EFFECTS OF PRESCRIBED BURNING ON NATIVE AND EXOTIC HERPETOFAUNA IN FLORIDA PINE FLATWOODS IN SAVANNAS PRESERVE STATE PARK

by

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Jon A. Moore, and has been approved by the members of her/his supervisory committee. It was submitted to the faculty of The Honors College and was accepted in partial fulfillment of the requirements for the degree of Bachelor of Arts in Liberal Arts and Sciences.

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ABSTRACT

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Florida's pine flatwoods are pyrogenic ecosystems that require frequent fires to regenerate the herbaceous layer and suppress crowding vegetation. Human development has hindered these natural fires and consequently affected the herpetofauna (amphibian and reptile) species. Anthropogenic encroachment, in addition to fire suppression, has also provided ideal habitats for invasive species within native environments. Exotic species are often found in developed areas around buildings and roads, and it is likely this pattern continues into the park. This eight-month coverboard survey focuses on the effects various fires may have on herpetofauna in the area and explores the level of intrusion exotic species exhibit within the communities. Minimal differences among herpetofauna composition between transects were found. However, a convincing percentage of exotic species were found only within the first ten meters of the transects while all native species were at least 25 meters into a transect.

To anyone who can recognize the beauty and awe-inspiring qualities of nature, always venture into the unknown with respect in hand for those who may already call it home.

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INTRODUCTION

Located throughout South Florida is an ecosystem dependent upon fire to maintain natural functioning and composition. Pine flatwoods found in southeast Florida are pyrogenic ecosystems that thrive upon frequent fires every two to seven years (Austin 1999). Cyclical burnings reduce hardwood competitors, germinate seeds, cycle nutrients, and increase the sustainability of some species populations (Abrahamson and Hartnett 1990). The ideal structure of south Florida's pine flatwoods includes a shrub layer of saw palmetto (*Serenoa repens*), gallberry (*Ilex glabra*), and fetterbush (*Lyonia lucida*), mixed underneath a canopy of southeastern slash pine (*Pinus elliottii* var. *densa*). In healthy communities with sufficient sunlight, a herbaceous layer of wire grass (*Aristida stricta*) with many other diverse species is also present (Abrahamson and Hartnett 1990). Communities dependent upon fire, such as pine flatwoods, are very important to herpetofaunal species (Moseley et al. 2003).

Since the 1977 establishment of Savannas Preserve State Park (2,115 ha) (5,227 acres), located in Martin and St. Lucie counties, different pine flatwood communities have experienced widely diverse fire regimes (Florida Department of Environmental Protection 2003a). Noticeable differences among vegetation composition have occurred within the ecosystem due to the range of natural and prescribed fires that have taken place. With the proper frequency and intensity, prescribed burning has become an important technique in managing pine flatwood communities (Brose and Wade 2002).

Different prescribed burning techniques vary in the effects felt by amphibian populations in the area. Schurbon and Fauth (2003) found that amphibian abundance significantly decreased after a burn. Another study (Moseley et al. 2003) in Di-Lane Plantation Wildlife Management Area in Burke County, Georgia found that the diversity and abundance of amphibian, salamander, and anuran species did not vary between burned and unburned stands of bottomland hardwood forest. However, reptile abundance and diversity were higher in the burned areas. The opportunity for greater thermoregulation in burned stands with more open vegetation may be responsible for the increases (Moseley et al. 2003). As ectothermic animals, snakes are reliant upon external temperature to maintain body heat. Basking in the sun or lying underneath an object warmed by the sun are two examples of such behavior (Bartlett and Bartlett 2003). Burned stands will have a thinner canopy allowing sunlight to penetrate down to the forest floor. Species richness for all herpetofaunal species encountered was similar between burned and unburned stands despite greater litter depth in unburned stands and more bare ground in burned stands (Moseley et al. 2003).

Fire may also affect the ability of exotic species to populate an area. Invasive species threaten the integrity of entire ecosystems by disrupting natural functions. The number of exotic species established within Florida has increased at accelerating rates, with species occurring in mostly urban settings in the southern half of the state (Meshaka et al. 2004). With most of the surrounding land developed, it is very important to study the extent of exotic species intrusion into natural areas of the preserve (FDEP 2003). Currently, the Florida Fish and Wildlife Conservation Commission (2004) lists 48 reptile and 4 amphibian exotic species that can be found in areas in which they were absent during pre-Columbian generations. Invasive species will continue to be an important focus in protecting natural areas as their populations grow and spread throughout the state. Many exotic species within Savannas Preserve State Park are commonly observed along the roads and trails, suggesting that the establishment of such species can most easily occur in disturbed areas (FDEP 2003b, Meshaka et al. 2005, H. T. Smith unpubl. data). The main unimproved road that runs from the preserve's Walton Road entrance to the canoe launch provides an ideal environment where the introduction and transfer of invasive species within the park is plausible. Fire may also create a disturbed habitat in which exotic species can easily establish themselves. The most common species encountered along heavily traveled areas within the park before this study initiated included the Cuban brown anole (*Anolis sagrei*) and the Cuban treefrog (*Osteopilus septentrionalis*) (C. A. Goethel pers. observ.).

Among methods previously used to study herpetofauna abundance, diversity, and richness are artificial coverboards (Houze and Chandler 2002, Gerald et al. 2006). The coverboards are sheets of plywood or other similar material cut to specified sizes and used to sample various species in natural settings. They are easy to set up and do not have to be checked daily. Damage to the natural environment is reduced through the use of coverboards by limiting the disturbance of natural cover objects, such as decaying logs, which may be easily damaged. By design, they mimic microclimates that would be found under the natural objects. Recommendations for sizes of artificial coverboards vary from 30.4 cm x 30.4 cm x 2 cm to 61 cm x 61 cm x 1.3 cm, of suggested plywood (Dorcas and Richardson, U.S. Fish and Wildlife Service 2000, Houze and Chandler 2002). A study within Jenkins County, Georgia, compared coverboard and natural cover surveys in sampling salamander species (Houze and Chandler 2002). They concluded that the coverboards were adequate in determining the general salamander species composition of the area, with only one species encountered strictly under natural cover. Therefore, most of the species encountered under natural objects were also found underneath the coverboards, supporting that coverboards are an effective, general sampling technique (Houze and Chandler 2002).

The Florida Department of Environmental Protection (FDEP) acknowledges that "in the management of Savannas Preserve State Park, preservation and enhancement of natural conditions is all important" (2003b: p.3). In order to uphold these goals, "…additional plant and animal surveys, targeting specific taxa, such as amphibians and reptiles…" should be conducted within the preserve (FDEP 2003b: p.19). Previous studies suggest that the use of prescribed burning affects herpetofauna in the area. With the multiple treatments being used in Savannas Preserve State Park, it is important to study the possible species repercussions.

This study focuses on general herpetofauna within pine flatwoods, species variation among burn treatments, species composition in relation to distance from an unimproved road, and exotic species in comparison with native species. My first hypothesis was that the highest abundance and diversity would occur in the "ideal" pine flatwoods that had experienced the most natural fire regime through prescribed burning. My second hypothesis was that the abundance of exotic species would be highest in the disturbed areas closest to the road and decrease further into the pine flatwoods. Thus, herpetofauna species abundance and diversity were compared between four different sections of pine flatwoods, each with a unique fire history, at the preserve. This artificial coverboard survey was conducted from 23 July 2006 to 22 March 2007. Four transects were placed in different burn treatments of pine flatwoods within Savannas Preserve

State Park using the unimproved road as a midpoint between two opposing linear transects. Along each transect, an artificial coverboard was placed every 5 meters, up to 35 meters, into the ecosystem.

SAVANNAS PRESERVE STATE PARK

One of Florida's most beautiful, natural attractions is Savannas Preserve State Park, located between the Indian River Lagoon and U.S. Highway 1 in Martin and St. Lucie Counties. Diverse wildlife and unique ecosystems make the park one of the "…highest-quality natural ecosystems in Southeast Florida" (FDEP 2003b: p.26). The park spans over 16 kilometers running north to south with a variable width of 4 kilometers to less than 300 meters. The preserve includes part of the Atlantic Coastal Ridge and the Eastern Flatlands, with most of the area 12 to 19 feet above mean sea level (FDEP 2003b). Savannas Preserve State Park is part of the Florida Greenways and Trails System, a statewide system that aims to provide recreational areas and alternate transportation routes while incorporating conservation management (FDEP and Florida Greenways Coordinating Council 1999, FDEP 2003b). Many state and federal agencies are involved with the management of Savannas Preserve State Park, including the Department of Agriculture and Consumer Services, Division of Forestry (DOF), Florida Fish and Wildlife Conservation Commission (FWC), Department of State, Division of Historical Resources (DHR), Florida Department of Environmental Protection (FDEP) - Florida Park Service (FPS), FDEP Office of Coastal and Aquatic Managed Areas (CAMA), and the FDEP Bureau of Beaches and Wetland Resources. Volunteer efforts, such as student research, are also incorporated to aid with various research projects within the park (FDEP 2003b).

