Habitat Use And Seasonal Activity Of Selected Snakes On John F. Kenned

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HABITAT USE AND SEASONAL ACTIVITY OF SELECTED SNAKES ON JOHN F. KENNEDY SPACE CENTER, FLORIDA

by

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ABSTRACT

An intensive, replicated monthly sampling of snake communities inhabiting four habitat types was conducted at John F. Kennedy Space Center, Brevard County, Florida from November 2002 through October 2003. Thirteen species (580 individuals plus 74 recaptures) plus one hybrid were captured. The three most commonly captured species, *Coluber constrictor, Thamnophis sirtalis*, and *Thamnophis sauritus*, combined made up 85% of the sample. These three species were active during every month of the year, but showed modal activity patterns typical of Temperate Zone snakes. Monthly snake captures were correlated with monthly captures of potential prey species and with mean monthly temperature. Species richness in the four habitat types varied from nine to 12. Drift fences in ruderal habitats had the highest species richness, while fences in swales captured the greatest number of individuals. The most dissimilar habitat pair was scrub and swale, while the most similar pair was ruderal and hammock. Box traps proved more effective for targeting the largest snake species, while funnel and box traps were equally effective for targeting other species.

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INTRODUCTION

Snakes are one of the most stable components of the overall biotic community (Fitch 1982). When compared with other vertebrate taxa, however, relatively few studies have addressed the importance of snakes in biotic communities (Vitt 1987). Drift fencing can be used to provide baseline data on the species richness, relative abundance, activity patterns, and habitat associations of snakes within a community (Campbell and Christman 1982; Corn 1994; Enge and Wood 1998; Greenburg et al. 1994), but differences in ecology, behavior, and capture success among species must be considered (Campbell and Christman 1982; Corn 1994; Gibbons and Semlitsch 1981). In particular, researchers have noted a trapping bias against adults of large snake species using traditional drift fencing methods (Enge 1998; Fitch 1992; Dodd and Franz 1995; Greenberg et al. 1994). The opportunity to establish drift fences in the present study arose as part of an investigation into sampling techniques for a large snake species, *Drymarchon couperi*, on John F. Kennedy Space Center (KSC).

KSC is located on the northern part of Merritt Island, a barrier island off the east coast of central Florida. While long-term snake sampling has been conducted at KSC (Seigel et al. 2002), no intensive, replicated drift fencing for snakes has been undertaken. The present study was conducted, in part, to provide a systematic, replicated monthly sampling of larger snake species. The following questions were addressed: (1) Of two trap designs, which is more effective for targeting large snakes? (2) What are the seasonal activity patterns of snakes on KSC? (3) How do snake assemblages differ among four habitat types?

MATERIALS AND METHODS

Study Area

John F. Kennedy Space Center encompasses 57,000 hectares on the northern part of Merritt Island, a barrier island off the east coast of central Florida. While the site is owned by the National Aeronautics and Space Administration (NASA), lands not actively utilized by NASA are jointly managed by the U.S. Fish and Wildlife Service (USFWS) and the National Park Service (NPS). This study took place on land managed by the USFWS as Merritt Island National Wildlife Refuge (MINWR). An area encompassing scrub, freshwater swale, hammock, and ruderal habitats was chosen as the study site based on anticipated management activities and accessibility. Because these habitats are contiguous, any snake captured could potentially be found in any of the habitat types sampled.

Habitats

Scrub

Florida scrub is characterized by evergreen, xeromorphic shrubs including oaks (*Quercus* spp.), palms, and ericaceous shrubs (Schmalzer 2003) occupying well-drained, sandy soils. As defined here, scrub encompasses oak scrub, oak-saw palmetto (*Serenoa repens*) scrub, and scrubby flatwoods (Myers 1990). Within the study area, scrub soils are distributed along relict dunes separated by freshwater swale marshes (Huckle et al. 1974).

Freshwater Swale

Plant species composition of swale marshes on this study site varies with the size, hydrology (Schmalzer et al. 1999), and fire history of the wetland, but all swales consist of graminoid communities dominated by beardgrass (*Andropogon* spp.), sand cordgrass (*Spartina bakeri*), and/or sawgrass (*Cladium jamaicense*) (Schmalzer and Hinkle 1985). The swales in this study have experienced varying degrees of human disturbance and fire suppression. Hydroperiod is highly variable depending on rainfall and wetland size.

Hammock

Hammock on this study site is a temperate hardwood forest with a moderate to high soil water content that is dominated by evergreen species including cabbage palm (*Sabal palmetto*), live oak (*Q. virginiana*), and saw palmetto (Platt and Schwartz 1990). Species composition varies with hydrology, elevation, and fire history.

Ruderal

The term ruderal, also commonly referred to as disturbed, refers to any natural community altered by human activities to the point that the original vegetation is almost entirely replaced by exotic species and/or weedy native species. Taylor (1998) includes roadsides, old fields, lawns, and fence rows as ruderal sites. The total area of Florida uplands referred to as ruderal is approximately 14.5 million acres and continues to grow as humans continue to alter natural communities (Taylor 1998).

Sampling

Linear drift fences were installed in six replicate sites within each of the four habitats, resulting in 24 total fences. A minimum of 100 m separated all fences (Campbell and Christman 1982). Fences were comprised of two 7.6 m sections of 0.5 m high aluminum flashing buried 10 to 15 cm into the soil, allowing 1.2 m between sections for placement of a large box trap. Box traps consisted of a 1.2 m x 1.2 m x 0.45 m wooden frame screened with 6 mm (¼ inch) hardware cloth following Rudolph et al. (1999), making a total fence length of 16.5 m. One single-opening funnel trap made of 6 mm hardware cloth was placed on each end of the fence. The funnel traps designed for this study followed the basic design of Fitch (1987) with slight modifications. Funnel traps consisted of a 1.8 m tube with a diameter of approximately 30.5 cm. Both trap types were designed to allow the capture of large adult *D. couperi*, and consisted of funnel entrances that were approximately 33 cm across at the wide end with a 7.6 cm opening at the apex, with inward-projecting wire points to prevent escape (Fitch 1951). Neither trap type allowed for the capture of snake species or individuals small enough to escape through 6 mm hardware cloth mesh. Because the box trap met the drift fence in two locations, while the funnel traps each met the fence in one location, trap capture probability was assumed to be equal between the two types. All traps were partially covered in shade cloth and provided with a moistened sponge to keep small animals from dessicating.

Bury and Corn (1987) noted habitat disturbance and an associated inhibition of captures following fence installation, and suggested waiting at least 30 days between installation and the beginning of trapping. Fences in this study were initially installed in August and September of

2002, but data collection for this study did not commence until November 2002. The 12-month sampling period ran from November 2002 through October 2003. With the exception of March 2003 (eight days), fences were opened each month for a minimum of 14 days during the spring, summer, and fall seasons. Sampling during the winter season was considerably higher (up to 29 days per month) as these data were also part of a *D. couperi* study with particular interest in this time period. During periods of heavy rainfall, which resulted in the flooding of several fences, affected fences were kept closed until water levels receded, resulting in temporary lower sampling effort at these sites. Because of the variability in sampling effort, analyses were based on snake captures per fence-day, defined as captures per fence per 24 hours. Total number of fence-days in the entire 12-month sampling period was 4630. Throughout the study, conditions at all fences were similar except that the burn unit encompassing one swale fence was unexpectedly burned in early February.

When traps were open, fences were checked daily. For each snake captured, species, fence location, and trap type were recorded. Snakes were sexed using a blunt probe. Snout-vent length (SVL = distance from tip of snout to posterior edge of anal scute) and tail length to the nearest 0.5 cm, and live body mass to the nearest 0.1 g, were recorded for each individual. Most snakes were individually marked by implanting a passive integrated transponder (PIT) tag subcutaneously approximately 20 scale rows anterior to the vent. Due to time limitations and low recapture rates, snakes deemed too small or slender for PIT tagging were not marked. This included most snakes less than 50 cm in SVL, and the majority of *Thamnophis sauritus* captures. Snakes were released immediately after processing, ca. 3 m from the capture site. In addition to captures in traps, on three occasions a snake was hand-captured in immediate proximity to a fence, and was thus included as a capture at that fence. All other vertebrates captured were identified to species and released.

Data Analysis

Scientific and common names follow Collins and Taggart (2002). Snakes were classified as juvenile or adult following reference to adult size ranges given by Ernst and Ernst (2003) and Rossman et al. (1996). As size ranges reported in the literature vary within a species, snakes of intermediate size were not assigned to either age class. Because juvenile snakes were largely excluded in this study, only adults were used in analysis where appropriate. Recaptured individuals were also excluded from analysis where appropriate. A Welch one-way analysis of variance (ANOVA) was performed on the total number of snakes captured per fence-day in each of the four seasons. Seasons were defined as winter (December, January, and February), spring (March, April, and May), summer (June, July, and August), and fall (September, October, and November). Because sampling started between seasons, for analysis purposes November 2002 data were combined with September and October 2003 data as the fall season where appropriate. Because seasons cannot be considered independent, the p-values for the Welch one-way ANOVA were reduced to 0.0127 using the Dunn-Sidak method in order to avoid a Type I error. In all other tests, the alpha level was set at 0.05. Species richness and species abundance were investigated by habitat using a one-way ANOVA. For abundance analysis, data were log-transformed. To estimate similarity of species composition between habitat types, Jaccard's Index was calculated between all pairs of habitats. In order to examine seasonal activity patterns, captures per fence-day per month were plotted for the three most commonly trapped species. Spearman's rank correlation was performed on total monthly snake, anuran, and lizard captures, and mean monthly rainfall. Efficiencies of trap types and a potential baiting bias were investigated using a Chi-square test. Chi-square was also used to determine whether sex ratios differed significantly from equality.

