HERPETOFAUNAL ASSEMBLAGES OF FOUR VEGETATION TYPES IN THE CADDO LAKE AREA OF NORTHEAST TEXAS

by

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ABSTRACT

The Longhorn Army Ammunition Plant (LHAAP) is a military facility in Harrison County, Texas. The herpetofauna of the LHAAP were surveyed in each of 4 habitat types, i.e., bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine. During 1996 and 1997, 2,028 individual amphibians of 17 species and 1,397 individual reptiles of 28 species were recorded. Species richness values for the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas were 38, 35, 28, and 28, respectively, and individual abundance values were 1,188, 1,373, 526, and 338, respectively. A Monte Carlo analysis showed that the species composition among the 4 vegetation types differed significantly ($P = 0.005$). Differences in herpetofaunal assemblages seemed to be related to the moisture gradient across the vegetation types. Because only 46.7% of the species were found in every habitat type, future management practices on LHAAP should attempt to maintain a diversity of vegetation communities.

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INTRODUCTION

Caddo Lake forms the eastern boundaries of Harrison and Marion counties in northeastern Texas and the western boundary of Caddo Parish in northwestern Louisiana. Due to its distance from large population centers, educational institutions, and research facilities, the flora and fauna in the Caddo Lake area have not been thoroughly studied. However, the area's location in the ecotone between the western grasslands and the eastern forest of the Austroriparian biotic Province gives importance to a better understanding of its ecology and biodiversity (Dice 1943, Blair 1950, Hardy 1995).

In 1993, a 3,038 ha (7,500 acre) portion of Caddo Lake was designated as a "Wetland of International Importance" under the provisions of the 1971 Ramsar treaty (Hardy 1995). Also in 1993, Congressman Jim Chapman and the Texas Department of Parks and Wildlife presented a research and development proposal for the Caddo Lake area (Anonymous 1993). In 1994, the Texas Regional Institute for Environmental Studies (TRIES) received a grant from the United States Department of Defense to direct research efforts to create a data base which would be used to help develop management strategies for certain tracts of land managed by the U. S. military (Fleet and Whiting 1995).

The Longhorn Army Ammunition Plant (LHAAP) is a 3,440 ha (8,500 acre) facility in Harrison County, Texas that is bordered to the north by the Big Cypress Bayou of Caddo Lake. The land that is now LHAAP was partially logged between 1900 and 1920. However, some bottomland stands were made up of trees too small to be merchantable at that time, and were not logged. In 1941, the land for LHAAP was purchased by the federal government to be a site for the manufacture of military armaments and logging was completely excluded from the facility until 1969. The logging activities since 1969 have been restricted to the upland pine areas, thus some bottomland stands may have never been harvested (Walker and Brantley 1978). Currently, LHAAP is a federal Superfund cleanup site and no military hardware is being manufactured. Because of its status as a military facility, LHAAP falls under the research directives of TRIES (Fleet and Whiting 1995). A survey of the area's reptile and amphibian communities is among these directives.

Based on museum collections, Hardy (1995) compiled a comprehensive list of the amphibians and reptiles occurring in the Caddo Lake watershed. However, no studies have been conducted on the herpetofaunal assemblages associated with the habitat types surrounding Caddo Lake. Because herptiles may play a significant role in the energy flow of an ecosystem (Burton and Likens 1975, Fitch 1982, Parker and Plummer 1987, Zug 1993), a greater understanding of their habitat needs could be important for the future protection and management of LHAAP and Caddo Lake.

OBJECTIVES

The objectives of this study were to: 1) elucidate the herpetofaunal assemblages occurring in selected vegetation types on the LHAAP of Harrison County, Texas; 2) compile abundance, richness, and species diversity indicies for the herptiles in each of the selected vegetation types; and 3) compare the herpetofaunal assemblages of the selected vegetation types. These data gave a greater understanding of herpetofaunal assemblages and helped provide the information necessary to develop effective management strategies for the LHAAP and Caddo Lake.

LITERATURE REVIEW

Because their roles have been historically considered negligible, herpetofaunal assemblages have often been ignored when considering the energy flow of an ecosystem. However, studies have been conducted which seem to contradict this supposition. Burton and Likens (1975) estimated the biomass of salamanders in the Hubbard Brook Experimental Forest, New Hampshire, to be twice the avian biomass and equal to the small mammal biomass. Zug (1993) reported that a study was conducted on the effect of caiman predation of adult fish in nutrient-poor South American lakes. The study found that nutrient cycling resulting from predation doubles the magnesium, phosphorous, potassium, and sodium available for use by other organisms in the system. Fitch (1982) estimated the biomass of a northeastern Kansas population of ringneck snakes (Diadophis punctatus) to be 5.06 kg/ha. The estimated biomass of the prey items needed to maintain this snake biomass was 15.18 kg/ha/yr. Copperheads (Agkistrodon contortrix) had an estimated biomass of 0.80 kg/ha and annually consumed an estimated 1.60 kg/ha of prey biomass. Parker and Plummer (1987) noted that the biomass of a central Arkansas population of rough green snakes (Opheodrys aestivus) was 7.1 kg/ha. This was greater than the maximum biomass values for birds or carnivorous mammals. Using growth rates reported in Plummer (1985), they calculated the annual biomass production of this population to be 4.0 kg/ha/yr, which converts to 7,902 kcal/ha/yr. This amount of energy flow exceeded that of birds or mammals. These studies provide evidence that herptiles may have a greater ecological function than has been previously realized.

East Texas Herptiles

The herpetofauna of eastern Texas have been fairly well documented. Most North American field guides and handbooks include herptiles occurring in the East Texas region (Ditmars 1936, Bishop 1943, Smith 1946, Wright and Wright 1949, Wright and Wright 1957, Stebbins 1985, Behler and King 1991, Conant and Collins 1991, Ernst et al. 1994). Texas field guides and handbooks likewise include East Texas herptiles (Burt 1938, Raun 1965, Dixon 1987, Garnett and Barker 1987). Parks and Cory (1938) published a survey of the fauna and flora of the Big Thicket area of southeastern Texas; the checklist included 63 reptilian and 26 amphibian species. This survey was one of the first herptile checklists for the eastern Texas area.

Blair (1950) published a report on the geographical location and general descriptions of the biotic provinces of Texas. Included in this report was a description of the herpetofauna of the Austroriparian Province. He reported that a minimum of 26 species of snakes, 10 species of lizards, 2 species of land turtles, 17 species of anurans, and 18 species of salamanders could be found in this portion of Texas. Eight of the salamander species and 4 of the anuran species are geographically limited in Texas to the Austroriparian Province.

Owen and Dixon (1989) correlated the species richness of Texas herptiles with geographical distribution. They compared numbers of species that occurred from east to west along gradients of decreasing precipitation; likewise, they compared numbers of species as they occurred from south to north along gradients of decreasing mean annual temperature. Using Two-Way Indicator Species Analysis (TWINSPAN), they were able to quantify some trends of herptile distribution in Texas. They found that turtles, toads, frogs, and salamanders increased in species richness west to east as precipitation increased. Although they found that lizards increased in species richness east to west, they concluded that habitat structure complexity was the determining factor for species richness in lizards as well as in the more evenly distributed snakes.

Herpetofaunal Habitat Association Studies Outside Of East Texas

Several studies that compare herpetofaunal communities among different habitat types have been conducted. Stockwell and Hunter (1989) compared the relative abundance of herptiles among 8 types of Maine peatland vegetation. Using drift fences and pitfall traps, they surveyed amphibians and reptiles occurring in 9 peatlands. The vegetation of each peatland was characterized as one or more of the following types: lagg, forested bog, wooded heath, shrub heath, moss, pools, streamside meadow, or shrub thicket. Anurans made up 94% of all captures, 5% were salamanders, and less than 1% were snakes. No significant differences were found in species composition or relative abundance among the 8 vegetation types. This suggests that the vegetation types being compared may have been ecologically too narrow to reflect the differences that occur in herpetological assemblages.

DeGraaf and Rudis (1989) surveyed reptile and amphibian communities in mixed hardwoods, red maple (Acer rubrum), and balsam fir (Abies balsamea) study areas in New England. Using drift fences and pitfall traps, they collected herptiles from a streamside stand and an upland stand of each habitat type. During the study, 2,080 individuals of 10 amphibian and 1 reptile species were captured. Three species of amphibians, wood frogs (Rana sylvatica), American toads (Bufo americanus), and red-backed salamanders (Plethodon cinereus), made up 90% of all captures. Some notable differences were found in the herpetofauna of the 3 vegetation types. In both streamside and upland stands, higher species richness and diversity values were recorded in the mixed hardwood and red maple areas than in the balsam fir areas. The authors suggested that the neutral soil pH and high understory density of the deciduous forests were more conducive to the needs of herptiles than the low soil pH and low understory density of the coniferous forests.

Lobisky and Hovis (1987) surveyed the birds, small mammals, and herptiles in longleaf pine (Pinus palustris) and slash pine (P. elliottii) areas of the Apalachicola National Forest, Florida. Over a period of 2 years, 2 spring and 2 fall surveys were conducted. Herptiles were collected using drift fence arrays with screenwire funnel traps. Species diversity and biomass were significantly greater in the longleaf pine area than in the slash pine area. However, no significant differences were found between the 2 vegetation types in numbers of individuals or species.

Pearson et al. (1987) studied the reptiles and amphibians of a longleaf-slash pine area of the De Soto National Forest, Mississippi. The study was conducted in regeneration, sapling, pole, sawtimber, and bayhead study areas. Herptiles were surveyed using diurnal and nocturnal foot searches, aquatic salamander traps, nocturnal anuran chorus counts, and trapping arrays made of drift fences with pitfall and funnel traps. Species richness was not significantly different among the habitat types. Toads, frogs, and lizards were more commonly recorded than salamanders, turtles, or snakes. Amphibians were most often found in the moist bayhead areas, whereas large numbers of lizards were recorded in the pole stands. Of the 27 species of snakes recorded, the black racer (Coluber constrictor) was the most common, occurring in all vegetation types.

Williams and Mullin (1987a, 1987b) conducted 2 reptile and amphibian studies in the Kisatchie National Forest, Louisiana. One study was in a loblolly pine (P. taeda)-shortleaf pine (P. echinata) area of the forest and the other was in a longleaf pine-slash pine area. Regeneration, sapling, poletimber, and sawtimber stands were sampled. In each stand type, transects were systematically searched, nocturnal censuses were conducted, and drift fence trapping arrays were established. Amphibians were found most often in the sawtimber stands, rarely in the poletimber stands, and almost never in the sapling and regeneration stands. The most probable reason for amphibians to favor the sawtimber stands was the large amount of shade and water in these stands. There was no significant difference in the numbers of reptiles occurring in the different vegetation types, however the sawtimber stands had significantly higher reptile diversity values than did the other stands. Because they rely less on moisture and more on habitat structure, the authors suggested that reptiles, rather than amphibians, would be suitable indicator species of habitat disturbance.

Herpetofaunal Habitat Association Studies Of East Texas

Several studies have been conducted which deal exclusively with the habitat associations of East Texas herptiles. In the Angelina National Forest, Rakowitz (1983) and Whiting et al. (1987) compared the herpetofaunal assemblages in seedling, sapling, pole, and sawtimber loblolly pine-shortleaf pine stands. Five transects were established in each of the 4 stands. Four drift fences and 16 covered funnel traps were installed on each of the 20 transects. Four hardwood boards were placed near each transect for artificial cover. For 3 winters and 3 springs, herptiles were trapped and anuran breeding choruses were surveyed. Six hundred forty-nine amphibians represented by 15 species were recorded, as were 764 reptiles represented by 23 species. Amphibians, especially the anurans, were dominant in the winter, while spring counts were dominated by reptiles. However, the coal skink (Eumeces anthracinus) was an exception; 42 individuals were recorded during winter, but only 2 were recorded in spring. Although more amphibian species were recorded during spring, more than twice as many amphibian individuals were recorded during winter. Lizards had different compositions and different numbers among the habitat types. Relatively high numbers of six-lined racerunners (Cnemidophorous sexlineatus) and fence lizards (Sceloporus undulatus) were found in the seedling area.

Reid (1992) and Reid and Whiting (1994) compared the herpetofauna of 5 pitcher plant bogs to that of 5 adjacent pine stands in the Angelina National Forest, Texas, for 1 year. Each of the 10 areas had trapping arrays made up of 3 drift fences and 18 shaded funnel traps. Half of the funnel traps were made of screenwire and half were made of hardware cloth, ensuring that herptiles of different sizes had the potential of being captured. For the months of February, May, and August, the arrays were operated for 28 consecutive days. For each of the remaining months, arrays were operated for 7 consecutive days. During these sample periods, traps were checked and a 15-minute time-area search was conducted on each study area at least once every 2 days. During this study, 1,068 individuals of 38 species were captured or observed. In the bogs, 480 individuals of 28 species were recorded, while 588 individuals of 28 species were recorded in the pine stands. More amphibians were recorded in the bogs than in the forests whereas reptiles dominated in the adjacent pine forests. Species diversity was significantly higher in the bogs than in the forests, but no significant difference was found in evenness between the 2 habitat types. Amphibians accounted for 13.3% of the recorded herptiles, and dwarf salamanders (Eurycea quadridigitata) were 48.6% of these. Reptiles made up the remaining 86.7% of recorded herptiles, 93.3% of which were lizards. Ground skinks (Scincella lateralis) were 48.8% of all individuals and they were prominent from March through May. March was the peak month for amphibian captures, probably due to the breeding season. September had the highest number of snake captures, presumably due to pre-winter relocating.

Fisher and Rainwater (1978) conducted an extensive survey of the herpetofaunal assemblages among 4 habitat types of the Big Thicket National Preserve. During the summer of 1975 and the spring of 1976, data were collected by a series of systematic searches on foot, by canoe, and by car. The designated habitat types were bottomland hardwood forest, wet pine-hardwood forest, dry pine-hardwood forest, and palmetto-hardwood forest. Most data were collected during daytime surveys on foot in which the observer would walk a random path through the forest and record all herptiles seen or heard. A total of 195 hours was spent conducting 59 of these surveys, during which observers recorded 1,470 individuals of 44 species. The 16 species of amphibians accounted for 69% of the individuals and the 28 species of reptiles made up the remaining 31% of individuals. Among the 4 habitat types, there were differences in species and individual densities. However, this could be accounted for by the different number of hours spent surveying each habitat. Species composition did differ among the habitat types. Reptiles were 63% of the herptiles recorded in the dry pine-hardwood forest, while amphibians dominated the wetter forest types. It was also noted that the herptile densities varied by season. In late spring, when newly hatched herptiles were not yet prominent in the forest and the weather was dry, the density of observed herpetofauna was low. In the early summer, however, when juveniles began to emerge and rainfall was frequent, the densities were higher.

Jackson (1973) studied the relative abundance and distribution of reptiles and amphibians in the Stephen F. Austin Experimental Forest in Nacogdoches County, Texas. Four collecting periods were conducted each month for 9 consecutive months. During each collecting period, the observer spent 2.5 hours searching upland areas and 2.5 hours searching lowland areas. The searching method included raking leaves, looking under logs and periodically digging a few inches into the soil. During this study, 1,100 individuals of 41 species were observed. In the lowland areas, 423 individuals of 16 amphibian species were recorded while only 60 individuals of 8 amphibian species were recorded in the upland areas. There were 286 individual reptiles of 21 species in the lowland areas and 331 individual reptiles of 15 species in the upland areas. The lowlands had a relatively high number of reptilian species due to the presence of aquatic turtles and aquatic snakes. The uplands had such a large number of individual reptiles because of the sizable populations of green anoles (Anolis carolinensis) and fence lizards. Seasonal fluctuations occurred in population densities. Because of emerging juveniles, most amphibian numbers increased in the summer months; however, northern leopard frogs (Rana pipiens) were more common in the autumn months. In addition to the description of the herpetofauna occurring in the generalized upland and lowland areas, distributions were also noted at 5 points along the moisture gradient, "A" through "E". Point "A", an upland dry area, was dominated by green anoles and fence lizards. Point "B", characterized as an upland wet site, had the highest number of copperheads. Point "C" was a transitional area between lowland and upland and had a low number of herptiles. The "D" portion of the moisture gradient was characterized as having moist to muddy soil most of the year. The highest numbers of observations for most herptiles were made on point "D". Few herptiles were observed on point "E", an area that was usually flooded.

Jackson (1973) also used 8 funnel traps and 4 turtle traps to sample aquatic areas. Half of the traps were placed in lowland aquatic areas, and half were placed in upland aquatic areas. No turtles were trapped during the 9-month study. The aquatic funnel traps yielded 4 gulf coast water dogs (Necturus beyeri) and 1 three-toed amphiuma (Amphiuma tridactylum).

