SNAKE ECOLOGY OF THE RED HILLS REGION

OF SOUTH GEORGIA AND NORTH FLORIDA

by

KIMBERLY JO SASH

(Under the Direction of John P. Carroll)

ABSTRACT

Longleaf pine forests of the southeast were once one of the most extensive ecosystems in North America. Snakes are one component of this system for which we have a limited understanding. I used radio telemetry and trapping on 2 sites to better understand community ecology, habitat use, and classify habitat requirements. I radio-tagged 2 sympatric species, corn and gray rat snakes. Partitioning of habitat did exist, corn snakes prefer upland habitat and gray rat snakes prefer bottomland habitat. I documented captures of 1,802 individuals representing 19 different species from 2003-2005. Intact upland sites are necessary to many snakes including some threatened species. Intact upland is best managed with prescribed burning and is necessary to provide open pine forest snake species with proper habitat.

INDEX WORDS: Gray rat snake, Eastern rat snake, Corn snake, Habitat use, Snake community structure, Red Hills, *Elaphe*, *Pantherophis*, Radio telemetry, Trapping, Longleaf pine ecosystem

SNAKE ECOLOGY OF THE REDHILLS REGION OF SOUTH GEORGIA AND NORTH FLORIDA

by

KIMBERLY JO SASH

B.S., The University of Wisconsin, 2002

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2007

SNAKE ECOLOGY OF THE REDHILLS REGION

OF SOUTH GEORGIA AND NORTH FLORIDA

by

KIMBERLY JO SASH

Major Professor: John P. Carroll

Committee: William E. Palmer
Steven Castleberry

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
December 2007

ACKNOWLEDGEMENTS

This thesis would not have been possible without the edits by my committee members in particular my advisor, John P. Carroll. I would like to thank William E. Palmer and John P. Carroll for giving me the opportunity to work on an amazing project. Aaron T. Fisk, thank you for the opportunities to expand on this project. Steven Castleberry, thank you for taking the time to edit this thesis. This project was so large in scale that it would not have been possible without the help from lots of people. I would have never been here if it were not for Seth Stapleton, I would like to thank him for setting up the project and some of the 2003 data presented in this thesis. Thanks to Shane Wellendorf and the gamebird lab technicians and interns at Tall Timbers Research Station. I would also like to acknowledge my interns, Jessica Murdock, Sara Ruane, Jennifer Danielson, and Pierson Hill for all their hard work and dedication to the project. Land managers, Eric Staller, Chuck Martin, and Jerome Golden, thank you for your patience with my snake traps all over your woods. I would like to thank the Bradfordville Animal Hospital and Dr. Alex 'Steve' Steverson for your generosity and help. Thanks also to Bruce Means, Lisa Baggett, Kaye Gainey, and Brant Faircloth for help and support along the way. Lastly, thanks to my friends and family for your encouragement and interest in my work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Introduction

Longleaf pine (*Pinus palustris*) forests of the southeastern U.S.A. were once one of the most extensive forest ecosystems in North America. During pre-settlement times the forest covered over 92 million acres. The longleaf pine ecosystem formerly extended from southeastern Virginia to eastern Texas dominating mainly the Coastal Plain, but also extended to the Piedmont, and Ridge and Valley regions (Van Lear et al. 2005). This ecosystem was sustained by fire ignited by Native Americans and/or lightning strikes. Fires kept stands open and depressed hardwood succession (Means 1982, 1996). Comprised of mainly upland stands, many other unique ecotones made up more rare habitats within the longleaf ecosystem. A variety of sinks, depressional wetlands, and hammocks were also important components.

The longleaf ecosystem was reduced to less than 3 million acres of forest today (Landers et al. 1995). This 97% decline is among the most severe removal of any ecosystem on record (Earley 2004). It is ranked the third most endangered ecosystem in the U.S.A. (Noss 1988). The forests were logged, converted to farms and cities, and altered due to the suppression of fire. Fire suppression altered forest succession and structure which resulted in habitat loss to many species at risk (Means 1996).

Red Hills Ecosystem

The unique and widespread longleaf ecosystem includes a variety of species dependent on this type of landscape (Means 1982, 1996, Noss 1988, Landers et al. 1995, Van Lear 2005). During the last half of the 18th and 19th centuries much of the Red Hills of northern Florida and southern Georgia were cleared for agriculture, but some of the longleaf forests were maintained.

As farming declined in the area, many northern industrialists purchased the numerous small farms and created large plantations. These were managed for hunting bobwhites and other wildlife during winter. Many of these lands continue to persist as wild quail-hunting plantations and with their large continuous tracts of land have remained a strong hold of longleaf and second growth pine ecosystems.

With the preservation and management of this ecosystem and because of pioneering efforts of Herbert Stoddard and others the longleaf ecosystem became a system of aesthetic and research importance. The sparseness of the pine trees due to frequent fire allows high levels of sunlight to reach the forest floor, encouraging a species rich understory. Sixty-nine percent of the mammal species and over one-third of the bird species characteristic of the longleaf ecosystem forage primarily on or near the ground, demonstrating the essential role played by fire in maintaining ground cover for wildlife communities (Engstrom 1993). About 40% of the 1,600+ plant species in the Atlantic and Gulf Coastal Plains are restricted to the longleaf-dominated landscapes (Van Lear 2005), an extremely high level of endemism (Walker, 1998), and among the most species-rich plant communities outside the tropics (Peet and Allard 1993). Many of these plant species also depend on fire to aid in germination, reduction of competition, control invasive species, and to maintain the canopy open for light.

Herpetofaunal species in this system have received less attention even though the ecosystem overlaps in range with 73 amphibian and 95 reptile species. Of the few studies that exist, most report that an alarming percentage of herpetofauna are imperiled (Guyer and Bailey, 1993). Many of these species have federal listing or are of concern. The eastern indigo snake (*Drymarchon corais*), Mississippi gopher frog (*Rana capito sevosa*), Louisiana pine snake (*Pituophis ruthveni*), flatwoods salamander (*Ambystoma cingulatum*) and gopher tortoise

(*Gopherus polyphemus*) are all federally listed. The Florida Pine snake (*Pituophis melanoleucus mugitus*), the southern hognose snake (*Heterodon simus*), Eastern diamondback rattlesnake (*Crotalus admanateus*), and black pine snake (*Pituophis melanoleucus lodingi*) are all species of concern that are found associated with the longleaf ecosystem. The gopher tortoise is also known as a keystone species providing shelter in its burrow for at least 332 commensal species including the federally listed indigo snake and the gopher frog (Landers and Speake 1980, Means and Campbell 1982).

Because of the decline of the longleaf ecosystem it is important to understand the distribution, population dynamics, and habitat requirements of both plant and animal in this system (Walker 1998, Trani 2002). In addition, better understanding the species relying on this system will give us the ability to learn how to restore the longleaf ecosystem and manage many of these rare species. The shifting of longleaf to hardwood or mixed pine-hardwood forests has left many species in peril. Over 30 species are listed as federally endangered or threatened (Van Lear 2005). It is apparent that the herpetofaunal community may be taking the biggest hit due to habitat loss. Declines are happening not only within this ecosystem but it is widely accepted that herpetofaunal populations are declining on a global scale (Green 1997, Gibbons 2000, Houlahan et al. 2000, Brodman et al. 2002, Jensen et al. 2003). Yet, little is known about the composition of herptile populations and their impact across the landscape (Pitt 2001).

Herpetofaunal populations benefit from their ecothermy in that they eat infrequently, but are efficient at the conversion of food energy to biomass, allowing them to produce many offspring. Both amphibians and reptiles tend to predominate in terrestrial vertebrate communities, both in biomass and density (Pough 1983), making them important diet items for other species of wildlife. Herpetofauna occupying the longleaf forest are integral parts of the functioning forest. Managing and conservations efforts should be based on well-documented information of herptile population ecology (Guyer and Bailey 1993), although little work has been conducted in the Southeast to document the movement and usage of habitat of herpetofauna (Trani 2002).

The secretive nature of herpetofaunal species makes them particularly difficult study specimens (Weatherhead 1985). This is no exception with snake species that are secretive and known for their cryptic coloration. The greatest constraint in conservation planning for either individual species or entire snake assemblages is the fundamental lack of basic biological information on most species (Dodd 1993). Our knowledge of preferred habitat use and habitat variation is largely based on qualitative, anecdotal observations (Reinert 1993). Within the Southeast, studies of the black racer (*Coluber constrictor*) (Plummer and Congdon 1994), gray rat snake (*Elaphe obsoleta spiloides*) (Mullin and Cooper 2000), eastern hognose (*Heterodon platirhinos*) (Plummer and Mills 2000), Eastern diamondback (Martin and Means 2000), corn snake (*Elaphe g. guttata*) (Franz 1995) and, cottonmouth (*Agkistrodon piscivorus*) (Cook 1983) have examined spatial or activity patterns but studies on population dynamics are lacking.

Examining snake population dynamics is particularly important in the Southeast because of the role of snakes in predator-prey dynamics. In particular, northern bobwhite is an important species on the plantations of the southeast both economically generating $193 million in 1991 and culturally (Burger et al. 1999). Snakes have been identified as predators of bobwhite quail nests in the southeast (Staller 2005). Understanding predator prey dynamics and habitat use by snakes give us more educated methods of managing both snakes and quail.

Objectives

Studies identifying spatial use and community structure of snake populations are required for proper management. A snake ecology project was started in 2003 at Tall Timbers Research Station and Pebble Hill Plantation with the following goals:

1. To document habitat selection, habitat use, and home ranges for the gray rat snake (*Pantherophis obsoleta spilodes*) and corn snake (*Pantherophis guttata guttata*) in a upland pine ecosystem managed with frequent fire.
2. To illustrate snake community structure and habitat associations in a managed upland pine system.
3. To describe snake movement trends both seasonally and within habitat types to predict their impact as a predator in a managed upland pine system.

Study Area

Tall Timbers Research Station and Land Conservancy is located in Leon County Florida and is comprised of 1,300 ha dominated by upland pine forest (65%). Pebble Hill Plantation is a 1,200 ha plantation located in Thomas and Grady Counties, Georgia. Both sites are made up of upland pine, mixed hardwood drains, fallow fields, and wetlands. Both Tall Timbers and Pebble Hill are located in the Redhills, an area between Tallahassee, Florida and Thomasville, Georgia and bordered by the Ochlockonee and the Aucilla rivers. Tall Timbers is made up of second growth forest consisting of loblolly, shortleaf and longleaf pine and primarily has old field groundcover. The southern portion of Tall Timbers is bordered by Lake Iamonia, the lake edges are dominated by bottomland plants like beautyberry, smilax, and buttonbush and a hardwood component. Pebble Hill also has second growth forest of loblolly, shortleaf, and longleaf with both old field and wiregrass groundcover. Fingerlike drains run throughout the property carrying water to the Ochlockonee River. The drains harbor bottomland plant species and hardwoods.

Tall Timbers and Pebble Hill are actively managed for northern bobwhite and other wildlife species. The management regime includes: roller-chopping, disking, prescribed fire, herbicide application, timber harvesting and supplemental feeding. Application of supplemental feed is made to 1/2 of each study site on a weekly basis. The other 1/2 of each study site remains unfed serving as a "control" area. As part of a regional study on predation, predator control has been applied to each plantation in a cross-over (Jones and Kenward 1989) design. Predator control began initially at Pebble Hill during 2001-2003 with Tall Timbers as a control site and these were then crossed-over to Tall Timbers where it continued during 2004-2006.

Literature cited

Burger, L.W., D.A. Miller and, R.I. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 27: 1010-1018.

Brodman, R., C. Spencer, and A. Resetar. 2002. Historical changes of reptiles and amphibians of northwest Indiana fish and wildlife properties. American Midland Naturalist 147: 135-144.

Cook, D. G. 1983. Activity patterns of the cottonmouth water moccasin, Agkistrodon piscivorous lacepede, on a northest Florida headwater stream. University of Florida, 1983.

Dodd, Kenneth C. 1993. Chapter 9 Strategies for snake conservation. Snakes Ecology and Behavior. R.A. Seigel and J.T. Collins eds. p. 363-388.

Earley, L.S. 2004. Looking for Longleaf. University of North Carolina Press.

Engstrom, R.T. 1993. Characteristic mammals and birds of longleaf pine forests. Tall Timbers Fire Ecology Conf. 18, 127-138.

Franz, R. 1995. Habitat use, movements, and home range in two species of rat snakes (genus *Elaphe*) in a north Florida sandhill. Florida Fish and Wildlife Conservation Commission. Nongame Widlife Program Project Report. Tallahassee, Fl.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The global decline of retiles, déjà vu amphibians. BioScience 50: 653-666.

Green, D.M. 1997. Amphibians in decline: Canadian studies of a global problem. Herpetological Conservation 1: 339.

Guyer, G., Bailey, M.A. 1993. Amphibians and reptiles of longleaf pine communities. Tall Timbers Fire Ecology Conf. 18: 139-157.

Houlahan, J.E., C.S. Findlay, B.R. Schmidt, A.H. Meyer, and S.L. Kuzmin. 2000. Quantitative evidence for global amphibian population declines. Nature 404: 752-755.

Jensen, J.B., M.A. Bailey. E.L. Blankenship, and C.D. Camp. 2003. The relationship between breeding by the gopher frog *Rana capito* (Amphibia: Ranidae) and rainfall. The American Midland Naturalist 150: 185-190.

Jones, B., and Kenward, M.G. 1989. The design and analysis of cross-over trials. Chapman and Hall. London, UK.

Landers, J.L., and Speake, D.W., 1980. Management needs of sandhill reptiles in southern Georgia. Proc. Annu. conf. Southeast. Assoc. Fish wildlife Agencies 34: 515-529.

Landers, J. Larry, Van Lear, David H., Boyer, William D. 1995. The longleaf pine forests of the Southeast: Requiem or renaissance? Journal of Forestry 93: 38-44.

Martin, W.H. and D. B. Means. 2000. Distribution and habitat relationships of the eastern diamondback rattlesnake (*Crotalus adamanteus*). Herpetological Natural History 7: 9-34.

