Journal of the South Carolina Academy of Science 3(1):1-12 Fall 2005

A SURVEY OF HERPETOFAUNAL DIVERSITY IN A LONGLEAF PINE FOREST ECOSYSTEM

Jeffrey D. Camper

Department of Biology, Francis Marion University, Florence, SC 29501-0547
jcamper@fmarion.edu

ABSTRACT

Amphibians and reptiles were sampled at eight sites in five different habitats in the sandhills of South Carolina. Four sites were sampled on the Carolina Sandhills National Wildlife Refuge and four on the adjacent Sand Hills State Forest. Species richness, species diversity, community evenness, and capture rate were measured at each site. Habitats sampled included longleaf pine/turkey oak sandhills, riparian forest, two permanent ponds, one temporary pond and a pocosin wetland. Species diversity was greatest for riparian forest, temporary pond, and pocosin wetland sites. Capture rates were greater at three refuge sites. Capture rates were also greater on the refuge for data from all four sites combined. Thirteen species of snakes were documented on the refuge by nocturnal road collecting. A comparison of pre-treatment and post-treatment data at a clearcut site showed that species richness, species diversity and community evenness were lower after the clearcut. Species richness and number of captures of salamanders were lower on the state forest.

INTRODUCTION

Due to extensive habitat destruction public lands may provide the best opportunities for preserving biodiversity. Only with thorough inventories and monitoring can the biota of public lands be accurately documented (Gibbons et al., 1997). One ecosystem that was severely negatively impacted was longleaf pine (*Pinus palustris*) forests. These were once the most abundant upland terrestrial habitat of the southeastern coastal plain. However, they have been reduced to about three percent of their former distribution (Ware et al., 1993). Longleaf pine forests had very high levels of habitat and plant species diversity (Means, 1996). This community had among the highest amphibian and reptile diversity of any temperate zone ecosystem (Guyer, Bailey, 1993). For example, species richness ranged from 27 to 36 species of amphibians and reptiles in sandhills and flatwoods in Florida (Mushinsky, 1984; Enge, Marion, 1986; Labisky, Hovis, 1987; Stout et al., 1988). Fifty species were found in Mississippi longleaf pine forests (Pearson et al., 1987) and 44 species were documented in longleaf pine forests in Louisiana (Williams, Mullin, 1987).

Even though species richness was greater in more mesic habitats within longleaf pine forests (Campbell, 1980; Williams, Mullin, 1987), many sensitive species of amphibians and reptiles need the drier habitats of these forests (Martof et al., 1980). These include the gopher frog (*Rana capito*), flatwoods salamander (*Ambstoma cingulatum*), tiger salamander (*Ambstoma tigrinum*), gopher tortoise (*Gopherus polyphemus*), eastern indigo snake (*Drymarchon couperi*), southern hognose snake (*Heterodon simus*), eastern diamondback

rattlesnake (*Crotalus adamanteus*), and at least three species of pine snakes (*Pituophis* spp.). All have some form of legal protection in at least part of their geographic range. The flatwoods salamander and eastern indigo snake are listed as threatened under the US Endangered Species Act. Tuberville et al. (2000) documented the decline in *H. simus* and *C. adamanteus* has also declined (Martin, Means, 2000). The objective of this study was to determine amphibian and reptile species richness and species diversity for five different habitats in a national wildlife refuge and an adjacent state forest.

MATERIALS AND METHODS

This study was conducted in the Sand Hills State Forest (SHSF) and adjacent Carolina Sandhills National Wildlife Refuge (CSNWR) in Chesterfield Co., South Carolina. Each encompass 18,600 ha with large tracts of restored longleaf pine/turkey oak (*Quercus laevis*) forest, riparian forest, wetlands and permanent artificial ponds and lakes. The SHSF receives no state funding and must generate revenue for the state via timber harvest, stump removal, and sale of pine cones and fallen pine needles (Jones, 1995 pers. comm.). However, the SHSF contains populations of the federally endangered red-cockaded woodpecker, *Picoides borealis* (RCW), so stands of longleaf pine are managed for this species. The CSNWR is managed primarily for longleaf pine forest habitat and is much less fragmented than the SHSF.

Habitats sampled included longleaf pine/turkey oak forest, riparian forest, permanent artificial ponds, a natural temporary pond and a shrub bog (pocosin) wetland (Table 1).

Table 1. Habitat and site descriptions for eight sites sampled in the Sand Hills State Forest and the Carolina Sandhills National Wildlife Refuge, Chesterfield Co., South Carolina.