Whiting (1993) characterized the presence and relative abundance of birds, small mammals, and herptiles among upland pasture, wet meadow, woodland, and hardwood forest habitat types on the proposed Fort Boggy State Park in Madison County, Texas. Two study areas were selected for each of the 4 habitat types; 1 member of each pair had been previously mowed and grazed and the other was not mowed and grazed. For the purpose of surveying herptiles, artificial cover, time-area searches, and drift fences with screenwire funnel traps, hardware cloth funnel traps, and pitfall traps were used. Herptiles were surveyed during winter and spring. The observers recorded 59 individuals of 16 species during the winter and 154 individuals of 25 species during the spring. Due to a large amount of ground cover, the highest number of individuals was recorded in the hardwood forest area which had not been mowed and grazed. The highest numbers of species were recorded in the unmowed/ungrazed woodland during the winter, and in the unmowed/ungrazed meadow during the spring. The pasture sites had the lowest numbers of species and individuals, presumably due to a lack of ground cover. Overall, the mowed/grazed areas had lower numbers of herptiles than did the unmowed/ungrazed areas. This was probably because the regular mowing of these areas tended to decrease the type of debris that herptiles use for refuge.

Ford et al. (1991) studied the species diversity and seasonal abundance of snakes in the 32.2-ha Shef's Wood of Smith County, Texas. For a period of 4 years, they used drift fences and hardware cloth-covered box traps to sample the snakes occurring in upland deciduous woodland, lowland floodplain, and upland coniferous woodland habitat types. The upland deciduous woodland had the greatest species richness with 99 individuals of

17 species. The lowland floodplain had the highest number of individuals, 142 of 15 species. The upland coniferous woodland produced only 72 individuals of 10 species. The authors stated that the low number of species for this stand was possibly the result of replacing native hardwood with shortleaf pine. Nevertheless, the species diversities of the 3 habitats were above the mean for this latitude (Vitt 1987). Seasonal differences occurred in the peak captures of the 2 most common species. The copperhead was most commonly trapped in July, while the cottonmouth (Agkistrodon piscivorous) was trapped most often in October.

SIGNIFICANCE

Its 1993 designation as a "Wetland of International Importance" underscores Caddo Lake's ecological significance. In addition, the U. S. Fish and Wildlife Service has categorized the area as a Resource Category One, the highest class of wetland, and considers it to be one of the most biologically diverse areas in Texas. Including its associated watershed, the area provides habitat for approximately 216 species of birds, 47 species of mammals, and 90 species of herptiles (Anonymous 1993).

Because herptiles are ectothermic, they expend less metabolic energy than do mammals or birds. Therefore, they are better able to convert food energy to biomass and, as a result, herpetofaunal assemblages tend to dominate terrestrial vertebrate communities (Pough 1983). In addition, herptiles help regulate prey population densities and provide a source of food to other vertebrate predators (Pacala and Roughgarden 1984, Schoener and Spiller 1987, Guyer and Bailey 1993). Because herpetofaunal assemblages function as important components of their communities, this project significantly contributes to the understanding of the Caddo Lake ecosystem and to the development of land management strategies for the LHAAP.

METHODS

This study compared the herpetofaunal assemblages among 4 different vegetation types on the Longhorn Army Ammunition Plant in Harrison County, Texas (Figure 1). These vegetation types were pure pine, mixed pine-hardwood, sideslope hardwood, and bottomland hardwood stands classified by tree size as sawtimber. Two study areas of at least 10 ha each were selected from each vegetation type. Within each study area, 4 circular plots, each measuring 69.1 m in radius (1.5 ha) were established. The borders of the circular plots were at least 10 m apart. A total of 32 plots were used for this study.

Vegetation Sampling

To compare herpetofaunal assemblages in the different vegetation types, it was necessary to quantify the habitat characteristics of these vegetation types. To characterize the habitat of the 8 study areas, each of the 32 plots were divided into 5 subplots, thus a total of 160 subplots. Subplot A was at the study plot's center. The centers of subplots B, C, D, and E were 46 m due north, east, south, and west, respectively, of the center of subplot A. Each subplot was 11.28 m in radius, thus each subplot was 0.04 ha (Figure 2).

Plants between 0.5 m and 3.0 m in height were considered to be understory vegetation. At the subplot center, the understory within a 2.52-m radius (0.002 ha) was recorded (Figure 2). For each understory plant, stem diameter at ground level, plant height, and common name were recorded on a standardized data sheet (Appendix A).

Figure 1. Location of Harrison County in Texas and location of study areas where herpetofaunal assemblages were sampled 16 March through 30 June 1996, 27 September through 23 October 1996, and 19 March through 23 June 1997. Study areas were located on the Longhorn Army Ammunition Plant in Harrison County, Texas. Areas 1 and 3 are sideslope hardwood, 2 and 4 are bottomland hardwood, 5 and 6 are mixed pine-hardwood, and 7 and 8 are pure pine.

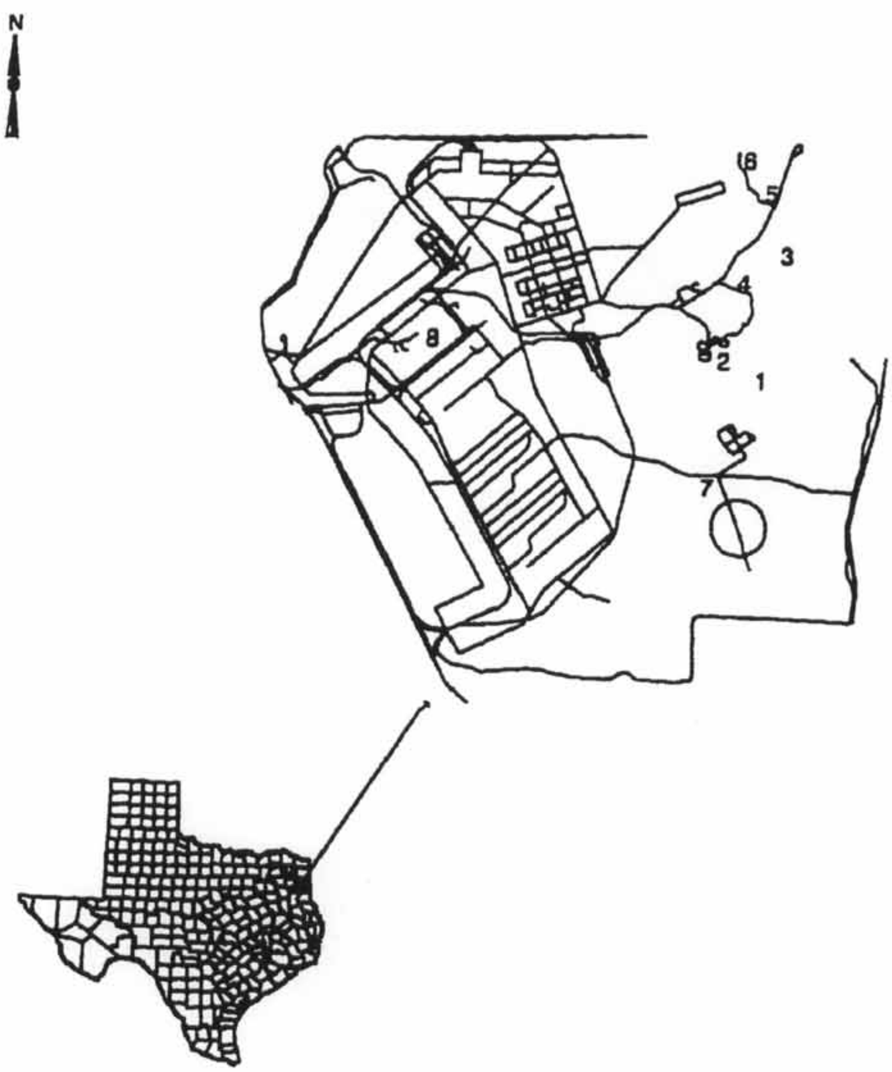
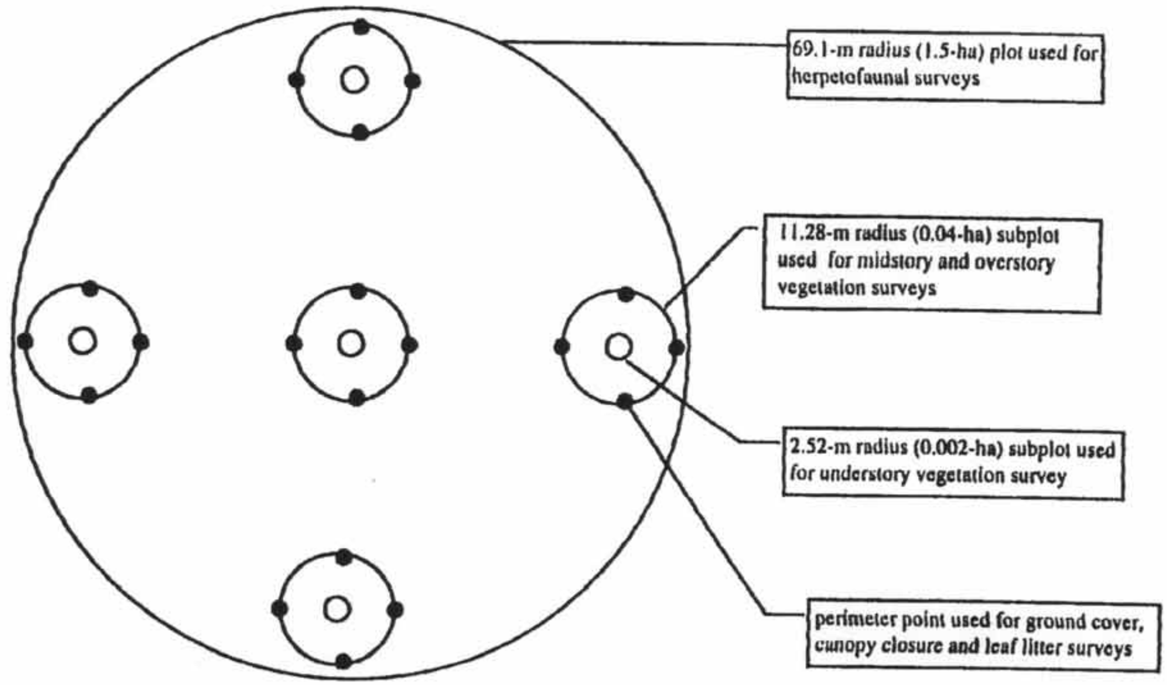


Figure 2. Diagram of the design used for the vegetation surveys at the Longhorn Army Ammunition Plant in Harrison County, Texas. The vegetation surveys were conducted on each of the 32 plots used in the 1996 and 1997 herpetofaunal surveys.



Vegetation taller than 3.0 m, but below the canopy was considered midstory and all trees with crown in the canopy were considered overstory. The diameter at breast height (DBH), common name, and height of each midstory and overstory plant within the 0.04-ha subplot (Figure 2) were recorded on a standardized data sheet (Appendix B).

The perimeter of each subplot was marked at the 4 cardinal directions. Ground cover and crown closure were recorded at each of these perimeter points (Figure 2). Ground cover was measured by placing a 1.10-cm diameter metal rod vertically at the perimeter point. All vegetation that was below 0.5 m in height and was touching the rod was recorded. The number of times that the rod was touched was recorded in the categories of grass, herb, or woody on a standardized data sheet (Appendix C). If no living vegetation was touching the rod, litter or soil, as appropriate, was recorded.

Crown closure was measured using a sighting tube made of a 3.0-cm diameter section of PVC pipe with cross hairs on both ends. At each perimeter point, an observer pointed the tube vertical and sighted through it. Vegetation that was in the line of sight with both sets of crosshairs was recorded as understory, midstory, and/or overstory on a standardized data sheet (Appendix C). The absence of overhead obscurity in any of the categories was also recorded.

In the autumn, leaf litter from each of the subplot perimeters was surveyed (Figure 2). A 1-m square frame was placed on the ground at each perimeter point. The depth of the leaf litter was measured at 5 points within the frame and recorded on a standardized data sheet (Appendix D). All litter within the frame was gathered and returned to Stephen F. Austin State University (SFASU) for further analysis. The gathered litter was sorted, weighed, and characterized by its composition of deciduous leaves, coniferous needles, woody material, and humus.

Herptile Sampling

The trapping arrays used in this study were variations of those used by Fitch (1951), Vogt and Hine (1982), Whiting et al. (1987), Reid (1992), and Whiting (1993). One main drift fence array and 1 accessory drift fence were installed on each of the 32 plots. Each drift fence array was installed near plot center and consisted of three 9.14- x 0.91-m (30- x 3-ft) erosion control cloth drift fences radiating from a central point. The fences were positioned at approximately 120° to one another. The bottom portion of each fence was buried in order to prevent animals from crossing under it. Within each plot, 1 accessory drift fence was installed approximately 40 m from plot center and consisted of one 9.14- x 0.91-m erosion control cloth drift fence. Funnel traps, 60 cm long and 18 cm in diameter, were made of 0.84-cm (0.25-in) hardware cloth mesh and placed on both sides of both ends of each drift fence. Thus, 16 hardware cloth funnel traps were used for each plot, 64 for each study area, and 512 for the entire study.

Because smaller animals can escape through the mesh of the hardware cloth, aluminum screenwire funnel traps and pitfall traps were also installed. Pitfall traps were constructed of 2 l plastic buckets, 14 cm deep and 17 cm in diameter, or tin cans, 17 cm deep and 15 cm in diameter, and buried to ground level. In order to allow precipitation to drain from them, small holes were made in the bottom of each pitfall trap. The 2 l plastic buckets were installed at the center of each main array and the tin cans were installed at both ends of each accessory drift fence. However, because the high water table in the bottomland areas would flood pitfall traps, screenwire funnel traps were used in those areas in the place of pitfall traps. Therefore, excluding the bottomland areas, 12 pitfall traps were installed in each study area, and 72 pitfall traps were used for the entire study.

When pitfall traps were used at the center of main drift fence arrays, 2 screenwire funnel traps were placed near the opposite end of each arm of the array. Four screenwire funnel traps were used for each drift fence in the bottomland hardwood areas. Thus, 24 screenwire funnel traps were used for each of the 6 drier areas, and 64 screenwire funnel traps were used in each of the 2 bottomland areas. Therefore, 272 screenwire funnel traps were used in the entire study.

The drift fence trapping method best surveys those herptiles that move horizontally on the forest floor. However, some herptiles, such as treefrogs, utilize the vertical component of the forest and are, therefore probably undersampled by drift fence trapping methods. In order to better survey those animals, the trapping method described by Moulton et al. (1996) was used. One-m sections of 5-cm diameter PVC pipe were inserted vertically into the ground to a depth of approximately 10 cm. One pipe was installed near each main drift fence array and each accessory drift fence. Thus, 8 PVC treefrog traps were used for each study area and 64 PVC treefrog traps were used for the entire study.

Eight turtle traps were constructed from chicken wire. One turtle trap was placed in the aquatic area in each of the 8 bottomland hardwood plots. The traps were baited with punctured cans of sardines and placed at a depth of water such that the top of the trap was above the water's surface, thereby allowing trapped animals to surface for air.

In order to create artificial cover to be used by herptiles, one 1.22- x 2.44-m (4- x 8-ft) sheet of plywood and one 1.22- x 1.22-m (4- x 4-ft) sheet of plywood were placed near each main drift fence array. Therefore, 8 artificial cover boards were used for each study area and 64 for the entire study (Figure 3, 4).

In addition to the above trapping methods, herptiles that were seen and captured within the 1.5 ha plots while checking traps were recorded and included in data analysis. All herptiles seen or heard were recorded as incidental observations, but were not included in data analysis.

The herptile survey was conducted from 16 March through 30 June, 1996, 27 September through 23 October 1996, and 19 March through 23 June 1997. The main drift fence arrays and artificial cover boards were used throughout the entire study. The turtle traps and the accessory drift fences were set on 13 June 1996. The turtle traps were used through 30 June 1996 and the accessory drift fences were used throughout the remainder of the surveys. The PVC treefrog traps were set on 27 September and used throughout the remainder of the surveys. During the surveys, all traps and artificial covers were checked every 2 to 3 days. All captured animals were marked so that they could be recognized as previously recorded individuals. Amphibians and lizards were marked by toe clipping, snakes were marked by removing the adjacent ventral and dorsal scales immediately anterior to the cloaca, and turtles were marked by notching the carapace. Recaptured animals were recorded, but excluded from the data analysis.