Means, D.B., Campbell, H.W. 1982. Effects of prescribed fire on amphibians and reptiles. Wood, G.S. (Ed.), Prescribed fire and wildlife in Southern forests. Belle Baruch Forest Science Institute, Clemson University, Georgetown, DC, pp. 89-96.

Means, D.B. 1996. Chapter 15. Longleaf pine forest, going, going,…Eastern old-growth forest: Prospects for rediscovery and recovery. Mary Byrd Davis ed. Island Press, Washington D.C.

Mullin, S.J., and R.J. Cooper. 2000. Home ranges of rat snakes (*Colubridae: Elaphe*) in different habitats. Herpetological review 31: 20-22.

Noss, Reed F. 1988. The longleaf pine landscape of the southeast: Almost gone and almost forgotten. Endangered species update 5: 1-8.

Peet, R.K., and D. J. Allard. 1993. Longleaf pine-dominated vegetation of the southern Atlantic and eastern Gulf Coast region, USA. Proceedings, Tall Timbers Fire Ecology Conf. 18.

Pitt, W.C. 2001. Density of prairie skinks (*Eumeces septentrionalis*) in old-field habitats. The American Midland Naturalist 146: 86-93.

Plummer, M.V., and J.D. Congdon. 1994. Radiotelemetric study of activity and movements of racers (*Coluber constrictor*) associated with a Carolina bay in South Carolina. Copeia 1994: 20-26.

Plummer, M.V., and N.E. Mills. 2000. Spatial ecology and survivorship of resident and translocated hognose snakes (*Heterodon platirhinos*). Journal of Herpetology 34: 565-575.

Pough, F.H. 1983. Amphibians and reptiles as low-energy systems. Behavioral energetics: the cost of survival in vertebrates. Ohio University Press, Columbus. W.P. Aspey and S.I Lustick, eds. p. 141-188.

Reinert, H.K. 1993. Chapter 6 Habitat selection in snakes. Snakes Ecology and Behavior. R.A. Seigel and J.T. Collins eds. p. 201-233.

Staller, E.L., William E. Palmer, John P. Carroll, Ryan P. Thorton, D. Clay Sisson 2005. Identifying predators at Northern bobwhite nests. Journal of Wildlife Management 69: 124-132.

Trani, M.K., 2002. Terrestrial ecosystems. Wear, D.N., Greis, J.G. (Eds.), Southern Forest Resource Assessment. USDA Forest Service GTR SRS-53: 1-45.

Van Lear, D. H., Carroll, W.D., Kapeluck, P.R., Johnson, R. 2005. History and restoration of the longleaf pine-grassland ecosystem: Implications for species at risk. Forest Ecology and Management 211: 150-165.

Walker, J., 1998. Ground layer vegetation in longleaf pine landscapes: an overview for restoration management. In: Proceedings of the Longleaf Pine Ecosystems Restoration Symposium. Longleaf Alliance Report no. 3: 2-13.

Weatherhead, P.J., Charland M. B. 1985. Habitat selection in an Ontario population of the snake, Elaphe obsoleta. Journal of Herpetology 19: 12-19.

CHAPTER 2

HABITAT USE AND HOME RANGE OF GRAY RAT AND CORN SNAKES IN THE RED HILLS REGION OF NORTH FLORIDA AND SOUTH GEORGIA

Introduction

The Red Hills of the Southeast is a unique habitat characterized by high biodiversity. Although modified by settlement much of this biodiversity remains relatively intact, but threatened by urbanization and other land use. The Red Hills was once dominated by the formerly widespread longleaf-wiregrass ecosystem. Conversion of habitat, mainly to agriculture, commenced with the arrival of settlers. Since the early 1900's, farm abandonment and purchase of much of the region by northern industrialists for recreational hunting has lead to reforestation. During much of the 20^{th} century reforestation has lead to an ecosystem dominated by loblolly pine (*Pinus taeda*) rather than longleaf pine (*Pinus palustris*), and loss of many of the ground cover species. Where fire, which is a key component of the original ecosystem, is suppressed succession continues resulting in further degradation of habitat quality (Means 1982, 1996).

The longleaf wiregrass ecosystem is unique both in terms of its vastness at one time covering over 92 million acres (Van Lear et al. 2005) and because of the unique ecotones it provides. For these 2 reasons a variety of species depend on this ecosystem as at least partial specialists (Means 1982, 1996, Noss 1988, Landers 1995, Van Lear et al. 2005). The sparseness of the pine trees due to frequent fire allows high levels of sunlight to reach the forest floor, encouraging a species rich understory. Sixty-nine percent of the mammal species and over one-third of the bird species characteristic of the longleaf ecosystem forage primarily on or near the ground, demonstrating the essential role played by fire in maintaining ground cover for mammalian and avian communities (Engstrom 1993). Herpetofaunal species in this system have received less attention even though the ecosystem contains 74 amphibian and 96 reptile species. Of the few studies that exist most report that an alarming percentage of herpetofauna are imperiled (Guyer and Bailey 1993). Several of these species have federal listing or are species of concern. Declines are happening not only within this ecosystem, but it is widely accepted that herpetofaunal populations are declining on a global scale (Green 1997, Gibbons 2000, Houlahan et al. 2000, Brodman et al. 2002, Jensen et al. 2003). Yet, little is known about the composition of herptile populations and their impact across the landscape (Pitt 2001).

Radio telemetry studies on rat snakes have been taking place since the early 1980's. Studies have reported a diversity of home range sizes and habitat use, suggesting that these species may behave differently across their distribution (Blouin-Demers and Weatherhead 2001, Durner and Gates 1993, Fitch 1963, McAllister 1995, Mullin et al. 2000, Stickel et al. 1980, Weatherhead 1985, 1989). Additionally, in areas of the Red Hills where extensive land management practices manipulate the landscape for northern bobwhite (*Colinus virginianus*) habitat choices of snakes may differ from other locations within their distribution. The loss of intact longleaf-wiregrass ecosystems could also play a role in how the rat snake now uses the landscape. Rat snake habitat use and home range have been examined in northern (Weatherhead 1985, 1989) and central (Durner and Gates 1993) regions, but data for the southern region is lacking.

In this study we investigated habitat use and movement of 2 sympatric species of rat snake, the gray rat snake [*Pantherophis* (*Elaphe) obsoleta spiloides*] and the corn snake [*Pantherophis* (*Elaphe) guttata guttata*] on 2 managed bobwhite quail plantations in the Southeast.

Study Site

This project was conducted at Tall Timbers Research Station (TT) (Figure 2.1) in north Florida and Pebble Hill Plantation (PH) in South Georgia (Figure 2.2). Both sites are located in the Red Hills region of the Gulf Coastal Plain and are managed by Tall Timbers Research Station and Land Conservancy, Inc, based in Tallahassee, Florida. Tall Timbers is a 1,300 ha research station in Leon County dominated by second growth upland pine forest (53%). It also consists of bottomland drains and wetlands (26%), fallow fields, and old-field vegetation (6%). Pebble Hill Plantation is a 1,200 ha plantation located in Grady and Thomas counties, Georgia. Pebble Hill is composed of upland pine forest (60%), cypress swamps and drains (16%), planted pines (15%) and fallow fields (4%). Ground cover is a combination of undisturbed native and old-field vegetation.

Both sites are actively managed for northern bobwhite and other wildlife species. Management includes: roller-chopping, disking, prescribed fire, herbicide application, timber harvesting and supplemental feeding. Application of supplemental feed is made to 1/2 of each study site on a biweekly basis. The other 1/2 of each study site remains unfed serving as a "control" area. As part of a regional study on predation, predator management has been applied to each plantation to investigate the impacts of meso-mammalian predators on northern bobwhite abundance and demographics. Predator control initially began at Pebble Hill during 2001-2003, and then switched to Tall Timbers during 2004-2006.

Methods

I captured corn and rat snakes in 36 drift fence arrays and opportunistically on each study site. Snakes weighing >300g and appearing in good health were implanted with 4g, 31mm x 14mm x 11mm, R1170 radio transmitters (Advanced Telemetry Systems, Inc). Dr. Alex

Steverson performed the procedure at the Bradfordville Animal Hospital, Tallahassee, Florida. Isoflurane was used to anesthetize snakes restrained in PVC tubing. Radios were implanted in the peritoneal cavity following the methods of Reinert and Cundall (1982). Snakes were kept in 50 x 26 x 32 cm glass aquariums, provided with a heating pad, unlimited water, and held for 24 to 48 hours for observation subsequent to surgery. Snakes were released at the site of capture when each individual resumed activity and exhibited normal behavior.

Radio Telemetry

Tracking of radio-tagged individuals began 24 hours after release. I used homing methods to locate each snake (White and Garrott 1990) between the hours of 0700–1700, times were randomly varied daily for each snake. Locations for each snake were recorded 4 times per week during March to September. After this period, radio-tagged snakes were located 2 to 3 times per week, due to decreased activity levels resulting from seasonal weather changes. Visual verification at each location was made when possible. Date, time, general habitat type, ground cover, prescribed burn status, cover type, height and activity was recorded for each observation. Additionally, I recorded if the snake moved >2 m from its previous location. Any movement >2m was considered a true movement (Weatherhead and Charland 1985). This gave me 2 datasets, a total-locations dataset and a movements-only dataset. Snake locations were recorded via 12-channel global positioning unit (GPS) and entered to both a relational database and a GIS database.

Analysis

The coordinates were used in conjunction with the animal movement extension in ArcView 3.2 to determine minimum convex polygon (MCP; Jennrich and Turner 1969) and kernel home ranges. Through bootstrapping methods I determined that 20 locations per individual were necessary to gain a representative home range size.

To determine habitat use for gray rat and corn snakes I used compositional analysis. For analysis I determined that 5 habitat types were available to the snakes: UPLAND mainly consisting of pine and old field vegetation; DRAIN was comprised mainly of hardwoods; PLANTED PINE was mainly loblolly pine planted from 1987-1989, FIELD was comprised mainly of small patches of old field maintained by disking and burning, and OTHER included wet areas, roads and buildings. The movements-only dataset was used throughout all analyses to give more conservative estimates of habitat use.

I used Compositional analysis 6.2 plus (Smith 2004) run for 1000 iterations to determine 2^{nd} and 3^{rd} order habitat use (Johnson 1980) using MCP home ranges. For the 2^{nd} order I considered the whole study site as being available to the snakes and for 3^{rd} order I considered available habitat to be all that found with the animals home range. The multivariate (Wilks' λ) test was used to determine if habitat use was different from availability for all habitats simultaneously. Corn snakes and rat snakes were analyzed separately with covariates sex and site (PH or TT). Covariates were added in SAS and analyzed using MANOVA.

Additionally, I analyzed micro-habitat cover types used at each location. I classified cover types into 9 categories: TREE, STUMPHOLE, BURROW, DEADFALL, NONE, UNKNOWN, SNAG, PILE, and OTHER. I calculated mean use for each cover type for both gray rat and corn snakes. I also analyzed how often gray rat and corn snakes used the same cover item they had previously used.

Finally, I assessed activity of radio-tagged snakes relative to the habitats where they were found. Activity was converted to 2 categories, if the snake was moving or resting. A snake was considered to be resting if it was coiled or in a resting position, if the snake was stretched out or seen moving it was defined as moving. Habitat was converted to 4 categories, upland, drain, field, and other. Planted pine was not used for this analysis because it was used so infrequently.

Results

Home range

Eighteen rat snakes (11 males and 7 females) and 9 (male) corn snakes were used in the analysis. Overall, male rat snakes had the largest mean MCP home ranges (8.9 ha), followed by male corn snakes (7.9 ha), and then female rat snakes (5.6 ha). There was no differences in home range size between species (MCP t = 0.22, 25 df, P=0.82; 95% Kernel t = -0.18, 25 df, P=0.85; 50% Kernel t = -0.78, 25 df, P=0.44) (Figure 2.3). Male and female gray rat snakes exhibited no differences in MCP home range, but I found differences between the 95% and 50% Kernel home ranges (MCP t = 1.21, 16 df, P=0.24; 95% Kernel t = 2.28, 16 df, P=0.03; 50% Kernel t = 2.41, 16 df, P=0.02) (Figure 2.4). Additionally, if only males of each species of rat snake were compared no differences existed (MCP t = 0.66, 18 df, P=0.51; 95% Kernel t = 0.68, 18 df, P=0.50; 50% Kernel t = 0.14, 18 df, P=0.88) (Figure 2.5).

Macro-habitat use

At the 2nd order corn snakes were found in habitats types different from what would be expected by random chance (χ^2 = 14.9, 4 df, P=0.005). FIELD was ranked first over the other available habitat types (Table 2.1). At the 2nd order gray rat snakes were found in habitats types different from what would be expected by random chance (χ^2 = 18.37, 4 df, P=0.001). UPLAND habitat ranked first over other available habitats (Table 2.2).

At the 3rd order corn snakes (χ^2 =58.12, 8 df, P<0.001) chose different habitat types more then they were available within their home range. Within their MCP home range UPLAND habitat ranked first (Table 2.3). At the 3rd order rat snakes (χ^2 = 30.66, 4 df, P<0.001) chose different habitat types more then they were available within their home range (Table 2.4). Rat snakes chose DRAIN habitat over other available habitat types.

I found site and sex covariates had no effect for either species on habitat use (2nd order corn snakes (F =1.53, 4 df, P=0.35, 3rd order F = 0.87, P=0.55) (2nd order rat snakes F = 1.67,4 df, P=0.23, 3rd order F = 1.69, P=0.22).

Micro-habitat use

Corn snakes preferred underground locations over all other cover objects available. Rat snakes preferred trees as cover objects more than any other existing cover. Three of the nine potential cover objects exhibited significant differences between corn and gray rat snake usage (Table 2.5). Of the 18 rat snakes tracked 13 (72%) visited the same hardwood tree greater than once. Trees were used more by rat snakes (t = 3.19, 25 df, P=0.003) than corn snakes. I found no significant differences between male and female gray rat snakes regarding cover usage (Table 2.6). Burrows (t = -3.43, 25 df, P=0.002) and no cover (t = -3.14, 25 df, P=0.004) were used more by corn snakes (Figure 2.6) than gray rat snakes. From the corn snakes tracked 4 of 9 (44.4%) visited the same burrow more then once, 2 of 9 (22%) visited the same tree.

