain large trees and abundant food resources) for BCFS in urbanized areas as well as residential and agricultural lands in rural areas (Action 2). Incentives focused on developing long-term protections for private lands that maintain suitable habitat for BCFS may be particularly beneficial. Private lands that support suitable habitat can help sustain BCFS local populations and contribute to corridors that connect local populations.

Insufficient prescribed fire (in which intervals between fires are longer than appropriate) may have a larger negative impact on quality of existing natural habitats than any other factor. In pine-dominated natural communities regular fire is essential to maintain appropriate habitat quality for BCFS. On the BICY study site, in slash pine forests, a fire return interval of either 3 or 6 years supported a healthy BCFS local population (Kellam et al. 2013). Further studies are needed to better understand appropriate fire regimes across the range of habitat types occupied by BCFS.

Figure 8. An area of south Florida slash pine forest that has been maintained by frequent fire. Photograph by Ralph Arwood.

Habitat quality for BCFS also is dependent on availability of nest sites and sufficient year-round food resources.

At BICY, almost all BCFS nests were in cypress trees (Kellam et al. 2013), but habitat use by BCFS varied seasonally with the availability of seasonal food items (Kellam et al. 2013). Overall, the recent BICY study has clearly shown the importance of the cypress dome swamp–pine forest habitat mosaic (Kellam et al. 2013) for BCFS.

There are concerns that the densities of fire-adapted species such as the cabbage palm, a midstory component in the BICY study area, might not be readily returned to normal levels by fire after an extended period of fire suppression (D. Sowell, Florida Forest Service, personal communication). If it was believed that cabbage palms or other species increased too greatly in numbers or distribution and were not being suitably controlled by fire within a given habitat, then other management activities should be applied appropriately. Such problems might be addressed through large-scale activities such as hydrologic restoration. In some situations, more targeted management activities (e.g., selective removal, manual herbicide injection) may be necessary.

Figure 9. Exterior view of a pond cypress swamp forest that shows dense cypress trees and abundant bromeliads growing on the trunks of the trees. Photograph by Ralph Arwood.

In urbanized areas, including golf courses, city parks, and residential areas, suitable BCFS habitat can become fragmented and isolated from other patches of suitable habitat. Big Cypress fox squirrel local populations occupying urbanized areas will benefit when the relative size and connectivity of suitable habitat patches are increased. The formation of habitat corridors will increase the connectivity of isolated habitat patches, thereby effectively increasing the amount of available habitat (Action 2). Identifying potential corridors that can also be use by other species will increase the conservation value of these corridors. The installation of native mast-producing trees along a fencerow could form a corridor from 1 habitat patch to another, while also providing valuable food resources. Increased connectivity among patches should allow those sites to support larger, more viable BCFS local populations. However, potential road mortality should be considered when planning habitat corridors. Road mortality incidents in urbanized and natural areas should be reviewed to determine if patterns exist. If they do, modifications to avoid or minimize such incidents should be made (e.g., elevated roadways, signage, or road crossing barriers).

Habitat mapping (Action 4) can provide necessary information to identify potential corridors connecting sites within and between core conservation areas. Sites supporting interspersed pine forest and cypress forest habitats may provide important hubs for connectivity where they exist, but other important habitat types used by BCFS can also be included in potential corridor areas. Appropriate habitats within the BICY should be considered for designation as a BCFS core

conservation area. Additionally, a network of important conservation areas for BCFS may include Corkscrew Swamp Sanctuary and Florida Panther National Wildlife Refuge along with a number of state parks, state forests, and wildlife management areas. Among areas of urbanized habitat, county and city parks could play important roles for conservation if habitat management guidelines (Action 3) could be applied to provide techniques for maintaining and enhancing habitat values for BCFS in park planning documents.

Habitat Management

Action 3 Develop habitat management guidelines and monitoring recommendations for public land managers and private landowners.

Land managers will need to have a clear understanding of appropriate habitat management strategies for BCFS. Through monitoring, managers will be able to make adaptive management decisions. When managers are better informed they can produce more effective conservation of BCFS while also meeting other management objectives.

There are few data regarding the relationship between fire frequency and habitat use by fox squirrels in natural areas. For BCFS, the best available data on the effects of prescribed fire on population viability come from the Raccoon Point area of BICY (Kellam et al. 2013). Prescribed burning was applied experimentally. The period between burns was either every 3 or every 6 years. The season for burning was varied among spring, summer, and winter. Results of the study indicated that seasonally varied prescribed fire, applied with a return interval of approximately 3 years, maintained an open tree canopy, with low or sparse understory vegetation that supported a healthy BCFS local population (J. Kellam, National Park Service, personal communication).

Hydrology also is a significant issue within cypress forest habitats. Natural hydrology maintains the essential vegetative structure and composition of the cypress dome community. Sustained hydroperiods are crucial to hindering the growth of many shrub and tree species that, in drier conditions, would create a dense understory in those habitats (FNAI 2010). Shortened hydroperiods or altered hydrology (i.e., physical changes in the flow or abundance of surface water) allow invasion of mesophytic species, such as hardwoods, which can alter the understory and replace cypress over time (FNAI 2010). Kellam et al. (2013) found that cypress

Figure 10. Interior view of a pond cypress dome swamp forest that shows large mature cypress trees with smaller cypress trees at the margin of the dome in the background. Photograph by Bob and Janie Hinson.

domes with reduced or restricted hydroperiods had more dense understory and midstory shrub layers and reduced occupancy by BCFS.

In urban habitats, such as golf courses, access to stable and diverse food sources is important and includes both native and non-native species such as pines, cabbage palms, fig trees and queen palms (Jodice and Humphrey 1992). Retention or recruitment of large, mature trees is critical for nesting and cover in all developed habitats, both urban and rural (e.g., pasture, ranches) for long-term maintenance of BCFS local populations in those areas.

Population Management

No specific population management actions are currently proposed for the BCFS. Nest boxes have been used as a population management tool in other areas of the fox squirrel range (Weigl et al. 1989). BCFS have only been reported nesting in tree cavities in urbanized habitat on golf courses (Jodice and Humphrey 1992, Ditgen et al. 2007). No BCFS tree cavity nests were found within the BICY study area (Kellam et al. 2013) and this behavior has not been documented in other natural habitats (J. Kellam, personal communication). There are concerns that squirrel poxvirus may negatively impact survivorship and productivity in BCFS local populations. To reduce the possibility of disease outbreaks occurring, the concentration of fox squirrel local populations should be avoided because it may increase the spread of the disease. If outbreaks of squirrel poxvirus or other diseases occur, outreach to local communities may be necessary, with recommendations to limit use of bird feeders until outbreaks have subsided.

Predation is not believed to limit local population size or density for BCFS, so predator control is not currently recommended. Most predation is expected to be opportunistic. Predators of BCFS include raptors (e.g., red-shouldered hawks [*Buteo lineatus*] and barred owls [*Strix varia georgica*]), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), foxes (*Vulpes* spp.), and dogs (Weigl et al. 1989, Koprowski 1994).

Mortality rates caused by vehicles may be high in some local populations or at specific sites. For situations where data indicate that vehicle-caused mortality is an issue, additional actions may be proposed. Poisoning from pesticides or other sources has not been documented as a significant source of mortality. Storms, especially hurricanes, or other unexpected environmental events can cause high rates of mortality in local populations (Weigl et al. 1989). However, the range of BCFS is considered large enough to keep catastrophic weather events from causing mortality range-wide. Impacts from catastrophic weather events should be studied, but such studies will be extremely difficult to execute given the unplanned nature of those events.

At this time, translocation is not recommended for management of BCFS. Translocation has been used as a management tool for some fox squirrel subspecies with varying levels of success (Dawson et al 2009), but anticipated problems outweigh the benefits in using translocation as a population management tool for BCFS. Translocation of 6 BCFS from a golf course in Naples to BICY produced a low rate of establishment (Jodice 1993). One translocated fox squirrel traveled at least 32 km (12.4 mi) toward the capture site, 1 was predated within 5 days, and 1 slipped off its collar. Movement patterns of the other 3 translocated animals suggested dispersal. Additional concerns about translocation include the possible spread of squirrel poxvirus, the need to better delineate BCFS's extent of occurrence, the need to find out whether all individuals (i.e., males,

females, and subadults) are equally likely to become established at a release site, and a lack of understanding of the ability of BCFS to adapt to unfamiliar habitats (e.g., if moved from urbanized habitat to natural habitats, live oak forests to cypress–slash pine forests, etc).

Under current rules regulating wildlife rehabilitation, a rehabilitated BCFS should be released "at or near the point of capture, or onto habitat where such wildlife naturally occur, and which will biologically support the species" (Rule 68A-9.006, F.A.C.). The release of a rehabilitated BCFS into habitats beyond the point of capture can be problematic and should be treated like a translocation, with similar concerns, particularly if the origin of an animal is not known. The appropriate release of rehabilitated BCFS is also discussed in Action 17. If further research and conservation actions address these concerns, translocations may be considered in the future.

Monitoring and Research

Due to the difficulty of observing and trapping Big Cypress fox squirrels within the core of their range (the Big Cypress Swamp watershed), the ecology and status of the BCFS in natural habitats is largely unknown. Until recently, knowledge of BCFS ecology was based upon studies of BCFSs inhabiting golf courses, radio-collared urban BCFS translocated to natural habitats, or studies of other fox squirrel subspecies. Although a 4-year (2007 to 2011) BCFS study within BICY has provided new information on home range size and habitat use within cypress dome swamp-pine forest mosaic habitats (Kellam et al. 2013), there is a lack of understanding of their ecology in the varying habitats that BCFS occupy throughout their range. In addition, information on BCFS's EOO, AOO, and population densities within natural habitats is largely unknown. To address these concerns and the data gaps identified by the BRG and peer reviewers, and to achieve the conservation goals and objectives, Monitoring and Research actions have been identified to answer basic questions about the population status, trend, and distribution of the BCFS and to confirm the taxonomic status of the subspecies.

The following are the most critical information needs to assess BCFS population status and trends. In the next 5 to10 years, research should focus on these needs.

Action 4 Develop a geographic information system (GIS) based habitat model to identify areas to survey for presence or absence.

Action 5 Develop an occupancy-based survey protocol to determine presence or absence of BCFS in potential habitat.

To develop a GIS-based habitat model to identify survey sites, known BCFS locations (e.g., field observations) should be projected over appropriate GIS layers. A University of Florida (UF) and FWC-administered web survey collected fox squirrel occurrence locations from the public throughout Florida during 2011 to 2012. Data from this survey can be used for initial GIS mapping (Appendix 3). Then BCFS occupancy surveys and habitat information gained from future ecology research can be combined to generate accurate GIS-based habitat models. Occupancy studies can be designed to incorporate abundance measures, when appropriate (MacKenzie 2005, MacKenzie and Royle 2005), though that should be expected to increase logistical costs for those studies. Habitat models should be developed at multiple scales, ranging from site-specific to landscape level, to assess BCFS's preferred habitats (Action 10). This can

be done by applying Species Distribution Models (SDMs) to associate occurrence locations with predictive environmental variables (e.g., canopy cover, land cover type, et al.) using statistical procedures to generate habitat suitability estimates (Guisan and Thuiller 2005). A SDM can be the basis for developing a map depicting the probability of occurrence across the BCFS range. Sites with a high probability of occurrence and known occurrence locations from the web survey should provide guidance to select sites for further surveys.

To effectively manage BCFS, it is imperative that reliable occupancy-based survey techniques are developed for both natural and developed habitats throughout the BCFS range. To date, only 1 occupancy-based BCFS survey technique has proven effective (confirmed by trapping results) when implemented in cypress dome swamp–pine forest mosaic habitats (Appendix 1; Kellam et al. 2013). MacKenzie and Royle (2005) and MacKenzie (2005) discuss additional design considerations for effective occupancy studies. MacKenzie (2005) makes the point that that typical presence or absence surveys are not always reliable for making sound management decisions.

Kellam et al. (2013) determined the best indicator of current BCFS nest occupancy (confirmed by trapping results) was the combined presence of freshly stripped cypress bark on trees (as determined by color), freshly stripped cypress bark incorporated into BCFS nest structures (Figure 12), and adjacent, freshly utilized food items. They regarded nests with recent, but not freshly stripped bark as a sign of recent occupancy. The recent nests were frequently used year-round by radio-collared BCFS. Nests that had not been maintained and were not associated with freshly utilized food items were termed old and were rarely used by radio-collared BCFS (Kellam et al. 2013). Even when using radio telemetry to identify nest trees, locating nests can be difficult (Figure 11). See Appendix 6 for a detailed description of the BCFS occupancy survey technique applied by Kellam et al. 2013.

Figure 11. Recently used Big Cypress fox squirrel nest in a bromeliad (circled in red), near the top of a cypress tree. Photograph by Courtney Tye, FWC.

Camera-based and sighting-based surveys can be applied to augment and improve occupancy-based survey techniques to determine BCFS

presence. These types of studies must be conducted across all natural habitats that BCFS are known to use over the expected EOO in order to best understand habitat use and occurrence. Data from range-wide sighting and trapping (Action 8) surveys and genetic analyses can be combined to assist with the development of accurate range maps for BCFS and other fox squirrel subspecies within Florida (Action 9). Development and implementation of the protocols should involve statisticians and species experts to ensure the recommended methodologies are reliable.