RESULTS AND DISCUSSION

Trap Types

Snakes were captured in traps a total of 651 times (3 remaining captures were by hand), 308 in funnels and 343 in boxes. For all snake species combined, the efficiencies of the two trap types were not significantly different (Chi-square = 1.88, $p > 0.05$, Table 1), nor was there a significant difference for the three most common species captured (Table 1). However, a significant difference was found between trap types for the two largest species captured, *Masticophis flagellum* (Chi-square = 3.86, $p < 0.05$, Table 1) and *D. couperi* (Chi-square = 5.44, $p < 0.05$, Table 1). For these two species, box traps captured significantly more individuals than funnel traps. Of 21 *M. flagellum* captures, the seven largest individuals were captured in box traps, and of nine *D. couperi* trapped, the five largest individuals were captured in box traps. Thus, although the funnel traps were designed to mimic the box trap entrances, and were made extra long to facilitate the capture of large snakes, the box traps still proved more effective in capturing large snake species, and particularly large individuals of the largest species. A confounding factor to consider is the possibility of an unintentional baiting bias between the two trap types. Fitch (1951) noted accidental trap-baiting in his studies, and Dodd and Franz (1995) suggested that active foraging snake species such as *Coluber constrictor* and *M. flagellum* will be drawn to traps through activity of captured prey species. While traps in this study were not intentionally baited, a wide variety of vertebrates (Appendix A) and invertebrates that could potentially serve as bait for snakes were captured. In order to investigate whether there was an

Table 1. Chi-square values for comparisons of box and funnel traps at drift fences at John F. Kennedy Space Center, FL.

Species	N	Chi-square
All species combined	651	1.88
Coluber constrictor	390	2.96
Drymarchon couperi	9	5.44*
Masticophis flagellum	21	3.86*
Thamnophis sirtalis	86	1.16
Thamnophis sauritus	77	0.12

* indicates box trap was significantly more effective at the $p = 0.05$ level.

unintentional baiting bias between the two trap types, a chi-square analysis was performed to determine if potential vertebrate snake prey, besides snakes, was captured more frequently in box traps than in funnel traps. No significant difference was found (Chi-square = 2.22, $p > 0.05$). It appears that the large amount of space within the boxes as compared to the narrow funnel trap tunnel may determine whether a large snake will be more likely to continue into a trap.

Capture Mortality

Fifteen of 654 total captures were mortalities, making a total capture mortality of 2.3 percent. Nine of the 15 mortalities occurred in funnel traps, and six occurred in box traps. Five of the 15 mortalities occurred in four species, *C. constrictor, Elaphe guttata, Opheodrys aestivus,* and *Thamnophis sirtalis*, while the other 10, or 67%, occurred in just two species, *T. sauritus* and *Lampropeltis triangulum*. Five of the seven *T. sauritus* mortalities and all three *L. triangulum* mortalities were presumably due to hyperthermia after the individuals became trapped in the 6 mm hardware cloth used to construct both the funnel traps and the box traps. Of the remaining seven snake mortalities, four were likely caused by another vertebrate captured in the same trap, one was likely killed by fire ants (*Solenopsis evicta*), and two were of unknown causes.

Species Composition

Thirteen species of snakes plus one hybrid were captured during this study. Seventy percent of the 580 individuals captured were PIT tagged. Of 408 individuals initially tagged, 60 were recaptured one or more times, for a total of 74 recaptures (Table 2). In addition to the 13 species captured in the traps, one additional species, *Crotalus adamanteus*, was observed within the

Table 2. Total number of initial and recaptured snakes captured at drift fences at John F. Kennedy Space Center, FL from November 2002 through October 2003.

Species	Initial captures	Recaptures	Totals
Cemophora coccinea	10	0	10
Coluber constrictor	328	63	391
Drymarchon couperi	11	1	12
Elaphe alleghaniensis	14	0	14
E. guttata	15	0	15
Farancia abacura	5	0	5
Lampropeltis triangulum	5	0	5
Masticophis flagellum	17	4	21
Nerodia fasciata	15	0	15
N. fasciata x N. clarkii	1	0	1
N. floridana	1	0	1
Opheodrys aestivus	1	0	1
Thamnophis sauritus	76	1	77
T. sirtalis	81	5	86
Totals	580	74	654

study area during the sampling period. However, because it was observed on a sand road, and not in close proximity to any drift fence, it was not included in the analysis. In addition to the species mentioned above, another 13 snake species, 12 of which could potentially have been trapped in the habitats sampled, are known to occur on KSC (Seigel et al. 2002). Six of these, *Diadophis punctatus*, *Rhadinea flavilata*, *Storeria dekayi*, *Tantilla relicta*, *Regina alleni*, and *Seminatrix pygaea* would not likely be captured using the techniques employed in this study, and therefore no conclusions should be drawn regarding their relative abundances on the study area. The remaining six species are *Agkistrodon piscivorus, Heterodon platirhinos, Lampropeltis getula, Pituophis melanoleucus, Micrurus fulvius,* and *Sistrurus miliarius.* The first three are known to be relatively rare on KSC (Seigel et al. 2002, pers. comm. R. Seigel), and lack of their capture in this study supports this claim. *P. melanoleucus* is a highly fossorial species (Franz 1992), and less likely to be captured using drift fences. However, the box trap design used in this study has been utilized successfully to target *P. melanoleucus lodingi* in Texas (Rudolph et al. 1999). Therefore, lack of capture of *P. melanoleucus* may reflect a true rarity of this species on the study site. The final two species, *M. fulvius* and *S. miliarius,* are susceptible to trapping with drift fences and funnel traps (unpubl. data, D. Stevenson and K. Dyer), and therefore may also be relatively rare on the study site.

Of 654 total captures, *C. constrictor* accounted for the majority of the individuals (60%) and recaptures (85%). The next two most abundant species, *T. sirtalis* and *T. sauritus*, made up 13% and 12% of the sample, respectively. The remaining 10 species made up less than 4% of the sample each (Table 2).

Seasonal Activity Patterns

Gibbons and Semlitsch (1987) suggested that two distinct patterns of annual activity can be identified in Temperate Zone snakes, a unimodal pattern with a single peak centered on warm weather, and a bimodal pattern with activity peaks in spring and fall. Both of these patterns were observed in the present study. Table 3 gives the number of snakes captured each month for all species. For monthly analyses, recaptured individuals were counted only once in each month collected. Seasonal activity patterns for the three most commonly captured species are summarized below.

Coluber constrictor

Of 290 *C. constrictor* tagged, 51 individuals were recaptured a total of 63 times (30 male and 33 female), for a recapture rate of 22 percent. All recaptured animals were adults. Descriptive statistics for adult male and female *C. constrictor* are provided in Table 4. Both adults and juveniles were captured during every month of the study (Fig. 1). Adults displayed a strong unimodal activity pattern that peaked in May for both sexes. A total of 50 juveniles was captured, also with a peak in May. These data were similar to results from a drift fencing study in South Carolina (Gibbons and Semlitsch 1987) and road collection studies in southern Florida (Dalrymple et al. 1991) and southern Texas (Auffenberg 1949). All three of these studies found *C. constrictor* to display a unimodal activity pattern with a peak in late spring to early summer. These results differ, however, from a drift fencing study in central Florida (Dodd and Franz 1995), in which no clear activity pattern was observed for this species.

Table 3. Number of snakes captured each month from November 2002 through October 2003 at John F. Kennedy Space Center, FL. Recaptured snakes are counted once in each month captured.

Species	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Totals
Cemophora coccinea	0	0	0	0	0	3	0	2	4	0	1	0	10
Coluber constrictor	24	9	9	31	14	45	100	46	30	26	28	13	375
Drymarchon couperi	0	2	0	1	0	0	1	1	2	2	2	1	12
Elaphe alleghaniensis	0	0	1	1	2	0	5	1	0	0	2	2	14
E. guttata	2	1	1	0	0	2	2	2	1	3	0	1	15
Farancia abacura	0	0	0	0	0	0	2	0	2	1	0	0	5
Lampropeltis triangulum	0	0	0	0	0	1	1	0	1	0	0	2	5
Masticophis flagellum	0	0	0	1	1	0	4	5	2	2	3	1	19
Nerodia fasciata	0	2	1	3	5	0	2	1	0	0	0	1	15
N. fasciata x *N. clarkii*	0	0	0	0	0	0	0	0	0	0	0	1	1
N. floridana	0	0	0	0	0	0	0	0	0	0	1	0	1
Opheodrys aestivus	0	0	0	0	0	0	0	0	0	0	0	1	1
Thamnophis sauritus	0	5	2	4	3	8	20	12	4	5	8	6	77
T. sirtalis	11	5	3	6	0	12	15	13	7	3	3	7	85
Totals	37	24	17	47	25	71	152	83	53	42	48	36	635

Table 4. Descriptive statistics for adults of the three snake species most commonly captured at drift fences at John F. Kennedy Space Center, FL. Snout-vent lengths in cm; wet mass body weights in g. SD = standard deviation.