Activity

Of the 27 snakes tracked only 3 (11%) snakes failed to return to a site where they had been previously located using radio telemetry. Sixteen of the 27 (59%) snakes visited the same location over a month later from the first observation. Overall, 10 of 27 (37%) snakes had more then one location that was visited at least twice. Both species were found moving more through upland habitat (Figure 2.7) and rested more in upland or drain habitat (Figure 2.8). Male corn snakes were found moving 6% of observations (n = 516). Female gray rat snakes were found moving at 30% of observations (n = 305) whereas male gray rat snakes were found moving at 6.5% of observations (n = 470).

Overall, corn snakes were found in new locations more than gray rat snakes (*t* = -2.25, 25 df, P=0.03) (Figure 2.9). Male corn snakes were at new locations 56% (291 of 516) of observations. Male gray rat snakes moved to new locations slightly more than female rat snakes, males were found a new locations 47% (224 of 470) of the time compared with 44% (163 of 369) for female rat snakes (*t* = 0.56 16 df, P=0.57) . Neither site (*t* = 0.94, 25 df, P=0.35) nor sex (*t* = 1.46, 25 df, P=0.15) were significant characteristics in movement of the snakes to a new location.

Discussion

Home range

Home ranges of the rat snakes on my study areas were similar to what is reported in the literature (Durner and Gates 1993, Weatherhead and Hoysak 1989, Mullin et al. 2000). It has been suggested (Stickel and Cope 1947) that home ranges containing good foraging grounds will often be smaller than those with less productive habitats. This possibly explains why some of the variation in home range size (Durner and Gates 1993, 9.24 ha black rat female verses 5.6 ha reported here) might occur across the distribution of the rat snakes. Sexual differences in home range size for gray rat snakes were absent in the Red Hills, similar to findings in Maryland (Durner and Gates 1993), but different from rat snakes in Ontario where the female home ranges were much smaller (Weatherhead and Charland 1985, Weatherhead and Hoysak 1989).

Macro-habitat use

Second order habitat use suggests how an animal places its home range on the landscape. At the 2nd order corn snakes chose to have FIELD and UPLAND habitats within their home range. These habitats probably provided optimal foraging sites for corn snakes and contain burrows and other underground hiding places. OTHER, DRAIN, and PLANTED PINE likely did not provide good foraging habitat and although DRAIN likely has many resting sites, they are probably not the open pine sites that corn snakes prefer. Second order habitat use by gray rat snakes demonstrated that UPLAND within their home range again likely providing good foraging habitat. Previous studies have suggested that black rat snakes prefer edge habitat (Durner and Gates 1993). In my study OTHER ranked 2nd in the habitat choice of the gray rat snakes, because it is made up of roads, yards, buildings, and wet areas, it also suggests that the gray rat snakes in the Red Hills prefer some edge (as seen in Weatherhead and Charland 1985, Durner and Gates 1993, Blouin-Demers and Weatherhead 2001) or disturbance within their home range. DRAIN ranked 3rd and I hypothesize it is used for resting purposes since this species spend most of their time in hardwood tree refugia. FIELD and PLANTED PINE ranked last, but for different reasons. PLANTED PINE likely provides no cover for resting or foraging habitat. However, lack of use of FIELD, contrary to corn snakes might represent some differences in foraging behavior relative to types of habitats selected for refugia between foraging bouts. In most cases FIELD habitats on the study areas are associated with UPLAND habitat rather than DRAINS. In the case of gray rat snakes this likely means the most important areas are near the edge interface between UPLAND and DRAIN habitats whereas corn snake may be found throughout UPLAND habitats.

Third order habitat use revealed use of habitats within home ranges. At the 3rd order corn snakes use UPLAND over all other habitat types available. DRAIN ranked second which seems to not fit other data on corn snakes. However, it could be a result of the few corn snakes I did have that used DRAIN that would be considered more of a marshy area, therefore this might be a function of variability of habitat within my classified habitats. At the 3rd order gray rat snakes used DRAIN more than any other type of habitat followed by UPLAND, again suggesting that the interface between these two habitats is important.

Micro-habitat use

Corn and gray rat snakes are sympatric species often with overlapping home ranges. It appears they partition their home ranges possibly to reduce competition for hiding places between the two species. There was a preference for the gray rat snake to use hardwood trees and elevated positions where corn snakes preferred burrows and underground refugia. The gray rat snakes preference for hardwoods has been reported previously (Durner and Gates 1993). It is possible that as fire was suppressed and hardwoods encroached, the ecosystem transitioned to late successional forest, and gray rat snakes became more prolific.

The snakes demonstrated a familiarity with their home range, often visiting the same habitat feature several times throughout the tracking period. Specific foraging and refuge locating movements have been reported in other studies (Durner and Gates 1993, Weatherhead and Robertson 1990), suggesting the snakes preference for specific areas even beyond other locations that seem to be equivalent foraging or shelter areas. The preference for specific sites indicates the acquaintance of the snake with its home range (Stickel and Cope 1947, Durner and Gates 1993).

Activity

Snake movements are deterministic and occur in response to the requirements of foraging, predator avoidance, thermoregulation, or reproduction (Gibbons and Semlitsch 1987). Snakes were found at the same location frequently, either for just a few days up to 3 weeks before moving to a new location. Warmer spring and summer temperatures increase nocturnal movements in both species of rat snake, and due to our telemetry times many of these movements were missed. From camera data on northern bobwhite nests (n = 44) at TT and PH from 1999- 2005 about half (n = 25) of the nests were depredated by rat snakes were during hours when telemetry data was not collected (Staller et al. 2005).

Management suggestions and Future research

A mix of both drain and upland habitat would provide a good habitat for both corn and gray rat snakes. Drain habitat provides optimal hardwoods site for gray rats to thermoregulate while available upland habitat provides good foraging for both species. The retention of piles, stumpholes, deadfalls, and snags to provide adequate hiding, thermoregulation, and ecdysis sites would be beneficial for not only corn and rat snakes but also a variety of other wildlife and herpetofauna. The retention of places that provide underground refugia may be of particular importance. Planted pine was ranked very low as a habitat choice for either species and seems to provide neither adequate forage nor refugia.

From this study I gained a basic idea of how these species use the Red Hills landscape, but knowledge is still lacking on how land management practices effect the snakes. Hardwood removals are done with some frequency in this system with little known about the impacts on snake species. Gray rat snakes would probably be more affected by upland hardwood removals especially considering their reliance on hardwoods, and in most cases a single hardwood tree. But, it is possible that increasing numbers of hardwoods in uplands due to fire suppression could have also increase the number of gray rat snakes in comparison to uplands with little or no hardwoods. Additionally, ground compaction caused by large machinery could also have detrimental affects on corn snakes because of their dependence of underground refugia. Not only is this a call for more field studies but manipulative studies would be beneficial as well.

Literature cited

Blouin-Demers, Gabriel, and P.J. Weatherhead. 2001. Habitat use by black rat snakes (*Elaphe obsoleta obsoleta*) in fragmented forests. Ecology 82: 2882-2896.

Brodman, R., C. Spencer, and A. Resetar. 2002. Historical changes of reptiles and amphibians of northwest Indiana fish and wildlife properties. The American Midland Naturalist 147: 135-144.

Durner, G.M., and Gates, J.E. 1993. Spatial ecology of black rat snakes on Remington Farms, Maryland. Journal of Wildlife Management 57: 812-826.

Engstrom, R.T. 1993. Characteristic mammals and birds of longleaf pine forests. Tall Timbers Fire Ecology Conf. 18, 127-138.

Fitch, Henry S. 1963. Natural history of the black rat snake (*Elaphe o. obsoleta*) in Kansas. Copeia 4: 649-658.

Gibbons, J. W., Semlitsch, R.D. 1987. Activity patterns. In snakes. Ecology and evolutionary biology. Edited by R.A. Seigel, J. T. Collins, and S. S. Novak. Macmillan, New York. Pp. 369-421.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L.Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The global decline of retiles, déjà vu amphibians. BioScience 50: 653-666.

Green, D.M. 1997. Amphibians in decline: Canadian studies of a global problem. Herpetological Conservation 1: 339.

Guyer, G., Bailey, M.A. 1993. Amphibians and reptiles of longleaf pine communities. Tall Timbers Fire Ecology Conf. 18: 139-157.

Houlahan, J.E., C.S. Findlay, B.R. Schmidt, A.H. Meyer, and S.L. Kuzmin. 2000. Quantitative evidence for global amphibian population declines. Nature 404: 752-755.

Jennrich, R. I., and F. B. Turner. 1969. Measurement of non-circular home range. J. Theoretical Biology. 22: 227-237.

Jensen, J.B., M.A. Bailey. E.L. Blankenship, and C.D. Camp. 2003. The relationship between breeding by the gopher frog *Rana capito* (Amphibia: Ranidae) and rainfall. The American Midland Naturalist 150: 185-190.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61: 65-71.

Landers, J. Larry, Van Lear, David H., Boyer, William D. 1995. The longleaf pine forests of the Southeast: Requiem or renaissance? Journal of Forestry 93: 38-44.

McAllister, Andrew J. 1995. Wetland habitat use by the black rat snake, Elaphe obsoleta, in Eastern Ontario. Canadian Field Naturalist 109: 449-451.

Means, D.B., Campbell, H.W., 1982. Effects of prescribed fire on amphibians and reptiles. Wood, G.S. (Ed.), Prescribed fire and wildlife in Southern forests. Belle Baruch Forest Science Institute, Clemson University, Georgetown, DC, pp. 89-96.

Means, D.B. 1996. Chapter 15. Longleaf pine forest, going, going,…Eastern old-growth forest: Prospects for rediscovery and recovery. Mary Byrd Davis ed. Island Press, Washington D.C.

Mullin, S.J., R.J. Cooper, W.H.N Gutzke, and G.D. Zenitsky. 2000. Home ranges of rat snakes (Colubridae: Elaphe) in different habitats. Herpetological review 31: 20-22.

Noss, Reed F. 1988. The longleaf pine landscape of the southeast: Almost gone and almost forgotten. Endangered species update 5: 1-8.

Pitt, W.C. 2001. Density of prairie skinks (*Eumeces septentrionalis*) in old-field habitats. The American Midland Naturalist 146: 86-93.

Reinert, H.K., and D. Cundall. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia 1982: 702-705.

Smith, P. G. 2004. Automated log-ratio analysis of compositional data: software suited to analysis of habitat preference from radiotracking data. Bat Research News 45: 16.

Staller, E.L., William E. Palmer, John P. Carroll, Ryan P. Thorton, D. Clay Sisson 2005. Identifying predators at Northern bobwhite nests. Journal of Wildlife Management 69: 124-132.

Stickel, W.H., J.B. Cope. 1947. The home ranges and wanderings of snakes. Copeia 2: 127-136.

Stickel, L.F., W.H. Stickel, and F.C. Schmid. 1980. Ecology of a Maryland population of black rat snakes (*Elaphe o. obsoleta*). The American Midland Naturalist 103: 1-14.

Van Lear, D. H., Carroll, W.D., Kapeluck, P.R., Johnson, R. 2005. History and restoration of the longleaf pine-grassland ecosystem: Implications for species at risk. Forest Ecology and Management 211: 150-165.

Weatherhead, Patrick J., and Charland, M. Brent. 1985. Habitat selection in an Ontario population of the snake, *Elaphe obsoleta*. Journal of Herpetology 19: 12-19.

Weatherhead, P.J., and D.J. Hoysak. 1989. Spatial and activity patterns of black rat snakes (*Elaphe obsoleta*) from radiotelemetry and recapture data. Canadian Journal of Zoology 67: 463-468.

Weatherhead, P.J., and I. C. Robertson. 1990. Homing to food by black rat snakes (*Elaphe obsoleta*). Copeia 4: 1164-1165.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio tracking data. Academic press, Inc., San Diego.

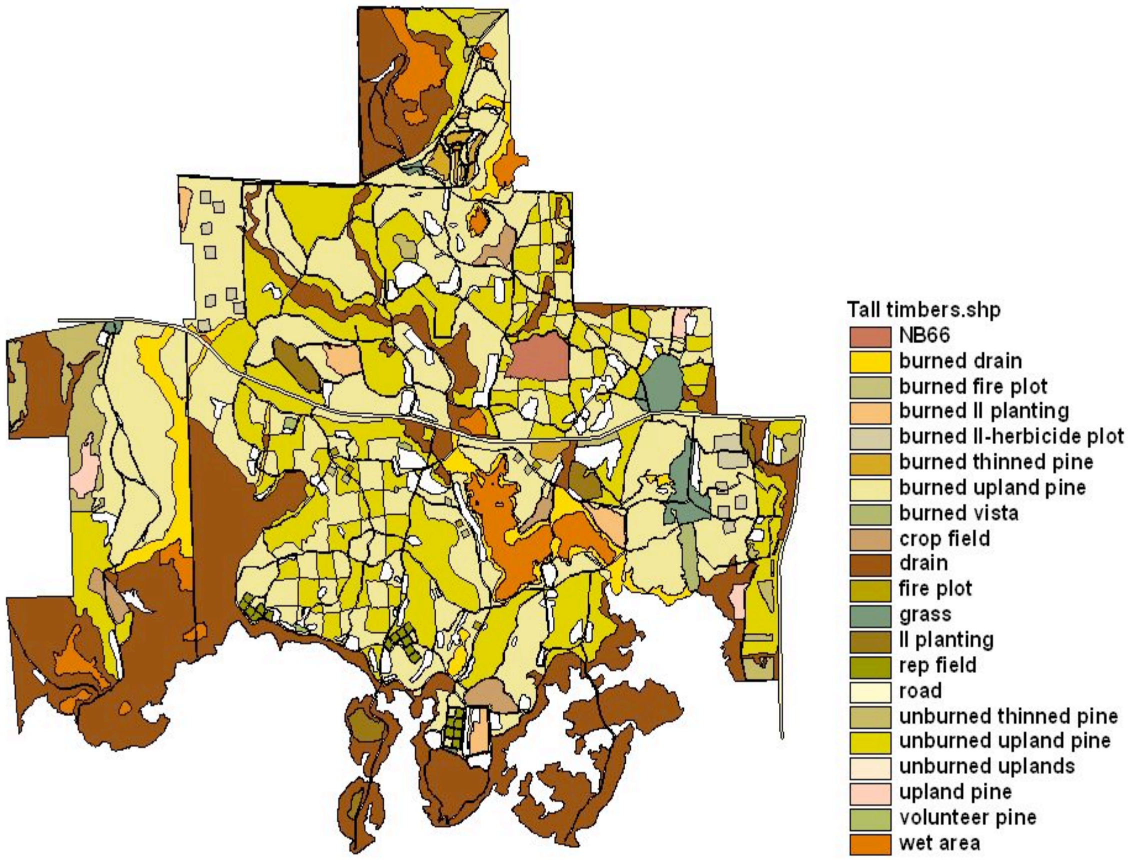


Figure 2.1. Land cover map of Tall Timbers Research Station and Land Conservancy, Inc. in the Red Hills region of North Florida (1,300 ha).

