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RESPONSE OF THE THREATENED SAND SKINK (NEOSEPS REYNOLDS!) AND OTHER HERPETOFAUNAL SPECIES TO BURNING AND CLEARCUTTING IN THE FLORIDA SAND PINE SCRUB HABITAT

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Master's Thesis

This is to certify that the Master's Thesis of

KRISTIE D. GIANOPULOS

with a major in Zoology has been approved
for the thesis requirement on April 24, 2001
for the Master of Science degree.

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RESPONSE OF THE THREATENED SAND SKINK (NEOSEPS REYNOLDSI) AND OTHER HERPETOFAUNAL SPECIES TO BURNING AND CLEARCUTTING IN THE FLORIDA SAND PINE SCRUB HABITAT

by

KRISTIE D. GIANOPULOS

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science
Department of Biology
College of Arts and Sciences
University of South Florida

May 2001

Co-Major Professor: Henry Mushinsky, Ph.D.
Co-Major Professor: Earl Mccoy, Ph.D.

Dedication

I wish to dedicate this work to my parents, Michael and Susan Liptak, whose love and unwavering support have enabled me to reach ever higher for my ideals.

Acknowledgments

I would like to thank my major advisors, Dr. Henry Mushinsky and Dr. Earl McCoy for making all of this possible. I have appreciated their willingness to share their knowledge and expertise without reserve and to give me their full attention no matter what else they were occupied with at the moment. I also wish to thank Dr. Susan Bell, who has also been very approachable and always willing to help. Special thanks go to Carolyn Meyer and Kristen Penney for their indispensable assistance, extraordinary patience, and enthusiasm for the sand skinks through many hours in the field, no matter how hot it was. I have appreciated their friendship and support. I especially thank my husband for remaining good-natured and supportive through the thick and thin of my accomplishing this work.

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RESPONSE OF THE THREATENED SAND SKINK (NEOSEPS REYNOLDSI) AND OTHER HERPETOFAUNAL SPECIES TO BURNING AND CLEARCUTTING IN THE FLORIDA SAND PINE SCRUB HABITAT

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An Abstract

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May 2001

Co-Major Professor: Henry Mushinsky, Ph.D.
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Florida scrub habitat is a naturally fire maintained habitat that is highly endangered because of great demand for land for agriculture and real estate. Maintenance of remaining patches of Florida scrub habitat requires active management. We experimentally investigated the effects of clearcutting and burning on sand skink populations in three patches of sand pine scrub. Each patch included a clearcut plot, a burned plot, and an undisturbed plot. Treatment plot boundaries were drawn in 1995 such that each plot was no different from any other plot in sand skink densities. The responses of sand skink and other herpetofauna populations were monitored over the following five-year period (1996-2000) immediately following clearcutting and burning.

Initially, sand skink captures in the burned and clearcut plots were lower than in the undisturbed plots. Over the five-year period, sand skink captures significantly increased in the clearcut plots. No clear trend occurred in the burned plots, although fluctuations from year to year were significant. After treatment, number of sand skink captures differed among treatment plots within each site. The treatments also did not affect sand skink distributions within the sites in the same way among the sites. The distribution of sand skinks within the three sites appeared to be influenced by an interaction between treatment plot and microhabitat characteristics. Sand skink presence has been related previously to low soil compaction, large soil particle size, low soil moisture, low soil temperature, large amounts of loose sand and bare ground, and low average understory vegetation. The treatment plot in which the sand skinks were found in the greatest numbers may have been more a function of the microhabitat characteristics rather than the treatment. Analysis of the distribution of individuals also indicated that sand skink distribution was clumped, especially near the centers of the three sites.

Analysis of herpetofaunal data from the experimental sites indicated that toward the end of the study, the number of species captured appeared to be converging among the undisturbed, clearcut, and burned plots. Diversity estimates, however, which incorporate number of individuals as well as number of species, indicated that the burned and undisturbed plots had greater herpetofaunal diversity than the clearcut plots. Comparisons were made with other studies performed in north central Florida (Ocala National Forest) and southern Florida.

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INTRODUCTION

Florida Scrub

Florida scrub habitat is thought to have dominated the Florida peninsula in the late Pleistocene (44,000-10,000 YBP), when its climate was cooler and drier. As water levels rose, the subsequent increases in moisture, temperature, and the frequency of electrical storms and lightning fires, caused a slow change in Florida's landscape. Florida scrub became more frequently found on the drier, nutrient-poor, sandy soils of the ancient dunes along the central ridge of Florida, where the scrub vegetation was not outcompeted by the southern pine forest beginning to dominate Florida's landscape. Fires caused by lightning and early human inhabitants gradually selected for the fire-dependent species found across Florida when European settlers arrived (MacAllister and Harper, 1998; Myers, 1990).

Modern Florida scrub habitat is situated along the Central Florida Ridge, extending from Clay and Putnam Counties south to Highlands County, as well as in various places along the coasts (Figure1)(Myers, 1990). Florida scrub consists of an association of fire-dependent species adapted to the well-drained nutrient-poor soils found in central Florida. Florida scrub is, by nature, a patchy habitat, which is surrounded by other habitats such as sandhill, xeric hammock, and wetlands areas (MacAllister and Harper, 1998). All of these are fire tolerant, and naturally burn more or less frequently depending on the extent of litter accumulation. Scrub habitat burns less frequently than surrounding habitats because it lacks the fine grasses, pine needles, and other fuels that accumulate and readily ignite. When scrub does burn, however, the fires are usually of high intensity and catastrophic so they often produce even-aged stands of sand pines in the areas that have burned (MacAllister and Harper, 1998). The normal fire periodicity for Florida scrub has been estimated to be between 30 and 60 years (Myers, 1990).

Florida scrub occurs on a loose soil composed almost entirely of sand, with little ability to retain water and nutrients. The sand is usually white, but occasionally

Figure 1. Distribution of major areas of sand pine scrub in Florida. (from Deyrup, 1989) Star indicates approximate location of study sites.

yellowish. The color of the sand indicates the age of the scrub because, over time, the acid from decaying litter leaches out the nutrients that color the soil. Therefore, the oldest scrub soils have the widest upper horizon of colorless soil (USFWS, 1996; Myers, 1990).

The plant association that composes scrub makes it one of the most distinctive habitats in Florida. Scrub habitat can have three major structural layers: a lower shrubby layer comprised of saw palmetto (*Serenoa repens*) and scrub palmetto (*Sabal etonia*), an upper shrub layer of evergreen oaks (sand live oak *Quercus geminata*, Chapman's oak *Q. chapmanii*, and scrub oak *Q. inopina*), rusty lyonia (*Lyonia ferruginea*), and/or rosemary (*Ceratiola ericoides*), and, when present, an overstory of sand pine (*Pinus clausa*)(Myers 1990; Abrahamson et al., 1984). If sand pines are present, they may form an open or closed canopy. Herbaceous species tend to be somewhat sparse (MacAllister and Harper, 1998). Bare patches of sand, scattered prickly pear cactus (*Opuntia* sp.), and numerous lichens are also often visible (Figure 2).

Florida scrub is a threatened ecosystem; it is home to at least 13 federally listed (22 state) endangered or threatened plants, and several species of federally listed vertebrates (MacAllister and Harper, 1998; Noss et al., 1992). Many more plant and vertebrate species occur only in Florida scrub. There are several reasons this unique habitat is swiftly disappearing. Fire suppression in Florida from 1920 to 1950 allowed the conversion of some patches of scrub to xeric hammock, with large oaks and few shrubs (MacAllister and Harper, 1998). The most severe threat existing today lies in the rapid expansion of the human population in Florida and the consequent increasing demand for real estate and building materials. Much former scrub has been developed into residential communities or used for agriculture (Christman, 1988). It was estimated in 1990 that over 70 percent of the major Lake Wales Ridge scrub habitat had been converted to other land uses (Myers, 1990). Some believe that as much as 90 percent of original scrub in Florida is already lost (USFWS, 1999,1993). Most of the scrub fragments that do remain are less than a few hundred hectares in area (Christman, 1988; McCoy and Mushinsky, 1994). The largest example of scrub habitat remaining on the Lake Wales Ridge in central Florida is 1,160 hectares (USFWS, 1996). The largest

Figure 2. Example of a sand pine scrub in central Florida. (photograph by J. Rowe)

remaining patch of scrub (approx. 100,000 ha) in Florida occurs in and around Ocala National Forest in north central Florida, where the sand pine scrub is managed primarily for pulp production (Greenberg et al., 1995).

Maintenance of Florida scrub is impossible where fire is suppressed, and recovery of overgrown scrub requires several growing season fires to return it to its previous state (MacAllister and Harper, 1998). However, increasing development nearby existing scrub areas poses a barrier to burning as a management tool. Smoke may hamper visibility by drifting onto roadways and landing strips, and smoke inhalation may cause harm to those with respiratory ailments residing in the area.

Recent studies have examined recovery of scrub vegetation and reptile communities after a fire as compared to recovery after harvest and reseeding (Greenberg et al., 1995; Greenberg et al., 1994). Greenberg et al. (1994;1995) thought that the disturbance caused by harvesting mimicked the effect of a high intensity fire in scrub, and so could present a viable alternative management tool in cases where burning was not feasible. Greenberg et al. (1995, 1994) found that burning with salvage logging and various methods of harvesting and reseeding in Ocala National Forest resulted in similar recovery for some, but not all, scrub plant and herpetofaunal species. We wanted to test this conclusion using a manipulative experiment with scrub patches in central Florida.

The Sand Skink

The primary focus of the manipulative experiment was to assess the immediate and longer term relative effects of clearcutting and burning of scrub on a small fossorial lizard endemic to Florida scrub, the sand skink (Neoseps reynoldsi Stejneger). The sand skink is restricted primarily to Florida scrub habitat, and is found in only seven counties of central Florida (Putnam, Orange, Osceola, Lake, Marion, Polk, and Highlands) (McCoy et al., 1999; Telford, 1998; USFWS, 1993) (Figure 3). The Federal government (U.S. Fish and Wildlife Service) listed the sand skink as a threatened species in 1987 (USFWS, 1993). The sand skink is a slender (approx. 5 mm. in diameter) burrowing lizard with a wedge-shaped head, a countersunk jaw, and highly reduced limbs, features which enable the sand-swimming motion characteristic of this lizard (Figure 4). The body is smooth, light-tan colored, and there is a black stripe through the eye. In juveniles, the stripe extends down the side of the body. The sand skink feeds on soft-bodied arthropod prey, especially termites and beetle larvae (Myers and Telford, 1965; Telford, 1959).

The sand skink moves through the sand in a serpentine motion. The tiny limbs are pressed into tiny grooves on the sides of the body to facilitate locomotion, but the limbs are used when the sand skink is on a flat surface (pers. obs.; Mushinsky and Gans, 1992). The sand skink requires areas with loose sand and sunny exposure and is not often found in areas with abundant plant roots (Christman, 1992). The looser sand seems to insulate the sand skinks from high temperatures as well as facilitate movement (Collazos, 1998; Andrews, 1994). The sand skink spends nearly all of its time underground, where it moves in the loose sand just beneath the surface. It probably does

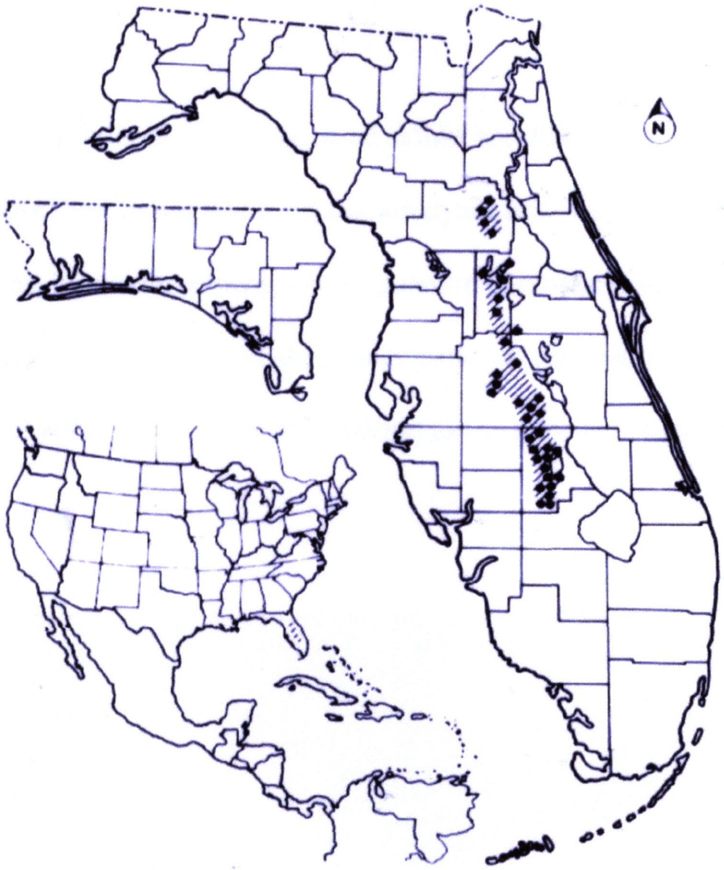

Figure 3. Distribution of the sand skink in Florida. Dots represent localities where sand skinks have been found. Taken from: Rare and Endangered Biota of Florida, Volume 3 (1992).

not regularly burrow to depths greater than 10 cm. (Telford, 1959). When the sand skink moves through an area just below the surface, it leaves nearly perfect sinusoidal tracks, by which its presence can be identified. It exhibits an annual activity cycle in which the period of greatest activity occurs between mid-February and mid-May, at which time mating occurs (this study; Sutton, 1996; Telford, 1959). Females lay two small eggs, and 25 mm (snout-vent length) neonates emerge from eggs in June and July (Andrews, 1994; Telford, 1959; Cooper, 1953). The sand skink's normal lifespan is unknown, but a recent analysis of growth data indicated that sand skinks may live at least 6 years (Sutton, 1996).

Because of their secretive nature, sand skinks are difficult to study and much is still unknown about their biology and population dynamics. Little is known about their movement patterns, home range sizes, and population parameters such as age structure, birth/mortality rates, distribution and abundance patterns, emigration/immigration patterns, etc. (USFWS, 1999). More information needs to be gathered about their

Figure 4. Adult Florida sand skink, *Neoseps reynoldsi* (photograph by H. Mushinsky).

behavior, lifespan, and diet choice/breadth, before a full understanding of the sand skink will be obtained.

Obtaining knowledge of skink populations' response to land management practices is necessary to conserve and prevent further harm to their populations, especially because current management practices may have resulted in the disappearance of the sand skink from Ocala National Forest (Telford, 1992). Researchers have recently failed to detect sand skinks on some sites in Ocala National Forest, and harvesting has been implicated as a possible cause, because the soil is completely disturbed to a depth of 15 cm and passed over by heavy machinery (Greenberg et al., 1995; Telford, 1992). As previously stated, the primary purpose of my study was to assess the effects of burning and clearcutting on sand skink populations in selected patches of scrub habitat. Data from the same locations from previous years (Navratil, 2000) are included and used to expand my conclusions. The secondary focus of my study was to examine the effects, if any, of the land management practices of burning and clearcutting on other herpetofaunal species captured in the scrub. For this analysis, my data are again compared to information gathered in past years on the same sites (Ravdal, 2000).

MATERIALS AND METHODS

Study Sites

My study was conducted on three areas of scrub owned by Walt Disney Imagineering, Inc. and located in Orange and Osceola Counties, near Kissimmee, Florida. The study sites were designated CW1, MW5, and MW7 by previous researchers, but for simplicity, I will hereafter refer to them as sites 1, 2, and 3 respectively. Site 1 was in the northwestern corner of Osceola County, and sites 2 and 3 were in the southwestern corner of Orange County. All sites were of similar size (site 1 = 4.72 ha, site 2 = 4.18 ha, and site 3 = 4.26 ha) and composed primarily of sand pine scrub. Site 1 was surrounded by fire lanes but beyond those were sand pine scrub and oak hammock on three sides and a cleared cattle pasture on the fourth side (Figure 5). Site 2 was bordered on three sides by canals and on the fourth by a mesic forest (Figure 6). Site 3 was bordered on two sides (N and E) by wetland and a canal, and on the south and west sides by an area of restored scrub habitat (Figure 7). This restored scrub site was part of a scrub restoration project which involved the spreading of scrub mulch and soils onto the experimental site. Sand skinks were released onto this scrub restoration site in 1994 and their populations monitored from 1994 to 2000 (Hill, 1999; Penney, pers. comm.). As a result, sand skink immigration and emigration between the scrub restoration site and site 3 were possible.

Sites 2 and 3 were approximately 200 meters apart and separated by a wetland and a canal.

In 1995, sites 1, 2, and 3 were divided into three plots: a harvest plot, a burn plot, and a control plot. The divisions were made according to preliminary data such that each plot had a similar amount of area as well as number of sand skinks (see Navratil, 2000). The harvesting was accomplished by clear cutting followed by roller chopping using a heavy machine (roller chopper) which top-kills lower story vegetation and completely disturbs the soil to a depth of 15 cm. Harvested areas were not reseeded. The harvesting and burning treatments were carried out during the summer of 1995 and winter of 1995 - 1996. The effectiveness of each burn was estimated by Navratil (2000) based on the percentages of ground layer, shrub layer, and canopy vegetation that were burned (Table 1).

	Date of burn	Ground layer, % burned	Shrub layer, % burned	% Trees killed by fire
Site1	2/12/96	97.8 %	81.2 %	54.7 %
Site 2	7/14/95	75.3 %	22.8%	35.0 %
Site 3	12/13/95	93.2 %	53.5 %	31.6 %

Table 1. Effectiveness (expressed as percent burned) of various fires in burning the ground layer, shrub layer, and overstory trees (from Navratil, 2000).

Sand Skink Data Collection

Traps and Marking Method

Following manipulation of the treatment plots on all three sites, pitfall trap arrays were installed for the monitoring of the sand skink populations. Each of the nine plots received 10 pitfall trap arrays, spaced uniformly 35 m from one another (Figures 5-7). Trap arrays consisted of aluminum flashing drift fences 2 m in length sunk approximately 45 cm into the ground. One 20 L bucket was sunk into the ground at each end so the bucket's top edge was just below the ground surface. The bottom of each bucket was drilled with several holes to promote drainage. During the trapping seasons, buckets were sheltered from heat and rain with lids supported by sticks placed in the ground next to the bucket's perimeter. During the sand skinks' inactive season, the traps were closed by tightly fitting the lids and covering them a few centimeters of soil. From 1996 to 2000, traps were opened and, during the period of greatest activity (February through May), sand skink populations were monitored in each plot. Activity is extremely limited during the summer and fall, so sand skinks were not monitored during this period (Sutton, 1996; Andrews, 1994). Data from 1996 to 1998 are presented in Navratil (2000), but also are referred to in the data analysis of this study. My research involved gathering information on the sand skinks during the 1999 and 2000 active period and data on soil compaction on the sites, as well as cataloging all other reptile and amphibian species trapped during that time.