			Snout-vent length			Body weight		
Species	Sex	N	Mean	Range	SD	Mean	Range	SD
C. constrictor	M	159	76.9	(50.3-121.1)	13.1	128.3	(22-535)	75.0
	F	112	83.6	(60.0-121.5)	14.7	175.1	(50-620)	116.4
T. sirtalis	M	44	59.2	(39.1-72.3)	8.5	84.4	(23-165)	34.3
	F	30	63.5	(44.3-83.0)	10.2	111.3	(24-330)	63.1
T. sauritus	M	27	47.4	(41.0-60.3)	5.0	25.4	(12-65)	11.5
	F	32	54.2	(42.8-64.7)	6.7	42.9	(11-85)	20.1

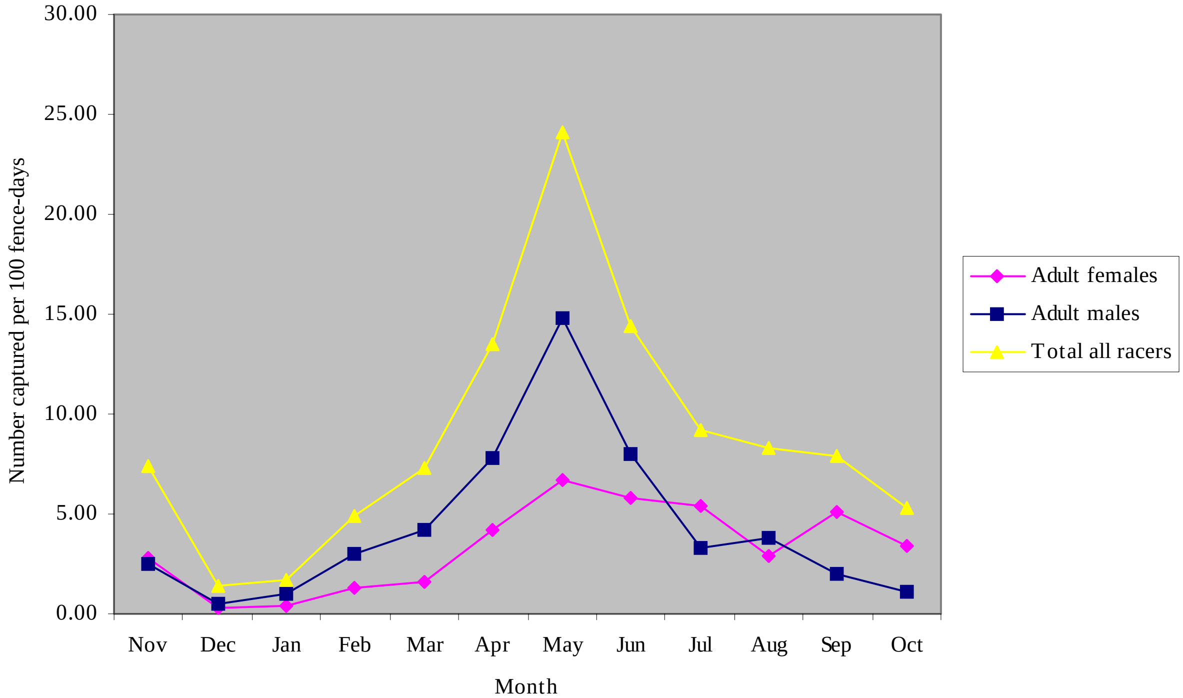

Figure 1. Monthly occurrence of *Coluber constrictor* by sex and age class from November 2002 through October 2003 at John F. Kennedy Space Center, FL. Recaptured individuals are included once in each month captured.

The observed sex ratio of adult *C. constrictor* was significantly different from 1:1 in February (Chi-square = 3.85, $p < 0.05$), May (Chi-square = 9.91, $p < 0.05$), and September (Chi-square = 4.84, $p < 0.05$), while the sex ratio did not differ from equality in any other month. In February and May, males were captured significantly more frequently than females, while in September, females were captured significantly more frequently than males. Snake primary sex ratios are generally assumed to be 1:1 (Parker and Plummer 1987). An observed secondary sex ratio that differs significantly from equality can be explained by several possibilities, including sexual differences in survivorship, habitat preference, or behavior, or by sampling bias (Parker and Plummer 1987). In the present study, the observed sex ratio in May was likely due to a sampling bias reflecting seasonal behavior differences between male and female snakes (Gibbons and Semlitsch 1987; Parker and Plummer 1987), as males are typically active earlier and more often during the spring mating season (Gibbons and Semlitsch 1987) (Fig. 1). The reason for the skewed sex ratios in February and September is not clear.

Thamnophis sirtalis

Of 70 *T. sirtalis* tagged, four adults were recaptured a total of five times (1 female and 4 males), for a recapture rate of seven percent. Descriptive statistics for adult male and female *T. sirtalis* captured are provided in Table 4. Adults were captured in all months except March (Fig. 2). Although these data are adjusted for sampling effort, March contained the shortest sampling

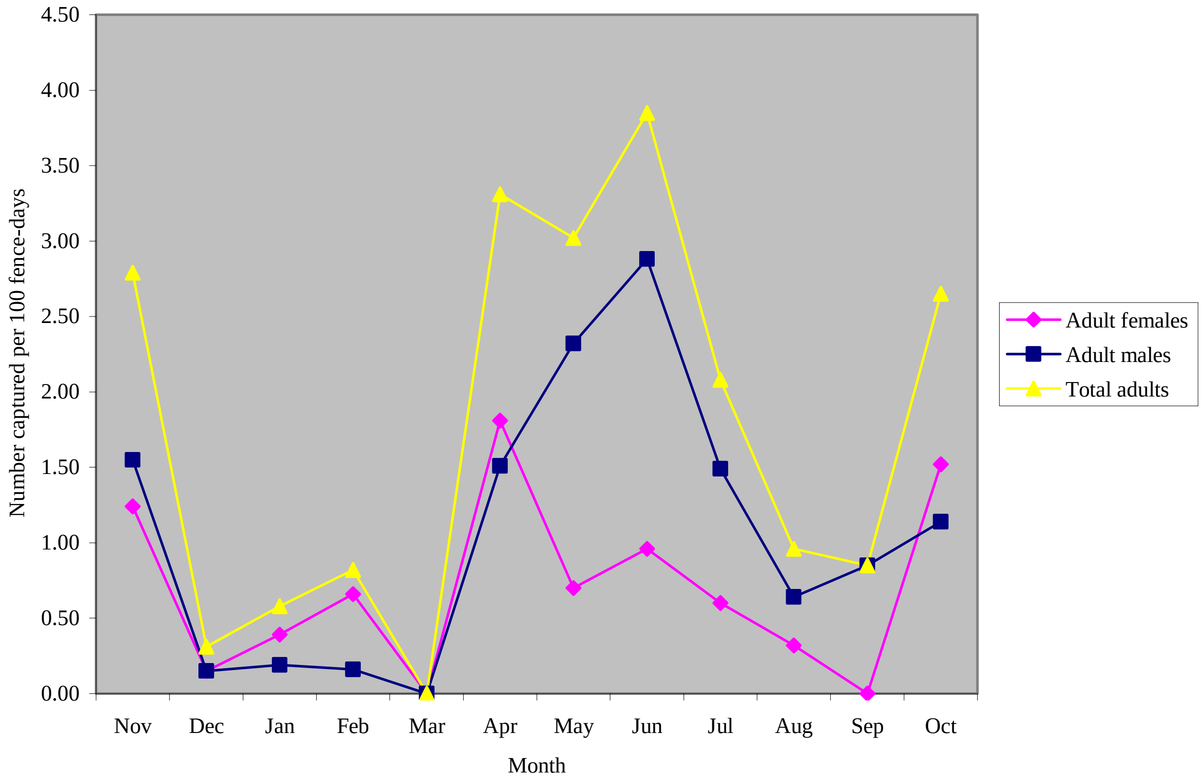

Figure 2. Monthly occurrence of adult *Thamnophis sirtalis* by sex from November 2002 through October 2003 at John F. Kennedy Space Center, FL. Recaptured individuals are included once in each month captured.

effort (192 fence-days) of any month of the year, so this result should be interpreted with caution. Adults displayed a bimodal activity pattern, with peaks in late spring to early summer and in fall for both sexes. Dalrymple et al. (1991) found *T. sirtalis* to be active year–round, with a similar bimodal activity pattern. Gibbons and Semlitsch (1987) found *T. sirtalis* to be active in all months of the year except January, but with no clear bimodal pattern. The observed sex ratio of adult *T. sirtalis* in the present study was 45 males to 30 females, which did not differ significantly from equality (Chi-square = 3.0, $p > 0.05$).