Action 6 Develop protocol for collecting and processing tissue samples for genetic analysis.

Action 7 Solicit collection of tissue samples from road-killed fox squirrels throughout the state.

Action 8 Conduct trapping to collect tissue samples using sites identified from reported locations, and based on gaps in data from road-killed specimens.

Action 9 Conduct genetic analyses to determine the current EOO and AOO for BCFS.

A re-examination of the systematic affinities of local populations of fox squirrels in the southeastern United States and a clearer delineation of subspecies ranges are needed to further conservation and management (Turner and Laerm 1993). Population genetics techniques can provide information on the relationship of BCFS to other fox squirrel subspecies and on movements by individual squirrels among local populations. However, standard genetic techniques based on mitochondrial DNA (mtDNA) may not be sufficient to address these issues for BCFS. Moncrief et al. (2010) could not delineate subspecies of fox squirrels or determine phylogeographic structure within subspecies using cytochrome-b sequences of mtDNA. Therefore, future genetic studies should examine segments of DNA that evolve more rapidly, such as microsatellites, amplified fragment length polymorphisms, and single nucleotide polymorphisms (Manel et al. 2003, Moncrief et al. 2010). Microsatellite analyses may be an appropriate starting point (Action 9) given the 26 polymorphic microsatellite markers developed for the fox squirrel by Fike and Rhodes (2009). Further, Moncrief et al. (2010) suggest the use of amplified fragment length polymorphisms.

A protocol for collecting and handling tissue samples for genetic analyses (Action 6) has been developed (Appendix 5). A network of partners has been organized to collect tissue samples for genetic analyses from road-killed fox squirrels statewide (Action 7). This network includes university researchers (e.g., at UF, University of Central Florida, and Florida Gulf Coast University), staff members of federal and state agencies (e.g., FWC, the Florida Department of Environmental Protection [DEP], Florida Forest Service, U.S. Forest Service, National Park Service [NPS], USFWS), as well as the public. The staff at BICY also has hair and tissue samples collected during previous work.

UF researchers will also conduct selective trapping near currently recognized limits of fox squirrel subspecies (Figure 5) and in areas of Florida under-represented with tissue samples (Action 5). This will ensure sampling is sufficient to precisely delineate the EOO for BCFS and other fox squirrel subspecies in Florida.

Fox squirrel location data collected from a UF–FWC web-based sighting survey (2011 to 2012), along with data from the BICY study (Kellam et al. 2013) and available observation records (1982 to present), will be used to generate GIS maps of potential trapping sites throughout the state (Action 4). After data analysis is completed, a detailed range map and a description of the EOO can be completed for each subspecies of fox squirrel in Florida (Action 9). .

Action 10 Determine habitat associations and clearly identify preferred habitat types.

There is a limited amount of information on habitat use for BCFS. Big Cypress fox squirrels have been documented inhabiting south Florida slash pine forests, pond cypress and bald cypress swamp forests, live oak woods, tropical hardwood forests, coastal broadleaf evergreen hammocks, mangrove swamps, and developed habitats including golf courses, city parks, and residential areas (Howell 1919, Moore 1956, Williams and Humphrey 1979, Duever et. al 1986, Jodice and Humphrey 1992, Ditgen et al. 2007, Eisenberg et al. 2011).

There are almost no data on preferred habitat types, optimal habitat conditions, or specific habitat features associated with the occurrence or abundance of BCFS. The extent to which BCFS occupy live oak forests, tropical hardwood forests, coastal broadleaf evergreen hammocks, and mangrove swamps remains poorly understood. Studies have consistently indicated that BCFS population densities are low across the species' range and have provided little insight into habitat preferences (Howell 1919, Moore 1956, Brown 1978, Williams and Humphrey 1979, Jodice 1990, Wooding 1997, Eisenberg et al. 2011). The most detailed work on habitat use and preference by BCFS in natural habitats was conducted at BICY (Kellam et al. 2013) (Figures 8, 9, and 10, Appendix 4, Appendix 6). The scarcity and low capture success (Weigl et al. 1989; Jodice 1990, 1993) of BCFS in natural habitats has resulted in most ecological studies being based on local populations occupying urbanized habitats such as golf courses (Jodice and Humphrey 1992, Ditgen et al. 2007, Eisenberg et al. 2011), or on individual squirrels from urban sites that were radio-collared and translocated to BICY (Jodice 1993, Dusek et al. 1998).

There is a need to analyze BCFS occurrence and habitat use across habitat types to better understand optimal habitat conditions and preferred habitats. Studies should be conducted across multiple sites of known BCFS occupancy to assess preferred habitat conditions. Studies also should evaluate the effects of various land management techniques (e.g., fire and mechanical treatments) on habitat use and abundance of BCFS. There are further needs for intensive studies like the BICY telemetry study (Kellam et al. 2013). There are also needs for less-intensive occupancy modeling studies based on mark–recapture surveys or camera-based surveys.

Action 11 Develop a scientifically sound monitoring protocol for BCFS.

Action 12 Develop a protocol to estimate density and abundance of BCFS in different habitat types.

Action 13 Implement a monitoring program to track BCFS local populations on a 5-year interval.

Effective survey protocols are necessary to assess local population trends over time. To be fully effective, such protocols must account for differences in detectability of BCFS among different habitats.

Lack of BCFS sightings during survey efforts in natural habitats is not always an indicator of absence, since BCFS are secretive in nature, occur in low densities, and have a low survey detection rate in known occupied habitats (Jodice 1990, 1993; Eisenberg et al. 2011). The problems associated with detecting and capturing BCFS mean that many local populations have not been monitored (Weigl et al. 1989, Kantola and Humphrey 1990). Effective survey protocols (Action 11) are necessary to assess local population trends over time (Action 13). Development of a monitoring protocol for BCFS that will yield dependable measures of population density and changes in population size over time (Action 13) will require coordination with statisticians and external experts to develop and will take multiple years to implement.

Although the capture rate of fox squirrels using live traps has historically been extremely low (Weigl et al. 1989), a recent research study in BICY developed new techniques for effectively trapping BCFS in natural habitats (Appendix 6; Kellam et al. 2013). These new trapping techniques for cypress swamp habitats and previously established ground trapping techniques (Jodice 1990, Ditgen et al. 2007) will make it possible to initiate mark-recapture and telemetry studies to measure BCFS local population density and abundance and demographic parameters in a variety of natural habitats (Action 14). Trapping also provides an opportunity to collect tissue samples for genetic analyses (Actions 6, 8, 9). Telemetry studies will also make it possible to more accurately assess habitat use, measure optimal habitat characteristics, and identify priority areas (Actions 1, 2, 15).

In addition, researchers at UF have been developing an individual BCFS recognition technique (based on unique fur color patterns and physical anomalies). Color patterns of fox squirrels in Florida are unique among individuals, and these patterns and markings can be used as markers for identification once a sound protocol is developed (Kiltie 1992). A reliable technique for recognizing individuals by appearance may improve opportunities for using remote cameras to obtain mark-recapture data.

Action 14 Initiate research to estimate demographic parameters (e.g. fecundity, juvenile survival, local population density, optimal habitat characteristics, etc) needed for robust population models and population viability analysis (PVA).

Big Cypress fox squirrel demographic parameters (i.e., fecundity, juvenile survival, local population density, population growth, recruitment, immigration and emigration rates, etc.) are essential for creating robust local population models, and accurate PVAs are currently unknown. Population viability analyses estimate the likelihood of a local population's extinction, compare proposed management options, and assess species recovery efforts. A PVA was carried out on the BCFS by using demographic information from the fox squirrel species as a whole (Root and Barnes 2006, Endries et al. 2009). Results revealed that small changes in the model had large impacts on local population trends. It is essential to note that these parameters may vary between local populations occurring in natural habitats (e.g., pinelands and cypress domes) and local populations that occur in urbanized habitats (e.g., city parks and golf courses). Therefore, to fill

these data gaps, research needs to be conducted in the variety of habitats that BCFS are known to occupy. Ground trapping and platform trapping techniques and radio telemetry methods should be used. Preferred trapping location can be mapped using BCFS sighting-record data and known, successful BCFS trapping sites within urbanized, agricultural, and natural habitats (Action 4). Consultation with species experts and statisticians may be needed to ensure the data collected are sufficient to achieve the desired objectives.

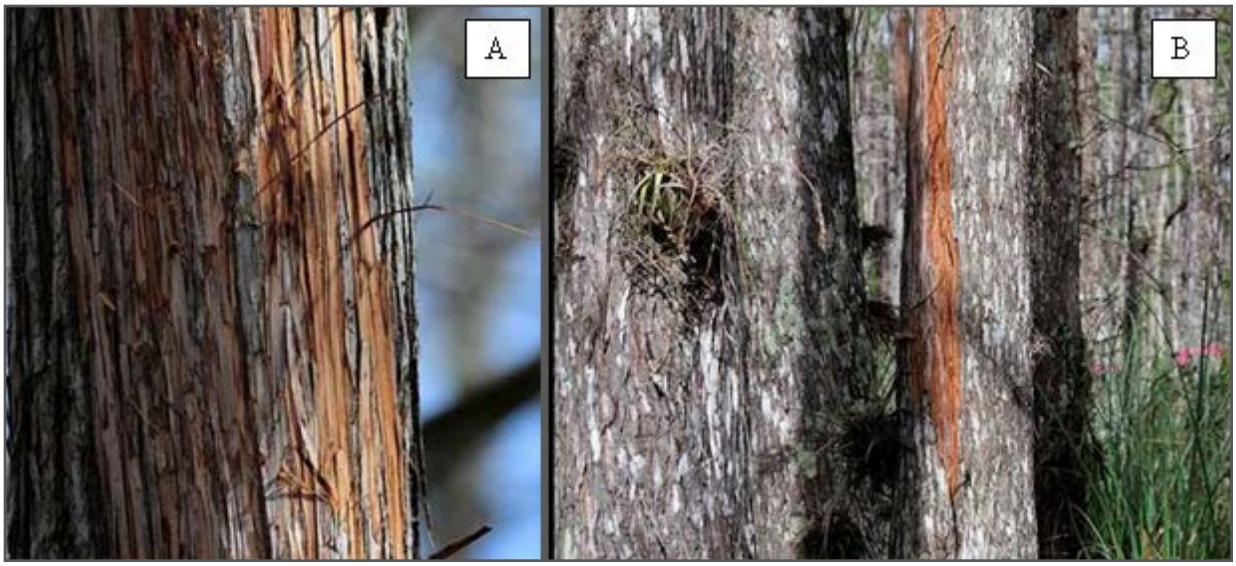

Figure 12. Cypress trees with patches where Big Cypress fox squirrels recently stripped the bark, an important nest building material, revealing the bark's inherent orange color before it oxidizes and turns gray. Stripped bald-cypress bark is an important visual sign of potential BCFS occupancy within cypress associated habitats (see Appendix 4 for further explanation).
A) Freshly stripped cypress bark—note the bright orange color. B) Freshly stripped cypress bark as it often appears when encountered during survey efforts (Kellam et al. 2013). Photographs by Ralph Arwood.

Action 15 Initiate research to determine the optimal composition and structure of priority BCFS habitat.

Although the Kellam et al. (2013) study provided new information on BCFS habitat use within cypress dome swamp–pine forest mosaic habitats, the optimal composition and structure of priority fox squirrel habitat throughout their range has yet to be determined. UF is currently (i.e., from 2013 to 2015) conducting research to determine the optimal composition and structure of sandhill and upland pine habitats for Sherman's fox squirrels in central and north Florida. A similar study within BCFS range needs to be designed and completed. This research should be conducted across habitat types occupied by BCFS and also account for variation in habitat management.

The effects of prescribed fire on habitat quality should be specifically examined. It will be important to measure fire-return interval and effects within habitats as well as across the ecotones between habitats. For example, Kellam et al. (2013) found that fire shaped habitat

boundaries and maintained open ecotones, which increased fox squirrel movement between habitats.

Small topographic (i.e., elevation) changes and natural hydrology also can be important for maintaining the integrity of natural communities. Past changes in hydrology may have changed habitat quality, altered ecotones, and had significant negative impacts on food availability for BCFS. Those are clear reasons to better understand the hydrology of these ecosystems.

Action 16 Develop GIS-based potential habitat maps stratified by habitat quality.

Data on BCFS presence and abundance (Action 12) among habitat types is an important component of the optimal habitat evaluation. However, to fully evaluate optimal BCFS habitat composition in terms of BCFS population growth and potential, data on demographics such as survival and fecundity (Action 14) must be obtained concurrently with the habitat data (Action 15). Once the optimal habitat composition and structure have been measured, GIS-based potential habitat maps stratified by habitat quality can be created.

Rule and Permitting Intent

This section identifies the current regulations addressing conservation of the BCFS, and discusses some of the potential issues with protections and the development of appropriate permitting guidelines.

Current Protections and Regulations

Action 17 Determine if current rule language (including rules related to taxidermy and release of rehabilitated animals) is sufficient to ensure conservation of the BCFS.