Habitat	Sand Hills State Forest	Carolina Sandhills NWR
Longleaf Pine / Turkey Oak Forest	51 ha fragment among clear cut and pine plantation	782 ha tract bordered by 3 tracts of similar size
Riparian Forest	Black Creek Floodplain selective cut – spring 1994	Black Creek Floodplain 18.9 km upstream from SHSF site
Permanent Pond	Flory Pond – 17.4 ha Slash Pine clear cut - winter 1997	McLeod Pond - surrounded by longleaf pine/turkey oak forest
Wetlands	Pocosin with numerous small pools - stump removal spring 1996	Vernal pool in longleaf pine/turkey oak forest

Sites at SHSF were sampled from February – October 1995 to 1998. However, not all months were sampled each year. The SHSF pocosin was sampled in July - August 1997 and February - May 1998. During 1996, the riparian forest and pond sites were sampled from February – June and in August. The longleaf pine forest site was sampled from April – June and in August in 1996. All CSNWR sites were sampled from February - April in 1997.

Each site contained at least one 16 m aluminum drift fence with eight 19L pitfall traps and two funnel traps. However, two 16 m aluminum drift fences with eight 19L pitfall traps and two funnel traps per drift fence were used to sample the temporary pond at the CSNWR. Each sampling site also contained from 1-8 wood and 4-9 metal coverboards, and linear transects of 102 cm-inside-diameter, 1 m-long polyvinyl chloride (pvc) pipe treefrog retreats. Wood coverboards were plywood that measured 1.24 m per side and metal coverboards

were 2 m by 1 m. More wood boards were placed at mesic sites and more metal boards at drier sites because amphibians prefer wood and reptiles metal coverboards, respectively (Grant et al., 1992). At the longleaf pine and wetland sites the pvc pipe transects were perpendicular to the drift fences. At the riparian forest and pond sites these transects paralleled shorelines. Coverboards and treefrog retreats were only checked when drift fences were in use. Hoop net turtle traps baited with canned cat food and funnel traps were used to sample the permanent ponds. Turtle trapping effort consisted of ten traps for one night at Flory Pond (SHSF) and nine traps for one night at McLeod Pond (CSNWR). Pools at the wetland sites were sampled by dip netting and with funnel traps. Unless otherwise stated, frog calls were recorded as the presence of the species and one capture of one individual for all analyses. Road collecting at night has been shown to be an effective way to sample snake communities (Fitch 1987). I made 13 night collecting trips along Wildlife Drive during 1995 and 1996 to survey the snake community on the CSNWR. Wildlife Drive is a 16.4 km long paved road that is closed to the public after dark. It has seven permanent ponds along it. All animals collected were marked by toe-clipping amphibians and lizards, PIT tagging snakes, and notching the marginal scutes of turtles prior to release at capture site. Data were combined from all sampling methods at each sampling site. One voucher specimen of each species from both the CSNWR and SHSF was deposited in the Charleston Museum, Charleston, SC.

Because of unequal trapping effort data was standardized as number of captures / 100 trap days for statistical analysis (deMaynadier, Hunter, 1998). One trap day (TD) is defined as one drift fence open for one day. The Mann-Whitney *U* Test was used to compare the number of captures / 100 TD between analogous habitats. With samples where n_1 and n_2 were too large for the Mann-Whitney *U* Test, the Z test was used instead (Zar, 1984). The Z test was used to test data pooled from all four sites within the SHSF and CSNWR, respectively. Species richness, species diversity (H') and community evenness (J') were calculated for each sampling site (Ludwig, Reynolds, 1988). An á $\leq$ 0.05 was considered significant in all hypothesis testing in this study.

RESULTS

Data from a total of 664 TD at the CSNWR and 1084 TD at the SHSF were used in this study. A total of 363 captures of 37 species with 30 recaptures were found at the CSNWR and 322 captures of 40 species with 32 recaptures were found at the SHSF. A capture rate of 1.05 captures / 100 TD at the CSNWR was greater than 0.36 captures / 100 TD at the SHSF ($Z=2.43$, $p<0.05$). Two species, the southern toad (*Bufo terrestris*) and the ground skink (*Scincella lateralis*) were captured at all eight sampling sites (Tables 2,3). Thirteen of 21 species of amphibians and 17 of 28 species of reptiles documented were found on both the SHSF and CSNWR.

The longleaf pine/turkey oak forest site in the SHSF was sampled for 292 TD whereas the CSNWR site was sampled for 100 TD. Fourteen species were documented at the SHSF site and seven at CSNWR. Community evenness was higher for the CSNWR site but species diversity was greater for the SHSF site (Table 3). The CSNWR site had a higher capture rate (Table 4; Mann-Whitney $U=86$, df=7, 14, $p<0.05$).