Thamnophis sauritus

Of 24 *T. sauritus* tagged, one adult male was recaptured once, for a recapture rate of 4 percent. Descriptive statistics for adult male and female *T. sauritus* captured are provided in Table 4. Adults were captured in all months except November (Fig. 3). Overall, adults displayed a bimodal activity pattern with a strong peak in late spring to early summer and a secondary peak in early fall, although fall activity differed between the sexes. Females were most numerous from August through October while males were most commonly captured in September, but not captured at all in August. Dalrymple et al. (1991) found *T. sauritus* to be active every month of the year, and observed a similar bimodal pattern. Males were most abundant in June through August, females were most numerous from May through July, and both sexes had a secondary activity peak in October. The observed sex ratio of adult *T. sauritus* in the present study was 30 males to 36 females, which did not differ significantly from equality (Chi-square = 0.545, $p > 0.05$).

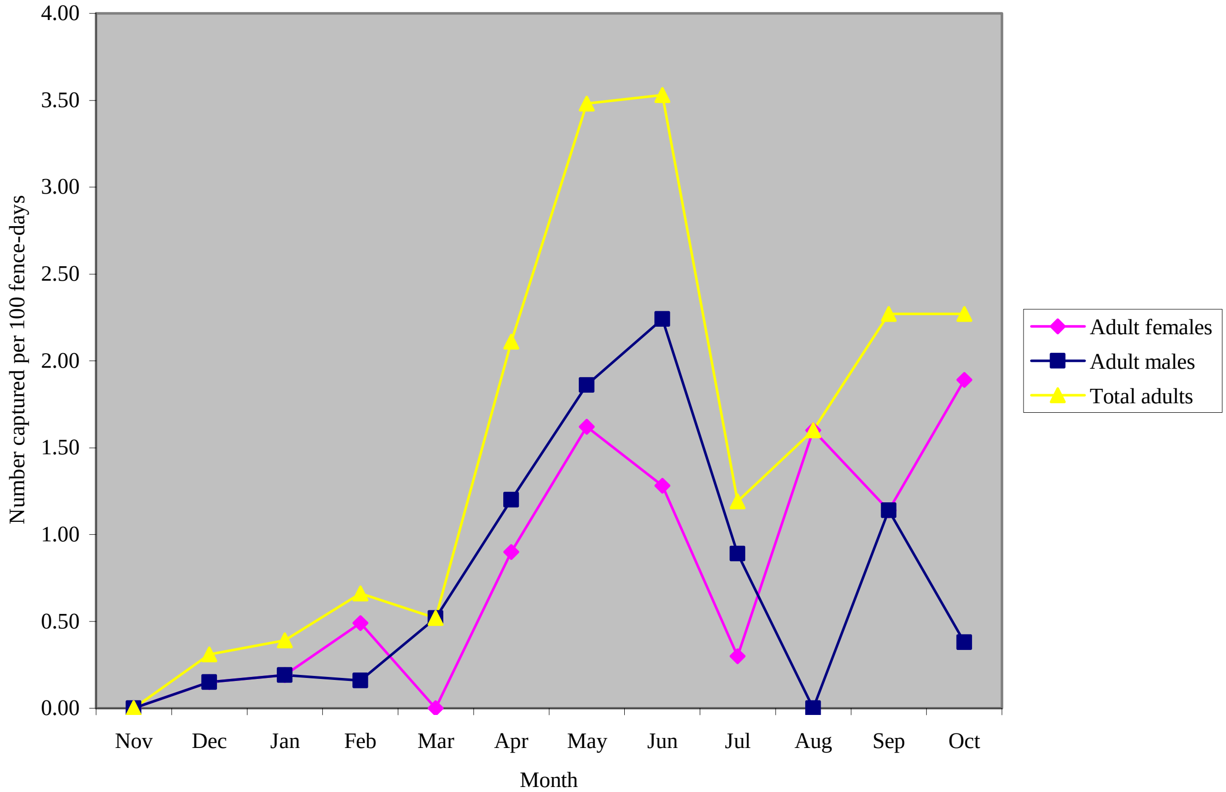

Figure 3. Monthly occurrence of adult *Thamnophis sauritus* by sex from November 2002 through October 2003 at John F. Kennedy Space Center, FL. Recaptured individuals are included once in each month captured.

Adults of the three most commonly captured species all displayed activity peaks from late spring to early summer, which corresponds to the typical breeding season for these species in the southeastern United States (Ernst and Ernst 2003; Rossman et al. 1996; Wright and Wright 1957). In addition to movements associated with reproductive behavior, observed seasonal activity patterns in snakes can be attributed to a number of other possible factors including thermoregulation, habitat use, prey abundance, predators, competitors, and sampling bias (Gibbons and Semlitsch 1987; Oliver 1947; Reinert 1993). In the present study, sampling bias was avoided by correcting for sampling effort throughout the year. In order to investigate other possible factors, Spearman's rank correlation was performed using the available data on weather conditions and prey abundance. There was a significant positive correlation between total number of snakes captured each month and mean monthly temperature ($r_s = 0.988$, $p < 0.001$), but no correlation with total monthly rainfall ($r_s = -0.109$, $p = 0.737$). A significant positive correlation also existed between total monthly snake captures and total monthly anuran ($r_s = 0.799$, $p = 0.002$) and lizard ($r_s = 0.934$, $p < 0.001$) captures, but there was no correlation with small mammal captures ($r_s = -0.396$, $p = 0.203$). Total captures per month of anurans ($r_s = 0.820$, $p = 0.001$) and lizards ($r_s = 0.797$, $p = 0.002$) were also significantly correlated with mean monthly temperature. These results suggest that temperature likely had an overriding influence on both snakes and their prey, but that other factors including reproduction contributed to the observed seasonal activity patterns.

Habitat Associations

Species Richness

Species richness in the four habitats varied from nine (swale) to 12 (ruderal) (Table 5). Mean species richness per fence was significantly different among habitat types ($F = 3.282$, $p = 0.042$). Tukey's HSD showed that mean species richness per fence was significantly lower in hammock than in ruderal ($p = 0.025$), while no significant differences existed among the other habitats. Two of the ruderal fences captured eight species each, the highest number of any fence, while one of the hammock fences captured only two species, the lowest number of any fence. All other fences captured between three and seven species each. Figure 4 shows the cumulative number of species captured over time in each habitat. As would be expected at the beginning of a study, the lines show an initial increase in slope as the most common species are captured. The slopes of the lines continue to increase for all habitats, however, and the number of species captured still appears to be increasing at the conclusion of the study. This is partly due to the fact that *Nerodia floridana*, *O. aestivus*, and the hybrid were not captured until the last two months of the sampling period.

Jaccard's Index

Jaccard's Index is based on the number of snake species shared by two communities, as well as the number of species unique to each. It does not take relative abundance or species evenness into account. The most dissimilar habitat pair in this study was scrub and swale, with a value of 0.462 (Table 6). These two habitats shared six species, while seven additional species were present in one or the other but not both. This is not surprising as scrub is a xeric community and

Table 5. Abundance and species richness of snakes trapped in four habitats from November 2002 through October 2003 at John F. Kennedy Space Center, FL. Recaptured snakes are counted once in each habitat captured.

Species	Ruderal	Hammock	Scrub	Swale	Totals
Cemophora coccinea	6	1	3	0	10
Coluber constrictor	92	55	99	98	344
Drymarchon couperi	4	2	1	4	11
Elaphe alleghaniensis	3	8	3	0	14
E. guttata	7	1	4	3	15
Farancia abacura	2	1	0	2	5
Lampropeltis triangulum	3	0	2	0	5
Masticophis flagellum	7	1	10	1	19
Nerodia fasciata	3	1	0	11	15
N. fasciata x *N. clarkii*	1	0	0	0	1
N. floridana	0	0	0	1	1
Opheodrys aestivus	0	0	1	0	1
Thamnophis sauritus	8	15	7	46	76
T. sirtalis	30	5	12	38	85
No. of individuals	166	90	142	204	602
No. of species	12	10	10	9	14
No. of fence-days	1181	1176	1185	1088	4630