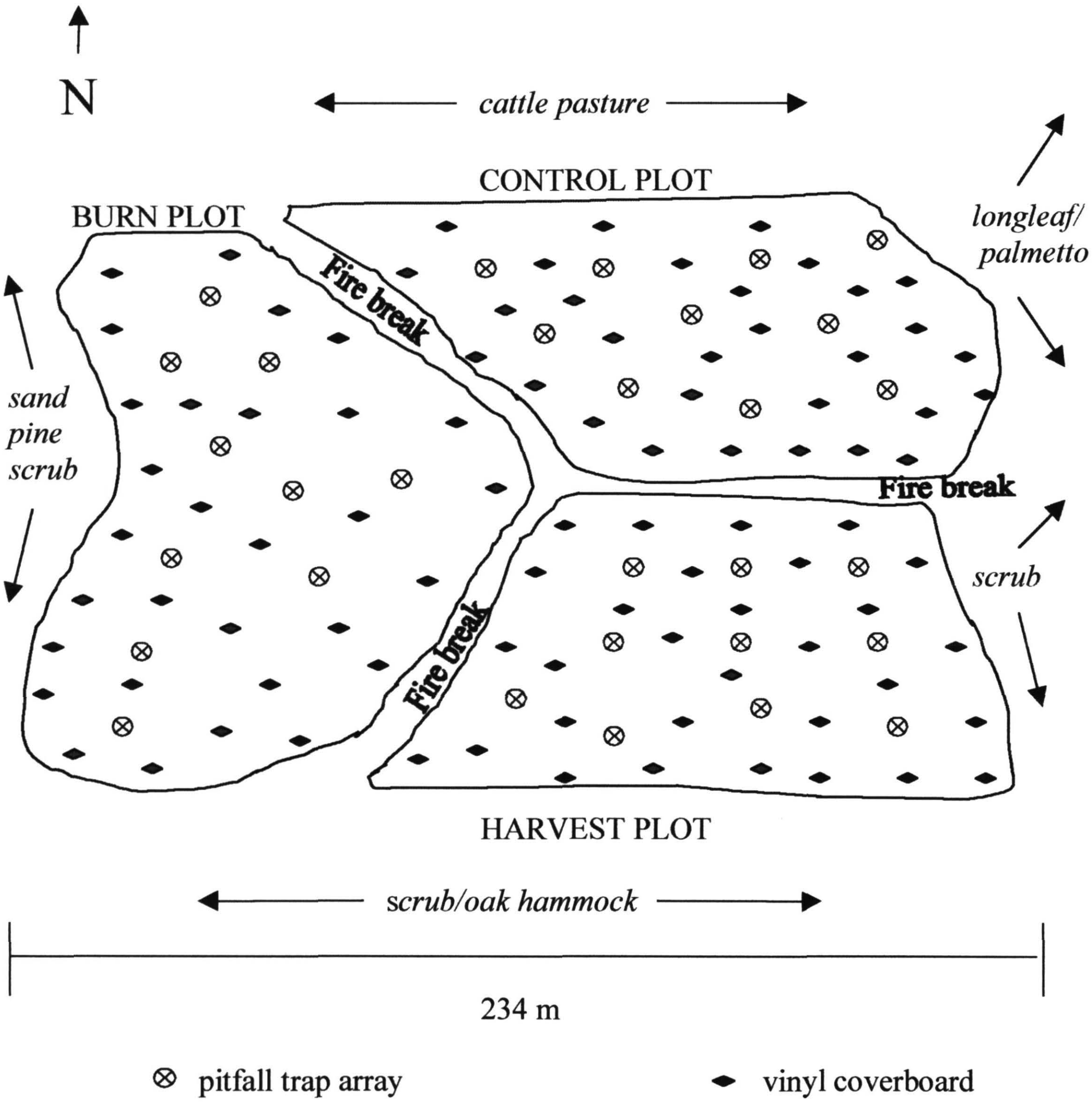

Figure 5. Schematic diagram of site 1 showing traps and coverboards.

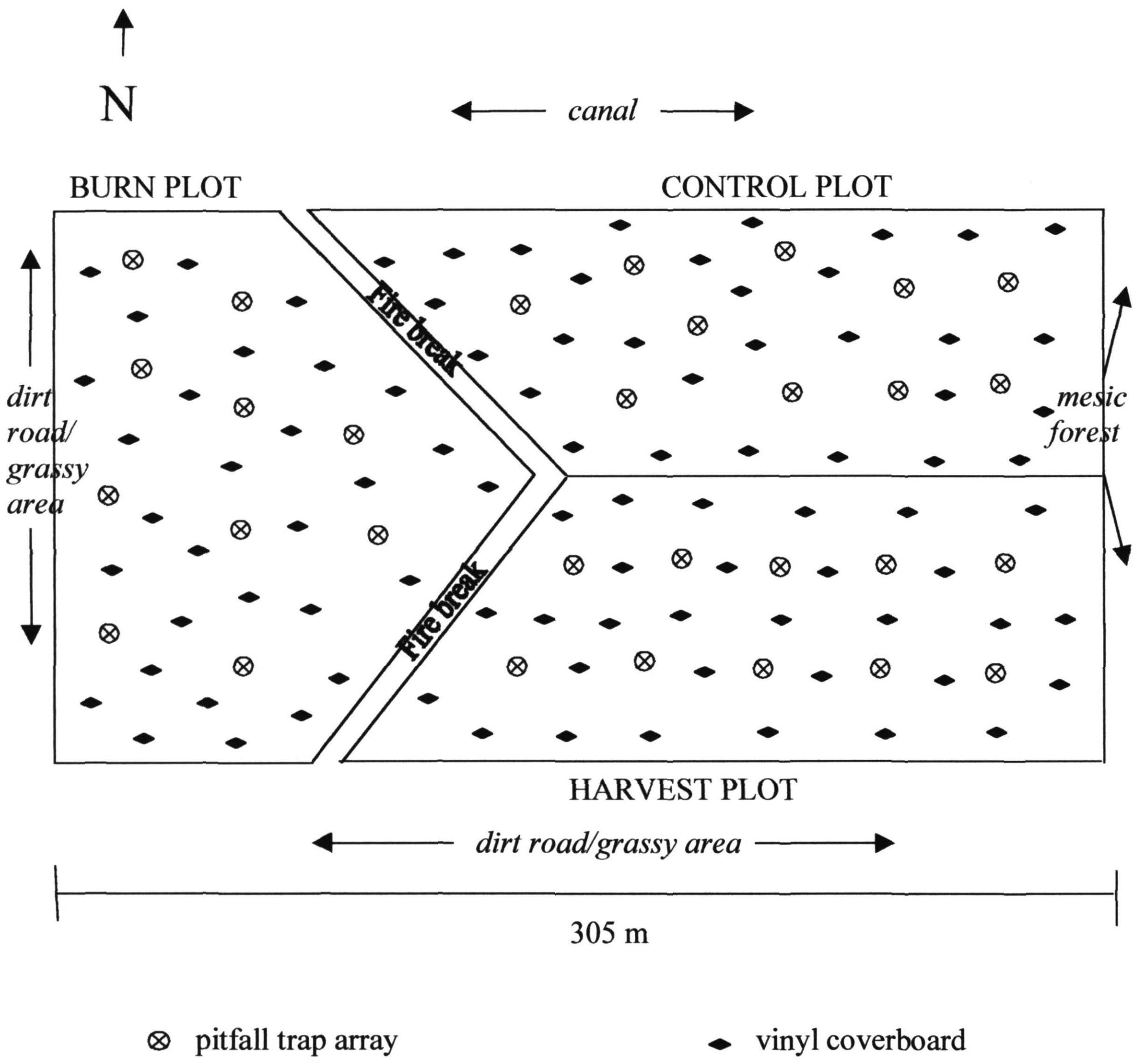

Figure 6. Schematic diagram of site 2 showing traps and coverboards.

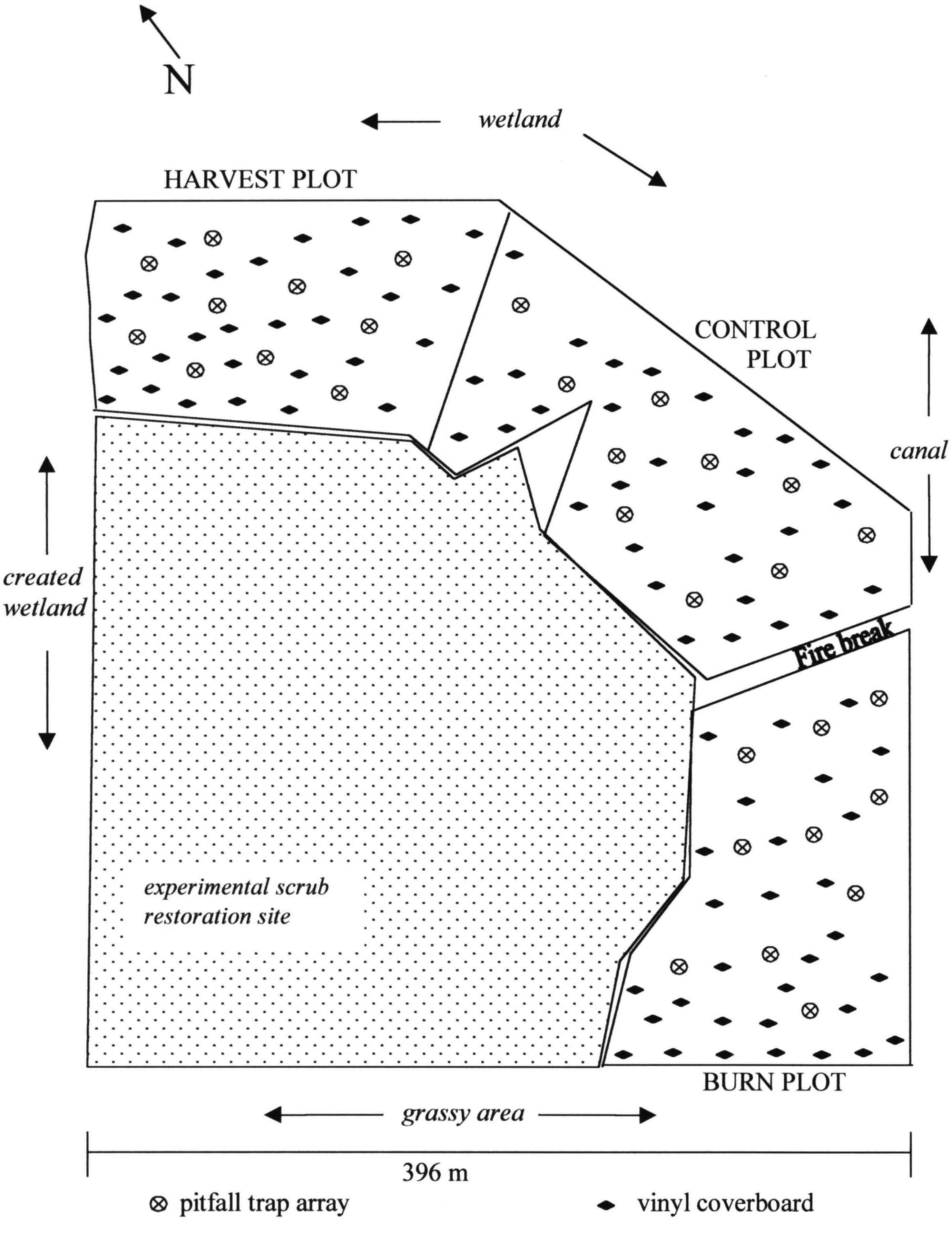

Figure 7. Schematic diagram of site 3 showing traps and coverboards.

In 1996 and 1997, all captured sand skink individuals were branded with a unique set of marks using a hand-held medical cauterizer. Branding proved to be a sufficient marking method only for relatively short periods of time (<1 yr), because rapid growth, frequent shedding, and abrasion obscured the marks on juveniles and adults. Previous researchers began using an alternative marking system with the sand skinks in 1998, and I continued using it through 2000. The marking method involved mixing a liquid polymer with a liquid hardener, placing it in a syringe, and injecting a small amount (approximately 1 μl) of the mixture through a syringe subcutaneously into the lizard. The polymer hardened within a few hours into a flexible, but permanent and stationary, mark. Often the mark could be distinguished with the unaided eye or, if necessary, viewed through polarized glasses while exposed to a black light which caused the polymer to fluoresce through the skin. I developed a marking scheme with which I was able to mark uniquely hundreds of individuals using injections at three of six chosen possible locations on the sand skink's body. I chose six separate locations on the ventral side of the sand skink as marking positions, but limited the number of injections to a maximum of three. Each color was assigned a number and each of the six locations allotted a numerical space. For instance, a sand skink with three marks of color 1 in positions one, two and three would have the number 111000 (Figure 8).

Traps were checked weekly from February 18 to May 18, 1999 and February 21 to May 24, 2000. Capture date and location were noted. Upon capture, all individuals were brought back to the lab at the University of South Florida in Tampa, housed separately in 3.75 L containers with 7 to 10 cm of sand, and fed termites. During the measuring and marking procedure, the sand skinks were cooled until they no longer exhibited a righting response. Sand skinks were measured (snout vent length, total tail length, and original tail length, to the nearest .01 mm), weighed to the nearest .01 g, and individually marked with the fluorescent polymer if not previously marked. An attempt was also made to determine the sex of adult animals by applying pressure posteriorly to the vent in the direction of the vent to expose the hemipenes, if present. We did not attempt to determine the sex of an adult individual if the tail seemed ready to autotomize, for fear of breaking the tail. Difficulty in correctly determining the sex of sand skinks without harming them made these data unreliable; errors would cause the data to indicate more female captures than were truly made (see also Sutton, 1996). Sand skinks were usually released within a week of capture near their capture location. If it could be determined at capture that a sand skink had been marked that season, it was released without further handling, as excessive handling can be detrimental to sand skinks (Sutton, 1996).

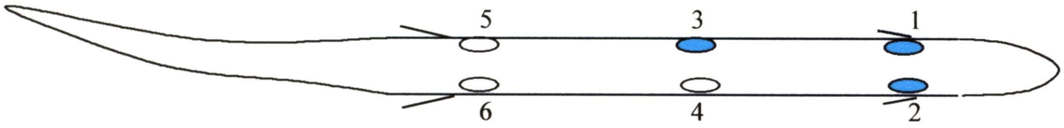

Figure 8. Dorsal view of a sand skink to illustrate the marking scheme used with fluorescent elastomer. Example shown is sand skink 111000; marking positions are marked with numbers in diagram.

Coverboards

Within each plot, sand skinks had been captured in small, localized areas from 1996 to 1998, suggesting that there could in fact be "patches" of sand skink activity in areas between the existing trap arrays. Several studies have indicated that coverboards can be useful and accurate in elucidating patterns in relative abundance and distribution (Sutton et al., 1999; Grant et al., 1992). Sutton et al. (1999) found that coverboards and pitfall drift fences were about equally capable of reflecting overall activity of sand skinks. To discover if and where there were localized patches occupied by sand skinks between traps, I added approximately four coverboards, constructed from discarded vinyl siding (approx. 80 x 60 cm), equidistant from each trap array (Figures 5-7). In areas where plant roots were at the surface, I added sand to create a sandy surface beneath the coverboard to facilitate recognition of the sand skink tracks.

Coverboards were lifted biweekly in the spring of 1999, and the ground beneath the coverboard was surveyed for the sinusoidal tracks characteristic of sand skink activity (Figure 9). To gather information on the relative amount of activity in an area, the ground beneath each coverboard was assigned a rating when it was checked: 0 = no tracks, 1 = 1-5 tracks, 2 = approximately ½ of space covered by tracks, and 3 = space completely covered by tracks. After the rating and location of the coverboard were recorded, the sand beneath the coverboard was smoothed over so new tracks could be seen two weeks later when coverboard was again checked. I assumed that the area under a coverboard was representative of the area in which it was placed. If coverboards attracted sand skinks by favorably changing the microhabitat, I assumed that they all equally attracted sand skinks.

Figure 9. Example of sinusoidal sand skink track (photograph by H. Mushinsky)

Microhabitat Variables

Because sand skinks travel through the sand as they move from place to place, microhabitat characteristics, such as soil compaction, could play a relevant role in determining sand skink distribution patterns. Soil compaction, as measured by a penetrometer, is actually a measure of the penetration resistance provided by the soil particles (Vazquez et al., 1991). To find a potential correlation between presence of sand skinks and amount of soil compaction on my sites, I measured soil compaction at every trap and at every coverboard using a penetrometer in the spring and summer of 2000. Penetrometer readings (kg/cm^2)were taken at four points equidistant from the center point of the aluminum flashing of each trap (Figure 10). Measurements were also taken at each of the four corners of every coverboard.

Because sand skink distribution may be affected by microhabitat variables other than soil compaction, I also gathered data on a number of other microhabitat features at every trap during June and July of 1999. A one meter by one meter quadrat was set up approximately 0.75 to 1 m from the center of the aluminum flashing of each trap. Within this quadrat, understory vegetation height was measured at four randomly selected points, litter depth was measured at four randomly selected points, percent cover by scrub species was estimated, and percent bare ground was estimated.

Other Herpetological Species Data Collection

The secondary herpetological study performed simultaneously with the main sand skink project involved gathering data from all captures of herpetological species. When any amphibian or reptile was captured, it was identified and its capture location recorded. None was marked, so recapture frequencies remained unknown. These data were collected during the same time periods the traps were open for sand skink capture:

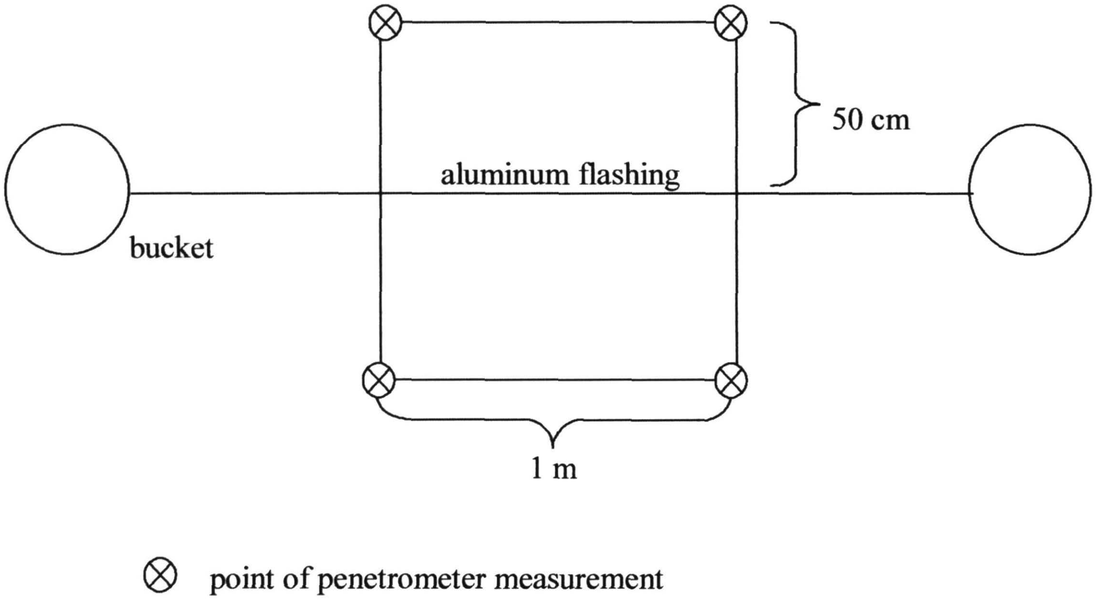

Figure 10. Points of penetrometer measurements around a trap array.

the spring seasons of 1999 and 2000. The nature of the traps caused a capture bias against some species such as large snakes, tree frogs, and lizards who could climb out of the buckets. Whenever one of these species was encountered during routine trapping, its presence and location was noted. In addition to notation of any encounter with reptiles or amphibians, surveys for the presence of active gopher tortoise burrows were done on all sites in June-July 2000. Gopher tortoises primarily occupy the more grassy sandhill habitat, but they are also present in scrub in lower densities (Christman, 1988). I completed the survey by systematically traversing all areas of the sites, while searching for active burrows. An active burrow was defined as one with signs of tortoise activity at the mouth, such as footprints, plastron scrapes, and fresh soil excavation. Notation was made whether the burrow was made by an adult or juvenile (< 20 cm in diameter at opening), and the location of the treatment plot where the burrow was found. Analyses of data were performed using PrismGraph, GraphPad Software, Inc. ©1996, Systat, SPSS Inc. ©1998, Microsoft Excel, Microsoft Co. ©1999, and Biodiversity, ©The Natural History Museum & The Scottish Association for Marine Science.

RESULTS

Sand Skinks

General Capture Data

During the spring of 1999, pitfall traps were open for 13 weeks (February 18 – May 18) and I made a total of 67 sand skink captures. During the spring of 2000, traps were open for 13.5 weeks (February 21 – May 24) and I made a total of 77 sand skink captures. Juvenile sand skinks comprised a greater percentage of the total captures during the year 2000 than during 1999 (Table 2).

The ratio of captured males to captured females (among adults whose sex was determined) remained fairly constant between 1999 and 2000 (Table 3). Females outnumbered males captured, however, the overall sex ratio of all sand skinks captured in 1999 and 2000 did not deviate from a 1:1 sex ratio ($X^2 = .304 < X^2_{(.05)} = 3.841$, df = 1). Again, this could be a result of failure on my part to detect hemipenes in some males which I then categorized as females. Sutton (1996), however, reported higher captures of female sand skinks than males, although the overall sex ratio in his study also did not significantly differ from a 1:1 sex ratio. The data from 1996 to 1998 on my sites indicate that the sex ratio of all captures during the first three years of the study did significantly deviate from a 1:1 ratio, with males outnumbering females ($X^2 = 4.72 > X^2_{(.05)} = 3.841$, df = 1)(Navratil, unpubl. data). This sex ratio was not different from 1:1 when adjusted with a correction factor for the fact that some sand skinks determined upon first capture to be one sex were then identified as the opposite sex upon recapture ($X^2 = 2.94 < X^2_{(.05)} = 3.841$, df = 1).

	1999		2000	
Adults	56	83.6%	52	67.5%
Juveniles	11	16.4%	25	32.5%
Total	67		77	

Table 2. Numbers and percentages of adult and juvenile sand skinks captured on all sites in 1999 and 2000. Individuals were considered juveniles if they were smaller than 47 mm SVL and their sex could not be determined.