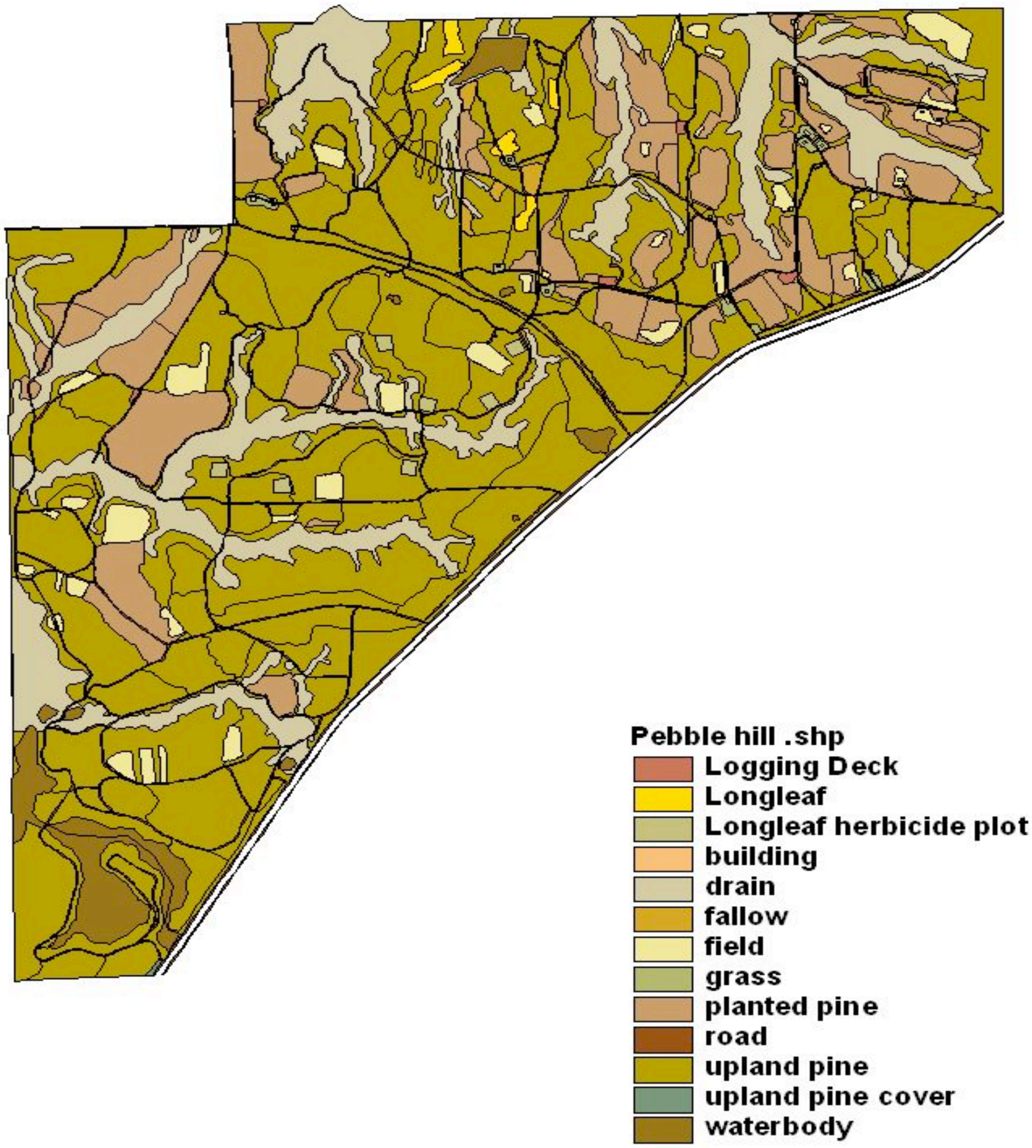


Figure 2.2. Land cover of Pebble Hill Plantation in the Red Hills region near Thomasville, Georgia(1,200 ha).

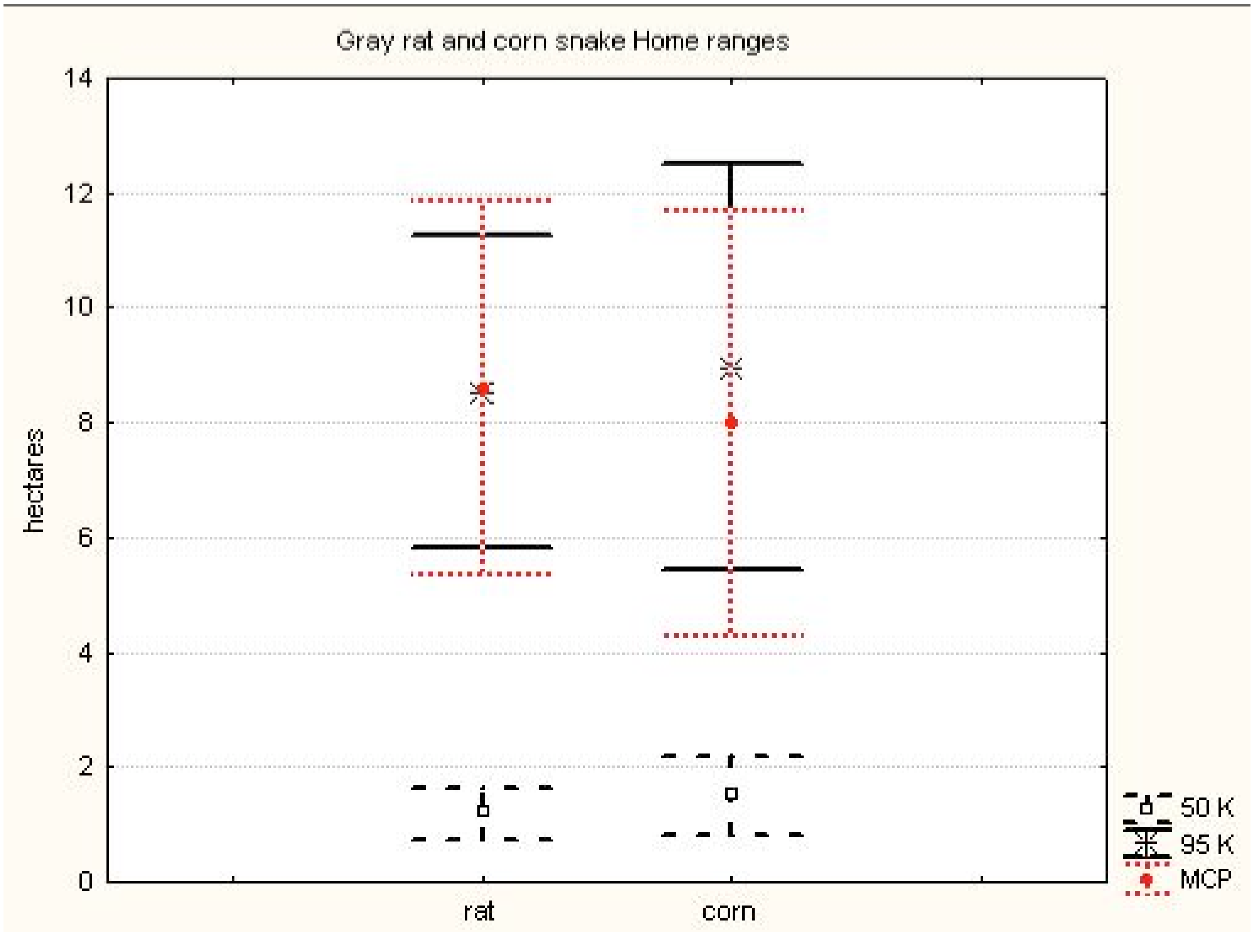


Figure 2.3. Mean home ranges with standard error for minimum convex polygon, 95% kernel, and 50% kernel home ranges. For 18 gray rat snakes (11 males and 7 females) and 9 (male) corn snakes at Tall Timbers Research Station and Pebble Hill plantation 2004-2005.

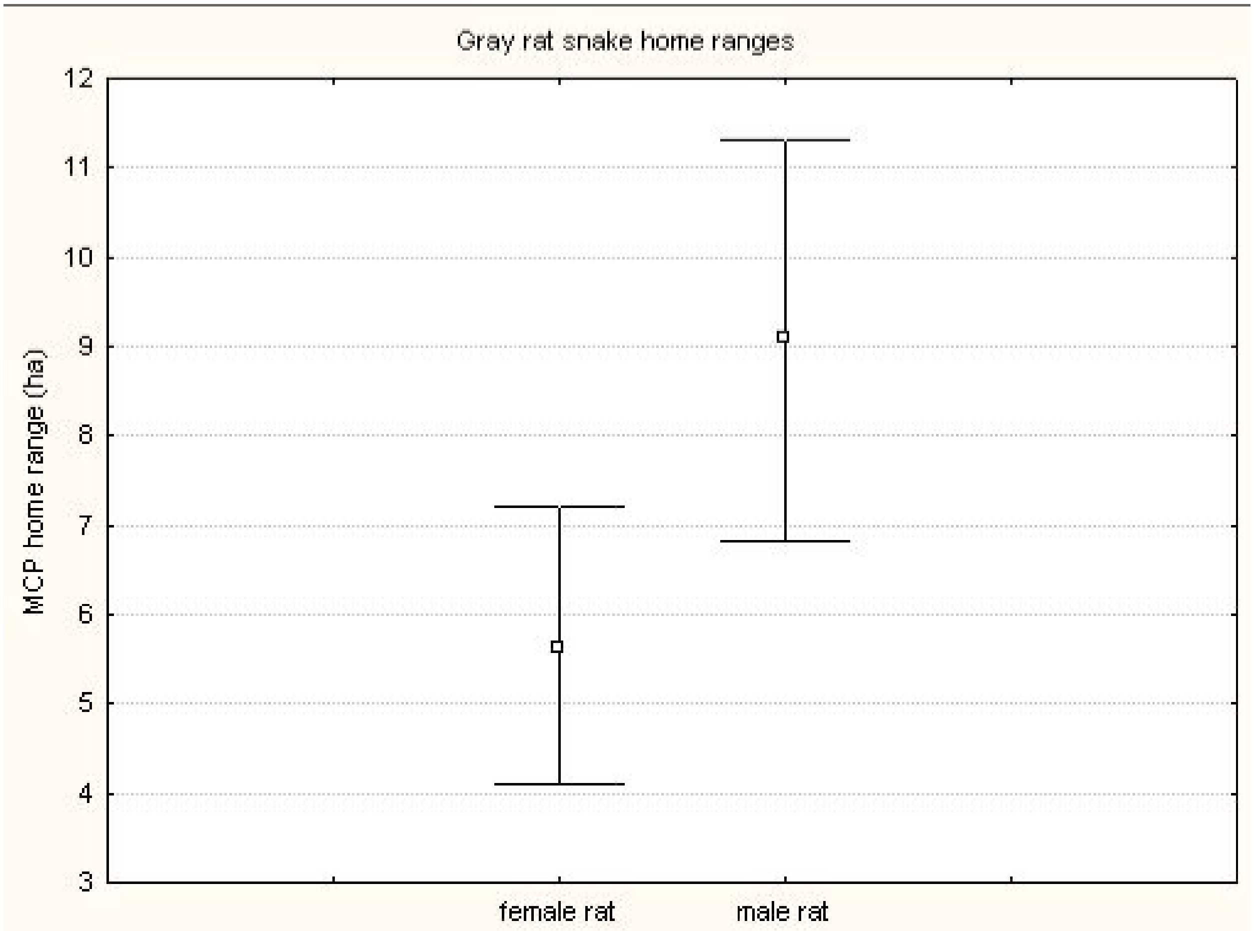


Figure 2.4. Minimum convex polygon, 95% and 50% kernel home ranges of male (n = 11) and female (n = 7) gray rat snakes at Tall Timbers Research Station and Pebble Hill plantation 2004-2005. Significant differences in home ranges size for both the 95% and 50% Kernel home ranges.