Figure 3. Diagram of the equipment used to survey the herpetofaunal assemblages in the sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

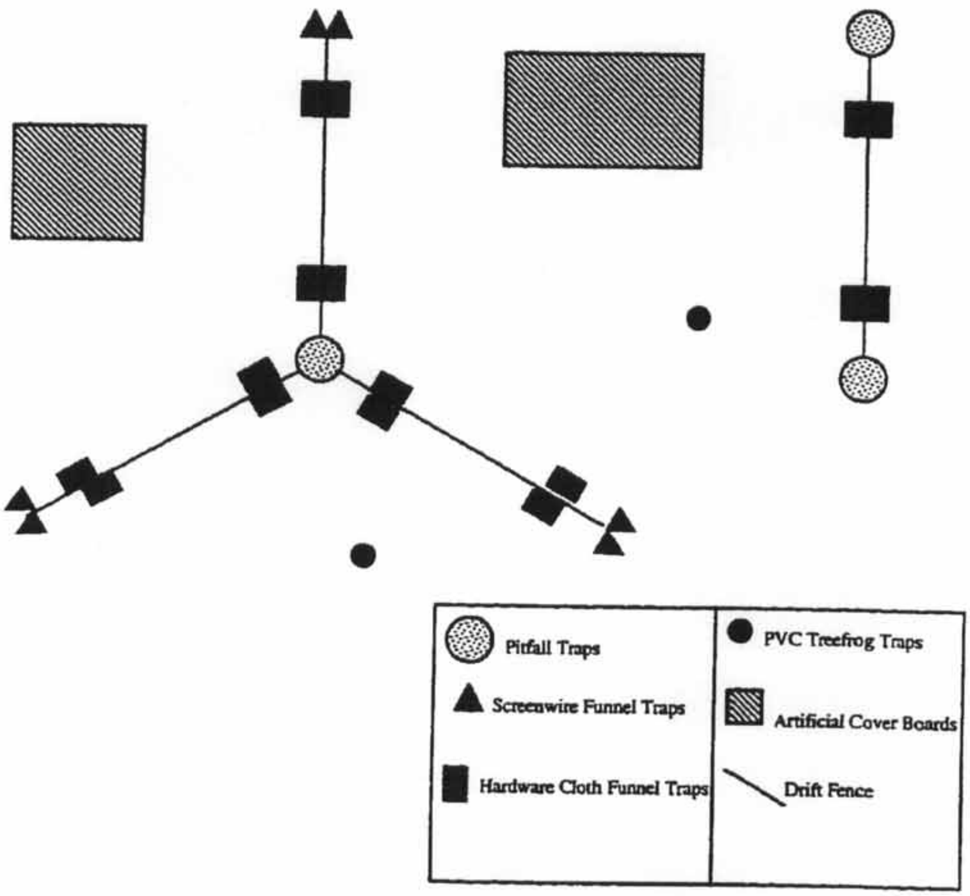
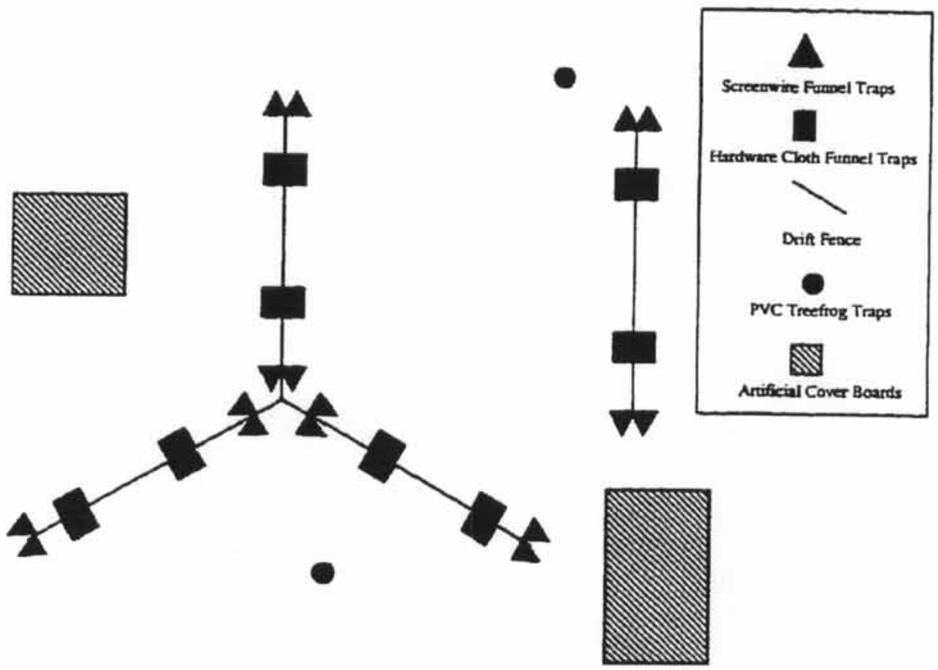


Figure 4. Diagram of the equipment used to survey the herpetofaunal assemblages in the bottomland hardwood study areas. Because of the high water table, screenwire funnel traps were used instead of pitfall traps in these areas.



Upon capture, data recorded for each animal were its common name, whether it was alive or dead, its recapture status, the mode of capture, and its location. These data were recorded on standardized data sheets (Appendix E). After processing, all animals were released near the point of capture.

Data Analysis

Vegetation Characteristics

Vegetation data were ranked by plot and the Kruskal-Wallis one-way analysis of variance was used to determine differences in the abundances of ground cover, canopy closure, leaf litter, and understory vegetation in the 4 vegetation types (Dowdy and Wearden 1991). The nonparametric Nemenyi test (Zar 1996) was used to make pairwise multiple comparisons when the Kruskal-Wallis test showed significance ($\alpha < 0.05$).

Frequency, density, and dominance were calculated for each midstory and overstory taxon in each study area and in each vegetation type. Frequency is the number of sampled subplots in which a particular taxon was found, density is the number of times a particular taxon is found per ha, and dominance is the basal area (m^2) of a particular taxon per ha. Relative frequency, relative density, and relative dominance were calculated for each taxon as the percentages of the total frequency, total density, and total dominance, respectively, in each study area and in each vegetation type. Importance values were determined by averaging the relative frequency, relative density, and relative dominance of each taxon (Barbour et al. 1987). Importance values of the 10 most dominant taxa were ranked by plot and analyzed using the Kruskal-Wallis one-way analysis of variance and Nemenyi multiple comparison test. Because the absence of taxa from some areas resulted in contingency table data that did not meet the requirements of the chi-square goodness-of-fit test, importance values for the midstory/overstory were tested using the Monte Carlo simulation program written for SAS (Appendix F). Results were considered significant at $\alpha < 0.05$.

Herpetofaunal Assemblages

For each vegetation type, number of individuals of each species, species richness, species diversity, and evenness were calculated. Species richness is the number of species. Species diversity is a measurement of the number of species, weighted to consider the relative numbers of individuals (Shannon and Weaver 1963). Evenness, a part of species diversity, measures the extent to which the number of individuals is evenly distributed among all species (Pielou 1975). Using the Monte Carlo simulation method, contingency table data were examined to determine if the herpetofaunal assemblages of the 4 habitat types differed significantly ($\alpha < 0.05$). Because different types of herptiles have different habitat needs, the data were also examined along taxonomic divisions. The numbers of herptiles, amphibians, reptiles, salamanders, anurans, lizards, and snakes in each vegetation type were compared by ranking the data by plot and using the Kruskal-Wallis test and the Nemenyi test (Dowdy and Wearden 1991 Zar 1996). Using the Monte Carlo simulation method, the species composition within each of these taxonomic divisions was tested for differences among the 4 vegetation types. Results were considered significant at $\alpha < 0.05$.

Because aquatic turtle traps were used only in the bottomland hardwood areas, the turtles captured in the aquatic turtle traps were excluded from the analyses. Also, because the number of captured turtles was small, no analyses were performed on the turtle group.

Because pitfall traps were excluded and additional screenwire traps were used in the bottomland hardwood areas, the trapping method used in the bottomland hardwood areas was different from the trapping method used in the other vegetation types. Therefore, in order to determine if treatment differences were the result of different trapping methods, additional Monte Carlo, Kruskal-Wallis, and Nemenyi tests were performed. These additional tests excluded the herptiles that were captured in screenwire funnel traps and pitfall traps.

In order to quantify the similarities of the herpetofaunal assemblages between the different vegetation types, Sorensen's percent similarity was calculated (Smith 1992). Sorensen's percent similarity is based on the relative abundance of each taxon in each vegetation type. The summation of the lowest relative abundance for each taxon that 2 vegetation types have in common is the percent similarity between those 2 vegetation types. The percent similarity was calculated for each of the 6 possible pairs of vegetation types.

DESCRIPTION OF STUDY AREAS

The study areas used in the herpetofaunal survey of LHAAP were numbered 1 through 8 (Figure 1). Areas 2 and 4 were bottomland hardwood stands. These areas had permanent waterways running through them and consequently were frequently inundated. Areas 1 and 3 were sideslope hardwood stands located near areas 2 and 4, respectively. These areas were mesic and were at a higher elevation than the bottomland hardwood areas. Areas 5 and 6 were mixed pine-hardwood stands. These areas were less mesic and were at a higher elevation than were the sideslope hardwood areas. Areas 7 and 8 were pure pine stands. These areas were the least mesic and were at the highest elevation of the 4 vegetation types surveyed.

Soils

The soils of the LHAAP have been classified by the United States Department of Agriculture (USDA) and the Soil Conservation Service (SCS) (1994). These soils were generally described as the Scottsville type in the uplands, and as the Iuka-Socagee-Sardis types in the bottomlands. The classification of the soil types found in each study area is given in Table 1.

The soils in area 2 have been classified as predominantly Socagee silty clay loam with small areas of Guyton-Cart complex. Found in the flood plains near large streams, these

Table 1. Soil types found in each study area used in the herpetofaunal survey of the Longhorn Army Ammunition Plant in Harrison County Texas. These soils were classified by the United States Department of Agriculture and the Soil Conservation Service (1994).

Study Area		Soil Types
Bottomland Hardwood		
	Area 2	Predominantly Socagee silty clay loam
		Small amount of Guyton-Cart complex
	Area 4	Sardis-Mathiston complex
Sideslope Hardwood		
	Area 1	Predominantly Eastwood very fine sandy loam, 5-20% slopes
		Small amount of Scottsville very fine sandy loam, 0-2% slopes
	Area 3	Eastwood very fine sandy loam, 1-5% slopes
		Scottsville very fine sandy loam, 0-2% slopes
Mixed Pine-Hardwood		
	Area 5	Eastwood very fine sandy loam, 1-5% slopes
		Scottsville very fine sandy loam, 0-2% slopes
	Area 6	Eastwood very fine sandy loam, 1-5% slopes
		Scottsville very fine sandy loam, 0-2% slopes
Pure Pine		
	Area 7	Predominantly Scottsville very fine sandy loam, 0-2% slopes
		Small amount of Eastwood very fine sandy loam, 5-20% slopes
	Area 8	Predominantly Scottsville very fine sandy loam, 0-2% slopes
		Small amount of Eastwood very fine sandy loam, 5-20% slopes

soils are frequently flooded and are strongly acidic. They are poorly drained and primarily contain hardwoods. The soils in area 4 have been classified as the Sardis-Mathiston complex. These frequently flooded soils are found on nearly level floodplains and are strongly acidic. The Sardis type is found on low ridges near streams and the Mathiston type is found on low flats adjacent to side slopes. Like those from area 2, these soils also best support bottomland hardwoods.

The soil in area 1 has been classified as Eastwood very fine sandy loam, 5-20% slopes. This is a very acidic soil with moderate available water capacity, and rapid runoff. These soils are well suited for hardwoods, pines and pastures. The soils in area 3 have been classified as Eastwood very fine sandy loam, 1-5% slopes and Scottsville very fine sandy loam, 0-2% slopes. These are very acidic soils with a high available water capacity and slow to medium runoff. These soils are suitable for woodlands and pastures.

The soils in areas 5 and 6 have been classified as Eastwood very fine sandy loam, 1-5% slopes and Scottsville very fine sandy loam, 0-2% slopes. These are the same soils as those described for area 3.

The soils in areas 7 and 8 have been classified as small areas of Eastwood very fine sandy loam, 5-20% slopes, within predominantly Scottsville very fine sandy loam, 0-2% slopes. The Eastwood very fine sandy loam, 5-20% slopes was the same soil type found in area 1 and the Scottsville very fine sandy loam, 0-2% slopes, was found in areas 3, 5, and 6.

Vegetation Characteristics

Ground Cover and Crown Closure

The number of times that grass, a herbaceous plant, or a woody stem was counted in the ground cover survey was 235, 168, 107, and 113 in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively (Table 2). The data collected during the ground cover and crown closure surveys were analyzed using the Kruskal-Wallis test (df = 3), a nonparametric one-way analysis of variance.

Table 2. Ground cover and crown closure data given in number of times each category was scored in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

	Ground Cover					Crown Closure		
	Grass	**Herb**	**Woody**	**Litter**	**Soil**	**Over**	**Mid**	**Under**
Bottom	138	53	44	37	11	74	60	20
Sideslope	106	18	44	61	1	70	95	27
Mixed	26	10	71	82	0	38	91	34
Pine	25	0	88	90	2	61	70	51

Significant differences were found among the vegetation types in the number of times that ground cover and overhead obscurity was counted (Table 3). There was no significant difference in the number of times that a woody stem was counted in the ground cover survey, however the amount of grass and herbaceous ground cover was found to be significantly different among the vegetation types ($P < 0.005$ and 0.01, respectively). A Nemenyi test was used to make pairwise comparisons of the amount of grass and herbaceous ground cover from the different vegetation types (Table 3). The amount of grass in the bottomland hardwood and sideslope hardwood areas was found to be significantly more than the amount of grass in the mixed pine-hardwood and pure pine areas ($P < 0.05$). The amount of herbaceous ground cover in the bottomland hardwood areas was found to be statistically the same as the amount of herbaceous ground cover in the sideslope hardwood areas, but significantly more than the amount of herbaceous ground cover in the mixed pine-hardwood and pure pine areas ($P < 0.05$) (Table 3).

The ground cover survey was conducted so that litter was counted only if no living vegetation was touching the survey rod and soil was counted only if no living vegetation

Table 3. Kruskal-Wallis one-way analysis of variance for data collected during the ground cover and crown closure surveys in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas. Based on the Nemenyi pairwise comparisons, vegetation types with a common letter in a particular category were statistically the same in that category and vegetation types without a common letter in a particular category were significantly different in that category ($P < 0.05$).

	Mean Ranks by Forest Type				**Kruskal-Wallis**	
	Bottom	**Sideslope**	**Mixed**	**Pine**	**H Statistic**	***P* Value**
Overhead Obscured	14.19 ^{a}	23.81 ^{b}	13.38 ^{a}	19.00 ^{a,b}	19.93	< 0.005
Ground Cover						
Grass	25.94 ^{a}	21.56 ^{a}	10.56 ^{b}	7.94 ^{b}	20.30	< 0.005
Herbaceous	24.19 ^{a}	19.00 ^{a,b}	14.81 ^{b,c}	8.00 ^{c}	12.77	< 0.01
Woody	12.19	12.88	18.81	22.13	6.25	ns
Litter	7.81 ^{a}	14.38 ^{a,b}	20.75 ^{b}	23.06 ^{b}	12.83	< 0.01
Soil	24.56 ^{a}	13.81 ^{b}	12.00 ^{b}	15.63 ^{b}	8.48	< 0.05

or litter was touching the survey rod. Therefore, the amount of litter and soil counted in the ground cover survey of a particular area reflected the extent to which living vegetation was lacking from that area's floor. Litter was counted the most times in the pure pine areas and the fewest times in the bottomland hardwood areas and bare soil was counted the most times in the bottomland hardwood areas and the fewest times in the mixed pine-hardwood areas (Table 2). The Kruskal-Wallis one-way analysis of variance found that the amount of exposed litter and bare soil differed significantly among the vegetation types ($P < 0.01$, 0.05, respectively). A Nemenyi test showed that the number of times litter was counted in the bottomland hardwood areas was significantly fewer than the number of times litter was counted in the mixed pine-hardwood and pure pine areas ($P < 0.05$) (Table 3). The Nemenyi test also showed that the amount of bare soil in the bottomland hardwood areas was significantly more than the amount of bare soil in the other vegetation types ($P < 0.05$) (Table 3).

During the crown closure survey, the number of times that the sky was obscured by either understory, midstory, or overstory was 154, 192, 163, and 182 in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively (Table 2). The Kruskal-Wallis analysis showed that the overhead obscurity was significantly different among the 4 vegetation types ($P < 0.005$) (Table 3). The Nemenyi test showed that the amount of overhead obscurity in the sideslope hardwood areas was significantly greater than the amount of overhead obscurity in the mixed pine-hardwood and bottomland hardwood areas ($P < 0.05$), but statistically the same as the amount of overhead obscurity in the pure pine areas (Table 3).

Leaf Litter

The data obtained from the leaf litter survey were averaged by vegetation type and are given in Table 4. The bottomland hardwood areas had the lowest average depth of leaf litter and the lowest average weight of pine needles, woody material, humus, and total litter. A Kruskal-Wallis analysis showed that there was a significant difference among the 4 vegetation types in the categories of litter depth, weight of pine needles, weight of deciduous leaves, and total weight of litter ($P < 0.05$) (Table 5). A Nemenyi test showed the depth of litter in the bottomland areas to be significantly less than the depth of litter in the mixed pine-hardwood and pure pine areas ($P < 0.01$), but the same as the depth of litter in the sideslope hardwood areas (Table 5). Also, the Nemenyi test showed that the

Table 4. The mean of the sampled depth of litter and mean of the sampled weight of pine needles, deciduous leaves, woody material, humus, and total litter in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

	Vegetation Type			
	Bottom	**Sideslope**	**Mixed**	**Pine**
Depth of Litter (cm)	2.38	3.25	4.85	3.80
Weight of Pine Needles (gm)	0.83	5.37	173.27	302.71
Weight of Deciduous Leaves (gm)	201.47	333.60	153.55	97.83
Weight of Woody Material (gm)	74.75	186.75	163.64	150.52
Weight of Humus (gm)	75.43	490.24	434.64	433.35
Weight of Total Litter (gm)	352.45	1025.69	925.11	984.38

Table 5. Kruskal-Wallis one-way analysis of variance for data collected during the leaf litter survey. These data were collected from the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas. Based on the Nemenyi pairwise comparisons, vegetation types with a common letter in a particular category were statistically the same in that category and vegetation types without a common letter in a particular category were significantly different in that category ($P < 0.05$).