	1999		2000	
Males	19	33%	20	35%
Females	30	53%	34	60%
Adults of undetermined sex	8	14%	3	5%
Total	57		57	

Table 3. Sex of all sand skinks captured in 1999 and 2000.

Natural History Data

Average snout vent length (SVL), tail length, total length, and mass from sand skinks measured in 1999 and 2000 are presented in Table 4. Data from male and female sand skinks were combined because there no evidence of sexual dimorphism has been found in Florida sand skinks (Shockley, 1997). The smallest (39.1 mm SVL) and largest (64.3 mm SVL) individuals were captured in 2000 on site 3.

Insufficient data have prevented researchers from accurately determining the length of time a sand skink can live. Telford (1959) thought the lifespan of the sand skink to be no more than about 3 years based on his data, but Sutton (1996) recalculated the lifespan to be at least 6 years based on growth data obtained in his study. My data from one individual extend the known upper age limit for sand skinks. One female sand skink in my study was captured in 1996 with a SVL of 58.4 mm, indicating that it was in its third or later year in 1996, based on Sutton's (1996) growth curve. The same individual was recaptured in 1998 when it was remarked with the polymer, and then recaptured again in 1999 and 2000. Its SVL in 2000 was 62.9 mm, near the extreme of reported elsewhere for female sand skinks (Telford, 1959). When recaptured (twice) in 2000, this sand skink appeared healthy and, at the time of its second capture in 2000 (May), was obviously gravid. An estimate of this sand skink's age in 2000 based on Sutton's (1996) growth curve, is 8 years, assuming it was 3 years old at first capture in 1996. Because in my study only one sand skink was captured after more than 2 years post-marking, I do not know if this age of 8 years is atypical for a sand skink. It does show, however, the possibility of a sand skink lifespan of 8 years, longer than that estimated by either Telford (1959) or Sutton (1996).

Size Distributions

The size distributions on each site over all five years of the study generally show that the largest proportion of the sand skinks captured in the spring active season were those in the 50 to 60 mm snout-vent length size range (Figures 11-13). Assuming that those captured were representative of the composition of the entire populations during the spring seasons, the size distributions show that there were fewer juveniles in the population than adults. Kruskal-Wallis one-way ANOVAs indicated that there were no significant differences in size distributions among sites in any given year. There were also no differences in size distributions among years within any of the sites.

1999	Adults (N=52) Mean +/- 1 SD	Juveniles (N=11) Mean +/- 1 SD	All Individuals Range
Snout vent length (mm)	55.5 +/- 3.7	44.2 +/- 2.4	40.1 - 62.0
Tail length (mm)	45.1 +/- 13.4	38.0 +/- 8.6	10.4 - 67.4
Total length (mm)	102.3 +/- 17.9	84.9 +/- 9.4	64.4 - 191.0
Mass (g)	1.2 +/- 0.2	0.5 +/- 0.1	0.4 - 1.7

2000	Adults (N=52) Mean +/- 1 SD	Juveniles (N=24) Mean +/- 1 SD	All Individuals Range
Snout vent length (mm)	56.7 +/- 3.3	44.5 +/- 3.4	39.1 - 64.3
Tail length (mm)	49.1 +/- 12.1	36.2 +/- 14.5	9.3 - 66.5
Total length (mm)	106.5 +/- 12.0	80.6 +/- 16.2	53.5 - 127.3
Mass (g)	1.4 +/- 0.2	0.6 +/- 0.1	0.3 - 2.1

Table 4. Body size measurements taken in 1999 and 2000 on adult and juvenile sand skinks.

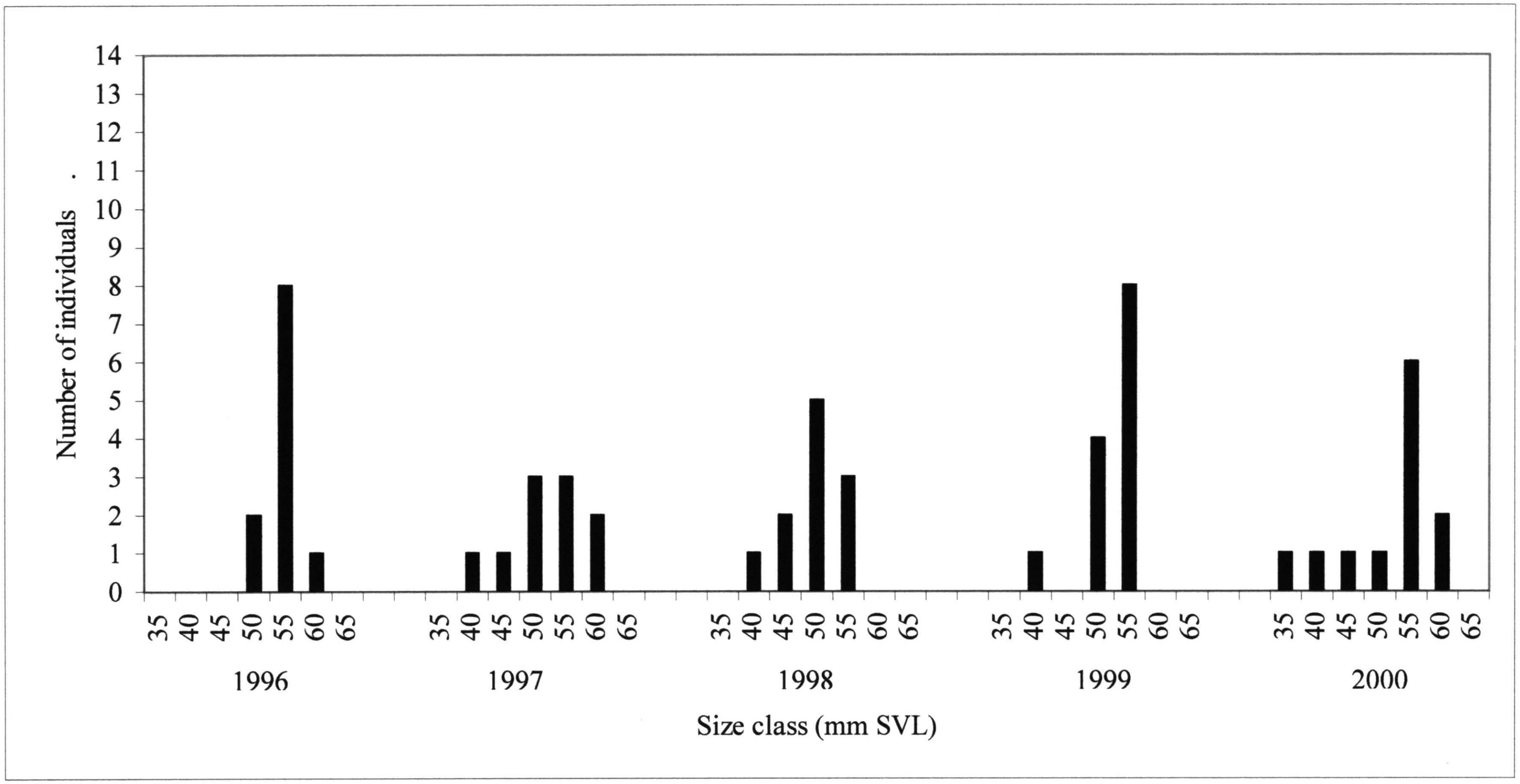

Figure 11. Size class distribution of sand skinks captured on site 1. Each size class begins at the labeled SVL (mm) and ends at the next labeled SVL (mm). Same year sand skink recaptures were excluded.

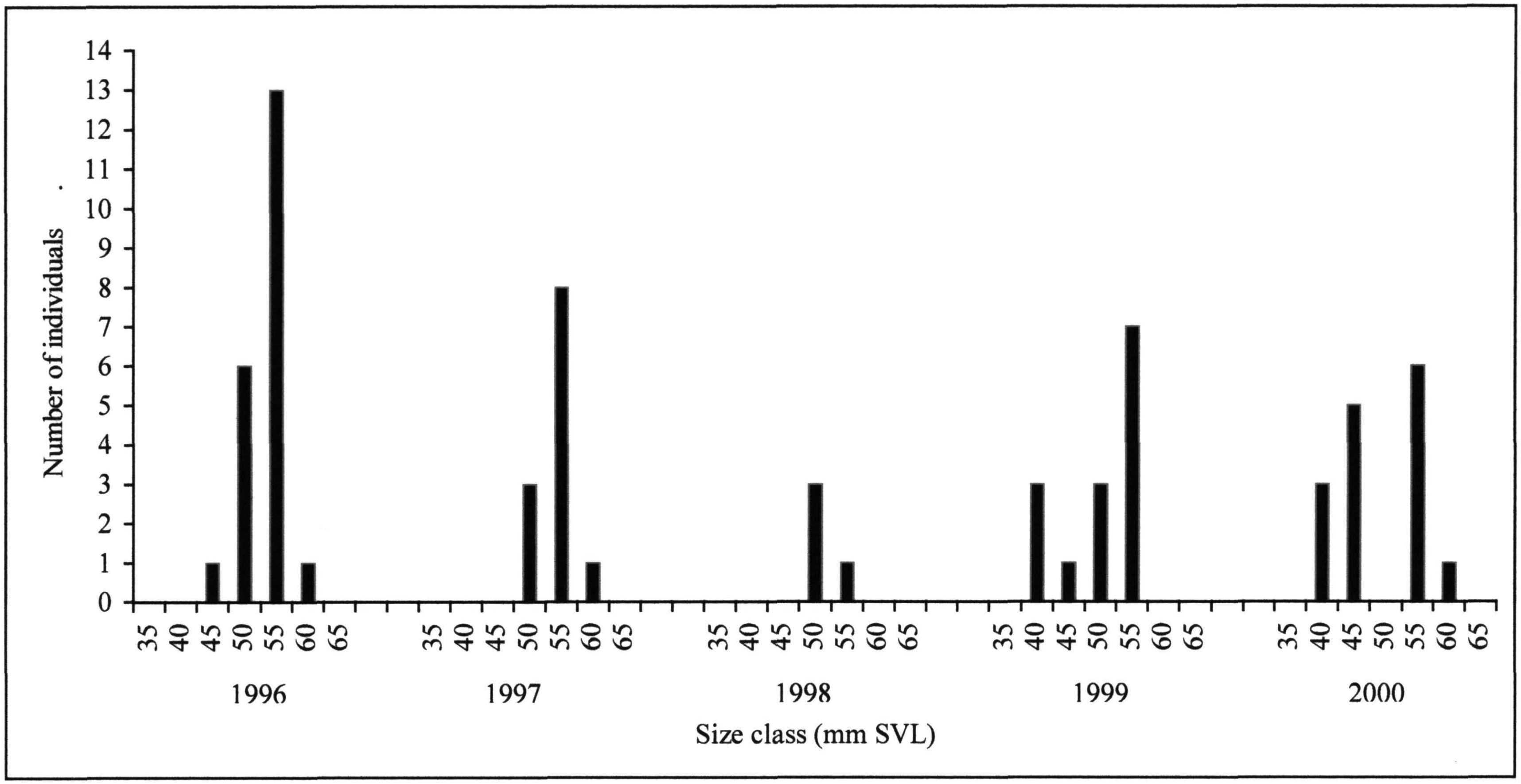

Figure 12. Size class distribution of sand skinks captured on site 2. Each size class begins at the labeled SVL (mm) and ends at the next labeled SVL (mm). Same year sand skink recaptures were excluded.

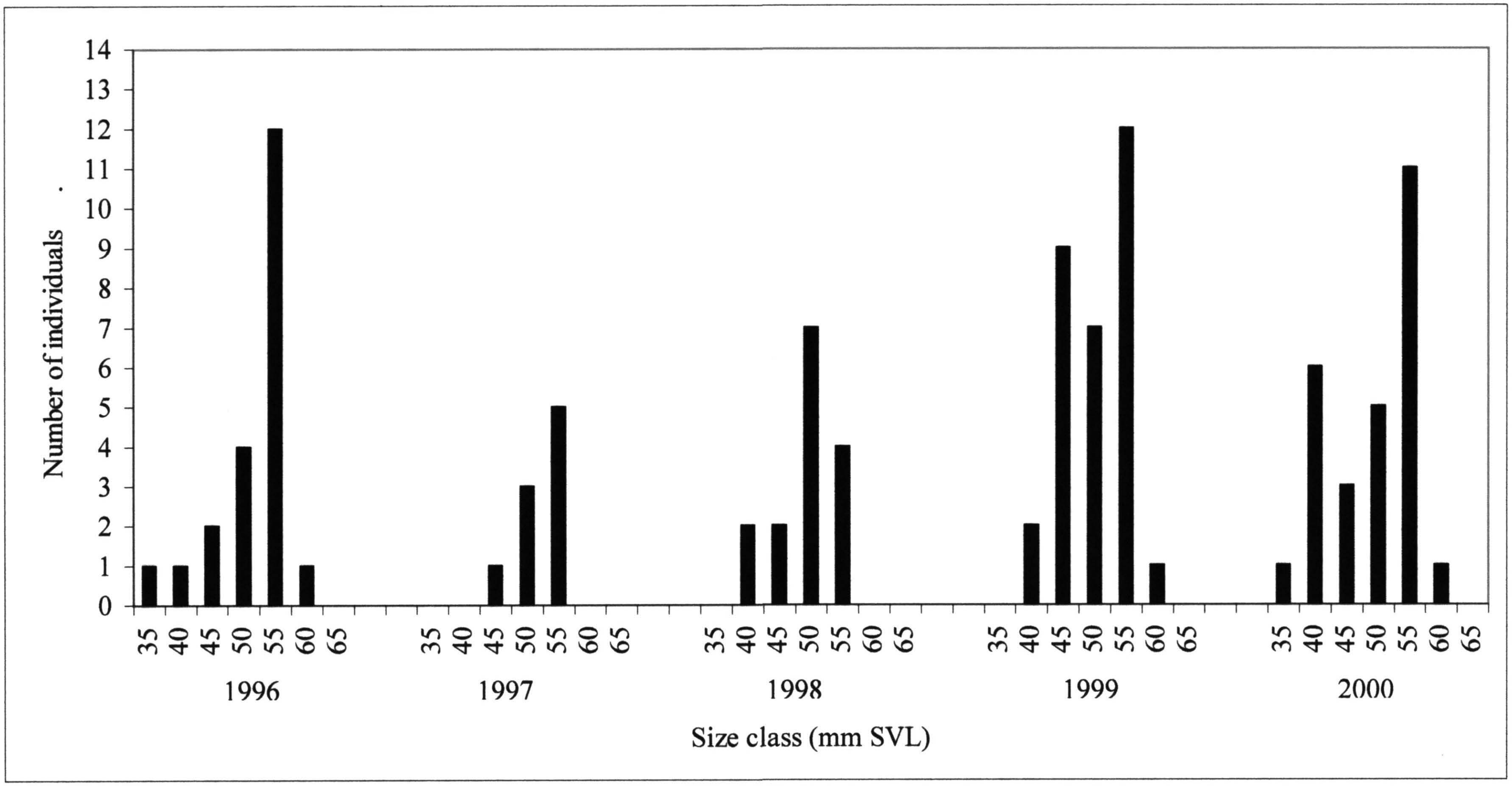

Figure 13. Size class distribution of sand skinks captured on site 3. Each size class begins at the labeled SVL (mm) and ends at the next labeled SVL (mm). Same year sand skink recaptures were excluded.

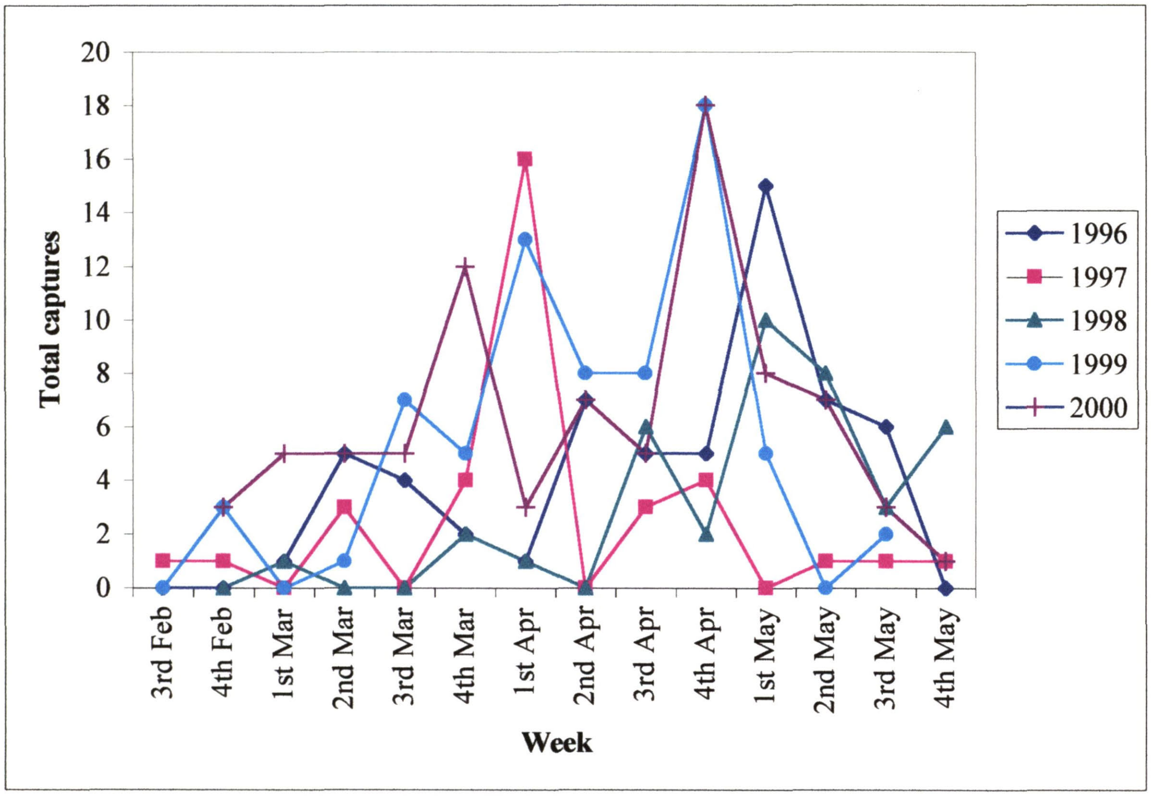

Figure 14. Total number of sand skinks captured by week in 1996-2000 on all sites. Data from 1996-1998 are from Navratil, 2000.

Activity Period

Sand skinks were most active from early March to late May, with peak activity in most years in mid-late April (Figure 14). During all years except 1997, sand skink activity showed a smaller peak in activity followed by a larger peak. Telford (1959) reported a similar increased active period for sand skinks (early March to early May); the activity period observed on my sites began and ended about two weeks later than reported by Sutton (1996)(mid-February to late April).

Comparisons Among Treatments and Sites

Sand skink captures made on each site and each treatment from 1996 to 2000 were divided into first time captures and same and other year recaptures (Table 5). First time captures were defined as those that had never been captured before and same year recaptures as those that had been captured earlier that season and recaptured in the same season.

Sand skink captures were also divided into adult and juvenile captures that were made on each site on each treatment plot. On site 1, there were consistently fewer captures made in the harvest plot than either the control or burn plots over the five years of the study (Figures 15-17). Recall that the treatment plot boundaries were drawn based on known sand skink presence, so sand skinks did exist in approximately equal numbers in all areas of the site before treatment. It appears that, in the site 1 harvest plot, it may be several more years before it is hospitable again to significant sand skink occupation. The reverse was true on site 2, where sand skink captures decreased on the control and burn plots over the years while captures made on the harvest plot increased, especially in the last two years of the study (Figure 16). On site 3, in general, the control plot contained more sand skinks than either the burn or harvest plots in most years, but on the harvest plot there was a steady increase in the number of sand skinks captured as the vegetation recovered from clear cutting (Figure 17). Nearly twice as many sand skink were captures made on site 3 as on site 1 or site 2, despite the fact that site 3 was intermediate in size. The number of juvenile captures were not different among

		CONTROL				BURN				HARVEST				**Total captures**
		1st time captures	other yr recaptures	same yr recaptures	total captures overall	1st time captures	other yr recaptures	same yr recaptures	total captures overall	1st time captures	other yr recaptures	same yr recaptures	total captures overall	
Site 1	1996	3	-	0	3	8	-	0	8	0	-	0	0	11
	1997	8	0	0	8	1	0	0	1	1	0	0	1	19
	1998	8	0	0	8	3	0	0	3	1	0	0	1	23
	1999	5	1	0	6	7	0	0	7	2	0	0	2	28
	2000	4	2	2	8	6	1	1	8	2	0	1	3	35
Site 2	1996	6	-	4	10	8	-	1	9	8	-	4	12	31
	1997	3	1	1	5	4	0	0	4	5	0	0	5	23
	1998	2	1	0	3	1	0	0	1	3	0	0	3	11
	1999	3	0	0	3	6	0	1	7	5	1	0	6	26
	2000	1	1	0	2	2	0	0	2	10	3	2	15	23
Site 3	1996	13	-	1	14	3	-	0	3	5	-	0	5	22
	1997	5	0	0	5	1	0	0	1	5	0	0	5	17
	1998	10	0	0	10	3	0	0	3	6	1	1	8	34
	1999	11	3	0	14	11	1	1	13	9	0	0	9	63
	2000	10	3	0	13	2	2	1	5	15	3	3	21	57
Total		92	12	8	112	66	4	5	75	77	8	11	96	423

Table 5. Sand skink captures from 1996 to 2000 in each treatment plot of each site (1996-1998 data from Navratil, 2000). Numbers include dead individuals, and do not include those captured by Navratil in the fall seasons of 1996 and 1997.

treatments on any of the sites over all years, as indicated by all possible comparisons between treatments with Mann-Whitney U tests ($p \geq 0.10$ on all sites). The number of juvenile captures within the harvest plots was different among years (Kruskal Wallis Test, $H = 9.191$; $p = 0.05$). Juveniles appeared to be moving into the harvest plots as the vegetation recovered. In 2000, the percent juvenile captures of the total captures in the harvest plots was much higher (39%) than in other plots (control plots:24%;burn plots:8%) and nearly double that found in more mature scrub by Sutton (1996)(23%) and by Telford (1959;1998)(16% and 18%, respectively).

