THE EFFECTS OF PRESCRIBED BURNING AND THINNING AS FUEL REDUCTION TREATMENTS ON HERPETOFAUNA IN THE UPPER PIEDMONT OF SOUTH CAROLINA

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ABSTRACT

Due to heavy fuel loads resulting from years of fire suppression, upland pine and mixed pine hardwood forests in the Upper Piedmont of South Carolina are at risk of severe wildland fire. The National Fire and Fire Surrogate Study (FFSS) is being conducted on the Clemson Experimental Forest to study the effects of prescribed burning and thinning on a multitude of factors, including herpetofauna. Herpetofuana are an important component in forest ecosystems because they compose a large portion of biomass and are indicators of environmental quality. Although research has been conducted on herpetofauna in the Coastal Plain and Appalachian Mountains, insufficient data currently exist for the Piedmont.

Herpetofauna were sampled before and after the following four treatments were applied to each treatment area: thinning (T1), prescribed burning (B), thinning followed by prescribed burning (T2), and untreated control (C). Drift fences with pitfall traps, modified pitfalls, unmodified pitfalls, and hand captures were used to sample herpetofauna in this study. A total of 1,317 reptiles and amphibians representing 40 species was captured in the overall sampling period from 9 September 2000 to 9 January 2002. Total post-treatment data collection from 11 April 2001 to 9 January 2002 resulted in 1,146 captures representing 40 species. Suborder Lacertilia was the dominant taxon (47.7%) followed by Order Anura (25.7%), Suborder Serpentes (14.2%), Order Caudata (7.9%), and Order Testudines (4.5%). *Sceloporus undulatus hyacinthinus* was the most abundant species in the study. There were no significant treatment effects on abundance for any of the five taxa when comparing among and between treatments. When comparing richness, T1 had a significantly higher number of snake species than burn treatments. T2 treatments had significantly more *A. carolinensis* captures than the burn or control, and there were significantly more *E. fasciatus* captures in T2 and T1 than in the control. The T1 and T2 treatment reduced the average basal area, which reduced canopy coverage, increasing the amount of light reaching the forest floor.

The drift fence pitfall arrays accounted for 32.3% of total captures. Modified pitfalls also accounted for a significant portion of captures (30.4%). The results of unmodified pitfall and hand capture made up 19.2% and 18.0% of total captures respectively. Both drift fence pitfall arrays and modified pitfalls caught 30 species. Twenty-five species were caught in unmodified pitfalls and 19 species were caught by hand.

Hand capture was the most efficient method for turtles and arrays were the most efficient trap type for snakes. More lizard species were caught in unmodified pitfalls and arrays and more snake species were caught in modified pitfalls. Overall, fewer species were caught by hand, but this capture method caught snake species that would have otherwise gone undetected. The center pitfall in the array was most effective for anurans and lizards. Although limited treatment effects were detected, thinning was found to increase the abundance of two lizard species. This study produces essential baseline data which will be used in conjunction with additional post-treatment monitoring of the effects of fire and fire surrogate treatments in the Upper Piedmont of South Carolina.

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CHAPTER I

INTRODUCTION

The FFSS was initiated in the Clemson Experimental Forest (CEF) in spring 2000 to study the ecological and economical consequences of four fuel reduction treatments over a 5-year period. The FFSS is a national study, taking place on thirteen replicated study sites in the United States:

1. Mission Creek, North-Central Washington, Wenatchee National Forest.
2. Hungry Bob, Blue Mountains of Northeast Oregon, Wallowa-Whitman National Forest.
3. Lubrecht Forest, University of Montana, Northern Rockies, Western Montana.
4. Southern Cascades, Northern California, Klamath National Forest.
5. Blodgett Forest Research Station, University of California-Berkely, Central Seirra Nevada, California.
6. Sequoia National Park, Southern Sierra Nevada, California (satellite to Blodgett Forest Research Station Site).
7. Southwest Plateau, Coconino and Kaibab National Forests, Northern Arizona.
8. Jemez Mountains, Santa Fe National Forest, Northern New Mexico.
9. Ohio Hill Country, lands managed by the Ohio Division of Forestry and Mead Paper Company.
10. Southeastern Piedmont, Clemson Experimental Forest, Northwestern South Carolina.
11. Southern Coastal Plain, Myakka River State Park, Southwest Florida.
12. Gulf Coastal Plain, Solon Dixon, Andalusta, Alabama.

13. Southern Appalachain Mountains, Green River Game Land, Polk County, North Carolina.

Southeastern forests with historically short-interval, low- to moderate-severity fire regimes have become denser and the quantity of forest fuels has increased greatly. This condition is mostly due to successful fire suppression efforts, which has decreased ecosystem integrity and increased the risk of large-scale wildfires. Each year South Carolina suppresses nearly 4,500 wildfires. Most of these fires (80%) are caused by negligent debris burning or by arson. Since 1970, an average of one catastrophic wildfire of 1,000 acres or more has occurred each year in South Carolina. This average increases during droughty years. In 1985, there were 10 wildfires that averaged over 2,000 acres in size.

It has been proposed that fuel reduction treatments such as prescribed fire, and fire "surrogates" such as cutting and mechanical fuel treatments, could restore historical ecosystem processes and increase forest sustainability. The objective of the FFSS is to use prescribed fire and thinning to understand how vegetation, fuel and fire behavior, soils, wildlife, entomology, pathology, and treatment cost and utilization economics are affected by these fuel reduction treatments. The major objectives of the FFSS are as follows (Executive Summary from the Final Proposal):

1. Quantify the initial effects (first five years) of fire and fire surrogate treatments on a number of specific core response variables (mentioned above).
2. Provide an overall research design that (a) establishes and maintains the study as an integrated national network of long-term interdisciplinary research sites utilizing a common "core" design to facilitate broad applicability of results; (b) allows each site to be independent for purposes of statistical analysis and modeling, as well as being a component of national network; and (c) provides flexibility for investigators and other participants responsible for each research site to augment-without compromising the core design as desired to

address locally important issues and to exploit expertise and other resources available to local sites.

3. Within the first five years of the study, establish cooperative relationships, identify and establish network research sites, collect baseline data, implement initial treatments, document treatment costs and short-term responses to treatments, report results, and designate FFSS sites as demonstration areas for technology transfer to professionals and for the education of students and the public.

4. Develop and maintain an integrated and spatially referenced database format to be used to archive data for all network sites, facilitate the development of interdisciplinary and multi-scale models, and integrate results across the network.

5. Identify and field test, in concert with resource managers and users, a suite of response variables or measures that are: (a) sensitive to the fire and fire surrogate treatments; and (b) both technically and logistically feasible for widespread use in management contexts. This suite of measures will form much of the basis for management and monitoring of operational treatments designed to restore ecological integrity and reduce wildfire hazard.

6. Over the life of the study, quantify the ecological and economic consequences of fire and fire surrogate treatments in a number of forest types and conditions in the Unites States. Develop and validate models of ecosystem structure and function, and successively refine recommendations for ecosystem management.

The goal of this thesis was to assess the effects of prescribed fire and thinning for fuel reduction on herpetofauna in the Upper Piedmont of South Carolina. Forestry and agriculture are the two largest forms of land use in the United States. Therefore, forestry and agricultural operations may have a substantial impact on wildlife within the area (Alig et al., 1998). Because these practices encompass such large areas in the United States, the effects of forest management practices on reptiles and amphibians have become an increasingly important issue in current wildlife research (Bury et al., 1980; Gibbons, 1988; deMaynadier and Hunter, 1995; Russel et al., 1999; Lyon et al., 2000).

The interest in herpetofauna research is partly due to the current decline in amphibian and reptile populations across the United States and other countries (Wyman, 1990; Pechmann and Wilbur, 1994; Gibbons et al., 2000). Scientists are currently attempting to document the assumption that declines are a direct result of anthropogenic factors and not entirely a natural phenomenon. Research interest also stems from the natural history and physiological characteristics of herpetofauna that make them valuable research subjects alone or in conjunction with avifauna, mammals, plants, and arthropods. For example, some amphibians are completely aquatic and others exhibit an aquatic stage but need terrestrial habitat to complete their life cycle. As a result, monitoring forest management activities in terrestrial areas may determine changes in the amphibian component (Bennett et al., 1980). The permeable skin of amphibians is sensitive to acid rain, herbicides, pesticides, and other pollutants. This sensitivity, when combined with natural histories involving aquatic and terrestrial environments, short life spans, and small home ranges, allows amphibians to be good indicators of environmental quality (Pechmann and Wilbur, 1994).

More than 130 species of reptiles and amphibians have been documented in South Carolina (Martof et al., 1980; Conant and Collins, 1998). High species density (Kiester, 1971) coupled with a large degree of forest management in a variety of habitats (Sharitz et al., 1992) makes South Carolina an ideal area for the study of forest management effects on herpetofauna. Studies assessing the effects of fire and silvicultural treatments on herpetofauna have been conducted in the Coastal Plain and Appalachian Mountains but research is lacking in the Piedmont region of South Carolina.

Because salamanders can occur in densities higher than birds and small mammals (Burton and Likens, 1975; Hairston, 1987), they are significant contributors to the energy flow of the particular ecosystem in which they occur (Pough et al. 1987). Amphibians, specifically salamanders, are efficient (40-80%) biomass converters and important components of the food chain. They contribute significantly to the energy flow of ecosystems as a consumer of small invertebrates and as prey for fish, small mammals, birds, and snakes (Pough et al., 1987). When salamander populations decline, the ecosystem is temporarily deprived of an efficient source of energy.

The objectives of this study were to determine the effects of burn, thin, and thin and burn treatments in the Piedmont of South Carolina on herpetofauna species richness and abundance and to compare the efficiency of trapping methods for the capture of herpetofuana.

CHAPTER II

LITERATURE REVIEW

Fuel Reduction Issues

A reduction in forest and range health and an increase in the number of people moving to the wildland/urban interface have increased the threat of wildland fire in the United States. The federal government funds the Forest Service and Department of Interior with the Federal Fire Protection Budget to reduce fuel loads by using fuel treatments such as prescribed fire and thinning (Gorte, 2000). Although prescribed fire (as a unique term and procedure) has been used since the 1940's to reduce fuels and enhance wildlife habitat, the process of humans burning the southern landscape for various reasons predates European settlement of the region (Johnson and Hale, 2000). Fluctuations in wind, humidity, topography, fuel moisture and type add an element of risk, and the direct products of burning organic material (carbon monoxide, particulate matter, and hydrocarbons) have resulted in increased regulations governing the use of prescribed burning (Wade, 1985). Another fuel treatment, commercial thinning, opens the forest but also produces more fuel in the form of logging slash, the unmerchantable limbs, tops, and stumps of the trees (Nyland, 1996).

The 1970s brought an end to intense fire suppression and an interest in the ecological benefits of fire in the forest. However, fire suppression continues today because of the property damage resulting from wildfires and prescribed fires gone out of control. Continued suppression has resulted in an unnatural accumulation of ground and ladder fuels that could lead to catastrophic wildfires across the United States (Gorte 2000). Studies have shown that an increase in available fuel, as much as 16 tons/acre over 18 years, will increase the chances, intensity, and magnitude of wildland fire (Sackett, 1975). Wildland fire could be detrimental to soils, watersheds, wildlife, and timber resources in a region with historically frequent (5-25 year) light to moderate surface fires. At the wildland/urban interface, or the area "where combustible homes meet combustible vegetation", the result is loss of human life (Gorte, 2000). Construction of homes in the wildland urban interface has been increasing since the 1940's and has created challenges for federal, state, and local agencies responsible for fighting fires (Cohen, 1999).

We now realize that determining the effects of fuel management activities such as prescribed burning, commercial thinning, and salvage logging must be an integral part of forest management. The knowledge of how much fuel is removed, how much is loaded back in the forest over time, and a host of other fuel and fire variables will determine if the benefit of lowering the risk of wildland fire is worth the cost of fuel management (Gorte, 2000).

History of Fire in the Piedmont

Fire is not new to the Piedmont landscape (Denevan, 1992; Frost, 1996). Early accounts suggest that American Indians burned frequently and extensively to clear land, improve hunting grounds, induce food plants to flower, and for various other reasons (Komarek, 1974; Pyne et al., 1996). Frequent fire modified much of the South and resulted in a more open, savannah-like landscape dominated by pure pine, pure hardwood stands, and mixed pine/hardwood stands (Nelson, 1957).

Although early European settlers adopted Indian burning practices, their arrival spelled an end to extensive Indian burning in North America. It is estimated that foreign disease of European origin caused a 90 percent decrease in indigenous peoples of the Western Hemisphere by 1650 (Denevan, 1992; McCleery 1993). Burning in the Piedmont landscape has not returned to presettlement levels since this decline. Another ignition source was lightning (Komarek, 1974; Pyne et al., 1996). In the South, lightning is common in warmer months and occurs frequently enough without rain to ignite fuels and start fires. At present, extensive lightning fires are not commonplace because contiguous amounts of fuels do not exist at presettlement levels. Piedmont fuels occur on a fragmented landscape separated by roads, agriculture, and urbanization (Sharitz et al., 1992).

Wildland fire existed at much higher levels during pre-industrial times (34–86 million ha/yr) than at present (5-7 million ha/yr) (Leenhouts, 1998). Excluding urban and agricultural areas, it is estimated that prescribed burning could take place on 18-43 million ha/yr if historic fire regimes were restored. The process by which biomass is reduced during the combustion of organic material during a fire is termed "biomass burning". In fire dependant communities the biomass removed is returned by new growth. Fire also heats the soil, recycles nutrients, and modifies the wildlife community. Burning also results in CO, CO_2, NO, and hydrocarbon emissions, which cause health problems and are consequently regulated by the EPA (Ottmar et al. 1996; Leenhouts, 1998). If the amount of prescribed burning were returned to pre-industrial levels, emissions from burning would be compounded with current agricultural and fossil fuel emissions. Presently, the effect of these additional emissions on human health and the atmosphere is not fully understood (Leenhouts, 1998).