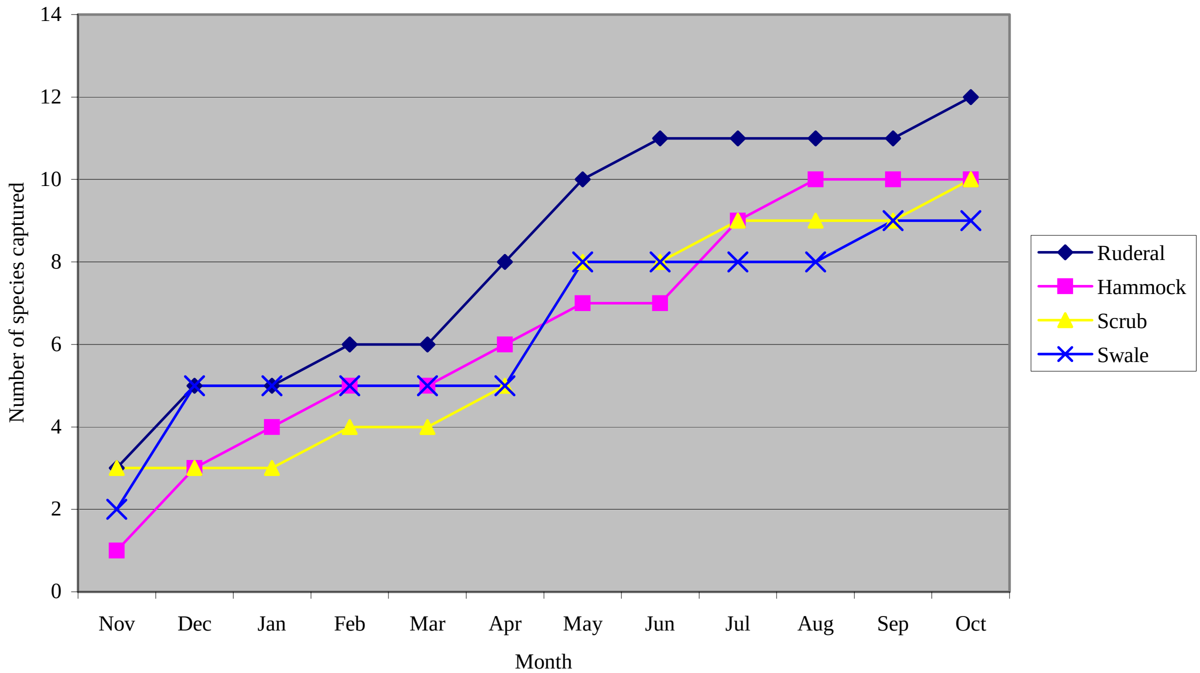

Figure 4. Cumulative number of snake species captured by month from November 2002 through October 2003 at John F. Kennedy Space Center, FL.

Table 6. Comparisons of similarity of snake communities inhabiting four habitats at John F. Kennedy Space Center, FL from November 2002 through October 2003.

Comparison	Sj
Ruderal vs. Hammock	0.8333
Ruderal vs. Scrub	0.6923
Ruderal vs. Swale	0.6154
Hammock vs. Scrub	0.6667
Hammock vs. Swale	0.7273
Scrub vs. Swale	0.4615

swale is a mesic community. Three species of semi-aquatic snakes, *Farancia abacura, Nerodia fasciata, and N. floridana*, were captured in swales, while none of these was captured in scrub. Similarly, four mainly terrestrial or arboreal species, *Cemophora coccinea, L. triangulum, Elaphe alleghaniensis*, and *O. aestivus*, were represented in the scrub sample, while none was captured at any swale fence. The most similar habitat pair was ruderal and hammock, with a value of 0.833 (Table 6). These two habitats shared 10 species, while 2 additional species were unique to ruderal. Hammock had no unique species. The remaining habitat pairs shared from 8 to 9 species, with the number of unique species in each habitat ranging from 1 to 4.

Relative Abundance

The number of snakes captured in the four habitats varied from 90 in hammocks to 204 in swales (Table 5). The relative abundance of the most common species captured in each habitat are shown in Figure 5. When investigating relative abundance across seasons and habitats, mean number of snakes captured per fence was significantly lower in winter when compared to the other seasons (Welch ANOVA, $F = 12.801$, $p = 0.001$). However, post hoc testing did not allow determination of where that difference occurred among the habitat types. Therefore, data were pooled in order to investigate relative abundance throughout the year. Mean number of snakes captured per fence was significantly different among habitat types ($F = 4.026$, $p = 0.022$). Tukey’s HSD test showed that mean number of snakes captured per fence was significantly higher in swale than in hammock ($p = 0.016$), while no significant differences existed among the other habitats. For hammocks this was largely due to relatively low *C. constrictor* captures when compared with the other habitat types. This can perhaps be explained by habitat selection

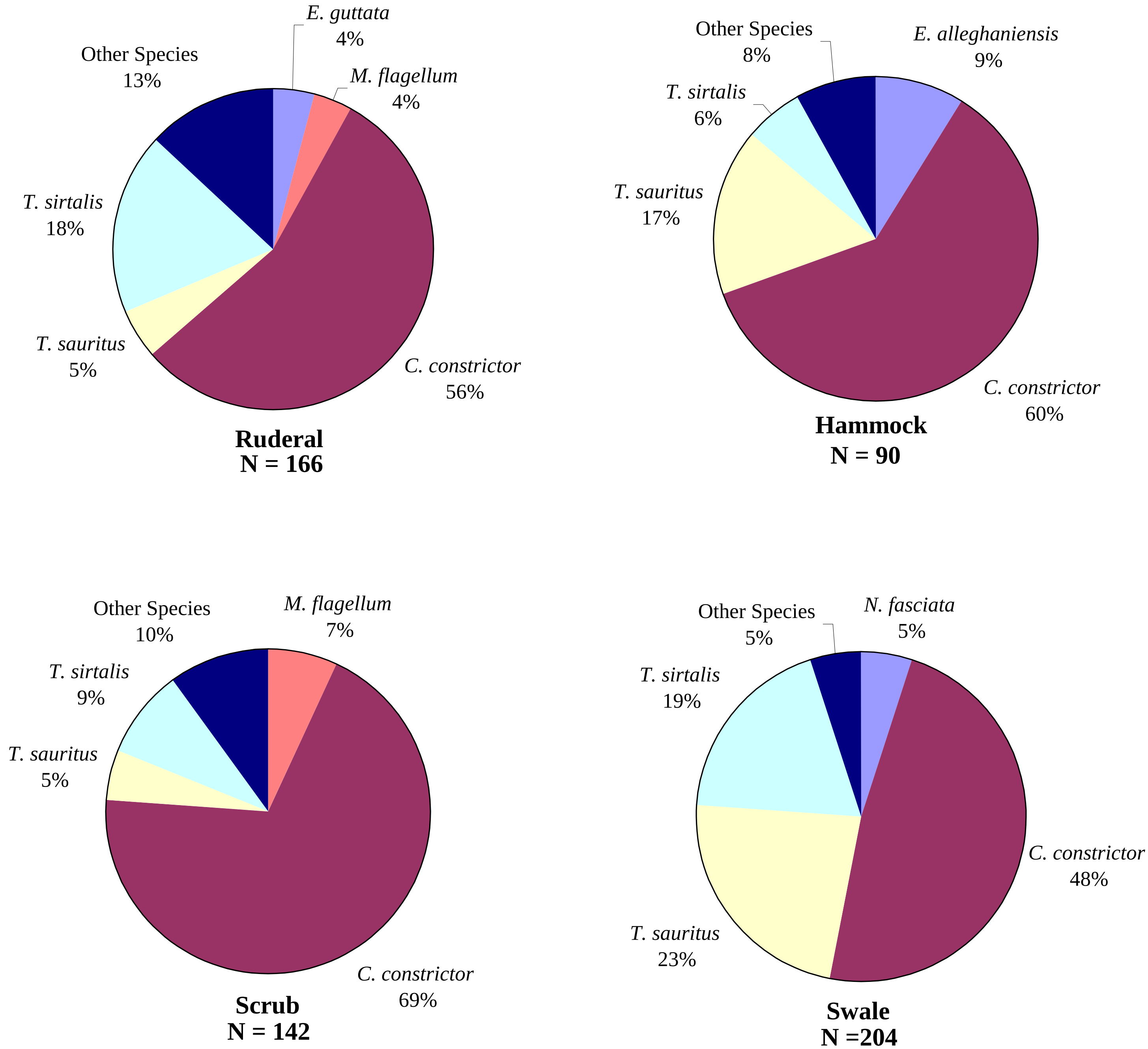

Figure 5. Composition of the most commonly captured snakes in four habitats from November 2002 through October 2003 at John F. Kennedy Space Center, FL.

associated with thermoregulation. *Coluber constrictor* is an active predator and maintains a relatively high body temperature when compared with less active species (Brown and Parker 1982; Fitch 1982). Digestion, speed, and foraging efficiency are all directly affected by body temperature, making thermal conditions an important factor in habitat selection in snakes (Reinert 1993). *Coluber constrictor* in central Florida may select more open habitats during the winter, while shifting habitat use more towards shady hammocks in the summer. This did occur to some extent, as *C. constrictor* was captured at hammock fences least frequently of all habitat types in winter, spring, and fall, but surpassed scrub captures in summer (Fig. 6). When looking at all species combined, however, hammock fences captured fewer snakes per 100 fence-days than all other habitats in every season (Fig. 7). As for the highest number of individuals being captured at swale fences, this is largely explained by swales having the highest capture rate of *T. sauritus* and *T. sirtalis*. Swale fences captured more *T. sauritus* than any other habitat type in every season (Fig. 8), and captured more *T. sirtalis* than any other habitat type in all seasons except winter (Fig. 9).