Management focus is given to the restoration and maintenance of natural processes and species composition that are vital to the unique ecosystems of Savannas Preserve State Park. Cultural and recreational uses are also important. Historically, areas of the park were part of the world-renowned pineapple plantations of Jensen Beach, as well as recreational areas common to equestrian activities, fishing, and other uses (FDEP 2003b). Today, activities include biking, hiking, canoeing, fishing, wildlife viewing, picnicking, and horseback riding (FDEP 2003a).

The eastern portion of St. Lucie County, including portions of the preserve, contains the Anastasia Formation of Pleistocene limestone, sand, and clay based sediments (Brown et al. 1990). Most pine flatwood soils are sandy spodosols, a soil that contains a spodic subsurface horizon of organic matter combined with aluminum and/or iron, and has an upper boundary no more than two meters deep (Brown et al. 1990). Soils within Savannas Preserve State Park are comprised mainly of sediments characteristic of the Pleistocene age of higher sea levels, with marine terrace and shelly sands (FDEP 2003b). It is believed that most of the area was part of a historic waterway similar to today's Indian River Lagoon (FDEP 2003b). The pine flatwoods of Savannas Preserve State park are comprised of poorly drained soils, including Waveland, Lawnwood, and Immokalee sands (FDEP 2003b, Natural Resources Conservation Service). Immokalee soils are similar to most found in Florida's flatwood ecosystems, a typical ground-water podozol (Austin 2003). Both Lawnwood and Waveland soils are smooth sands with acidic characteristics organic matter up to nine percent with a low clay content (Natural Resources Conservation Service 2007).

According to the Florida Natural Areas Inventory (FNAI) (FDEP 2003b), physical factors determine the species found within an area of pine flatwoods. These factors include climate, geology, soil, hydrology, and fire frequency (FDEP 2003b). Within Savannas Preserve State Park, the majority of the water received in the community is through precipitation (FDEP 2003b). The area that encompasses the four transects is compact; all transects therefore have similar climate and geology. There are, however, variations in soils and hydrology dependent upon the relative distances to the main basin marsh and dispersed wet prairies. Therefore, the main contributors to any differences in species composition are the aforementioned factors, plant community structure, anthropogenic structures, and fire frequency. Fire frequency was manipulated among the transects during this study.

PRESCRIBED BURNING

For thousands of years, humans have used fire to manipulate the natural environment to improve wildlife areas, hunting, pest management, crop management, as well as fireproofing and reducing vegetation for travel routes (Long 1999, DOF 2006a). Elevated fuel levels aided by occasional freezes, natural plant mortality, and the dry season encouraged frequent ignition from lightning (DOF 2006a). Historically, fires occurred at short intervals, creating a rich and diverse ecosystem inhabited by a variety of plants and animals (Long 1999, Austin 2003). Due to continued fragmentation of natural habitats in Florida, the natural pine flatwoods fire cycle has been suppressed (Abrahamson and Hartnett 1990). The only known way to fully maintain Florida's ecosystems is through the implementation of prescribed burning at specific intervals, seasons, and intensities (DOF 2006a). Without fire every several years, pine flatwoods will gradually succeed into a hammock community with reduced pine populations and dominating broad-leaved trees (Austin 2003). Today, prescribed burning is used to restore and maintain the processes and overall characteristics of Florida's ecosystems (Long 1999). Fragmented ecosystems that quickly accumulate fuel levels, due to fast and constant plant growth, often require assistance from trained personnel to reduce the risk of detrimental wildfires and restore the natural structure of the community (DOF 2006a). The management technique may be employed to reduce fuel loads in forests with a high-risk of experiencing a stand-replacing wildfire (Brose and Wade 2002). Other reasons for implementing a prescribed burn regime include ecological and wildlife concerns, general protection, forest management, range management, water management, improved access, aesthetics, and exotic species control (DOF 2006a).

Historically, pine flatwoods were the most common ecosystem found throughout southern Florida (Abrahamson and Hartnett 1990, Austin 2003). Fires initiated by ranchers and lumbering activities quickly reduced the acreage of such ecosystems in the 1920s (Austin 2003). Today, prescribed burning has been employed as a cost effective way to maintain and restore the natural functions and composition found within many of Florida's ecosystems (Long 1999). Savannas Preserve State Park includes a variety of fire dependent ecosystems such as sand pine scrub, scrubby flatwoods, and pine flatwoods. Prescribed fire is an important feature in maintaining these natural communities and many species that inhabit them (FDEP 2003b). Prescribed burns today take place in over 1.5 million acres in Florida and are used to properly manage forests, grazing pastures, and agricultural areas, as well as being a significant step in ecological restoration (Long 1999).

The vegetation and animal class and population structures of an area are affected by the variable fire histories created by implementing various management tactics. In many of Florida's ecosystems, natural and prescribed fires promote a rich and diverse array of plant and animal life. Burning prompts seed germination and resprouting in a variety of plants adapted to live in areas dependent upon fire (Long 1999). Increased quality and quantity of shrubs, herbs, and grasses, necessary for some wildlife, occurs with normal burning. After a fire, nutrients are captured by the new plants and are introduced into the ecosystem (Long 1999). A higher production of seeds, flowers, and fruit also increases the available food supply to wildlife in the area (Long 1999, DOF 2006a). For example, southeastern slash pine (*Pinus elliottii* var. *densa*) seeds are an essential diet component for many of Florida's mammals, including the state listed species of special concern Florida mouse (*Podomys floridanus*) (Austin 2003). One of the most well-adapted plant species to fire is *P. elliottii* var. *densa*, with very thick bark and protective outer layers on seedlings to protect from extreme temperatures. The species is endemic to the United States' coastal plain and has slowly repopulated stands once dominated by longleaf pines (*Pinus palustris*) (Austin 2003).

Prescribed burning maintains the vegetative composition needed for some species to thrive in a community. Gopher tortoises (*Gopherus polyphemus*) are currently listed by the state of Florida as a Species of Special Concern, but have recently been selected for reclassification to Threatened status. The species greatly benefits from vegetation maintenance created by prescribed burning with fire opening the canopy and allowing shrub and herbaceous species to repopulate the newly exposed areas. Many of these plant species are essential for the diet of *G. polyphemus*, such as the berries from the saw palmetto (*Serenoa repens*), blackberries (*Rubus sp.*), gopher apple (*Licania michauxii*), and pawpaw (*Asimina sp.*) (Nelson 1996, Puckett and Franz 2001). In addition to encouraging important vegetation growth, the sunny areas are also used for nesting and basking by *G. polyphemus* and other species (Puckett and Franz 2001).

Benefits extend further, since the burrows dug by *G. polyphemus* create a habitat for over 360 other species, many of which are protected species (Puckett and Franz 2001). Commensal species include the state and federally listed Threatened Eastern indigo snake (*Drymarchon corais couperi*) and several state protected Species of Special Concern including the Florida pine snake (*Pituophis melanoleucus mugitus*), Florida gopher frog (*Rana capito aesopus*), Florida mouse (*Podomys floridanus*), and Florida burrowing owl (*Athene cunicularia floridana*) (Puckett and Franz 2001, FWC 2004).

Many of these animals use the burrow as a refuge from predators, extreme weather, and fire. Others, such as the *P. floridanus*, cannot survive without a burrow. For these reasons, *G. polyphemus* is considered to be a keystone species in Florida, signifying the importance of protecting and maintaining the habitats necessary for the species survival (Puckett and Franz 2001).