Fuel moisture content is the most important factor influencing fire frequency in the Piedmont. The heavy clay soils of the Piedmont retain moisture near the surface, thereby keeping understory fuels too wet to burn. In order for fire to occur, the fuels must be dry enough to burn and an ignition source must be present (Christensen, 1981). Topography and soil moisture vary greatly from the dry ridgetops to the mesic riparian areas. Historically, dry uplands burned more frequently than mesic lowlands. The bulk of species in areas with high fire frequencies were fire adapted and tolerant of much drier conditions than their mesic counterparts (Christensen, 1981; Cowell, 1995).

Fire and Herpetofauna

There has been much research in the past 25 years focusing on the effects of fire on fauna. Once thought to be detrimental to all wildlife, fire is now seen as an essential management tool used to accomplish a variety of tasks (Devet and Hopkins, 1967; Hooper, 1969). In more than 35 years of intense fire research in the Southeast, there are few cases where fire consistently has a negative effect on herpetofauna. *Agkistrodon piscivorus* (cottonmouth) (Komarek, 1969), *Terrapene carolina* (box turtle) (Scott, 1996), and *Ophisaurus ventralis* (eastern glass lizard) (Means and Campbell, 1981) are three reptile species documented in the literature as being killed by fire.

Cases where herpetofauna benefit or escape from prescribed fire are much more common. Komarek (1969) found *Crotalus adamanteus* (eastern diamondback rattlesnake) used charred stump holes for basking. He witnessed *Hyla cinerea* (green treefrog) escaping a light surface fire and a *Psuedacris crucifer* (spring peeper) chorus that continued calling immediately following a grass fire. In a high-intensity wildfire in sand-pine scrub, frogs were unaffected (Greenberg et al. 1994a). Small mammals may escape the intense heat of the fire by remaining under the soil, where after a few centimeters in depth, temperatures do not reach lethal levels (Howard et al., 1959). Similarly, herpetofauna survive by retreating under rocks or into burrows (Kahn, 1960).

Recent reports on the direct effects of fire on fauna have had similar results. Research has shown that the indirect effects of fire are much more influential than the direct effects (Lyon et al. 2000). Preliminary results from a study in upland hardwood/pine forests in the Upper Piedmont of South Carolina suggest there are no detrimental effects of prescribed fire on herpetofauna (Floyd et al., 2001).

Studies have found certain species of herpetofauna to be fire dependant (Lee, 1974; Lillywhite et al., 1977; Landers and Speake, 1980; Means and Campbell, 1981). Prescribed fire has been found to maintain and increase *Gopherus polyphemus* (gopher tortoise) populations in southern Georgia. In addition, as many as 32 species of herpetofauna have been known to use *G. polyphemus* burrows (Landers and Speake, 1980). Over time the indirect changes in vegetation and habitat structure caused by burning have selected for these species (Lillywhite, 1977). These same selective pressures also influence other species that are often associated with broadleaf evergreen forests with a lower frequency of fire (Means and Campbell, 1981).

Mushinsky (1985) researched the effects of fire frequency on *Cnemidophorus s. sexlineatus* (six-lined racerunner) in the Florida sandhills and correlated the indirect effects of fire on herpetofauna. Reptiles and amphibians were most abundant in the plots burned every one and seven years and the least abundant in control plots and plots burned every two years. The two-year burns resulted in a dense grass and forb layer preventing many sandhill species from becoming established. *C. S. sexlineatus* preferred plots with open exposed sand and sparse vegetation. The most abundant species were more common in the frequently burned rather than protected areas.

McLeod and Gates (1998) conducted a study in Maryland to determine the effects of forest cutting and burning on herpetofauna. They compared burned and unburned hardwood/pine stands. The study sites were approximately 50 years old and occurred on abandoned agricultural fields, and *Pinus taeda* (loblolly pine) was the predominant tree species. The number of species captured did not differ between treatments and controls; however, there were significant treatment effects for abundance. Amphibians and some small snakes were significantly more abundant in unburned pine than burned pine. *Carphophis amoenus* (worm snake), *Storeria dekayi* (brown snake), and *Thamnophis sirtalis* (garter snake) were more abundant in unburned than burned stands. Conversely, *Coluber constrictor* (black racer) and *Lampropeltis getula* (kingsnake) were more abundant in burned than unburned stands. Similar results were found in a study in Florida sand pine scrub (Greenberg et al., 1994a).

Prescribed burning reduces basal area, canopy cover, and litter depth, which lowers humidity and increases the temperature of the forest floor microclimate (Chen et al., 1993; McLeod and Gates, 1998). Burning also reduces the amount of standing and down coarse woody debris, which can be essential refugia for amphibians (Hassinger, 1989; Baughman 2000). In a census of herpetofauna following a community restoration, high intensity, prescribed fire in the Southern Appalachians there were no differences between burn and control areas for most of the herpetofauna species captured (Ford et al., 1999). However, drift fence arrays with pitfalls were only sampled for a total of 14 days prior to the burn and for two periods of 14 days after the burn. The length and time of year the trapping session were conducted was probably not sufficient to accurately determine treatment effects. Only ten species of herpetofauna were captured. Time constrained searches were also used in the study but were not sufficient for the same reasons. Conversely, Kirkland et al. (1996) found that significantly higher numbers of *Bufo americanus* were caught in the burned forest than unburned forest in a central Appalachian study.

Timber Harvest and Herpetofuana

Research assessing the effects of silvicultural practices on herpetofauna has been conducted in the Southern Appalachians (Bruce and Boyce, 1984; Ash, 1988; Petranka et al., 1993, 1994; Ash and Bruce, 1994; Mitchell et al., 1997) and Coastal Plain (Phelps and Lancia, 1995; Perison et al., 1997; Cromer et al., 2001) of South Carolina, but few studies have focused on the Piedmont. A study in the Appalachian Mountains of North Carolina found that *Plethodon jordani* disappeared from clearcut plots over a period of four summers. There were 60 percent fewer salamanders in the clearcut during the first summer when compared to the forested control sites. Only one salamander was seen during the second summer and none in the third summer. *Plethodon glutinosus* were found at lower numbers, but followed the same trend. Sex and age classes declined at the same rate. The decrease in salamanders was attributed to changes in soil moisture, litter depth, and changes in prey numbers or type. As a result of their response to changes in microclimate, Ash (1988) suggested that salamanders could be used as moisture indicators during stand regeneration.

Petranka et al. (1993, 1994) and Petranka (1994) concluded that clearcutting is detrimental to salamander populations in Western North Carolina. He estimated that millions of salamanders are killed every year during forest operations and that it would take 50-70 years for forests to recover to predisturbance levels.

Ash and Bruce (1994) questioned the sampling methods of Petranka et al. (1993, 1994) and stated that salamander populations could return to 50 percent of forested population levels within 13 years after harvest. They concluded that sound sampling methods, site selection, and statistical analysis are needed to accurately determine the effects of clearcutting. In a central Appalachian study, mature hardwood forest, a recent clearcut, and white pine stand had similar species richness but differed in abundance. Amphibian abundance was higher in the hardwood forest than in the clearcut and white pine forest. Lower amphibian abundance was attributed to the unfavorable forest floor microhabitats, shallow soils, and longer distance from the nearest wetland. Stands with deep soils and nearby breeding wetlands had a higher number of captures (Mitchell et al. 1997).

In Maryland, adults of three species of salamander, one toad species, and two frog species were more abundant in uncut plots. However, adult skinks and snakes were more abundant in cut plots than uncut plots (McLeod and Gates 1998). In Virginia, removal of the forest canopy adversely affected salamanders over a three-year post harvest sampling period. Soil temperature was highest and percent leaf litter moisture was lowest in the treatments where most of the canopy had been removed. However, the percent soil moisture was highest in the clearcut and group selection plots. The drier microhabitat of the harvested stands may limit the time salamanders can spend feeding.

Since low and high degrees of canopy removal significantly affected salamander abundance, small clearcuts within a forest landscape may have a lesser impact on salamander populations than many small selective cuts that produce equivalent amount of timber (Harpole and Haas 1999). Similar results were observed in another Virginia study comparing uncut forest to clearcuts of age seven, six, and two years (Blymer and McGinnes 1977).

After a timber harvest in a South Carolina blackwater bottomland, fewer salamanders were captured in skidder and helicopter clearcut harvested treatments. The opposite was true for lizards and large snakes (Perison et al. 1997, Phelps and Lancia 1995). A study in harvest created gaps in a South Carolina bottomland hardwood study had similar results. Salamanders were more abundant in uncut controls than in logged gaps (Cromer et al, 2001).

Conversely, Messere and Ducey (1998) found that salamander distribution did not vary significantly between forest, gap edge, and within gaps one year after a group selection cut. He concluded that the understory, litter, and soils might not have been disturbed to a degree that decreased salamander survivorship in gaps. Russell (2000) studied the effects of clearcutting and mechanical site preparation in upland forest on adjacent isolated wetlands. Although there was no overall effect on the herpetofauna community, snakes and turtles showed an initial decrease in abundance but increased to pretreatment levels after 1.5 years. Treatment of adjacent upland habitat seemed to favor *Rana clamitans* after 1.5 years but not *Coluber constrictor*. Baughman (2000) found no difference in salamander and anuran captures between control and harvested areas in intensively managed loblolly pine forests. He also found that snake captures increased after harvest but lizard captures did not.

Studies on the effects of selective harvest methods such as thinning and small group selection on herpetofauna are limited. In Washington, thinning did not have an effect on the presence of terrestrial salamanders. However, the capture rate of *Plethodon vehiculum* (western red-backed salamander) in Washington was significantly higher in control plots than thinned plots. The decline in salamander captures may result from the use of heavy machinery during the thinning operation, resulting in compacted soil in trail ruts. Although the abundance of *P. vehiculum* decreased, investigators suggested that the population would recover when the growth of understory vegetation accelerated after thinning (Grialou et al., 2000).

The current consensus is that a mosaic of disturbed and undisturbed patches throughout the landscape provides a variety of habitats that favors some species over others (Franklin and Forman, 1987; Cole et al., 1997). In some cases area specific management may be needed (Diller and Wallace, 1994). This study examines the effects of prescribed fire and thinning on herpetofauna communities in the Upper Piedmont of South Carolina to evaluate one impact of fuel reduction treatments to help managers in the Southeastern Piedmont make important decisions.

CHAPTER III

MATERIALS AND METHODS

Study Area

The FFSS was conducted on the Clemson Experimental Forest (CEF) in the upper Piedmont of Northwestern South Carolina, USA. The CEF was acquired in 1933 and is administered by the Clemson University College of Agriculture, Forestry, and Life Sciences for academic use, timber production, and recreational purposes (Sorrels, 1984). The 7,024-hectare CEF is located Anderson, Oconee, and Pickens County and divided into a north and south portion by US Hwy 76/123. Some of the CEF borders US Army Corps of Engineer shoreline along Lake Hartwell, a 22,640 hectare reservoir built from 1955-1963 (Metts, 1999).

The Piedmont Physiographic Province covers nearly 34% of South Carolina. The region is characterized by rolling topography with a southeast decrease in elevation (Myers et al., 1986). The mean annual temperature and precipitation are 16° C and 134cm, respectively (Southeast Regional Climate Center 2002a, 2002b). In the past, 95 percent of the land in the Piedmont was in agriculture. At present, 68 percent is forested and composed of mixed hardwood pine forests and loblolly pine (*Pinus taeda*) plantations. Forest habitats in the CEF occur in two different subregions of the Piedmont Province. Portions of the north forest in Pickens County lie in the Lower Foothills Subregion of the Piedmont Foothills Region. This subregion has an elevation from 213 – 335 meters above mean sea level. It is also a transition zone between the steeper mountain regions and the rolling topography of the southern Piedmont. The clayey soils are mostly of the Cecil, Madison, and Pacelot series, drain well and are of variable depths. Forests dominate this subregion but large agricultural areas still exist. The remaining area of the CEF lies in the Interior Plateau Subregion of the Midlands Plateau Region. The gently sloping topography of this subregion has elevations ranging from 152 – 305 meters above mean sea level. This region was historically known as the Upper or Inner Piedmont. Soils are clayey and composed mostly of the Cecil, Appling, Durham, Madison, and Hiwassee series. Although forests make up large portion of this subregion, significant areas are still in agriculture (Myers et al., 1986).

A total of 12 study sites was established in the CEF during spring 2000 to serve as treatment plots in a randomized block design (Table 1). Sites were selected based on stand age, size, tree composition, and wildfire vulnerability. Study sites ranged in age from 15 to 60 years and were blocked by tree size to reduce variability. Each of three blocks (replications) contains four treatment plots composed primarily of pulpwood-sized trees (dbh 15-25 cm, Replication 1; R1), sawtimber-sized trees (dbh >25 cm, Replication 3; R3), and a mixture of pulpwood and sawtimber-sized trees (Replication 2; R2).

Large contiguous and homogeneous stands are uncommon in the Piedmont so sites were located throughout the north forest and south forest of the CEF. Since location was not a blocking factor, treatment plots did not need to be contiguous. Each site was a minimum of 14 hectares to accommodate the 10-hectare study plot and a buffer area of about 20 meters. ArcView GIS software was used to randomly place 40 grid points that fit the shape of each plot. Grid points were spaced 50 meters apart and numbered from the northeast corner and went from east to west in a zig-zag pattern. Each grid point was marked with a piece of 1-meter rebar that was driven 30 cm into the ground. Rebar and trees facing the rebar were painted orange and circular metal tags corresponding to the assigned grid point (1 – 40) were attached (Figure 1).

Study sites were composed primarily of planted *P. taeda* but a component of *Pinus echinata* (shortleaf pine), *Pinus virginiana* (Virginia pine), and various hardwood species were also present. The time since last thinning was at least 10 years and the time since last prescribed or wild fire was at least 5 years. Litter and woody debris occurred at high enough levels in each site to fuel a potentially catastrophic fire. This condition is characteristic of many Piedmont pine plantations.