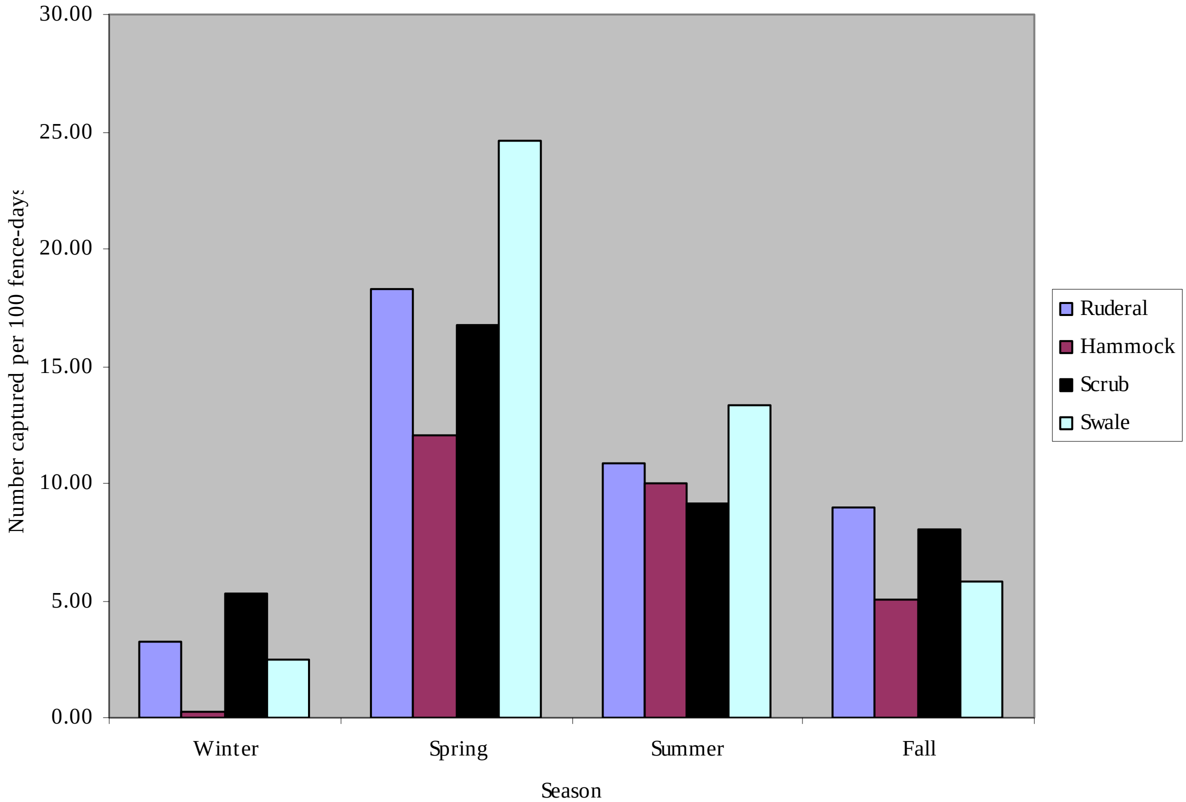

Figure 6. Relative abundance of *Coluber constrictor* by season and habitat, including recaptures, from November 2002 through October 2003 at John F. Kennedy Space Center, FL.

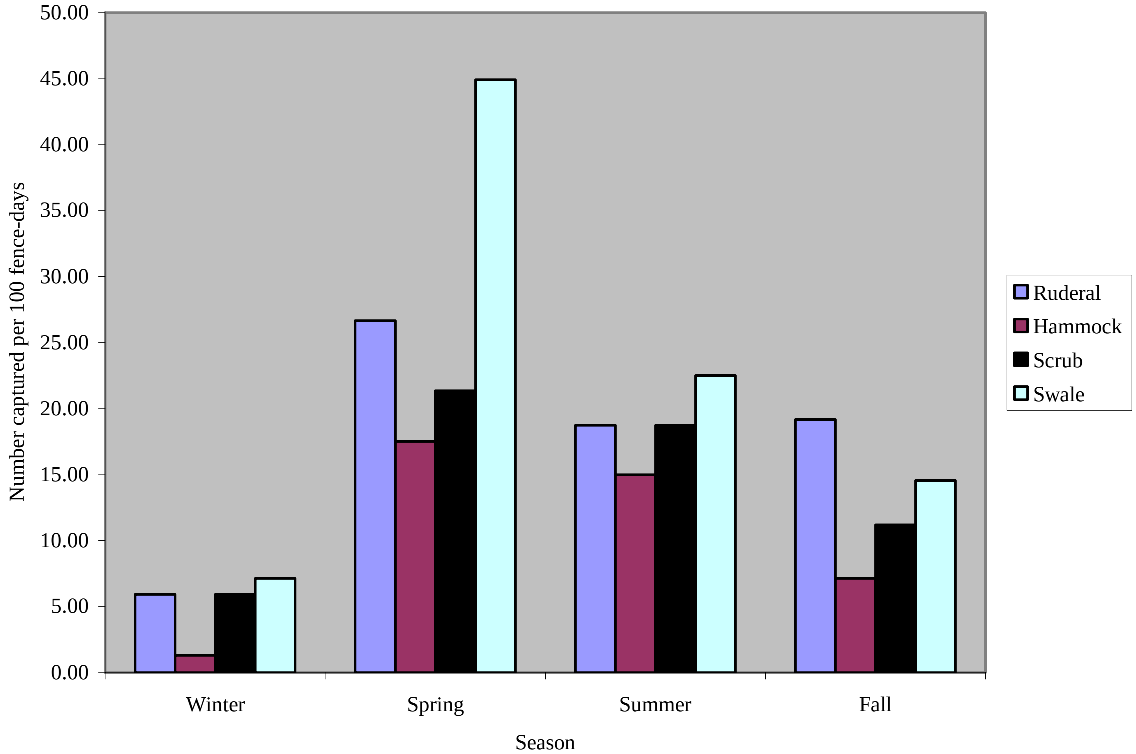

Figure 7. Relative abundance of all snake species captured by season and habitat, including recaptures, from November 2002 through October 2003 at John F. Kennedy Space Center, FL.

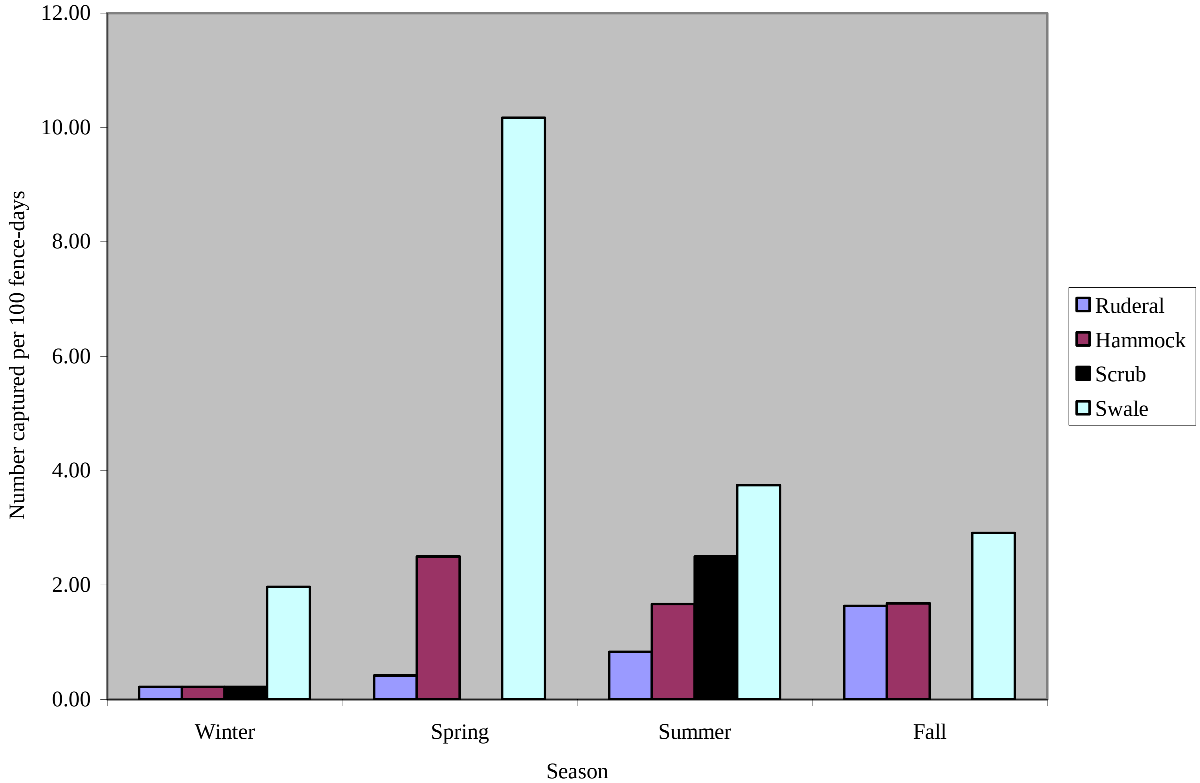

Figure 8. Relative abundance of *Thamnophis sauritus* by season and habitat, including one recapture, from November 2002 through October 2003 at John F. Kennedy Space Center, FL.