	Mean Ranks by Forest Type				**Kruskal-Wallis**	
	Bottom	**Sideslope**	**Mixed**	**Pine**	**H Statistic**	***P* Value**
Depth of Litter	7.94^{a}	$13.63^{a,b}$	25.50^{c}	$18.94^{b,c}$	15.32	< 0.05
Weight of Deciduous Leaves	17.63^{a}	$27.50^{a,b}$	13.13^{a}	7.75^{c}	17.11	< 0.05
Weight of Pine Needles	6.44^{a}	10.56^{a}	20.88^{b}	18.63^{b}	26.44	< 0.05
Weight of Total Litter	4.88^{a}	22.00^{b}	18.63^{b}	20.50^{b}	16.90	< 0.05

total weight of the litter in the bottomland areas was significantly less than the weight of the litter in the other vegetation types ($P < 0.001$) (Table 5).

Understory Vegetation

In the vegetation survey, 58 taxa of plants were found in the understory. The family, scientific and common names of these 58 taxa are listed in Appendix G. Plants that were not identified down to the species level were grouped by genera and treated as a single species during analysis.

The most abundant understory plants in the bottomland hardwood areas were panic grass (Panicum spp.), broadleaf chasmanthium (Chasmanthium latifolium), greenbrier (Smilax spp.), blackberry (Rubus spp.), sweet gum (Liquidambar styraciflua), and deciduous holly (Ilex decidua). In the sideslope hardwood areas, panic grass, American beautyberry (Callicarpa americana), deciduous holly, flowering dogwood (Cornus florida), greenbrier, and winged elm (Ulmus alata) were the most abundant understory plants. In the mixed pine-hardwood areas, American beautyberry, sweetgum, southern red oak (Quercus falcata), greenbrier, muscadine grape (Vitis rotundifolia), and winged elm were the most abundant understory plants. In the pure pine areas, sweetgum, southern red oak, water oak, and loblolly pine were the most abundant understory plants. Table 6 shows the 15 most abundant trees, shrubs, and woody vines found in the understory, the number of times each of those taxa were counted in each vegetation type, and the total number of trees, shrubs, and woody vines found in the understory of each vegetation type. The mixed pine hardwood and pure pine areas had more woody understory than did the bottomland hardwood and sideslope hardwood areas, but the

Table 6. Fifteen most abundant understory trees, shrubs, and woody vines and the total number of trees shrubs and woody vines recorded in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

Scientific name	Common name	Vegetation Type			
		Bottom	Sideslope	Mixed	Pine
Ilex decidua Walt.	deciduous holly	20	35	17	14
Cornus florida L.	flowering dogwood	0	31	3	2
Quercus falcata Michx.	southern red oak	1	2	26	35
Quercus nigra L.	water oak	2	4	14	25
Quercus phellos L.	willow oak	11	4	6	0
Liquidambar styraciflua L.	sweetgum	24	14	47	91
Carya tomentosa Nutt.	hickory	0	17	5	1
Smilax spp.	greenbrier	40	25	25	18
Ligustrum spp.	privet	6	2	7	1
Pinus taeda L.	loblolly pine	0	1	81	25
Rubus spp.	blackberry	33	14	18	1
Ulmus alata Michx.	winged elm	13	19	24	15
Callicarpa americana L.	American beautyberry	10	49	116	10
Ampelopsis arborea (L.) Koehne	peppervine	3	5	3	20
Vitis rotundifolia Michx.	muscadine grape	6	12	25	6
Total Understory Trees, Shrubs, and Woody Vines		218	293	438	328

Kruskal-Wallis analysis showed that the difference was not significant ($P > 0.05$).

Midstory and Overstory Vegetation

During the survey of the midstory and overstory vegetation, 52 taxa of plants were recorded. The family, scientific and common names of these 52 taxa are listed in Appendix H. Plants that were not identified to the species level were grouped by genera and treated as a single species during analysis. Also, standing dead trees were identified only as snags and were treated as a species during analysis. The frequency, density, and dominance of each midstory and overstory taxon was calculated for each study area and each vegetation type. The average of the relative frequency, relative density and relative dominance for a particular taxon is that taxon's importance value. Importance values were calculated for each study area and each vegetation type. Twenty three taxa made up 95.64% of all importance values. Those 23 taxa and their importance values are given by area in Table 7. The relative frequency, relative density, relative dominance, and importance value for each midstory and overstory species found in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas are listed in Appendices I, J, K and L, respectively.

In the bottomland hardwood stands, 25 taxa of midstory/overstory vegetation were recorded. Sweetgum, willow oak (Quercus phellos), snags, and deciduous holly were the most dominant bottomland midstory/overstory trees with importance values of 21.66, 15.70, 13.27, and 12.21, respectively. In the sideslope hardwood areas, 34 taxa of midstory/overstory vegetation were recorded. The most dominant midstory/overstory trees in the sideslope areas were sweetgum, southern red oak, winged elm, and flowering dogwood with importance values of 18.28, 14.04, 11.80, and 7.09, respectively. In the mixed pine-hardwood areas, 32 taxa of midstory/overstory vegetation were recorded. The most dominant midstory/overstory trees in the mixed pine-hardwood areas were loblolly pine, winged elm, sweetgum, and southern red oak with importance values of 32.57, 15.72, 15.52, and 8.96, respectively. In the pure pine study areas, 36 taxa were recorded in the midstory/overstory. The most dominant trees in the midstory/overstory of the pure pine areas were loblolly pine, sweetgum, southern red oak, and snags with importance values of 33.62, 25.73, 5.73, and 4.96, respectively. The pure pine areas had the most

Table 7. Importance values of the 23 most important midstory and overstory taxa found in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

Scientific name	Common name	Vegetation Type			
		Bottom	Sideslope	Mixed	Pine
Acer rubrum L.	red maple		1.09	0.73	1.59
Ilex decidua Walt.	deciduous holly	12.21	3.60	1.10	1.17
Cornus florida L.	flowering dogwood	0.32	7.09	0.86	0.47
Diospyros virginiana L.	common persimmon	0.17		0.73	1.26
Quercus falcata Michx.	southern red oak	2.12	14.04	8.96	5.73
Quercus lyrata Walt.	overcup oak	5.30			
Quercus nigra L.	water oak	8.17	5.71		3.92
Quercus phellos L.	willow oak	15.70	3.87	5.70	2.15
Quercus stellata Wangh.	post oak	0.43	5.64	0.61	0.84
Liquidambar styraciflua L.	sweetgum	21.66	18.28	15.52	25.73
Carya spp.	hickory	3.14	3.61	2.89	0.25
Morus rubra L.	red mullberry	0.44	1.12	0.95	0.72
Nyssa sylvatica Marsh.	blackgum	2.30	2.61	1.42	0.63
Fraxinus pennsylvanica Marsh.	green ash		0.79	0.81	1.78
Pinus echinata Mill.	shortleaf pine		0.20	0.28	3.03
Prunus serotina Ehrh.	black cherry		0.13	0.51	2.16
Pinus taeda L.	loblolly pine		2.97	32.57	33.62
Taxodium distichum (L.) Rich.	bald cypress	2.49			
Celtis laevigata Willd.	sugarberry	1.62	0.12	0.86	0.23
Planera aquatica (Walt.) J. F. Gmel.	water elm	2.68	0.12		
Ulmus alata Michx.	winged elm	1.31	11.80	15.72	4.44
Ulmus americana L.	American elm	3.07	5.57	1.37	0.94
	snag	13.27	4.98	4.39	4.96

number of taxa recorded in the midstory/overstory, however, the overstory of these areas was, with few exceptions, entirely loblolly pine. Using the Monte Carlo simulation method, the importance values of the midstory/overstory taxa were shown to be significantly different among the 4 habitat types ($P < 0.005$). Additionally, each of the 15 most important midstory/overstory taxa were analyzed using the Kruskal-Wallis and Nemenyi tests (Table 8). The Krusakal-Wallis analyses showed that there was a significant difference in the importance of deciduous holly, southern red oak, water oak, willow oak, hickory, loblolly pine, and snags among the 4 vegetation types.

Summary of Study Area Description

Bottomland Hardwood

The bottomland hardwood areas were frequently flooded and had very acidic soils (Table 1). The canopy was moderately unobscured (Table 2), especially near the permanent water bodies. As a result, the bottomland hardwood areas had more grass and herbaceous ground cover than did the mixed pine-hardwood or pure pine areas ($P < 0.05$) (Table 3). However, the frequent floods in the bottomland hardwood areas scoured the ground and resulted in them having relatively little litter depth or litter weight and a large amount of bare soil (Table 3,4, 5). The most abundant understory plants in the bottomland hardwood areas were 2 genera of grasses, i.e., broadleaf chasmanthium (Chasmanthium latifolium) and panic grass (Panicum spp.), 2 genera of woody vines, 1 species of hardwood tree, and 1 species of shrub (Table 6). Generally, the bottomland hardwood areas lacked substantial vertical structure in the understory. The most dominant plants in the midstory/overstory were 3 species of hardwood trees, snags, and 1 species of shrub (Table 7).

Sideslope Hardwood

The sideslope hardwood areas were mesic and were located adjacent to, but at a higher elevation than the bottomland hardwood areas. The soils in the sideslope hardwood areas are very acidic with moderate to high available water capacity and slow to rapid runoff (Table 1). The canopy in the sideslope hardwood areas was closed and the ground cover

Table 8. Kruskal-Wallis one-way analysis of variance for the 15 most important midstory/overstory taxa. These data were collected from the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas. Based on the Nemenyi pairwise comparisons, vegetation types with a common letter in a particular category were statistically the same in that category and vegetation types without a common letter in a particular category were significantly different in that category ($P < 0.05$).

	Mean Ranks by Forest Type				**Kruskal-Wallis**	
	Bottom	**Sideslope**	**Mixed**	**Pine**	**H Statistic**	***P* Value**
red maple	10.00	16.54	14.12	23.38	2.65	ns
deciduous holly	27.56 ^{a}	15.61 ^{a,b}	12.51 ^{b}	10.29 ^{b}	16.33	< 0.005
flowering dogwood	12.38	23.75	15.69	14.19	6.87	ns
southern red oak	6.38 ^{a}	23.75 ^{b}	20.14 ^{b}	15.75 ^{b}	15.34	< 0.005
overcup oak	24.00	14.00	14.00	14.00	6.82	ns
water oak	22.09 ^{a}	18.93 ^{a,b}	5.48 ^{b}	19.51 ^{a}	15.17	<0.005
willow oak	26.75 ^{a}	11.49 ^{b}	15.42 ^{a,b}	12.44 ^{b}	13.49	<0.005
post oak	14.75	22.64	11.51	17.23	5.93	ns
sweet gum	15.08	15.82	12.27	22.91	5.56	ns
hickory	19.92 ^{a}	21.38 ^{a,b}	16.92 ^{a,b}	7.89 ^{b}	9.97	<0.01
blackgum	19.94	19.08	17.42	9.75	6.25	ns
loblolly pine	5.48 ^{a}	11.52 ^{a,c}	23.14 ^{b,c}	25.92 ^{b}	25.25	<0.005
elm	7.12 ^{a}	21.44 ^{b,c}	25.43 ^{b}	12.14 ^{a,b}	17.60	<0.005
snag	27.26 ^{a}	16.34 ^{a,b}	9.75 ^{c}	12.75 ^{b,c}	15.93	<0.005

consisted of a large amount of grass, a moderate amount of herbaceous vegetation, and a small amount of bare soil (Table 2, 3). The depth of litter in the sideslope hardwood areas was moderate, but the weight of the litter was high (Table 4, 5). The most abundant understory plants in the sideslope area were panic grass, 2 species of shrubs, 1 species of woody vine, and 2 species of hardwood tree (Table 6). These plants gave the understory in the sideslope hardwood areas a substantial vertical component. The most dominant midstory/overstory plants in the sideslope hardwood areas were 3 species of hardwood trees (Table 7).

Mixed Pine-Hardwood

The mixed pine-hardwood areas were less mesic and at a higher elevation than the sideslope hardwood areas. They had soils that were very acidic with high available water capacity and slow to medium runoff (Table 1). The canopy in the mixed pine-hardwood areas was moderately closed and the ground cover had little grass or herbaceous vegetation and no bare soil (Table 2, 3). The litter in the mixed pine-hardwood areas was deep and was relatively heavy (Table 4, 5). The most abundant plants in the understory of the mixed pine-hardwood areas were 2 genera of woody vines, 1 shrub, and 2 species of hardwood trees, and 1 species of coniferous tree (Table 6). These plants gave the mixed pine-hardwood areas had a moderate level of vertical structure in the understory. The most dominant midstory/overstory plants were 3 species of hardwood trees and 1 species of pine (Table 7).

Pure Pine

The pure pine areas were the least mesic and had the highest elevation of the surveyed vegetation types. They had soils that were very acidic with moderate to high available water capacity and slow to rapid runoff (Table 1). The canopy in the pure pine areas was closed and the ground cover had little grass, no herbaceous vegetation, and little bare soil (Table 2, 3). The litter in the pure pine areas was moderately deep and was relatively heavy (Table 4, 5). The most abundant plants in the understory of the pure pine areas were 3 species of hardwood trees and 1 species of pine (Table 6). These plants gave the pure pine areas a moderate level of vertical structure in the understory. The most dominant midstory/overstory plants were 1 species of hardwood tree and 1 species of pine (Table 7).

RESULTS AND DISCUSSION

During the 1996 and 1997 surveys, 3,425 individuals of 45 species were recorded (Table 9, 10). There were 103 salamanders of 6 species, 1,925 anurans of 11 species, 30 turtles of 5 species, 687 lizards of 4 species, and 680 snakes of 19 species recorded during the study. In the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, 1,188, 1,373, 526, and 338 individuals of 38, 35, 28, and 28 species were recorded, respectively (Figure 5, 6) (Table 11) (Appendix M).

Species diversity indices were calculated by vegetation type using the Shannon-Wiener formula (Table 11) (Barbour et al. 1987). The diversity indices for the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas were 3.48, 3.40, 3.95, and 3.88, respectively. Using Pielou's formula (1975), species evenness was calculated for each vegetation type (Table 11). The species evenness values for the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas were 0.665, 0.663, 0.821, and 0.807, respectively. Even though they had fewer herptile individuals and species than the bottomland hardwood and sideslope hardwood areas, the mixed pine-hardwood and pure pine areas had higher species diversities because the herptiles from those areas were more evenly distributed among their species than were the herptiles from the bottomland hardwood and sideslope hardwood areas. The low evenness values for the bottomland hardwood and sideslope hardwood areas were caused primarily by large numbers of a single species, the bronze

Table 9. Numbers of reptiles by species recorded in the bottomland hardwood (BH), sideslope hardwood (SH), mixed pine-hardwood (Mx), and pure pine (PP) study areas.

Species	BH	SH	Mx	PP	Total	Percent
Turtles						
Terrapene carolina	02	03	02	04	11	0.32
Trachemys scripta	09	06	-	-	15	0.44
Graptemys pseudogeographica	01	-	-	-	01	0.03
Chelydra serpentina	02	-	-	-	02	0.06
Macroclemys temminckii	01	-	-	-	01	0.03
Subtotal turtles	15	09	02	04	30	0.88
Lizards						
Anolis carolinensis	20	58	31	42	151	4.41
Eumeces fasciatus	26	31	36	30	123	3.59
Eumeces laticeps	36	85	77	55	253	7.39
Scincella lateralis	28	62	13	57	160	4.67
Subtotal lizards	110	236	157	184	687	20.06
Snakes						
Storeria dekayi	06	03	-	-	09	0.26
Storeria occipitomaculata	-	01	-	01	02	0.06
Virginia striatula	-	-	-	02	02	0.06
Lampropeltis calligaster	-	02	-	-	02	0.06
Lampropeltis getula	15	08	20	06	49	1.43
Lampropeltis triangulum	-	02	08	05	15	0.44
Coluber constrictor	18	14	20	14	66	1.93
Opheodrys aestivus	-	01	-	01	02	0.06
Elaphe obsoleta	09	18	13	06	46	1.34
Heterodon platirhinos	-	-	01	-	01	0.03
Thamnophis proximus	38	57	27	23	145	4.23
Farancia abacura	04	02	01	-	07	0.20
Nerodia cyclopion	10	01	01	-	12	0.35
Nerodia erythrogaster	26	14	09	01	50	1.46
Nerodia fasciata	57	18	15	-	90	2.63
Nerodia rhombifera	05	01	03	-	09	0.26
Regina rigida	03	-	-	-	03	0.09
Agkistrodon contortrix	29	44	25	19	117	3.42
Agkistrodon piscivorus	31	18	02	02	53	1.55
Subtotal snakes	251	204	145	80	680	19.85
Subtotal reptiles	376	449	304	268	1397	40.79

Table 10. Numbers of amphibians by species and total numbers of herptiles recorded in the bottomland hardwood (BH), sideslope hardwood (SH), mixed pine-hardwood (Mx), and pure pine (PP) study areas.