Two rules currently in the F.A.C. provide protections for the BCFS as a listed species. Based on the BSR findings, the FWC proposes to maintain the listing status as State Threatened under Rule 68A-27-.003, F.A.C., which states, “No person shall take, possess, or sell any of the endangered or threatened species included in this subsection, or parts thereof or their nests or eggs except as allowed by specific federal or state permit or authorization.” Rule 68A-27.007, F.A.C. provides the requirements for issuing permits for both incidental and intentional take of Threatened species, including the BCFS.

Although these 2 rules provide the basis for protection of BCFS, interpretation of activities that lead to take is difficult without a better understanding of the life history of the BCFS. Issuance of any permits in accordance with Rule 68A-27.007, F.A.C., is also dependent on identifying activities causing take and developing guidance for issuing permits to minimize impacts while allowing otherwise lawful activities. Considerations for permitting are provided below, but a lack of information about BCFS local populations outside of golf courses and BICY limits recommendations for specific permit conditions. To address this, actions identified in the Monitoring and Research section (Actions 11, 12, 13, and 14) will provide data needed to determine human-caused impacts. Those results will be used to provide guidance in determining the level of protection needed to achieve conservation goals (Action 18). If it is determined that some activities may lead to take as defined in Rule 68A-27.001, F.A.C., or it is determined that

the rule language is not adequate to provide protections and enforcement, the rule may be amended to ensure adequate protection for BCFS.

Two other rules may have an impact on BCFS conservation. Take for possession through taxidermy is a rule that may need to be revised. Taxidermy is covered under Rule 68A-12.004, F.A.C., which specifies "Possession or Sale of Birds or Mammals; Taxidermy Operations and Mounting Requirements." Language in Rule 68A-12.004, F.A.C., allows for taxidermy of any road-killed fox squirrels without a permit. Although the rule prohibits the taxidermy of listed species without a permit, it includes a provision for taxidermy of road-killed fox squirrels, without distinguishing between listed and unlisted subspecies, thereby leading to confusion over the legality of collecting road-killed BCFS for taxidermy. Revisions to the rule should protect BCFS from collection for taxidermy, account for the similarity of appearance of all fox squirrel subspecies, and address uncertainty about the limits or extent of the BCFS range. Until genetic work is completed (Action 9), the limits of the BCFS range cannot be accurately defined relative to other fox squirrel subspecies. Although the Caloosahatchee River has been provided as a potential northern range limit for the BCFS (Moore 1956, Williams and Humphrey 1979), results from the UF–FWC web-based survey (Appendix 3) show fox squirrels occur in close proximity to the river along both sides.

Any rule or permitting changes should allow for road-killed BCFS to be collected as part of permitted scientific studies (Appendix 3 and Appendix 5). One way to address this would be to modify scientific collecting permits (Action 18) by inserting a provision that would allow persons working on behalf of the permittee to collect road-killed BCFS.

The rule that addresses the release of rehabilitated BCFS may also need to be revised. Rule 68A-9.006, F.A.C., "Wildlife Rehabilitation Permit" specifies that the release of rehabilitated animals occur "at or near the point of capture, or onto habitat where such wildlife naturally occur, and which will biologically support the species." Release of animals near the point of capture should not create any unintended consequences. However in situations where animals are considered waifs (their origin is unknown), release can be problematic if it is allowed to occur on any suitable habitat where the species occurs. Squirrel poxvirus, recently detected in BCFS (Kellam 2010), can produce high rates of mortality in infected local populations. A further complication is that squirrel poxvirus has an incubation period of 7 to 14 days before tumors become visible (Kilham 1955, Hirth et al. 1969). Depending on the length of rehabilitation, infected squirrels could be inadvertently released into healthy local populations. Uncertainty in range of fox squirrel subspecies could also lead to release of individuals into genetically unique local populations. To prevent unintended impacts to BCFS local populations, permitting for rehabilitation facilities that care for fox squirrels should include conditions to prevent release of fox squirrels of unknown origin into any wild local populations and to only release fox squirrels of known origin at the point of capture.

Permitting Considerations

Action 18 Determine the level of protection needed through permitting to achieve conservation goals for the BCFS.

Permits issued through Rule 68A-27.007, F.A.C., address both intentional and incidental take. Intentional take is only authorized for "scientific or conservation purposes which will benefit the survival potential of the species." Permits of this type are usually referred to as scientific collecting permits. These permits should only be issued for the take of BCFS if they further the conservation and protection of the BCFS, as outlined in this plan or other planning documents developed for accepted conservation purposes.

Incidental take is take that occurs during otherwise lawful activities, such as land clearing for development purposes. Land management activities that benefit wildlife are exempt from any permitting requirements, if they are not inconsistent with management plans for listed species. Permits for the incidental take of BCFS are authorized only if "there is a scientific or conservation benefit and only upon a showing by the applicant that the permitted activity will not have a negative impact on the survival potential of the species." Few permits for incidental take are currently issued under the existing rule and permitting system. Currently, technical assistance information related to fox squirrels on FWC's website provides limited guidelines for surveying for fox squirrels, and recommends avoiding active nest trees by limiting activity within a 38-m (125-ft) buffer. This current buffer distance and the concept of protecting only active nest trees may not be adequate for protection. Buffer distances of 250 m (820 ft) from BCFS nest sites may be appropriate to avoid disturbance in some situations (Appendix 8). Recommended buffer distances would not be applied to land management activities that benefit wildlife in accordance with Rule 68A-27.007, F.A.C.

To address conservation requirements outlined in rules (i.e., F.A.C.), mitigation may be needed to achieve a scientific or conservation benefit. Minimization and avoidance measures may also be needed to prevent a negative impact on the survival potential of BCFS. In some cases, if avoidance of impacts is possible, no additional permitting measures should be required.

For the permitting process to be effective, detailed criteria should be applied that are based on a good understanding of BCFS local populations, including the fact that these squirrels are often not easy to observe. Thus, it should be expected that an effective permitting process for BCFS may not be as straight-forward as the process that had been followed in the past. To develop adequate avoidance, minimization, and mitigation measures for this process the following issues need to be addressed:

- Identifying sites occupied by BCFS can be difficult, but that is necessary to achieve conservation goals.
  - Detection may depend on squirrel signs (i.e., stripped bark, nests, etc), and not solely on seeing a BCFS.
  - Survey techniques for BCFS are not able to reliably detect BCFS when they are present. Currently, the only reasonably reliable methods are those developed at BICY for interspersed cypress swamp and slash pine forest habitats. See Appendix 6 for additional details of the BICY survey procedure.

  - Current survey methods for detecting fox squirrels encourage the use of walking transects, which under-represent presence (Jodice 1990, 1993; Eisenberg et al. 2011; J. Kellam, personal communication).
  - Methods for detecting BCFS in urban areas or other natural habitats have not been tested.
- The current guidelines for avoiding active nest trees probably do not provide adequate protection and may lead to unintended take.
  - BCFS are secretive and difficult to observe. In BICY, researchers observed squirrels about 40% of the time, even when radio-tracking indicated that the squirrels were in a particular tree. Young were only seen on 2 occasions (in over 2,000 radio-tracking locations), and squirrels were tracked to many different nests (i.e., 403 nests in 923 ha [2,2801 ac]) (J. Kellam, personal communication).
  - Potentially occupied nests can sometimes be identified by the presence of freshly stripped cypress bark, but BCFS also use nests with signs that indicate less recent maintenance. The definition of an active nest has been developed through research at BICY, but needs continued improvement and testing at sites beyond BICY before being incorporated into permitting guidelines and technical assistance documents.
  - Inactive nests can be important resources that BCFS use as refuges to avoid predators and protection during storms.
- Habitat protections need to be incorporated into avoidance recommendations and permitting guidelines. This is necessary to address the BSR findings that the primary threat to BCFS is loss of habitat and habitat fragmentation.
  - Ecotones can be important components of BCFS habitat. On BICY, BCFS tend to construct the majority of their nests in areas where cypress domes meet pine forest edges, an indication that BCFS need to have a combination of cypress dome swamp and pine forest habitats available year-round to meet their resource needs. Without the combination of pine forest habitat, which provides food resources, adjacent to cypress domes, which provide nest sites, the area would no longer successfully support BCFS (Kellam et al. 2013).
  - Connectivity between BCFS local populations is important and needs to be better understood to address habitat fragmentation. It will be particularly important for local populations that occupy urban sites to be connected with each other and with those occupying natural habitats. Data from Monitoring and Research actions (Actions 1, 2, 15, and 16) can guide the development of mitigation measures that address fragmentation.
- Life history requirements of the BCFS need to be incorporated into avoidance recommendations and permitting to prevent local population declines.
  - Disturbance impacts are not well understood for BCFS. When disturbed, BCFS will sometimes go up the closest tree or point of refuge (e.g., nest or bromeliads). Going to the top of a tree may make disturbed individuals susceptible to avian predators.
  - Buffer distances should be based on disturbance level and foraging needs. These distances may need to differ based on the type of disturbance and habitat where that occurs. For example, analysis of movements by BCFS at BICY (Kellam et al. 2013) revealed that males travel, on average, about 150 m (about 500 ft) within a 24-hour period (Kellam et al. 2013). However, during some seasons, BCFS moved more than 250 m (820 ft) to forage (Appendix 8; Kellam et al. 2013).

  - If disturbance involves the take of foraging habitat, buffers may need to be greater than if disturbance is limited to activities that do not take foraging habitat. Types of activities that would be allowable within a buffer may need to be identified.
- BCFS behaviors in urban local populations may differ from those in local populations occupying natural areas. Those differences need to be considered when developing protections and permitting guidelines.
  - Fox squirrels may spend more time on the ground in golf courses, and more time in trees in natural habitats (Ditgen et al. 2007, Kellam et al. 2013).
  - In both urbanized and natural habitats, BCFS are occupying forested areas or sites where stands of trees and an open understory are present.
  - Disturbance and tolerance for human activity may differ between urban and natural-area local populations.
  - Additional research actions may be needed to identify characteristics of urban local populations.
- Mitigation measures should be developed to meet the objectives outlined in this plan, and should be guided by the results of the Monitoring and Research section.
  - Translocation and reintroduction of BCFS is not currently recommended as a form of mitigation. Movement of urban squirrels into natural areas has led to high rates of mortality among translocated individuals (Jodice 1993). There are also concerns about the risk of spreading disease, specifically squirrel poxvirus, into otherwise robust local populations. Translocation without adequate disease testing could lead to significant declines in otherwise healthy local populations. It would be difficult to ensure that only disease-free individuals are translocated. There is not enough information on potential disease transmission to justify translocation as an option at this time. Translocation could be re-evaluated in the future once sufficient information is obtained and adequate follow-up research is completed.
- Data gaps that limit the ability to determine when, or to what extent, a "…permitted activity will not have a negative impact on the survival potential of the species" need to be considered high priorities for action.

Additional details related to permitting considerations can be found in Appendix 8.

Law Enforcement

Action 19 Train law enforcement officers to identify fox squirrels, their nests, evidence of presence, and habitat to identify potential take situations.

To enforce rules and protections developed under Action 17 and Action 18, law enforcement officers will need to be able to identify fox squirrels, nests, and situations in which take may occur. Training materials should be developed to provide law enforcement officers with awareness of current rules and permitting guidelines, along with the biological background for those protections (Action 19).

In addition, input from FWC law enforcement officers may be needed to improve awareness and compliance with recommended changes to the rule that regulates taxidermy of wildlife (Rule

68A-12.004, F.A.C.; see Rule and Permitting Intent). FWC law enforcement officers will be able to provide information to taxidermists and the public regarding that change and the reasons for it.

Incentives and Influencing

Implementation of this plan will require the cooperation of multiple partners. Public lands alone may not meet requirements for effective BCFS conservation. Efforts should be made to encourage private landowners to implement habitat management activities that improve habitat quality and the abundance of food resources for BCFSs in urban areas and rural developed lands (with rural including both residential and agricultural areas). Private lands can provide suitable habitat for BCFS local populations and will be essential for creating and maintaining corridors between local populations. Urban and rural developed lands typically have a reduced understory and may provide suitable habitat for BCFS, at least in the short-term while large trees remain available in those areas. Eisenberg et al. (2011) noted that retention of large trees for nest sites and cover in urban and rural developed lands could be a significant threat to maintaining the quality of those areas for BCFS, because when large trees die, they often are not replaced. Incentives to plant trees and retain large trees could be important for maintaining habitat quality in those areas.

County growth management plans and land development planning processes provide an avenue by which FWC can influence the manner in which land use changes proceed, so that the resulting areas are better managed to enhance the conservation of the BCFS. For example, BCFS local populations can exist in urbanized habitats on sites such as golf courses (Jodice and Humphrey 1992, USFWS 2002, FWC 2005, Ditgen et al. 2007), but such urban sites are able to support fox squirrels only when the habitat provides sufficient food and other needed resources, such as nest sites. Incidents of BCFS road mortality should be analyzed to determine if patterns exist. Mortality reports can be analyzed in conjunction with data on locations that support BCFS and landcover assessments when planning future road development to reduce vehicle-caused mortality.