Treatments

Because treatments were planned and described by the US Forest Service, the description was taken directly from the Southeastern Piedmont Study Plan (Waldrop, 2000). One of four treatments, as defined by FFS protocols, was assigned to each treatment area within a block using a random number table. Treatments included thinning (R1T1, R1T2, R2T1, R2T2, R3T1, R3T2), prescribed burning (R1B, R2B, R3B), and an untreated control (R1C, R2C, R3C). The prescribed burn for the thin/burn treatment was not implemented until after data collection for this thesis was completed, therefore, thin/burn treatments are designated as T2 in this thesis to distinguish them from the thin treatment (T1). During the 2000 growing season, southern pine beetles killed most of the trees in the original R1T1. In Winter 2000, the original R1T1 was replaced with a new R1T1 in Liberty, SC. However herpetofauna trapping continued in the original R1T1 until 9 January 2002.

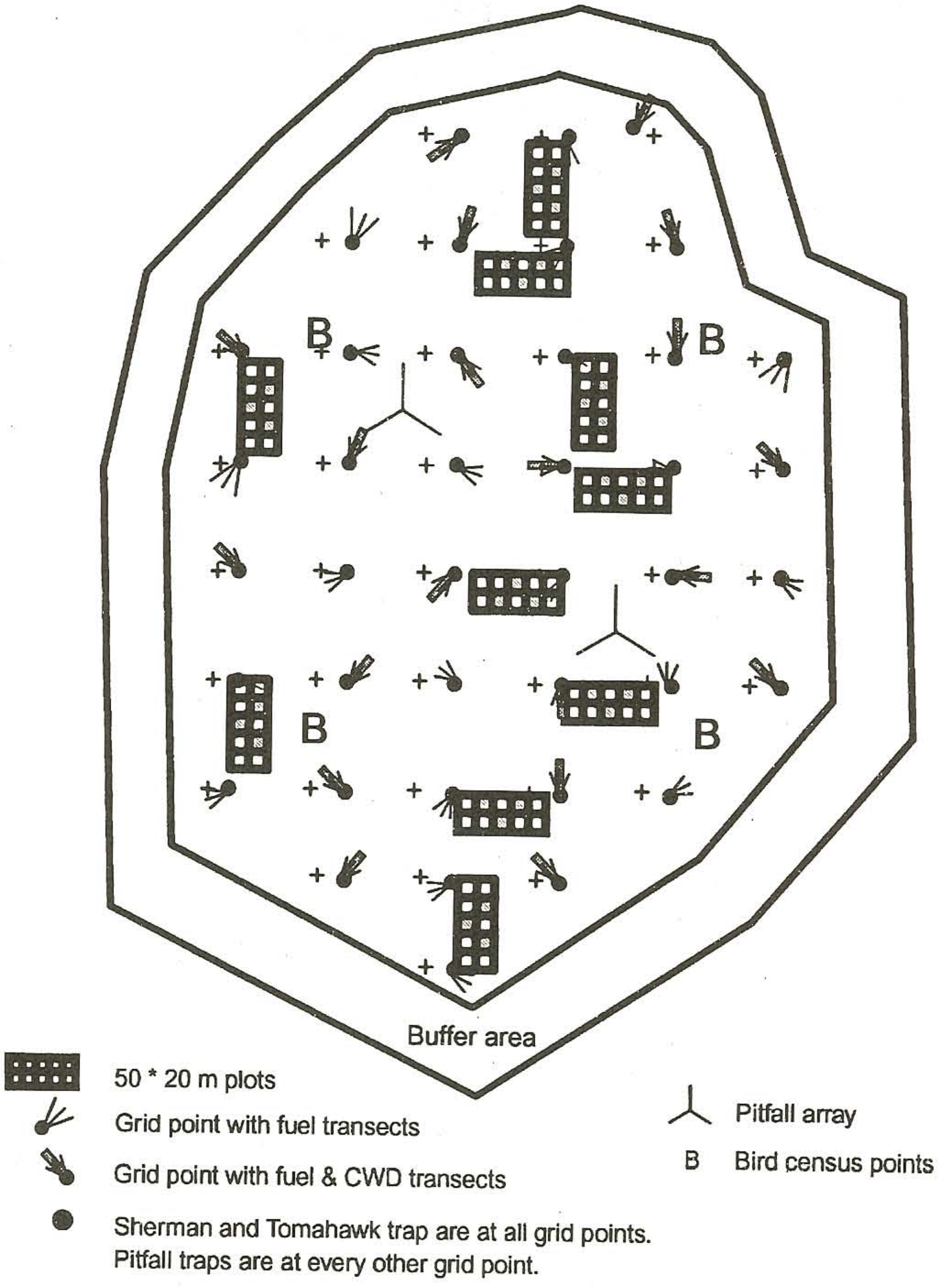

Figure 1. Typical treatment area layout for all sample and data collection on the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina (Waldrop 2000).

The levels of thinning and prescribed burning were defined by FFS protocols to be sufficiently heavy so that if a wildfire occurred on a day with weather conditions at the 80^{th} percentile, 80 percent of the overstory trees would survive. Eightieth-percentile weather conditions during the wildfire season for the Piedmont of South Carolina (February through early April) would include a high temperature of 22° C, low relative humidity of 34%, and peak 5-minute windspeed of 13m/sec (NCDC daily observations for Greenville/Spartanburg airport). These parameters were used in the fire behavior prediction system (BEHAVE) to determine the maximum flame height that would occur with southern pine fuels. BEHAVE predicted a flame height of 3.1 m. Estimates of overstory tree mortality at this level of fire intensity (Waldrop and Van Lear, 1984; Waldrop and Lloyd, 1988) are far below 80 percent without fuels treatment. However, experience with prescribed burning in similar stands suggests that flame lengths and mortality would be much greater under those weather conditions, suggesting the difficulty of predicting fire behavior and mortality in southern stands. Therefore, thinning and burning levels were prescribed that reduced fuels and followed standard silvicultural practices for managed stands in the Piedmont.

Thinning was conducted by contract and specified as a thinning from below, which removed overtopped trees and trees positioned in the lower crown. Small, merchantable-sized trees and diseased or insect-infested trees were selected first. Other trees were removed as necessary to provide a residual basal area of approximately 18 m^2/ha. This was a heavy thinning because treatment areas had basal areas ranging from 28 to 37 m^2/ha. Thinning operations were conducted in the winter of 2000-2001

Table 1. Location and size of each treatment area on the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Replication*	Treatment*	Division	Size (ha)*
1	Control	North Forest	16
1	T1	North Forest	17
1	Burn	South Forest	17
1	T2	North Forest	27
2	Control	South Forest	15
2	Burn	North Forest	21
2	T1	South Forest	14
2	T2	South Forest	17
3	Control	South Forest	22
3	Burn	North Forest	20
3	T1	South Forest	17
3	T2	South Forest	18

*Taken from the Southeastern Piedmont Study Plan with permission from author (Waldrop 2000).

Table 2. Dates of T1 treatment implementation on the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Replication	Treatment	Start	Finish
1	T1	11-Jan-01	18-Jan-01
1	T2	11-Jan-01	22-Jan-01
2	T1	18-Dec-00	18-Jan-01
2	T2	25-Jan-01	1-Feb-01
3	T1	5-Feb-01	21-Feb-01
3	T2	26-Feb-01	7-Mar-01

Table 3. Dates of burn treatment implementation on the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Replication	Treatment	Date Burned
1	Burn	10-Apr-01
2	Burn	12-Apr-01
3	Burn	11-Apr-01
1	T2	15-Mar-02
2	T2	25-Mar-02
3	T2	28-Mar-02

(Table 2). Residual slash remained spread over the treatment area. Prescribed burning of each treatment was conducted in the spring of 2001 and spring 2002 (Table 3).

Trapping Methods

A total of 24 drift fence/pitfall trap arrays, 120 modified pitfall traps, 120 unmodified pitfall traps and area-constrained searches was used to sample herpetofauna (Figure 2). Trap installation began in May 2000 and ended in August 2000. Two drift fence/pitfall arrays were randomly assigned to each half of the treatment plot. The array design was similar to that used by Crosswhite et al. (1999) with one array placed in the upper half (gridpoints 1-20) and one in the lower half (gridpoints 21-40). Drift fence/pitfall arrays were Y-shaped with 10-m arms spaced 120° from each other. Each array had four pitfalls (19-liter plastic buckets) with one pitfall in the center of the array and one at each arm end. Black nylon silt fencing was used to construct the drift fences. Silt fencing comes factory made in rolls that are 27 m long and 30 or 50 cm tall with preattached wooden stakes. Heights of both 30 cm and 50 cm were used in this study.

Once the location for each array was determined, a center point was flagged and the first arm was positioned along magnetic north from the center. The second and third arms were positioned from the first arm. A tape was stretched 10 meters for each arm and the endpoint was flagged. A one-meter strip of forest floor was cleared of litter for the length of each arm. Once the ground was cleared a DitchWitch trencher was used to dig a 10.5 m trench that was 8 - 10 cm wide and 10 - 15 cm deep. The location for each pitfall was marked and a hole was dug so that the trench equally divided the pitfall at each arm end. Pitfalls were placed in the holes and soil was packed in any open spaces. The silt fence was then rolled to fit the length of each arm, placed in the trench, and

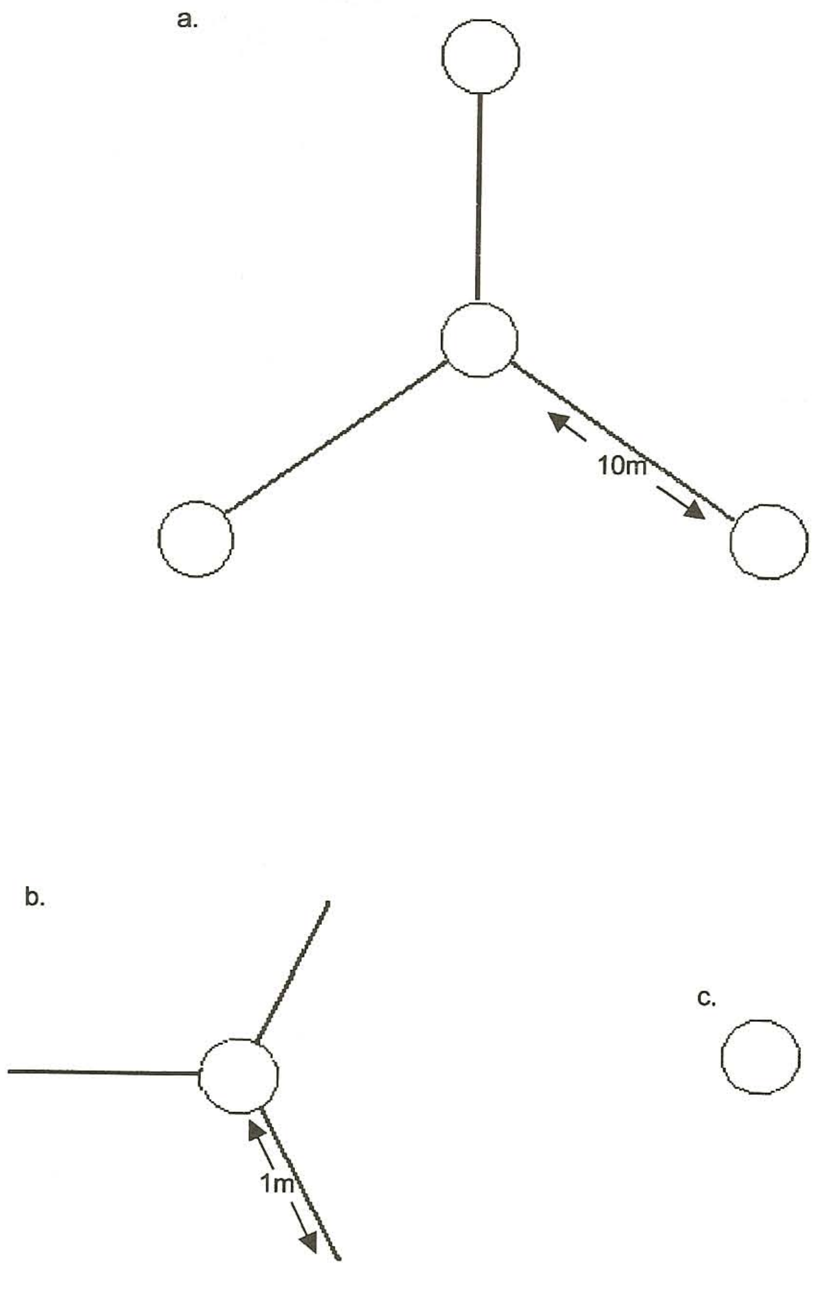

Figure 2. Top view of the drift fence/pitfall arrary (a), modified pitfall (b), and unmodified pitfall (c) used on the Piedmont site of the National Fire and Fire surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina. Figures are not drawn to scale.

supported by driving the stakes in the ground. There was one stake at the end of each 10 m arm and at 2-3 m intervals. Extra stakes were attached to the fence with a stable gun if additional support was needed or when the fence was cut to fit. The trench was filled with soil on both sides of the fence and packed. The pitfalls in the array were numbered starting from the north arm (B1). Array captures were coded on the datasheet as A# (1 or 2) and B# (1 – 4).

Modified pitfalls (19 liter plastic buckets) were located at the midpoint of grid location 1, 5, 9, 13, 17, 21, 25, 29, 33, and 37 for a total of 10 modified pitfalls per treatment plot. Finding the corresponding odd and even gridpoint and pacing 25-m to the midpoint designated modified pitfalls. Locations were offset 2-3 meters if they interfered with a vegetation sampling plot. Modified pitfalls were constructed by burying the bucket flush with the ground and digging three 1-m long, 8-cm wide, and 8-cm deep trenches at 120° angles to center of the bucket opening. Three 1-m sections of 30-cm aluminum roof flashing were placed vertically in each trench and seated against the lip of the pitfall. Flashing was supported with 45-cm pieces of rebar and driven into the ground. Cable ties were used to attach the flashing to the rebar. The trench was filled on both sides of the flashing and packed. Modified pitfall captures were coded on the datasheet as M# (1 - 37).