Both riparian forest sites sampled were along Black Creek, a coastal plain black water creek that flows southeast into the Great Pee Dee River (Table 1). The SHSF site had the

Table 2. Numbers of captures (recaptures included) and observations of amphibians from eight sites sampled at the Sand Hills State Forest (SF-first number) and the Carolina Sandhills National Wildlife Refuge (NWR-second number), Chesterfield Co., South Carolina.

Species	Longleaf Pine	Riparian Forest	Ponds	Wetlands
Caudata	SF/NWR	SF/NWR	SF/NWR	SF/NWR
Eurycea cirrigera		0/4	0/1	
Notophthalmus viridescens				0/111
Plethodon chlorobryonis		2/7		7/0
Pseudotriton ruber	0/5		0/6	1/2
Siren intermedia			0/1	
Siren lacertina			1/0	
Anura:	SF/NWR	SF/NWR	SF/NWR	SF/NWR
Acris gryllus			39/1	2/4
Bufo fowleri			0/1	0/ 3
Bufo terrestris	7/9	24/36	1/4	14/6
Gastrophryne carolinensis		4/0	1/0	1/2
Hyla andersonii			1/0	1/ 3
Hyla cinerea		1/0	1/0	
Hyla femoralis		1/0		1/3
Hyla chrysocelis	1/0	1/1		1 / 1
Pseudacris crucifer		0/3		1 /15
*Rana capito**				2/0
Rana catesbeiana	4/0	0/1		
Rana clamitans	1/0	2/7	12/1	24/1
Rana sphenocephala		2/0	1/1	1/1
Rana virgatipes		1/0	10/1	0/1
Scaphiopus holbrookii				0/4

*Two males were heard calling on 11 May 1996. Neither specimens nor a breeding population has been verified.

mature pond pine (*Pinus serotina*) selectively cut in spring 1994 (Jones, 1995 pers. comm.). With 25 species (9 amphibians, 16 reptiles) this site had the highest species richness of all eight sites sampled (Table 4). The CSNWR site yielded 17 species (7 amphibians, 10 reptiles). The southern toad was the most abundant amphibian at both sites (Table 2). The six-lined racerunner (*Cnemidophorus sexlineatus*) and ground skink were the most abundant reptiles at the SHSF site whereas green anoles (*Anolis carolinensis*) and ground skinks were the most abundant species at the CSNWR site (Table 3). Ten species were found at both sites and community evenness was greater for the SHSF site (Table 4). Even though trapping effort was greater at the SHSF site, capture rate was higher at CSNWR (Table 4; Mann-Whitney U=278; df=17, 25; $p<0.05$).

The pocosin at the SHSF had been selectively cut in 1993 and had stumps removed in spring 1996 (Jones, 1995 pers. comm.). Both species richness and diversity were the second highest of all eight sites sampled (12 amphibians, 11 reptiles; Table 4). Ten species of anurans have been observed at this site including the gopher frog (*Rana capito*) and the pine barrens treefrog (*Hyla andersonii*, Table 2). The Southern toad and bronze frog (*Rana clamitans*) were the most abundant amphibians at this site. The six-lined racerunner, eastern fence lizard (*Sceloporus undulatus*) and ground skink were the most abundant reptiles at this site (Table 3).

The temporary pond at the CSNWR was breeding site for eastern newts (*Notophthalmus viridescens*) and spring peepers (*Pseudacris crucifer*). Twelve species of frogs and two species

of salamanders were found at this pond (Table 2). Three *H. andersonii* were found at this pond on 14 April 1996. Six species of lizards and snakes and no turtles were found at this site (Table 3). The lizards *S. undulatus* and *S. lateralis* were the most abundant reptiles at this site.

Table 3. Numbers of captures (recaptures included) and observations of reptiles from eight sites sampled at the Sand Hills State Forest (SF-first number) and the Carolina Sandhills National Wildlfe Refuge (NWR-second number), Chesterfield Co., South Carolina.