Action 20 Develop or enhance incentive programs to encourage implementation of habitat management practices consistent with habitat management guidelines that benefit BCFS.

Incentive programs offering technical and financial assistance to private landowners to restore and manage habitat conditions that benefit BCFS should be encouraged. Incentives would come largely through existing state- and federally administered landowner assistance programs. Minor changes could be made to those programs to include criteria and projects that specifically benefit BCFS. Available incentive programs include the Florida Forest Stewardship Program, Wildlife Habitat Incentives Program, Environmental Quality Incentives Program (EQIP), Landowner Assistance Program, and Partners for Fish and Wildlife Program. These programs are voluntary for landowners and can provide financial incentives, depending on available funding, for wildlife conservation and habitat management on private lands. In addition to these incentive programs, property tax exemptions are available for conservation easements.

Prescribed fire is a habitat management tool which can be difficult for private landowners to use. Throughout the state, multiple agencies and organizations have worked together to create prescribed fire strike teams that support land managers to increase prescribed burning. Entities

like The Nature Conservancy, Florida Forest Service, FWC, and DEP have collaborated to form the Northeast Florida Resource Management Support Team, Lake Wales Ridge Prescribed Fire Strike Team, and other fire strike teams throughout the state. While successful at this endeavor, these teams function primarily on public lands and there has been little emphasis in applying this type of tool on private lands. Efforts should be made to meet requests from private landowners for financial and logistical assistance (e.g., manpower, burn authorizations) in applying prescribed fire.

Once habitat management guidelines are developed (Action 3) and habitat preferences of BCFS are better understood (Action 10), additional management practices can be encouraged. Updated habitat management recommendations should be incorporated into the Florida Wildlife Conservation Guide (FWCG), an online public resource currently maintained by FWC, to facilitate effective land use planning, project design, and management of natural communities. Further, management recommendations should be used to guide FWC staff review of proposed developments, road construction, and other projects that would change land use.

Big Cypress fox squirrels will use suitable areas on agricultural lands and on other developed lands such as golf courses and parks. Owners and managers of these lands should be encouraged to implement management practices that will maximize benefits for BCFS local populations. They should be provided with habitat management guidelines (based on Action 3) and information about incentive programs, particularly EQIP.

Creation or enhancement of habitat corridors on private and public lands (Action 2) should be encouraged through application of existing incentive programs, where possible. To provide corridors among agricultural lands, native trees could be planted along fencerows to supply cover where fields otherwise lack trees. Using trees such as pines and mast-producing hardwoods would provide both cover and food. For BCFS conservation to be most effective, development of effectual corridors will be essential to promote successful movement by individuals.

Incentives should be developed to encourage landowners, land managers, and developers to maintain or enhance habitats for BCFS on their lands. The incentives should encourage them (Action 20) to implement habitat management actions that are known to benefit BCFS (Action 3).

Habitat Management

FWC will work with property owners and managers to encourage their use of appropriate habitat management guidelines (see Appendix 4 for further details). FWC staff should update and maintain information on BCFS in the FWCG with information on habitat use, diet, movements, and disturbance or buffer distances.

Protections and Permitting

Incentives should be developed (Action 20) to encourage landowners and managers to maximize benefits for BCFS through management and conservation of their lands. If lands are slated for development or conversion to other uses, conservation measures should focus on avoidance and minimization of impacts to BCFS and its habitats; the permitting structure can provide tiered incentives to encourage avoidance first, followed by minimization, although both of these are

secondary to using incentives to maintain or increase benefits for BCFS through management and conservation. Only where disturbance or other negative impacts cannot be avoided and minimization is not sufficient should recommendations for permitting be followed, including the need to mitigate for impacts to local populations and habitats.

Education and Outreach

Action 21 Disseminate habitat management guidelines and monitoring protocols to private landowners and public land managers.

Action 22 Develop a comprehensive outreach program (brochures, kiosks, Project Wild, Land Use Planning, etc.) to target a variety of audiences.

Action 23 Develop a strategy to ensure our partners, stakeholders, and the public are aware of rule and permitting changes.

Education and outreach are important components of imperiled species conservation. Actions 21, 22, and 23 will target a variety of audiences and situations. People who are well informed of the benefits of conserving imperiled species and their habitats are more likely to support those efforts. Outreach efforts should be applied broadly to encompass multiple scenarios, outreach tools, and media. The FWC fox squirrel webpage should maintain current species information. Social media outlets are another medium to publicize information. Efforts should be coordinated with partners to take advantage of other existing resources and materials.

As natural communities and habitat parameters preferred by BCFS are better understood (Action 10), management guidelines to achieve those conditions can be developed. Communication of management guidelines to land managers through online information, workshops, or other means will be an important component of outreach efforts.

Vehicle-caused mortality of BCFS along roadways is an ongoing issue, especially for local populations occupying sites in urban areas. To help address this issue, outreach can be used to increase awareness and public interest in fox squirrels and to remind people that fox squirrels are vulnerable to road mortality. Creative messaging, perhaps similar to the “Give Them a Brake” campaign for road worker safety, may assist in communicating that information.

Key outreach messages should include:

- Identification of the BCFS and appropriate habitat.
- Robust BCFS local populations indicate high-quality habitat conditions.
- Effective habitat management for BCFS benefits other wildlife and can be compatible with management for other imperiled species such as the red-cockaded woodpecker.
- BCFS have specific needs for food resources, which change seasonally, and for nest sites; individuals often use multiple nest sites.
- BCFS are relatively wide ranging, so conservation is dependent not only on public lands, but also on minimizing habitat degradation and negative impacts from habitat fragmentation on other lands.

- Feeding of BCFS by people is a problem that can lead to higher mortality and higher rates of disease (e.g., squirrel poxvirus and mange) by concentrating individuals. Feeding can also cause individuals to become habituated to people (Figure 13), which can increase chances of vehicle-caused mortality and other impacts, such as predation by cats and dogs.
- The BCFS has a relatively low reproduction rate, which means local populations will be slower to overcome the impacts of diseases and other sources of mortality; they will also be slower to respond to habitat restoration efforts.
- Once optimal or high-quality BCFS habitat is degraded, restoration of the habitat requires an expensive and lengthy management process.
- The BCFS is charismatic. Many people have expressed a strong interest in viewing wildlife, and BCFS are unique, with easily recognizable colors and patterns. Efforts to promote viewing of the BCFS may increase public support for this species.
- Necessary protections to prevent take from development and land-use changes, including buffer distances for nests.
- Big Cypress fox squirrels are vulnerable to vehicle-caused mortality. Drive cautiously where they are known to occur and "give them a brake."
- Rehabilitators should know how and where to release BCFS whose origins are not known ("waifs"). Waifs should not be released in priority conservation areas.

Many Floridians believe there is intrinsic value to natural resource conservation. These individuals gain a sense of comfort in knowing that imperiled species are protected, whether or not they have any plans to view the species or the habitat supporting the species. As such, simply knowing management for imperiled species is occurring on State conservation lands will enhance the quality of life for some Floridians.

Coordination with Other Entities

No specific actions have been identified for this section. However, Actions 7, 9, and 11-16 will require coordination among multiple agencies, universities, and other organizations. Rule and permitting guidelines (Actions 17 and 18) and interpretations of them should be provided to FWC staff in the Office of Conservation Planning Services, as well as permitting staff, for distribution to partners and stakeholders as appropriate to enhance coordination.

Restoration of viable BCFS local populations across the species' range will depend to a large extent on the success of sustaining or increasing BCFS local populations within identified core conservation areas (Appendix 9). A regional or landscape approach, as is suggested for core conservation areas, is essential for long-term conservation of viable BCFS local populations. This approach will require successful coordination among management partners.

Successful adoption of the habitat conservation measures (Actions 1 and 2) in this plan will require effective partnerships and coordination among many land managers, species experts, and stakeholders. Coordination and management for BCFS across state and federal conservation lands will be essential for conservation of this species. Lead agencies for conservation lands that are identified as supporting, or having the potential to support, BCFS should consult with FWC when developing management strategies.

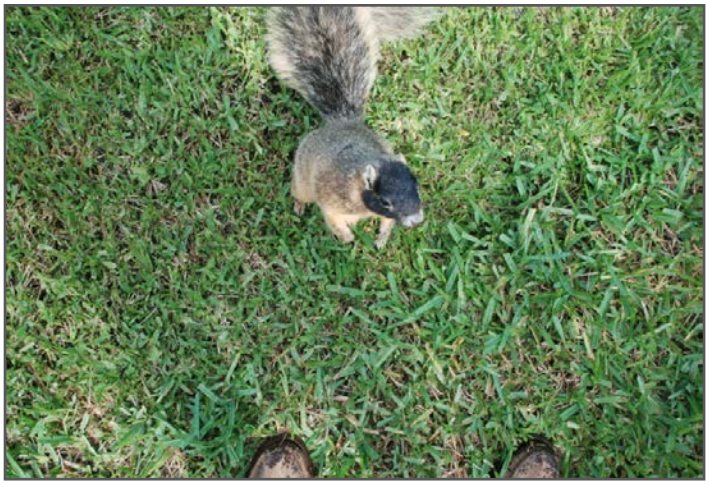

Figure 13. A habituated, urban fox squirrel in Naples, Florida. Squirrels that become habituated as a result of being fed can become more vulnerable to threats such as disease and vehicle mortality. Photograph by Jerry L. Walrath.

Many state conservation lands are required to have a management plan approved by the Acquisition and Restoration Council, or the agency's governing board. Specifically, s. 253.034(5), Florida Statutes (F.S.), says in part that all land management plans shall include an analysis of the property to determine if significant natural resources, including listed species, occur on the property. If significant natural resources occur, the plan shall contain management strategies to protect those resources. The Florida Forever Act (s. 259.105, F.S.) adds that all state lands with imperiled species habitat shall include as a consideration in the management plan the restoration, enhancement, management, and repopulation of such habitats. State conservation lands are essential to the conservation of the BCFS and other imperiled species, and must continue to play a major role in their recovery.

Table 1. Big Cypress Fox Squirrel *(Sciurus niger avicennia)* Conservation Action Table

NOTE: An explanation of acronyms used is below the table.

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
4	2	1	Identify priority conservation areas throughout the range of the BCFS to ensure habitats with the greatest potential to benefit the species are protected, connected, and improved.	Habitat Conservation & Mgmt	EXPANDED	YES	YES	$25-50k	Existing budget	HSC, WHM	DEP, FFS, USFS, USFWS, WMD, County Environmental Land Programs	Effective at achieving desired outcome.	Feasible and already under way.	Yes, habitat conservation is necessary for long term survival.
4	3	2	Maintain, enhance, and encourage the creation of habitat corridors on public and private lands through existing habitat conservation programs and incentive programs.	Habitat Conservation & Mgmt	NEW	YES	YES	$50-100k	SWG , Existing, Grant, and other	HSC, CPS	DOACS, NRCS, Land Trusts or NGOs, DEP, FFS, USFS, USFWS, County Environmental Land Programs	Effective at achieving desired outcome.	Feasible and already under way.	Yes, critical to survival.
4	3	3	Develop habitat management guidelines and monitoring recommendations for public land managers and private landowners.	Habitat Conservation & Mgmt	NEW	YES	YES	$0-25k	Existing budget	HSC	UF, Big Cypress National Preserve, NPS	Effective at achieving desired outcome.	Feasible and already under way.	Yes, the information is critical for influencing and promoting beneficial habitat management.
2	1	4	Develop a geographic information system (GIS) based habitat model to identify areas to survey for presence or absence.	Monitoring & Research	EXPANDED	YES	YES	$25-50k	SWG , Existing, and other	HSC, FWRI	UF, Big Cypress National Preserve, NPS	Effective at achieving desired outcome.	Feasible and already under way.	Yes, these data are critical for assessing the status of this species.
2	2	5	Develop an occupancy-based survey protocol to determine presence/absence of BCFS in potential habitat.	Monitoring & Research	EXPANDED	YES	NO	$25-50k	SWG , Existing, and other	HSC, FWRI	UF, Big Cypress National Preserve, NPS	Effective at achieving desired outcome.	Potentially feasible, but not clear if a methodology can be developed that will not require an excessive commitment of time and resources.	Yes, this protocol is important for assessing the status and persistence of BCFS populations in existing habitat.
1	1	6	Develop protocol for collecting and processing tissue samples for genetic analysis.	Monitoring & Research	ONGOING	YES	YES	$0-25k	SWG , Existing, and other	HSC, FWRI	UF, FNAI, NPS, Camp Blanding JTC, FPS, WMD, USFWS, FPS, DEP,FFS,USFS, Pepperdine University	Effective at achieving desired outcome.	Feasible and already under way.	Yes, this protocol is critical to assessing the taxonomic status and EOO of BCFS.
1	1	7	Solicit collection of tissue samples from road-killed fox squirrels throughout the state.	Monitoring & Research	EXPANDED	YES	YES	$0-25k	SWG , Existing, and other	HSC, FWRI, LE	UF, FNAI, NPS, Camp Blanding JTC, FPS, WMD, USFWS, FPS, DEP,FFS,USFS, Pepperdine University	Effective at achieving desired outcome.	Feasible and already under way.	Yes, data from these animals are important for assessing the taxonomic status and EOO of BCFS.
1	1	8	Conduct trapping to collect tissue samples using sites identified from reported locations, and based on gaps in data from road killed specimens.	Monitoring & Research	ONGOING	YES	YES	$0-25k	SWG , Existing, and other	HSC, FWRI	UF, FNAI, NPS, Camp Blanding JTC, FPS, WMD, USFWS, FPS, DEP,FFS,USFS, Pepperdine University	Effective at achieving desired outcome; dependent on sample size acquired.	Feasible and already under way.	Yes, data from these animals are important for assessing the taxonomic status and EOO of BCFS.
1	1	9	Conduct genetic analyses to determine the current EOO and AOO for BCFS.	Monitoring & Research	EXPANDED	YES	NO	$50-100k	SWG , Existing, and other	HSC, FWRI	UF, FNAI, NPS, Camp Blanding JTC, FPS, WMD, USFWS, FPS, DEP,FFS,USFS, Pepperdine University	Effective at achieving the desired outcome.	Feasible, expansion of an existing project.	Yes, expansion of an existing effort; results will improve understanding of the AOO and EOO.
3	1	10	Determine habitat associations and clearly identify preferred habitat types.	Monitoring & Research	ONGOING	YES	YES	$25-50k	SWG , Existing, and other	HSC, FWRI	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible and already under way.	Yes, these data are critical for effective habitat management which will improve the status of BCFS populations across the EOO.
3	3	11	Develop a scientifically sound monitoring protocol for BCFS.	Monitoring & Research	ONGOING	YES	NO	$25-50k	SWG , Existing, and other	HSC, FWRI	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible and already under way.	Yes, size and trends are unknown for most populations and those data are necessary for assessing the status of BCFS.
3	3	12	Develop a protocol to estimate density and abundance of BCFS in different habitat types.	Monitoring & Research	ONGOING	YES	NO	$0-25k	SWG , Existing, and other	HSC, FWRI	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible and already under way.	Yes, population levels and desired habitat conditions largely unknown and necessary for assessing the status of this species.
3	3	13	Implement a monitoring program to track BCFS populations on a 5-year interval.	Monitoring & Research	NEW	YES	NO	$25-50k	Existing Budget	HSC	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Potentially feasible, but unclear about the time and resources needed to accomplish this across the EOO.	Yes, these data are critical for understanding population trends and how populations respond to habitat management.