Unmodified pitfalls (19-liter plastic buckets) were located at the midpoint of grid locations 3, 7, 11, 15, 19, 23, 27, 31, 35, and 39 for a total 10 pitfalls per treatment plot. Unmodified pitfalls were located in the same fashion as modified pitfalls. Holes were dug and pitfalls were buried flush with the ground. Unmodified pitfall captures were coded on the datasheet as P# (3 – 39).

A cordless drill was used to make eight to twelve 1/8 inch holes in the bottom of each pitfall. Sponges were placed in all completed pitfalls to prevent capture desiccation when not in use. In addition, pitfalls were covered with plastic lids and a rock or excess soil was used to weight the lid on the pitfall opening to prevent inadvertent captures. Pitfalls remained closed until trap installation was complete and pretreatment data collection began.

Any herpetofauna caught while walking within the treatment plots or male anurans that were vocalizing were counted as hand captures if they occurred within the 10-hectare sample area.

Trap Checking Regime

Pre- and post-treatment data were collected following national protocol guidelines and site-specific guidelines established for this study. Each person checking traps recorded data on separate datasheets (Figure A-1). National protocol required a 10-day sampling period for pre- and post-treatment data. Because traps were distributed randomly throughout each 10-hectare plot, all 12 sites could not be checked once per day. During pre-treatment and post-treatment protocol data collection each replication was sampled during a different 10-day period throughout fall 2000. When traps were opened, any standing water was bailed and cleaned free of mud and debris.

To collect pretreatment protocol data, traps were opened on 9 September 2000 and closed 19 September 2000 for Replication 1, opened 7 October 2000 and closed 17 October 2000 for Replication 2, and opened 28 October 2000 and ended 7 November 2000 for Replication 3. Traps were opened for 11 calendar days in order to have a complete 10-day (240 hr) sampling period. The order and time that traps were opened was the same for the first day as it was for the eleventh day. For example, R1T2 was opened on the 9th at 9:00 AM so only 15 hours of sampling remained in that day. The remaining 9 hours were made up on the 19th when R1T2 was closed at 9:00 AM to make a full 24-hour day. The nine 24-hour sampling days between the 9th and 19th made up the remaining 216 hours needed to complete the 10 day sampling period. When pre-treatment data collection ended on 7 November, traps in Replication 3 remained open and traps in Replication 1 and 2 were opened. All traps were open by 14 November 2000. From November 2000 to March 2000 traps were checked once per week and at least twice per week from April 2000 to January 2002.

Although monitoring was continuous, post-treatment data collection did not officially begin until all treatments had been implemented. For analysis, post-treatment data collection began 11 April 2001. Post-treatment protocol data were collected from 8 October 2001 - 18 October 2001 (R1), 22 October 2001 – 1 November 2001 (R2), and 5 November 2001– 15 November 2001 (R3). Since traps were already open, the traps in the replication to be monitored were cleaned the day that protocol collection began. When protocol data were collected the pitfalls remained open. Although the T2 treatment was not complete, data from these treatment plots were used in analysis and served as additional T1 treatments. The T2 designation was retained for clarity during analysis.

Usually two people monitored pitfalls, each taking one half of the treatment plot. The same individual worked the same half throughout the study. When one person was checking pitfalls he/she followed approximately the same route that was used by the second person. Once routes were established, two people could check each treatment plot in 20 to 30 minutes depending on the number of captures. Driving time between plots varied from 2 – 20 minutes.

Marking Techniques

All herpetofauna captured were identified to species, marked, sexed, weighed, and measured. Taxonomy followed that of Conant and Collins (1998), Highton and Peabody (2000), and Martof et al. (1980). Latin names were entered on the datasheet as an abbreviated four letter code derived from the first two letters of the generic and species epithets. There were two exceptions to this coding scheme; *Rana sphenocephala* (RASH) and *Pseudotriton ruber schneki* (PSSC). RASH was created to keep *Rana sphenocepala* separate from *Rana sp.* (RASP). PSSC was used to keep *Pseudotriton ruber schneki* separate from *Pseudotriton ruber ruber* (PSRU). Salamanders, anurans, and lizards were marked by toe clipping the fourth outermost toe on the right rear foot with a pair of small scissors (Donnelly, 1989). Snakes were marked by scale clipping the end of the fifth ventral plate using the anal plate in front of the transverse vent as a starting point. The first ventral scale past the anal plate was skipped and counting from one started thereafter. Turtles were marked using a file to notch the second marginal scute counting from the right of the nuchal scute. Scale clipping and scute notching methods were modifications of those used by Woodbury (1953).

Sex was determined in adult snakes by probing for hemipenes with lubricated silver or stainless steel probes. The sex of salamanders, anurans, turtles, and lizards was determined when distinguishing external characteristics were present. All captures were weighed with an Ohaus[R] CS electronic balance in grams. Snout to vent lengths were taken for anurans, lizards, and snakes in centimeters. Tail lengths were taken for snakes and lizards and carapace length was taken for turtles. Initially, measurements were taken on salamanders but this was discontinued due to the fast rate of dessication during handling. Captures were marked and released where they were caught. Snakes were sometimes taken to the field vehicle to be marked then released at the capture location. The capture, marking, and handling techniques used in this study were approved by the Clemson University Animal Research Committee (ARC) (Animal Use Protocol Number 00-087).

Vegetation

Studies of herpetofauna typically require vegetation analysis but usually not to the degree utilized in this study. The detail of the data collection by the USDA Forest Service for vegetation, fuels, and fire behavior followed the methods presented in the Southeastern Piedmont Study Plan (Waldrop, 2000).

All vegetation variables were measured on all, or a portion of, ten 0.1-ha sample plots located systematically throughout each treatment area. Sample plots were established at grid points 2,6,10,14,18,22,26,30,34, and 38. Each plot was 50 by 20 m in size. The long side of sample plots began at a grid point and followed a cardinal direction so that it usually ended at another grid point. The direction of the long side was chosen using random numbers from 1 to 4, representing north, east, south, or west, respectively.

At the time of measurement, cloth tapes were stretched along the two 50 m outer sides of the sample plot and another parallel and half way between the first two. Other tapes were placed perpendicular to those on the long sides and at 10-m intervals. The result was 10 subplots, each 10 by 10 m in size.

All trees 10-cm dbh or larger were measured in 5 of the 10 subplots. National protocols called for measurements in all 10 subplots. However, Southern Piedmont forests were too dense to allow for sampling all stems. At each tree, an aluminum nail was used to place a numbered aluminum tag on the tree, approximately 2.5 m above ground. For each tree, the tree number, species, dbh, status, total height, merchantable height, height to live crown, height to dead crown, and crown condition were recorded. Dbh was measured by d-tape and recorded to the nearest mm. Status included: standing live, standing dead, dead and down, and harvested. All heights were estimated to the nearest meter. Crown condition was an estimate of percent cover. Incidence of diseases and/or beetles was recorded for each tree. Diseases were identified by causal species, and beetles were identified as southern pine beetle or *Ips*. Increment cores were extracted from 3 randomly selected trees to establish product age.

Saplings (trees >1.4-m tall and < 10-cm dbh) and shrubs were measured on the same five 10 by 10-m subplots, as were larger trees. Saplings were recorded by species, status, and dbh class. Status included live, topkilled, or harvested. Dbh classes included <3-cm, 3-6-cm, and >6-cm. Shrubs were recorded by species and the estimated percentage of the area crown cover.

A total of 20 quadrats (1-m^2) was established in each vegetation sample plot to measure the herbaceous layer. Quadrats were located at the upper-right and lower-left corner of each 10 by 10-m subplot (Figure 1). All trees < 1.4 m tall were recorded by origin and height class categories. Origin categories included first-year seedling, established seedling, or sprout. Height classes included < 10-cm, 10 to 50-cm, and 50 to 139-cm. Shrubs (<1.4-m tall) and all herbaceous species were recorded by species, cover class, and origin class. Cover classes included <1%, 1 to 10%, 11 to 25%, 26 to 50%, 51 to 75%, and > 75%. Origin class included germinant, established plant, or sprout.

Fuels and Fire Behavior

The amount of forest floor material was determined by destructively sampling the forest floor material as opposed to estimating the weight by developing regression equations. Samples were randomly selected in areas that represent the full range of forest floor depth on the each treatment area. A pilot study using 2 forest floor samples from each grid point was conducted to determine the sample size needed for the remaining areas. Based on the dry weight of litter and duff (F and H combined) samples, the sample size equation (Schaeffer et al., 1979) predicted that a total of 25 samples per treatment area would estimate the true population mean to within 2 percent. Therefore, one litter and one duff sample was collected at each of the 40 grid points in the remaining treatment areas.

A wooden frame was used along with a cutter to collect each sample by layer (L and F/H) and each layer was bagged separately. Due to rapid decomposition rates in the Southeast, F and H layers are often indistinguishable and must be combined. After careful removal of the frame, each layer was measured in the center of each side of the square foot sample and recorded on the sample bags. The eight depths measured were then averaged by layer for that particular sample. To ensure the collection of all organic material, the duff sample was collected past the soil surface. Each sample was then washed to remove the soil and rock portion. They were air-dried and then dried in an oven set at 85°C until a constant weight was reached. The different size classes of woody material and other components (cones, bark and other vegetation parts) were separated out of the individual samples. The separation process supplements the woody material inventory by determining the woody component incorporated in the forest floor.

The amount of forest floor material removed by the prescribed fire is critical for defining vegetation and soil responses and smoke production. A series of eight steel duff pins was used to determine the amount of forest floor material removed. The eight steel pins were located on two perpendicular axes located at the far end of each woody fuel transect and marked with engineering flags to aid in relocating. Each pin was pushed into the forest floor and mineral soil until the head of the pin was flush with the top of the litter layer. The location of the pins had to be determined once other activities around the grid points were defined so that they were located in undisturbed areas. After the fire, each pin was relocated and the distance from the top of the pin to the top of the remaining forest floor was measured. The total distance from the top of the pin to mineral soil was also recorded for each pin.

The down-dead woody fuels were measured before and after treatment using Brown's (1974) planar intercept method. Fuel was classified by size class (0-1/4 in. = 0-6mm, 1/4-1 in. = 6-25mm, 1-3 in. = 25-75mm, and 3+ in. = 75+mm), decay class condition (sound and rotten), and the number of intercepts and diameters of 3+ in. diameter material by species. Three 50-ft transects were established approximately 6 ft away from each grid point and in a randomly selected direction. This method produced a total of 72,000 ft of fuel transects throughout the FFSS. All transects had a common starting point, and the outer two transects were 45 degrees apart (Figure 1). The beginning and end points were permanently marked with spikes and blue stake chasers.

Fuel transect measurement began on the end farthest from the grid point for the two outer transects and at the end closest to the grid point for the center transect. One- and 10-hour fuels intercepts were counted along the first 6 ft, and 100-hour fuels were counted along the first 12 ft. Fuels in the 1000-hr class were recorded by species, diameter, and decay class along the entire 50-ft transect. Litter and duff depth were measured to the nearest 0.1 in. at 12, 25, and 40 ft along every transect. Aboveground height of dead and down wood was measured along 1-ft sections beginning at 12, 25, and 40 ft.

Samples for estimating fuel moisture were collected just prior to the application of the burn treatments. Forest floor samples were collected by layer to represent the plot condition. These samples were collected in moisture proof bottles, weighed, oven-dried at 95°C until there was no more weight loss, and then re-weighed. Woody fuel moisture content samples were also collected by the different woody fuel size classes as defined previously. Moisture content was determined for the live fuel component. This was done by vegetation class (grass, forb and shrub) and sampled to represent the entire plot. The moisture content was determined on an oven dry-basis as defined above.

Fire behavior was documented at each burn treatment plot to qualify the fire intensity between fire treatment plots. Flame length was measured as an ocular estimate on the flame front. Rate of spread was estimated by timing the movement of the flaming front to cover a known distance. Flaming and smoldering stage duration were measured during the course of the burn. The flame length and rate of spread were taken as sets of measurements at regular intervals (i.e. every 15 minutes), throughout the lighting phase at selected grid points. In addition, flaming and smoldering duration were ocularly estimated at the same selected grid points. Prior to and during the burning operations on the fire treatment plots, ambient temperature, relative humidity, and wind speed and direction were collected as fire parameters (Waldrop, 2000).

Prescribed Burns

R1B, R2B, and R3B were burned in April 2001. R1B was burned on April 10. Relative humidity was 51% at the time the fire started and dropped to a low of 42% at 1520. Temperatures ranged from 22° C at 1230 to 30° C at 1520. Eye-level wind speeds ranged from 5 to 8 km/hr and were mainly from the southwest. Forest floor samples were collected at 1030; moisture content was found to be 91% for the duff and 17% for the litter layer. Moisture content of 10-hr timelag fuels was 13% at 1030.

Fire lines were almost unnecessary as the treatment area is bounded by Lake Hartwell on the west and an existing logging road on the east. Hand lines were established on small portions of the north and south sides. A backing fire was set by hand at 1230 along the northeast side to burn into a southwesterly wind. Strip headfires were set in parallel lines approximately 3 to 5 m apart.

Fire intensity was generally low with flame heights below 1 m. Heat-sensitive paints placed on tiles 1 m above ground showed temperatures generally below 150° C throughout the burn unit. Occasional hot spots occurred in areas where southern pine beetle attacks created unusually high fuel loads. In these areas, flames reached into the crowns of dead trees and temperatures reached as high as 350 to 400° C. Flames covered the entire burn unit and all burning was completed by 1700.

R2B was burned on April 12, 2001. Relative humidity was 56% at the time the fire started and dropped to a low of 45% at 1600. Temperatures ranged from 23° C at

1230 to 29° C at 1545. Eye-level wind speeds ranged from 5 to 10 km/hr and were mainly from the south. Forest floor samples were collected at 1000; moisture content was found to be 70% for the duff and 13% for the litter layer. Moisture content of 10-hr timelag fuels was 12% at 1000.