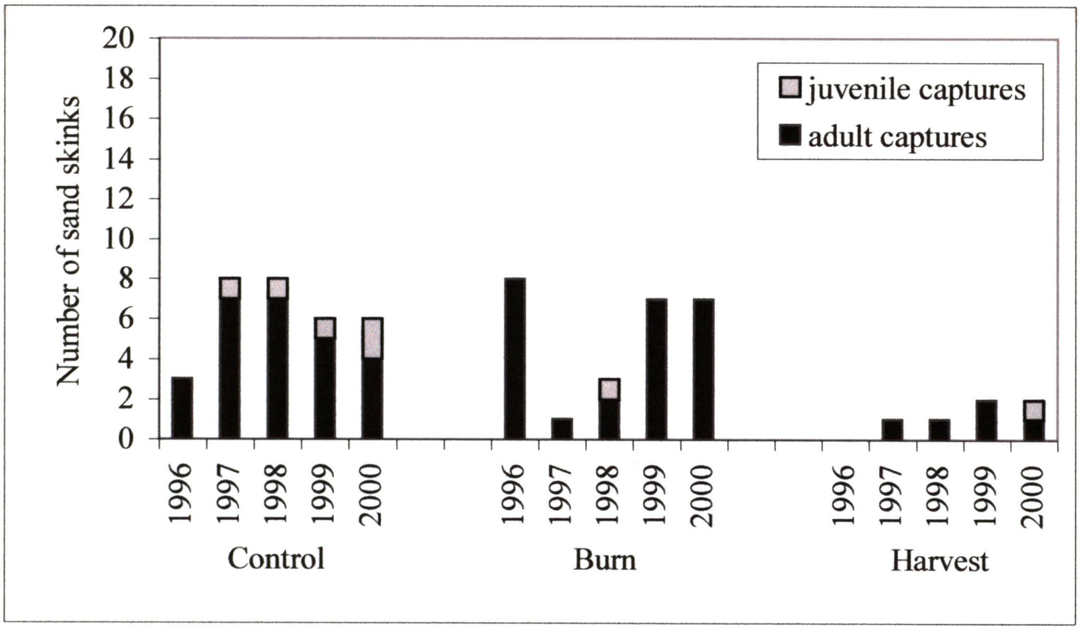

Figure 15. Adult and juvenile captures made on site 1 during 1996 to 2000 on all treatment plots (1996-1998 data from Navratil, 2000). Same year recaptures were excluded, as well as fall captures by Navratil in 1996 and 1997.

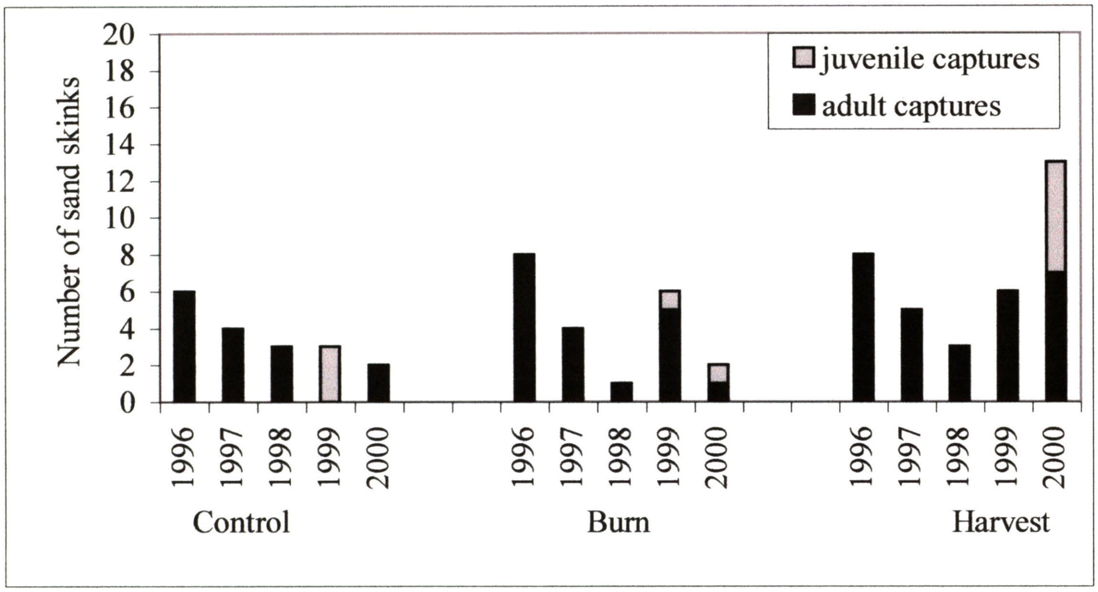

Figure 16. Adult and juvenile captures made on site 2 during 1996 to 2000 on all treatment plots (1996-1998 data from Navratil, 2000). Same year recaptures were excluded, as well as fall captures by Navratil in 1996 and 1997.

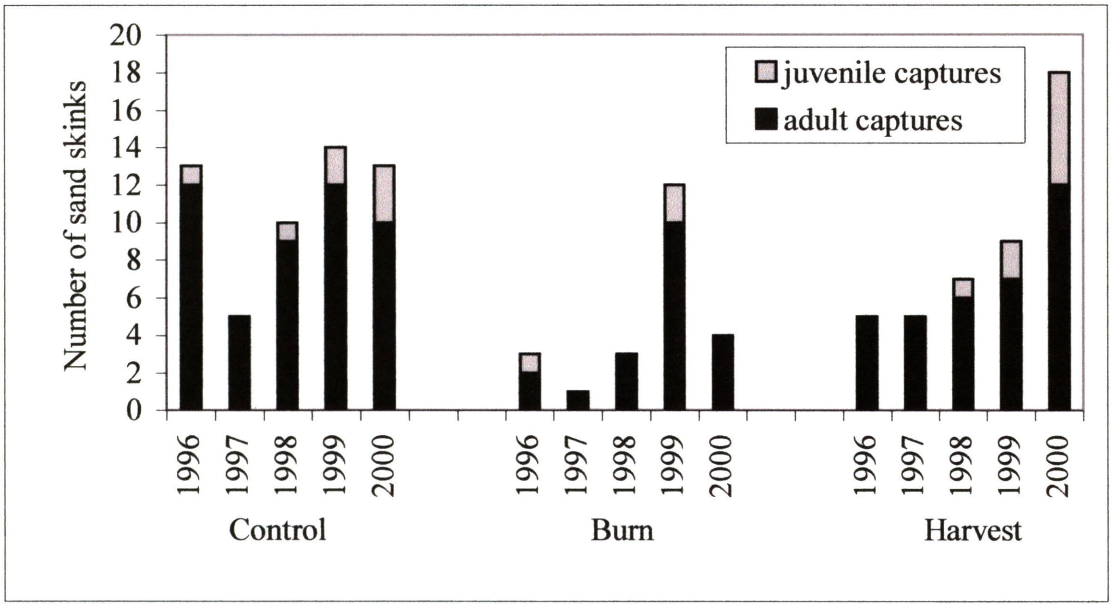

Figure 17. Adult and juvenile captures made on site 3 during 1996 to 2000 on all treatment plots (1996-1998 data from Navratil, 2000). Same year recaptures were excluded, as well as fall captures by Navratil in 1996 and 1997.

		Chi-squared value	p value
All sites combined	1996	9.710	p<.01
	1997	3.813	ns
	1998	5.600	ns
	1999	2.324	ns
	2000	12.463	p<.005
		Chi-squared value	p value
Site 1	1996	8.909	p<.05
	1997	6.250	p<.05
	1998	6.500	p<.05
	1999	3.125	ns
	2000	2.632	ns
Site 2	1996	0.452	ns
	1997	0.154	ns
	1998	0.286	ns
	1999	1.625	ns
	2000	23.273	p<.001
Site 3	1996	13.300	p<.01
	1997	2.909	ns
	1998	4.900	ns
	1999	1.167	ns
	2000	8.829	p<.025

Table 6. Chi-square tests for independence among the three treatments within each year in terms of sand skink captures. Degrees of freedom for all tests were 2.
P values greater than 0.10 are denoted by "ns".

I performed Chi-square tests to determine whether the number of sand skink captures in each treatment was different than that expected if there was no difference among treatments (Table 6). In most years, treatments did not different from one another in number of sand skink captures. On site 1, differences existed among treatments because only one or no captures were made in the harvest plot during those years, while several captures were made on the other treatment plots (Table 5). In later years, however, more captures began to be made in the harvest plot, and consequently no significant differences were detected between the harvest plot and the control or burn plots. On sites 2 and 3, a similar phenomenon occurred in that distinct differences among treatment plots were not observed until the last year, 2000. On site 2 in 2000, more captures were made in the harvest plot (15 total) than either the burn (two total) or control plots (two total). On site 3 in 2000, 21 total captures were made in the harvest and only five in the burn and 13 in the control. In other years, these differences were not so pronounced and, in fact, sometimes there were more sand skink captures in the burn plot than the harvest plot on sites 2 and 3 (Table 5).

	Plot	Chi-squared value	p value
All sites combined	Control	6.974	ns
	Burn	18.986	p<.001
	Harvest	33.872	p<.001
	Plot	Chi-squared value	p value
Site 1	Control	2.688	ns
	Burn	7.630	ns
	Harvest	3.714	ns
Site 2	Control	9.364	p<.10
	Burn	8.083	p<.10
	Harvest	18.977	p<.001
Site 3	Control	7.000	ns
	Burn	17.077	p<.005
	Harvest	22.818	p<.001

Table 7. Chi-square tests for independence among years within treatments in terms of sand skink captures. Degrees of freedom for all tests were 4. P values greater than 0.10 are denoted by “ns”.

Different numbers of sand skink captures were made in different years. I performed Chi-square tests to test for independence among years within each treatment plot (Table 7). The variation among years in the control plots was not significant on site 1 and 3, but sand skink captures were different among years on site 2. On site 2, however, the variation among years was significant on all treatment plots at the $p=0.10$ level in the control and burn plots, and with a stronger difference ($p<0.001$) among years in the harvest plot. In addition to the variation among years on site 2, sand skink captures were not the same in all years on the burn and harvest plots of site 3.

Natural History Comparisons

Among-treatment comparisons were made of mass, SVL (snout-vent length), and total length measurements of sand skinks captured (Figures 18-20). Same year recaptures were excluded to avoid duplication of individuals within years in the data set. A Mann-Whitney U test showed that the sand skinks captured in the burn plots weighed significantly more than those captured in the control plots (Mann-Whitney $U = 545.5$; $p = 0.0059$). The sand skinks captured in the burn plots were also significantly larger than those captured in the harvest plots (Mann-Whitney $U = 656.5$; $p = 0.024$). No difference existed among treatments in measurements of total length (Kruskal Wallis $H = 1.56$; $p = 0.458$). These results are unlike those found in previous years, where no differences among treatments in any measurement were detected (Navratil, 2000).

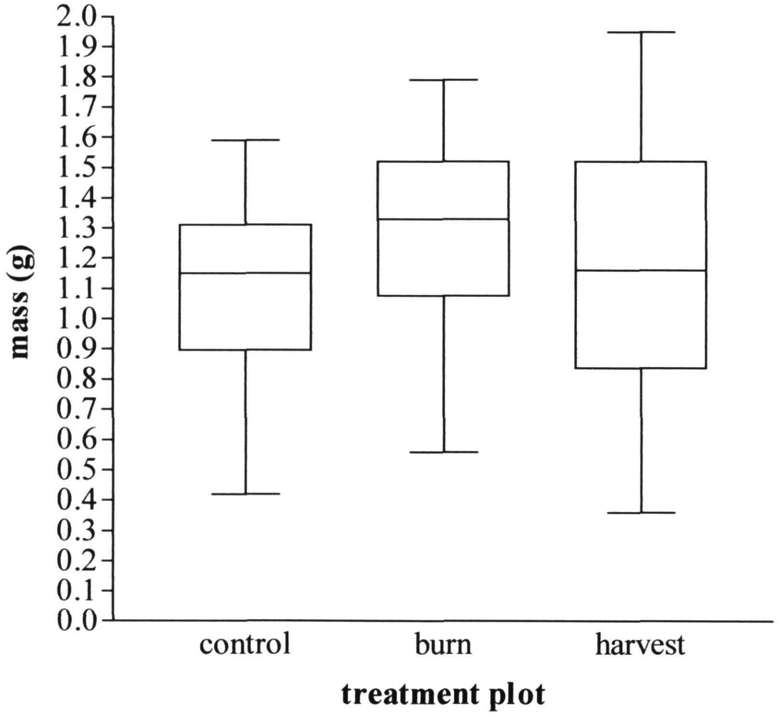

Figure 18. Mass of sand skinks captured in 1999 and 2000 on all sites.

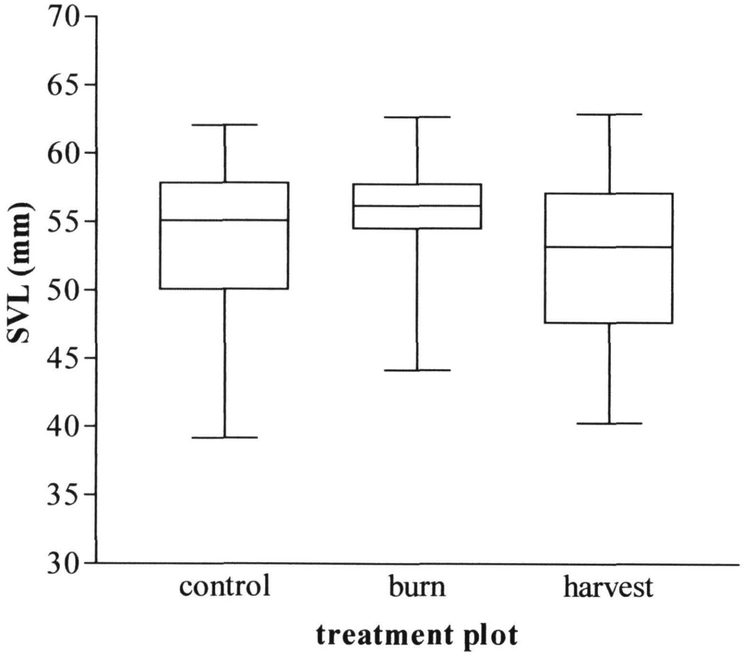

Figure 19. Snout-vent length (SVL) of sand skinks captured in 1999 and 2000 on all sites.

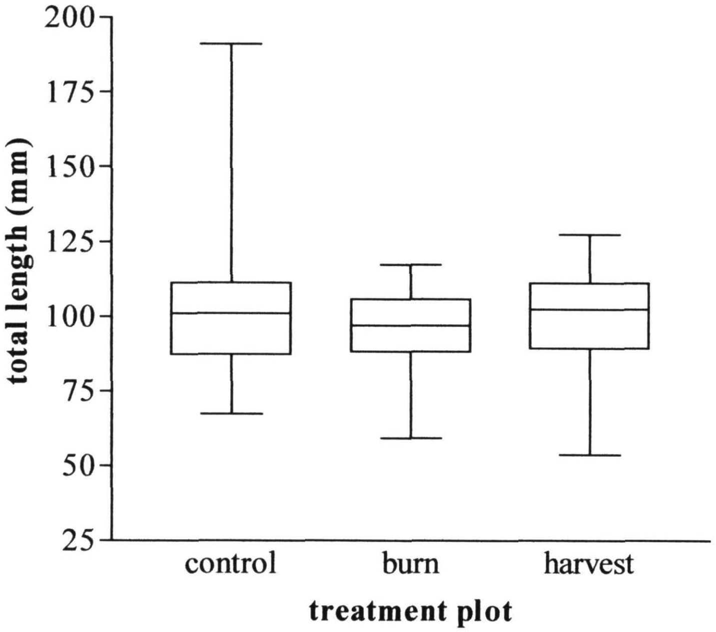

Figure 20. Total length of sand skinks captured in 1999 and 2000 on all sites.

Recapture Data

Some individual sand skinks were recaptured in subsequent years after original capture, making some study of sand skink growth and movement possible. Recapture rate (percent of the total captures which were recaptured sand skinks) varied with year and by site. The most reliable recapture data are from 1999 and 2000, because recaptures in these years were those marked with the fluorescent polymer which was more easily distinguished than the cauterized brands used prior to 1998. The recapture rates were higher in 2000 than 1999 because they included individuals marked in 1998 as well as 1999 (Table 8). It is interesting to note, however, the variability in recapture rates among sites and treatments (Table 9). The greatest recapture rates occurred on site 3 in 1999 and site 2 in 2000. Site 3 was the only site where recaptures were ever made on all three treatments (year 2000).

Growth and Movement

One advantage to marking animals for future identification as recaptured individuals is the fact that information about growth can be gleaned. Size-based age estimates are difficult to determine in sand skinks and very little data on known-aged individuals exist, so I chose not to graph sand skink size against estimated age. Instead, I used recapture data to plot the change in SVL of sand skinks between initial capture and subsequent capture against the SVL at initial capture (Figure 21), because doing so would show a slow-down in growth as sand skinks became larger. Between-capture intervals

	Year marked		
Year recaptured	1998	1999	2000
1999	5	2	
2000	3	11	5

Table 8. Numbers of recaptured sand skinks in 1999 and 2000 and the years in which they were marked.

1999				
	Control	Burn	Harvest	Total
Site 1	12.5 %	0.0	0.0	5.9
Site 2	0.0	0.0	16.7	6.7
Site 3	23.1	8.3	0.0	11.8
Total	16.7	4.0	5.9	9.1

2000				
	Control	Burn	Harvest	Total
Site 1	33.3 %	14.3	0.0	20.0
Site 2	50.0	0.0	26.7	27.8
Site 3	18.8	60.0	11.8	21.1
Total	25.0	30.8	16.7	22.5

Table 9. Percentages of total sand skink captures that were recaptures (polymer-marked sand skinks) in 1999 and 2000 by site and treatment.

ranged from one week to 24 months. Sutton (1996) suggested that excessive handling could be detrimental to the growth of individuals. As a result, those recaptured within less than one month from original capture (4 sand skinks) were excluded from the data set used for the regression because any initial decreases in SVL could yield a misleading result by weighting that decrease equally with changes that occurred over much longer periods of time. The regression demonstrates that the larger an individual was at initial capture, the less likely it was to increase in length over time from that point. This phenomenon is consistent with the asymptotic growth curve estimated by Sutton (1996).

In regards to movement of the recaptured sand skinks, across all sites, nine marked individuals were recaptured within the same year from 1996 to 2000, and all of them were sand skinks was recaptured in the same trap. On site 1, every sand skink that was captured and then recaptured in a different year was also found in the same trap as originally captured. Site 3 not only had more recaptured sand skinks, but there also seemed to be more movement, especially to non-adjacent areas (Table 10). These data suggest that, in general, sand skinks did not often move much farther than about 35 meters (the distance between traps). Of the 48 total sand skink recaptures, only seven (14%) were recaptured in a different treatment plot than their original capture. Of these seven, only one sand skink was not captured in an adjacent plot. All recaptures in different plots from original capture were between years, so this indicates that sand skinks may be more likely to move larger distances between active seasons, but not within an active season.