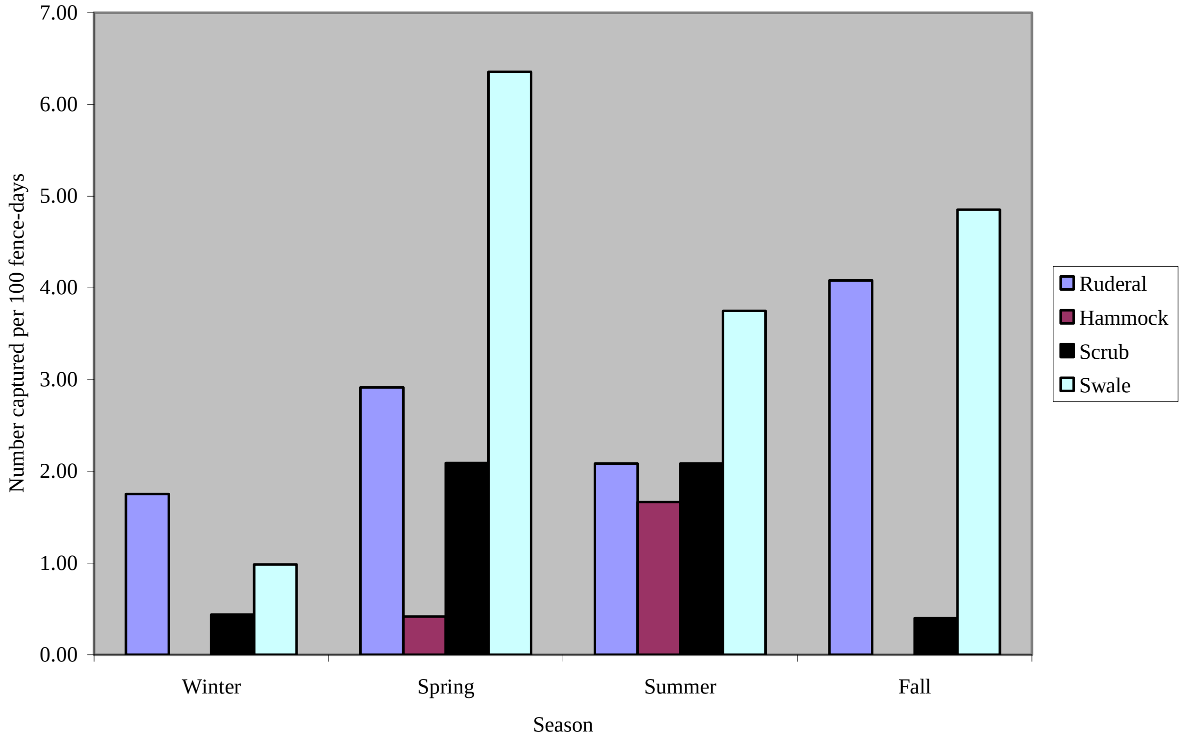

Figure 9. Relative abundance of *Thamnophis sirtalis* by season and habitat, including recaptures, from November 2002 through October 2003 at John F. Kennedy Space Center, FL.

SUMMARY

The snakes of John F. Kennedy Space Center were sampled from November 2002 through October 2003 to obtain quantitative data on their seasonal activity patterns and habitat use, and to compare two trap types for capturing large snakes. A total of 580 individuals representing 13 species and one hybrid was captured. The three most commonly captured species, *C. constrictor*, *T. sirtalis*, and *T. sauritus*, together made up 85% of the 654 total captures.

Due to the mild winters in central Florida, snakes were active during every month of the year. *Coluber constrictor* was found to display a unimodal activity pattern with a strong peak in May. *Thamnophis sirtalis* and *T. sauritus* both displayed bimodal activity patterns, with one peak in late spring to early summer and a second peak in the fall. Monthly snake captures were correlated with monthly captures of potential prey species and with mean monthly temperature.

Species richness varied from nine to 12 species, but the number of species captured in all four habitats still appeared to be increasing at the conclusion of the study. Swale fences captured the greatest number of individuals, while ruderal fences had the highest species richness. Based on Jaccard's Index, the most dissimilar habitat pair was scrub and swale, while the most similar pair was ruderal and hammock. The mean number of snakes captured per fence was significantly different among habitat types. This difference was largely explained by the relatively low number of *C. constrictor* captures in hammocks, and the relatively high number of *T. sirtalis* and *T. sauritus* captures in swales.

Drift fencing proved highly effective for capturing larger snakes in the four habitat types. Future studies could be improved by using traps with a smaller mesh size and/or including pitfall traps to target smaller species and juveniles. Results from this study suggest that box traps can be utilized effectively to target large snakes, while funnels of standard size (Fitch 1987) should be used for smaller species.

APPENDIX A: SPECIES LIST AND SUMMARY BY HABITAT OF ALL VERTEBRATES CAPTURED.

X denotes a species observed within close proximity to a drift fence, but not actually captured in a trap. Recaptured snakes are counted once in each habitat captured.

Scientific Name	Common Name	Ruderal	Hammock	Scrub	Swale	Total
AMPHIBIANS						
CAUDATES						
Siren lacertina	greater siren	0	0	0	1	1
TOTAL CAUDATES		0	0	0	1	1
ANURANS						
Acris gryllus dorsalis	Florida cricket frog				X	
Bufo quercicus	oak toad	10	1	33	12	56
B. terrestris	southern toad	17	29	11	13	70
Eleutherodactylus planirostris	greenhouse frog	4	8	1	X	13
Gastrophryne carolinensis	eastern narrowmouth toad	12	21	3	X	36
Hyla cinerea	green treefrog	11	26	13	1	51
H. femoralis	pine woods treefrog	25	12	30	19	86
H. gratiosa	barking treefrog	4	1	12	10	27
H. squirella	squirrel treefrog	41	31	13	4	89
Pseudacris ocularis	little grass frog				X	
Rana grylio	pig frog	16	3	39	48	106
R. sphenocephala	Florida leopard frog	434	302	187	490	1413
Scaphiopus holbrookii	eastern spadefoot	27	54	34	7	122
TOTAL ANURANS		601	488	376	604	2069
TOTAL AMPHIBIANS		601	488	376	605	2070
MAMMALS						
Cryptotis parva	least shrew	14	4	5	9	32
Dasypus novemcinctus	nine-banded armadillo	0	1	0	0	1
Didelphis virginiana	Virginia opossum	15	9	12	9	45
Glaucomys volans	southern flying squirrel	1	0	0	0	1
Neofiber alleni	round-tailed muskrat	0	0	0	5	5
Ochrotomys nuttalli	golden mouse	1	4	4	0	9
Oryzomys palustris	marsh rice rat	7	2	6	47	62
Peromyscus gossypinus	cotton mouse	80	88	88	38	294
P. polionotus niveiventris	southeastern beach mouse	4	0	19	0	23
Rattus norvegicus	norway rat	0	0	1	0	1
Scalopus aquaticus	eastern mole	1	0	0	0	1
Sciurus carolinensis	eastern gray squirrel	1	5	0	0	6
Sigmodon hispidus	hispid cotton rat	166	20	54	49	289
Spilogale putorius	eastern spotted skunk	7	16	64	17	104
Sylvilagus floridanus	eastern cottontail	2	0	0	0	2
S. palustris	marsh rabbit	0	0	2	2	4
TOTAL MAMMALS		299	149	255	176	879

Scientific Name	Common Name	Ruderal	Hammock	Scrub	Swale	Total
REPTILES						
CROCODILIANS						
Alligator mississippiensis	american alligator	2	3	1	1	7
TOTAL CROCODILIANS		2	3	1	1	7
TURTLES						
Apalone ferox	Florida softshell	2	0	12	0	14
Deirochelys reticularia chrysea	Florida chicken turtle	1	0	0	0	1
Gopherus polyphemus	gopher tortoise	2	1	X	0	3
Kinosternon baurii	striped mud turtle	0	3	2	0	5
K. subrubrum steindachneri	Florida mud turtle	0	0	0	1	1
Pseudemys floridana peninsularis	peninsula cooter	0	0	1	0	1
Terrapene carolina bauri	Florida box turtle				X	
TOTAL TURTLES		5	4	15	1	25
LIZARDS						
Anolis carolinensis	green anole	7	8	3	1	19
A. sagrei	brown anole			X		
Cnemidophorus s. sexlineatus	six-lined racerunner	97	8	81	18	204
Eumeces inexpectatus	southeastern five-lined skink	2	9	1	0	12
Ophisaurus ventralis	eastern glass lizard	1	1	0	4	6
TOTAL LIZARDS		107	26	85	23	241
SNAKES						
Cemophora coccinea	Florida scarlet snake	6	1	3	0	10
Coluber constrictor	southern black racer	92	55	99	98	344
Drymarchon couperi	eastern indigo snake	4	2	1	4	11
Elaphe alleghaniensis	eastern rat snake	3	8	3	0	14
E. guttata	eastern corn snake	7	1	4	3	15
Farancia abacura	eastern mud snake	2	1	0	2	5
Lampropeltis triangulum	scarlet kingsnake	3	0	2	0	5
Masticophis flagellum	eastern coachwhip	7	1	10	1	19
Nerodia fasciata	Florida water snake	3	1	0	11	15
N. fasciata x *N. clarkii*	Hybrid	1	0	0	0	1
N. floridana	Florida green water snake	0	0	0	1	1
Opheodrys aestivus	rough green snake	0	0	1	0	1
Thamnophis sauritus	peninsula ribbon snake	8	15	7	46	76
T. sirtalis	eastern garter snake	30	5	12	38	85
TOTAL SNAKES		166	90	142	204	602
TOTAL REPTILES		280	123	243	229	875
TOTAL ALL TAXA		1180	760	874	1010	3824