Species	**Longleaf Pine**	**Riparian Forest**	**Ponds**	**Wetlands**
Testudines	SF/NWR	SF/NWR	SF/NWR	SF/NWR
Kinosternon subrubrum		0/ 1	4/0	
Sternotherus odoratus			0/2	
Pseudemys concinna			3/0	
Terrapene carolina				1/0
Trachemys scripta		1/0	10/20	
Squamata: Sauria	SF/ NWR	SF/NWR	SF/NWR	SF/NWR
Anolis carolinensis	1/0	4/4	1/2	2/4
Cnemidophorus sexlineatus	1/0	8/0	8/4	5/0
Eumeces fasciatus	6 /1	6/1		
Eumeces laticeps	1/0	3/0	1/0	1/0
E. inexpectatus	5/6	1/0		1/0
Scincella lateralis	9 /5	8/4	1/5	6/19
Ophisaurus ventralis				1/0
Sceloporus undulatus	7/7	0/2	3/1	6 /10
Serpentes:	SF/NWR	SF/NWR	SF/NWR	SF/ NWR
Agkistrodon piscivorous		2/0	2/1	2/0
Carphophis amoenus	2/0			
Coluber constrictor		1/0	1/0	0/1
Crotalus horridus		1/0		
Diadophis punctatus		1/1	0/2	0/1
Elaphe obsoleta		2/1		
Lampropeltis getula		1/0		
L. triangulum	1/0	1/0		2/0
Nerodia fasciata			4/2	
Nerodia taxispilota		1/0		
Storeria dekayi		0/3		
Tantilla coronata	2/1	4/0	1/0	0/1
Thamnophis sirtalis		0/1		
Virginia striatula		2/1		1/0

The permanent ponds sampled included Flory Pond on the SHSF and McLeod Pond on the CSNWR. Both are artificial impoundments caused by the damming of small streams. Species diversity, community evenness, and capture rate were higher at the CSNWR site but species richness and trapping effort were greater at the SHSF site (Table 4). Capture rate was greater at McLeod Pond on the CSNWR (Table 4; Mann-Whitney U=333; df=18, 21; $p<0.05$). Eleven species were found at both sites (Tables 2,3). Carpenter frogs (*Rana virgatipes*), bronze frogs and southern cricket frogs were the most abundant amphibians at Flory Pond whereas red salamanders and southern toads were the most abundant at McLeod

Pond (Table 2). Yellow-bellied sliders (*Trachemys scripta*) were the most abundant reptile in both ponds. Flory Pond had a 17.4 ha clear cut on its north side during the winter of 1996. Because the clear cut occurred during the study and adjacent to the sampling site, I compared data from Flory Pond before and after the clear cut (Table 5). Although trapping effort was about 25% greater after the clear cut, species diversity and community evenness were greater before the clear cut. Species richness decreased by one-third after the clear cut (Table 5).

Fewer captures of salamanders were recorded on the SHSF (Table 6). Only 11 captures of three species were recorded from the SHSF whereas 108 captures of five species were recorded on the CSNWR. Whereas terrestrial salamanders were captured at all sites on CSNWR, they were found only at the pocosin and riparian forest sites on SHSF (Table 2).

Road collecting along Wildlife Drive yielded 13 species of snakes (Table 7). Six of these species were not found at any of the eight sampling sites (Table 3). The most frequently encountered snake on Wildlife Drive at night was the pygmy rattlesnake (*Sistrurus miliarius*) which was not found at any of the eight sampling sites nor on the SHSF. The mole kingsnake (*Lampropeltis calligaster*) and glossy crayfish snake (*Regina rigida*) were two secretive and

Table 4. Summary statistics for amphibian and reptile captures from eight sites sampled at the Sand Hills State Forest (SF) and the Carolina Sandhills National Wildlife Refuge (NWR), Chesterfield Co., South Carolina. Capture rate is number of captures / 100 TD where one trap day (TD) is one drift fence open for one day. Trapping effort is in TD.

Measure	Longleaf Pine		Riparian Forest		Ponds	
Wetlands	SF	NWR	SF	NWR	SF	NWR
Species Richness	14	7	25	17	21	18	23	22
Species Diversity (H')	2.25	1.75	2.50	2.04	2.26	2.32	2.49	1.77
Community Evenness	0.853	.899	0.777	0.573	0.742	0.803	0.794	0.720
Trapping Effort	292	100	343	141	343	141	106	282
Capture Rate	1.17	4.86*	0.98	3.25*	1.50	2.20*	3.45	3.14

*Significant at P<0.05, Mann-Whitney *U* test.

Table 5. Data from the Sand Hills State Forest, Chesterfield Co., South Carolina before and after clear cutting along the north side of Flory Pond. One trap day (TD) is one drift fence open for one day.

Parameter	Before Clear cut	After Clear cut
Trapping effort (TD)	143	193
Number of captures	49	46
Species richness	18	10
Species diversity (H')	2.34	1.53
Community evenness	0.827	0.664

Table 6. Numbers of salamander captures during sampling at the Sand Hills State Forest (SHSF) and Carolina Sandhills National Wildlife Refuge (CSNWR), Chesterfield Co., South Carolina. Recaptures are excluded.