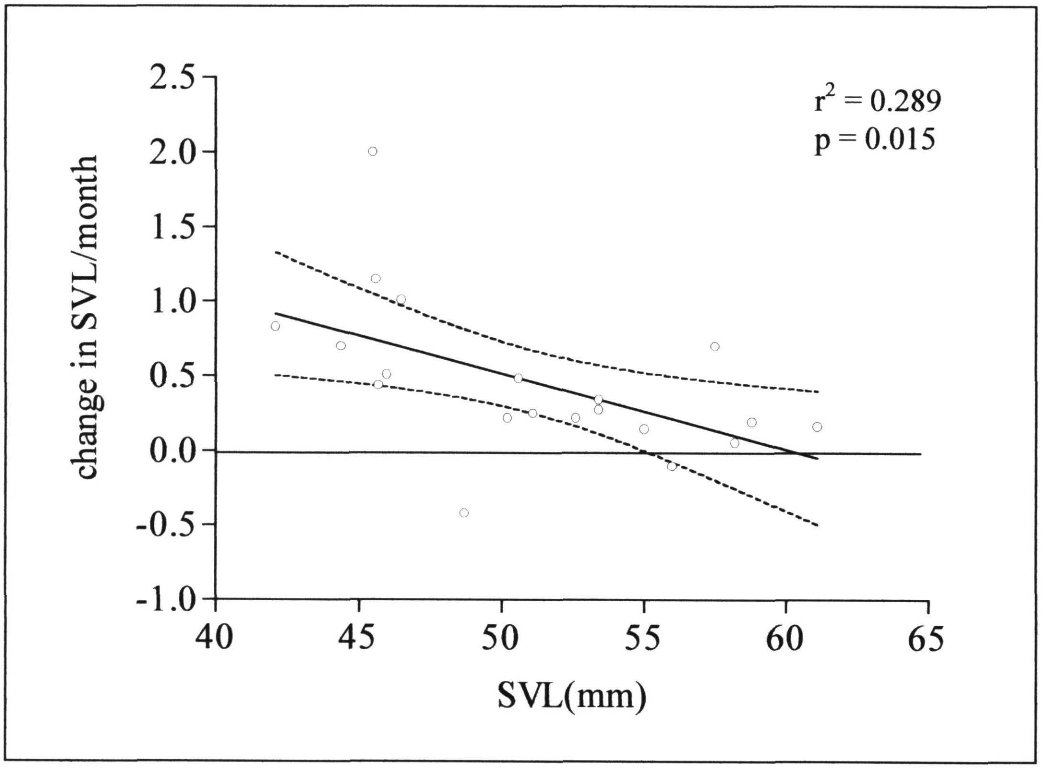

Figure 21. Tendency for change in SVL over time to decrease as sand skinks grow larger. Upper and lower lines signify the 95% confidence interval. One outlier was excluded and three other sand skinks were also excluded to bring all between-capture intervals in the data set to at least one month. Data are from 1996 to 2000.

	Same year (all same trap)	Different years		
		Same trap	Different adjacent trap	Different non-adjacent trap
Site 1	3	2	0	0
Site 2	2	2	1	0
Site 3	5	1	3*	9

Table 10. Number of times sand skinks on each site were captured within the same year and different years, and where they were subsequently captured from 1996-2000. Numbers do not indicate number of individuals; the same sand skink could be counted more than once, for example, when captured four different years, twice in the same trap and twice in different traps. All sand skinks recaptured within the same year were recaptured in the same trap as originally caught. Data from 1996-1998 are from Navratil, 2000. * One sand skink was captured in an adjacent trap on the experimental site.

Coverboards

To gain information about the habitat use by sand skinks in areas between traps, I uniformly distributed 30 vinyl coverboards on each of the nine treatment plots. The ground beneath all 270 coverboards was checked for sand skink tracks once every two weeks from February to May of 1999. The number of coverboards showing tracks at some time during the February to May 1999 season varied among treatments as well as among sites (Figure 22). On sites 1 and 3, the control plots showed more sand skink activity in that more coverboards showed marks at some time during the sampling period in the control plots than in the harvest or burn plots. On site 2 however, the harvest plots

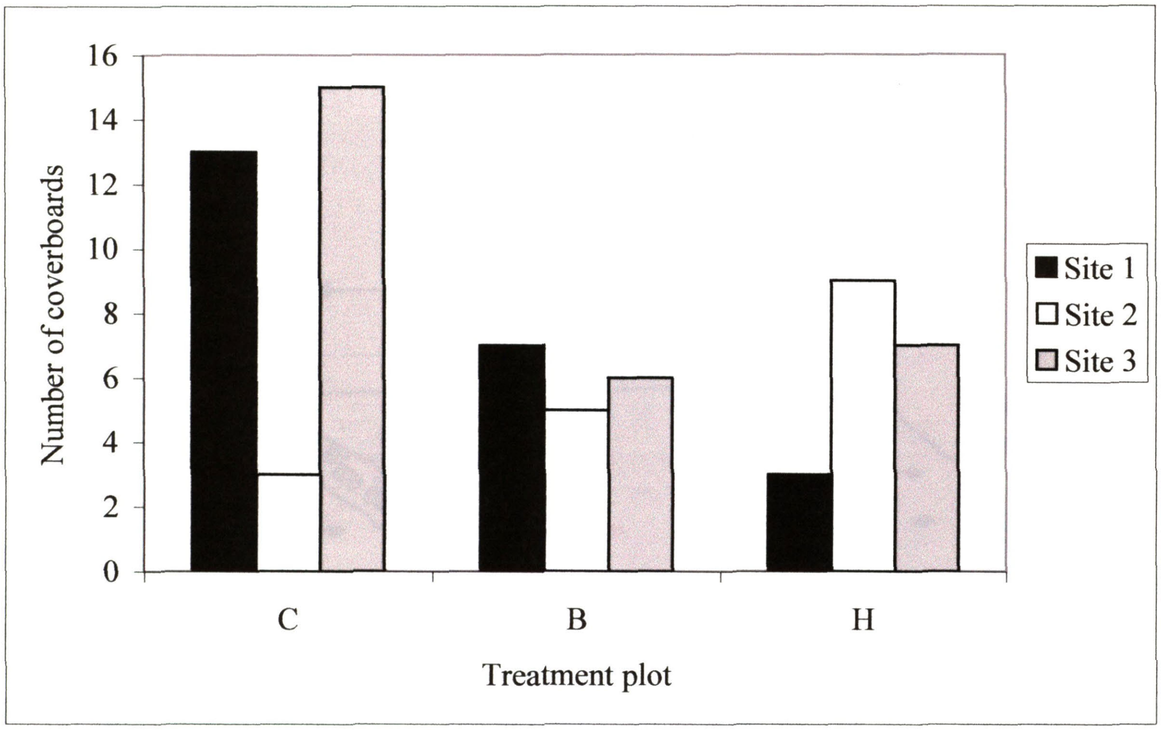

Figure 22. Number of coverboards out of 30 showing marks at some time within each treatment section on the three sites. Data are from the February to May 1999 sampling season. C = control plot, B = burn plot, and H = harvest plot.

showed more activity than either the burn or control plots. The coverboard data are consistent with the relative number of 1999 total captures on different treatment plots on site 1 (Table 5). On sites 2 and 3, however, the coverboard data and pitfall trap capture data were contradictory. The coverboards on sites 2 and 3 showed more activity in the harvest plots than the burn plots, whereas there were more total pitfall trap captures in the burn plots than the harvest plots in 1999 (Figures 16-17). The fact that the coverboard and pitfall trap data contradicted each other in some areas indicates that making definite conclusions about sand skink activity based on one sampling technique may not be advisable.

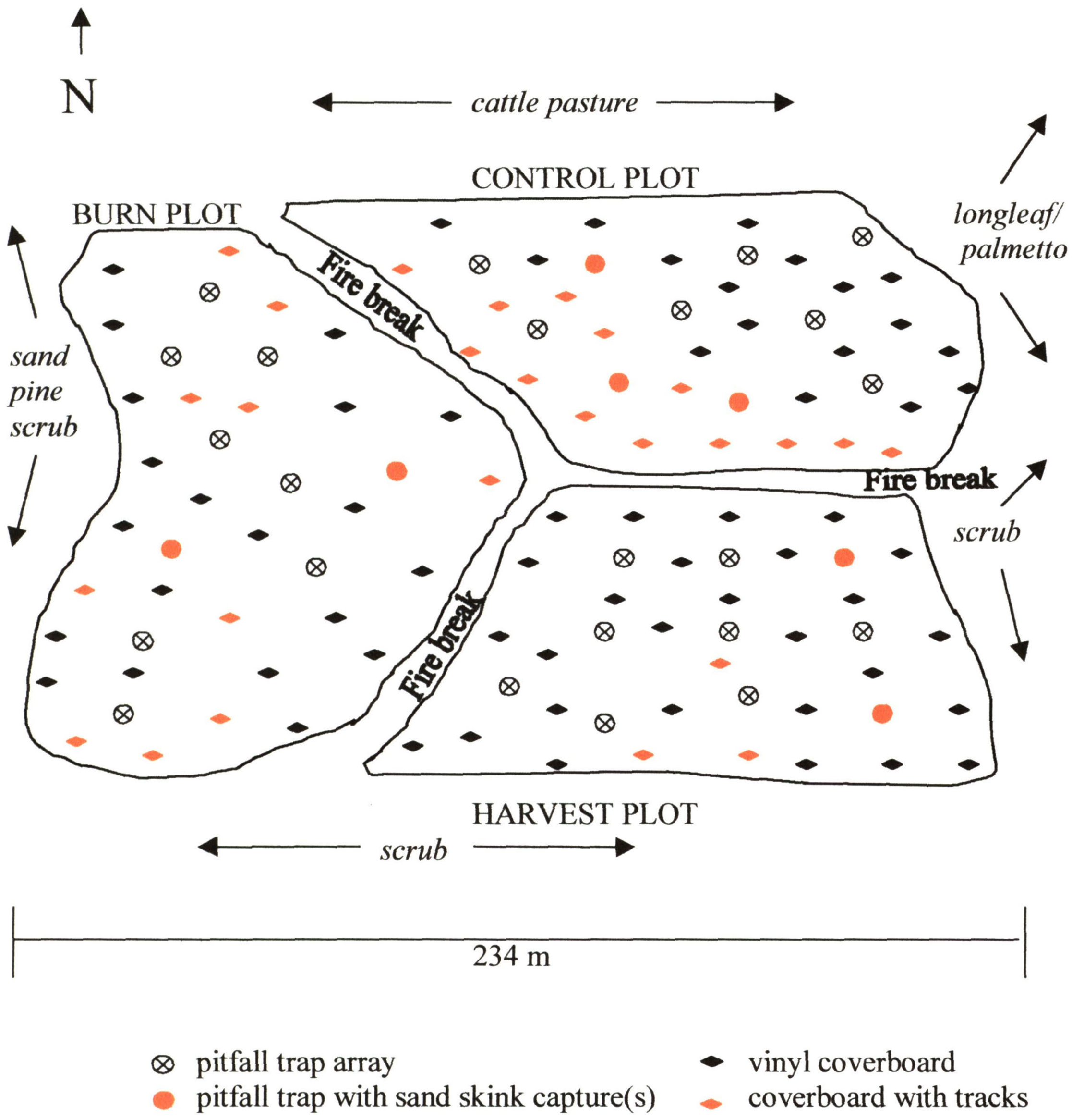

Figure 23. Diagram of site 1 showing the distributions of pitfall traps with sand skink captures in 1999 and coverboards with tracks at least one time in 1999.

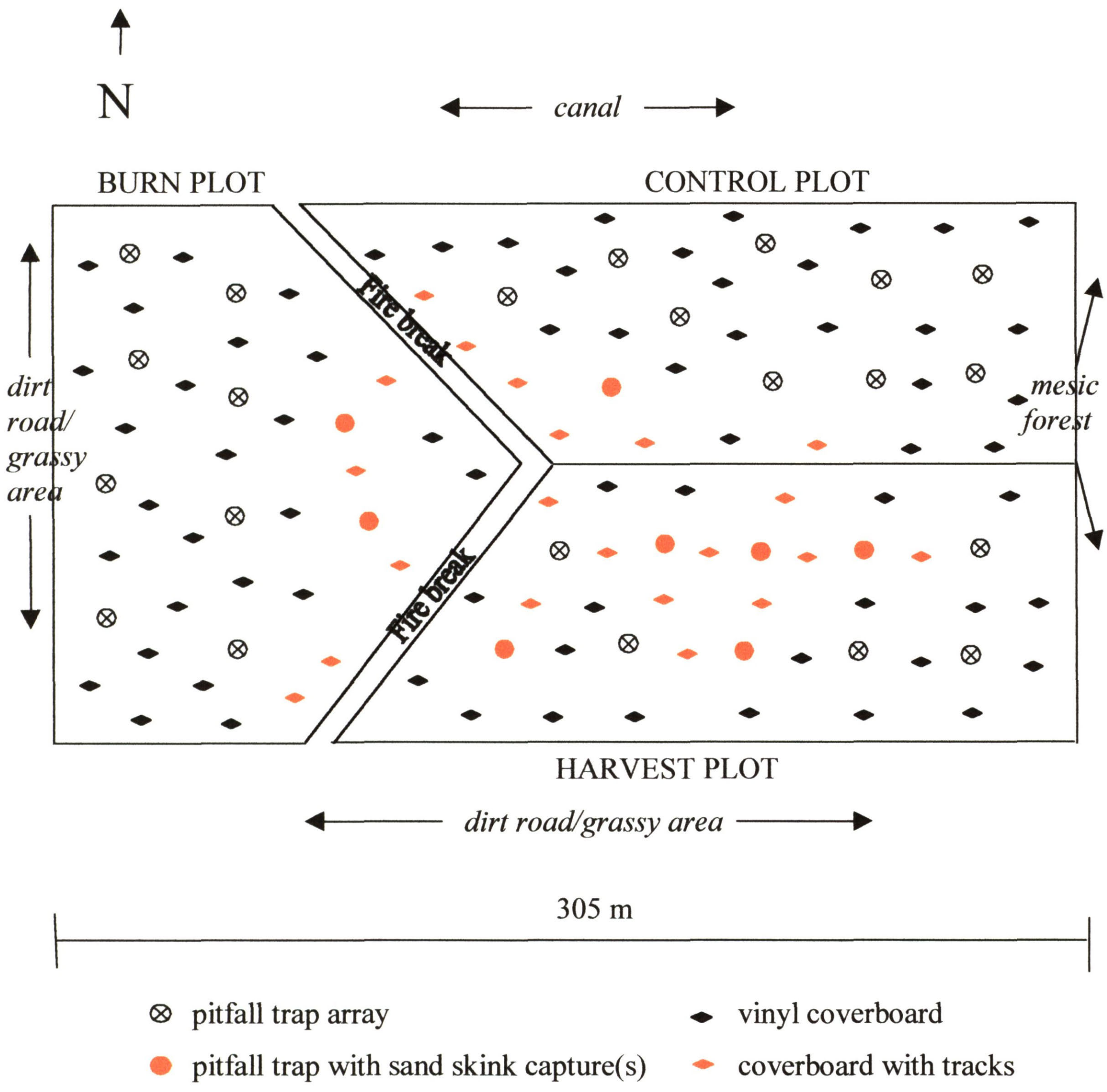

Figure 24. Diagram of site 2 showing the distributions of pitfall traps with sand skink captures in 1999 and coverboards with tracks at least one time in 1999.

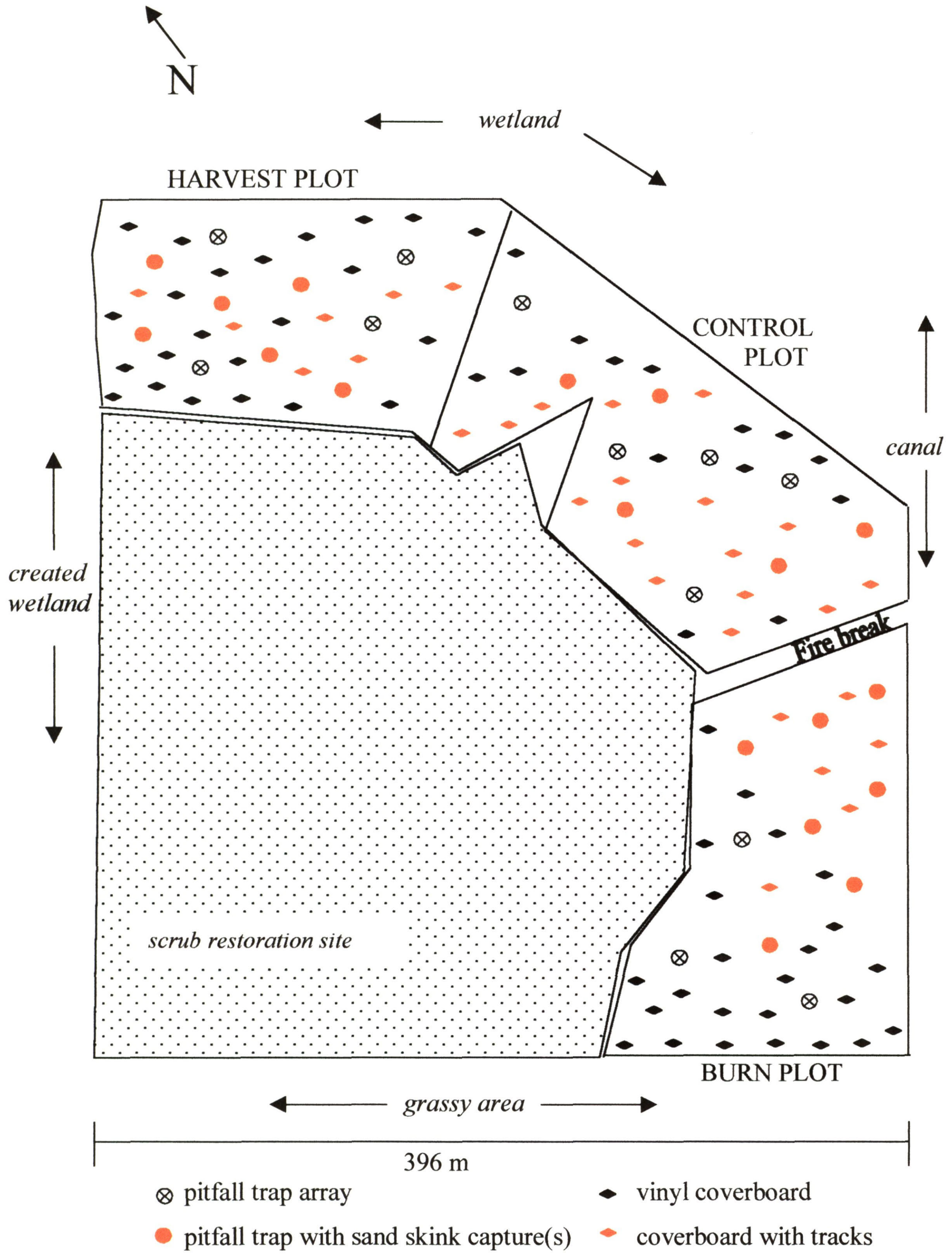

Figure 25. Diagram of site 3 showing the distributions of pitfall traps with sand skink captures in 1999 and coverboards with tracks at least one time in 1999.

The spatial distribution of coverboards showing marks appeared to differ among treatments and among sites (Figures 23-25). I used a statistical resampling technique to determine if the distributions of coverboards with tracks were nonrandom. I used only coverboards that were observed with tracks more than once to insure greater accuracy. Unfortunately, insufficient sample size prohibited analyses on all treatment plots except control plots of site 1 and site 3. For each control plot, I measured the distance between all pairs of coverboards after setting the distance between any two adjacent coverboards at a unit of one. The result was a matrix containing the distances between every possible combination of two coverboards. With each matrix, I calculated that distance between each coverboard with tracks and its nearest coverboard with tracks, then averaged these distances to obtain an average "nearest neighbor" distance. I then resampled (with replacement) the matrix 1000 times, and recalculated this average "nearest neighbor" distance each time, to yield a bootstrapped distribution from which I could obtain a probability for the existing average distance. A failure to reject the hypothesis of a random distribution of coverboards with marks was indicated by an insignificant p value. The coverboards with tracks were randomly distributed in the control plot of site 3 ($p=0.58$). On the control plot of site 1, however, the hypothesis of random distribution was rejected ($p<0.01$).