APPENDIX B: DRIFT FENCE COORDINATES

Fence	Habitat	Latitude	Longitude
1HA1	Hammock	206'5.9"	4016'18.5"
1HA2	Hammock	206'1.3"	4016'25.8"
2HA1	Hammock	205'55.6"	4016'9.8"
2HA2	Hammock	205'56.7"	4016'2.8"
3HA1	Hammock	204'50.0"	4015'25.8"
3HA2	Hammock	204'41.8"	4015'31.9"
1RU1	Ruderal	206'5.1"	4016'28.1"
1RU2	Ruderal	206'1.1"	4016'35.3
2RU1	Ruderal	205'39.9"	4016'9.9"
2RU2	Ruderal	205'55.4"	4016'13.7"
3RU1	Ruderal	203'57.1"	4016'46.5"
3RU2	Ruderal	203'37.7"	4016'57.5"
1SC1	Scrub	206'13.8"	4016'38.7"
1SC2	Scrub	206'19.9"	4016'37.5"
2SC1	Scrub	204'54.9"	4016'13.1"
2SC2	Scrub	205'29.8"	4016'10.9"
3SC1	Scrub	203'48.3"	4017'4.9"
3SC2	Scrub	204'3.1"	4016'40.6"
1SW1	Swale	206'5.9"	4016'48.7"
1SW2	Swale	206'23.4"	4016'32.2"
2SW1	Swale	204'51.2"	4016'8.2"
2SW2	Swale	205'25.9"	4016'12.1"
3SW1	Swale	203'44.0"	4017'7.7"
3SW2	Swale	203'43.9"	4017'4.7"

LIST OF REFERENCES

Auffenberg, W. 1949. The racer, *Coluber constrictor stejnegerianus* in Texas. Herpetologica 5:53-58.

Brown, W. S., and W. S. Parker. 1982. Niche dimensions and resource partitioning in a Great Basin Desert snake community. Pp. 59-81, *In* N. J. Scott, Jr. (Ed.). Herpetological Communities. U.S. Fish and Wildlife Service, Wildlife Research Report 13. 239 pp.

Bury, R. B., and P. S. Corn. 1987. Evaluation of pitfall trapping in northwestern forests: Trap arrays with drift fences. Journal of Wildlife Management 51:112-119.

Campbell, H. W., and S. P. Christman. 1982. Field techniques for herpetofaunal community analysis. Pp. 193-200, *In* N. J. Scott, Jr. (Ed.). Herpetological Communities. U.S. Fish and Wildlife Service, Wildlife Research Report 13. 239 pp.

Collins, J. T., and T. W. Taggart. 2002. Standard Common and Current Scientific Names for North American Amphibians, Turtles, Reptiles, and Crocodilians. Fifth Edition. Publication of The Center for North American Herpetology, Lawrence, KS. iv + 44 pp.

Corn, P. S. 1994. Straight-line drift fences and pitfall traps. Pp. 109-117, *In* W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster (Eds.). Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, DC. 364 pp.

Dalrymple, G. H., T. M. Steiner, R. J. Nodell, and F. S. Bernardino, Jr. 1991. Seasonal activity of the snakes of Long Pine Key, Everglades National Park. Copeia 1991:294-302.

Dodd, C. K., Jr., and R. Franz. 1995. Seasonal abundance and habitat use of selected snakes trapped in xeric and mesic communities of north-central Florida. Bulletin Florida Museum Natural History 38, Pt. I:43-67.

Enge, K. M. 1998. Herpetofaunal survey of an upland hardwood forest in Gadsden County, Florida. Florida Scientist 61:141-159.

Enge, K. M., and K. N. Wood. 1998. Herpetofaunal surveys of the Big Bend Wildlife Management Area, Taylor County, Florida. Florida Scientist 61:61-87.

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

Fitch, H. S. 1951. A simplified type of funnel trap for reptiles. Herpetologica 7:77-80.

Fitch, H. S. 1982. Resources of a snake community in prairie-woodland habitat in northeastern Kansas. Pp. 83-97, *In* N. J. Scott, Jr. (Ed.). Herpetological Communities. U.S. Fish and Wildlife Service, Wildlife Research Report 13. 239 pp.

Fitch, H. S. 1987. Collecting and life-history techniques. Pp. 143-164, *In* R. A. Seigel, J. T. Collins, and S. S. Novak (Eds.). Snakes: Ecology and Evolutionary Biology. MacMillan and Co., New York, NY. 529 pp.

Fitch, H. S. 1992. Methods of sampling snake populations and their relative success. Herpetological Review 23:17-19.

Franz, R. 1992. Florida pine snake. *In* P. E. Moler (Ed.). Rare and Endangered Biota of Florida Volume III: Amphibians and reptiles. University Press of Florida, Gainesville, FL. 291 pp.

Gibbons, J. W., and R. D. Semlitsch. 1981. Terrestrial drift fences with pitfall traps: An effective technique for quantitative sampling of animal populations. Brimleyana 7:1-16.

Gibbons, J. W., and R. D. Semlitsch. 1987. Activity patterns. Pp. 396-421, *In* R. A. Seigel, J. T. Collins, and S. S. Novak (Eds.). Snakes: Ecology and Evolutionary Biology. MacMillan and Co., New York, NY. 529 pp.

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

Huckle, H. F., H. D. Dollar, and R. F. Pendleton. 1974. Soil Survey of Brevard County, Florida. U. S. Department of Agriculture, Soil Conservation Service, Washington, D. C. 123 pp. & maps.

Myers, R. L. 1990. Scrub and high pine. Pp. 150-193, *In* R. L. Myers and J. J. Ewel (Eds.). Ecosystems of Florida. University of Central Florida Press, Orlando, FL. 765 pp.

Oliver, J. A. 1947. The seasonal incidence of snakes. American Museum Novitates 1363:1-14.

Parker, W. S., and M. V. Plummer. 1987. Population ecology. Pp. 253-301, *In* R. A. Seigel, J. T. Collins, and S. S. Novak (Eds.). Snakes: Ecology and Evolutionary Biology. MacMillan and Co., New York, NY. 529 pp.

Platt, W. J., and M. W. Schwartz. 1990. Temperate hardwood forests. Pp. 194-229, *In* R. L. Myers and J. J. Ewel (Eds.). Ecosystems of Florida. University of Central Florida Press, Orlando, FL. 765 pp.

Reinert, H. K. 1993. Habitat selection in snakes. Pp. 201-240, *In* R. A. Seigel and J. T. Collins (Eds.). Snakes: Ecology and Behavior. The Blackburn Press, Caldwell, NJ. 414 pp.

Rossman, D. A., N. B. Ford, and R. A. Seigel. 1996. The garter snakes: Evolution and ecology. University of Oklahoma Press, Norman, OK.

Rudolph, D. C., S. J. Burgdorf, R. N. Conner, and R. R. Schaefer. 1999. Preliminary evaluation of the impact of roads and associated vehicular traffic on snake populations in eastern Texas. Pp. 129-136, *In* G. L. Evink, P. Garrett, and D. Zeigler (Eds.). Proceedings of the Third International Conference on Wildlife Ecology and Transportation. FL-ER-73-91, Florida Department of Transportation, Tallahassee, FL.

Schmalzer, P. A. 2003. Growth and recovery of oak-saw palmetto scrub through ten years after fire. Natural Areas Journal 23:5-13.

Schmalzer, P. A., S. R. Boyle, and H. M. Swain. 1999. Scrub ecosystems of Brevard County, Florida: A regional characterization. Florida Scientist 62:13-47.

Schmalzer, P. A., and C. R. Hinkle. 1985. A brief overview of plant communities and the status of selected plant species at John F. Kennedy Space Center, Florida. Unpublished report, Kennedy Space Center, FL.

Seigel, R. A., R. B. Smith, J. D. Demuth, L. M. Ehrhart, and F. F. Snelson, Jr. 2002. Amphibians and reptiles of the John F. Kennedy Space Center, Florida: A long-term assessment of a large protected habitat (1975-2000). Florida Scientist 65:1-12.

Taylor, W. K. 1998. Florida Wildflowers in Their Natural Communities. University Press of Florida, Gainesville, FL. 370 pp.

Vitt, L. J. 1987. Communities. Pp. 335-365, *In* R. A. Seigel, J. T. Collins, and S. S. Novak (Eds.). Snakes: Ecology and Evolutionary Biology. MacMillan and Co., New York, NY. 529 pp.

Wright, A. H., and A. A. Wright. 1957. Handbook of Snakes of the United States and Canada. Comstock Publishing, Ithaca, NY. 1105 pp.