Species	BH	SH	Mx	PP	Total	Percent
Salamanders						
Eurycea quadridigitata	-	-	-	02	02	0.06
Ambystoma maculatum	02	06	03	02	13	0.38
Ambystoma opacum	03	32	05	06	46	1.34
Ambystoma talpoideum	11	07	-	05	23	0.67
Amphiuma tridactylum	01	-	-	-	01	0.03
Siren intermedia	18	-	-	-	18	0.53
Subtotal salamanders	35	45	08	15	103	3.01
Anurans						
Acris crepitans	46	28	41	01	116	3.39
Pseudacris streckeri	01	-	-	-	01	0.03
Pseudacris triseriata	05	36	12	-	53	1.55
Hyla cinerea	35	74	64	16	189	5.52
Hyla chrysoscelis/versicolor	04	16	03	16	39	1.14
Rana catesbeiana	28	36	05	01	70	2.04
Rana clamitans	535	619	84	07	1245	36.35
Rana utricularia	58	17	02	03	80	2.34
Gastrophryne carolinensis	05	11	-	06	22	0.64
Bufo valliceps	57	35	03	05	100	2.92
Bufo woodhousei	03	07	-	-	10	0.29
Subtotal anurans	777	879	214	55	1925	56.20
Subtotal amphibians	812	924	222	70	2028	59.21
Total herptiles	1188	1373	526	338	3425	100.00

Figure 5. Numbers of amphibians, reptiles and total herptiles recorded in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

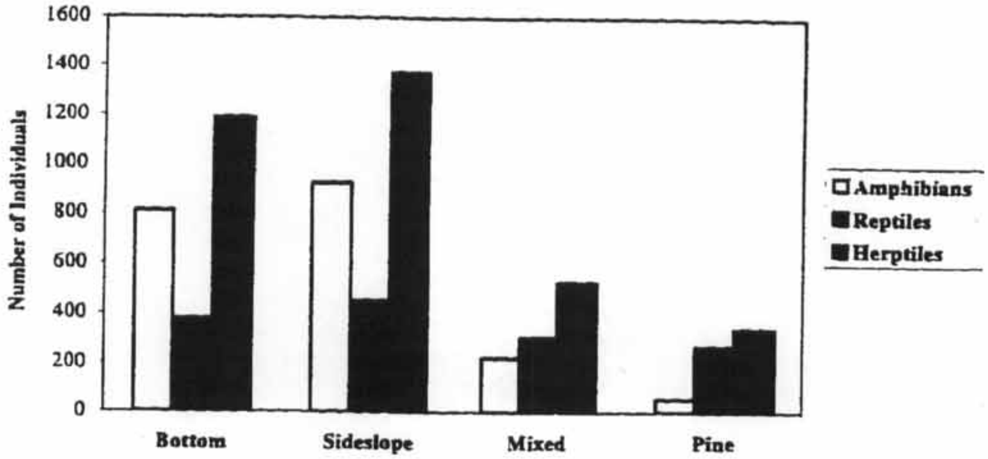


Figure 6. Species of amphibians, reptiles, and herptiles recorded in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

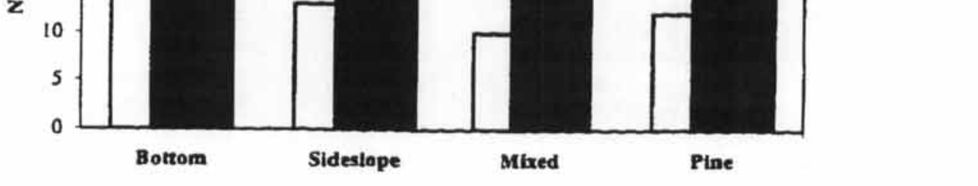


Table 11. Individual abundance, species richness, species diversity, and evenness values for the herptiles recorded on the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, pure pine study areas, and inclusively for all 4 vegetation types.

	Abundance	Richness	Diversity	Evenness
Bottom	1,188	38	3.49	0.665
Sideslope	1,373	35	3.40	0.633
Mixed	526	28	3.95	0.821
Pine	338	28	3.88	0.807
All Areas	3,425	45	3.82	0.696

bronze frog (Rana clamitans), captured in those 2 vegetation types. A Monte Carlo analysis of contingency table data showed that the composition of herptile species differed significantly among the 4 vegetation types ($P = 0.005$) and a Kruskal-Wallis analysis showed that the numbers of individual herptiles differed significantly among the 4 vegetation types ($P < 0.005$) (Table 12). A Nemenyi test showed that the numbers of individual herptiles in the bottomland hardwood and sideslope hardwood areas were significantly more than the numbers of individual herptiles in the mixed pine-hardwood and pure pine areas ($P < 0.002$) (Table 12).

Because screenwire funnel traps were used in the place of pitfall traps in the bottomland hardwood areas, the trapping method used in those areas was different from the trapping method used in the other vegetation types. However, the numbers of individuals trapped by each survey technique (Table 13) show that the numbers of herptiles captured in screenwire funnel traps in the bottomland hardwood areas were

Table 12. Kruskal-Wallis one-way analysis of variance for the numbers of individual amphibians, reptiles, and total herptiles recorded in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas. Based on the Nemenyi pairwise comparisons, vegetation types with a common letter were statistically the same in the corresponding category and vegetation types without a common letter were significantly different in the corresponding category ($P < 0.05$).

	Mean Ranks by Forest Type				Kruskal-Wallis	
	Bottom	Sideslope	Mixed	Pine	H Statistic	*P* Value
Amphibians	24.50^{a}	$22.38^{a,b}$	14.63^{b}	4.50^{c}	22.366	< 0.005
Reptiles	20.13^{a}	24.38^{a}	11.19^{b}	10.31^{b}	12.879	< 0.005
Herptiles	24.75^{a}	23.88^{a}	12.69^{b}	4.69^{b}	25.138	<0.005

Table 13. Numbers of individual herptiles captured by each of the survey techniques used in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

Means of Capture	Vegetation Type			
	Bottom	Sideslope	Mixed	Pine
Hardware cloth funnel trap	1,025	1,160	426	215
Screenwire funnel trap	79	61	15	29
Pitfall trap	-	30	14	32
PVC treefrog trap	18	54	38	23
Aquatic turtle trap	5	-	-	-
Artificial cover board	14	7	5	12
Hand Captured	47	61	28	27

similar to the numbers of herptiles trapped in both pitfall traps and screenwire funnel traps in the sideslope hardwood areas. When the herptiles captured in screenwire funnel traps and pitfall traps were excluded, a Kruskal-Wallis analysis again showed that the numbers of individuals differed significantly among the 4 vegetation types ($P < 0.005$) (Table 14). Additionally, a Nemenyi test which excluded herptiles captured in screenwire funnel traps and pitfall traps, showed that the bottomland hardwood and sideslope hardwood areas had significantly more herptiles than did the mixed pine-hardwood and pure pine areas ($P < 0.02$). Both the Kruskal-Wallis and Nemenyi tests gave the same results whether screenwire funnel traps and pitfall traps were excluded or included in the analyses. In order to determine if the species composition was biased because of the different trapping methods, a Monte Carlo analysis which excluded the herptiles captured in screenwire funnel traps and pitfall traps was used. This analysis showed that the species composition still differed significantly across the 4 habitat types ($P = 0.005$). Because these data demonstrate that the trapping methods used in the bottomland hardwood areas produced similar results as those used in the other vegetation types, the herptiles captured in screenwire funnel traps and pitfall traps were included in the remainder of the analyses. The numbers of individuals from each species captured by each survey technique are given in Appendices N, O, P, and Q for the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively.

Table 14. Kruskal-Wallis one-way analysis of variance for the numbers of individual herptiles, excluding those captured in screenwire funnel traps or pitfall traps, recorded in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas. Based on the Nemenyi pairwise comparisons, vegetation types with a common letter had similar numbers of herptiles and vegetation types without a common letter had significantly different numbers of herptiles ($P < 0.05$).

	Mean Ranks by Forest Type				Kruskal-Wallis	
	Bottom	Sideslope	Mixed	Pine	H Statistic	P Value
Herptiles	25.00[a]	23.50[a]	12.50[b]	5.00[b]	24.50	<0.005

Amphibians

Amphibians were 59.21% of the captured individuals. There were 812, 924, 222, and 70 amphibians from 16, 13, 10, and 12 species captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively (Table 10, Figure 5, 6). A Monte Carlo analysis showed that the amphibian species composition differed significantly among the 4 vegetation types ($P = 0.005$). A Kruskal-Wallis test showed that the numbers of amphibians differed significantly among the 4 vegetation types ($P < 0.005$) (Table 12). A Nemenyi test showed that the number of individual amphibians in the pure pine areas was significantly lower than the numbers of individual amphibians in the other 3 vegetation types ($P < 0.02$) (Table 12). The Nemenyi test also revealed that the numbers of individual amphibians in the bottomland hardwood areas and the sideslope hardwood areas were statistically the same, as were the numbers of individual amphibians in the sideslope hard wood and mixed pine-hardwood areas (Table 12).

There were 35, 45, 8, and 15 individual salamanders of 5, 3, 2, and 4 species captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively (Table 10, Figure 7). A Monte Carlo analysis showed that the species composition of salamanders differed significantly among the 4 vegetation types (P = 0.005). However, a Kruskal-Wallis analysis of variance showed that there was no significant difference in the numbers of individual salamanders captured in the 4 vegetation types (Table 15).

The marbled salamander (Ambystoma opacum) was captured in all 4 vegetation types and was the most abundant salamander species. Twenty four (52.17%) of the marbled salamanders were captured during the autumn portion of the survey, which corresponded with their breeding season (Conant and Collins 1991). Eighteen lesser sirens (Siren intermedia) and 1 three-toed amphiuma were captured in the bottomland hardwood areas. These aquatic salamanders were captured during periods of heavy rain when the water bodies adjacent to the bottomland hardwood areas rose to at least the level of the drift fences and drift fence arrays in the bottomland hardwood areas. The difference in salamander species composition shown by the Monte Carlo analysis probably reflects the 19 aquatic salamanders unique to the bottomland hardwood areas and the disproportionate number of marbled salamanders (69.57%) captured in the sideslope hardwood areas.

In the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, 777, 879, 214, and 55 individual anurans of 11, 10, 8, and 8 species were

Figure 7. Numbers of salamander individuals and species captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

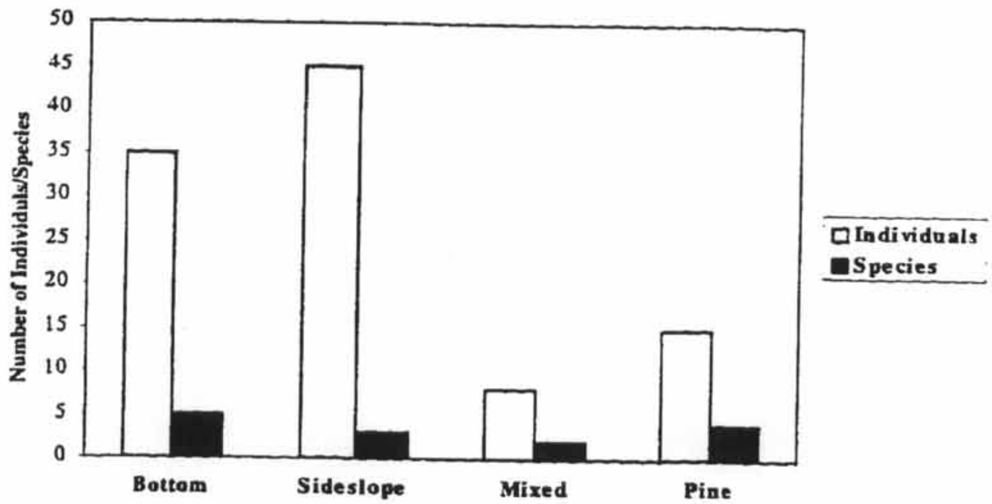


Table 15. Kruskal-Wallis one-way analysis of the numbers of individual salamanders and anurans captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas. Based on the Nemenyi pairwise comparisons, vegetation types with a common letter had similar numbers of anurans and vegetation types without a common letter had significantly different numbers of anurans ($P < 0.05$).

	Mean Ranks by Forest Type				Kruskal-Wallis	
	Bottom	Sideslope	Mixed	Pine	H Statistic	*P* Value
Salamanders	18.63	21.63	10.50	15.38	6.561	ns
Anurans	24.50 [a]	22.38 [a,b]	14.63 [b]	4.50 [c]	22.366	< 0.001

captured, respectively (Figure 8, 9). A Monte Carlo analysis showed that the anuran species composition differed significantly among the 4 vegetation types ($P = 0.005$). A Kruskal-Wallis test showed that among the 4 vegetation types, there was a significant difference in the numbers of anurans captured ($P < 0.001$) (Table 15). A Nemenyi test showed the bottomland hardwood and sideslope hardwood areas had similar numbers of anurans as did the sideslope hardwood and mixed pine-hardwood areas. The Nemenyi test also showed that the pure pine areas had significantly fewer numbers of anurans than did the other 3 vegetation types ($P < 0.02$) (Table 15).

The most abundant species of anuran, amphibian, and herptile was the bronze frog which made up 61.39% (1,245) of all captured amphibians and 36.35% of all captured herptiles. Five hundred thirty-five, 619, 84, and 7 individual bronze frogs were captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively. Approximately 95% of the bronze frogs captured in the bottomland hardwood and sideslope hardwood areas were newly metamorphosed juveniles. These juveniles were probably hatched in or near the bottomland hardwood areas and were probably using the sideslope hardwood areas as migratory routes to other water bodies. In study area 3, a sideslope hardwood area that had permanent water on 3 sides, 598 bronze frogs were captured, while in study area 1, a sideslope area that has a permanent water body on only 1 side, 21 bronze frogs were captured. The numbers of bronze frogs captured in the bottomland areas adjacent to areas 3 and 1 were 332 and 203, respectively. The 2 sideslope areas were probably so different in numbers of captured

Figure 8. Numbers of anuran individuals captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

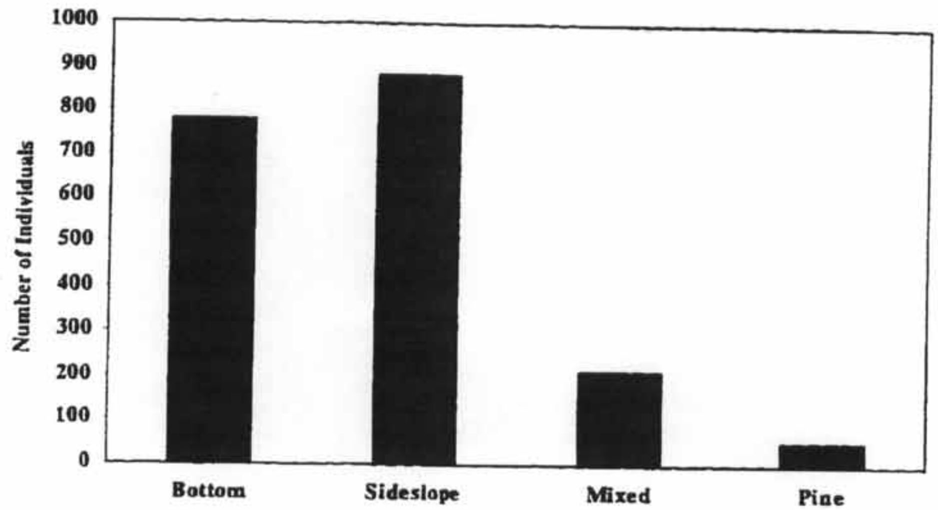
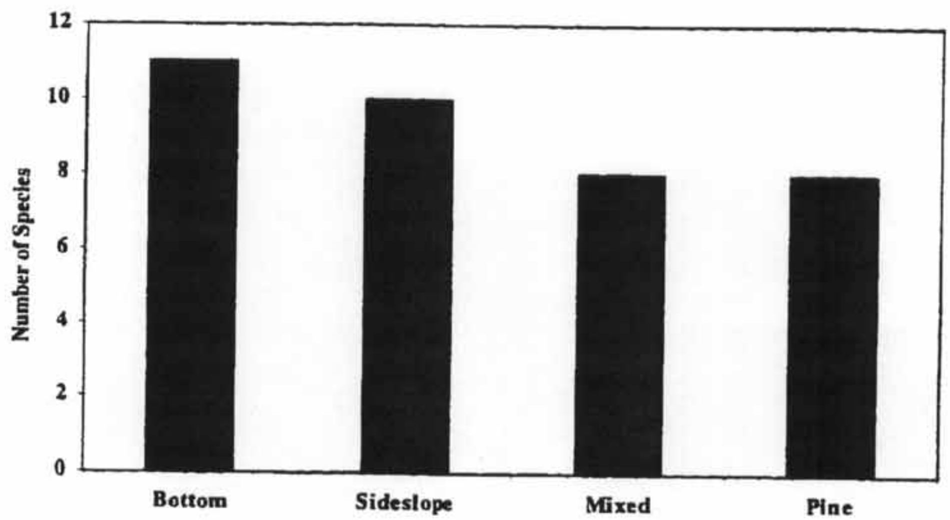


Figure 9. Species of anurans recorded in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.



bronze frogs because more water near area 3 gave rise to more opportunities for juvenile bronze frogs to use it as a route away from their natal ponds. Because of the difference between the 2 sideslope hardwood areas in numbers of bronze frogs captured, the ranked data seem to indicate higher numbers of individual amphibians and anurans in the bottomland hardwood areas rather than in the sideslope hardwood areas where more amphibians and anurans were actually captured. Because the bronze frogs were probably only passing through these areas, the ranked data probably better reflect ecological reality.