Despite the fact that statistical analysis of the distribution of coverboards showing activity could not be performed on all treatment plots, some interesting observations can still be made. For instance, on site 2, sand skinks were present in a centralized area on the site (Figure 2). Very unsuitable habitats (canals, dirt roads, and mowed grassy areas) nearly surround site 2, and the distribution of sand skink activity on site 2 may have been simply a function of sand skinks encountering inhospitable areas around the edges of the site and subsequently traveling in the opposite direction. The outside edges of the burn and control plots on site 2 were quite overgrown and the soil filled with dense tree roots (pers. obs.). In contrast to site 2, site 3 showed sand skink activity was observed throughout all plots on site 3 (Figure 24). Site 3, like site 2, is bordered primarily by unsuitable habitat as well (wetland, canal, and pasture). The large experimental site adjacent to site 3, however, may have provided area for the sand skinks to move through among the treatment plots. Also interesting is the fact that on all treatment plots on all sites, except on the site 1 harvest plot, wherever sand skinks were captured in pitfall traps, their presence was also detected by at least one adjacent coverboard. The detection of sand skinks by trap captures as well as coverboards in my study is consistent with the findings of Sutton et al. (1999) that the ability of coverboards to detect accurately sand skink presence is comparable to that of pitfall traps. In the site 1 harvest plot, only one sand skink was captured in each of the two traps where captures were made, indicating low densities which may explain the inability of nearby coverboards to detect their presence.

Recall that sand skink activity was given a rating each time a coverboard was checked, where 0=no tracks, 1=1-5 tracks, 2=approximately ½ of space covered by tracks, and 3=space completely covered by tracks. Average coverboard activity ratings varied among treatments as well as among sites (Figure 26). Mean ratings were low and the variances high because many coverboards never showed sand skink tracks when they were checked.

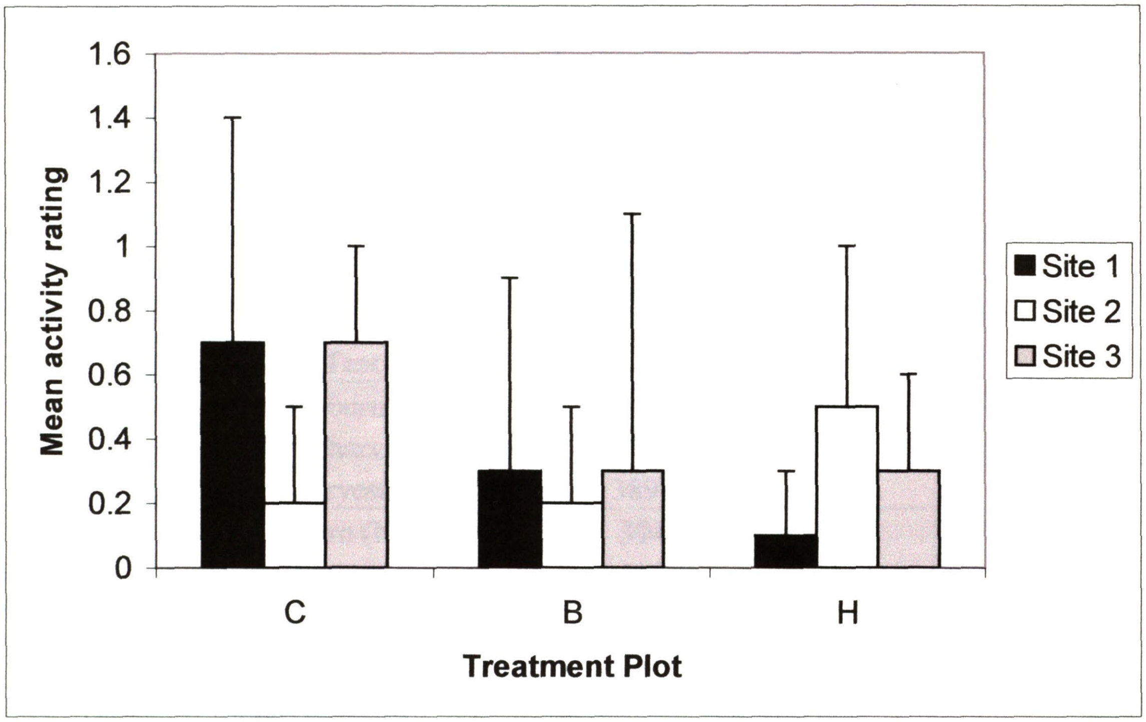

Figure 26. Ratings of sand skink activity under coverboards for the control, burn, and harvest sections of each site. Means are reported +/- 1 S.D. All data are from February to May 1999. See text for information on rating system. C = control plots, B = burn plots, and H = harvest plots.

To assess statistical differences in the average activity ratings among treatments, Kruskal-Wallis tests were performed on all sites combined and on each site individually (Table 11). The presence of significant differences among treatments on sites 1 and 3 ($p<0.01$ for both) prompted me to do Mann-Whitney tests on those sites to determine where the difference existed (Table 11). The differences in sand skink activity between the control and harvest plots were significant on both sites 1 and 3, meaning that there was significantly less sand skink activity detected on the harvest plots than on the control plots on those two sites.

	Test Statistic	**Significance Level 1**
Kruskal-Wallis Test		
All sites (N=270)	7.868	0.020*
Site 1 (N=90)	9.670	0.008**
Site 2 (N=90)	2.897	0.235
Site 3 (N=90)	9.255	0.010*
Mann-Whitney Test		
All sites, control-burn (N=180)	3408	0.078
All sites, control-harvest (N=180)	3327	0.034*
All sites, burn-harvest (N=180)	3897	0.748
Site 1, control-burn (N=60)	394.0	0.404
Site 1, control-harvest (N=60)	287.0	0.013*
Site 1, burn-harvest (N=60)	338.0	0.087
Site 3, control-burn (N=60)	313.0	0.039*
Site 3, control-harvest (N=60)	296.0	0.021*
Site 3, burn-harvest (N=60)	444.0	0.933

Table 11. Kruskal-Wallis and Mann-Whitney U tests performed on coverboard rating averages from 1999. Significance levels of $p < 0.05$ are marked with "*", and those of $p < 0.01$ with "**".

Distribution: Edge versus Middle of Sites

Sand Skink Detection

As indicated on the diagrams of the sites (Figures 5-7), non-scrub habitat such as canals or roads bordered one to all sides of individual sites. I examined the distribution of pitfall traps and coverboards that detected sand skinks. The distribution of traps and coverboards that detected sand skinks appeared to be centered more toward the middle of the sites than along the outside edges, particularly on site 2 (Figures 23-25). I asked if the proportion of pitfall traps and coverboards detecting sand skinks was higher in the middle of the sites than on the outside edges bordering non-scrub habitat. If higher detection along the outside edges existed, I asked how deeply into the site this difference in detection existed. To do the comparison between the edges and middle of the sites, I first drew a line at approximately 25m into the site (1 row of traps and coverboards) from the non-scrub edges and performed a G test to compare the likelihood of detection on the edge and the middle. If a significantly higher detection in the middle than along the edges at 25m existed, I increased the distance to 40m (2 rows of traps and coverboards), then 50m (3 rows of traps and coverboards), then 65m (4 rows of traps and coverboards) and performed the G test again each time. When the difference disappeared, I was then able to say that an edge effect existed at least into the site to the distance at which the last significant difference was found. I could detect no edge effect on site 1, but I could detect an edge effect on sites 2 and 3 (Table 12). The effect persisted to at least 50m on site 2 and 50-65m on site 3. Because site 3 was adjacent to a scrub restoration area (Figure 7), I tested the edge effect both with and without the edge that was adjacent to the scrub restoration area, and the two tests produced different results (Table 12).

Edge Width	Site 1	Site 2	Site 3	
			A	B
25m	0.407	0.001	0.023	0.078
40m	0.401	<.001	0.030	0.037
50m	1.000	<.001	0.324	0.013
65m	-	0.284	-	0.324

Table 12. Results (p values) of G tests for higher detection in the middle of sites than along non-scrub edges of different widths. "A" refers to the exclusion of the restoration site adjacent to site 3 as scrub habitat, and "B" refers to the inclusion of the restoration site as scrub habitat.

Microhabitat Variables

The microhabitat features of the middle of the sites may constitute the best habitat for the sand skinks within the sites, so I compared the measured microhabitat features of the middle with those of the outside edges of those two sites that exhibited an edge effect in terms of sand skink distribution. I compared percent cover by scrub species, percent bare ground, mean litter depth, mean understory vegetation height, and mean soil compaction between the middle and edge of sites 2 and 3. The edge on site 3 was set at approximately 40m. Percent cover by scrub species was slightly less in the middle of the sites, but was not statistically significant (Mann-Whitney U = 303.5, p = 0.376). Significant differences existed in mean understory vegetation height, percent bare ground, mean litter depth, and mean soil compaction between the outside edges and the middle of sites 2 and 3 (Table 13). Mean vegetation height and mean litter depth were both higher along the non-scrub edges than in the middle of the two sites. Understory vegetation and percent ground cover were correlated in other scrub sites (Collazos, 1998), and Hill (1999) found that sand skink abundance was negatively correlated with litter cover. Understory vegetation has also been found to be negatively correlated with the presence of termites, which are a food source to sand skinks (Collazos, 1998). Percent bare ground was higher in the middle of two of my sites, and mean soil compaction was lower in the middle of the sites. Loose surface sands have been found to be negatively correlated with soil temperature at depths of 5, 10, and 15 cm, and sand skink density was negatively correlated with soil temperature at the same depths (Collazos, 1998), so it is logical that sand skinks would be found more often in areas with loose surface sands.

Areas with large amounts of loose surface sands may offer better opportunities for the sand skink to thermoregulate under the summer sun in Florida scrub. Low compaction areas also represent areas where the sand skinks can spend less energy moving through the soil, because there is less penetration resistance. Collazos (1998) found that sand skinks density was positively correlated with amount of large soil particle sizes, which was itself negatively correlated with soil compaction. Areas with large soil particles sizes, and therefore low soil compaction, may be more likely to be occupied by sand skinks, because they offer less penetration resistance. The information available from this and other studies indicate that sand skinks are most often found in areas with large amounts of loose sand with large particles sizes, and with high amounts of bare ground but with some canopy (up to 18cm)(Table 13). They tend not to be found in areas with high soil moisture, high soil temperature, small soil particle size, and high soil compaction. They are also not found in areas with substantial litter cover and understory vegetation.

	Edge	Middle	p value
Percent cover by scrub species (%)	89.4 +/- 35.7	96.8 +/- 50.9	0.376
Mean understory vegetation height (cm)	106.0 +/- 136.6	51.6 +/- 31.8	0.041*
Mean litter depth (cm)	6.02 +/- 6.59	3.78 +/- 4.70	0.035*
Percent bare ground (%)	16.5 +/- 21.2	29.5 +/- 24.4	0.028*
Mean soil compaction (kg./sq. cm)	.119 +/- .039	.101 +/- .037	0.002**

Table 13. Differences between outside edges and middle of sites 2 and 3 in terms of various microhabitat characteristics measured. P values are from non-parametric and parametric one-tailed t tests. Those p values less than 0.05 are denoted with a single asterisk and that less than 0.01 is denoted with a double asterisk.

	Spearman's r	significance level	study
Positive correlations			
canopy density	0.355 to 0.374	*	Collazos, 1998
percent bare ground	0.413	***	this study
amount of loose sand	0.409	*	Collazos, 1998
large soil particle size	0.193 to 0.515	*	Collazos, 1998
Negative correlations			
understory vegetation height	-0.294	*	this study
litter cover	-0.402 to -0.452	**	Hill, 1999
soil moisture A	-0.560	*	Collazos, 1998
B	-0.368	*	Hill, 1999
soil temperature, 5 cm depth	-0.551	*	Collazos, 1998
soil temperature, 10 cm depth	-0.572	*	Collazos, 1998
soil temperature, 15 cm depth	-0.557	*	Collazos, 1998
small soil particle size A	-0.324 to -0.606	*	Collazos, 1998
B	-0.478	**	Hill, 1999
soil compaction	-0.243	*	this study

Table 14. Significant correlations between various microhabitat variables and sand skink abundance in three studies. Significance levels at the $p < 0.05$ level are denoted by "*", the $p < 0.005$ level denoted by "**", and the $p < 0.001$ level denoted by "***". Collazos (1998) measured canopy density at heights of 6 and 18 cm above the ground.

Soil Compaction

I measured soil compaction at every trap and every coverboard because the degree of soil compaction in an area could influence spatial distribution of the sand skinks. Data on the degree of soil compaction on the sites and within the treatments could shed light on the nature of the soil the sand skinks were encountering on the sites. Mean compaction levels of each trap and coverboard on each treatment plot are shown visually in Figure 27. Figure 28 displays the average degree of soil compaction on each site and treatment. Mann-Whitney tests were performed to detect differences in compaction among treatments within sites, utilizing the average (of 4 points at each sampling area) surface compaction measured at every trap and coverboard (Table 15). The greatest differences were found within site 3, where the soil compaction on the burn plot was the greatest and on the harvest, the least.

The presence of sand skinks and low soil compaction could be correlated, so I performed nonparametric Spearman's rank correlations on the average compaction measurements at every trap and sand skink captures in 1999 and 2000 to determine if sand skink captures and low soil compaction were correlated on my sites (Table 16). It is interesting to note that, although often insignificant, the majority of the correlations were negative, meaning that low soil compaction was related to higher sand skink captures. The significant negative correlation between compaction and sand skink captures on site 3 control plot is perhaps more meaningful in terms of sand skink distribution because the most captures of all the nine treatment plots in 1999 and 2000 were made in that control plot (Table 5). I also performed Spearman's correlations on soil compaction and the average coverboard ratings for sand skink activity. The results of these correlations are given in Table 17. Strong negative correlations were present between soil compaction and sand skink activity at coverboards on all three control plots, and on the burn plot of site 3 as well. These results perhaps are a better representation of what was occurring, because the coverboards were more numerous and spread throughout the sites, including the sites' outside edges where traps were scarce. In summary, where sample sizes were high, a negative correlation existed between soil compaction and sand skink presence in the control and burn plots, meaning sand skinks were found mostly in areas with loose soils. Significant correlations were not found in the harvest plots possibly because the

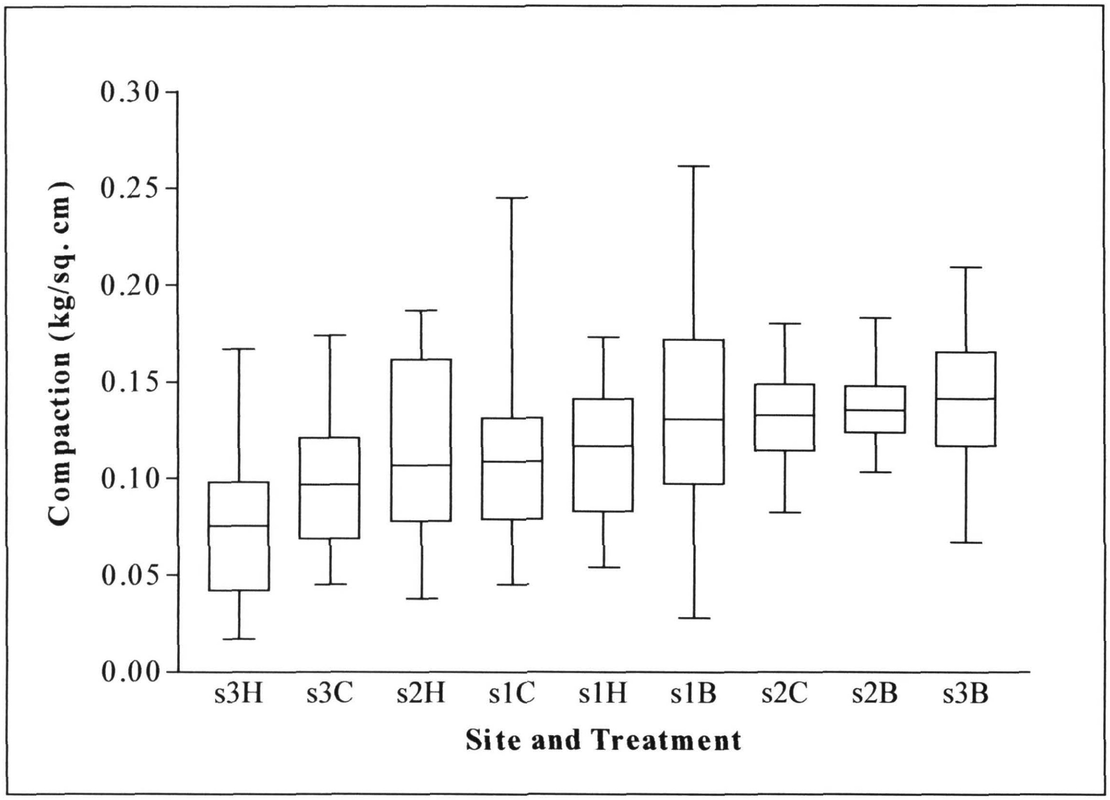

Figure 27. Box and whisker plots for mean soil compaction at every trap and coverboard (N=40 for each treatment plot). The notation "s1C" indicates site 1 control plot, and so on (C=control plot, B=burn plot, H=harvest plot).

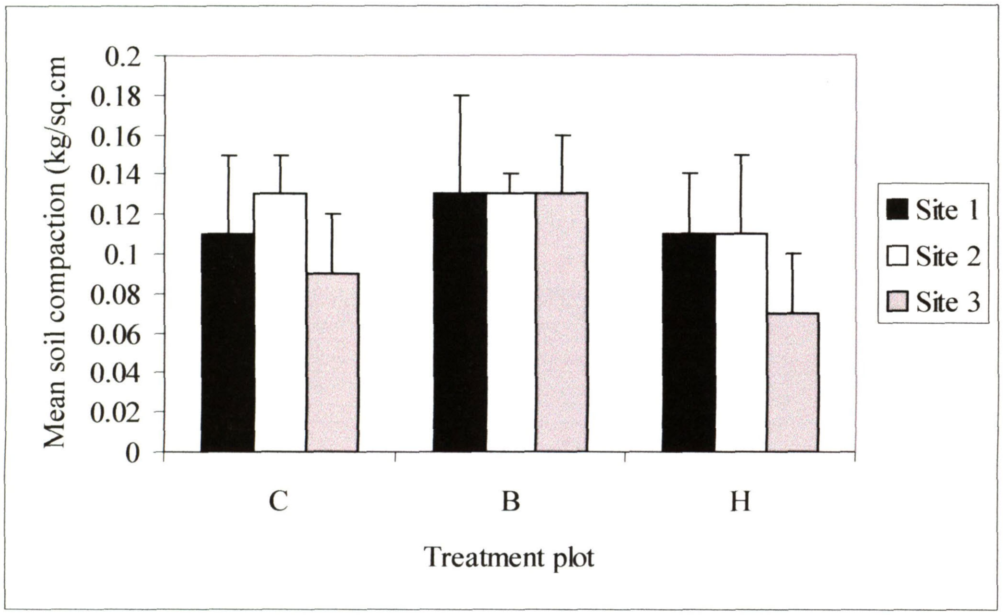

Figure 28. Soil compaction (kg/cm^2) by every treatment on the three sites. Means are given +/- 1 SD. C = control plots, B = burn plots, and H = harvest plots.

	Test Statistic, U	Significance Level
Mann-Whitney U Test		
Site 1, control-burn (N=80)	572.0	0.029*
Site 1, control-harvest (N=80)	718.0	0.433
Site 1, burn-harvest (N=80)	605.0	0.062~
Site 2, control-burn (N=80)	685.5	0.357
Site 2, control-harvest (N=80)	617.0	0.079~
Site 2, burn-harvest (N=80)	559.0	0.031*
Site 3, control-burn (N=80)	327.5	<.0001****
Site 3, control-harvest (N=80)	501.5	0.004**
Site 3, burn-harvest (N=80)	163.0	<.0001****

Table 15. Mann-Whitney U tests performed on soil compaction averages. Significance levels of $p < 0.05$ are marked with "*",those of $p < 0.01$ with "**", and those of $p < 0.0001$ with "****". Non-significant, but of interest, values are marked with "~".

soil had been completely disturbed during the clear cutting process. As a result of the clear cutting, the harvest plots may have contained low compaction substrates throughout and was therefore suitable for sand skinks throughout in terms of soil compaction.

	Spearman's r	Significance Level
Site 1 control	-0.374	0.279
Site 1 burn	-0.466	0.179
Site 1 harvest	-0.069	0.865
Site 2 control	-0.290	0.407
Site 2 burn	-0.568	0.088~
Site 2 harvest	0.184	0.607
Site 3 control	-0.640	0.049*
Site 3 burn	-0.355	0.313
Site 3 harvest	-0.212	0.560

Table 16. Spearman's correlations between the average compaction measurements at every trap and sand skink captures in 1999 and 2000. The significance level of $p< 0.05$ is denoted by an "*". A non-significant, but of interest, value is marked with "~". N=20 for all correlations.