It is important to keep in mind that some species may not benefit from frequent fire. Many animals may perish if they have not developed adaptations to resist the extreme heat, initial reductions in vegetation, and other repercussions of fire (Austin 2003, Schurbon and Fauth 2003). Slower moving species may become trapped and unable to escape even a small fire. Animals reliant upon leaf litter, plants, and fallen logs for protection may become easier prey, therefore predators receive greater benefits (Long 1999). A study (Schurbon and Fauth 2003) executed within Francis Marion National Forest, South Carolina, found short-term decreases in amphibian abundance in southeastern pine communities immediately following a fire. The leaf litter that many species use for protection against desiccation and predation is significantly reduced during a burn. Reduced cover characteristics, paired with the possibility of migration and direct killings due to a fire, may explain why abundance drops so dramatically. Considerations should be given to the effects of fire on the amphibian members of a community. Burns occurring every five years will allow for incomplete burning that will leave ample amounts of refuge for amphibians while adequately serving the needs of the vegetation (Schurbon and Fauth 2003).

Prescribed burning benefits wildlife and encourages the natural functioning of an ecosystem, but these fires also benefit people. Some anthropogenic benefits of prescribed burning include reduced risk of destructive wildfires, increased visibility for hunting and other recreational purposes, and improved access for travel, hiking, and other related activities (Long 1999). In general, prescribed burning reduces the amount of fuel in an area therefore reducing the intensity and risk of spontaneous wildfires (Long 1999, Brose and Wade 2002). Subsequent fire intensity is instantly reduced after a fuel-reduction burn, creating more easily suppressed future fires that may be necessary to regulate risk (DOF 2006a). Prescribed fires are one of the most natural ways of reducing high fuel loads that may threaten surrounding developed areas, yet most burns should occur on at least a three to five year cycle to maintain effectiveness (Monroe and Long 1999, Brose and Wade 2002). Areas that have recently been burned can act as a fire-break to prevent a fire from spreading into other properties (DOF 2006a).

Specific measures of reduced wildfire risk were examined in a study based on the 1998 severe drought experienced in Northern Florida (Brose and Wade 2002). Fuel characteristics were collected from several stands of southeastern slash pine (*Pinus elliottii* var. *densa*) and/or longleaf pine (*Pinus palustris*) ecosystems and then entered into a fire simulation program. Results indicated that prescribed fires slightly decreased the gallberry (*Ilex glabra*) and saw palmetto (*Serenoa repens*) cover for the first year and increased the amount of open space and herbaceous species for several years. After five years, the well-adapted shrubs grew back similar to pretreated heights. The fuel load was heaviest in the untreated stands and lightest directly following a prescribed burn or thinning management technique. During drought conditions, flame height was the longest in all of the untreated pine flatwoods, reaching up to seven meters, but fell significantly (80%) following a burn. Even after five years, the maximum flame height reached only four meters. In untreated stands, fires spread at over 18 meters a minute with only an 11.3 kilometers per hour wind. Prescribed burns suppressed the rate down to 2.3 meters a minute after one year, but increased as vegetation returned in subsequent years. Without management techniques such a prescribed burning, wildfires that ignite in pine stands void of recent fuel load reductions will likely result in an uneven, hot fire that would kill most of the stand and become extremely difficult to control (Brose and Wade 2002).

The most important factor that determines the characteristics of a fire in pine flatwoods is the age and growth of vegetation within the ecosystem (Brose and Wade 2002). Prescribed burns can significantly reduce the amount of damage caused by fires by reducing the intensity and rate of spread (Long 1999, Brose and Wade 2002). A single prescribed fire can benefit the direct property owner as well as surrounding neighbors and the general public (DOF 2006a). Yet, before any action can be taken towards initiating a burn, Florida law requires specific certifications to be met (Florida Legislature 2006).

Florida legislature (2006), under Statute 590.125, promotes the use of prescribed burning to better the public, the environment, and the economy (DOF 2006b). All burns designated to confront environmental issues, such as restoration and wildlife management, are considered certified burns. Noncertified burns pertain to those ignited for wildland or land-clearing purposes. Florida Statute 590.125 requires for both certified and noncertified burning: (1) consent of landowner, (2) adequate fire breaks, (3) ample personnel and equipment to control the fire, and (4) authorization from the DOF before ignition. A written prescription containing a site description, map, number of personnel that will be present, desired weather characteristics, desired fire behavior, and anticipated smoke impact, is required before a certified burn can occur. In addition, a trained and experienced Certified Prescribed Burn Manager must also be present for the entire burn. Other laws may affect and/or require other information or considerations before a prescribed burn can take place (DOF 2006b). Despite the extremely diverse benefits and the safety measures in place, executing a prescribed burn faces many difficulties.

Two of the most frequently encountered concerns related to prescribed burning are the spread of fire onto properties within a close proximity to the burn area and smoke related health issues. Prescribed burn managers today consider these to be serious factors, and fires are often postponed due to inappropriate conditions for these reasons. Wind must be from the proper direction and at the correct speed to carry smoke away from sensitive areas (Long 1999, DOF 2006b). Fuel loads and drought conditions must also meet certain standards set by the DOF or the burn will not be permitted. Due to these constraints, burning activities are often limited to only a few suitable days a year (Long 1999). The threat of property damage and health complications from smoke inhalation, combined with early to mid-twentieth century policies encouraging fire suppression, have skewed the public perception of prescribed burning (Long 1999, Martí et al. 2005). Figures such as Smokey the Bear and Bambi, combined with educational programs, persuaded the public that all forest fires were horribly destructive and that is was critical to prevent such scenarios (DOF 2006a). Despite these historical influences, some progress has been made in recent years. The general public is becoming more aware of the great benefits to ecosystems and to the people living around these lesser or undeveloped areas, that are gained through prescribed fires (Martí et al. 2005). Future implementations of prescribed burns will rely heavily upon public support and understanding. In order to increase these factors, people involved with the process should continue to learn and develop new, improved techniques and efforts should be made to continue educating the public (DOF 2006b).

Savannas Preserve State Park has and will continue to “implement prescribed burning as a tool to enhance fire-dependent native plant communities and to prevent damaging wildfires from occurring” and “…educate and inform nearby residential communities, businesses, and local governments about the critical needs for and benefits of using prescribed fire in the preserve” (FDEP 2003b: p.4). To increase safety during prescribed fires, mowed edges and other similar areas are being created along the burn zones to divide the preserve. Edges with reduced vegetation will help decrease the likelihood that a fire in one zone will be able to jump into another unprepared section (FDEP 2003b). Recently burned pine flatwoods will have a slower rate of fire movement and smaller flames than in overgrown areas. Slower spread rates and shorter flames are much easier to control, therefore increasing the safety of developed areas near uncleared land (Brose and Wade 2002). A limited number of prescribed burns have been implemented within Savannas Preserve State Park due to public hesitation and resistance, even though several legislative acts directly promote such activities (Martí et al. 2005).

One of the main problems faced by the park’s prescribed burn program is smoke screening. Land uses surrounding Savannas Preserve State Park include slightly dense single and multi-family residential developments, commercial areas, other managed natural areas, and recreational facilities, including Port St. Lucie’s Sandhill Crane Park, on the western edge of the pine flatwoods studied in this research. Due to a conglomeration of homes, hospitals, and schools that are close to the preserve, burning within Savannas is often met by difficult challenges to balance the needs of the natural ecosystems and the health of the surrounding community. Often, natural forces are used to help upkeep this balance, such as burning pine flatwoods during the dry season when northwest winds, that can carry smoke away from sensitive areas, are present. Adequate notice is given to all surrounding landowners before initiating burns. Currently, educational programs explaining the costs and benefits of prescribed fire are in place and open to the public. Residents are encouraged to attend the programs and/or meet with park staff for any questions or concerns they may have (FDEP 2003b). As prescribed burning continues within Savannas Preserve State Park, neighboring communities are expected to increase their support of such activities (Martí et al. 2005). As human tolerance increases and fuel levels decrease, changes will be made to the fire management regime within the park to resemble more natural burning regimes. For now other techniques, such as roller chopping, will also be implemented to reduce vegetation levels (FDEP 2003b).

EXOTIC SPECIES

Exotic species are plants or animals that have been introduced into an area they have never occupied. Many non-indigenous species have been introduced through human activities and often succeed at establishing a population due to the lack of natural predators. Exotic species may out-compete native species through higher survival rates, by the spread of diseases or parasites that greatly affect natives species who are not equally resistant, and by increased adaptability to altered habitats (FDEP 2003b). Florida is home to the highest number of exotic reptile and amphibian species, more than any other state in the country, with a total 40 different species now established (Meshaka et al. 2004). South Florida, despite the sporadic rainfall, poor soil, and drastic seasons, still provides habitat for a highly diverse community of native herpetofauna, although far less diverse than northern Florida. In contrast, the number of exotic reptile and amphibian species declines in the north and central part of the state (Meshaka and Ashton 2005). The highest diversity of invasive species occurs in southern Florida, often in areas that have been heavily disrupted with human interference (Meshaka et al. 2004). All of the non-indigenous species now inhabiting Florida were introduced through human activities, and currently both state and federal laws prohibit the release of any exotic species (Meshaka et al. 2004).