An existing road was used as a fire line on the east side but plowed lines were necessary on all other sides. A backing fire was set by hand at 1100 along the northern side to burn into a southerly wind. Strip headfires were set in parallel lines approximately 3 to 5 m apart. Fire intensity was generally low with flame heights below 1 m. Heat-sensitive paints showed temperatures generally below 150° C throughout the burn unit. An area of high intensity occurred where erosion gullies created a chimney effect, allowing flames to carry into the crowns of a few trees. In these areas, temperatures 1 m above ground reached as high as 300° C. Flames covered the entire burn unit and all burning was completed by 1600.

R3B was burned on April 11, 2001. Relative humidity was 46% at the time the fire started and remained at that level much of the afternoon. Temperatures ranged from 24° C at 1230 to 29° C at 1515. Eye-level wind speeds ranged from 4 to 9 km/hr and were mainly from the south. Forest floor samples were collected at 1030; moisture content was found to be 59% for the duff and 17% for the litter layer. Moisture content of 10-hr timelag fuels was 15% at 1030.

Existing logging roads were used as fire lines on the east and south sides and the majority of the west side. Hand lines were established along the north side. A backing fire was set by hand at 1230 along the north side to burn into a southerly wind. Flanking fires were set perpendicular to the backing fire; each was approximately 10 m long. Spot fires were used throughout the burn unit to burn areas not covered by the flanking fires.

Fire intensity was moderate with flame heights generally between 1 and 2 m. Heat-sensitive paints showed temperatures ranging from 100 to 200° C throughout the burn unit. Occasional hot spots occurred in areas where southern pine beetle attacks created unusually high fuel loads. In these areas, temperatures reached 300° C. Flames covered the entire burn unit and all burning was completed by 1900. Burn treatments for R1T2, R2T2, and R3T2 were not implemented until March 2002, after herpetofauna data collection had ended, and are not described in this study. The burn treatment results were taken directly from the Clemson Fire Description (R. Phillips, personal communication, March, 2002).

Coarse Woody Debris

Sample plots were established at every other grid point on all treatment areas. At each sampled grid point, a strip-plot (4-m by 20-m) was established with the center woody fuel transect line serving as the strip-plot center line (Figure 1). Within each strip-plot only logs or parts of logs that were at least 1 m in length and had a large end diameter 15 cm or greater were measured and counted. The small end (>7.62-cm) and large end diameters were measured on all qualifying logs or parts of logs that fell within the boundaries of the strip-plot. If a piece extended outside the strip-plot, diameters were measured at the line of intercept of the strip-plot boundary and CWD piece. Piece lengths were the lengths of the CWD within the strip-plot area. The length of the entire piece was measured to determine the midpoint of the CWD. If the midpoint was within the strip-plot, the piece was given an additional rating of "1" for the Indicator Variable.

If the midpoint fell outside the strip-plot the piece was given a rating of "0" for the Indicator Variable (Waldrop, 2000).

In addition the species (if possible) and decay class of each log were recorded. The following 5 decay classes were be used to rate the CWD (from Thomas 1979):

Class 1	Bark is intact; twigs are present; wood texture is sound; log is still round; original wood color.
Class 2	Bark is intact; twigs are absent; wood texture is sound or becoming soft; log is still round; original wood color.
Class 3	Bark is falling off; twigs are absent; wood texture is hard; log is still round; original color of wood is faded.
Class 4	Bark is absent; twigs are absent; texture of wood is soft, blocky pieces; shape of log is oval; wood has faded to light yellow or gray.
Class 5	Bark is absent; twigs are absent; wood texture is soft and powdery; shape of log is oval; wood has faded to light yellow or gray.

Environmental Analysis

Precipitation (cm) and current, maximum, and minimum temperatures (°C) were recorded each time pitfalls were monitored. Rain gauges and thermometers were placed at three locations throughout the study site (R1TB, R2TB, and R3C). Precipitation and temperature data were also obtained from the Agricultural Weather Office at Clemson University (D. Linvill, personal communication, March, 2002). The current weather conditions were noted on the datasheet during each observation.

Statistical Analysis

Herpetofauna data were summarized for all captures from 9 September 2000 – 9 January 2002, post-treatment captures from 11 April 2001 – 9 January 2002, pre- and post-treatment protocol captures, captures by trap type, and captures by month. Captures were totaled for each species within five major taxa (Orders Caudata, Anura, and Testudines, and Suborders Lacertilia and Serpentes) for each sampling period, trap type, and month. The numbers of species captured were summarized in the same way. Raw data were entered in spreadsheets and converted to datasets for use in analysis.

Captures from 11 April 2002 – 9 January 2002 were used for treatment effect tests. The experimental units for analysis of treatment effects were 1 for Burn, 2 for Control, 3 for T2, and 4 for T1. Tests for treatment effects on abundance and richness were conducted on overall treatment totals, taxa totals and for 10 individual species with the highest abundance. These species included: *Anolis carolinensis* (green anole), *Bufo fowleri* (fowler's toad), *Carphophis a. amoenus* (eastern worm snake), *Eumeces fasciatus* (five-lined skink), *Gastrophryne carolinensis* (eastern narrowmouth toad), *Plethodon teyahalee* (southern appalachian salamander), *Rana catesbieana* (bullfrog), *R. clamitans melanota* (green frog), *Scincella lateralis* (ground skink), *Sceloporus undulatus hyacinthinus* (northern fence lizard), *Tantilla coronata* (southeastern crowned snake), and *Terrepene c. carolina* (eastern box turtle).

All captures from 9 September 2000 – 9 January 2002 were used for trap efficiency analysis. Experimental units for the analysis of pitfall efficiency in arrays were 1 for B1, 2 for B2, 3 for B3, and 4 for B4. Experimental units for the analysis of efficiency for all trap types were 1 for array, 2 for hand captures, 3 for modified pitfall, and 4 for unmodified pitfall. Tests were conducted to detect differences in abundance and richness between the three trap types and four pitfalls in arrays for each of the five taxa.

The General Linear Model (GLM) procedure and Least Significant Difference (LSD) tests in SAS (1999) were used to test for treatment effects and differences in trap efficiency. Pre- and post-treatment protocol data were not analyzed due to the low number of captures during the 10-day sampling periods. The level of significance was set at $\alpha=0.05$ for all statistical tests.

Vegetation and fuels data were summarized for pre- and post-treatment periods. All trees <1.4 m tall, shrubs <1.4m tall and all herbaceous species were grouped into eight major lifeforms: seedling, vine, forb, grass, shrub, moss, fern, and sedge. The grouping of lifeforms followed the designations given by Radford et al. (1968). The frequency of occurrence for each lifeform was calculated for each treatment plot and this was used to obtain an average frequency and standard deviation for that frequency for each treatment type. Basal area (m^2/ha), average individual species basal area (m^2/plot), and average dbh were calculated from the overstory data. Basal area was calculated for each replication and treatment and averaged to obtain the total basal area for each treatment type. The basal area and dbh for each tree species was obtained for each treatment plot and used to obtain an average basal area and average dbh for each tree species in each treatment type.

The average decay class, small-end diameter, large-end diameter, and length in plot for CWD data were calculated for each treatment type. The average pre-treatment litter depth and weight and duff depth and weight were calculated for each treatment type. Litter and duff consumed and litter and duff remaining were obtained for the burn treatments.

CHAPTER IV

RESULTS

Herpetofauna

A total of 1,317 reptiles and amphibians representing 40 species was captured in 163,968 trap nights during the overall sampling period from 9 September 2000 to 9 January 2002 (Table A-1). Suborder Lacertilia was the most abundant taxon making up 49.1% of total captures. Order Anura (23.5%), Suborder Serpentes (13.7%), Order Caudata (9.2%), and Order Testudines (4.6%) made up the remaining portion of captures. The majority of captures, 52.8% squamates and 28.6% amphibians occurred from April 2001 to October 2001 (Figure 3). Total post-treatment data collection period from 11 April 2001 – 9 January 2002 resulted in 1,146 captures representing 40 species for 92,064 trap nights (Table A-2). Suborder Lacertilia was the dominant taxon (47.7%) followed by Order Anura (25.7%), Suborder Serpentes (14.2%), Order Caudata (7.9%), and Order Testudines (4.5%).

S. u. hyacinthinus was the most abundant species in the overall sampling period and in the total post-treatment sampling period representing 25.5% and 24.3% of total captures respectively. *B. fowleri*, *A. carolinensis*, *E. fasciatus*, and *T. coronata* were the next four dominant species representing 34% of total captures in the overall sample period and 36% in the post-treatment sampling period. Pre-treatment protocol data collection yielded 60 captures of 13 species (Table A-3) and post-treatment data collection yielded 15 captures of 7 species (Table A-4).

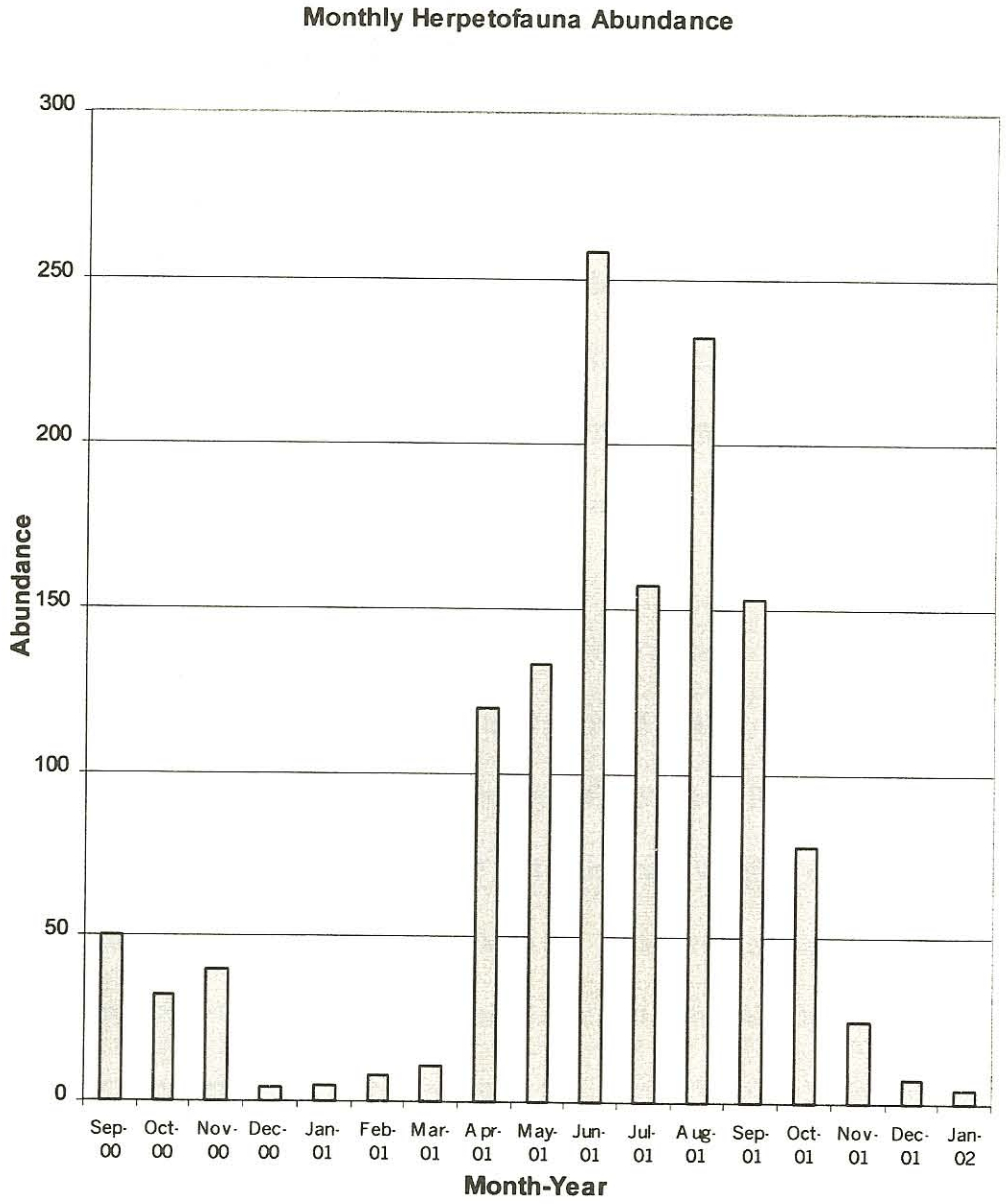

Figure 3. Monthly herpetofauna abundance for all captures in the Piedmont Site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

There was a total of 49 recaptures representing 9 species for the overall sampling period. Only three of the 49 recaptures occurred before the post treatment sampling period and these were *S. u. hyacinthinus* recaptures occurring on 30 November 2000, 1 February 2001, and 27 March 2001. *A. carolinensis*, *E. fasciatus*, and *S. u. hyacinthinus* made up 67.3% of recaptures. *S. u. hyacinthinus* made up 44.9% of recaptures of which 81.8% were males. *B. fowleri*, *R. catesbeiana* (bullfrog), and *R. c. melanota* (green frog) made up 26.5% of recaptures, most (84.6%) were juveniles. Two species, one *T. coronata* (southeastern crowned snake) and one *T. c. carolina* (eastern box turtle) made up the remaining recaptures.