Hardy (1995) listed the gulf coast toad (Bufo valliceps) as a species that probably could be found in Harrison County, Texas, but that never had been recorded from there. On 20 April 1997, a gulf coast toad was captured in a hardware cloth funnel trap located in area 1, a sideslope hardwood area. The specimen was returned to SFASU and was verified by Dr. Fred Rainwater, Professor of Biology. The specimen was preserved and deposited in the Stephen F. Austin Vertebrate Museum. This county record was reported to Herpetological Review (Fleet and Autrey 1997). Subsequent to the initial gulf coast toad, 99 additional individuals were captured.

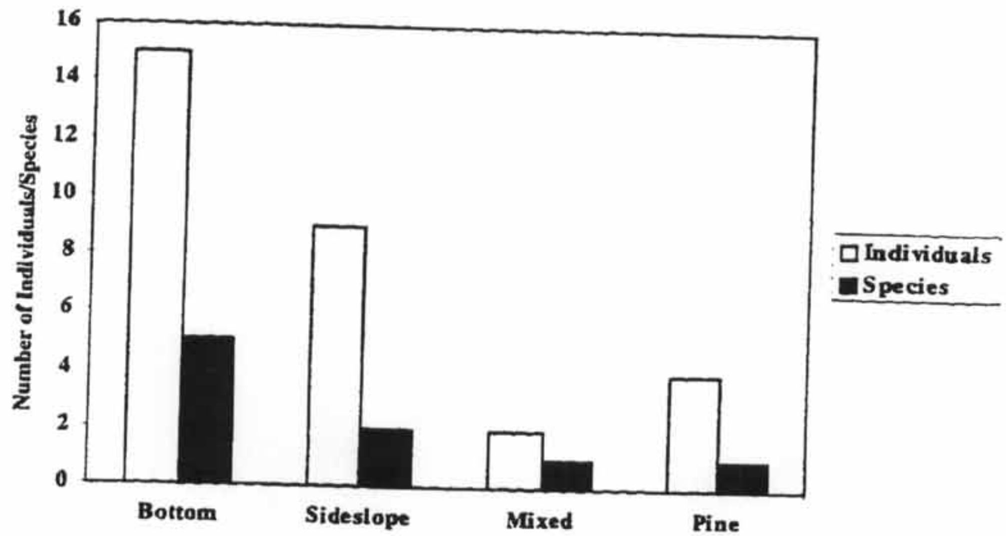
DeGraaf and Rudis (1989) suggested that the lower pH associated with coniferous needles was a possible explanation for the lack of amphibians in conifer stands. However, while the soils in the bottomland hardwood and sideslope hardwood areas of the LHAAP have been described as very to strongly acidic (USDA and SCS 1994), large numbers of amphibians were recorded in those areas. Therefore, the explanation offered by DeGraaf and Rudis does not seem applicable in this case. The low numbers of amphibians in the mixed pine-hardwood and pure pine areas of the LHAAP were probably the result of low levels of moisture in those areas. In the case of the more aquatic anurans, such as those in the genus Rana, the distance from the mixed pine-hardwood and pure pine areas to permanent bodies of water was probably a factor. Of the 1,395 captured ranids, only 102 (7.31%) were captured in the mixed pine-hardwood or pure pine areas.

Reptiles

Twenty-eight species of reptiles made up 40.79% (1,397) of the individual herptiles captured during the herpetofaunal surveys (Table 9). In the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas, 376, 449, 304, and 268 individual reptiles of 22, 22, 18, and 16 species were captured, respectively (Figure 5, 6). A Monte Carlo analysis showed that the reptile species composition differed significantly among the 4 vegetation types ($P = 0.005$). A Kruskal-Wallis test showed that the numbers of reptiles differed significantly among the 4 vegetation types ($P <$ 0.005) (Table 12). A Nemenyi test showed that significantly more reptiles were captured in the bottomland hardwood and sideslope hardwood areas than in the mixed pine-hardwood and pure pine areas ($p < 0.05$) (Table 12).

Thirty individual turtles from 5 species were captured. Fifteen, 9, 2, and 4 individual turtles of 5, 2, 1, and 1 species were captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively (Table 9, Figure 10). The 8 aquatic turtle traps used in the bottomland hardwood areas yielded 5 red-eared sliders (Trachemys scripta). Because the numbers of turtles were small and because the

Figure 10. Numbers of individuals and species of turtles captured on the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.



use of aquatic turtle traps biased the survey, turtles were excluded from the Monte Carlo, Kruskal-Wallis, and Nemenyi analyses and no analyses were performed on the turtle group. However, it is noteworthy that only 2 species of turtles were captured in areas other than the bottomland hardwood areas, i.e., the terrestrial three-toed box turtle (Terrapene carolina) and the red-eared slider. The three-toed box turtle was captured in relatively small numbers in all 4 vegetation types and the red-eared slider was only captured in the bottomland hardwood and sideslope hardwood areas. The red-eared sliders captured in the sideslope hardwood areas primarily were adult females and hatchlings. Presumably, the adult females were moving into the sideslope hardwood areas from the bottomland hardwood areas for oviposition. The remaining 3 turtle species are aquatic and would not be expected to travel any great distance from permanent water bodies. One of these species, the alligator snapping turtle (Macroclemys temminckii) is listed as threatened in Texas.

Four species of lizards were represented by 687 individuals. All 4 species were captured in all 4 vegetation types. In the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, 110, 236, 157, and 184 individual lizards were captured, respectively (Table 9, Figure 11, 12). A Monte Carlo analysis showed that the lizard species composition differed significantly among the 4 vegetation types (P = 0.005). A Kruskal-Wallis test showed that the numbers of individual lizards differed significantly among the 4 vegetation types ($P < 0.05$) (Table 16). A Nemenyi test showed that the number of individual lizards in the sideslope hardwood areas was significantly greater than the numbers of individual lizards in the other vegetation types ($P < 0.05$) (Table 16). However, the numbers of individual lizards in the pure pine areas were statistically the same as the numbers of individual lizards in the mixed pine-hardwood areas and the numbers of individual lizards in the mixed pine-hardwood areas were statistically the same as the numbers of individual lizards in the bottomland hardwood areas (Table 16).

With 253 individuals captured, the broadhead skink (Eumeces laticeps) was the most abundant lizard and reptile, and the second most abundant herptile captured. There were 36, 85, 77, and 55 broadhead skinks captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, respectively.

Figure 11. Numbers of individual lizards and snakes captured on the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

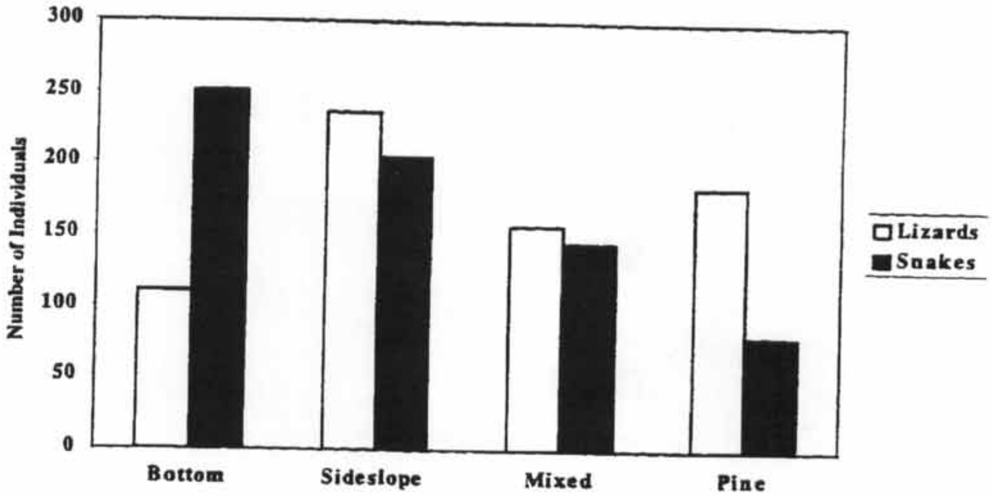


Figure 12. Species of lizards and snakes captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

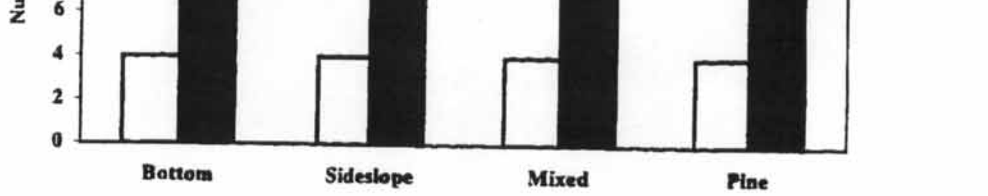


Table 16. Kruskal-Wallis one-way analysis of variance for the numbers of individual lizards and snakes captured in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas. Based on the Nemenyi pairwise comparisons, vegetation types with a common letter were statistically the same in the corresponding category and vegetation types without a common letter were significantly different in the corresponding category ($P < 0.05$).

	Mean Ranks by Forest Type				Kruskal-Wallis	
	Bottom	Sideslope	Mixed	Pine	H Statistic	P Value
Lizards	10.06^{a}	22.81^{b}	$14.06^{a,c}$	19.06^{c}	8.527	<0.05
Snakes	25.19^{a}	$19.81^{a,b}$	14.56^{b}	6.44^{c}	17.405	<0.001

According to Conant and Collins (1991), most skinks prefer to use terrestrial debris for refuge. The small amount of such habitat in the bottomland hardwood areas is a possible explanation for the relatively few numbers of five-lined skinks (Eumeces fasciatus) and ground skinks in those areas. The lack of substantial vertical structure in the understory of the bottomland hardwood areas is probably the reason that the two arboreal lizards, i.e. the green anole and the broadhead skink, were found in low numbers in those areas. The fewest ground skinks were captured in the mixed pine-hardwood areas. Deep litter layers decreased the ability of the observer to see and capture ground skinks and is a possible reason that few ground skinks were captured by hand in the mixed pine-hardwood areas. However, ground skinks in the mixed pine hardwood areas were captured in low numbers by every survey method used (Table 17). It is possible that the deep litter layer in the mixed pine-hardwood provided enough habitat for ground skinks that they were infrequently required to move. As a result, the ground skinks in the

Table 17. Numbers of ground skinks captured by each of the survey techniques used in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.

Means of Capture	**Vegetation Type**			
	Bottom	**Sideslope**	**Mixed**	**Pine**
Hardware cloth funnel trap	5	12	2	15
Screenwire funnel trap	9	17	4	8
Pitfall trap	-	7	3	18
Artificial cover board	4	4	1	6
Hand captured	10	22	3	10

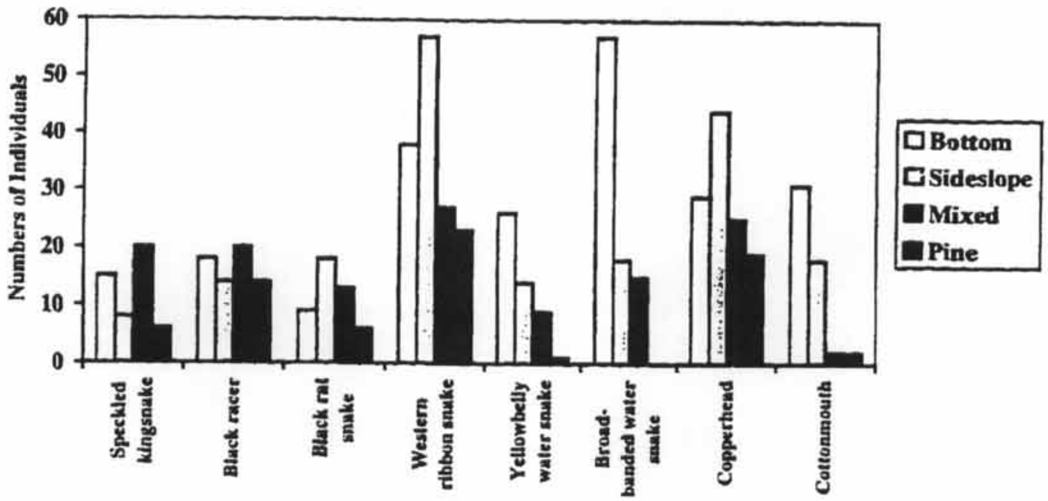
mixed pine-hardwood areas would infrequently be captured by the survey methods used in this study.

Eighteen species of snakes were represented by 680 individuals. In the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas, 251, 204, 145, and 80 individual snakes of 13, 16, 13, and 11 species were captured, respectively (Table 9, Figure 11, 12). A Monte Carlo analysis showed that snake species composition differed significantly among the 4 vegetation types ($P = 0.005$). A Kruskal-Wallis test showed that there was a significant difference in the numbers of individual snakes captured among the 4 vegetation types ($P < 0.001$) (Table 16). A Nemenyi test showed that the numbers of individual snakes in the bottomland hardwood and sideslope hardwood areas were significantly more than the number of individual snakes captured in the pure pine areas ($P < 0.01$). However, the number of individual snakes captured in the sideslope hardwood areas was not significantly more than the number of individual snakes captured in the mixed pine-hardwood areas but the number of individual snakes captured in the mixed pine-hardwood areas was significantly more than the number of individual snakes captured in the pure pine areas (Table 16).

The 8 most abundant species of snakes made up 90.58% of all snake captures. Five of these snakes, i.e., the speckled kingsnake (Lampropeltis getula), the black racer, the black rat snake (Elaphe obsoleta), the ribbon snake (Thamnophis proximus), and the copperhead, are considered to be generalists in their habitat and/or their prey preferences (Conant and Collins 1991). These 5 snakes were relatively evenly distributed among the 4 vegetation types, although in each case, the fewest were captured in the pure pine areas. The remaining 3 snakes, i.e. the yellowbelly water snake (Nerodia erythrogaster), the broad-band water snake (Nerodia fasciata), and the cottonmouth, are aquatic or semiaquatic snakes and were found primarily in the bottomland hardwood and sideslope hardwood areas (Figure 13).

The relatively few snakes in the mixed pine-hardwood and pure pine areas are likely related to the lack of moisture in those areas. Eight of the recorded snake species, the ribbon snake, the mud snake (Farancia abacura), the green water snake (Nerodia cyclopion), the yellowbelly water snake, the broad-banded water snake, the diamondback water snake (Nerodia rhombifera), the glossy crawfish snake (Regina rigida), and the cottonmouth, are considered to be aquatic or semiaquatic (Conant and Collins 1991). Because the mixed pine-hardwood and pure pine areas were at the highest elevation and at the greatest distance from a permanent water source, only 84 of the 369 (22.76%) individuals from the 8 aquatic/semiaquatic snake species were captured in those areas

Figure 13. Distribution of the 8 most abundant snakes in the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine study areas.



(Table 9). Fifty of the 83 aquatic/semiaquatic snakes captured in the mixed pine-hardwood and pure pine areas were ribbon snakes. These ribbon snakes probably were in those areas to feed on the anurans associated with the ephemeral ponds that occurred there. Also, because many snake species prey upon amphibians, it is likely that the fewest snakes were found in the mixed pine-hardwood and pure pine areas because those areas had the fewest amphibians.

CONCLUSIONS

The 1996 and 1997 surveys provided a relatively brief glimpse of the herpetofaunal assemblages in 4 vegetation types from the LHAAP. Even though it would be impossible to completely describe these assemblages from such a brief glimpse, enough information was gathered to make broad comparisons between them.