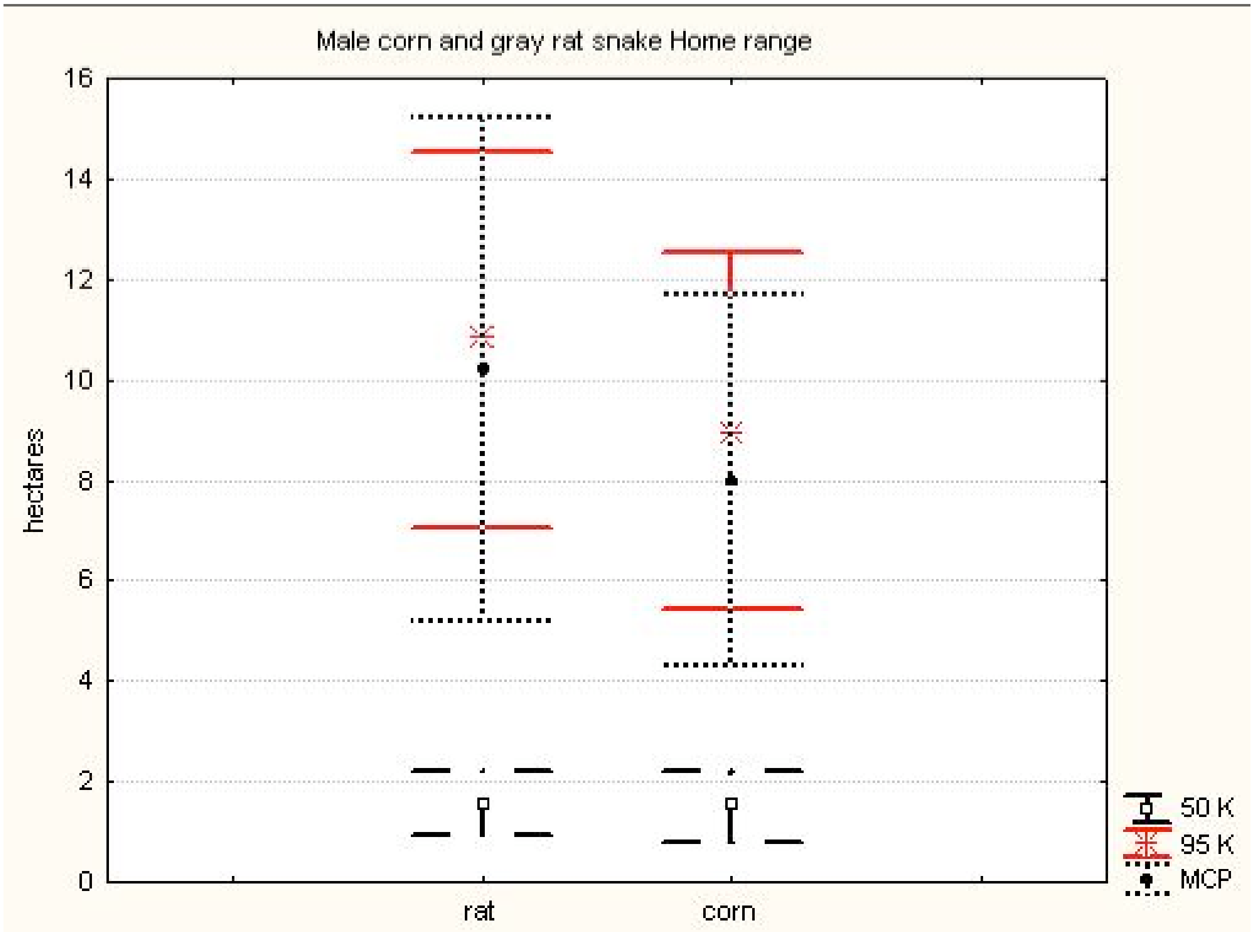


Figure 2.5. Minimum convex polygon, 95% and 50% kernel home ranges of male gray rat snakes (n = 11) and male corn snakes (n = 9) at Tall Timbers Research Station and Pebble Hill plantation 2004-2005. No significant differences in home range sizes between the males of the two species.

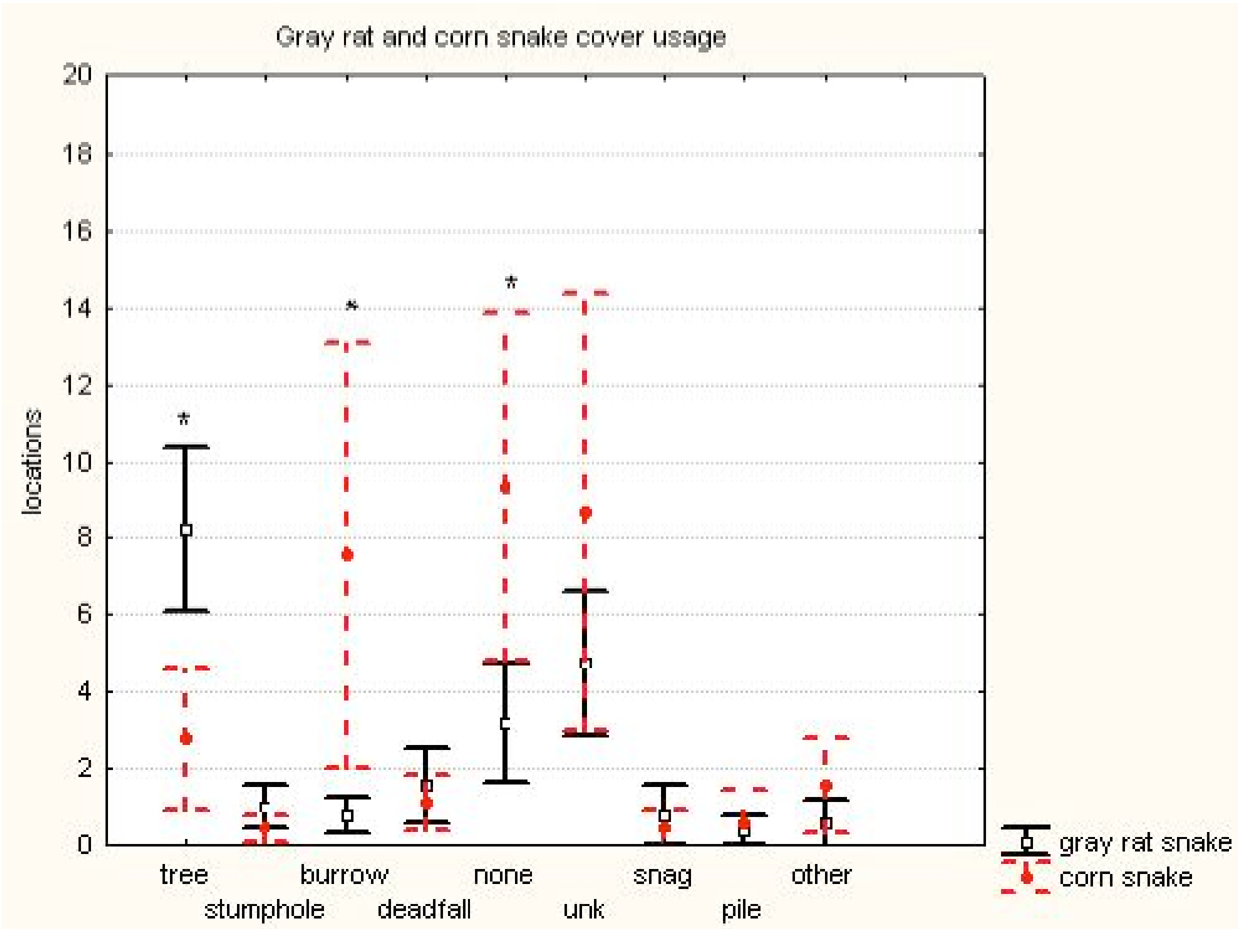


Figure 2.6. Cover usage and SE for gray rat snakes (n = 18) and corn snakes (n = 9) at Tall Timbers Research Station and Pebble Hill plantation 2004-2005. * Denotes significant difference in usage between species.

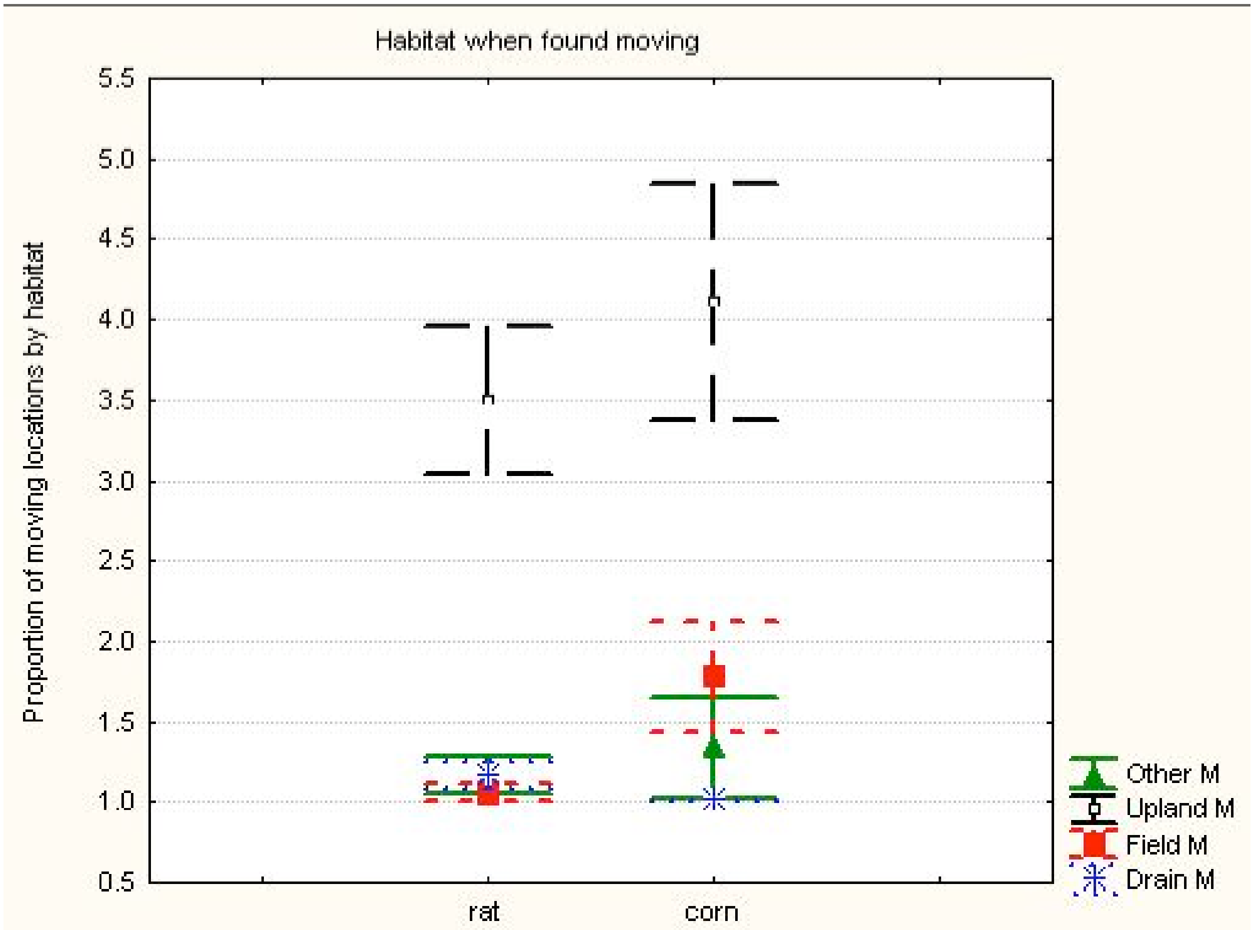


Figure 2.7. Activity of moving corn (n = 9) and gray rat (n = 18) snakes throughout habitat types based on mean number of locations with SE at Tall Timbers Research Station and Pebble Hill plantation 2004-2005.

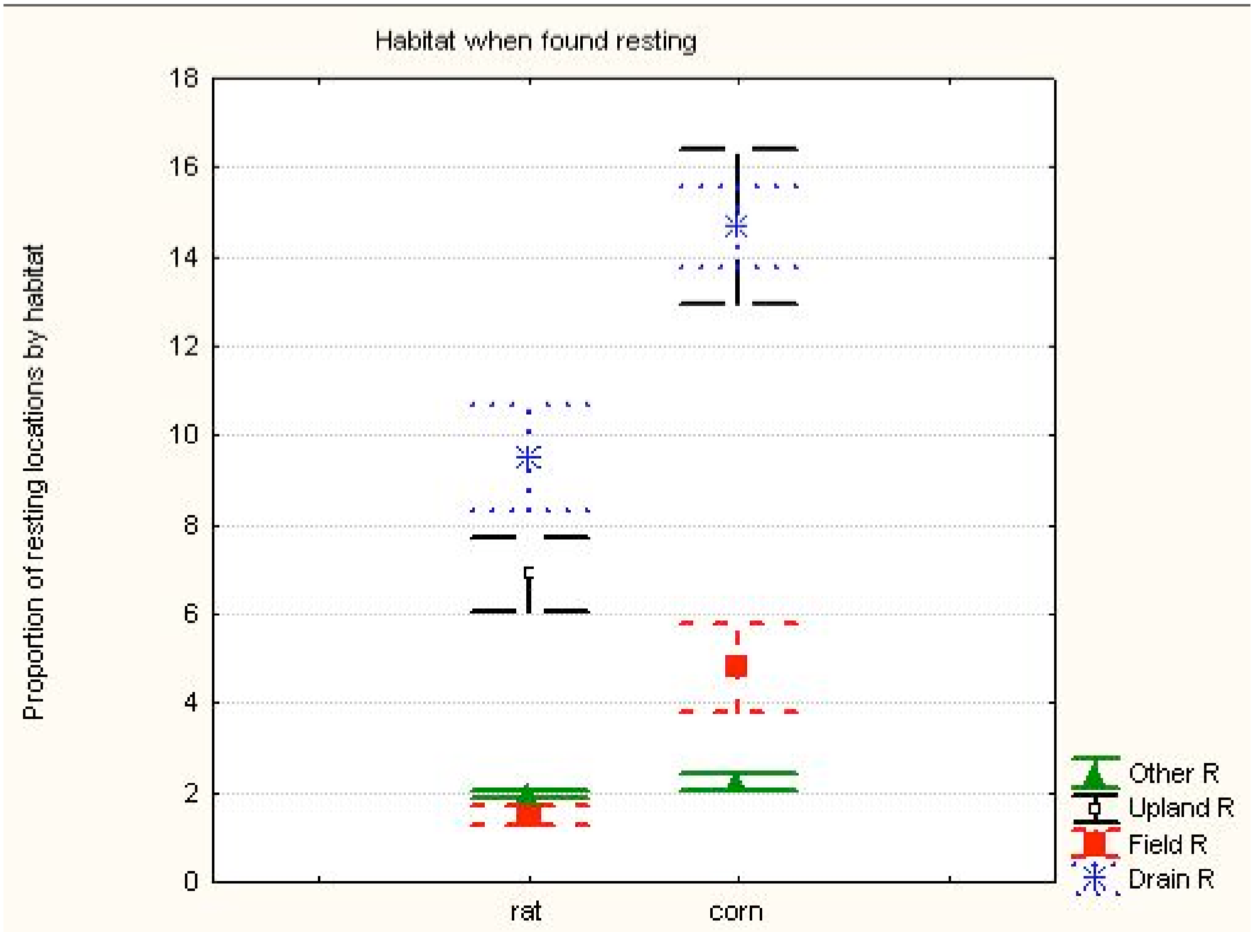


Figure 2.8. Activity of resting corn (n = 9) and gray rat (n = 18) snakes throughout habitat types based on mean number of locations with SE at Tall Timbers Research Station and Pebble Hill plantation 2004-2005.