There were no significant treatment effects on abundance for any of the five taxa when comparing among and between treatments (Table 4). When comparing replications, R1 for suborder serpentes was significantly different from R2 (p=0.0332). When comparing richness, the thin treatment had significantly higher number of snake species than the burn treatment (p=0.0257) (Table 5). There were no significant treatment effects when comparing the total treatment abundance and richness. Of the 10 individual species chosen for analysis, there were significant treatment effects on *A. carolinensis* and *E. fasciatus* (Table 6). T2 had significantly more *A. carolinensis* captures than the burn (p=0.0271) or control (p=0.0114). There were significantly more *E. fasciatus* captures in the thin/burn and thin than in the control (p=0.0463 and p=0.0138).

not burned

Trap Efficiency

The drift-fence pitfall arrays accounted for 32.3% of total captures. Modified pitfalls also accounted for a significant portion of captures (30.4%). The results of unmodified pitfall and hand capture were similar making up 19.2% and 18.0% of total

Table 4. Mean herpetofauna abundance (captures/treatment) for the total post-treatment sampling period in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

	Anura	Caudata	Testudines	Lacertilia	Serpentes	Overall
Burn	12.6 a	3.0 a	3.6 a	39.7 a	9.6 a	13.7 a
Control	37.3 a	8.3 a	4.3 a	27.7 a	14.3 a	18.4 a
T2	22.0 a	12.0 a	5.0 a	60.3 a	12.3 a	22.3 a
T1	26.0 a	7.0 a	4.0 a	54.7 a	18.0 a	21.9 a

Means not followed by the same letter within columns differ significantly at $p<0.05$.

Table 5. Mean herpetofauna richness (number of species/treatment) for the total post-treatment sampling period in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

	Anura	Caudata	Testudines	Lacertilia	Serpentes	Overall
Burn	2.7 a	2.0 a	1.3 a	4.6 a	3.0 a	2.7 a
Control	5.7 a	2.0 a	1.0 a	5.0 a	4.7 ab	3.7 a
T2	4.3 a	4.0 a	1.0 a	5.3 a	5.3 ab	4.0 a
T1	4.0 a	3.7 a	1.0 a	5.0 a	6.0 bc	3.9 a

Means not followed by the same letter within columns differ significantly at $p<0.05$.

Table 6. Average abundance of individual species for each treatment in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Species	Burn	Control	T2	T1
Anolis carolinensis	5.0 a	2.0 a	17.7 b	7.3 ab
Bufo fowleri	9.0 a	2.7 a	12.7 a	20.3 a
Carphophis a. amoenus	1.3 a	4.7 a	4.4 a	3.3 a
Eumeces fasciatus	7.0 ab	4.3 a	9.6 b	11.7 b
Gastrophyrne carolinensis	2.0 a	3.0 a	4.7 a	3.0 a
Plethodon teyahalee	1.7 a	8.7 a	5.7 a	1.7 a
Rana catesbieana	1.3 a	9.0 a	2.3 a	5.2 a
Scincella lateralis	5.2 a	3.3 a	3.0 a	4.6 a
Sceloporus undulatus hyacinthinus	22.7 a	14.7 a	28.0 a	27.7 a
Tantilla coronata	7.0 ab	5.7 a	4.3 a	9.3 a
Terrapene c. carolina	3.3 a	4.3 a	5.0 a	4.0 a

Means not followed by the same letter within columns differ significantly at $p<0.05$.

captures respectively. Both drift-fence pitfall arrays and modified pitfalls caught 30 species. Twenty-five species were caught in unmodified pitfalls and 19 species were caught by hand (Table A-5).

There were no significant differences in capture efficiency between trap types for anura, caudata, or lacertilia or for overall capture abundance. Significantly higher numbers of *T. c. carolina* were caught by hand than by array (p=0.0003), modified pitfall (p=0.0001), and unmodified pitfall (p<0.0001). Modified pitfalls caught significantly more *T. c. carolina* than unmodified pitfalls (p=0.0441). Arrays caught significantly higher numbers of snakes than modified pitfalls (p=0.0036), unmodified pitfalls (p=0.0016), and hand (p=0.0006) (Table 7).

There were no significant differences in capture efficiency for richness between trap types for anura, caudata, and testudines. Unmodified pitfalls caught significantly more lizard species than hand capture (p=0.0338). Significantly more snake species were caught in the array and modified pitfalls than by unmodified pitfalls (p=0.0348) and hand (p=0.0348). Overall there were significantly fewer species caught by hand (p=0.0249) than by the other three trap types (Table 8).

When comparing the efficiency of pitfalls in arrays for abundance, there was no significant difference in capture efficiency for snakes or salamanders. Significantly more anurans were caught in Pitfall 4 (B4) than B1 (p=0.0343), B2 (p=0.0300), and B3 (p=0.0420). Significantly more lizards were caught in B4 than B1 (p=0.0117), B2 (0.0060), and B3 (p=0.0083). The efficiency of B1, B2, and B3 did not vary significantly for anurans or lizards. Tests were not complete for turtles because of the low number of array captures for that taxon. For all taxa, B4 was more efficient than B2 (p=0.037) and B3 (p=0.0300) but not B1 (Table 9). Significantly more anuran species were caught in

Table 7. Capture abundance for array, hand, modified, and unmodified trap types in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

	Anura	Caudata	Testudines	Lacertilia	Serpentes	Overall
Array	34.3 a	20.0 a	3.8 a	53.0 a	32.3 b	30.5 a
Hand	18.7 a		13.0 b	42.3 a	5.0 a	19.8 a
Modified	35.0 a	14.0 a	3.7 a	68.0 a	13.0 a	26.7 a
Unmodified	15.0 a	9.5 a	1.3 a	52.0 a	9.7 a	17.8 a

Means not followed by the same letter within rows differ significantly at $p<0.05$.

Table 8. Species richness for array, hand, modified, and unmodified trap types in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

	Anura	Caudata	Testudines	Lacertilia	Serpentes	Overall
Array	5.3 a	4.0 a	1.5 a	5.3 ab	6.0 a	4.6 a
Hand	3.7 a		1.0 a	4.0 a	3.3 b	3.0 b
Modified	5.0 a	5.3 a	1.0 a	5.3 ab	4.0 a	4.1 a
Unmodified	3.7 a	3.2 a	1.0 a	5.7 bc	3.3 b	3.4 b

Means not followed by the same letter within rows differ significantly at $p<0.05$.

B4 than in B1 (p=0.0030), B2 (p=0.0030), and B3 (p=0.0184). B1, B2, and B3 did not vary. B4 caught more salamander species than B3 (p=0.0338) and B1 caught more snake species than B1 (p=0.0369). For all taxa, B4 caught more species than B3 (p=0.0356) (Table 10).

Vegetation

Seedlings (30.4%), vines (27.6%), and forbs (13.6%) composed 71.6% of the sampled understory. Grass, shrub, moss, fern, and sedge lifeforms made up the remaining understory component. There was a positive response from shrub, forb, and grass and negative response from seedling, vine, and moss lifeforms to burning. However, the same trend occurred in the control site with forbs. Treatment effects on ferns and sedges were negligible because of their low frequency of occurrence. There was a positive response from seedlings, vines, forbs, grasses, and shrubs and a negative response by the mosses in the control sites. More seedlings and vines were found in thinned sites but fewer forbs, grasses, shrubs, and mosses occurred after thinning (Table 11).

Burning and thinning reduced the average basal area (m^2/ha) by 25% and 22.9%, respectively. There was a decrease in average basal area in the controls, possibly due to the loss of large dbh trees to natural disturbance, but only by 5.6% (Table 12). The majority of basal area in pre- and post-treatment stands were composed of *P. taeda, P. echinata, P. virginiana, Liriodendron tulipifera* (tulip poplar), and *Quercus alba* (white oak). Fewer species made up the average total basal area in post-treatment plots than in pre-treatment plots. The five largest diameter tree species in pre-treatment plots were P. taeda, L. tulipifera, P. virginiana, Q. alba, and Q. falcate. In post-treatment plots, L. tulipifera and Q. alba were replaced by Q. nigra and P. echinata.

Table 9. Capture abundance for array pitfalls in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

	Anura	Caudata	Testudines	Lacertilia	Serpentes	Overall
B1	4.0 a	7.0 a		11.6 a	8.3 a	7.6 ab
B2	3.3 a	3.0 a		10.3 a	8.3 a	6.3 a
B3	5.0 a	3.0 a	1.5 a	11.0 a	9.7 a	6.2 a
B4	22.0 b	7.0 a	2.0 a	20.0 b	6.0 a	11.9 b

Means not followed by the same letter within rows differ significantly at $p<0.05$.
B (1-4) was the numbering scheme used to designate pitfalls within arrays. B1 was the pitfall at the end of the array arm facing true north and B4 was the center pitfall. B2 and B3 were numbered clockwise from B1.

Table 10. Species richness for array pitfalls in the Piedmont Site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

	Anura	Caudata	Testudines	Lacertilia	Serpentes	Overall
B1	2.0 a	2.7 ab		4.0 a	4.3 a	3.3 ab
B2	2.0 a	2.0 ab		4.0 a	3.7 ab	2.9 ab
B3	3.0 a	1.3 a	1.0 a	4.3 a	2.7 bc	2.6 a
B4	5.0 b	3.0 bc	1.5 a	4.7 a	3.7 ab	3.7 bc

Means not followed by the same letter within rows differ significantly at $p<0.05$.

Table 11. Total number of occurrences of eight lifeforms per 200 subplots averaged for each treatment in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Lifeform		Burn	SD	Control	SD	T1	SD	T2	SD
Seedling	Pre	308	155	163	64	231	104	238	137
	Post	271	103	228	84	250	95		
Vine	Pre	236	95	117	60	185	71	248	141
	Post	224	82	266	172	259	111		
Herb	Pre	78	35	57	45	109	26	142	18
	Post	136	25	131	98	106	27		
Grass	Pre	85	15	51	32	76	62	97	55
	Post	153	17	55	36	60	34		
Shrub	Pre	85	30	43	17	62	37	71	50
	Post	93	20	64	38	31	6		
Moss	Pre	74	45	60	14	63	73	87	90
	Post	9	8	20	20	27	35		
Fern	Pre	20	16	15	3	17	12	28	21
	Post	19	18	11	7	9	9		
Sedge	Pre	16	5	6	5	12	2	17	2
	Post	18	7	16	10	8	7		

Table 12. Average pre- and post-treatment basal area (m^2/ha) for each treatment in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Treatment		Rep 1	Rep 2	Rep 3	Mean
Burn	Pre	87.7	117.4	113.0	106.0
	Post	70.5	95.3	74.3	80.0
Control	Pre	132.3	144.7	126.7	134.6
	Post	111.6	144.3	127.0	127.0
T1	Pre	114.7	95.0	145.8	118.0
	Post	78.2	74.1	122.2	91.0

Fuels

Coarse woody debris decay class decreased (i.e. became more sound) as a result of the thin treatment and burn treatment but increased in control plots. Fewer pieces of CWD were recorded after the thin treatment and burn treatment, but the average length in the sampling plot increased after treatment. CWD loading increased in the controls. The average small end diameter (15.5 cm) and average large end diameter (20.7 cm) remained fairly constant throughout the study (Table 13).

The average pretreatment litter and duff depths were 26.4 mm and 25 mm. The average pre-treatment litter weight and duff weight was 160.8 g and 90g respectively. Burning consumed an average of 42.2 mm of litter and 5.8 mm of duff. After the burn, an average of 2.3 mm of litter and 16.5 mm of duff remained.

Rainfall and Temperature

Monthly precipitation (cm) varied largely between October 2000 (0.1) and 2001 (2.5), November 2000 (13.5) and 2001 (3.7), and January 2001 (8.8) and 2002 (15). Precipitation for September 2000 and 2001 and December 2000 and 2001 was similar. From February 2001 to August 2001 the smallest amount of precipitation occurred in April (2.3) and the largest in March (17.1). More than 9 cm of precipitation was recorded for each month from June to August (Figure 4). Average maximum monthly temperatures (°C) did not vary greatly from 2000, 2001, and 2002, but average minimum monthly temperatures did vary. The lowest average monthly temperature occurred in December 2000 (-1.9), and the highest average monthly temperature occurred in August 2001 (31.3) (Figure 5).

Table 13. Coarse woody debris sample size, decay class, end diameter, and length in plot for each treatment in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Treatment	Year	N	Decay Class	Small end diameter (crn)	Large end diameter (cm)	Length in plot (cm)
Burn	Pre	96	3.4	15.3	20.3	307.1
	Post	67	2.8	15.8	20.8	345.4
Control	Pre	66	3.5	15.6	23.3	307.9
	Post	80	3.9	15.5	19.5	303.2
T1	Pre	101	3.5	15.2	18.8	294.3
	Post	89	2.3	14.2	20.4	337.8
T2	Pre	84	3.2	16.7	22.0	364.8