The rate of success an invasive species experiences after initial introduction relies heavily on the following five characteristics: (1) rapid maturation, (2) a long, productive breeding season, (3) species prey on invertebrates, (4) thrive in human-altered habitats, and (5) succeed in natural areas as well (Meshaka et al. 2004). Essentially, a fast reproductive rate paired with a variable diet and many suitable habitats are the key components for successful introduced species establishment in Florida (Meshaka et al. 2004). Because some exotic species have the capability of surviving in anthropogenic settings, human encroachment only minimally threatens their survival in comparison with the extreme effects development has on native species (Delis and Mushinsky 2005).

Most of the parks at both state and federal levels include some form of infrastructure that aids human visitors traveling from one point to another. Yet, these same trails and roadways help disperse invasive species further into our protected natural areas (Smith and Engeman 2004, Moore and Smith 2006). The population of an exotic species within a park such as Savannas Preserve State Park may increase if improvements to walkways and other transportation paths are made in the future (Moore and Smith 2006). Roadways, created to assist humans across areas simultaneously speed the spread of invasive species into ecosystems and hinder natural accumulations of leaf litter possibly leading to reduced herpetofauna populations (Smith et al. 2005). It is important to research how much of an impact the unimproved trails are having in our state parks and to record the extent of intrusion once an exotic species is introduced into a natural area. Future studies will help personnel make well informed decisions concerning the access given to the public within protected areas and the amount of exotic species aided in the process.

Early invaders, such as the greenhouse frog (*Eleutherodactylus planirostris*), Cuban treefrog (*Osteopilus septentrionalis*), and Cuban brown anole (*Anolis sagrei*) often traveled through cargo shipping routes between Florida and the West Indies, although there is the possibility that even earlier trade may be responsible for some introductions (Meshaka et al. 2004). Regardless of timeframe, human disturbance in one way or another has helped every exotic herpetofauna species found in Florida. Today's dispersal methods include the release of pets as well as the exchange of plants, construction equipment, and other materials that have a space large enough to accommodate at least one small individual. One example of an exotic species that has been aided by the increases in human transportation is the Indo-Pacific gecko (*Hemidactylus garnotii*) (Meshaka et al. 2004).

H. garnotii is an exotic that has been reported in disturbed areas of Florida pine flatwoods. The species is native to Southeast Asia, the East Indies, and the South Seas islands (Conant and Collins 1998). Since the species introduction in 1963, successful breeding within Florida's landscape has led to an established population in 30 counties (Meshaka et al. 2004). Seven other counties are also affected, but breeding populations have not been present for ten years (FWC 2004). Dispersal of these exotic species has been aided by human transportation and interactions across the state through foliage, construction, and other shipment-based trades (Meshaka et al. 2004). *H. garnotii* has also been introduced into many southern and central Florida communities by residents trying to control roach populations (Carmichael and Williams 2003). Unfortunately, the gecko only feeds on small roaches and insects, contributing little help towards the homeowners' intended goal (Carmichael and Williams 2003). *H. garnotii* is an all-female, parthenogenetic, cryptic species that can produce up to three clutches per year (Meshaka et al. 2004). The eggs are composed of a calcareous shell, enabling the survival of the clutch in areas devoid of moisture levels needed for most other lizards producing parchment-shelled eggs (Punzo 2005). Multiple release sites combined with the species unisexual trait, have allowed for fast expansion across the state (Carmichael and

Williams 2003). Within Savannas Preserve State Park, the unimproved roads, sidewalks, and parking lots have added to the increasing range of many exotic species further into the natural area (Meshaka et al. 2005, Moore and Smith 2006). *H. garnotii* is a nocturnal insectivore that can feed on a range of arthropods, resulting in minimal competition with the mostly diurnal, native lizards in Florida. Feeding sites may, however, include locations native frogs use for feeding (Punzo 2005). No extensive threats of *H. garnotii* to native species have been discovered (FWC 2004).

The greenhouse frog (*Eleutherodactylus planirostris*), native to Cuba, the Bahamas, Cayman Islands, Central and South America, and the West Indies, was introduced to South Florida in 1875 (Fuller and Benson 1999, Carmichael and Williams 2003, FWC 2004, Meshaka et al. 2004). The species has established itself in 33 counties, with 4 more counties recently reporting sightings. Increasing populations threaten a variety of ecosystems statewide in addition to developed areas (FWC 2004). Common locations of the species include homes and gardens as well as moist, vegetated tracts of land (Carmichael and Williams 2003). *E. planirostris* is the only ground-dwelling species of the genus, traveling no more than a few centimeters above the ground (Fuller and Benson 1999). Unlike any native Florida anuran, this exotic species does not experience a tadpole stage. Instead, the young have direct development, hatching as small, fully developed frogs. This process reduces the need for the female to find a suitable water source for reproduction; only a minutely damp area is needed to successfully produce young (Carmichael and Williams 2003). Moist leaf litter is the most common location for the eggs of *E. planirostris* to be laid. Interactions with natives may include competition with other amphibian species and possible predation by native snakes and other frog-eating species (FWC 2004).

One predator of *E. planirostris* is the Cuban treefrog (*Osteopilus septentrionalis*), an exotic anuran introduced most likely from a Cuban cargo ship in 1931 (FWC 2004), although some researchers believe the species may be native to the Florida Keys (Fuller and Benson 1999, Meshaka et al. 2004). Prior to the 1960s, the population was contained within Dade county and the Florida Keys (Carmichael and Williams 2003). Now the species is established and/or breeding in 38 counties and present in 6 other counties (FWC 2004). Statewide trends in population show an expansion across the state, with most northern counties only recently being invaded (FWC 2004). *O. septentrionalis* negatively affects native frog species through direct predation (Fuller and Benson 1999, Meshaka 2000). Affected species include the southern toad (*Bufo terrestris*), narrow mouthed toad (*Gastrophryne carolinensis*), southern leopard frog (*Rana sphenocephala*), green treefrog (*Hyla cinerea*), and squirrel treefrog (*Hyla squirella*) (Fuller and Benson 1999). Indigenous snakes are also affected, since they may eat the exotic species, replacing native prey items with *O. septentrionalis*. Native wildlife are not the only impacted individuals from the introduction of the species. Since quick acclimations to living in developed areas occurs, the species is often seen around homes on windows and doors (Carmichael and Williams 2003). Although their simple presence around buildings poses no serious threats, larger scaled scenarios have occurred. *O. septentrionalis* have been responsible for occasional power outages caused by the attractiveness of buzzing transformers to the species (Fuller and Benson 1999).

The Cuban brown anole (*Anolis sagrei*) is native to the West Indies and has been present in southern Florida, including the Keys, for decades (Carmichael and Williams 2003), with introductions occurring possibly as early as 1887 (FWC 2004). Successful reproduction has allowed for the species to spread into 53 counties, with only 1 county minimally affected (FWC 2004). For some species, multiple points of introduction are partially responsible for the large region of inhabitance, such as with *A. sagrei* (Meshaka and Ashton 2005). The nursery plant business provided suitable habitat for the reproductive preferences of female *A. sagrei* to lay eggs in low, leafy vegetation. With human population growth in the 1970s came a demand for tropical vegetation at newly developed sites. *A. sagrei* individuals were transported overnight to various locations throughout Florida. A lifespan of three years provided the introduced species enough time to reproduce if suitable mates could be found (Carmichael and Williams 2003).

A. sagrei is well adapted to living in disturbed areas regardless of available natural cover. This exotic is much less arboreal compared to its native counterparts, the green anole (*Anolis carolinensis*), staying much closer to the ground (Conant and Collins 1998). In general, most *A. sagrei* are found in developed and disturbed environments while the *A. carolinensis* are more common in less developed areas, although suitable habitat includes flatwood ecosystems (Carmichael and Williams 2003, FWC 2004). *A. sagrei* preys mostly on insects and has been reported to occasionally eat young native *A. carolinensis* (Gerber and Echternacht 2000). Regardless of reason, astounding decreases in *A. carolinensis* populations occur in areas that include *A. sagrei* populations (Carmichael and Williams 2003, Meshaka et al. 2004). Increased predation skills learned by cats from the large *A. sagrei* populations may be one reason for the differences in abundance within a single area (Carmichael and Williams 2003). It is possible that *A. sagrei* helps *A. carolinensis* by serving as a similar prey item for many of Florida's native birds, snakes, and other animals (Carmichael and Williams 2003). The Savannas Preserve State Park Unit Management Plan lists the primary habitat for *A. sagrei* as ruderal and developed areas (FDEP 2003b).