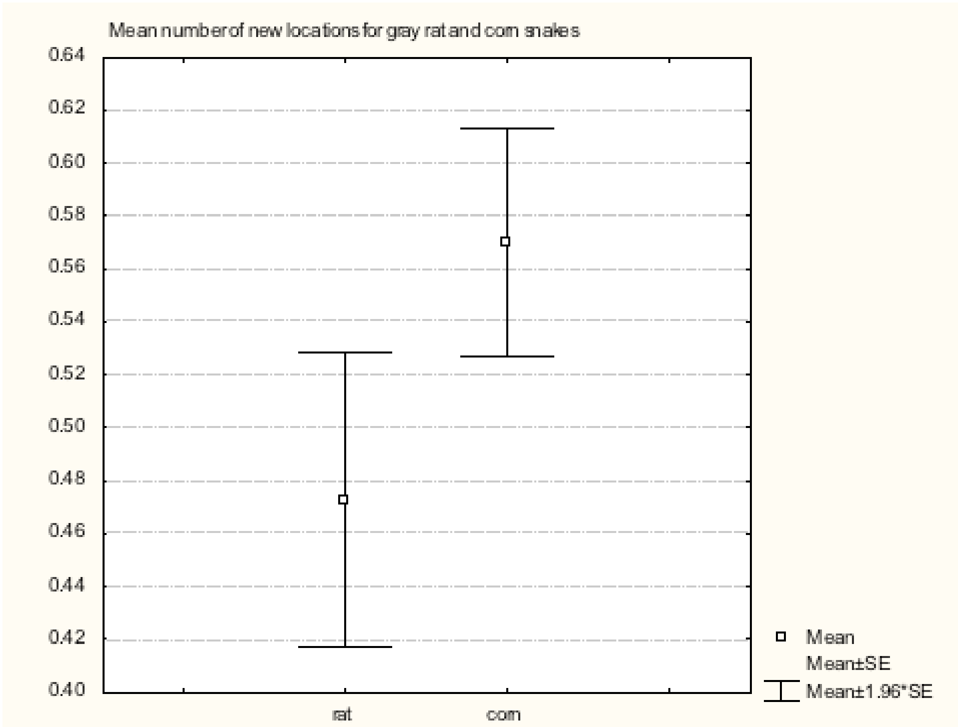


Figure 2.9. Proportion of locations when gray rat snakes (n = 18) and corn snakes (n = 9) were found at a new location at Tall Timbers Research Station and Pebble Hill plantation 2004-2005. Corn snakes moved to a new location significantly more than gray rat snakes.

Table 2.1. Second order habitat use of corn snakes (mean±SE, n = 9) and habitat ranking using compositional analysis at Tall Timbers Research Station and Pebble Hill plantation during 2004-2005. A negative log-ratio difference suggests that the column habitat is used relatively more than the row habitat. A larger rank number means the more selected for habitat.

	Field	Upland	Drain	Other	Rank
Field					**4**
Upland	**-0.285 ± 0.318**				**3**
Drain	**-5.931 ± 1.289**	**-5.646 ± 1.356**			**1**
Other	**-1.351 ± 0.282**	**-1.066 ± 0.291***	**4.580 ± 1.213***		**2**
Planted pine	**-6.156 ± 1.171**	**-5.871 ± 1.240**	**-0.225 ± 0.875**	**-4.805 ± 1.044**	**0**

Table 2.2. Second order habitat use of gray rat snakes (mean±SE, n = 18) habitat ranking using compositional analysis at Tall Timbers Research Station and Pebble Hill plantation during 2004-2005. A negative log-ratio difference suggests that the column habitat is used relatively more than the row habitat. A larger rank number means the more selected for habitat.

	Field	Upland	Drain	Other	Rank
Field					**1**
Upland	**2.379 ± 0.889**				**4**
Drain	**0.992 ± 1.035**	**-1.387 ± 0.809**			**2**
Other	**1.358 ± 0.916**	**-1.021 ± 0.521**	**0.366 ± 0.816**		**3**
Planted pine	**-1.952 ± 1.054**	**-4.331 ± 0.806**	**-2.944 ± 0.955**	**-3.310 ± 0.826**	**0**

Table 2.3. Third order habitat use of corn snakes (mean±SE, n = 9) and habitat ranking using compositional analysis at Tall Timbers Research Station and Pebble Hill plantation during 2004-2005. A negative log-ratio difference suggests that the column habitat is used relatively more than the row habitat. A larger rank number means the more selected for habitat.

	Field	Upland	Drain	Other	Rank
Field					1
Upland	1.099 ± 1.044				4
Drain	0.968 ± 1.556	-0.132 ± 1.154			3
Other	-4.911 ± 0.966*	-6.011 ± 0.299	-5.879 ± 1.115		0
Planted pine	0.060 ± 1.410	-1.040 ± 1.231	-0.908 ± 1.194	4.971 ± 0.962	2

Table 2.4. Third order habitat use of gray rat snakes (mean±SE, n = 18) and habitat ranking using compositional analysis at Tall Timbers Research Station and Pebble Hill plantation during 2004-2005. A negative log-ratio difference suggests that the column habitat is used relatively more than the row habitat. A larger rank number means the more selected for habitat.

	Field	Upland	Drain	Other	Rank
Field					2
Upland	1.026 ± 1.093				3
Drain	3.077 ± 1.017	2.052 ± 0.467*			4
Other	-2.703 ± 1.408	-3.729 ± 0.773	-5.780 ± 0.810		0
Planted pine	-0.489 ± 1.310	-1.514 ± 0.950	-3.566 ± 0.906	2.214 ± 1.185	1

Table 2.5. Comparison of structure use in gray rat (n = 18) and corn (n = 9) snakes at Tall Timbers Research Station and Pebble Hill plantation during 2004-2005. *Denotes significant difference between species.

Coverage type	t-value	df	P
tree	3.19	25	0.00*
stumphole	1.32	25	0.19
burrow	-3.43	25	0.00*
deadfall	0.58	25	0.56
none	-3.14	25	0.00*
unknown	-1.62	25	0.11
snag	0.56	25	0.57
pile	-0.41	25	0.68
other	-1.62	25	0.11

Table 2.6. Comparison of structure use in gray rat snakes male (n = 11) and female (n = 7) at Tall Timbers Research Station and Pebble Hill plantation during 2004-2005.

Coverage type	t-value	df	P
tree	-1.19	16	0.24
stumphole	-1.23	16	0.23
burrow	-0.27	16	0.78
deadfall	-0.93	16	0.36
none	-0.53	16	0.59
unknown	0.23	16	0.81
snag	0.12	16	0.90
pile	-0.16	16	0.86
other	-0.04	16	0.96

CHAPTER 3

COMMUNITY STRUCTURE AND HABITAT ASSOCIATIONS OF SNAKES IN THE RED HILLS REGION OF THE GULF COASTAL PLAIN

Introduction

The Red Hills of South Georgia and North Florida contain remnants of longleaf-pine wiregrass (LLPWG) ecosystem on relatively fertile sites. These areas have high biodiversity and harbor many threatened and endangered species. In contrast to native intact longleaf ecosystems, many areas in the Red Hills are old field habitats that were once heavily farmed.

Management of these systems includes use of frequent fire. Fire frequency was thought to be 1-3 years. The sparseness of the pine trees due to frequent fire allows high levels of sunlight to reach the forest floor, encouraging a species rich understory (Engstrom, 1993). Snake species in this frequently burned system have received less attention then other wildlife inhabitants of the Red Hills (Dodd 1987, 1993). Of the few studies that exist, most report that an alarming percentage of the specialist herpetofauna are imperiled (Guyer and Bailey, 1993, Tuberville et al. 2000). Many of these species have federal listing or are of concern. The LLPWG ecosystem is thought to harbor a different suite of snake species relative to old field lands. Further, there is some evidence that the snake community has changed over the past 30 years in the Red Hills. An understanding of the snake communities in these habitats is critical for conservation planning (Pitt 2001).

Our objectives were:

1) Quantify the snake community
2) Define habitat relationships for each species caught
3) Classify habitat requirements for each species caught

Study site

This project was conducted at Tall Timbers Research Station (TT) in north Florida and Pebble Hill Plantation (PH) in South Georgia. Both sites are located in the Red Hills region of the Gulf Coastal Plain and are managed by Tall Timbers Research Station and Land Conservancy, Inc, based in Tallahassee, Florida. Tall Timbers is a 1,300 ha research station in Leon County dominated by second growth upland pine forest (53%). It also consists of bottomland drains and wetlands (26%), fallow fields, and primarily old-field vegetation (6%). Pebble Hill Plantation is a 1,200 ha plantation located in Grady and Thomas counties, Georgia. Pebble Hill is composed of upland pine forest (60%), cypress swamps and drains (16%), planted pines (15%) and fallow fields (4%). Ground cover is a combination of undisturbed native and old-field vegetation. Upland basal areas are managed at 9-13m^2/ha (40-60ft^2/acre) basal area with heavier basal areas in pockets of regeneration. Drain habitat is typically between 11-16m^2/ha (50-70ft^2/acre) hardwood basal area.

Both PH and TTRS are managed with frequent fire. Each year approximately 50-70% of each study site was prescribed burned. Mechanical treatments were used to reduce hardwood encroachment including roller-chopping and mowing. Rotational or strip disking was used in fields to maintain early-successional old-field plant communities.

Methods

Snakes were captured using drift fence arrays consisting of four 15-m silt fences radiating from a central point. Each array had four hardware cloth funnel traps at each respective end and one wooden box trap in the middle to maximize captures (Fritts 1988, Greenberg at al. 1994, Linnell et al. 1998). Traps were checked once per day in the morning and were set for three weeks out of the month from March to October. I placed 15 traps at Tall Timbers and 15 at

Pebble Hill. In 2003, traps were randomly placed across both Tall Timbers and Pebble Hill in four major habitat types: native ground cover, upland, field, and drain. Additionally, six traps at TT are arranged in a 2 x 3 grid (150 m spacing) to study movement patterns.

Upon capture, target species (all non-venomous snakes with the exception of cottonmouths captured at TT) were weighed, measured [snout-vent length (SVL)], and sex was determined by probing for hemipenes. All target species were marked with PIT (Passive Integrated Transponder; 2 x 12 mm, InfoPet Identification Systems) tags (Keck 1994). PIT tags were injected subcutaneously into each snake (anterior to the cloaca, lateral to the midline) using 12 gauge Trocar needles. Tags and needles were sterilized with absolute ethanol and read with a PIT tag reader to ensure proper function prior to insertion. The PIT tagging technique had no obvious deleterious effects on the snakes (Keck 1994). PIT tags are superior to other forms of marking in that they last over time like scute clippings and provide quick, accurate readings. My methods followed those of Reading and Davies (1996) and Keck (1994).

Habitat

I used landcover maps for both study sites and divided the landscape into habitat types based on plant groundcover. I distinguished 4 different habitat types were investigated for differences in species composition. Native ground cover habitat consisted of longleaf pine, wire-grass, and brackenfern. Upland habitat consisting mainly of old field vegetation, including partridge pea and other legume species, beauty berry (*Callicarpa americana*), *Rubus* species, and pines. Drain habitat consisting of smilax species, cinnamon fern, and bottomland hardwoods. And fields that are harrowed yearly and allowed to grow fallow. Additionally, each trap was buffered to classify the mosaic of habitat types within a specific area. I used the average movement of a gray rat snake (Stapleton 2005) approximately 127.9 meters to buffer each trap, the 6.3 ha buffer is approximately equal to a home range. The buffer was then overlayed with the landcover map for each study site to provide the habitat types (upland, field, and drain) surrounding each trap. Upland and field habitats were combined to give a total upland percentage around each trap. Nineteen species captured were used in the analysis.

Results

Snake Community Richness

During 3 trapping seasons (16,416 trap nights), we caught 1802 individuals from a total of 19 species of snakes. Of these 19 species, 5 were captured with the greatest frequency; southern black racer (*Coluber constrictor priapus*), corn snake [*Pantherophis* (*Elaphe) guttata guttata*], gray rat snake [*Pantherophis* (*Elaphe) obsoleta spilodes*], eastern coachwhip (*Masticophis flagellum flagellum*), and the Florida cottonmouth (*Agkistrodon piscorvorus conanti*). We caught 15 species at PH and 16 species at TT; however, several species were found at only one of the two study sites. Dusky pigmy rattlesnake (*Sistrurus miliarius*), Eastern kingsnake (*Lampropeltius getula*), and Florida pine snake (*Pituophis melanoleucus*) were caught only in the PH site, while Eastern mud snake (*Farancia abacura*), Florida green water snake (*Nerodia floridana*), peninsula ribbon snake (*Thamnophis sauritus*), and rough green snake (*Opheodrys aestivus*) were captured only at the TT site (Table 3.1).

Habitat and Species Composition

Three traps located in areas of native ground cover captured a total of 226 individuals representing 13 species. Twelve traps located in drain habitat captured 675 individuals representing 14 species. Six traps were located in fields and captured 324 individuals from 12 species. There were 13 traps in upland sites which caught 869 individuals and 14 species.