	Spearman's r	Significance Level
Site 1 control	-0.508	0.004**
Site 1 burn	-0.481	0.007**
Site 1 harvest	0.179	0.343
Site 2 control	-0.625	0.0002***
Site 2 burn	0.135	0.485
Site 2 harvest	0.011	0.955
Site 3 control	-0.573	0.0009***
Site 3 burn	-0.534	0.002**
Site 3 harvest	-0.010	0.957

Table 17. Spearman's correlations between the average compaction measurements at every coverboard and average rating of sand skink activity in 1999. The significance level of $p<0.05$ is denoted by "*", $p< 0.01$ by "**", and a level of $p< 0.0001$ by "***".

Other Amphibians and Reptiles

Capture Data

I captured a total of 631 amphibians and reptiles during Feb. to May 1999 and 2000. During the 13 weeks that traps were open in 1999, I captured 249 reptiles (12 species) and 54 amphibians (5 species). During the 13.5 weeks that traps were open in 2000, I captured 278 reptiles (13 species) and 50 amphibians (4 species). Table 18 shows these data in relation to data obtained from 1996 to 2000, on a per week basis because traps were open for different numbers of weeks during each of the 5 years. After 1997, the number of reptiles captured increased steadily over the next three years, but the number of amphibians captured increased for the next year only, then decreased again in 1999 and 2000. The number of species captured per week followed this same pattern.

Several species of reptiles and amphibians were trapped on my sites. From 1996-2000, 12 snake species, 9 lizard species, 1 tortoise species, 6 frog species, and 3 toad species were observed or captured. During 1999 and 2000, I captured four species not previously captured in 1996-1998 (Table 19). Those species include *Bufo quercicus* (1), *Micrurus fulvius* (2), *Farancia abacura* (2), and *Rhadinaea flavilata* (2). (Numbers in parentheses are numbers of individuals captured.) Several species (9) were captured during 1996-1998 that I did not capture. Those species include *Acris gryllus* (1), *Elaphe guttata* (1), *Heterodon simus* (1), *H. platyrhinos* (2), *Ophisaurus ventralis* (1), *Rana capito* (5), *R. grylio* (1), *R. utricularia* (21), and *Rhineura floridana* (1). With the exception of *R. utricularia*, the number of individuals captured indicates that all of the species listed above were relatively rare on the sites. Some of them were more likely to be passing through the sites than residing there (H. Mushinsky, pers. comm.). I observed several *Coluber constrictor* individuals, but never captured them in traps although they had been trapped prior to 1999-2000 on the sites (Ravdal, 2000). An unidentified rattlesnake was also seen on the site 1 burn plot (Ravdal, 2000). The proportions in which individual reptile and amphibian species were captured in 1999 and 2000 are given in Table 20. *Cnemidophorous sexlineatus*, *Neoseps reynoldsi*, and *Eumeces inexpectatus* comprised the majority of reptile captures in both 1999 and 2000, as well as *Tantilla relicta* in 1999. *Bufo terrestris* and *Gastrophryne carolinensis* comprised most of the amphibian captures during both years.

Year	Weeks	Reptiles	Reptile species	Amphibians	Amphibian species
1996	15.5	19.6 (303)	.97 (15)	16.6 (257)	.52 (8)
1997	17	7.8 (133)	.77 (13)	3.8 (64)	.24 (4)
1998	13	11.3 (147)	.85 (11)	12.8 (166)	.39 (5)
1999	13	19.2 (249)	.92 (12)	4.2 (54)	.39 (5)
2000	13.5	20.6 (278)	.96 (13)	3.7 (50)	.30 (4)

Table 18. Number of reptiles, reptile species, amphibians, and amphibian species captured per week from 1996 to 2000. Weeks equals the number of weeks traps were open each year. Numbers in parentheses indicate the absolute numbers of individuals and species captured. Data from 1996-1998 from Ravdal, 2000

Reptiles	Type of animal	1996	1997	1998	1999	2000	Total captures
* *Cnemidophorus sexlineatus*	Lizard	X	X	X	X	X	336
* *Neoseps reynoldsi*	Lizard	X	X	X	X	X	293
* *Tantilla relicta*	Snake	X	X	X	X	X	151
* *Eumeces inexpectatus*	Lizard	X	X	X	X	X	138
* *Sceloporous woodi*	Lizard	X	X	X	X	X	32
Scincella laterale	Lizard	X	X	X	X	X	28
* *Anolis carolinensis*	Lizard	X	X	X	X	X	13
* *Cemophora coccinea*	Snake	X	X	X	X	X	10
* *Gopherus polyphemus*	Tortoise	X	X	X	X	X	9
* *Diadophs punctatus*	Snake	X	X		X		5
Thamnophis sirtalis	Snake	X			X	X	3
Rhadinaea floridana	Snake		X	X			2
Seminatrix pygaea	Snake		X		X		5
* *Coluber constrictor*	Snake	X					4
* *Ophisaurus ventralis*	Lizard	X					1
* *Heterodon simus*	Snake	X					1
* *Heterodon platyrhinos*	Snake		X				2
* *Elaphe guttata*	Snake			X			1
Anolis sagrei	Lizard				X		1
Farancia abacura	Snake					X	2
* *Rhineura flavilata*	Lizard					X	2
* *Micrurus fulvius*	Snake					X	2
Amphibians							
* *Bufo terrestris*	Toad	X	X	X	X	X	285
* *Gastrophryne carolinensis*	Frog	X	X	X	X	X	147
* *Scaphiopus holbrooki*	Toad	X	X	X	X	X	121
* *Eleutherodactylus planirostris*	Frog	X	X	X	X	X	11
Rana utricularia	Frog	X		X			18
* *Bufo quercicus*	Toad			X	X		2
Acris gryllus	Frog	X					1
* *Rana capito*	Frog	X					5
Rana grylio	Frog	X					1

Table 19. Herpetofaunal species observed on all sites in different years. Data from 1996-1998 are from Ravdal 2000. Species considered characteristic of Florida scrub (Christman, 1988) are denoted by an asterisk.

	Type of animal	% of 1999 captures	% of 2000 captures
Reptiles			
Cnemidophorus sexlineatus	Lizard	30.1	35.5
Neoseps reynoldsi	Lizard	28.5	30.9
Tantilla relicta	Snake	15.7	8.6
Eumeces inexpectatus	Lizard	10.4	12.6
Sceloporous woodi	Lizard	5.2	3.6
Scincella laterale	Lizard	4.4	3.2
Anolis carolinensis	Lizard	1.6	1.4
Seminatrix pygaea	Snake	1.6	0
Cemophora coccinea	Snake	0.8	0.7
Diadophis punctatus	Snake	0.8	0
Anolis sagrei	Lizard	0.4	0
Thamnophis sirtalis	Snake	0.4	0.4
Farancia abacura	Snake	0	0.7
Gopherus polyphemus	Tortoise	0	1.1
Micrurus fulvius	Snake	0	0.7
Rhineura flavilata	Lizard	0	0.7
	Total	100	100
Amphibians			
Gastrophryne carolinensis	Frog	40.7	46
Bufo terrestris	Toad	38.9	30
Scaphiopus holbrooki	Toad	13	12
Eleutherodactylus planirostris	Frog	5.6	12
Bufo quercicus	Toad	1.9	0
	Total	100	100

Table 20. Species of reptiles and amphibians captured and the proportions in which they were captured in 1999 and 2000 on all sites combined.

Gopher Tortoise Surveys

Because gopher tortoise burrows were surveyed by using a different method than pitfall trapping, the results were not combined with those of other species. When and if trapped, they were included in diversity estimates, etc., but the results of the surveys themselves are provided in Table 21. Site 2 had the highest number of active burrows, and it was the only site immediately surrounded on three sides by mowed grassy areas. Many of the burrows were along the edge of the scrub patch, and on more than one occasion, I observed tortoises grazing in the grassy area adjacent to the site. This is similar to what Christman (1988) observed in various central Florida scrubs. He noted, however, that burrows within the scrub were nearly always associated with roads or the bases of fallen trees. I did not observe this to be the case deeper into the interior of my sites. Tortoises may have been placed onto the sites by Disney when other Disney-owned sites were being developed. The number of tortoises introduced to the sites, if any, was unknown to me.

		Control	Burn	Harvest
Site 1				
	Adult	0	4	7
	Juvenile	1	0	1
Site 2				
	Adult	1	6	10
	Juvenile	0	0	1
Site 3				
	Adult	3	3	3
	Juvenile	0	0	1

Table 21. Results of surveys for active gopher tortoise burrows on all sites in 2000. Juvenile burrows were those that were < 20cm diameter at burrow opening.

Comparison Among Treatments

It is interesting to compare the different proportions of species that were captured in control, burn, and harvest (Table 22). Amphibian captures seemed to vary more in terms of location than reptile captures. In many years, reptile captures were relatively evenly divided among the three treatment plots. One thing to note, however, is that captures in the burn treatment were always intermediate between the harvest and control. In regards to amphibians, a consistent order of abundance among treatments did not seem to exist.

	Control	Burn	Harvest
Reptiles			
1996	33.8 %	33.4	32.8
1997	33.6	26.6	39.9
1998	41.3	25.8	32.1
1999	30.5	29.7	39.8
2000	26.4	30.0	43.6
Amphibians			
1996	18.5	26.9	54.6
1997	29.7	20.3	50.0
1998	36.6	20.8	42.6
1999	42.6	31.5	25.9
2000	30.0	36.0	34.0

Table 22. Percent reptiles and amphibians captured in each treatment plot during 1996-2000 trapping seasons.

Because sample sizes differed among treatments, direct comparison of number of species captured is not justified. Species accumulation curves can be used, however, to extimate how many species are in the population from which samples are taken. New species are added to a sample as sample size increases, but at a certain number of species, larger and larger samples sizes do not produce any additional species. It is at this number of species the accumulation curve asymptotes, and is equal to the estimated number of species in the population. Species accumulation curves were plotted for samples in 1999 and 2000 for each individual plot (Figures 29 - 30). The results show that in 1999 and 2000, the expected order of treatments in terms of species richness was control > burn > harvest. In 2000, however, all treatment plots seemed to be reaching equal number of

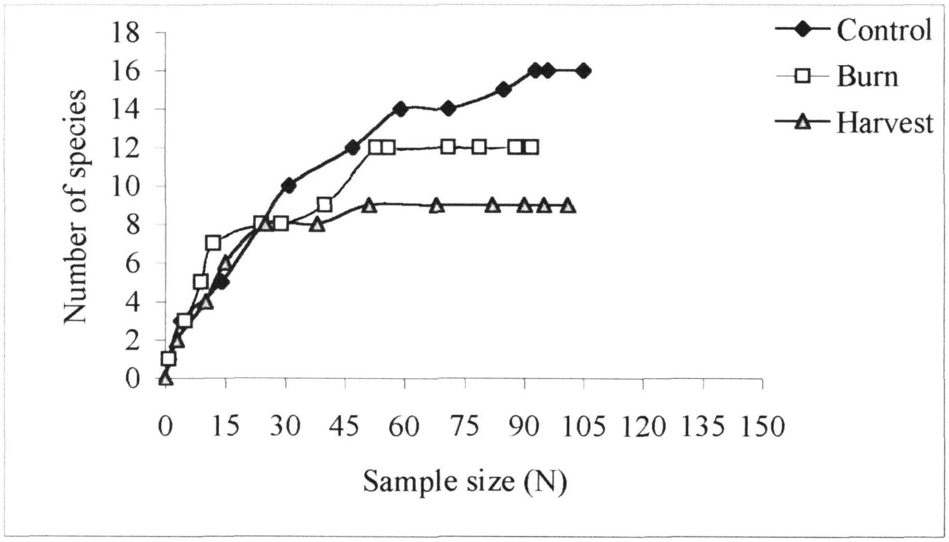

Figure 29. Species accumulation curves for control, burn, and harvest plots in 1999 showing number of species captured as a function of sample size.

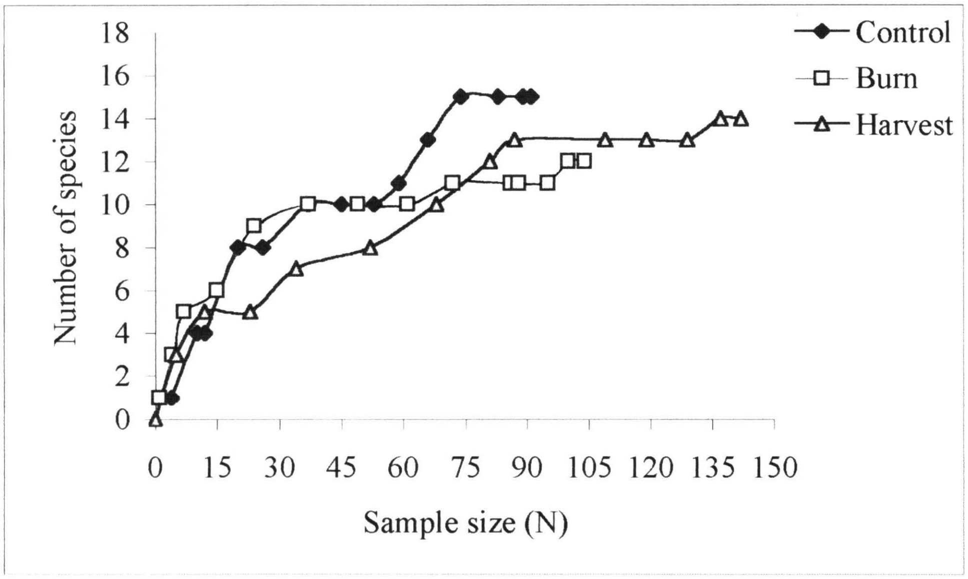

Figure 30. Species accumulation curves for control, burn, and harvest plots in 2000 showing expected number of species as a function of sample size.

species. In prior years, the order of expected species in the treatments based on rarefaction was burn>control>harvest (Ravdal, 2000).

Ludwig and Reynolds (1988) recommend Hill's N1 and N2 for evaluation of species diversity. Both indices incorporate numbers of individuals and species, but Hill's N1 incorporates rarer species in its calculation to a greater degree than N2, which is more a measure of the number of very abundant species. Hill's N2 is affected by sample size while N1 is not. The herpetofaunal species diversity, as indicated by Hill's N1, has been consistently lower in the harvest plot than the control and burn when data from all sites are combined (Figure 31; Table 23).

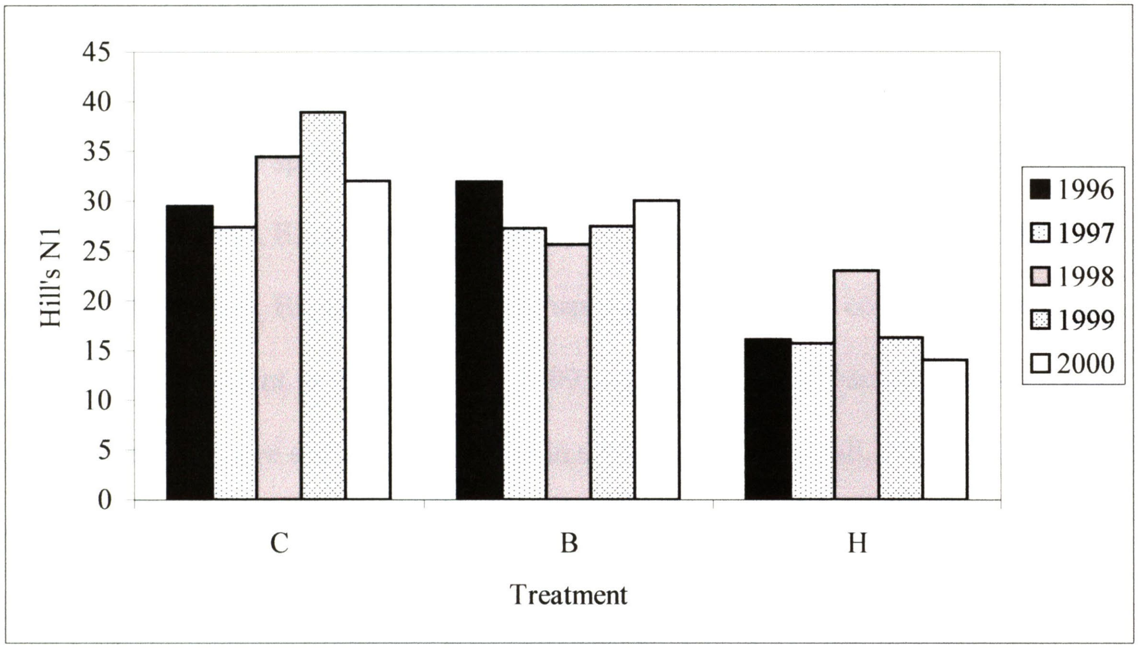

Figure 31. Hill's N1 over all years within treatment plots when data from all sites are pooled. Hill's N1 increases with increasing diversity. C=control plots, B=burn plots, and H=harvest plots. Data from 1996-1998 are from Ravdal, 2000.

		Control	Burn	Harvest	all treatments
site 1	1999	23.135	24.047	10.445	32.961
	2000	11.96	19.349	10.715	25.253
site 2	1999	32.204	11.968	9.776	18.305
	2000	25.692	12.308	10.358	16.604
site 3	1999	19.082	13.099	15.268	19.017
	2000	19.191	23.348	9.421	17.904
all sites	1999	38.913	27.461	16.309	
	2000	31.977	29.975	14.013	

Table 23. Hill's N1 species diversity index for all sites and treatments in 1999 and 2000.

Evenness indices are used to uncover how the species abundances (number of individuals) are distributed among the species (Ludwig and Reynolds, 1988). Evenness is low if one or a few species comprise most of the individuals in the sample. I used the modified Hill's ratio, E5, as recommended by Ludwig and Reynolds (1988). The modified Hill's ratio, E5, is not affected by sample size. Table 24 contains the evenness index for the treatment plots and sites in 1999 and 2000. E5 approaches zero as a single species becomes more and more dominant in a community. Overall, site 1 had greater species evenness than either of the other two sites, and overall the control plots had greater evenness than the burn or harvest plots. Overall, in 1999, the most abundant species on all sites were *Neoseps reynoldsi*, *Eumeces inexpectatus*, *Tantilla relicta*, and *Cnemidophorous sexlineatus*. In 2000, *Tantilla relicta* was not abundant, but the three aforementioned species remained dominant. *Eumeces inexpectatus* was not dominant in the harvest plot in either year.

		Control	Burn	Harvest	all treatments
site 1	1999	-0.045	-0.043	-0.105	-0.031
	2000	-0.091	-0.054	-0.103	-0.041
site 2	1999	-0.032	-0.091	-0.114	-0.058
	2000	-0.040	-0.088	-0.107	-0.064
site 3	1999	-0.055	-0.082	-0.070	-0.056
	2000	-0.055	-0.045	-0.119	-0.059
all sites	1999	-0.026	-0.038	-0.065	
	2000	-0.032	-0.034	-0.077	

Table 24. Modified Hill's ratio, E5, an evenness index, for all sites and treatments in 1999 and 2000. C=control plot, B=burn plot, and H=harvest plot.

Year(s)	C-B	C-H	B-H
1996	0.892**	0.823**	0.886**
1997	0.859**	0.814**	0.802*
1998	0.796**	0.796**	0.924**
1999	0.903**	0.760~	0.800*
2000	0.804**	0.772	0.853
1999 and 2000	0.898**	0.795**	0.862**

Table 25. Horn's Index of Community Similarity (R_0) for reptiles and amphibians captured in treatments of all sites. Values closer to 1.0 indicate greater community similarity among treatments. P values are based on 1000 bootstrapped samples of numbers of each reptile and amphibian species, where p<.10 is denoted by a "~", p<.05 by a "*", and p<.01 by a "**". C=control plots, B=burn plots, and H=harvest plots. Data from 1996-1998 are from Ravdal (pers. comm.)

I also used Horn's Index of Community Similarity (Horn, 1966) to find the degree of community overlap in the herpetofauna among the different treatments. Horn's Index can be used when treatments consistently yield different sample numbers with equal sampling effort. The results of the index computation are given in Table 25. The numbers of individuals captured of each amphibian and reptile species were resampled 1000 times and the index recalculated each time to obtain a probability distribution from which the p values could be drawn. High community similarity is evident in all treatment comparisons, though some were less similar than others, most often in the comparison between the control and harvest plots in any given year.