Table 1. Big Cypress Fox Squirrel *(Sciurus niger avicennia)* Conservation Action Table

Objective(s) Addressed	Team Assigned Priority Level	Action Item Number	Action Items	Conservation Action Category	Ongoing, Expanded or New Effort?	Authority	Man Power	Estimated Cost To Implement	Funding Source(s)	Lead for Implementation: FWC Program(s) and/or Section(s)	External partners	Likely Effectiveness	Feasibility	Urgent?
3	1	14	Initiate research to estimate demographic parameters (e.g. fecundity, juvenile survival, population density, optimal habitat characteristics, etc.) needed for robust population models and population viability analysis (PVA).	Monitoring & Research	NEW	YES	NO	$100k+	SWG , Existing, and other	FWRI	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Not clear about the demand needed to accomplish across the range of this species.	Yes, these data are critical due to understanding the status, and viability of individual populations and the overall BCFS population across its EOO.
4	3	15	Initiate research to determine the optimal composition and structure of priority BCFS habitat.	Monitoring & Research	ONGOING	YES	NO	$25-50k	SWG , Existing, and other	FWRI	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible and already underway.	Yes, preferred or optimal habitat conditions are largely unknown; this is necessary for effective conservation and management of BCFS across habitats.
3	2	16	Develop GIS-based potential habitat maps stratified by habitat quality.	Monitoring & Research	EXPANDED	YES	YES	$0-25k	SWG , Existing, and other	HSC	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible and already under way.	Yes, these data are critical for understanding the AOO of, and developing effective management strategies for, BCFS.
4	1	17	Determine if current rule language (including rules related to taxidermy and release of rehabilitated animals) is sufficient to ensure conservation of the BCFS.	Protections & Permitting	NEW	YES	YES	$0-25k	Existing budget	HSC, Legal	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible.	Yes, this is critical to ensure there is a good regulatory framework providing effective protections to achieve conservation objectives for BCFS.
4	1	18	Determine the level of protection needed through permitting to achieve conservation goals for the BCFS.	Protections & Permitting	NEW	YES	YES	$0-25k	Existing budget	HSC, Legal	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible.	Yes, this is critical to ensure there is a good regulatory framework providing effective protections to achieve conservation objectives for BCFS.
4	3	19	Train law enforcement officers to identify fox squirrels, their nests, evidence of presence, and habitat to identify potential take situations.	Law Enforcement	NEW	YES	YES	$0-25k	Unknown	HSC, LE	UF, Big Cypress National Preserve, NPS	Effective at achieving the desired outcome.	Feasible.	Yes, this is an essential element of a sound regulatory framework that maintains effective protections.
4	4	20	Develop or enhance incentive programs to encourage implementation of habitat management practices consistent with habitat management guidelines that benefit BCFS.	Incentives & Influencing	NEW	YES	YES	$0-25k	Existing budget	CPS	DOACS NRCS, USFWS, FFS	Highly effective at achieving the desired outcome.	Feasible - relationships with many landowners already exist, but they require more information on desired habitat parameters.	No, existing programs promote habitat management and restoration activities, which generally benefit BCFS; existing activities include the use of prescribed fire.
4	1	21	Disseminate the habitat management guidelines and monitoring protocols to private landowners and public land managers.	Education & Outreach	NEW	YES	YES	$0-25k	Existing budget	HSC, CPS	NRCS, FFS, USFWS, NPS, county governments	Effective at achieving the desired outcome.	Feasible	Yes, this information is critical for better habitat management and monitoring to benefit local BCFS populations.
4	3	22	Develop a comprehensive outreach program (brochures, kiosks, Project Wild, Land Use Planning, etc.) to target a variety of audiences.	Education & Outreach	NEW	YES	YES	$0-25k	SWG , Existing, Grant, and other	CPS, Project Wild	NGOs, UF IFAS, DEP, county and municipal governments	Effective at achieving the desired outcome.	Feasible	Yes, it is important to engage a variety of audiences on multiple issues.
4	1	23	Develop a strategy to ensure our partners, stakeholders, and the public are aware of rule and permitting changes.	Education & Outreach	NEW	YES	YES	$0-25k	Existing budget	OPA, HSC, OCR	UF, Big Cypress National Preserve, FFS, DEP, NPS, county governments	Effective at achieving the desired outcome.	Feasible	Yes, this is critical for ensuring protections are effective and that there is compliance and prevent take.

Acronyms used in this table:

AOO:	Area of Occupancy
BCFS:	Big Cypress fox squirrel
CPS:	Conservation Planning Services, a Section of the FWC's Division of Habitat and Species Conservation
DEP:	Florida Department of Environmental Protection
DOACS:	Florida Department of Agricultural and Consumer Services
EOO:	Extent of Occurrence
FFS:	Florida Forest Service
FNAI:	Florida Natural Areas Inventory
FPS:	Florida Park Service
FWC:	Florida Fish and Wildlife Conservation Commission
FWRI:	Fish and Wildlife Research Institute, the research branch of the FWC
GIS:	Geographic information system
HSC:	Habitat and Species Conservation, a Division of the Florida Fish and Wildlife Conservation Commission
JTC:	Joint Training Center
LE:	Law enforcement
NGO:	Non-governmental organization(s)
NPS:	National Park Service
NRCS:	National Resource Conservation Service
OCR:	Office of Community Relations, administered by the FWC
OPA:	Office of Policy and Accountability
PVA:	Population viability analysis
SWG:	State wildlife grant
UF:	University of Florida
USFS:	United States Forest Service
USFWS:	United States Fish and Wildlife Service
WHM:	Wildlife and Habitat Management, a Section of the FWC's Division of Habitat and Species Conservation
WMD:	Water Management District(s)

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APPENDICES

Appendix 1. Further information on resource use by Big Cypress fox squirrel (BCFS) at Big Cypress National Preserve (BICY) as reported by Kellam et al. (2013).

Within the BICY BCFS study area, cypress domes and pine forests represented respectively 31.9% and 42.8% of the total available habitat (Table A). However, based on radio telemetry results, male and female BCFS used cypress domes and pine forests 79.7% and 13.6% of the time, respectively, (Table A). This dominant use of cypress domes was recorded on a year-round basis (Figure A) (Action 10).

Table A. An analysis by Kellam et al. (2013) of available habitat types at the BICY study site (row 1) and habitat use by BCFS, based on locations of radio-collared individuals (row 2). Habitat categories are based on vegetation classification maps produced by Welch et al. (1999) who conducted a GIS analysis of vegetation data. They identified 14 available habitat types, which were re-classified into 7 general habitat types to conform to existing standardized BICY habitat definitions.

Habitat Type	Cypress Dome	Pine Forest	Pine with Cypress Associated	Hardwood Hammock	Disturbed	Cypress Prairie	Marsh
Available Habitat Amount (ha) and % N = 923 ha	294 ha 31.9%	395 ha 42.8%	70 ha 7.6%	12 ha 1.3%	18 ha 2.0%	127 ha 13.8%	7 ha 0.8%
Utilized Habitat - Percent of observations	79.7%	13.6%	6.2%	0.2%	0.1%	0.1%	0.0%

The majority of the BCFS nests located during the BICY study were located in cypress trees. Of the 403 BCFS nest trees recorded, 98.8% were in bald cypress, 1.0% were in cabbage palm, and 0.2% were in slash pine (Action 10). Although the dominant habitat type within the BICY BCFS study area is primarily unlogged, fire-maintained, old-growth pinelands, only 1 BCFS nest was found in a pine tree. The pine nest tree was located in a pine–cypress transitional area referred to as “pine with associated cypress” (Burch 2011), and the nest was constructed from pine sticks and stripped cypress bark.

The BICY BCFS study also documented a strong correlation between seasonal food item availability and BCFS movements and habitat use (Figures A and B; Action 10). Within the BICY study area, at least 12 food items were used by BCFS, with the proportion of each in the diet varying seasonally (Figure B).

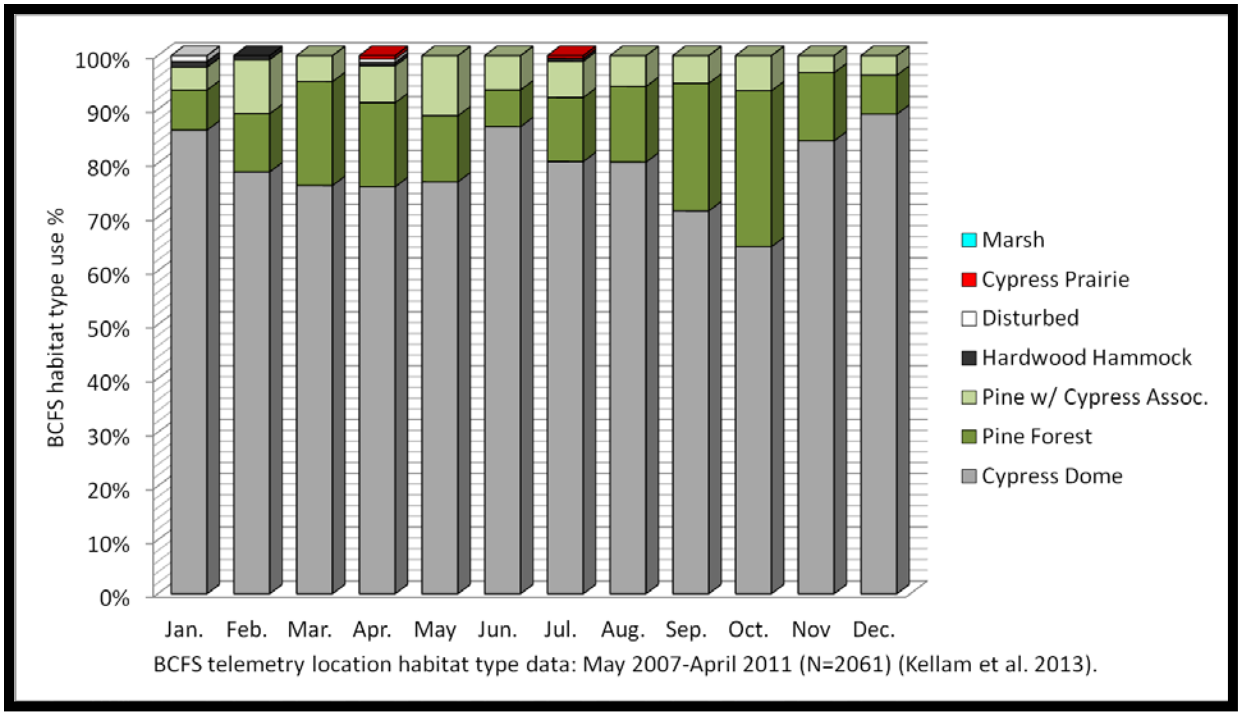

Figure A. Frequency of habitat use by BCFS in the BICY study area, recorded monthly, as determined from telemetry locations of 10 male and 10 female BCFS (*n* = 2061), recorded between May 2007-April 2011 (N=2061) (Kellam et al. 2013).