Species	SHSF	CSNWR
Eurycea cirrigera	0	5
Plethodon chlorobryonis	9	7
Pseudotriton ruber	1	13
Notophthalmus viridescens	0	89
Siren intermedia	0	1
Siren lacertina	1	0
Total	11	108
÷ 2 = 77.45, df = 1, P<0.05		

Table 7. Snakes encountered on 13 nights of road collecting during 1995-1996 along Wildlife Drive in the Carolina Sandhills National Wildlife Refuge, Chesterfield Co., South Carolina.

Species	Number of Captures or observations
Agkistrodon contortrix	5
Agkistrodon piscivorus	1
Cemophora coccinea	1
Crotalus horridus	1
Lampropeltis calligaster	1
Lampropeltis triangulum	3
Nerodia fasciata	1
Regina rigida	1
*Sistrurus miliarius**	14 (1 recapture included)
Storeria occipitomaculata	1
Tantilla coronata	4
Thamnophis sirtalis	2
Virginia striatula	1
Total number of species (captures)	13 (36)

possibly rare species found only on Wildlife Drive (Table 7). Two species of snakes listed in South Carolina as species of special concern were found dead on other roads during this study. On 2 June 1995 I found one *H. simus* in the SHSF and on 16 April 1996 I found one gravid female northern pine snake (*Pituophis melanoleucas*) in the CSNWR.

DISCUSSION

That species richness was similar between CSNWR and SHSF, despite greater trapping effort at the latter, was not unexpected. However, capture rates were greater at three CSNWR sites possibly indicating greater abundance at those sites (Table 4). Approximately 72 species of amphibians and reptiles have been documented at CSNWR (Garton, Sill, 1976) whereas only 55 species have been documented on SHSF (Camper, 1999). Garton and Sill (1976) found 63 species using time constrained searching, road collecting, and three different types of aquatic sampling. The difference in species richness probably reflects differences in sampling methods. Their sampling methods allowed them to search more localities and more habitats. Even though they found more species, I found five species (*P. ruber, Eumeces fasciatus, Diadophis punctatus, R. rigida* and *S. miliarius*) that they did not find.

Neither study found any salamanders of the genus *Ambystoma* which occur in this region (Conant, Collins, 1991). Since the termination of my study, tiger salamanders (*A. tigrinum*) and marbled salamanders (*A. opacum*) have been documented on the CSNWR (Blihovde, 1998; Irwin, 1999 pers. comm.). The latter species was found along the Lynches River where I did not sample. For two *Ambystoma* species to go undetected despite a considerable amount of effort to inventory CSNWR shows that long term sampling using many techniques is needed to thoroughly inventory public lands (Gibbons et al., 1997).

The reason for the significantly greater species diversity and higher species richness for the SHSF longleaf pine/turkey oak forest site is unclear but may be an artifact of greater sampling effort at the SHSF site. However, mean capture rate was significantly higher at

CSNWR and more than double that at the SHSF site (Table 4). Although similar, the soils at the SHSF site are characterized by more loam and shallower subsoil with a dense sandy clay loam layer (Morton, 1995). Perhaps the soils at the SHSF site retain more moisture and therefore are better habitat for amphibians and reptiles. The 14 species I found at the longleaf pine forest on SHSF were comparable to what was found in Florida sandhills.

Campbell (1980) found 12 species and Campbell and Christman (1982) found 13 species. However, most other studies of southeastern coastal plain pine forest habitats have reported much higher species richness ranging from 27 to 50 (Mushinsky, 1984; Labisky, Hovis, 1987; Pearson et al., 1987; Williams, Mullin,1987; Stout et al., 1988). More mesic sites were more productive in studies at other longleaf pine sites in Florida (Campbell, 1980) and Louisiana (Williams, Mullin, 1987). Perhaps lower species richness was due to sampling in only two upland localities in this study that were not near water.

The riparian forest sites sampled in this study (Table 4) had greater species richness than reported by Clawson et al. (1997) for a site in Alabama. A comparable value of 23 species was reported for a riparian forest in South Carolina (Phelps, Lancia, 1995). The SHSF site had the highest species richness of all eight sites sampled (Table 4) and was one of only two sites on the SHSF where terrestrial salamanders were captured.

Temporary ponds in the southeastern coastal plain are known to have high herpetofaunal species richness (Dodd, Charest, 1988; Dodd, 1992; Russell et al., 2002a). Large numbers of *N. viridescens* captured at the wetland CSNWR site may have depressed community evenness values and increased capture rates (Table 4). Dodd (1992) found 42 species at one temporary pond in Florida sandhills and Russell et al. (2002a) found 56 species using five temporary ponds in the lower coastal plain of South Carolina. Both were greater than found in this study. However, the ponds studied by Dodd (1992) and Russell et al. (2002a) were completely surrounded by drift fences.