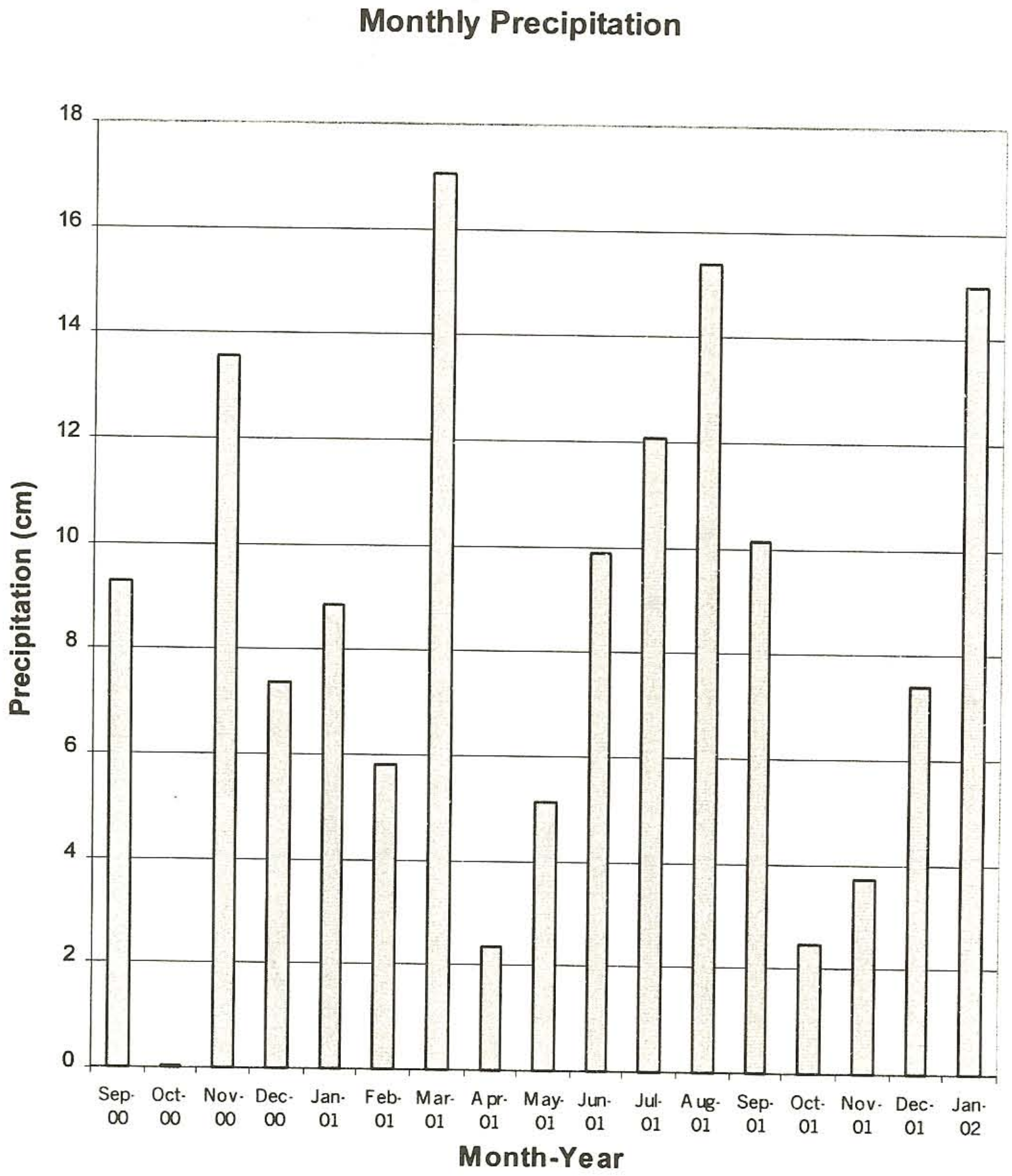

Figure 4. Monthly precipitation from 1 September 2000 to 31 January 2002 in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

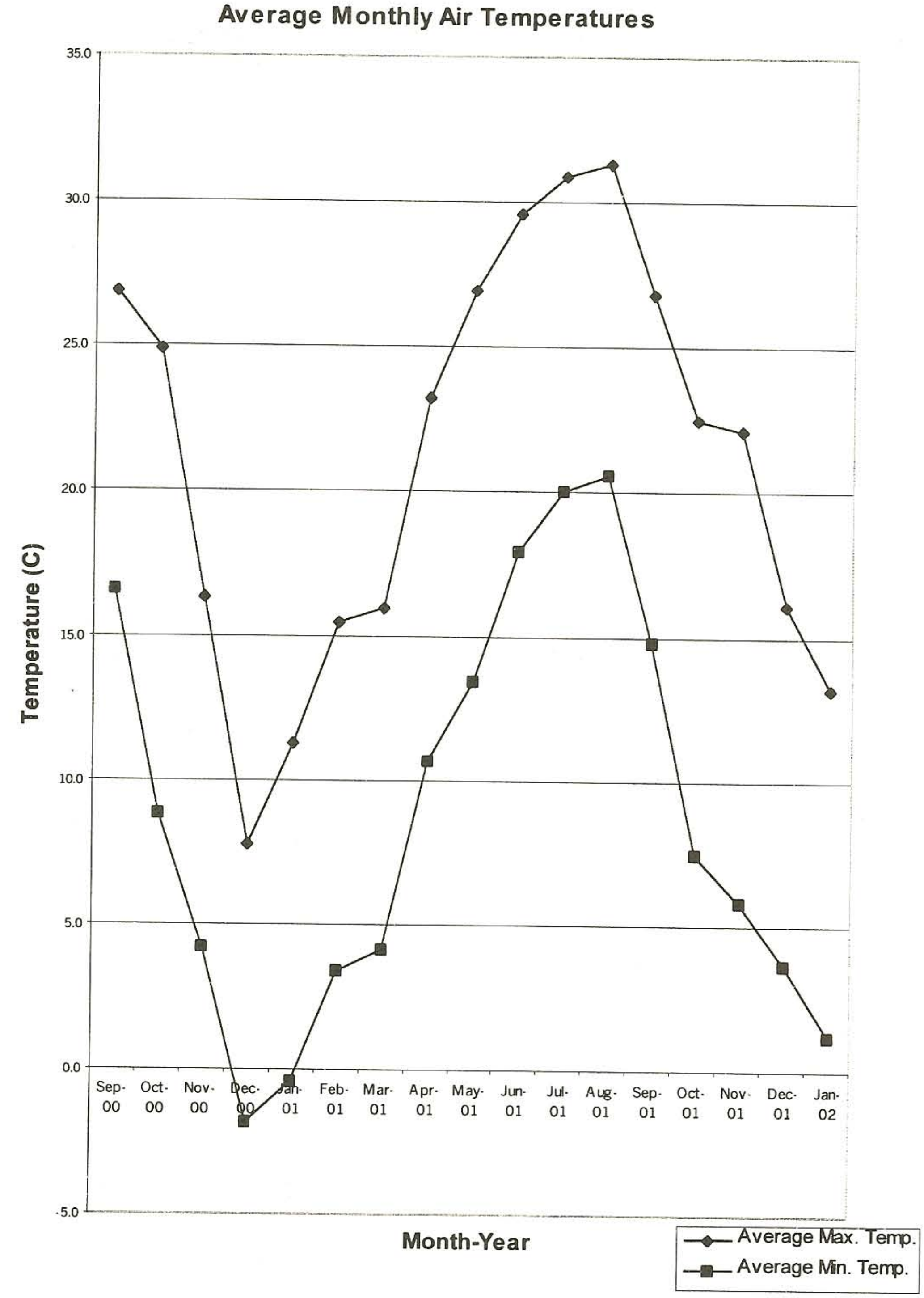

Figure 5. Average monthly maximum and minimum air temperatures from 1 September 2000 to 31 January 2002 in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

CHAPTER V

DISCUSSION

Herpetofauna

The effects of prescribed fire and timber harvest on herpetofauna have been documented from the Coastal Plain of South Carolina (Means and Campbell, 1981; Perison et al., 1997), but insufficient data currently exist on the effects of such treatments in the Piedmont. Studies in the fire dependant longleaf pine ecosystem are well documented, and land management now implements prescribed burning to sustain this habitat type. However, timber harvest is still a more controversial practice. Although research on the effects of thinning are limited, timber harvest in the form of clearcutting and group selection have been found to be both beneficial and detrimental to herpetofauna.

At the order and suborder level, there were no treatment effects on abundance. Although post-treatment sampling occurred throughout the peak months of activity (April - October) more sampling is needed during this time in successive years to detect treatment effects. Much of the amphibian abundance and richness in this study can be explained by the presence of adjacent breeding wetlands and streams and the amount of rainfall. Amphibians made up 33.6% of total post-treatment captures, and for the most part, were composed of species not characteristically found in upland pine plantations. This could due to the presence of adjacent breeding habitat to the treatment areas.

Order Anura (Frogs and Toads)

For anurans, proximity to breeding wetlands are important factors governing abundance on a given site. In a Pennsylvania study, Ross et al.(2000) found that higher abundance and richness occurred in plots that contained water or were close to wetlands which served as breeding habitat. In the FFSS, beaver ponds were near R3C and R2TB and a lake cove was close to R3T. Metts (1999) studied beaver ponds on the CEF and found anurans to be more abundant in this wetland type than in the control wetland (undammed streams). The presence of beaver ponds may explain the high number of anuran captures (n=171, 58%) from these three sites. In addition, the majority of *Rana* and *Bufo fowleri* captures were juveniles or recently metamorphosed individuals captured migrating from breeding pools.

Order Caudata (Salamanders)

The single occurrence of a juvenile *Ambystoma opacum* (marbled salamander) in R2TB can be explained by the presence of temporary breeding pools along the periphery of the adjacent beaver pond. *A. opacum*, like other ambystomatid salamanders of the Southeast, rely on temporary pools for breeding (Gibbons and Semlitsch, 1991). Streams were another factor influencing captures on this study. Perennial streams were present adjacent to the buffer zones in R1C, R1T, R1TB, R2B, R2TB, R3B, R3C, and R3TB. Intermittent streams were present within R1TB, R2B, and R3TB. Salamanders such as *Eurycea cirri*gera (southern two-lined salamander) and *Gyrinophilus porphyriticus dunni* (carolina spring salamander) are associated with streams and seeps but were occasionally captured 50m from the nearest breeding source on this study. *Eurycea* are known to venture far from water during heavy rains (Conant and Collins 1998); however, the presence of *G. porphyriticus dunni* far from preferred habitat is noteworthy.

Conversely, stand composition rather than proximity to water was the determining factor in amphibian abundance in a New Hampshire study involving three forest types. The coniferous forest type supported the lowest number of frog and salamander species. Lower richness was attributed to the acidity of the leaf and humus layer and shallower litter depths in coniferous stands (DeGraaf and Rudis, 1990). In the FFSS study large portions of each plot were composed of *Pinus* but sampling efforts were not focused on stands with different compositions.

Recent genetic work on *Plethodon* has resulted in some taxonomic changes that were recognized in this study. The presence of *Plethon* (woodland salamanders) in the FFSS was expected, but the occurrence of *P. teyahalee* provides additional evidence that this member of the *Plethodon glutinosus* (slimy salamander) complex occurs in the CEF. Two species of the *P. glutinosus* complex, *P. cholorobryonis* (Atlantic coast slimy salamander) and *P. teyahalee*, were captured in this study. *P. cholorobryonis* has large dorsal and lateral white spotting with little variation in spot size from flank to dorsum. *P. teyahalee* has white spotting along the flanks like *P. chlorobryonis* but differs from the former by having a dorsum flecked with white "pindots". *P. teyahalee* often has red spots on the front legs but this form has not been recorded from the CEF.

According to range maps, the CEF is on the edge of *P. teyahalee* distribution but the occurrence of this species in the north and south forest confirms its presence. Both *P. chlorobryonis* and *P. teyahalee* can be distinguished in the field based on morphological characteristics. However, their ranges overlap and form a parapatric hybrid zone in

Anderson, Abbeville counties and the extent of hybridization in the CEF and lower Piedmont is not fully understood. Genetic work should be performed on these two species to determine if species designation is warranted.

Genetic studies on the *Plethdon jordani* (Jordan's Salamander) have established four new species in the *P. jordani* complex (*P. metcalfi, P. amplus, P. meridianus, and P. jordani*). Following the Law of Priority, salamanders formerly named *P. jordani* and *P. clemsonae* from Northwestern South Carolina are now recognized as *P. metcalfi* (southern gray-cheeked salamander). In the southern part of its range, which includes the CEF, a dark venter and lack of red pigment on the legs characterize *P. metcalfi*. Because the variation previously known as *P. clemsonae* still exists in northern Oconee County, some individuals of *P. metcalfi* may have white spotting along the flanks and dorsum or dorsal flecking (Highton and Peabody 2000). The range of *P. metcalfi* is more certain and most likely does not occur in the south forest. All known records of *P. metcalfi* have come from the north forest. R1C, near Six Mile Creek in the north forest, was the only plot in the FFSS where this species was detected.

Suborder Lacertilia (Lizards)

A. carolinensis was more abundant in T2 than burn and control and *E. fasciatus* was more abundant in T2 and T1 than control. Since T2 was not burned until after sampling was completed, T2 and T1 were the same treatment for this thesis. *A. carolinensis* and *E. fasciatus* seem to benefit from conditions created by overstory removal. Thinning removes a portion of the overstory and results in an increase in temperature and exposure of sunlight to forest floor materials. Reptiles utilize the heat from sunlight for thermoregulation and obtain this energy by basking (Zug 1993).

Thinning also provides habitat for ground dwelling and arboreal lizards. It is likely that *A. carolinensis* and *E. fasciatus* were more abundant because of their increased activity within the plot due to the faster attainment of active temperatures (Phelps and Lancia, 1995; Perison et al., 1997). *A. carolinensis* is often associated with disturbed areas with abundant sunlight (Martof et al. 1980). This corresponds to its positive response to the thin treatment. *E. fasciatus* is characteristically found near mesic areas (Gibbons and Semlitsch 1991, Conant and Collins 1998) and were caught in relatively high numbers in FFSS plots that were in close proximity to water. It appears that *E. fasciatus* used the thinned condition for thermoregulation as did *A. carolinensis*.

S. u. hyacinthinus was the most common species encountered in the study and was more abundant in burn, T1, and T2 than control but this difference was not significant. This species is found throughout the state and occurs in open, disturbed habitats and open dry forests. Lee (1974) studied *Sceloporus woodi* (florida scrub lizard) and found that this species preferred the open conditions created by burning. He noted that a thick herbaceous understory was not favorable. Kahn (1960) studied *Sceloporus occidentalis* (western fence lizard) and noted movement from unburned areas to burned areas. Movement from unburned and unthinned areas surrounding the treatment plots may have resulted in the increase in abundance. The less open canopy condition of the controls does not allow much light to reach the forest floor resulting in a lower number of attractive basking sites for *S. u. hyacinthinus*.

C. s. sexlineatus was the only lizard species to occur in one plot. Three individuals were captured in the same unmodified pitfall (P27) in R2B, one was a hand capture, and none were captured more than once. The pitfall location was situated on the edge of the treatment plot near an open roadside edge. Adjacent to the P27, a portion of *P. taeda* attacked by southern pine beetle had been removed. The removal created a gap containing several large piles of logging slash and little herbaceous vegetation. Open conditions with little understory cover are favorable for *C. s. sexlineatus* (Mushinsky 1985).