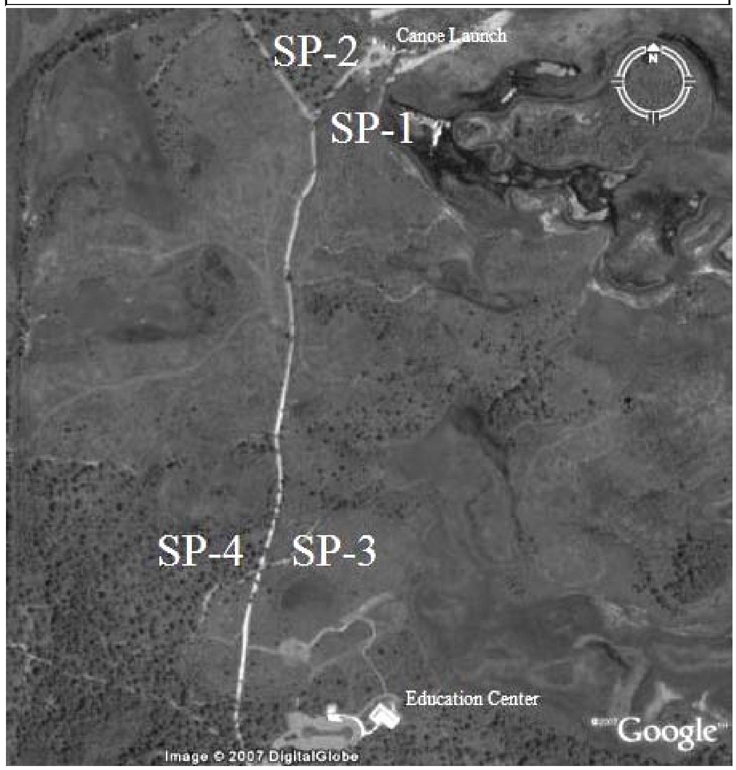
Concern over the increasing abundance and diversity of invasive species rises out of the diminishing populations of similar native species and their predators. A limited amount of research has shown that it is common to find a competitive relationship between exotic and native individuals that occupy similar niches (Meshaka et al. 2004). An estimated 10 million people will move into Florida in the next 25 years, making the statewide population around 25 million. As human populations continue to grow and infrastructures stretch further into natural settings, concerns over an exotic species epidemic that may spread further throughout the state will intensify (Meshaka and Babbitt 2005, Meshaka et al. 2004).

MATERIALS AND METHODS

Study Sites.– The study was conducted at four different areas of pine flatwoods within Savannas Preserve State Park in St. Lucie County. The mean annual precipitation where the four sites are located for 2000 to 2006 is 143.6 cm (FPS unpubl. data). During the survey, from July 2006 to March 2007, the total rainfall was only 74.7 cm. Annual rainfall for 2006 was 122 cm, 101.6 cm less than the rainfall for 2005, and drought conditions have persist into 2007 (FPS unpubl. data). The mean annual temperature for Savannas Preserve State Park is 23.3 ˚C, with January and February as the two coldest months, with average lows of 13 ˚C, and July and August as the two warmest, with average highs of 32 ˚C (The Weather Channel 2007). Artificial coverboard techniques used in this research follow or exceed the suggestions given by the Catawba River Corridor Coverboard Program (Dorcas and Richardson 2001). The main unimproved road connecting the Education Center off Walton Road to the canoe launch in the basin marsh was used as a dividing line between sites. Each transect begins at the edge of the dirt road and runs perpendicular into the selected area for 35 meters. At every 5 meter increment, we placed a 61 cm x 122 cm sheet of plywood of variable thickness, centered on the transect line parallel to the road (the thickness of the coverboards varied from 1.3 to 1.9 centimeters). The Catawba River Corridor Coverboard Program (Dorcas and Richardson 2001) suggests at least 20 pieces of plywood, 61 cm x 61 cm or larger, be used when conducting an artificial coverboard survey. A total of 28 coverboards were placed in the four transects, but within the first week the first board in Transect 3 was unlawfully removed from the study site in violation of Florida Administrative Code 62D-

2, leaving a total of 27 boards. A handheld GPS was used to pinpoint the location of each individual coverboard. Scientific names used concerning herpetofauna are based upon Conant and Collins (1998) third edition of *Reptiles and Amphibians: Eastern/Central North America*.

Figure 1. Map of transects within Savannas Preserve State Park.



Transect 1 (SP-1), located slightly west of the Savannas basin marsh, was roller chopped in February 2005 and burned on 7 March 2005 with a prescribed fire. The 2005 burn was an attempt to reduce an overwhelming density of *S. repens* that out competed most other species after a burn years earlier (FPS unpubl. data). The *P. elliottii* var. *densa*) in the locality experienced 100% mortality in an earlier fire and still have not sufficiently reappeared in the area. The only canopy in the area is provided by several *P. elliottii* var. *densa* and several cabbage palms (*Sabal palmetto*) that run along the unimproved road. Scattered among the *S. repens* are gallberry (*Ilex glabra*) and love vine (*Cassytha filiformis*). Plow scars are common in the area, creating a unique environment that may provide different microhabitats to the species commonly found in the pine flatwood and nearby marsh ecosystems.

Transect 2 (SP-2) runs opposite of Transect 1 and is an example of a well kept, natural pine flatwoods. The ecosystem was burned during a prescribed fire on 22 December 2004 (FPS unpubl. data). *P. elliottii* var. *densa* are scattered in the area that is also evenly populated with *S. repens*, *I. glabra*, and wiregrass (*Aristida beyrichiana*). Rusty lyonia (*Lyonia ferruginea*) and the endemic pennyroyal (*Piloblephis rigida*) are also common. This section encompasses the most diverse vegetation among the four transects in this study.

Transect 3 (SP-3) runs east from the main trail towards the basin marsh, with a wet prairie further south. The area was roller chopped in February 2005 and burned on 7 March 2005 with a prescribed fire (FPS, unpubl. data). Unlike SP-1, which experienced these same treatments, more *P. elliottii* var. *densa* persist. The transect runs along an old, unimproved road now densely covered with herbaceous species including *Piloblephis rigida*. All of the *P. elliottii* var. *densa* in the area are located north and south of the transect, with no canopy directly overhead of any of the coverboards.

Transect 4 (SP-4), although located in between two sections of pine flatwoods that were chopped in June 2005, has experienced no recent manipulation, leaving a dense overgrowth of vegetation (FPS unpubl. data). *S. repens* has grown over a meter high, creating a thick impenetrable shrub layer that also includes *I. glabra*. *P. elliottii* var. *densa* are well established in the area, creating a dense layer of pine needles that often crowd out herbaceous species. Such a decrease in the complexity and richness of the herbaceous layer is expected as pine flatwoods mature (Abrahamson and Hartnett 1990). Transect 4 has the potential for a large wildfire if it is left in it's untreated condition. The likelihood of suppressing such a fire would be extremely difficult given the available fuel at ground level, with potentially high flames and fast rate of movement across the area. Mortality of *P. elliottii* var. *densa* in the area could reach 100 percent if such a fire occurs (Brose and Wade 2002).

Survey Methods.– Coverboards were placed directly on top of the ground cover, vegetation, and leaf litter. After a one-week establishment period, the artificial coverboards were checked once a week for eight months. The temperature, estimated cloud cover, wind direction, and wind speed were determined prior to data collection for each respective day. Daily rainfall was tabulated using South Florida Water Management District's records for the S-49 area encompassing Savannas Preserve State Park. Rainfall data were collected from the FPS monitoring station after surveys were completed. Since venomous insects and reptiles could have been present underneath the boards, each artificial coverboard was lifted up facing away from observers using a long snake stick (U.S. Fish and Wildlife Service 2000). The leaf litter was then gently prodded to encourage the movement of any species that may be residing underneath the surface level of leaf litter and other debris. Any species found was carefully identified, with only minimal handling of specimens that may be difficult to distinguish. After inspection, the coverboards were gently lowered back onto the leaf litter in the same position. Often during a period of slight to moderate rainfall, a variety of species could be found foraging and wandering among the herbaceous and shrub layers of the transects. Species opportunistically observed in places other than underneath the coverboards were also recorded, included in the transect they were found in and at the correct distance from the unimproved road, if applicable. These sightings provided many additionally useful observations to the research survey. Any species found in an area other than the four transects was grouped into a fifth category labeled “Other”. These areas include the pavilion structures near the education center and canoe launch, unimproved roads, sidewalks, and other human related structures.