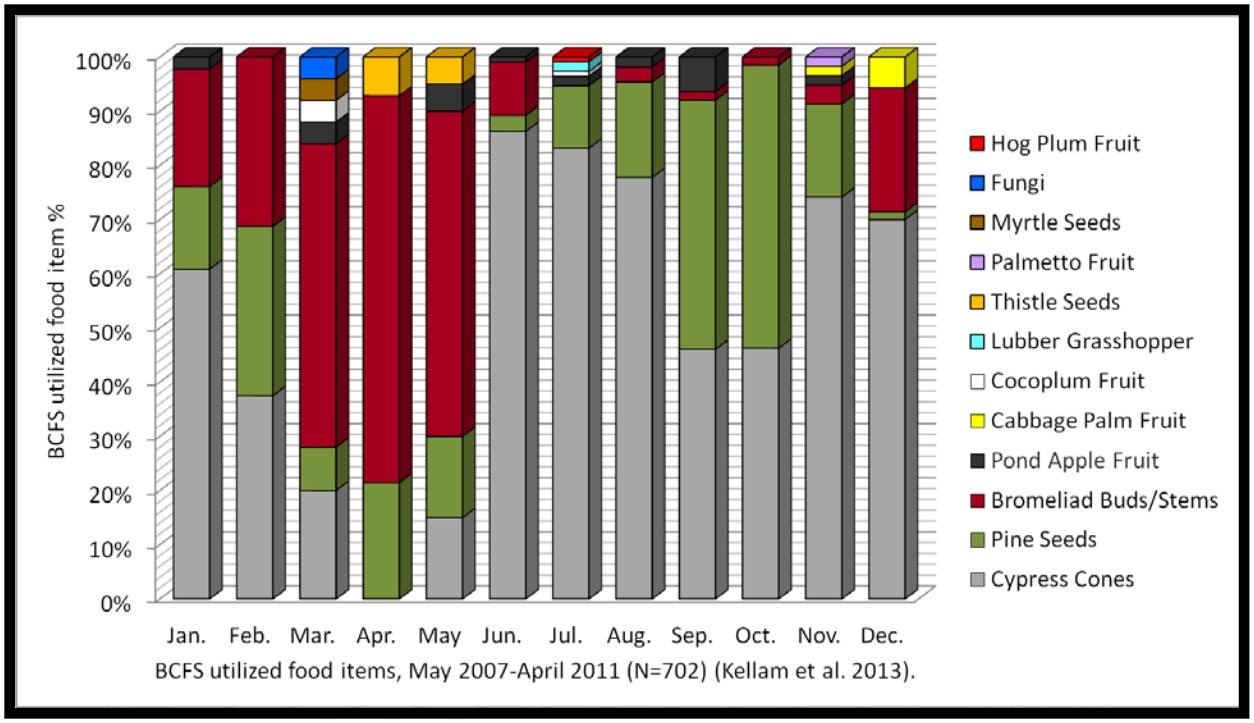

Figure B. Frequency of food item use by BCFS in the BICY study area, recorded monthly (n = 702) for 10 male and 10 female radio-collared BCFS between May 2007-April 2011 (Kellam et al. 2013).

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Appendix 2. Additional information on squirrel poxvirus and mange, as potential threats to the viability of Big Cypress fox squirrel (BCFS) local populations.

Squirrel poxvirus is an infectious disease that typically results in a condition sometimes called fibromatosis (Robinson and Kerr 2001). Fibromatosis refers to the presence of benign, cutaneous tumors (fibromas) formed by the disease. In infected squirrels, fibromas often form on multiple parts of the body at the same time (Terrell et al. 2002). Squirrel poxvirus has a reported incubation period of 7 to 14 days before tumors become visible (Kilham 1955, Hirth et al. 1969). High rates of morbidity and mortality in infected squirrels have been reported (Terrell et al. 2002). Squirrel poxvirus typically either goes into remission or leads to mortality in < 2 months (Kilham 1955). In 1998, a widespread outbreak of squirrel poxvirus in gray squirrels in Florida infected > 200 squirrels, across 7 counties, with high rates of mortality (Terrell et al. 2002). In 2010, a squirrel poxvirus-infected BCFS was documented within Big Cypress National Preserve (BICY) (Kellam 2010). As a result, the National Park Service (NPS) consistently monitored BCFSs in BICY for signs of squirrel poxvirus outbreak, with ongoing outreach efforts to inform the public how to identify and report squirrels showing symptoms of the disease (Kellam 2010; J. Kellam, NPS, personal communication).

There has been little documentation of mange in BCFS. Most information comes from rehabilitators who receive sick squirrels. The Conservancy of Southwest Florida provided information on BCFS they received over 5 years. During that time they received 22 BCFS. Of those, 2 were reported to have mange; 1 of those died.

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Appendix 3. Description of the University of Florida (UF)–Florida Fish and Wildlife Conservation Commission web-based fox squirrel survey, with selected results.

To build a species distribution model of fox squirrels in Florida, fox squirrel sightings were collected from 20 August 2011 to 30 April 2012. A web-based tool was created to allow both natural resource professionals and the general public to submit fox squirrel sighting locations throughout Florida. Participants were encouraged to provide pictures of fox squirrels through email to further verify the validity of sightings received from the public. The Google map application recorded georeferenced locations (latitude and longitude in decimal degrees) submitted by survey participants. Along with the georeferenced fox squirrel locations, each participant was encouraged to submit the following information: date of the sighting, name, organization, email address and choose their affiliation from the following 2 choices: general public or natural resource professional (e.g., biologist, UF Institute of Food and Agricultural Sciences extension, forester, land manager, etc). A comment box allowed participants to enter further sighting information such as surrounding land use, behavior, individual description, etc. The survey was announced to state, federal, county, and private professionals as well as to the general public through email lists, various newsletter articles, flyers, and word of mouth at meetings and other events.

The survey produced 4,221 sighting locations from 2,673 individuals throughout the state of Florida. Of the participants, 74% were from the general public and the remaining 26% were submitted by natural resource professionals. Of the total sightings reported, 157 were within the accepted range of the Big Cypress fox squirrel (BCFS) (Figure A). At the accepted northern extent of the BCFS range, the Caloosahatchee River, BCFS were reported occurring along the northern and southern side of the river (i.e., within the range of the both Sherman's fox squirrel and the BCFS) (Figure B). Some of the sightings that occurred on each side of the river were less than 1.6 km (1 mi) apart on opposite sides of the river, where the river is only 0.16 km (0.1 mi) wide and near a bridge. These facts and the near continuous distribution of fox squirrel sightings across the Caloosahatchee River raise questions about whether the river is a barrier to dispersal or movement by fox squirrels and whether there is a discrete separation between the subspecies as had been previously thought.

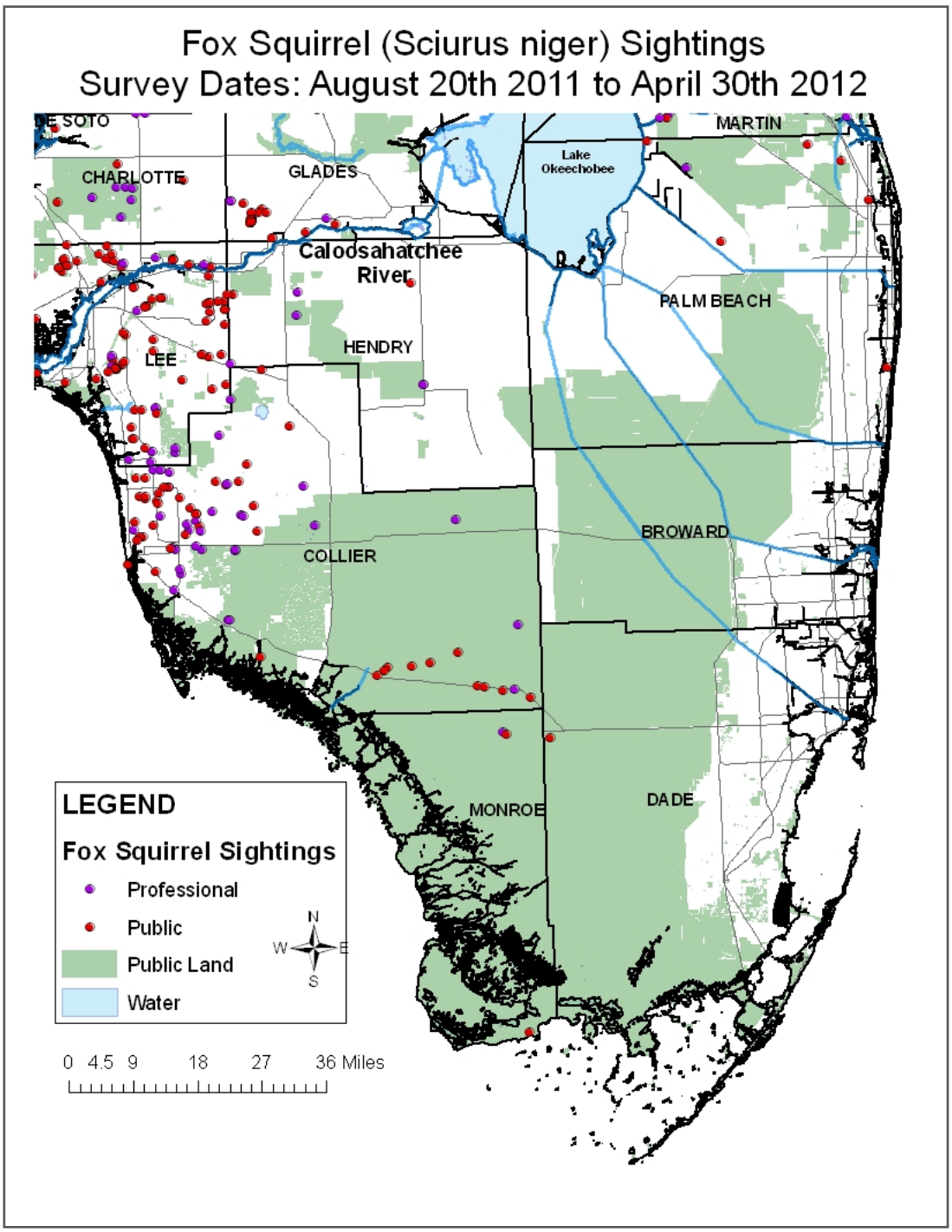

Figure A. Map showing all sightings reported during UF-FWC web-based fox squirrel survey from within the accepted BCFS range, as well as some of the sighting reports received from north and east of that range.

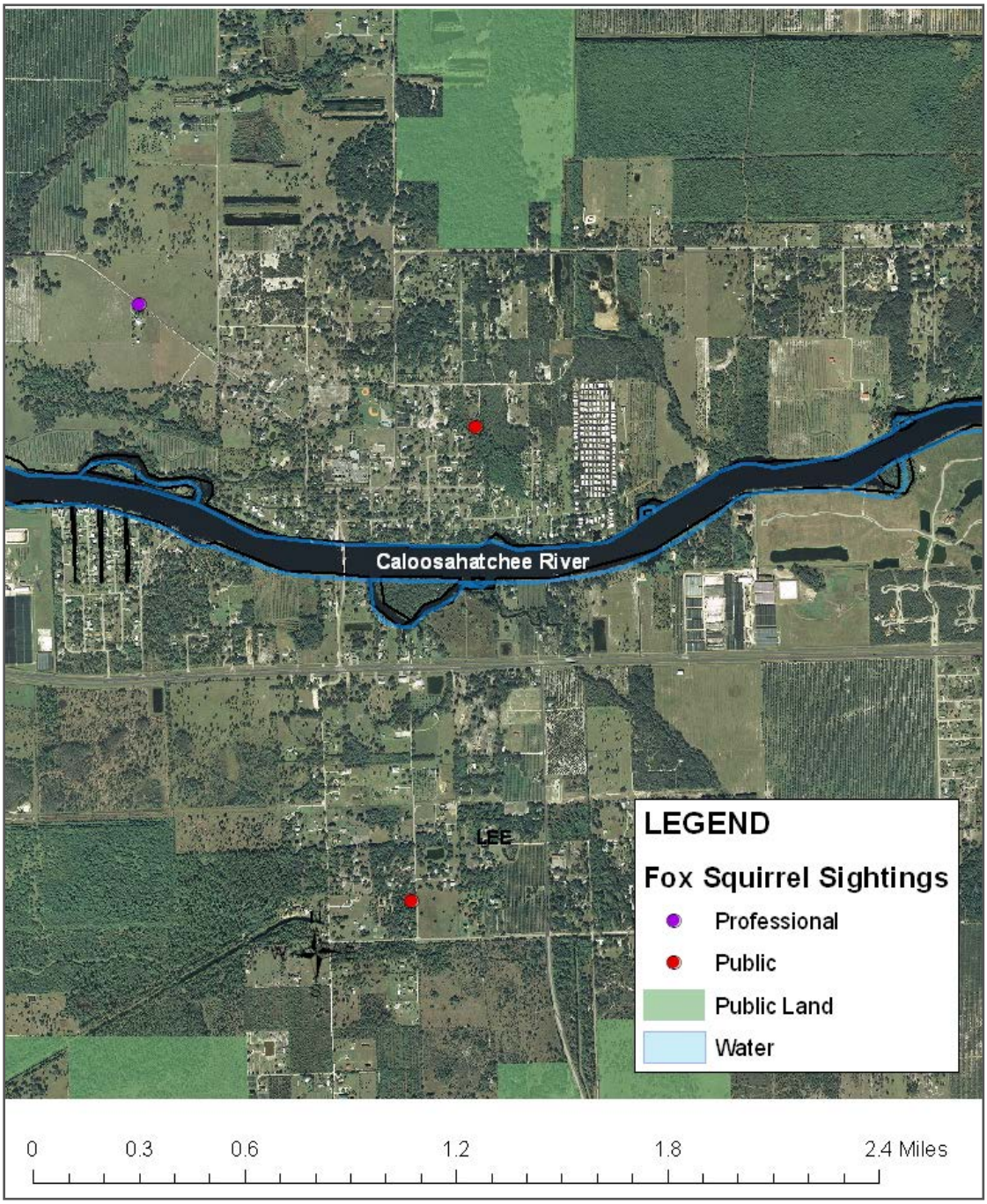

Figure B. A more detailed map showing selected fox squirrel observations reported on both the northern and southern sides of the Caloosahatchee River, the generally accepted northern limit of the BCFS's range.