The bottomland hardwood areas had the lowest elevation and the most moisture of the 4 vegetation types. They had more grass and herbaceous ground cover than did the mixed pine-hardwood or pure pine areas ($P < 0.05$) (Table 3). However, the frequent floods in the bottomland hardwood areas resulted in them having relatively little litter depth or litter weight and a large amount of bare soil (Table 3, 4, 5). Generally, the bottomland hardwood areas lacked substantial vertical structure in the understory. The sideslope hardwood areas had a higher elevation and less moisture than the bottomland hardwood areas. In these areas, the ground cover had a large amount of grass, a moderate amount of herbaceous vegetation, and a small amount of bare soil (Table 2). The depth of litter in the sideslope hardwood areas was moderate, but the weight of the litter was high (Table 4, 5). The understory in the sideslope hardwood areas had a substantial vertical component. The mixed pine-hardwood areas had a higher elevation and less moisture than the sideslope hardwood areas. These areas had little grass or herbaceous vegetation and no bare soil (Table 2). The litter in the mixed pine-hardwood areas was deep and was relatively heavy (Table 4, 5). The mixed pine-hardwood areas had less understory vertical structure than the sideslope hardwood areas but more than the bottomland hardwood areas (Table 6). The pure pine areas had the highest elevation and the least moisture of the 4 vegetation types. These areas had little grass, no herbaceous vegetation, and little bare soil (Table 2). The litter in the pure pine areas was moderately deep and was relatively heavy (Table 4, 5). The pure pine areas had approximately the same level of vertical structure in the understory as the mixed pine-hardwood areas (Table 6).

As indicated by the Monte Carlo, Kruskal-Wallis, and Nemenyi analyses, the bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine areas each had a distinct herpetofaunal assemblage. In order to quantify the differences between the vegetation types, Sorensen's percent similarity (Smith 1992) was calculated for each of the 6 possible pairs of vegetation types (Table 18). These calculations show that the bottomland hardwood and sideslope hardwood areas were the most similar (80.43%) and the bottomland and pure pine areas were the least similar (29.58%). The remaining similarities are intermediate and seem to reflect distances on the moisture and elevation gradients.

A majority of the differences in individual abundance and species richness among the vegetation types can be best related to available moisture. At the LHAAP, the bottomland hardwood areas had the greatest herptile species richness of the 4 vegetation types. Primarily, this was the result of 2 aquatic salamanders and the 3 aquatic turtles that were captured in those areas, but would not be expected to occur in the other vegetation types. The Kruskal-Wallis one-way analysis and the Nemenyi pairwise comparisons showed a general trend of more herptiles occurring in the 2 vegetation types that had lowest

Table 18. Sorensen's percent similarity of herpetofaunal assemblages between each of the 6 possible pairs of vegetation types.

	Similarity by Vegetation Types			
	Bottom	**Sideslope**	**Mixed**	**Pine**
Bottom	-	80.43	50.20	29.58
Sideslope		-	58.31	43.32
Mixed			-	60.06

elevations and the most moisture, i.e., the bottomland hardwood and sideslope hardwood areas, than in the 2 vegetation type that had the highest elevations and the least moisture, i.e., the mixed pine-hardwood and the pure pine areas. Because amphibians need aquatic habitat for breeding and many snakes and turtles rely on amphibians as a source of food, or on water for habitat, areas with little or no available water will necessarily have fewer amphibians, snakes, and turtles than those areas with adequate available water. The sideslope hardwood and bottomland hardwood areas had the most available moisture and the highest numbers of amphibians, snakes, and turtles. However, the numbers of amphibians and snakes in the sideslope hardwood areas were statistically the same as the numbers of amphibians and snakes in the mixed pine-hardwood areas. This probably reflects the presence of temporary pools in the mixed pine-hardwood areas that served as breeding habitat for some amphibians. During the March through June 1996 survey, eastern Texas was experiencing a severe drought. Because the mixed pine-hardwood and pure pine areas had the highest elevation and were the farthest from permanent water bodies, the drought probably had the greatest impact on these two vegetation types.

Therefore, it is possible that these data reflect an exaggerated difference between areas with high available water and areas with low available water.

In addition to moisture level, complexity of the habitat structure can help to explain some of the differences in the herpetofaunal assemblages in different vegetation types. Terrestrial lizards require ground cover debris for refuge and arboreal lizards rely upon a complex vertical structure in the understory for habitat. The reduced level of both of these is a possible reason for the low number of individual lizards in the bottomland hardwood areas. Likewise, the abundance of ground cover and vertical structure in the understory is a possible reason for the high number of individual lizards in the sideslope areas. This explanation is supported by the presence of moderate numbers of lizards in the mixed pine-hardwood and pure pine areas, which had moderate levels of ground cover and vertical structure in the understory.

Since 1941, most of the land at the LHAAP has not been logged (Walker and Brantley 1978). As a result, much of the forested areas have maintained their structural integrity and therefore, are able to support diverse herpetofaunal assemblages. Although 45 species were recorded during the study, only 21 (46.67%) were recorded in all 4 vegetation types. Therefore, in order to promote healthy herpetofaunal assemblages, future land management strategies on the LHAAP should attempt to maintain a diversity of vegetation types while protecting the land from overuse.

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APPENDICES

Apppendix A. Data sheet for recording understory vegetation on the study areas used for the herpetofaunal surveys at the Longhorn Army Ammunition Plant in Harrison County, Texas.

Study area:_____
Plot number:____
Subplot letter:___

Dr. R. R. Fleet
Box 13003 SFA
Nacogdoches, TX 75962
(409) 468-3601

Understory Vegetation Data
1/500 ha: r=2.52 m
Plants 0.5 - 3.0 m tall
LONGHORN AMMO DUMP

____
Name

__ __ __ __
Date

Species Name	Species Code	Diameter (cm)	Height (feet)
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __
______	__ __	__ __ __	__ __. __

Appendix B. Data sheet for recording overstory and midstory vegetation on study areas used for the herpetofaunal surveys at the Longhorn Army Ammunition Plant in Harrison County, Texas.

Study area:_____
Plot number:____
Subplot letter:___

Dr. R. R. Fleet
Box 13003 SFA
Nacogdoches, TX 75962
(409) 468-3601

Overstory and Midstory
Vegetation Data
1/25 ha: r=11.28m
Longhorn Ammo

Name

Date

Species		Diameter	Height
Name	Code	(cm)	(feet)

Appendix C. Data sheet for recording ground cover and canopy closure on study areas used for the herpetofaunal surveys at the Longhorn Army Ammunition Plant in Harrison County, Texas.

Study area:____

Plot number:___

Dr. R. R. Fleet
Box 13003 SFA
Nacogdoches, TX 75962
(409) 468-3601

Ground Cover
&
Crown Closure
LONGHORN AMMO DUMP

______ Name

__ __ __ __ Date

Ground cover
(<0.5 m tall: No. hits per pin)

Subplot	Species group[1]						Crown closure[2]		
letter	Grass	Herb	Woody	Litter	Soil		Over	Mid	Under

1. Use dot tally
2. Use Y=yes, leave blank if no

Appendix D. Data sheet for recording leaf litter depth on study areas used for the herpetofaunal surveys at the Longhorn Army Ammunition Plant in Harrison County, Texas.

Return to B. Autrey or R. Daniel
Department of Biology
Stephen F. Austin State University
Nacogdoches, Tx 75962

LHAAP
Leaf Litter Data

Observer:____________________ Date:__________ ___ ___ ___ ___

Study Area:__________________ Vegetation Type:____________________

Plot:______ Subplot:______

Litter Depth (cm):______ ______ ______ ______ ______

Plot:______ Subplot:______

Litter Depth (cm):______ ______ ______ ______ ______

Plot:______ Subplot:______

Litter Depth (cm):______ ______ ______ ______ ______

Plot:______ Subplot:______

Litter Depth (cm):______ ______ ______ ______ ______

Plot:______ Subplot:______

Litter Depth (cm):______ ______ ______ ______ ______

Five litter depths taken from within 1 m^2. All litter from within 1 m^2 placed in a large bag. A soil sample from within 1 m^2 is placed in a small bag. The soil bag and location-identifying card are placed in the litter bag.

Appendix E. Data sheet for recording herptiles from the survey conducted on the Longhorn Army Ammunition Plant in Harrison County, Texas.

HERPTILE SURVEY

Observer ____________

Date ____________ ___ ___ ___

Habitat type ____________ Study area ____________

R. R. Fleet
Box 13011
Nacogdoches, TX 75962
(409) 468-2267

Common name	Species code	Plot no.	Alive	How recorded	Recap.	Comments

Alive: 1=yes,2=no,3=probably dying.

Recapture: 1=yes,2=no,3=unknown(escaped or seen only)

Appendix F. The Monte Carlo program used to test the null hypothesis that the composition of communities are the same. This program was written for SAS by Dr. J. Kelly Cunningham, Associate Professor of Mathematics and Statistics at Stephen F. Austin State University in Nacogdoches, Texas. The Monte Carlo program analyzes contingency table data by determining the unlikelihood that those data are distributed randomly.

```
options linesize=80;
data critters;
input c1 c2 c3 c4;
cards;
Enter row-by-column data here.
proc iml; use critters;
read all var {'c1' 'c2' 'c3' 'c4'} into ob;
nrep=1000;
pvalue=0;
c=ncol(ob);
r=nrow(ob);
rsums=ob * j(c,1,1);
print ob rsums;
do i=1 to r;
E=E//j(1, c, rsums[i]/c);
end;
chi2=sum(((ob-E)##2)/E);
prob=1-probchi(chi2, r * (c-1));
print chi2 prob;
do rep=1 to nrep;
ob=j(r,c,0);
do i=1 to r;
     do k=1 to rsums[i];
          j=int(c # uniform(0) +1);
ob[i,j]=ob[i,j]+1;
     end;
end;
teststat=sum(((ob - E)##2)/e);
pvalue=pvalue + (chi2>teststat);
end;
pvalue=nrep-pvalue;
alpha=0.01;
p0=0; p1=1;
do i=1 to 50;
     pavg=(p0+p1)/2;
     alphaAvg=probbnml(pavg, nrep, pvalue);
     a= (alphaAvg<alpha); b=1-a;
     p1=a # pavg + b#p1;
     p0=b # pavg + a#p0;
end;
pvalue=pvalue/nrep;
print pvalue;
print p0 alphaAvg p1;
```

Appendix G. Understory vegetation found on the study areas used for the herpetofaunal survey of the Longhorn Army Ammunition Plant in Harrison County, Texas (Correll and Johnston 1970, Nixon 1985).

Family name **Scientific name**	**Common name**
Aceraceae	
Acer rubrum L.	red maple
Alismataceae	
Sagittaria spp. L.	arrowhead
Anacardiaceae	
Rhus copallina L.	wing rib sumac
Toxicodendron radicans (L.) Kuntze	poison ivy
Aquifoliaceae	
Ilex decidua Walt.	deciduous holly
Asteraceae	
Xanthium spp. L.	cocklebur
Betulaceae	
Carpinus caroliniana Walt.	American hornbeam
Bignoniaceae	
Bignonia capreolata L.	cross vine
Caprifoliaceae	
Lonicera japonica Thunb.	Japanese honeysuckle
Cornaceae	
Cornus florida L.	flowering dogwood
Ebenaceae	
Diospyros virginiana L.	common persimmon
Ericaceae	
Vaccinum arboreum Marsh.	tree sparkleberry
Fabaceae	
Albizia julibrissin (Willd.) Durazz.	silktree
Fagaceae	
Quercus falcata Michx.	southern red oak
Quercus lyrata Walt.	overcup oak
Quercus marilandica Muenchh.	blackjack oak
Quercus nigra L.	water oak
Quercus phellos L.	willow oak
Quercus stellata Wangh.	post oak
Hamamelidaceae	
Liquidambar styraciflua L.	sweetgum
Hippocastanaceae	
Aesculus pavia L.	red buckeye

Appendix G. (continued).

Family name Scientific name	Common name
Hypericaceae	
Ascyrum stans Michx.	St. Andrew's cross
Jublandaceae	
Carya tomentosa Nutt.	hickory
Lauraceae	
Sassafras albidum (Nutt.) Nees	sassafras
Leguminosae	
Cercis canadensis L.	eastern redbud
Gleditsia triacanthos L.	honey locust
Robina pseudoacacia L.	black locust
Liliaceae	
Smilax spp.	greenbrier
Loganiaceae	
Gelsemium sempervirens (L.) St. Hil	Carolina jessamine
Menispermaceae	
Cocculus carolinus (L.) DC.	Carolina snailseed
Moraceae	
Morus rubra L.	red mullberry
Myricaceae	
Myrica heterophylla Raf.	waxmyrtle
Nyssaceae	
Nyssa sylvatica Marsh.	blackgum
Oleaceae	
Chionanthus virginicus L.	fringe tree
Forestiera acuminata (Michx.) Poir.	swamp privet
Fraxinus caroliniana Mill.	Carolina ash
Fraxinus pennsylvanica Marsh.	green ash
Ligustrum spp.	privet
Pinaceae	
Pinus taeda L.	loblolly pine
Poaceae	
Arundinaria gigantea Michx.	southern cane
Chasmanthium latifolium	broadleaf chasmanthium
Panicum spp.	panic grass
Rhamnaceae	
Berchemia scandens (Hill) K. Koch	Alabama supplejack
Rubus spp.	blackberry

Appendix G. (continued).

Family name Scientific name	Common name
Rosaceae	
Crataegus marshallis Egglest.	hawthorn
Prunus serotina Ehrh.	black cherry
Rhamnaceae	
Rhamus caroliniana Walt.	Carolina buckthorn
Rubiaceae	
Cephalanthus occidentalis L.	common buttonbush
Sapotaceae	
Bumelia lanuginosa (Michx.) Pers.	gum bumelia
Taxodiaceae	
Taxodium distichum (L.) Rich.	bald cypress
Ulmaceae	
Celtis laevigata Willd.	sugarberry
Planera aquatica (Walt.) J. F. Gmel.	water elm
Ulmus americana L.	American elm
Ulmus alata Michx.	winged elm
Verbenaceae	
Callicarpa americana L.	American beautyberry
Vitaceae	
Ampelopsis arborea (L.) Koehne	peppervine
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
Vitis aestivalis Michx.	summer grape
Vitis rotundifolia Michx.	muscadine grape

Appendix H. Midstory and overstory vegetation found on the study areas used for the herpetofaunal survey of the Longhorn Army Ammunition Plant in Harrison County, Texas (Nixon 1985).

Family name / **Scientific name**	**Common name**
Aceraceae	
Acer negundo L.	boxelder
Acer rubrum L.	red maple
Anacardiaceae	
Rhus copallina L.	wing rib sumac
Rhus glabra L.	smooth sumac
Araliaceae	
Aralia spinosa L.	devil's walking stick
Asteraceae	
Baccharis halimifolia L.	eastern baccharis
Aquifoliaceae	
Ilex decidua Walt.	deciduous holly
Ilex opaca Ait.	American holly
Ilex vomitoria Ait.	yaupon
Betulaceae	
Betula nigra L.	river birch
Carpinus caroliniana Walt.	American hornbeam
Caprifoliaceae	
Viburnum rufidulum Raf.	rusty blackhaw
Cornaceae	
Cornus florida L.	flowering dogwood
Cupressaceae	
Juniperus virginiana L.	eastern red cedar
Ebenaceae	
Diospyros virginiana L.	common persimmon
Ericaceae	
Vaccinum arboreum Marsh.	tree sparkleberry
Euphorbiaceae	
Sapium sebiferum (L.) Roxb.	Chinese tallow tree
Fagaceae	
Quercus alba L.	white oak
Quercus falcata Michx.	southern red oak
Quercus laurifolia Michx.	laurel oak
Quercus lyrata Walt.	overcup oak
Quercus marilandica Muenchh.	blackjack oak
Quercus nigra L.	water oak

Appendix H. (continued).

Family name Scientific name	Common name
Fagaceae (continued).	
Quercus phellos L.	willow oak
Quercus stellata Wangh.	post oak
Hamamelidaceae	
Liquidambar styraciflua L.	sweetgum
Hippocastanaceae	
Aesculus pavia L.	red buckeye
Jublandaceae	
Carya spp.	hickory
Lauraceae	
Sassafras albidum (Nutt.) Nees	sassafras
Leguminosae	
Cercis canadensis L.	eastern redbud
Gleditsia triacanthos L.	honey locust
Robina pseudoacacia L.	black locust
Meliaceae	
Melia azedarach L.	chinaberry tree
Moraceae	
Morus rubra L.	red mullberry
Nyssaceae	
Nyssa sylvatica Marsh.	blackgum
Oleaceae	
Chionanthus virginicus L.	fringe tree
Forestiera acuminata (Michx.) Poir.	swamp privet
Fraxinus caroliniana P. Mill.	Carolina ash
Fraxinus pennsylvanica Marsh.	green ash
Pinaceae	
Pinus echinata Mill.	shortleaf pine
Pinus taeda L.	loblolly pine
Rosaceae	
Crataegus spp.	hawthorn
Prunus serotina Ehrh.	black cherry
Rhamnaceae	
Rhamus caroliniana Walt.	Carolina buckthorn
Sapotaceae	
Bumelia lanuginosa (Michx.) Pers.	gum bumelia
Taxodiaceae	
Taxodium distichum (L.) Rich.	bald cypress

Appendix H. (continued).

Family name Scientific name	Common name
Ulmaceae	
Celtis laevigata Willd.	sugarberry
Maclura pomifera (Raf.) Scheid.	osage orange
Planera aquatica (Walt.) J. F. Gmel.	water elm
Ulmus alata Michx.	winged elm
Ulmus americana L.	American elm
Verbenaceae	
Callicarpa americana L.	American beautyberry

Appendix I. Common names, relative frequency, relative density, relative dominance, and importance values of the midstory and overstory vegetation from the bottomland hardwood areas.