Comparison with Other Studies

Mushinsky and McCoy (1995)

I compared the species composition of what I captured on my sites to those captured by Mushinsky and McCoy (1995) in scrub patches of varying sizes in central Florida. The data are presented in Table 26, where species are arranged in order of greatest to least number of sites trapped in (for my sites first, then Mushinsky and McCoy's sites). The Mushinsky and McCoy sites used in the comparison were the sites close in size to my own sites. None of their sites had been recently clear cut, but they may have been burned, so I used data only from the control and burn plots of my sites, so my data would be more comparable to theirs. Although I do not know the exact size of these plots combined, I estimated the total area covered by the burn and control plots within each site to be between 2 and 3 hectares. Because Mushinsky and McCoy trapped for 2 years, I separately denoted species observed before the last 2 years of trapping on my sites for comparison. I found that my sites had several species that Mushinsky and McCoy found only in large (170-190ha) and medium (25-50ha) sized scrub patches. Species they observed only in large(L) and medium(M) sized scrubs that were observed on my sites at some time between 1996 and 2000 include *O. ventralis*(L), *T. sirtalis*(L), *E. planirostris*(L,M), *H. platyrhinos*(M), *S. pygeae*(M), and *E. guttata*(M) (Mushinsky and McCoy, 1995). Mushinsky and McCoy observed two species that were never found on my sites: *Eumeces egregius* and *Masticophis flagellum*.

Species		Kissimmee sites			Mushinsky and McCoy (1995) sites			
		Site 1 2-3ha	Site 3 2-3ha	Site 2 2-3ha	LAK 6ha	EGL 6ha	BAR 5ha	COL 3ha
Gastrophryne carolinensis	F	X	X	X	X	X	X	X
Cnemidophorus sexlineatus	L	X	X	X	X	X	X	X
Eumeces inexpectatus	L	X	X	X	X	X	X	
Gopherus polyphemus	t	X	X	X	X	X	X	
Bufo terrestris	T	X	X	X	X		X	X
Neoseps reynoldsi	L	X	X	X	X	X		X
Tantilla relicta	S	X	*	X	X	X		X
Sceloporous woodi	L	X	X	*	X	X		X
Cemophora coccinea	S	X	X	X		X		X
Anolis carolinensis	L	X	X	X			X	
Scaphiopus holbrooki	T	X	X	X	X			
Scincella laterale	L	X	X	X		X		
Eleutherodactylus planirostris	F	X	X	X				
Bufo quercicus	T	X	*					X
Rana utricularia	F		*	*				X
Diadophis punctatus	S		*	X				
Heterodon simus	S	*	*					
Thamnophis sirtalis	S		X	*				
Coluber constrictor	S	X			X	X	X	X
Micrurus fulvius	S	X						
Anolis sagrei	L	X						
Seminatrix pygaea	S		X					
Farancia abacura	S		X					
Rhineura flavilata	L			X				
Elaphe guttata	S			*				
Rhadinaea floridana	S			*				
Heterodon platyrhinos	S	*						
Ophisaurus ventralis	L	*						
Crotalus adamanteus	S	*						
Rana capito	F		*					
Rana. grylio	F		*					
Opheodrys aestivus	S		*					
Eumeces egregius	L				X	X		X
Masticophis flagellum	S				X	X		X
1999/2000 species total		17	15	14	12	12	7	12

Table 26. Herpetofaunal species observed or captured on various scrub sites. Letters indicate type of animal (F=frog, L=lizard, S=snake, T=toad, and t=tortoise). Data from Kissimmee sites are from control and burn plots only. LAK, EGL, BAR, and COL are Mushinsky and McCoy denotations for some of their sites. X = species observed or trapped on site (Kissimmee, 1999 and 2000; Mushinsky and McCoy sites, 1994 and 1995). Additional species observed or trapped on sites in 1996 – 1998 are denoted by an asterisk (Ravdal, 2000).

Greenberg et al. (1994)

Greenberg et al. (1994) studied the response of reptile communities to wildfire and clear cutting in comparison to a mature forest in sand pine scrub in Ocala National Forest. They pitfall trapped for 13 months, and observed 18 reptile species among their burned, harvested, and control plots. Main differences between their and my studies include the fact that their burned areas were salvage logged with heavy machinery and their harvested areas were reseeded with sand pines. They trapped in 5-7 post-disturbance treatment plots. They mentioned that they captured four frog species, but their occurrence did not seem to be influenced by the treatments so they focused on reptiles. On my sites, the lack of treatment influence appeared to be the case with some but not all of the frog and toad species I observed (Table 27). The only reptile species which I found on every treatment and that Greenberg et al. never captured was the sand skink (Table 28). Greenberg et al. observed several reptile species that were never observed on my sites: *Crotalus adamanteus*, *Masticophis flagellum*, *Opheodrys aestivus*, *Pituophis melanoleucus*, and *Sistrurus miliarius*. The fact that Greenberg et al. observed the additional species could simply be a function of the fact that each of their treatment plots was at least 13.8ha, whereas mine were approximately 1.25 ha (Greenberg et al., 1994). In both my and their studies, *R. floridana* was found only in the burn plots. Between both of our studies, *M. fulvius*, *S. pygaea*, and *F. abacura* were never found in the burn plots.

		Control	Burn	Harvest
Bufo terrestris	Toad	XXXXX	XXXXX	XXXXX
Gastrophryne carolinensis	Frog	XXXXX	XXXXX	XXXXX
Scaphiopus holbrooki	Toad	XXXX	XXXXX	XXXXX
Rana utricularia	Frog	XX	XX	XX
Eleutherodactylus planirostris	Frog	XXXX	XX	
Bufo quercicus	Toad	X	X	
Rana capito	Frog	X		X
Acris gryllus	Frog			X
Rana grylio	Frog	X		

Table 27. Frog and toad species observed on different treatments on all sites from 1996 to 2000. Each X represents one year that species was observed or trapped.

Species on									
Kiss plots	ONF plots			Kiss. control	ONF control	Kiss. burn	ONF burn	Kiss. harvest	ONF harvest
All	All	*Cnemidophorus sexlineatus*	L	XXXXX	X	XXXXX	X	XXXXX	X
		Eumeces inexpectatus	L	XXXXX	X	XXXXX	X	XXXXX	
		Tantilla relicta	S	XXXXX	X	XXXXX	X	XXXXX	X
		Scincella laterale	L	XXX	X	XXXX	X	XXX	X
		Anolis carolinensis	L	XX	X	XXXXX	X	XX	X
		Sceloporous woodi	L	XX	X	XXX	X	XXXX	X
All	Some	*Gopherus polyphemus*	t	X		XXX	X	XXX	X
Some	All	*Coluber constrictor*	S	XX	X		X	XX	X
Some	Some	*Elaphe guttata*	S		X	X			X
		Micrurus fulvius	S	X	X				X
Some	None	*Farancia abacura*	S	X				X	
		Heterodon platyrhinos	S	X			X		
One	One	*Rhadinaea. floridana*	S			XX	X		
All	None	*Neoseps reynoldsi*	L	XXXXX		XXXXX		XXXXX	
Some	None	*Cemophora coccinea*	S	XXX		XXXXX			
		Diadophus punctatus	S	XX		X			
		Thamnophis sirtalis	S	X		XX			
		Seminatrix pygaea	S	X				XX	
One	None	*Heterodon simus*	S	X					
		Ophisaurus ventralis	L	X					
		Rhineura flavilata	L	X					
		Anolis sagrei	L			X			
None	All	*Eumeces egregius*	L		X		X		X
None	Some	*Masticophis flagellum*	S				X		X
		Sistrurus miliarius	S		X		X		
None	One	*Crotalus adamanteus*	S						X
		Pituophis melanoleucus	S						X
		Opheodrys aestivus	L				X		

Table 28. Reptile species comparisons between my Kissimmee, FL study (Kiss) and Greenberg et al. (1994) in Ocala National Forest (ONF). Letters indicate type of animal (L=lizard, S=snake, and t=tortoise). Each X represents one year that species was observed or trapped. Greenberg et al. trapped for 13 months (1 year).

DISCUSSION

The primary purpose of my study was to gather information about the effect of burning and clearcutting on sand skink populations in selected patches of sand pine scrub habitat. Control plots were set up at each of three sites to facilitate comparisons of any changes that occurred in sand skink populations on the burned and clearcut plots. Plot boundaries were drawn so each plot contained approximately equal sand skink densities prior to treatment. During the five years post-treatment, the total number of sand skinks captured in the control plots fluctuated from year to year, but not significantly. This enabled comparisons between the treatments and control.

During the five years following burning, the total number of sand skink captures made in the burn plots were not consistently greater or fewer than those made in the harvest or control plots. Those sand skinks captured in the burn plots, however, were significantly larger (longer SVL) than those captured in the harvest plots. This would have occurred if more juveniles were captured in the harvest plots than the burn plots, causing the mean SVL to be smaller in the harvest plots. The number of juvenile sand skink captures in the harvest plots, however, were not significantly greater than those in the burn plots. The sand skinks captured in the burn plots also weighed significantly more than those captured in the control plots, although there was no length difference between sand skinks captured in the burn plots and control plots. Therefore, the fact that larger sand skink were found in the burn plots could indicate that the burn plots were providing more insect prey via decaying logs than the other plots or that the adult sand skinks captured in the burn plots tended to be older (and therefore larger) than those captured in the harvest and control plots.

In the harvest plots, often fewer total sand skink captures were made than in the control plots, but the total number of sand skinks captured in the harvest plots significantly increased over the five years following clearcutting. This indicates that the conditions in the harvest plots became increasingly tolerable to sand skinks. Once the vegetation reached a certain level, the harvest plots may have offered better opportunities for thermoregulation, because there were still numerous patches of bare sand, but also ample shade. Soil compaction is correlated with subsurface temperatures (Collazos, 1998), and the harvest plots had lower soil compaction than the control and burn plots, so an area of bare sand in a harvest plot would not have become as hot under the summer sun as one in a control or burn plot. There was a negative correlation between sand skink presence and soil compaction, ie. sand skink were more likely to be detected in areas with lower soil compaction. After the clearcutting, the soil in the harvest plots was completely disturbed to a depth of at least 15 cm, which consequently reduced the soil compaction. The sand skinks may have been attracted to areas with lower soil compaction, and so were consequently found in the harvest plots in greater numbers as the vegetation grew and decaying dead vegetation attracted insect prey. In addition to the temperature moderating capacity of the looser sand, the growing vegetation may also have been better able to retain moisture than in the first years immediately following clearcutting. The ability of the vegetation to retain moisture could have been especially important in 2000, when rainfall levels were far below normal, and the death of sand skinks in traps was obviously from dessication rather than predation (pers. obs.). Juveniles may also have been dispersing into the harvest plots as the vegetation recovered and provided more shade. In the last year of the study, the proportion of juvenile to adult sand skink captures was much higher in the harvest plots than in the other plots and nearly double that found by Sutton (1996) and Telford (1958; 1998) in undisturbed scrub.

Treatment plot boundaries were drawn such that each plot was no different from any other plot in sand skink densities (Navratil, 2000), but, after treatment, sand skink captures differed among treatment plots within the sites. The treatments did not affect sand skink distributions within the sites in the same way on each site. This means that the distribution of sand skinks within the three sites appeared to be influenced by something more than just the treatment or absence of treatment. An interaction between treatment plot and microhabitat characteristics seemed to exist. Sand skink presence has been related to low soil compaction, large soil particle size, low soil moisture, low soil temperature, large amounts of loose sand and bare ground, and low average understory vegetation (this study; Hill, 1999; Collazos, 1998). The treatment plot the sand skinks were found in most often may have been more a function of the microhabitat characteristics present there than the treatment itself.

Populations increasing in size (or those with stable age distributions) are characterized by a predominance of young individuals (Krebs, 1994). Neither I nor Sutton (1996) saw a predominance of young individuals on our scrub sites among the captured sand skinks. Either the populations were not stable or the populations were and our sampling distributions did not show the true population distribution. On all three of my sites at the end of the study, however, the sand skink populations did not appear to be declining, based on the increased number of total captures over time on each site.

Little information has been collected about the distances sand skinks are capable of moving. My study has shown that within an active season, sand skinks did not appear to move outside of a small area. Between different years, however, the sand skinks were more likely to be found at least 35 m away from the location of last capture. Despite this fact, sand skinks were more likely to remain in the same treatment plot between years than move into a different plot within the sites. Sutton (1996) saw little movement of sand skink individuals within his sites when he trapped during one active season and one inactive season. More research is needed before definite conclusions can be made concerning the movement of sand skinks, but these data do show that sand skinks may travel farther at some times of the year than others.

Prior to this study, the maximum lifespan of a sand skink was estimated to be about 6 years. The longer term data I have gathered showed that at least one sand skink on one of my sites lived about 8 years. This is two years longer than the previously estimated lifespan, although more data need to be collected to substantiate these findings.

Herpetological species diversity was consistently lower in the harvest plots than in the burn and control plots. The harvest plots also showed lower species evenness than the burn and control plots, meaning that there was greater dominance in abundance by one or a few species in the harvest plots than in the burn and control plots. Harvesting seems to create a more uniform habitat, whereas during controlled burning, fire intensity may differ on a fine scale and create the different microhabitats needed by diverse reptile and amphibian species. Burning appeared to promote greater herpetofaunal species diversity in sand pine scrub than clearcutting.

There are several factors to consider with the management practice of clearcutting compared to controlled burning. Clearcutting with heavy machinery disturbs the soil more than controlled burning, harvesting may bring up lower, less-leached layers of soil and change the nutrient levels of the topsoil. Repeated harvesting may also remove too many already limited nutrients from the scrub system, whereas burning releases nutrients bound up in the vegetation. The persistence of the scrub species assemblage is dependent on low soil nutrient levels, so changes in the nutrient level could affect the floral species composition. If an area is harvested and all logs removed, termite abundance may be lower than it would be after a fire. Low prey abundance may cause sand skinks to take longer in colonizing harvested areas. On my sites, many of the logs were left, providing ample wood for termites and other insect prey. The sand skink abundance in the harvested plots on my sites may not have been as high in the later years of the study if all clearcut vegetation had been removed.

The soils on the harvest plots of all three sites were presumably disturbed to the same extent, but they differed in several ways. The soils in the site 2 and site 3 harvest plots were light gray and white like the control areas. The soil on the site 1 harvest plot was a rusty yellowish color, seemed to have a finer particle size, and did not drain as well as the control plot (pers. obs.). Collazos (1998) found sand skink density to be positively correlated with large soil particle sizes. On site 1, very few sand skinks were captured in the harvest plot as compared to captures made in the control or burn plots, implying that the latter two plots contained more favorable habitat than the harvest plot. The site 1 harvest plot was dominated by small resprouting sand pines and scrub hickory. The presence of scrub hickory and yellowish soils indicate a younger, more recently established scrub, because the nutrients have not been leached as much from acids released by decaying vegetation (Myers, 1990). Sand skinks may require areas with older scrub soils, in particular if they drain more quickly, support less vegetation, and tend to have larger particle sizes.

This study shows that the best land management technique for the conservation of the sand skink and general herpetofaunal diversity may depend more on the microhabitat features of an area than on the technique itself. The distribution of sand skinks is correlated with a number of microhabitat characteristics. Data should be gathered on the distribution and abundance of sand skinks and other herpetofauna and the microhabitat characteristics of an area before making a determination of whether to clearcut or perform controlled burning on a patch of scrub. The technique that produces the desired microhabitat characteristics within a relatively short period of time should be the technique implemented for that area.

Edge Effects and Their Implications for Long-Term Sand Skink Persistence

Sand skinks were more often detected by pitfall traps and coverboards in the middle of two sites than by those along the outside edges that bordered non-scrub habitat. This difference persisted as far as 50m into the two sites. Significant differences in microhabitat characteristics such as understory vegetation height, soil compaction, and percent bare ground existed between the edges and middle of these sites. Low understory vegetation, low soil compaction, and high percent bare ground were found in the center areas of the sites. I did not specifically study soil temperature on the sites, but Chen et al. (1995) found soil temperature to be higher along clearcut edges than deep into a forest (>30m) and sand skink density has been found to be negatively correlated with soil temperature (Collazos, 1998). Camargo and Kapos (1995) also found that soil moisture can be affected by distance from a non-forest edge, and sand skink presence was found to be negatively correlated with soil moisture (Hill, 1999).

I failed to find an edge effect on site 1, whereas an edge effect existed in sites 2 and 3. Because site 1 was not completely isolated from other scrub habitat, as was the case with sites 2 and 3, there was less edge bordering non-scrub habitat. Site 1 was part of a larger patch of scrub habitat. As a result, I was only examining a section of the larger scrub patch to detect an edge effect. If I had been able to gather data from the entire scrub patch and compared the middle core area to the edges of the scrub patch, I may have detected an edge effect.

Edge effects existed on the two sites that were smaller scrub patches and not on the one site that was part of a larger scrub remnant. Sand skinks may not be able to persist over a long period of time on the two isolated sites. On the two isolated sites, the edge effect extended into the site to such a distance that there was a very small amount of unaffected core remaining. Site 3 was adjacent to a scrub restoration site, which may be used more and more by sand skinks over time, provided the restoration site increasingly resembles scrub over time. If this occurs, the larger functional size of the scrub patch at site 3 may provide enough core area for the sand skinks to persist over a longer period of time. Site 2, however, was a completely isolated patch of scrub habitat, and given the fact that sand skinks were detected mainly only in the middle of the site (approx. 0.83 ha), site 2 probably did not provide enough core area to sustain the sand skink population occupying it over a long period of time.

The effects of edges on diversity, abundance, breeding success, and movement have been observed in a number of avian and mammalian species (Flaspohler et al., 2001; Yahner, 1986; Harris and McElveen, 1981; Stauffer and Best, 1980). Though edges were thought to be beneficial to conserving biological diversity (Harris, 1988), they are now recognized as also having a negative effect on the distribution and abundance of species that require undisturbed core habitat (Saunders et al., 1991). If sand skinks do not usually occupy scrub habitat along an edge that borders non-scrub habitat, then the area of suitable sand skink habitat in a fragment would be less than the entire area of the fragment itself. It is possible that if a scrub fragment reached a currently unknown critical small size, the sand skinks would not be able to persist in the fragment, because not enough core habitat would be available to them. More research is needed to determine exactly how deep into a scrub patch edge effects penetrate, so scrub patches of adequate size can be preserved for the effective conservation of the threatened sand skink.

Discussion of Sand Skink Sampling Methods: Pitfall Trapping and Coverboards

Both coverboards and pitfall traps were used to detect sand skinks in my study and, in some instances, the two methods provided conflicting information about relative sand skink activity in the treatment plots. For example, in 1999 more captures were made in pitfall traps in the burn plots than in the harvest plots, but a greater percentage of coverboards showed activity in the harvest plots than the burn plots. There are several possible reasons for the conflicting information. Pitfall traps may not have been numerous enough to sample the entire treatment plots, whereas coverboards were more numerous and sampled more area within the treatment plots. Sutton et al. (1999) reported that pitfall traps required greater trapping effort than coverboards to determine relative sand skink abundance. In other words, more pitfall traps were required than coverboards to gain the same information on relative abundance among their sites. In my study, all pitfall traps remained in the same locations throughout the five years of the study, and some sand skinks may have become trap-shy after being captured and learned to avoid capture in the future. Coverboards were only placed on the sites and checked for one year, so their locations were not as permanent as the pitfall traps. I did not use the coverboards as a means of capturing sand skinks, so it is less likely that the sand skinks may have avoided coverboards for the same reason as pitfall traps. Coverboards may have actually attracted sand skinks by changing the microhabitat and retaining moisture; if this were the case, then coverboards would show more activity than the pitfall trap captures indicated. I assumed, however, that if the coverboards attracted sand skinks, they attracted the sand skinks equally in all treatments. If this assumption was correct, then the coverboards should have accurately reflected the relative sand skink activity in each area they were placed.

I feel that in my study the coverboards were more accurate in indicating the relative sand skink activity levels than the pitfall traps. Three times as many coverboards than pitfall traps were placed on the sites, and so the sampling area covered by coverboards was greater than that covered by pitfall traps. If adjacent pitfall traps happened to be placed in unfavorable areas, they may not have detected sand skinks that resided between traps. However, because coverboards were placed throughout the areas between traps, the likelihood of the coverboards detecting sand skink activity between traps was greater.

There are several things to consider in a decision as to whether to use coverboards or pitfall traps to study sand skinks. Sutton et al. (1999) mention many of these considerations. They discuss in their paper the fact that coverboards cost considerably less and require less environmental disturbance than pitfall traps, but in their study coverboards and pitfall traps were equally effective in detecting sand skink presence. Sutton et al. (1999) reported, however, that more pitfall traps were required than coverboards to gain the same information on relative abundance among their sites. Repeated pitfall trapping also has the potential to harm sand skink individuals (Sutton, 1996). Coverboards appear to be the best solution for determining sand skink presence and relative activity, where distinguishing between individuals is not required. Pitfall trapping is most useful for situation where individual identity is needed to yield information about natural history, growth rates, movement patterns, etc. of sand skinks.

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