After 9 November 2006, all gopher tortoises (*Gopherus polyphemus*) found were marked with a number above each leg on the shell to eliminate double counts. The size, sex (determined by examining the plastral concavity), and location were also recorded.

RESULTS

During the 2006 to 2007 study, Savannas Preserve State Park received 5.8 cm of rain in July, 23.4 cm in August, 13.2 cm in September, 3.3 cm in October, 5.3 cm in November, 19.6 cm in December, 0.8 cm in January, 2.8 cm in February, and 0.5 cm in March for a total of 74.7 cm (FPS unpubl. data). Mean temperature during the study, at the time of each survey, was 25 ˚C, with a January average of 21.5 ˚C and an August average of 27.5 ˚C. The coldest temperature recorded during an actual survey was 13 ˚C on 18 January 2007 and the hottest, 32 ˚C, on 7 September 2006. The average time of survey was 3:00 pm, with two early morning surveys and several during early evenings before dusk. No surveys were conducted at night.

Out of the 35 days surveyed, 28 days (80%) included successful encounters, although several opportunistic observations occurred before the coverboard survey began. Eighty six individuals, comprised of 17 different species, were encountered between 3 May 2006 and 22 March 2007 (Table 1). Fifty four individuals (65%) were reptiles while the other 32 individuals (35%) were amphibians. Twenty nine individuals (33.5%) were encountered within the four transects, with the other 57 individuals (66.5%) observed by chance in areas other than the specified transect. The small overall number of animals encountered rendered statistical analyses impractical.

Twelve (41.5%) of the 29 herpetofauna found in the transects were in SP-1, and 12 (41.5%) were found in SP-4. SP-2 followed with 4 individuals (14%), and SP-3 with 1 (3%). Six different species were observed in SP-4, 5 in SP-1, 3 in SP-2, and 1 in SP-3 (Table 1). Excluding gopher tortoises (*Gopherus polyphemus*), 21 individuals were observed in the transects. Eight individuals (38%) were found in SP-1, 4 (19%) in SP-2, 0 in SP-3, and 9 (43%) in SP-4 (Table 2).

Out of the 54 reptiles observed, 6 individuals (11%) were in SP-1, 3 (5.5%) in SP-2, 1 (2%) in SP-3, and 9 (17%) in SP-4. The remaining 35 individuals (64.5%) were opportunistically observed in other, mostly disturbed, areas. From the 32 amphibians recorded, 6 (19%) were in SP-1, 1 (3%) in SP-2, 0 in SP-3, and 3 (9%) in SP-4. The remaining 22 individuals (69%) were opportunistically observed in other areas of Savannas Preserve State Park.

Table 1. Species found in each transect. Other represents opportunistic findings of individuals in other areas of the park.

Scientific Name	Common Name	SP-1	SP-2	SP-3	SP-4	Other	Total
Reptiles							
Anolis sagrei	Brown Anole	0	1	0	2	20	23
Gopherus polyphemus	Gopher Tortoise	4	0	1	3	7	15
Anolis carolinensis	Green Anole	1	0	0	0	3	4
Eumeces inexpectatus	S.E. Five-lined Skink	0	0	0	3	0	3
Ophisaurus ventralis	Eastern Glass Lizard	0	0	0	0	2	2
Scincella lateralis	Ground Skink	0	2	0	0	0	2
Elaphe guttata guttata	Corn Snake	0	0	0	0	1	1
Coluber constrictor priapus	Southern Black Racer	0	0	0	1	0	1
Hemidactylus garnotii	Indo-Pacific Gecko	0	0	0	0	1	1
Sistrurus miliarius barbouri	Dusky Pigmy Rattlesnake	1	0	0	0	0	1
Thamnophis sirtalis sirtalis	Eastern Garter Snake	0	0	0	0	1	1
Amphibians							
Osteopilus septentrionalis	Cuban Treefrog	0	0	0	0	14	14
Bufo quercicus	Oak Toad	5	0	0	1	3	9
Acris gryllus dorsalis	Florida Cricket Frog	0	0	0	0	5	5
Eleutherodactylus planirostris	Greenhouse Frog	0	0	0	2	0	2
Bufo terrestris	Southern Toad	1	0	0	0	0	1
Hyla femoralis	Pinewoods Treefrog	0	1	0	0	0	1
Total		12	4	1	12	57	86

All southeastern five-lined skinks (*Eumeces inexpectatus*) observed were encountered in SP-4. Contrastingly, all of the ground skinks (*Scincella lateralis*) were in SP-2. Six (67%) of the 9 oak toads (*Bufo quercicus*) observed were seen in a transect, with 5 (83%) of the 6 in SP-1. Both greenhouse frogs (*Eleutherodactylus planirostris*) encountered were in SP-4.

Table 2. Species found in transects, excluding *Gopherus polyphemus*.

Scientific Name	Common Name	SP-1	SP-2	SP-3	SP-4	Total
Reptiles						
Anolis sagrei	Brown Anole	0	1	0	2	0
Eumeces inexpectatus	S. E. Five-lined Skink	0	0	0	3	3
Scincella lateralis	Ground Skink	0	2	0	0	3
Anolis carolinensis	Green Anole	1	0	0	0	2
Coluber constrictor priapus	Southern Black Racer	0	0	0	1	1
Sistrurus miliarius barbouri	Dusky Pygmy Rattlesnake	1	0	0	0	1
Amphibians						
Bufo quercicus	Oak Toad	5	0	0	1	0
Eleutherodactylus planirostris	Greenhouse Frog	0	0	0	2	6
Bufo terrestris	Southern Toad	1	0	0	0	2
Hyla femoralis	Pinewoods Treefrog	0	1	0	0	1
Total		8	3	0	9	18

Coverboards were categorized into groups, with the first and second representing the initial 10 meters from the unimproved road into a transect. Coverboards three and four covered from 15 to 20 meters into the area. Boards five through seven covered 25 to 35 meters into each transect. Four of the 29 individuals (14%) located within a transect occurred within the first 10 meters. Another four herpetofauna (14%) were within 15 to 20 meters. The remaining 21 individuals (72%) were observed within the last 10 meters of the studied section, from 25 to 35 meters (Table 3).

Twenty four (52%) of the 46 native individuals encountered were located in one of the four transects. All of the natives observed in the designated study area were at least 15 meters from the unimproved dirt road, with most 25 to 35 meters from the edge. Contrastingly, 35 (87.5%) of the 40 exotic individuals encountered were located in disturbed areas, with the remaining 5 (12.5%) occurring within a transect. Four (80%) of the 5 invasive herpetofauna located within a transect occurred within ten meters from the unimproved road. Only one exotic individual (20%), *A. sagrei*, was more than 10 meters from the unimproved road.

Table 3. Relative distances from road species were found in the transects. Other represents opportunistic findings in other locations of the park, including disturbed areas.