Although little is known concerning herpetofaunal communities in pocosins (Wilbur, 1981; Sharitz, Gibbons, 1982; Richardson, Gibbons, 1993), evidence from this study indicates they may have high species diversity (Table 4). Species diversity values presented here are likely underestimates because relatively little trapping effort was expended at this site and because the location of the drift fence was up hill several meters away from most of the amphibian breeding pools.

The results from Flory Pond before and after the clear cut are not unexpected. It has been shown that clear cutting may negatively impact amphibian and reptile abundance and species richness (Blymyer, McGinnes, 1977; Enge, Marion, 1986; Pough et al., 1987; Williams, Mullin, 1987; Raymond, Hardy, 1991; Petranka et al., 1993, 1994; Grant et al., 1994; Dupuis et al., 1995; McLeod, Gates, 1998). However, the relationship between clear cutting and species diversity may not be straightforward because (Campbell, 1980) showed that clearcuts reduced abundance but not species richness and Russell et al. (2002b) found no changes in species richness or abundance six months and 1.5 years after clear cutting.

The differences in salamander captures were unexpected given the levels of species richness and diversity at SHSF. However, even in areas of relatively intact habitat on SHSF salamander captures were rare. The SHSF sells the leaf litter as pine straw for garden mulching and it is also illegally poached from intact forest stands (Jones, 1995 pers. comm.). Perhaps the removal of leaf litter in a xeric habitat such as sandhills longleaf pine/turkey oak forest may cause a decline in salamander populations even in relatively intact forest stands. Leaf

litter depth has been shown to be positively correlated with salamander abundance in the piedmont of South Carolina (Metts et al., 2001).

Road collecting was shown to be effective for sampling snakes (Dodd et al. 1989). With only 13 road collecting nights I was able to find 13 species and 36 individuals. Because snakes can easily escape pitfall traps (Enge 2001) their diversity was probably underestimated at the eight sampling sites. Six species that were not found at the sampling sites were found on the road. Two of these, *R. rigida* and *S. miliarius* had not been found at CSNWR before. Garton and Sill (1976) found 12 species and at least 21 individual snakes on roads at CSNWR. Most other road collecting studies of snakes in the southeast have reported similar species richness ranging from 11 to 16 species (Dodd et al. 1989 [and references cited therein]; Bernardino, Dalrymple 1992). Herpetological studies are continuing at the CSNWR (Messenger, 1999 pers. comm.) but more monitoring is needed on the SHSF.

ACKNOWLEDGMENTS

D. Jones of the South Carolina Forestry Commission assisted with several aspects of the study. J. W. Bethea, T. W. Knowles, D. T. Hill, B. Blihovde, and the Francis Marion University Ecology Club assisted with field work. This manuscript benefited from the suggestions of two anonymous reviewers. Support was provided by S. H. Bennett of the South Carolina Department of Natural Resources and Francis Marion University. Specimens were collected under a South Carolina Scientific Research Permit and CSNWR specimens were collected under Federal Permit 78951. F. Murphy and D. Green of the Sand Hills State Forest helped with access to sites and field work.

LITERATURE CITED

Bernardino FS, Dalrymple GH. 1992. Seasonal activity and road mortality of the snakes of the Pa-hay-okee wetlands of Everglades National Park, USA. Biological Conservation 62:71-75.

Blihovde WB. 1998. Geographic distribution. Ambystoma tigrinum tigrinum. Herpetological Review 29: 105.

Blymyer MJ, McGinnes BS. 1977. Observations on possible detrimental effects of clearcutting on terrestrial amphibians. Bulletin of the Maryland Herpetological Society 13: 79-83.

Campbell HW. 1980. St. Marks National Wildlife Refuge: Forestry Management and Non-game Wildlife. Gainesville (FL): U. S. Fish and Wildlife Service; 119p.

Campbell HW, Christman SP. 1982. The herpetological components of Florida sandhill and sand pine scrub associations. Herpetological Communities, NJ Scott ed., U. S. Fish and Wildlife Service, Wildlife Research Report 13, 163-171.

Camper JD. 1999. Herpetological studies on the Sand Hills State Forest. Unpublished Report. 13p.

Clawson RG, Lockaby BG, Jones RH. 1997. Amphibian responses to helicopter harvesting in forested floodplain of low order, blackwater streams. Forest Ecology and Management 90: 225-235.