Common name	Relative Frequency	Relative Density	Relative Dominance	Importance Value
boxelder	0.383	0.888	0.002	0.158
deciduous holly	10.345	26.270	0.002	12.206
flowering dogwood	0.766	0.175	0.006	0.316
common persimmon	0.383	0.088	0.048	0.173
tree sparkleberry	0.766	0.175	0.006	0.316
laurel oak	0.766	0.350	0.012	0.376
overcup oak	7.280	2.890	5.719	5.296
water oak	8.429	5.692	10.376	8.166
willow oak	13.027	9.370	24.694	15.697
post oak	0.766	0.175	0.344	0.429
sweetgum	10.728	27.758	26.482	21.656
hickory	4.981	2.539	1.901	3.140
chinaberry tree	0.383	0.175	0.004	0.187
red mullberry	0.766	0.350	0.206	0.441
blackgum	3.831	1.576	1.281	2.229
swamp privet	0.766	0.175	0.004	0.315
Carolina ash	2.682	0.788	0.067	1.179
hawthorn	0.766	0.175	0.041	0.327
bald cypress	2.299	1.313	3.862	2.491
sugarberry	2.682	1.313	0.857	1.618
water elm	4.981	2.102	0.970	2.684
winged elm	2.682	0.963	0.291	1.312
American elm	4.598	2.277	2.327	3.067
snag	12.644	9.982	17.169	13.265

Appendix J. Common names, relative frequency, relative density, relative dominance, and importance values of the midstory and overstory vegetation from the sideslope hardwood areas.

Common name	Relative Frequency	Relative Density	Relative Dominance	Importance Value
red maple	2.017	1.088	0.175	1.093
wing rib sumac	0.288	0.054	0.001	0.114
deciduous holly	4.611	5.927	0.266	3.601
rusty blackhaw	0.576	0.109	0.016	0.234
flowering dogwood	6.628	12.507	2.128	7.088
eastern red cedar	0.288	0.054	0.107	0.150
white oak	1.153	0.326	0.662	0.714
southern red oak	10.375	6.852	24.884	14.037
blackjack oak	0.576	0.109	0.230	0.305
water oak	5.764	2.175	9.193	5.711
willow oak	3.170	2.447	5.994	3.870
post oak	4.035	2.610	10.276	5.640
sweetgum	9.510	20.175	25.149	18.278
red buckeye	0.288	0.054	0.003	0.115
hickory	5.764	2.665	2.395	3.608
sassafrass	2.017	2.447	0.395	1.620
eastern redbud	1.441	1.360	0.102	0.967
black locust	0.288	0.054	0.007	0.117
red mullberry	2.305	0.435	0.612	1.118
blackgum	3.170	1.196	3.451	2.606
swamp privet	1.153	0.598	0.060	0.604
green ash	1.441	0.381	0.536	0.786
shortleaf pine	0.288	0.054	0.244	0.196
loblolly pine	2.594	3.480	2.841	2.972
hawthorn	1.153	0.218	0.021	0.464
black cherry	0.288	0.054	0.046	0.129
Carolina buckthorn	0.576	0.381	0.014	0.324
sugarberry	0.288	0.054	0.014	0.119
water elm	0.288	0.054	0.005	0.116
winged elm	10.375	19.898	5.111	11.795
American elm	7.205	6.743	2.771	5.573
American beautyberry	0.576	0.109	0.003	0.229
snag	8.646	4.133	2.166	4.982

Appendix K. Common names, relative frequency, relative density, relative dominance, and importance values of the midstory and overstory vegetation from the mixed pine-hardwood areas.

Common name	Relative Frequency	Relative Density	Relative Dominance	Importance Value
red maple	1.476	0.675	0.044	0.732
smooth sumac	0.369	0.368	0.012	0.250
devil's walking stick	0.369	0.061	0.005	0.145
eastern baccharis	0.738	0.184	0.005	0.309
deciduous holly	2.583	0.675	0.037	1.098
yaupon	0.369	0.061	0.010	0.147
rusty blackhaw	0.369	0.061	0.003	0.144
flowering dogwood	1.845	0.675	0.046	0.855
common persimmon	1.845	0.307	0.038	0.730
tree sparkleberry	1.476	0.368	0.012	0.619
Chinese tallow tree	0.369	0.061	0.001	0.144
southern red oak	10.107	8.103	8.066	8.957
blackjack oak	1.107	0.123	0.071	0.434
willow oak	6.273	3.929	6.905	5.702
post oak	0.369	0.123	1.342	0.611
sweetgum	11.070	20.994	14.497	15.520
hickory	5.166	2.149	1.340	2.885
honey locust	0.369	0.061	0.002	0.144
red mullberry	1.845	0.614	0.389	0.949
blackgum	2.583	0.552	1.127	1.421
swamp privet	0.738	0.123	0.002	0.288
green ash	1.476	0.368	0.588	0.811
shortleaf pine	0.369	0.061	0.403	0.278
loblolly pine	14.760	31.553	51.393	32.569
hawthorn	1.107	0.246	0.043	0.465
black cherry	1.107	0.368	0.064	0.513
gum bumelia	1.107	0.307	0.021	0.478
sugarberry	1.845	0.491	0.246	0.861
winged elm	14.760	23.389	9.022	15.724
American elm	3.321	0.491	0.306	1.373
American beautyberry	1.107	0.246	0.004	0.452
snag	7.011	2.210	3.957	4.393

Appendix L. Common names, relative frequency, relative density, relative dominance, and importance values of the midstory and overstory vegetation from the pure pine areas.

Common name	Relative Frequency	Relative Density	Relative Dominance	Importance Value
red maple	3.692	0.992	0.084	1.589
wing rib sumac	0.308	0.041	0.001	0.117
devil's walking stick	0.308	0.041	0.004	0.118
eastern baccharis	0.308	0.041	0.001	0.117
deciduous holly	2.462	1.033	0.028	1.174
river birch	0.615	0.124	0.025	0.255
American hornbeam	0.308	0.041	0.005	0.118
rusty blackhaw	0.615	0.165	0.041	0.274
flowering dogwood	0.923	0.455	0.045	0.474
eastern red cedar	0.923	0.124	0.017	0.355
common persimmon	3.077	0.661	0.036	1.258
tree sparkleberry	0.308	0.041	0.003	0.117
southern red oak	9.538	5.622	2.014	5.725
water oak	7.692	3.100	0.953	3.915
willow oak	4.308	1.364	0.771	2.148
post oak	1.538	0.703	0.292	0.844
sweetgum	12.308	54.444	10.439	25.730
hickory	0.615	0.124	0.009	0.250
sassafrass	1.538	1.033	0.133	0.902
eastern redbud	0.923	1.282	0.058	0.754
honey locust	0.308	0.041	0.002	0.117
red mullberry	1.846	0.289	0.020	0.718
blackgum	1.538	0.207	0.150	0.632
fringe tree	0.615	0.083	0.001	0.233
swamp privet	0.308	0.041	0.001	0.117
green ash	3.692	1.571	0.074	1.779
shortleaf pine	2.462	1.033	5.597	3.031
loblolly pine	12.000	16.040	72.817	33.619
hawthorn	0.923	0.165	0.155	0.415
black cherry	4.923	1.364	0.182	2.156
gum bumelia	0.308	0.041	0.008	0.119
sugarberry	0.615	0.083	0.003	0.234
osage orange	0.308	0.083	0.022	0.137
winged elm	7.385	4.837	1.110	4.444
American elm	2.154	0.413	0.247	0.938
American beautyberry	0.308	0.041	0.001	0.117
snag	8.000	2.232	4.652	4.962

Appendix M. Numbers of herptiles by species recorded in the bottomland hardwood (areas 2 and 4), sideslope hardwood (areas 1 and 3), mixed pine-hardwood (areas 5 and 6), and pure pine (areas 7 and 8) study areas.

Species	Study Area								
	Area 2	**Area 4**	**Area 1**	**Area 3**	**Area 5**	**Area 6**	**Area 7**	**Area 8**	**Total**
Eurycea quadridigitata								2	2
Ambystoma opacum	2	1	5	27	5		4	2	46
Ambystoma talpoideum	11		3	4				5	23
Ambystoma maculatum		2	2	4	3			2	13
Amphiuma tridactylum	1								1
Siren intermedia	16	2							18
Subtotal Salamanders	30	5	10	35	8	0	4	11	103
Acris crepitans	10	36	1	27	34	7	1		116
Pseudacris streckeri		1							1
Pseudacris triseriata	1	4	2	34	12				53
Hyla cinerea	5	30	8	66	28	36	13	3	189
Hyla versicolor/chrysoscelis		4	13	3		3	5	11	39
Rana catesbeiana	20	8	17	19	5		1		70
Rana clamitans	203	332	21	598	47	37	6	1	1245
Rana utricularia	36	22	4	13	1	1	2	1	80
Gastrophryne carolinensis		5		11			1	5	22
Bufo valliceps	25	32	18	17		3	3	2	100
Bufo woodhousei		3	3	4					10
Subtotal frogs/toads	300	477	87	792	127	87	32	23	1925
Subtotal amphibians	330	482	97	827	135	87	36	34	2028
Terrapene carolina		2		3	2		2	2	11
Trachemys scripta	5	4	6						15
Graptmys pseudogeographica	1								1
Chelydra serpentina	1	1							2
Macroclemys temenkii	1								1
Subtotal Turtles	8	7	6	3	2	0	2	2	30
Anolis carolinensis	17	3	33	25	10	21	17	25	151
Eumeces fasciatus	16	10	25	6	23	13	19	11	123
Eumeces laticeps	30	6	71	14	45	32	51	4	253
Scincella lateralis	19	9	30	32	10	3	17	40	160
Subtotal Lizards	82	28	159	77	88	69	104	80	687

Appendix M. (continued).

Species	Study Area								
	Area 2	Area 4	Area 1	Area 3	Area 5	Area 6	Area 7	Area 8	Total
Storeria dekayi	2	4	1	2					9
Storeria occipitomaculata			1				1		2
Virginia striatula								2	2
Lampropeltis calligaster			2						2
Lampropeltis getula	7	8	3	5	5	15	3	3	49
Lampropeltis triangulum			2		4	4		5	15
Coluber constrictor	8	10	7	7	6	14	6	8	66
Opheodrys aestivus				1			1		2
Elaphe obsoleta	8	1	8	10	2	11	2	4	46
Heterodon platirhinos						1			1
Thamnophis proximus	15	23	23	34	14	13	13	10	145
Farancia abacura	1	3	1	1	1				7
Nerodia cyclopion	8	2		1		1			12
Nerodia erythrogaster	13	13		14	8	1		1	50
Nerodia fasciata	37	20	1	17	8	7			90
Nerodia rhombifera	3	2		1		3			9
Regina rigida	2	1							3
Agkistrodon contortrix	12	17	29	15	6	19	14	5	117
Agkistrodon piscivorus	25	6	1	17	1	1	2		53
Total Snakes	141	110	79	125	55	90	42	38	680
Total Reptiles	231	145	244	205	145	159	148	120	1397
Total Herptiles	561	627	341	1032	280	246	184	154	3425

Appendix N. Numbers of herptiles recorded in the bottomland hardwood areas by hardware cloth funnel traps, screenwire funnel traps, artificial cover boards, hand captures, PVC treefrog traps, or aquatic turtle traps.

Species	Survey Technique					
	Hardware	Screenwire	Cover	Hand	PVC	Aquatic
Ambystoma maculatum	1			1		
Ambystoma opacum	2	1				
Ambystoma talpoideum	1	10				
Amphiuma tridactylum	1					
Siren intermedia	18					
Acris crepitans	13	21		12		
Pseudacris streckeri	1					
Pseudacris triseriata	2	1		2		
Hyla cinerea	23	1			11	
Hyla versicolor/chrysoscelis	3				1	
Rana catesbeiana	26	2				
Rana clamitans	509	23	1	2		
Rana utricularia	58					
Gastrophryne carolinensis	5					
Bufo valliceps	54	1		2		
Bufo woodhousei	2	1				
Terrapene carolina				2		
Trachemys scripta				4		5
Graptmys pseudogeographica				1		
Chelydra serpentina				2		
Macroclemys temenkii				1		
Anolis carolinensis	11			3	6	
Eumeces fasciatus	20	1	4	1		
Eumeces laticeps	35			1		
Scincella lateralis	5	9	4	10		
Storeria dekayi		4	2			
Lampropeltis getula	15					
Coluber constrictor	18					
Elaphe obsoleta	9					
Thamnophis proximus	28	3	3	4		
Farancia abacura	4					
Nerodia cyclopion	10					
Nerodia erythrogaster	26					
Nerodia fasciata	57					
Nerodia rhombifera	5					
Regina rigida	3					
Agkistrodon contortrix	29					
Agkistrodon piscivorus	30	1				

Appendix O. Numbers of herptiles recorded in the sideslope hardwood areas by hardware cloth funnel traps, screenwire funnel traps, pitfall traps, artificial cover boards, hand captures, or PVC treefrog traps.

Species	**Survey Technique**					
	Hardware	**Screenwire**	**Pitfall**	**Cover**	**Hand**	**PVC**
Ambystoma maculatum	6					
Ambystoma opacum	20	9	3			
Ambystoma talpoideum	6	1				
Acris crepitans	18	3			7	
Pseudacris triseriata	27	3	2		4	
Hyla cinerea	34	1				39
Hyla versicolor/chrysoscelis	8					8
Rana catesbeiana	36					
Rana clamitans	603	9	4		3	
Rana utricularia	17					
Gastrophryne carolinensis	9	2				
Bufo valliceps	33		1		1	
Bufo woodhousei	5	2				
Terrapene carolina			2		1	
Trachemys scripta			4		2	
Anolis carolinensis	37	6	3		5	7
Eumeces fasciatus	27	2	2			
Eumeces laticeps	82		1		2	
Scincella lateralis	12	17	7	4	22	
Storeria dekayi			1		2	
Storeria occipitomaculata					1	
Lampropeltis calligaster					2	
Lampropeltis getula	8					
Lampropeltis triangulum	2					
Coluber constrictor	12				2	
Opheodrys aestivus					1	
Elaphe obsoleta	18					
Thamnophis proximus	44	4		3	6	
Farancia abacura	2					
Nerodia cyclopion	1					
Nerodia erythrogaster	14					
Nerodia fasciata	18					
Nerodia rhombifera		1				
Agkistrodon contortrix	43	1				
Agkistrodon piscivorus	18					

Appendix P. Numbers of herptiles recorded in the mixed pine-hardwood areas by hardware cloth funnel traps, screenwire funnel traps, pitfall traps, artificial cover boards, hand captures, or PVC treefrog traps.

Species	**Survey Technique**					
	Hardware	**Screenwire**	**Pitfall**	**Cover**	**Hand**	**PVC**
Ambystoma maculatum	1		2			
Ambystoma opacum	4		1			
Acris crepitans	24	2	1		14	
Pseudacris triseriata	12					
Hyla cinerea	30		1			33
Hyla versicolor/chrysoscelis	3					
Rana catesbeiana	5					
Rana clamitans	84					
Rana utricularia	2					
Bufo valliceps	3					
Terrapene carolina					2	
Anolis carolinensis	18	3		1	4	5
Eumeces fasciatus	30	2	4			
Eumeces laticeps	70	1	2	2	2	
Scincella lateralis	2	4	3	1	3	
Lampropeltis getula	19				1	
Lampropeltis triangulum	7			1		
Coluber constrictor	20					
Elaphe obsoleta	12				1	
Heterodon platirhinos	1					
Thamnophis proximus	24	3				
Farancia abacura	1					
Nerodia cyclopion	1					
Nerodia erythrogaster	8				1	
Nerodia fasciata	15					
Nerodia rhombifera	3					
Agkistrodon contortrix	25					
Agkistrodon piscivorus	2					

Appendix Q. Numbers of herptiles recorded in the pure pine areas by hardware cloth funnel traps, screenwire funnel traps, pitfall traps, artificial cover boards, hand captures, or PVC treefrog traps.

Species	Survey Technique					
	Hardware	Screenwire	Pitfall	Cover	Hand	PVC
Eurycea quadridigitata		2				
Ambystoma maculatum	2					
Ambystoma opacum	4		2			
Ambystoma talpoideum	3		1	1		
Acris crepitans	1					
Hyla cinerea	6				1	9
Hyla versicolor/chrysoscelis	3					13
Rana catesbeiana	1					
Rana clamitans	7					
Rana utricularia	2				1	
Gastrophryne carolinensis	2	2	2			
Bufo valliceps	5					
Terrapene carolina			1		3	
Anolis carolinensis	26	3	2	1	9	1
Eumeces fasciatus	22	3	3	1	1	
Eumeces laticeps	47	1	3	3	1	
Scincella lateralis	15	8	18	6	10	
Storeria occipitomaculata		1				
Virginia striatula		2				
Lampropeltis getula	5	1				
Lampropeltis triangulum	5					
Coluber constrictor	14					
Opheodrys aestivus	1					
Elaphe obsoleta	6					
Thamnophis proximus	16	6			1	
Nerodia erythrogaster	1					
Agkistrodon contortrix	19					
Agkistrodon piscivorus	2					