Scientific Name	Common Name	0-10 Meters	15-20 Meters	25-35 Meters	Other	Total
Anolis sagrei	Cuban Brown Anole	2	0	1	20	23
Gopherus polyphemus	Gopher Tortoise	0	0	8	7	15
Osteopilus septentrionalis	Cuban Treefrog	0	0	0	14	14
Bufo quercicus	Oak Toad	0	1	5	3	9
Acris gryllus dorsalis	Florida Cricket Frog	0	0	0	5	5
Anolis carolinensis	Green Anole	0	0	1	3	4
Eumeces inexpectatus	S.E. Five-lined Skink	0	3	0	0	3
Ophisaurus ventralis	Eastern Glass Lizard	0	0	0	2	2
Eleutherodactylus planirostris	Greenhouse Frog	2	0	0	0	2
Scincella lateralis	Ground Skink	0	0	2	0	2
Thamnophis sirtalis sirtalis	Eastern Garter Snake	0	0	0	1	1
Bufo terrestris	Southern Toad	0	0	1	0	1
Coluber constrictor priapus	Southern Black Racer	0	0	1	0	1
Elaphe guttata guttata	Corn Snake	0	0	0	1	1
Hemidactylus garnotii	Indo-Pacific Gecko	0	0	0	1	1
Hyla femoralis	Pinewoods Treefrog	0	0	1	0	1
Sistrurus miliarius barbouri	Dusky Pigmy Rattlesnake	0	0	1	0	1
Total		4	4	21	57	86

Forty six individuals (53%) of the 86 encountered represent the 13 native species found during this study. The 46 encounters include 15 gopher tortoises (*Gopherus polyphemus*), 9 oak toads (*Bufo quercicus*), 5 Florida cricket frogs (*Acris gryllus dorsalis*), 4 green anoles (*Anolis carolinensis*), 3 southeastern five-lined skinks (*Eumeces inexpectatus*), 2 eastern glass lizards (*Ophisaurus ventralis*), 2 ground skinks (*Scincella lateralis*), 1 southern toad (*Bufo terrestris*), 1 southern black racer (*Coluber constrictor priapus*), 1 corn snake (*Elaphe guttata guttata*), 1 pinewoods treefrog (*Hyla femoralis*), 1 dusky pigmy rattlesnake (*Sistrurus miliarius barbouri*), and 1 eastern garter snake (*Thamnophis sirtalis sirtalis*).

Four exotic species, comprised of 40 individuals (47%), were encountered during this survey. Out of the 40 observations, 23 (57.5%) were Cuban brown anoles (*Anolis sagrei*), 14 (35%) Cuban treefrogs (*Osteopilus septentrionalis*), 2 (5%) greenhouse frogs (*Eleutherodactylus planirostris*), and 1 (2.5%) Indo-Pacific gecko (*Hemidactylus garnotii*).

The first species found directly underneath an artificial coverboard was a dusky pigmy rattlesnake (*Sistrurus miliarius barbouri*) in SP-1 located 30 meters from the unimproved dirt road during the seventh week, suggesting a minimum establishment period of seven weeks. Shed skin found the following week shows that the individual returned to the same coverboard after the initial observation. Pig frogs (*Rana grylio*) were not seen, but the call could be heard along the edge of the basin marsh near SP-1.

G. polyphemus individuals were observed in SP-1, SP-3, SP-4 and scat was present in SP-2. Burrows were found in SP-1, SP-3, and SP-4 by chance; no further effort was taken to locate burrows in other areas. Five Florida cricket frogs (*Acris gryllus dorsalis*), a nearly endemic species to Florida according to Meshaka and Ashton (2005), were observed near the main basin marsh during four different survey days, although their calls were often heard.

DISCUSSION

In general, herpetofauna observations in this study were low due to the drought conditions during most of the survey period. Without adequate rainfall, many species probably retreated to other areas of the preserve. This finding agrees with the conclusions of Houze and Chandler (2002) that encounters decreased with the absence of rainfall. It is common that amphibians utilize coverboards following rain, so deficient levels of precipitation may have decreased the attractiveness of the microclimate under the boards (J. A. Moore unpubl. data). The time of the surveys may have also affected the outcome. Preference may have been given to diurnal species, such as the oak toad (*Bufo quercicus*), since the majority of the surveys were during afternoon hours (Conant and Collins 1998). Differentiating the time of future surveys may yield higher individual observations to account for a variety of species characteristics. During a study evaluating the effectiveness of coverboards as a sampling method, it was found that the artificial boards were inadequate for determining species abundance and imitating natural cover temperature characteristics (Houze and Chandler 2002). Out of 175 total encounters, 43 (24.6%) individuals occurred underneath the artificial coverboards, and 132 (75.4%) under natural objects (Houze and Chandler 2002). Percentages stayed relatively the same throughout the seasons. Microclimate characteristics were compared using temperature data loggers placed under two artificial coverboards and two natural cover objects located no more than two meters apart. Although average temperatures were the same, the coverboards fluctuated up to 10 ˚C, compared to 3 ˚C under natural cover, especially in the late summer (Houze and Chandler 2002). Coverboards were also found to heat up and cool down much faster relative to natural cover (Houze and Chandler 2002). Temperature probe readings slightly north of Savannas Preserve State park found that temperatures underneath coverboards fully exposed to the sun reached up to 66 ˚C mid-day in the summer. The coverboards were most efficient during the evening and morning in summer and all day in the late fall and spring (J. A. Moore unpubl. data). Fast, fluctuating temperatures combined with minimal moisture underneath the artificial coverboards suggests that they do not mimic the microclimate found under natural cover. In general, encounters increased with rainfall and were unaffected by daily maximum and minimum temperatures. Overall, artificial coverboards showed results that did not increase with age, but regardless were still effective as short-term monitoring tools (Houze and Chandler 2002). Means and Franz (2005) also reported poor performance of coverboard surveys; they were greatly unsuccessful in comparison with drift fence funnel traps and PVC pipes.

One unique observation during this study was of two road-killed eastern glass lizards (*Ophisaurus ventralis*) on 10 August 2006 at approximately 4:50 pm. The individuals were found about one meter apart on the damp, unimproved dirt road between the roller-chopped pine flatwoods of SP-3 and the rougher pine flatwoods of SP-4. Both lizards were about 50 to 60 centimeters in length and were most likely hit simultaneously by the same vehicle on the east side of the road. Previously, at 2:30 pm, the individuals were not present. The species has been well documented in most of the natural areas managed by the FPS in Southeast Florida (FPS unpubl. data), but is rarely encountered because of its secretive habits. Road-kill studies are common within Florida State Parks, yet the occurrence of *O. ventralis* is uncommon (H. T. Smith unpubl. data). A daily road-kill survey conducted from 1995 to 1998, within the 4,642 ha (11,471 acre) Jonathan Dickinson State Park in Martin County, Florida discovered 256 road-killed herpetofauna, only 5 (1.953%) of which were *O. ventralis* (Rossmanith and Smith 2006). During a 44-month survey of herpetofauna species around Lake Jackson in Leon County, Florida from 2000 to 2003, only 14 of the 10,229 species (0.1369%) found were *O. ventralis* (Aresco 2005). In a two year survey of Paynes Prairie State Preserve in Alachua County, Florida, only 1 (0.0529%) *O. ventralis* was discovered out of the 1,891 road-killed individuals encountered (Dodd et al. 2004). The simultaneous finding of two road-killed *O. ventralis* individuals is very uncommon. These findings conflict with Ashton and Ashton's observation that the species can be found frequently on roadways during mid-morning and early evening surveys (Ashton and Ashton 1985: p.191).

It is very unlikely that these two individual Eastern glass lizards were engaged with each as a mating pair, as copulation for glass lizards in the region, according to the Georgia Museum of Natural History and the Georgia Department of Natural Resources, occurs during the spring season from March to May (2000). Also, a Tennessee artificial coverboard survey reported two female Eastern slender glass lizards (*Ophisaurus attenuatus longicaudus*) with clutches varying from five to eight eggs, underneath coverboards within two years. These observations took place late June to mid-July in 2004 and 2005 in a relatively open area containing tall grasses (Gerald et al. 2006). Due to the similarity in size and the close distance between the two, it is plausible to assume that one individual was scent-trailing the other or that they were exhibiting territorial behavior, although no supporting descriptions of these phenomena could be found in the literature.

O. ventralis were not found underneath the artificial coverboards during the study, making the survey technique inadequate for determining population size and density of this species within Savannas Preserve State Park. Such a finding is similar to a study of California legless lizards (*Anniella pulchra*), where 38 coverboards were checked 1292 times during 37 months. Only 100 legless lizards were discovered, most likely due to the combined effects of small population size of the species, a short amount of time observed, and a low number of coverboards (Kuhnz et al. 2005).

Species abundance and diversity within the four transects are relatively hard to compare due to a low number of overall sightings. The 12 individuals in SP-1 included 4 gopher tortoises, which may actually be only 2 individuals, depending upon whether or not the individuals were counted twice before being numbered. SP-3 was located directly along an old unimproved road with significant vegetation more than a meter away at all times. High species observations within SP-1 may be an effect of the increased herbaceous layer, open canopy, and proximity to the basin marsh. More sunlight and exposed ground cover allows reptiles to regulate their body temperature (Moseley et al. 2003), while a water source would reduce the risk of desiccation and increase reproduction sites for amphibians.