Appendix 4. Current guidelines for managing habitat to maximize habitat quality for the Big Cypress fox squirrel (BCFS).

The following general recommendations for habitat improvements have been extracted from various studies of BCFS that can be applied in natural and urban environments.

- Maintain a diverse assemblage of mast-producing trees across the landscape such as: slash pine, cabbage palm, fig, oaks, etc.
- Maintain an open understory
    - In natural areas, apply fire in intervals of 2 to 5 years. Monitor habitat conditions to determine optimal burn intervals.
    - Where burning is not feasible, mow, roller-chop, or graze to maintain an open understory.

Natural Habitats

Cypress Swamp and Slash Pine Forest Habitat Mosaic.— Work by Kellam et al. (2013) has produced important information on use of these interspersed habitats by BCFS. The interspersion of these habitats is important. Cypress trees are used predominantly for nest sites (98.8% of the observed nests were in cypress). But the BCFS foraged regularly through transitional areas (pine with associated cypress) and the pine forest habitat (Kellam et al. 2013). The BCFS depended on a broad range of seasonally available food items, which indicated the importance of maintaining a diverse understory and midstory in those habitats. There was a strong correlation between BCFS movements and the seasonal availability of food items (Appendix 1, Figure B) (Kellam et al. 2013).

The slash pine forest in the BICY study area is regularly maintained by prescribed fire as part of a long-term fire ecology study (the area is divided between 3-year and 5-year return intervals). Maintaining regular fire intervals has resulted in an open canopy with a low, sparse understory in the pine forest (Kellam et al. 2013). These habitat characteristics are known to be preferred by BCFS (Williams and Humphrey 1979, Duever et. al 1986, Humphrey and Jodice 1992, Eisenberg et al. 2011). In addition, hydrology of the cypress dome habitat in the BICY study area is largely unaltered (Kellam et al. 2013). The natural hydrology, with sustained hydroperiods, maintains an open canopy and a low understory within the cypress dome habitat by hindering the growth of many mesophytic shrub and tree species. Within the BICY BCFS study area, and elsewhere in BICY, cypress domes with naturally reduced or unnaturally restricted hydrologic conditions contained dense understory and midstory shrub layers and there were fewer signs of BCFS occupancy and use in those areas (Kellam et al. 2013).

It is also important to recognize that BCFS nests may be used regularly, even when those nests have not been freshly maintained. Kellam et al. (2013) believed nests that had recently stripped, but not freshly stripped, cypress bark present were regularly used by BCFS throughout the year. “Old” nests that were not maintained were rarely use by radio-collared BCFS (Kellam et al. 2013).

Other Natural Habitats.— Big Cypress fox squirrels have been found inhabiting: south Florida slash pine forests, pond-cypress and bald-cypress swamp forests, live oak woods, tropical

hardwood forests, coastal broadleaf evergreen hammocks, and mangrove swamps (Howell 1919, Moore 1956, Williams and Humphrey 1979, Duever et. al 1986, Humphrey and Jodice 1992). There has been little work done on BCFS use of these habitats. Little is known about factors affecting habitat quality for BCFS in these habitats.

Developed Habitats

There is limited information on the characteristics of urbanized habitats that increase suitability or benefits for BCFS. However, see Jodice and Humphrey (1992), Ditgen et al. (2007), Munim (2008), and Eisenberg et al. (2011) for additional details on use of urbanized habitats by BCFS. According to Jodice and Humphrey (1993), golf courses with a variety of native and non-native plants provide a stable food resource year-round for fox squirrels. Plants such as fig, queen palm, silk oak, and bottlebrush were commonly consumed by BCFS. Ditgen et al. (2007) stated the increased availability of food comprised of exotic and native trees and shrubs, coupled with the stability of the food resources on golf courses, increased summer reproduction, which was otherwise limited by food availability. However, the establishment of invasive, non-native plants, as identified by the Florida Exotic Pest Plant Council, is not encouraged.

The retention or restoration of large trees may be a significant determinant of habitat quality for BCFS in developed areas. Large trees, especially cypress trees, in appropriate areas on golf courses and other urban greenspaces can provide valuable nesting and resting sites (especially where native bromeliads are present), as well as nesting material (i.e., bark, Jodice and Humphrey 1992). Wildlife managers should provide information on resource needs and habitat requirements for BCFS to golf course designers and urban planners for inclusion in their plans.

There has been little or no work done on use of rural or agricultural developed lands by BCFS. However, general habitat recommendations (e.g., retention of large trees, maintenance of an open understory) are likely to apply in these areas as well.

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Appendix 5. Tissue collection protocol developed by the University of Florida and the Florida Fish and Wildlife Conservation Commission.

To investigate the distribution and to determine the evolutionary distinction among the 4 subspecies of fox squirrels (southern, Sherman's, Bachman's, and Big Cypress) recognized as occurring in Florida, I am requesting genetic samples from fox squirrels throughout Florida, using the following protocol.

Whole Specimen Collection

If possible, please collect the whole specimen. Whole specimens should be double bagged and frozen with a label stored inside the outer bag.

Tissue Collection

If collecting a sample, cut off an ear with scissors or a knife (sterile if possible) and place tissue in a labeled plastic bag, or in a labeled vial of 95% denatured ethanol. Store all samples in a standard freezer, including the vials to prolong the life of the sample.

Record the following information on a label and store with the sample:

- Collection date (Month, Date, Year)
- Locality information, including lat/longs or UTM's if possible (these can be obtained from Google Earth if you do not have a GPS unit).
- Name, affiliation, and contact information for the collectors.
- If submitting an ear sample (and not whole carcass) please include the following:
    - Gender of squirrel, if identifiable.
    - If possible, take pictures of the head, back and belly of the squirrel and email the photos to me.

Please contact me after collecting a sample/specimen to arrange for shipment.

If you have any questions, please call or email me.

Thank you!

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Appendix 6. Recommendations taken primarily from Kellam et al. (2013) for conducting surveys to determine the presence of the Big Cypress fox squirrel (BCFS) in cypress dome swamp–pine forest mosaic habitats.

Due to the secretive nature of BCFS and the low detection rates for them in known occupied habitats (Eisenberg et al. 2011; Jodice 1990, 1993), the Big Cypress National Preserve (BICY) BCFS study relied on non-sighting based survey methods to determine occupancy. Study surveyors conducted ground searches for 3 primary BCFS habitat-use indicators within cypress dome swamp–pine forest mosaic habitats: 1) The presence of BCFS nest structures (Figure 4), 2), the presence of stripped bark on the trunk and limbs of cypress trees (Figure 11), and 3) the presence of freshly utilized BCFS food items (Appendix 1, Figure A). The best indicator of current BCFS occupancy (confirmed by trapping results) is the presence of freshly stripped cypress bark (as determined by color) incorporated into BCFS nest structures and adjacent sign of freshly utilized BCFS food items. The BICY BCFS study photo-documented the general oxidation rate of fresh stripped cypress bark, which is typically a bright orange-red color when fresh (Figure 11) and a dull reddish brown or grey color when exposed to the elements > 2 months. Recent, but not current, BCFS occupancy was indicated by the combined presence of recently, but not freshly, stripped cypress bark on BCFS nests, stripped cypress bark on trees, and utilized food items. Although nests with recently stripped bark were regarded as a sign of recent occupancy, these nest types were frequently used year-round by radio-collared BCFS. Nests that were found in a state of ruin and not associated with utilized food items were termed *old* and rarely used by the BICY BCFS study.

An important BCFS food item that served as a sign of current occupancy within cypress domes during the wet season was the concentrated presence of floating, resinous oil droplets (typically 0.25 to 3 cm [0.09 to 1.18 in] in diameter) and cypress cone scale or resin-coated seed particles directly above and adjacent to submerged partially eaten fresh cypress cones. Optimal trapping sites contained multiple BCFS nests with freshly stripped bark incorporated, adjacent cypress trees with freshly stripped bark, and an abundance of freshly utilized BCFS food items.

Results of the BICY study showed that BCFS preferred to occupy a spatially integrated mosaic of cypress dome swamp–pine forest habitats that together provided year-round sources of food and optimal nesting conditions. Survey and monitoring efforts revealed that BCFS tended to construct the majority of their nests in discreet cypress domes at the edges of pine forest habitat. Little or no BCFS sign was observed during surveys within the interior of large, contiguous cypress dome swamp–cypress prairie mosaic habitats or within contiguous pine forest habitats. It could be easy to overestimate potential BCFS habitat when determinations are based on general habitat types at the landscape level. Results showed that habitat composition or habitat conditions and the proximity of both preferred habitats, assessed at a fine or local scale, best delineated BCFS habitat. Knowing the seasonal timing of BCFS habitat use (Appendix 1, Figure A) and food species utilization (Appendix 1, Figure B) will allow surveyors the ability to prioritize search habitats and focus BCFS sign search patterns.

The best time of year to conduct BCFS occupancy surveys within cypress dome swamp–pine forest mosaic habitats was in the dry season when water levels were receding and dormant deciduous cypress trees (November through March) had shed their needles, thereby improving visibility within the canopy. Cypress needle and twig accumulations on the forks of cypress tree

branches and corvids (*Corvus* spp.) and raptor nests can at times look like BCFS stick-based nests. Therefore, it was important to verify that a stick-based structure has been improved upon by BCFS if it is to be identified as a BCFS nest. Of the 403 BCFS nests documented within the BICY study area, 401 had stripped cypress bark incorporated into them; the other 2 nests incorporated Spanish moss (*Tillandsia usneoides*).

The duration of occupancy surveys for BCFS should be determined by effectiveness (rather than a preset, minimum survey time period). Effectiveness would be assessed by the quality of coverage for survey efforts within a survey area of given size (no matter how large or small). Reported techniques for BCFS occupancy surveys often rely on fixed or meandering sighting-based, walking transects, which are well documented as being unreliable and under-representing presence (Jodice 1990, 1993; Eisenberg et al. 2011). Due to the difficulties of observing BCFS, Kellam et al. (2013) recommended that sighting-based, walking surveys should be supplemented with surveys for specific signs (indicators) of BCFS presence: stripped cypress bark on trees, utilized food items, and, more importantly, potential BCFS nests. Areas where BCFS indicators are observed should be targeted for concentrated follow-up surveys. Protocols for follow-up surveys should be designed to reliably determine occupancy. Follow-up surveys should involve careful field monitoring by trained observers and include the possible use of baited trail cameras to determine occupancy. MacKenzie (2005) and MacKenzie and Royle (2005) provide additional recommendations for designing and carrying out effective occupancy studies.

Research has shown that gray squirrels (*Sciurus carolinensis*) prefer habitats that have dense understory and groundcover, and that larger forested habitat patches with those characteristics often contain high gray squirrel densities (Nixon et al. 1978, Brown and Batzli 1984). The primarily open habitat understory and canopy conditions within the BICY BCFS study area helped to explain the lack of a detectable gray squirrel local population. Therefore, when freshly stripped cypress bark nests were found during study survey efforts, there was a high degree of confidence that it was the result of BCFS activity. That was confirmed by trapping results and an absence of gray squirrel sightings (John Kellam, National Park Service, personal communication).