Traps were buffered to include the mosaic of habitat types surrounding each trap to see how upland and field habitat influenced species composition (Figure 3.1). Traps surrounded with 27-57% upland caught 15 species of snakes, traps with 58-79% upland caught 15 species, 80-87% upland caught 14 species, and traps with 88-100% upland caught 12 species of snakes. Seven species (Florida pine, scarlet snake (*Cemophora coccinea*), corn snake, Eastern diamondback (*Crotalus adamanteus*), Eastern hognose (*Heterodon platirhinos*), dusky pigmy rattlesnake, and Eastern coachwhip) were found only in areas with a threshold value of nearly 60% upland/field (Figure 3.2). Five species the Florida cottonmouth, southern black racer, eastern garter snake (*Thamnophis sirtalis*), banded water snake (*Nerodia fasciata*), and rat snake showed little reliance on upland or bottomland habitat (Figure 3.3). Cottonmouths were captured in both upland and field sites. Mean SVL was larger for cottonmouths captured in uplands (66.1 cm) and fields (58.8 cm) verses drains (45.4 cm). A significant difference in SVL only existed between upland and drain habitat (t = -3.844, 19 df, P=0.001).

Discussion

This project mainly focused on terrestrial snakes. Many of the small fossorial species are absent from our species list because of our capture methods. Although I did capture a few scarlet snakes and scarlet kingsnakes, ringneck snakes, worm snakes and crowned snakes were absent. The addition of coverboard surveys may have increased capture of these species. Aquatic snake captures were also lacking probably due to trap locations, no traps were located in water. Most aquatic snake captures appeared tied to heavy rain falls prior to capture. Overall, the most abundant terrestrial snakes captured were the southern black racer, followed by corn snake, cottonmouth (TT site only), eastern garter snake, rat snake, and coachwhip.

Snake captures differed between the two study sites. A portion of Tall Timbers is bordered by Lake Iamonia therefore influencing the capture of species tied to water, including banded water snake, mud snake, and cottonmouth. The exception was redbelly water snakes (*Nerodia erythrogaster*) were found more abundantly at PH, it has been noted that this species can be found in moist woodlands some distance from water especially during hot, humid summers (Clark 1949, Conant and Collins 1998).

Species known to be associated with upland habitat were found more frequently at the PH site. Five species, coachwhip, eastern diamondback, pigmy rattlesnake, eastern hognose, and Florida pine snake, were caught with greater frequency at PH. Many of these species are also associated with intact native ground cover that is lacking at the TT site. Soil type may also play a role in species differences. PH site has more sandy soil sites that are associated with many of the species only found on this site.

Also noteworthy is the capture of only a single eastern kingsnake (*Lampropeltis getula*) at PH. During 1976-1983, snakes were captured opportunistically from TT, a total of 24 eastern kingsnakes were captured and marked. During the course of our 3-year intensive trapping study at TT not a single kingsnake was captured. Declines in this species have been noted in previous studies (Krsyko 2002, Ernst and Ernst 2003, Krysko and Smith 2005), declines are speculated to be related to habitat loss, pet trade collection, road mortality, and fire ant predation.

The habitats where the traps were located were a good indicator of species composition. In all 4 habitat locations black racers constituted at least 40% of the total captures; black racers have been previously reported to be ubiquitous with regards to habitat (Conant and Collins 1998). The most dramatic differences in captures occur when comparing any of the other three habitats (field, upland, and native) to drain habitat. Rat snakes were a more common captures in the drain and less prevalent in the other habitat types. Coachwhips and corn snakes seem to have fairly similar habitat preferences. Additionally, their diet components are fairly similar, although the corn snake has a preference for warm-blooded prey, whereas the coachwhip will often consume lizards (Ernst and Ernst 2003). This may explain why capture rates of corn snake increase and coachwhip captures decline probably due to the lack of lizards and the increase in rodents populations found in fields. Interestingly, cottonmouths were frequently captured in drain habitat, but were also consistently captured in fields, and to a less extent also in uplands. This may suggest that cottonmouths require upland habitat within their home range as they increase in size, possibly serving as foraging grounds. Large cottonmouths were found occasionally at TT by technicians conducting radio telemetry Northern bobwhite that had been consumed by cottonmouths.

The decline in native long-leaf wiregrass habitat has been a concern to conservationists because this area was once so vast that numerous species depend on this ecosystem (Means 1982, 1996, Noss 1988, Landers et al. 1995, Van Lear 2005). Although conservation of this intact habitat is important we would also like to stress the importance of the frequently burned upland old field sites as comparable habitat preference for numerous species also known to be reliant on native sites. Florida pine snakes, Eastern diamondbacks, pigmy rattlesnakes, Eastern coachwhips, corn snakes, Eastern hognose snakes, scarlet and scarlet kingsnakes were all captured in comparable numbers on old field upland sites as well as native sites. Indicating that well managed upland sites can also support species thought to be longleaf wiregrass ecosystem specialists.

Many of the upland snakes require specific amounts of upland and field habitat within their home range. An understanding of basic habitat requirements for many snake species found in the southeast will not only make it easier to study these species but also to conserve species at the habitat level.

Literature cited

Clark, R. F. 1949. Snakes of the hill parishes of Louisiana. J. Tennessee Acad. Sci. 24:244-261.

Conant, R., and J.T. Collins. 1998. A field guide to reptiles and amphibians: Eastern and central North America. 3rd ed., expanded. Houghton Mifflin, Boston.

Dodd Jr, C.K., 1987. Status, conservation, and management. In Snakes. Ecology and evolutionary biology. Edited by R. A. Seigel, J. T. Collins, and S. S. Novak. Macmillan, New York. pp. 478-513.

Dodd Jr, C.K., 1993. Strategies for snake conservation. In Snakes. Ecology and evolutionary biology. Edited by R. A. Seigel, J. T. Collins, and S. S. Novak. Macmillan, New York. pp. 363-393.

Ernst, C. H. and E. M. Ernst. 2003. Snakes of the United States and Canada. Smithsonian Institution, Washington, D.C. 668 pp.

Engstrom, R.T. 1993. Characteristic mammals and birds of longleaf pine forests. Tall Timbers Fire Ecology Conf. 18, 127-138.

Fritts, T.H. 1987. The brown tree snake, *Bioga irregularis*, a threat to the Pacific Islands. Biological and Wildlife Service, Washington, DC 20240. 36 pp.

Greenberg, C.H., D.G. Neary, and L.D. Harris. 1994. A comparison of herpetofaunal sampling effectiveness of pitfall, single-ended, and double-ended funnel traps used with drift fences. Journal of Herpetology 28: 319-324.

Guyer, G., Bailey, M.A. 1993. Amphibians and reptiles of longleaf pine communities. Tall Timbers Fire Ecology Conf. 18: 139-157.

Keck, M.B. 1994. Test for detrimental effects of PIT tags in neonatal snakes. Copeia 1: 226-228.Landers, J. Larry, Van Lear, David H., Boyer, William D. 1995. The longleaf pine forests of the Southeast: Requiem or renaissance? Journal of Forestry 93: 38-44.

Krysko, K. L. 2002. Seasonal activity of the Florida kingsnake *Lampropeltis getula floridana* (Serpentes: Colubridae) in southern Florida. Amer. Midl. Nat. 148:102-114.

Krysko, K. L. and D. J. Smith. 2005. The decline and extirpation of kingsnakes *Lampropeltis getula*, in Florida. In: W.E. Meshaka, Jr., and K.J. Babbitt (eds.), Status and conservation of Florida amphibians and reptiles, pp. 132-141. Krieger Press, Malabar, Florida.

Landers, J. Larry, Van Lear, David H., Boyer, William D. 1995. The longleaf pine forests of the Southeast: Requiem or renaissance? Journal of Forestry 93: 38-44.

Linnell, M.A., R.M. Engeman, M.E. Pitzler, M.O. Watten, G.F. Whitehead, and R.C. Miller. 1998. An evaluation of two designs of stamped metal trap flaps for use in operational trapping of brown tree snakes (*Boiga irregularis*). The Snake 28: 14-18.

Means, D.B., Campbell, H.W., 1982. Effects of prescribed fire on amphibians and reptiles. Wood, G.S. (Ed.), Prescribed fire and wildlife in Southern forests. Belle Baruch Forest Science Institute, Clemson University, Georgetown, DC, pp. 89-96.

Means, D.B. 1996. Chapter 15. Longleaf pine forest, going, going,…Eastern old-growth forest: Prospects for rediscovery and recovery. Mary Byrd Davis ed. Island Press, Washington D.C.

Noss, Reed F. 1988. The longleaf pine landscape of the southeast: Almost gone and almost forgotten. Endangered species update 5: 1-8.

Pitt, W.C. 2001. Density of prairie skinks (*Eumeces septentrionalis*) in old-field habitats. The American Midland Naturalist 146: 86-93.

Reading, C.J., and J.L. Davies. 1996. Predation of Red-cockaded woodpecker young by a corn snake. Florida Field Naturalist 25: 67.

Stapleton, S. P. 2005. Snake ecology in the Red Hills of Georgia and Florida. Unpubl. M.S. Thesis. University of Georgia, Athens, Georgia. 159 p.

Tuberville, T.D., J.R. Bodie, J.B. Jensen, L. Laclaire, and J.W. Gibbons. 2000. Apparent decline of the southern hognose snake, *Heterodon simus*. Journal of the Elisha Mitchell Scientific Society 116: 19-40.

Van Lear, D. H., Carroll, W.D., Kapeluck, P.R., Johnson, R. 2005. History and restoration of the longleaf pine-grassland ecosystem: Implications for species at risk. Forest Ecology and Management 211: 150-165.

Table 3.1. Number of individual species collected from Pebble Hill and Tall Timbers during 2003-2005. A total of 19 species were caught using drift fences, 15 species were caught at PH and 16 species were captured at TT.

	Site		
Species	**PH**	**TT**	**Total**
Banded Water Snake	4	86	90
Black Racer	339	362	701
Coachwhip	89	36	125
Corn snake	126	131	257
Cottonmouth	14	167	181
Diamondback	37	21	58
Dusky pigmy rattlesnake	8	0	8
Eastern garter snake	84	96	180
Eastern hognose snake	10	1	11
Eastern kingsnake	1	0	1
Eastern mud snake	0	1	1
Florida green water snake	0	3	3
Eastern rat snake	86	61	147
Peninsula ribbon snake	0	1	1
Pine snake	17	0	17
Redbelly water snake	2	1	3
Rough green snake	0	1	1
Scarlet snake	3	2	5
Scarlet king snake	8	4	12

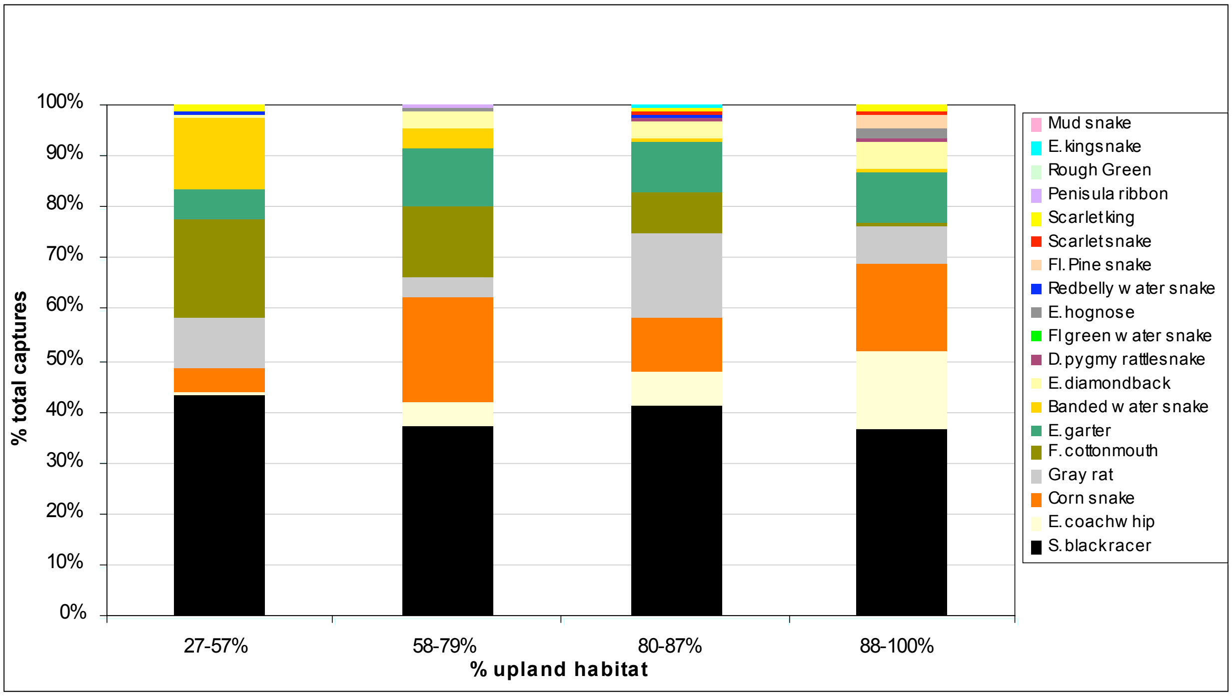
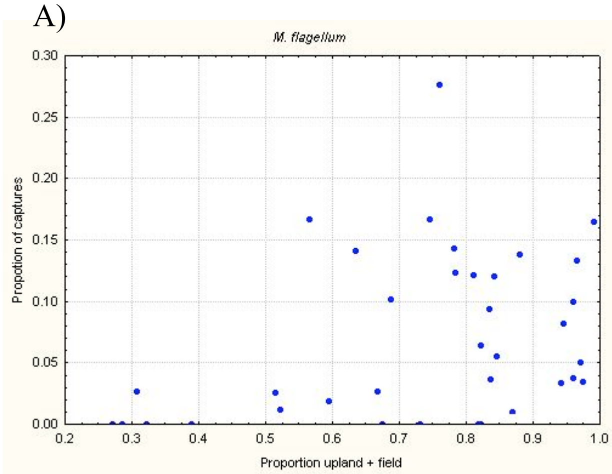
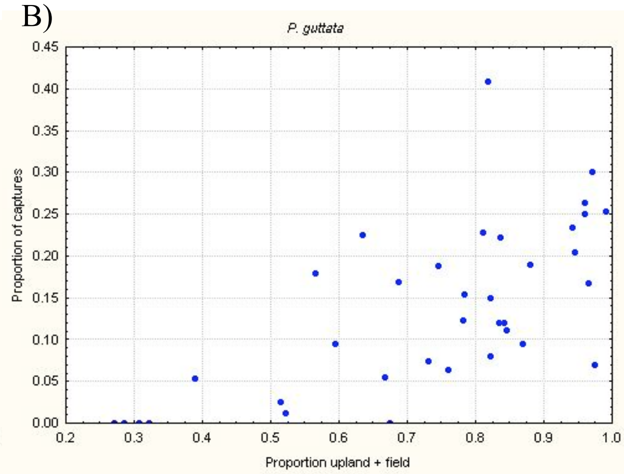


Figure 3.1. Composition of snake captures based on percentage upland and field habitat around each trap. The buffer covered an area of approximately 6.3 ha to include the mosaic of habitat types surrounding each trap. No trap was surrounded by less than 27% upland or field habitat. Upland and field habitats were combined because no field used was over 4 acres in size. Sample size includes19 species and 2,093 individuals.