All three Southeastern five-lined skinks (*Eumeces inexpectatus*) observed occurred within SP-4, where a thick layer of pine needles and other leaf litter cover most of the ground surface. The preference of the species for unburned, mature pine flatwoods coincides with the findings of a central Florida study (Greenberg et al. 1994) focused on herpetofauna within several different treatments of sandpine (*Pinus clausa*) scrub communities. The mature forest control area contained the largest average number of *E.*

inexpectatus in relation to the other three manipulated treatments. The preference of this species towards mature forest settings may be due to features such as shade and leaf litter, which were minimal in the other areas. Unlike Greenberg's findings, however, I did not observe any ground skinks (*Scincella lateralis*) in SP-4, the transect with the most ground debris and leaf litter. *S. lateralis* was only present in SP-2, the ideal pine flatwoods which may have a similar plant composition to that of the central Florida study (Greenberg et al. 1994).

The two more diverse transects were SP-4 with six different species and SP-1 with five species. More amphibian species were likely to be found in SP-1 due to the proximity of the basin marsh. Schurbon and Fauth (2003) found that amphibian populations were greatly affected by the distance to the nearest wetland. For example, oak toads (*Bufo quercicus*) were more prominent in SP-1. This could possibly be due to the availability of easily moveable soils, suitable for their subterranean digging habits used to avoid desiccation that may occur in burned stands with higher levels of sunlight reaching the ground cover (Moseley et al. 2003). But most likely, the availability of water contributed to such a finding, since the plow lines and the basin marsh provide ideal habitat for successful reproduction of the species. The pine woods treefrog also requires a body of water for reproduction, which explains its activity in transect 2 during moderate rainfall (Delis and Mushinsky 2005).

Due to the large distances *G. polyphemus* travel, over 550 meters per move in a Georgia study (Eubanks et al. 2003), the presence of scat within SP-2 does not guarantee another tortoise. Several marked tortoises reside in burrows present in SP-1, less than 40 meters from the beginning of SP-2. A year long study of *G. polyphemus* movements within an area found an average travel distance of 54 meters for females and 85 meters for males (Eubanks et al. 2003).

It is hard to determine whether or not the various fire regimes have made a significant impact on the herpetofauna species in the area. No differences in reptile or amphibian observations among the four transects are significant enough to reach a well-grounded conclusion. Meshaka et al. (2004) note that *O. septentrionalis* may inhabit pinelands that are left unburned, suggesting their potential presence in the vicinity of transect 4 of this study, although no individuals were found in any transect examined. Several studies (Greenberg et al. 1994, Moseley et al. 2003) have found that amphibian populations were unaffected by prescribed burning and clearing treatment areas in relation to unburned sections. Greenberg et al. (1994) found only reptile species composition differed between mature forest and disturbed or treated forest. Species abundance, diversity, and evenness were not affected. One reason may be the use of roads as dispersal mechanisms, where species can travel into areas that would otherwise be inhospitable and difficult to inhabit (Greenberg et al. 1994). In contrast, Moseley et al. (2003) found reptile diversity and abundance to increase after a burn in a Georgia hardwood community. General herpetofauna abundance, diversity, and richness were similar in burned and unburned sites (Moseley et al. 2003). It is possible that the different burned zones with Savannas Preserve State Park will only show minimal differences among herpetofauna with a more thorough study. This eight-month coverboard study was not able to account for historical differences and effects over time. Other factors, such as survey technique, may also need to be changed or expanded upon for future surveys. A diversity of survey techniques are needed to detect more species within the pine flatwood communities. Drift fence funnel traps and PVC pipes were found by Means and Franz (2005) to be exceptionally good in amphibian species surveys. Call surveys would also prove efficient in recording arboreal species and those that may enter into the pine flatwoods only at night. Further research is suggested to determine the effects of various pine flatwoods fire regimes on herpetofauna in other regions of Florida.

As hypothesized, exotic species were more abundant in disturbed areas (Smith and Engeman 2004, Meshaka et al. 2005, Moore and Smith 2006). The increasing occurrences of anthropogenic disturbance, such as roadways, into pristine natural areas help exotic species colonize sites by creating ecotones along which they can easily travel. “Jump-dispersal” mechanisms also contribute to the expansion of invasive populations in traveled areas. Several studies (Smith and Engeman 2004, Moore and Smith 2006) have reported that Northern curly-tailed lizards (*Leiocephalus carinatus armouri*) are most commonly found around buildings, roads, and other human created habitats. Moore and Smith (2006) noted that roads designed to aid anthropogenic travel may also serve as expressways for exotic species. With the species utilizing such structures, an edge effect is created where further infestation can occur into natural areas (Moore and Smith 2006). The spread of *L. carinatus armouri* has also been aided by landscaping practices through the use of open-bed trailers stacked with cut vegetation. Individuals hiding in the trimmings are transported across town, or even county, to the site where the vehicle finally stops (Smith and Engeman 2004). It is likely that the exotics found during this survey have been aided by these activities at some point with the higher populations found on or near the unimproved road. This coverboard survey also suggests that the presence of exotic species is more likely to occur in and around disturbed areas than in less impacted, natural ecosystems.

As discussed above, exotic species were found to be more common in disturbed areas and within the first few meters of a pine flatwoods ecosystem. The survey encountered roughly the same number of native individuals (53%) as exotic (47%). All of the 14 Cuban treefrogs (*Osteopilus septentrionalis*) encountered were under a sign located near the basin marsh within the first several weeks of the study. After the fifth week, *O. septentrionalis* individuals were no longer encountered, most likely due to removal by the Florida Park Service. It is likely that the actual number of this particular species should be lower; double counts of individuals may have occurred.

During this research one *H. garnotii* individual was opportunistically observed under a pavilion structure. A similar coverboard survey in other areas of Savannas Preserve State Park produced only one *H. garnotii* (.5%) out of 203 individuals (H. T. Smith unpubl. data). If the survey results are combined between the two separate studies, reporting similar results, it is obvious to assume that coverboards are not an adequate method for sampling arboreal gecko populations. A previous study (Meshaka et al. 2005) of gecko assemblages among buildings within Savannas Preserve State Park reported variable abundance of Indo-Pacific geckos (*Hemidactylus garnotii*) in relation to the presence of the wood slave (*Hemidactylus mabouia*), a more recent invader. As *H. mabouia* enters an area, the once dominant *H. garnotii* populations begin to fall (Meshaka et al. 2005). This study suggests that observational surveys around buildings and similar structures would provide a better estimate of invasive gecko populations within the park.

A similar coverboard study within other areas of Savannas Preserve State Park reported a total of 203 individuals comprised of 14 different species from 15 December 2003 to 1 March 2004. Boards were checked 22 times during the three and a half month survey (H. T. Smith et al. unpubl. data). Rainfall during the survey totaled 31.3 cm, with 14.5 cm in December, 5.8 cm in January, and 11 cm in February. Annual rainfall for the previous year, 2003, was 164.9 cm (FPS unpubl. data). The two most common species included ground skinks (*Scincella lateralis*) and greenhouse frogs (*E. planirostris*), which combined accounted for 62.5% of all individuals encountered. The study had lower abundances of oak toads (*Bufo quercicus*), Southeastern five-lined skinks (*Eumeces inexpectatus*), and brown anoles (*Anolis sagrei*) underneath the coverboards (H. T. Smith et al. unpubl. data). In contrast, these species were the most abundant underneath the coverboards during this survey, with six *B. quercicus*, three *A. sagrei*, and three *E. inexpectatus* representing 28.5%, 14%, and 14%, respectively, of the 21 individuals observed under the coverboards.

Overall, this eight-month artificial coverboard survey has proven that exotic species do favor disturbed areas; and at least in this study, rarely penetrated deep into an ecosystem. In contrast, all native herpetofauna found within the four coverboard transects were at least 15 meters distant from the unimproved road edge, and most of these were 25-35 meters away.

Future roadways and pathways into natural areas should consider encompassing large natural area buffer zones between them so that individual exotic herpetofauna invasions/penetrations do not coalesce. No significant differences in herpetofauna diversity could be determined between the four different fire treatment transects;

however, my sample sizes were small. The absence of species in SP-3 suggests that old pathways with minimal shrub coverage may have a long period of rehabilitation and recolonization for herpetofauna species. Although the 2006-2007 drought conditions undoubtedly affected my study; longer interval and more varied survey techniques may be needed to obtain large enough sample sizes to perform statistically convincing analyses on the effects of various burn treatments in pine flatwoods. In this fashion, prescribed fire planning and implementation can perhaps facilitate conservation of native herpetofauna species, while likewise hopefully slowing the spread of invasive exotics into Florida’s striking legacy of natural areas.

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