When future BCFS occupancy surveys are conducted in cypress-associated potential BCFS habitats that have a densely vegetated understory and dense canopy overstory (such as cypress with hardwood strands or cypress with hardwood hammocks), caution should be taken to verify the species of squirrel occupying a given nest or a given area. Potential BCFS nests need to be located and carefully monitored by field observers or trail cameras to verify occupancy, even when nests have stripped cypress bark and recently utilized food items are nearby. Sympatric gray squirrel and BCFS local populations do occur in some natural and urban habitat conditions. Gray squirrels have been documented chewing on and stripping bark from numerous tree species throughout their range (Packard 1956, Kenward and Parish 1986), including cypress trees (R. McCleery, UF, personal communication). In addition, gray squirrels and fox squirrels have similar food preferences and feeding strategies (Koprowski 1994). Many studies have shown gray and fox squirrels have overlapping nest parameters, including use of sticks, leaf drey, and stripped bark nest materials; nest sizes; nest heights; nest tree species; and nest tree diameter at breast height (a standard measure of tree size) (Fitzwater and Frank 1944, Moore 1957, Nixon and Hanson 1987, Koprowski 1994, Edwards and Guynn 1995).

During the BICY study, when a potential stick nest could not be verified as a BCFS nest from the ground, a trained tree climber ascended the nest tree to confirm the status of the structure. Potential BCFS tree cavity nests (determined by the presence of stripped bark near tree cavity openings or evidence of radio-collared BCFS use) were examined with a TreeTop Peeper elevated video inspection system (Sandpiper Technologies Inc., Manteca, California, USA). No tree cavity or leaf drey nests were found in the study area during the BICY BCFS study (Kellam et al. 2013).

Sign-based occupancy survey techniques for BCFS, such as those used during the BICY study, have not been developed for implementation within upland pine–hardwood co-dominant habitats, live oak woodlands, tropical hardwood forests, coastal broadleaf evergreen hammocks, mangrove swamps, non-native melaleuca (*Melaleuca quinquenervia*) and Brazilian peppertree (*Schinus terebinthifolius*)-associated habitats, agricultural habitats, or urbanized habitats.

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Appendix 7. Big Cypress fox squirrel (BCFS) platform and ground-based trapping techniques from Kellam et al. (2013).

Priority trapping sites were identified as those where a currently occupied BCFS nest tree (see Appendix 6) was present. The traps used were 61 x 18 x 18 cm (24 x 7 x 7 in) box traps constructed of 1.3 cm x 2.5 cm (0.5 x 0.9 in) wire mesh (model No. 605; Tomahawk Live Trap Co., Tomahawk, Wisconsin, USA). At each trapping site, either 1 to 2 traps were placed in shaded conditions on the ground adjacent to a priority nest tree during the dry season, or 1 trap was placed on a trapping platform constructed over water adjacent to a priority nest tree during the wet season. Palm fronds were affixed over each trap with the frond leaf tips oriented to nearly cover the trap entrance. The fronds helped to regulate trapping temperatures, and assisted in reducing bait consumption by and the unintended capture of American crows (*Corvus brachyrhynchos*) and fish crows (*Corvus ossifragus*).

Each trap was baited behind the trip plate with a dried, halved corncob and peanut butter. Loose dried corn and peanut butter were placed on the trip plate and near the trap door entrance. Peanut butter was also applied to tree trunks and vegetation directly above and adjacent to each trap in order to provide additional scent. Traps were wired open and pre-baited for 3 to 7 days prior to a trapping period. During a trapping period, traps were armed at dawn and checked every 2 hours until dusk, or as trapping success dictated. At the end of each trapping day, all of the traps were closed and wired shut.

Each trapping platform was 200 cm x 90 cm (78 in x 35 in), constructed approximately 95 cm (37 in) above ground level, and adjoined the base of a currently occupied BCFS nest tree. Wooden hollow-core doors were used for platforms because they were lighter and easier to attach wood legs to than cut plywood of suitable dimension. The top surface of each trapping platform was covered with a layer of cypress needle duff (approximately 2.5 cm [0.9 in] thick), upon which a baited trap was secured with bungee cords attached to screw-eye hooks.

When trapping over water at sites that contained multiple BCFS nests separated by wide tree canopy spacing, fallen cypress limbs (typically about 5 m [16.4 ft] in length) were horizontally lashed with rope between pairs of tree trunks (approximately 95 cm [37 in] above ground level) to provide a continuous pathway above the water from nest trees to trapping platforms. The lashed cypress limbs were also lightly scented with peanut butter and baited with loose dried corn.

The most effective trap placement strategy developed during the Big Cypress National Preserve BCFS study consisted of initially setting either the ground-based or platform-based traps adjacent to a priority nest tree and then setting approximately 10 additional ground-based traps in the adjacent pine forest edges where recently utilized BCFS food items (typically pine cones) had been located. Another effective strategy was to place a number of ground-based traps within the pine forest edge in an array set across and approximately perpendicular to the most probable BCFS travel route between the pine forest and the BCFS nest locations within the cypress dome (probable travel routes were determined by tree spacing and canopy characteristics).

Appendix 8. Recommended buffer distances for permitting guidelines to minimize or mitigate disturbance and take of Big Cypress fox squirrel (BCFS).

These buffer distance recommendations are based on the assessment of individual activity patterns around nest sites, as reported by Kellam et al. (2013) and J. Kellam (National Park Service, unpublished data).

Kellam et al. (2013) use a science-based approach to evaluate minimum buffer distances necessary to avoid disturbance to BCFS for permitting guidelines. Evaluations were based on movement distance recorded for radio-collared BCFS, with distance measured as the linear distance between 2 consecutive locations of an individual BCFS. A GIS analysis of male and female BCFS was conducted for overall home ranges (95% kernel) and core home ranges (50% kernel). In addition, differences in movement distances between males and females were compared.

Average Home Range Size

To conceptualize linear distance and core (50% kernel) home range areas, movement distance within the core area was used as an estimate of the diameter of a circular home range. This is not unreasonable because the distribution of location points often formed an irregular, or approximate circular shape. Based on that, then:

- Female BCFS (n = 10) have a core (50% kernel) home range diameter (mean ± 1 SD) of 117.4 ± 49.2 m (385.2 ft).
- Male BCFS (n = 7) have a core home range diameter of 303.0 ± 159.1 m (994.1 ft).

Movement Distances

Overall, the mean distance moved between locations in ≤24 hours (n = 428) was 237.8 ± 221.5 m (780.2 ft) for male BCFS (n = 219) and 138.7 ± 128.2 m (455.1 ft) for female BCFS (n = 209). This was then analyzed by season. Mean distance moved by BCFS in ≤24 hours during the wet season (1 May – 31Oct) was 262.8 ± 220.5 m for males (862.2 ft; n = 103) and 131.3 ± 122.8 m for females (430.8 ft; n = 96). Mean distance moved by BCFS in ≤24 hours during the dry season (1 Nov – 30 Apr) was 215.6 ± 220.9 m for males (707.4 ft; n = 116) and 145.0 ± 132.8 m for females (475.7 ft; n = 113).

Buffer Distance

A minimum BCFS nest site buffer distance of 150 m (approximately 500 ft; from a nest, or nest tree), would encompass the mean radii of male and female BCFS core home ranges, and the year-round mean of movements made by females within their ranges in ≤24 hours (95% kernel). A minimum buffer distance of 250 m (approximately 820 ft) from the nest site would be necessary to cover the year-round mean of movements made by male BCFS within their ranges in ≤24 hours (95% kernel). However, before any buffer distance was specified it would be important to understand the types of potential disturbance that might occur and the distribution of key resources (e.g., food resources), especially any unique or seasonally important resources that may occur outside that area.

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Appendix 9. Core Conservation Areas for Big Cypress fox squirrels (BCFS).

The areas listed below are the principal conservation lands recommended for inclusion as elements of core conservation areas for BCFS. These core conservation areas are identified as key lands that are considered important for effective BCFS management and conservation. These recommended core conservation areas and indicated priorities are based on current understanding of BCFS local populations and area of occupancy (AOO), information in the Florida Natural Areas Inventory conservation lands inventory database (http://www.fnai.org/conservationlands.cfm), data from the University of Florida–Florida Fish and Wildlife Conservation Commission web-based fox squirrel survey (Appendix 3), and available information from land managers. The core conservation areas should be re-evaluated periodically as new information becomes available on BCFS numbers, status of extant local populations, and AOO become available. The map (Figure A) shows the approximate location of each core area as a reference only (the map should not be interpreted as having any meaning other than approximate locations of sites identified in this list).

First Priority

Big Cypress – Fakahatchee Area

- Big Cypress National Preserve
- Fakahatchee Strand Preserve State Park
- Florida Panther National Wildlife Refuge
- Picayune Strand State Forest
- Collier-Seminole State Park
- Everglades National Park

Second Priority

Corkscrew – CREW Area

- Corkscrew Swamp Sanctuary (National Audubon Society)
- Corkscrew Regional Ecosystem Watershed (CREW) (SFWMD)
- CREW Wildlife Management Area (WMA)
- Caracara Prairie Preserve (Collier Co.)
- Pepper Ranch Preserve (Collier Co.)
- Flint Pen Strand (Lee Co.)
- Corkscrew Regional Mitigation Bank (SFWMD)
- Imperial Marsh Preserve (Collier Co.)

Third Priority 1

OK Slough Area

- Spirit of the Wild WMA
- Okaloacoochee (OK) Slough State Forest
- OK Slough WMA
- Dinner Island Ranch WMA

Third Priority 2

Six Mile Slough Area

- Six Mile Slough Preserve (Lee Co.)
- Wild Turkey Strand Preserve (Lee Co.)
- Six Mile Slough Preserve North (Lee Co.)
- Buckingham Trails Preserve (Lee Co.)

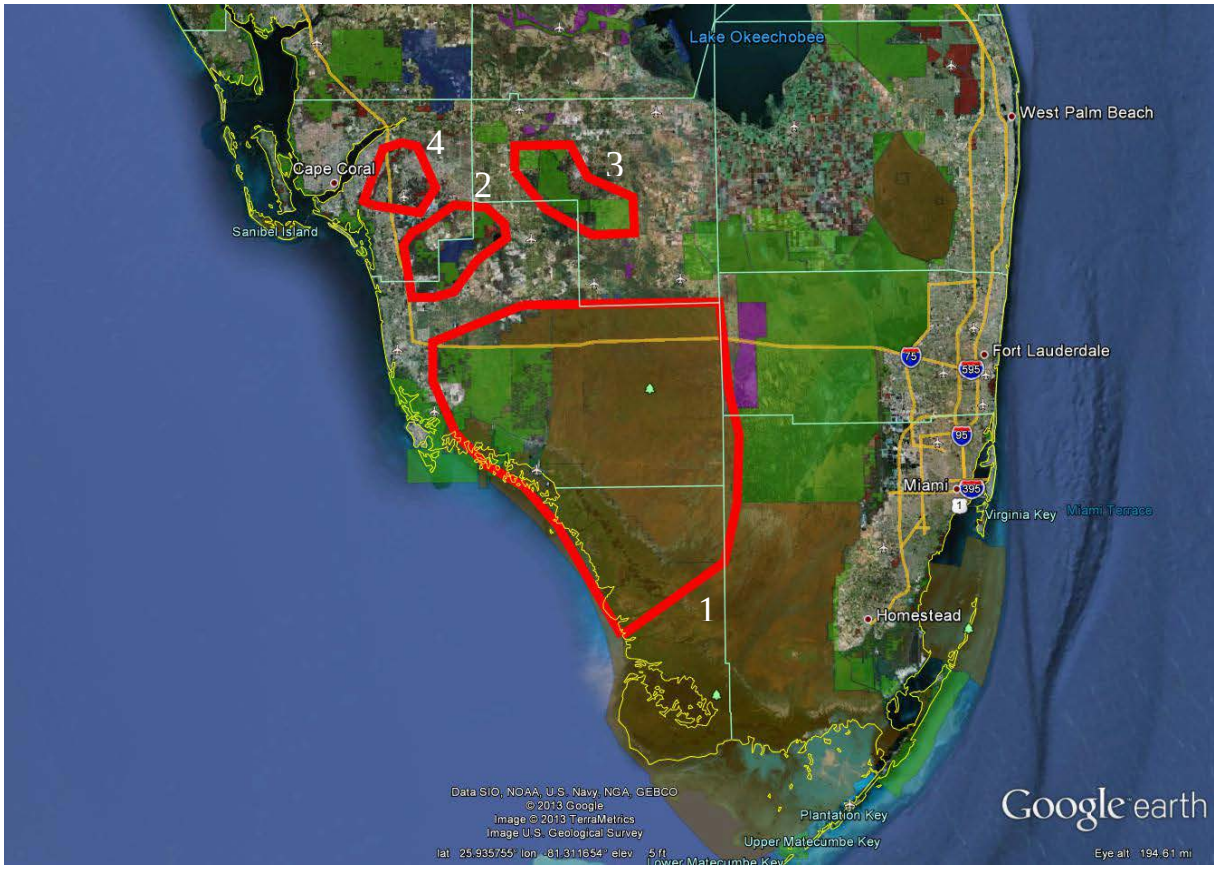

Figure A. Approximate locations of recommended BCFS core conservation areas. Locations are shown only as a reference for sites identified in the list above. The core conservation areas are: 1) Big Cypress – Fakahatchee Area, 2) Corkscrew – CREW Area, 3) OK Slough Area, and 4) Six Mile Slough Area. See the list above for details on the priority conservation lands encompassed by each core conservation area.