Conant R, Collins JT. 1991. A field guide to reptiles and amphibians of Eastern and Central North America. 3rd edition. Houghton Mifflin, Boston, MA.

deMaynadier PG, Hunter ML. 1998. Effects of silvicultural edges on the distribution and abundance of amphibians in Maine. Conservation Biology 12: 340-352.

Dodd CK, 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. Biodiversity and Conservation 1:125-142.

Dodd CK, Enge KM, Stuart, JN. 1989. Reptiles on highways in north-central Alabama, USA. Journal of Herpetology 23:197-200.

Dodd CK, Charest BG. 1988. The herpetofaunal community of temporary ponds in North Florida Sandhills: Species composition, temporal use, and management implications. Management of Amphibians, Reptiles, and Mammals in North America, RC Szaro, KE Severson, DR Patton eds., USDA Forest Service General Technical Report RM-166. 87-97.

Dupuis LA, Smith JNM, Bunnell F. 1995. Relation of terrestrial-breeding amphibian abundance to tree-stand age. Conservation Biology 9: 645-653.

Enge KM, 2001. The pitfalls of pitfall traps. Journal of Herpetology 35: 467-478.

Enge KM, Marion WR. 1986. Effects of clearcutting and site preparations on herpetofauna of a north Florida flatwoods. Forest Ecology and Management 14: 177-192.

Fitch HS. 1987. Collecting and life-history techniques. Snakes: Ecology and Evolutionary Biology, RA Seigel, JT Collins, SS Novak eds., MacMillan Publishing Company, New York, 143-164.

Garton JS, Sill BL. 1976. The amphibians and reptiles of the Carolina Sandhills National Wildlife Refuge. Unpublished Report. 25 p.

Gibbons JW, Burke VJ, Lovich JE, Semlitsch RD, Tuberville TD, Bodie JR, Greene JL, Niewiarowski PH, Whiteman HH, Scott DE, Pechmann JHK, Harrison CR, Bennett SH, Krenz JD, Mills MS, Buhlmann KA, Lee JR, Seigel RA, Tucker AD, Mills TM, Lamb T, Dorcas ME, Congdon JD, Smith MH, Nelson DH, Dietsch MB, Hanlin HG, Ott JA, Karapatakis DJ. 1997. Perceptions of species abundance, distribution, and diversity: lessons from four decades of sampling on a government-managed reserve. Environmental Management 21: 259-268.

Grant BW, Tucker AD, Lovich JE, Mills AM, Dixon PM, Gibbons JW. 1992. The Use of coverboards in estimating patterns of reptile and amphibian biodiversity. Wildlife 2001, DR McCullough, RH Barrett eds., Elsevier Science Publications, Inc., London, 379-403.

Grant BW, Brown KL, Ferguson GW, Gibbons JW. 1994. Changes in amphibian biodiversity associated with 25 years of pine forest regeneration: implications for biodiversity management. Biological Diversity: Problems and Challenges, SK Majumdar, FJ Brenner, JE Lovich, JF Schalles, EW Miller eds., The Pennsylvania Academy of Science, Philadelphia. 355-367.

Guyer C, Bailey MA. 1993. Amphibians and reptiles of longleaf pine communities. The Longleaf Pine Ecosystem: Ecology, Restoration and Management, SM Hermann ed., Proceedings of the Tall Timbers Fire Ecology Conference No. 18. Tall Timbers Research Station, Tallahassee, FL. 139-158.

Irwin, KJ. Carolina Sandhills National Wildlife Refuge. 1999.

Jones, WD. South Carolina Forestry Commission. 1995.

Labisky RF, Hovis JA. 1987. Comparison of vertebrate wildlife communities in Longleaf pine and slash pine habitats in north Florida. Ecological, Physical, and Socioeconomic Relationships Within Southern National Forests, HA Pearson, FE Smeins, RE Thill eds.,

Southern Forest Experiment Station. New Orleans, LA, General Technical Report SO-68, 201-228

Ludwig JA, Reynolds JF. 1988. Statistical Ecology. John Wiley & Sons, New York.

Martin WH, Means DB. 2000. Distribution and habitat relationships of the eastern diamondback rattlesnake (Crotalus adamanteus). Herpetological Natural History 7:9-34.

Martof BS, Palmer WM, Bailey JR, Harrison JR. 1980. Amphibians and reptiles of the Carolinas and Virginia. University of North Carolina Press, Chapel Hill, NC.

McLeod RF, Gates JE. 1998. Response of herpetofaunal communities to forest cutting and burning at Chesapeake Farms, Maryland. American Midland Naturalist 139: 164-177.