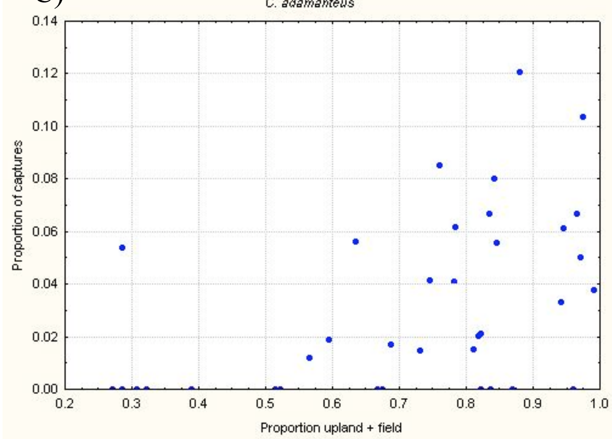
A)


M. flagellum
Proportion of captures
Proportion upland + field

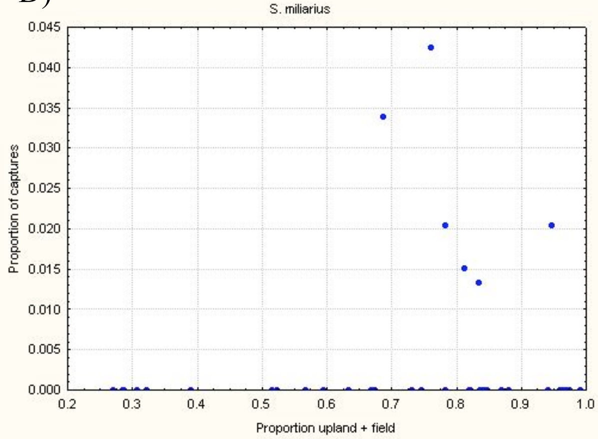
B)


P. guttata
Propotion of captures
Proportion upland + field

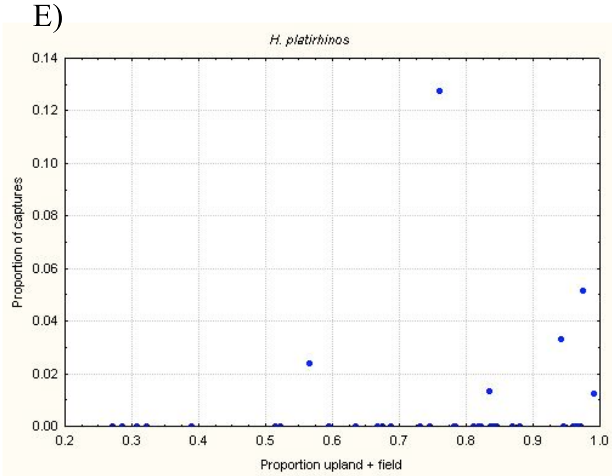
C)


C. adamanteus
Proportion of captures
Proportion upland + field

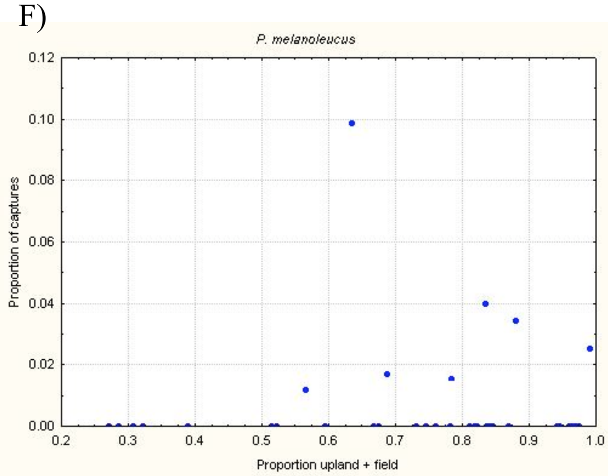
D)


S. miliarius
Proportion of captures
Proportion upland + field

E)


H. platirhinos
Proportion of captures
Proportion upland + field

F)


P. melanoleucus
Proportion of captures
Proportion upland + field

G)

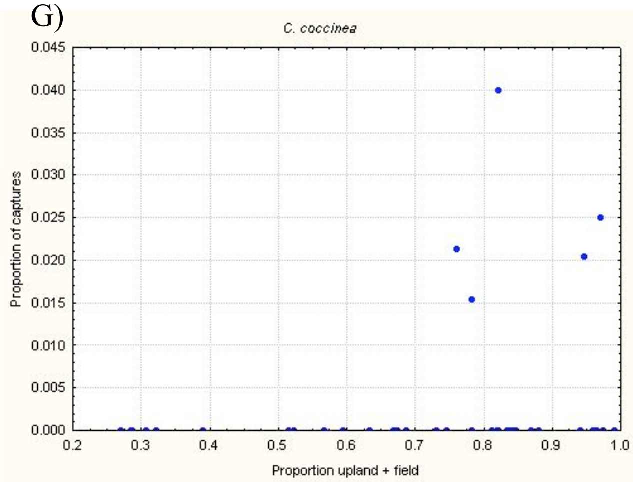


Figure 3.2. Proportion of captures in traps buffered to 6.3 ha, each point represents one of the 36 drift fence arrays. Seven species, A) eastern coachwhip, B) corn snake, C) eastern diamondback, D) dusky pigmy rattlesnake, E) eastern hognose, F) Florida pine and, G) scarlet snake demonstrate a reliance of nearly 60% upland habitat within their home range.

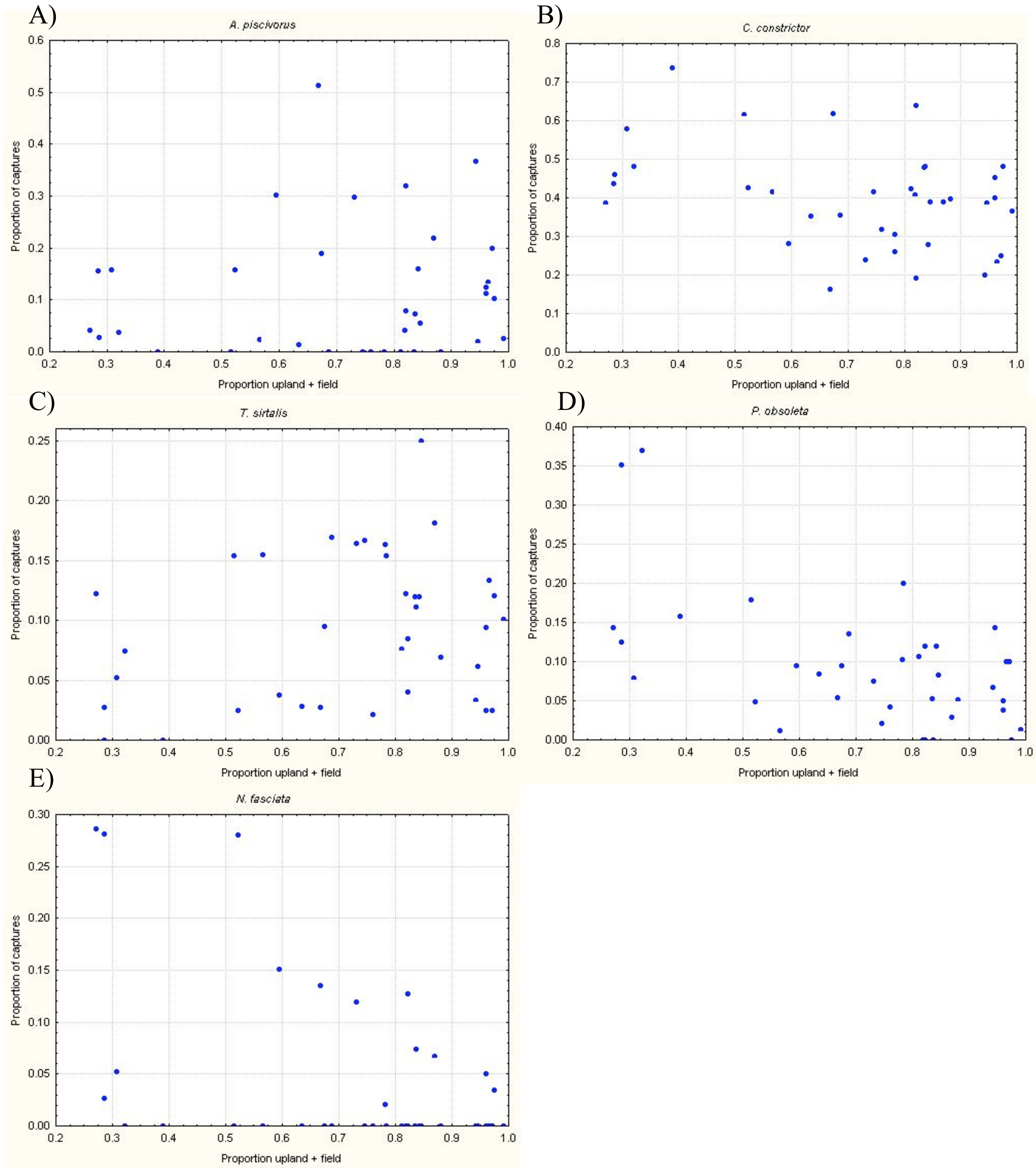


Figure 3.3. Proportion of captures in traps buffered to 6.3 ha, each point represents one of the 36 drift fence arrays. Four species, A) Florida cottonmouth, B) southern black racer, C) eastern garter snake, and D) rat snake show little preference for either upland/field or drain habitat. The

E) banded water snake was a higher proportion of captures at traps with more drain habitat surrounding, but also was captured in more upland areas.

CHAPTER 4

CONCLUSION

I analyzed habitat use and associations, seasonal and gender movement trends, and quantified the snake community of the Red Hills ecosystem of northern Florida and southern Georgia. An additional component of this study is to apply what I have learned to management recommendations and future studies.

From the data collected habitat requirements can be inferred for the community of snakes found in the Red Hills. Of the snakes I radio tracked most used multiple habitat types. Providing a mosaic of habitat types including field, upland, and drain would provide necessary habitat for most of the snakes in the Red Hills. Radio telemetry on corn and rat snakes demonstrated the importance of well maintained upland sites. Both corn and rat snakes used uplands for foraging grounds and uplands provided important refugia for corn snakes. Trapping data also illustrated reliance on uplands in many other species i.e. Florida pine snake, eastern hognose, and eastern diamondback, with many of these species having at least 60% upland habitat within their home range. Maintenance of upland habitat is critical for the habitat requirements for many snakes reliant on this system. Most importantly is the application of prescribed burning to maintain the longleaf-wiregrass ecosystem and old-field sites. One to three year burn cycles are necessary to sustain a grassland-scrub community with open forest structure and minimal hardwood encroachment allowing sunlight to reach the ground. This provides appropriate basking areas, adequate ground cover, and foraging areas with plentiful amounts of prey species.

Refugia such as snags, deadfalls, piles and, stumpholes were of particular importance to the corn and gray rat snakes I radio tracked. These structures provide safe places for digestion, ecdysis, thermoregulation, and probably also good places to forage. The application of prescribed burns aids in creating many of these micro-habitat structures important to snakes. The retention of stumps, deadfalls, snags, and debris piles provides this safe haven not only for snakes but a variety of herpetofauna and wildlife.

Land managers alter habitat without knowledge of the effects on non-target wildlife species. Land management activities, especially those destructive to the landscape should be conducted in the timely manner. Decisions on when to use heavy equipment for management activities also should be taken into consideration when snakes are active on the landscape. Breeding season for most of the snakes found in the Red Hills is in the spring or fall, coinciding with high activity of snakes and when they are most susceptible to mortality. Other effects of heavy equipment use such as; soil compaction, vegetation disturbance, edge, noise effects, and possibly direct mortality are relatively unknown.

Numerous manipulative experiments with snakes and the effects of habitat changes could be researched. Documenting the timing of burns and how growing verses non-growing season burns effects snake survival has been largely overlooked. Implantation of radios with body temperature, or other physiological sensors would provide new information on the micro-habitat requirements and optimal temperatures for both moving and resting. A through diet study would provide a wealth of missing information regarding the diet structure for many snake species. A diet study could include information regarding the size of the prey, the diversity of prey items, and perhaps the frequency of consumption. Stable isotopes studies may provide a unique and noninvasive look at the diet structure and trophic level of snakes.

A few modifications to my study design would prove useful. I recommend building sturdy box traps with treated plywood and added support on the doors. I began trapping in February and continued to October; in this climate trapping should begin in March and continue to November. Some evidence suggests that snakes may overtime avoid traps but due to low sample sizes and an open population that analysis was not probable with this study. In future, I would recommend moving the trap locations after the second year. Additional snake species were missed due to trap design, many of these species are small or fossorial. The addition of pit falls or coverboards along the fences would increase the sample size of these species.