Means DB. 1996. Longleaf pine forest, going, going, . . . Eastern Old-Growth Forests: Prospects for Rediscovery and Recovery, MB Davis ed., Island Press, Washington DC, 210-229.

Messenger, K. North Carolina State University. 1999.

Metts BS, Lanham JD, Russell KR. 2001. Evaluation of herpetofaunal communities on upland streams and beaver-impounded streams in the upper piedmont of South Carolina. American Midland Naturalist 145:54-65.

Morton R. 1995. Soil survey of Chesterfield County, South Carolina. USDA Soil Conservation Service.

Mushinsky HR. 1984. Fire and the Florida sandhill herpetofaunal community: with special attention to responses of Cnemidophorus sexlineatus. Herpetologica 41: 333-342.

Pearson HA, Lohoefener RR, Wolfe JL. 1987. Amphibians and reptiles on longleaf-slash pine forests in southern Mississippi. Ecological, Physical, and Socioeconomic Relationships Within Southern National Forests, HA Pearson, FE Smeins, RE Thill eds., Southern Forest Experiment Station. New Orleans, LA, General Technical Report SO-68, 157-165.

Petranka JW, Eldridge ME, Haley, KE. 1993. Effects of timber harvesting on southern Appalachian salamanders. Conservation Biology 7: 363-370.

Petranka JW, Brannon MP, Hopey ME, Smith CK. 1994. Effects of timber harvesting on low elevation populations of southern Appalachian salamanders. Forest Ecology and Management 67: 135-147.

Phelps JP, Lancia, RA. 1995. Effects of a clearcut on the herpetofauna of a South Carolina bottom land swamp. Brimleyana 22:31-45.

Pough FH, Smith EM, Rhodes DH, Collazo A. 1987. The abundance of salamanders in forest stands with different histories of disturbance. Forest Ecology and Management 20: 1-9.

Raymond LR, Hardy LM. 1991. Effects of a clearcut on a population of the mole salamander, Ambystoma talpoideum, in an adjacent unaltered forest. Journal of Herpetology 25: 509-512.

Russell KR, Guynn DC, Hanlin HG. 2002a. Importance of small isolated wetlands for herpetofaunal diversity in managed, young growth forests in the Coastal Plain of South Carolina. Forest Ecology and Management 63:43-59.

Russell KR, Hanlin HG, Wigley TB, Guynn DC. 2002b. Responses of isolated wetland herpetofauna to upland forest management. Journal of Wildlife Management 66: 603-617.

Richardson CJ, Gibbons JW. 1993. Pocosins, Carolina Bays, and Mountain Bogs. Biodiversity of the Southeastern United States: Lowland Terrestrial Communities, WH Martin, SG Boyce, AC Echternacht eds., John Wiley & Sons, Inc., New York, 257-310.

Sharitz RR, Gibbons JW. 1982. The Ecology of Southeastern Shrub Bogs (Pocosins) and Carolina Bays: a Community Profile. U. S. Fish and Wildlife Service, Division of Biological Services, Washington D. C. FWS/OBS-82/04.

Stout IJ, Richardson DR, Roberts RE. 1988. Management of amphibians, reptiles, and small mammals in xeric pinelands of Peninsular Florida. Management of Amphibians, Reptiles, and Mammals in North America, RC Szaro, KE Severson, DR Patton eds., USDA Forest Service General Technical Report RM-166, 98-108.

Tuberville TD, Bodie JR, Jensen JB, LaClaire L, Gibbons JW. 2000. Apparent decline of the southern hog-nosed snake, Heterodon simus. Journal of the Elisha Mitchell Scientific Society 116: 19-40.

Ware S, Frost C, Doerr PD. 1993. Southern Mixed Hardwood Forest: The Former Longleaf Pine Forest. Biodiversity of the Southeastern United States: Lowland Terrestrial Communities, WH Martin, SG Boyce, AC Echternacht eds., John Wiley & Sons, Inc., New York, 447-493.

Wilbur HM. 1981. Pocosin Fauna. Pocosin Wetlands: An Integrated Analysis of Coastal Plain Freshwater Bogs in North Carolina, CJ Richardson ed., Hutchinson Ross Publishing Co., Stroudsburg, PA, 62-68.

Williams KL, Mullin K. 1987. Amphibians and reptiles of longleaf-slash pine stands in central Louisiana. Ecological, Physical, and Socioeconomic Relationships Within Southern National Forests, HA Pearson, FE Smeins, RE Thill eds., Southern Forest Experiment Station. New Orleans, LA, General Technical Report SO-68, 116-120.

Zar JH. Biostatistical Analysis. 1984. 2nd edition. Prentice Hall, Englewood Cliffs, NJ.