Order Testudines (Turtles)

The presence of *T. carolina* in all sites is characteristic of this ubiquitous species. Although evidence concerning the direct effects of fire on herpetofauna is scant (Komarek, 1969), two instances of fire related mortality were documented for *T. carolina* by the USDA Forest Service crew. Other than this example, the FFSS area proved to be suitable for breeding and nesting. One instance of copulation was witnessed in RIC and evidence of nesting was seen in R3C. The single *Kinosternon s. subrubrum* (eastern mud turtle) capture occurred about 30 m from a stream in R3B. This capture occurred in April and was most likely a gravid female moving from the stream to upland habitat suitable for egg deposition.

Suborder Serpentes (Snakes)

The only treatment effect detected at the suborder level was for snake richness. More species were captured in thin than burn, but the difference pertains more to random encounter with a trap rather than the effects of the burn. The chance of catching additional species in the burn treatment may have been the same as in thin treatment. Additional species were present in the thin treatment, but *Elaphe o. obseleta* (black rat snake) and *Cemophora c. coccinea* (scarlet snake) were only represented by one capture.

Storeria occipitomaculata (redbelly snake) was represented by four captures and *Storeria dekayi* was represented by two captures. During the overall sampling period 50% of snake richness was made up of species that were represented by only one capture per plot.

Although five other species of constrictors (*Lampropeltis g. getula*, *Lampropeltis calligaster rhombomaculata*, *Lampropeltis t. triangulum*, and *Pituophis m. melanoleucus*) could occur in the FFSS, only one species, *E. o. obseleta*, was captured. This could be due to the low number of small mammals in the FFSS study, a primary food source for constrictors. Small mammal trap success was extremely low during pre- and post-treatment sampling periods. No small mammals were caught in live traps (sherman and tomahawk) for 9,600 trap nights. Snap trap (mouse and rat) success was 0.10% for 27,000 trap nights (three species). Small mammals were captured at low levels in herpetofauna traps (0.06% trap success, six species)(D. Kubacz, personal communication, April, 2002). Enge and Marion (1986) reported 0.5% trap success as being low. Small mammals, especially mice, are primary prey items for *Crotalus horridus* (timber rattlesnake) and *Agkistrodon contortrix mokasen* (northern copperhead) (Martof et al., 1980; Conant and Collins, 1998). Low abundance of small mammals may have also contributed to the absence of *A. c. mokasen* and *C. horridus* and constrictors in this study. Similar trends have been noted in other studies, but low levels of vertebrate prey could not be significantly correlated to low snake abundance (Enge and Marion, 1986).

Fifty percent of snake species captured in the FFSS (*C. a. amoenus*, *C. c. coccinea*, *Diadophis punctatus* (ringneck snake), *S. dekayi*, *S. occipitomaculata*, *T. coronata*, and *Virginia v. valeriae* (smooth earth snake) are considered to be secretive and nocturnal. They also require loose soil for burrowing and CWD, old stumps, and other surface debris for refugia during the day. Arthropods are the primary food source for most of these species, except for *C. a. amoenus*, which feeds chiefly on annelids (Martof et al., 1980; Barbour, 1960). *C. a. amoenus* and *T. coronata* were the most abundant snakes. The xeric habitats found in portions of the FFSS plots provided ideal habitat for *T. coronata*. Semlitsch et al. (1981) noted that xeric microhabitat was associated with high *T. coronata* abundance rather than a dominant vegetation type or macrohabitat.

C. a. amoenus is associated with more mesic conditions with leaf litter and moist soil (Clark, 1970). The transition zone between the upland and isolated wetland habitats supported high numbers of this species in the Coastal Plain (Russell, 2000). The transition zone between upland and stream or beaver pond habitat in FFSS plots provides suitable habitat for *C. a. amoenus* and other species captured that require mesic habitats. The proximity of the stream and/or beaver pond to R2TB, R3C, and R1TB explains the presence of the single juvenile *Regina septemvitatta* (queen snake) in R2TB and two juvenile *Nerodia sipedon* (northern water snake) in R1TB and R3C. These two snake species are semiaquatic to aquatic (Conant and Collins, 1998) and are common in the Upper Piedmont.

Trap Efficiency

Research assessing the effectiveness of drift fence pitfall traps has been conducted in a variety habitat types in the Southeast (Gibbons and Semlitsch, 1981; Bury and Corn, 1987; Greenberg et al., 1994b; Crosswhite et al., 1999). Few studies have looked at the effectiveness of drift fence pitfall arrays, modified pitfall traps, unmodified pitfall traps, and hand capture in the same study. Results of abundance analysis found that each sampling method effectively captured anurans, salamanders, and lizards. However, arrays were most effective at capturing snakes and hand capture was best for turtles. Crosswhite et al. (1999) researched the trapping efficiency of drift fence arrays with pitfall and funnel traps, funnel traps without drift fences, and time constrained searches in upland forests in Arkansas. Although the sampling period was short and limited to warmer months, trapping efficiency was highest for the drift fence arrays, followed by the funnel traps without fences, and then time constrained searches. As in the FFSS, *Sceloporus undulatus* was the most commonly captured species making up 42% of captures.

Crosswhite et al. (1999) found that salamanders and turtles were most effectively captured using time constrained searches. Hand capture of *T. carolina* in this study seemed to be the most productive method. This species may show more avoidance behavior of pitfalls than other species due to its highly terrestrial nature (Gibbons and Semlitsch, 1981).

Another study compared the effectiveness of drift fences with pitfall, single-ended, and double-ended funnel traps in Ocala National Forest, Forida. Pitfalls caught more lizards, anurans, and *Tantilla relicta* than the other two designs, and double-ended funnel traps accounted for 65% of captures excluding *T. relicta* (Greenberg et al., 1994b). However, the use of funnel traps may not be needed if the population of large snakes in a given area is too low to sample or if time/area constrained searches are sufficient to capture large snakes. The array efficiency for snakes, especially *T. coronata*, in the FFSS supports the findings of other trap efficiency studies. Preferred prey items for this species are centipedes and insect larvae (Martof et al., 1980; Conant and Collins, 1998). Arrays may capture more of the preferred *T. coronata* prey items than the other trap designs. In addition, the nocturnal nature of *T. coronata* may increase the amount of time spent foraging and consequently the amount of area covered in a given night. The benefit of a nocturnal nature, at least for squamates, would be less time spent basking or seeking shelter and more time foraging. This behavior would increase the chances of *T. coronata* encountering the large (approximately 20m) capture area of the array.

Interestingly enough, abundant species such as *S. u. hyacinthinus* were caught in all trap types with the same relative efficiency. This may be due to the diurnal nature of this species and the smaller amount of area it covers during active periods. However, during peak breeding activity in the spring, male *S. u. hyacinthinus* are actively seeking females and cover more area. Evidence of this increased activity was reflected by the increase in multiple male captures per pitfall. There were several instances where four or five different males were caught in a single pitfall during the spring. For most of the trapping session, one capture per pitfall was the usual observation.

Analysis of richness found that trap efficiency varied for lizards, snakes, and the overall number of species captured. Unmodified pitfalls were more efficient for lizards than hand capture because this trap type consistently caught more species of *Eumeces*. *A. carolinensis*, *S. u. hyacinthinus*, and *Scinella lateralis* were species common to both hand and unmodifed pitfall traps. However, unmodified pitfalls were more efficient at catching *Eumeces* than hand capture. For each replication, unmodified pitfalls consistently caught two or three species of *Eumeces*, but no more than one of three species were ever caught by hand. *Eumeces* are alert and very active lizards (Contant and

Collins, 1998) and are much more difficult to capture by hand than *A. carolinensis*, *S. u. hyacinthinus*, and *S. lateralis*.

The capture of more snake species by array and modified pitfalls resulted from the addition of silt fence or aluminum flashing to these trap types. The silt fence of the array and the aluminum flashing of the modified pitfall function as a drift fence. Studies have found drift fences in conjunction with pitfall traps increase the efficiency of arrays (Bury and Corn, 1987). Overall, fewer species of herpetofauna were captured by hand than any other method. Although hand capture produced fewer species, this method provided the only captures of *E. o. obseleta*, *Heterodon platirhinos* (eastern hognose snake), and *Thamnophis s. sirtalis* (eastern garter snake).

Not only did trap type efficiency vary, but the effectiveness of pitfalls in each array varied as well. The center pitfall of the array consistently captured more anurans and lizards than the three outer pitfalls. More anuran species were also caught in the center pitfall. One explanation is that the arms of the array functioned to funnel captures along the drift fence and into the center pitfall more often than the outer pitfalls. This could be due to the dynamics of the center pitfall, position of the array, or the tendency of anurans and lizards to respond similarly when encountering a drift fence. The center pitfall may capture more prey items, which would possibly attract more anuran and lizard captures. The water level in center pitfalls was sometimes higher than in the outside pitfalls so this may have attracted more anurans. Arrays were positioned on level areas and hillsides. Arrays on hillsides could have a funneling effect because captures would tend to move downslope rather than upslope. This pattern would be hard to analyze because there is only one center pitfall for each array. It would have taken three pitfalls in the center of the array, one at the inside angle of each arm, and paired pitfalls on the arm ends to obtain directional patterns for captures. Anurans and lizards may respond similarly when encountering a drift fence but this would also be hard to test. Due to the numerous possible combinations of directions an animal could go when hitting a drift fence, especially with reptiles where most movement seemed to be random, establishing directional trends for anurans and lizards for arrays would be difficult.

Precipitation, Temperature, and Vegetation

Precipitation and temperature are extremely important environmental variables that influence the activity of herpetofuana (Gibbons and Bennet, 1974; Gibbons and Semlitsch, 1981; Bury and Corn, 1987). The majority of captures for this study occurred during the warmer months of the year (April – October) after heavy rains. Increased abundance of amphibians, especially anurans, was a response to heavy spring and summer rains. Many of the captures were postmetamorphic juvenile *Rana* caught migrating from breeding wetlands adjacent to R3C. Salamanders were also captured after periods of rain during the warmer months. Time spent foraging in leaf litter where food is abundant decreases during dry weather (Jaeger, 1980). When the leaf litter is moist, and the threat of desiccation is minimized, salamanders are able to spend more time foraging. Fall, Winter, and early Spring salamander abundance was not high because most traps were not situated close to the mesic stream margins where higher salamander abundance was expected. In addition, Upper Piedmont pine forests without adjacent breeding habitat do not support large numbers of salamanders that exhibit a larval aquatic phase. This is probably why *Plethodon*, which does not exhibit an aquatic larval phase, was the most common salamander captured.

Temperature was likely the most influential variable governing reptile activity. Rainfall could not be correlated to *C. c. coccinea* or *T. coronata* activity in the Coastal Plain (Nelson and Gibbons, 1972; Semlitsch et al., 1981). The same probably holds true for these and other reptile species in the FFSS.

There were treatment effects on vegetation and fuels but correlating these changes to changes in the herpetofaunal community was not possible because fuel reduction treatments had limited effects on herpetofauna. Thinning appears to cause an increase in *A. carolinensis* and *E. fasciatus* abundance and snake richness. Other studies showed that a reduction in basal area has been found to cause an increase in adult skink abundance (McLeod and Gates, 1998) and snake abundance and diversity (Ross et al., 2000). Reducing the basal area, and consequently the canopy coverage, has been found to lower the humidity and increase the temperature of the forest floor microclimate (McLeod and Gates, 1998). These conditions are favorable for reptiles because thinning increases the area available for basking. There was a 22.9% decrease in basal area after the thin treatment, which could explain the increase in lizard abundance and snake diversity. However, this may only be temporary because seedling and vine lifeforms increased after the thin. Over time, vine and seedling cover will increase resulting in a decrease in the amount of light reaching the forest floor, thereby creating unfavorable conditions for reptiles (Perison et al., 1997).

CHAPTER VI

CONCLUSIONS

Prescribed burning and thinning for fuel reduction had minimal effects on herpetofauna in upland pine plantations of the Piedmont. Opening the forest canopy by thinning created favorable conditions for two lizard species (*A. carolinensis* and *E. fasciatus*). Adjacent breeding habitat appears to have influenced the abundance and richness of amphibians in a treatment area more than did prescribed fire and thinning. A variety of sampling methods was tested and provided sufficient data for all taxa. The majority of captures was taken by drift-fence pitfall arrays and modified pitfalls. Both trap types could be used to effectively sample upland forests across the Southeastern Piedmont.

These findings are based on intensive sampling of herpetofauna with a variety of methods, detailed analysis of treatment effects on vegetation and fuels, and knowledge of land use adjacent to treatment plots. Because prescribed burning and timber harvest have been documented as having definite effects on herpetofauna, further post-treatment research should be conducted to expand on the baseline data collected thus far. In future analysis, distinguishing the effects of environmental variables from treatment effects will be difficult but essential.

Disturbance has changed and will continue to change upland Piedmont herpetofuanal communities. Historically, fire shaped many of the plants and animals in the Piedmont landscape. Raising awareness of the importance of prescribed fire will continue to be part of the conservation and management of herpetofauana. Because prescribed burning and timber harvest have been documented as having definite effects on herpetofauna, further post-treatment research should be conducted to expand on the baseline data collected thus far.

APPENDICES

FFSS HERPETOFAUNA DATA SHEET PAGE OF

DATE OBSERVERS TIME: START END

TEMP: CURRENT MAX MIN PRECIP

WEATHER: CLEAR PARTLY CLOUDY CLOUDY RAINING PREV. RAINED

ZONE	TRAP	QTY	SPECIES	ID	SEX	TAIL	SVL	R	E	W	Comments

CODES FOR TRAPS:

P# = PITFALL M# = MODIFIED PITFALL B# = DRIFT FENCE BUCKET

H = HAND CAPTURE N =TURTLE MARGINAL SCUTE NOTCH R=RECAPTURE E=ESCAPE W=WEIGHT

SEX CODES

M = MALE F = FEMALE J = JUVENILE R = RECENT METAMORPH L = LARVAL U = UNKNOWN

Figure A-1. Herpetofauna data sheet used in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Table A-1. Number of captures by species for the overall sampling period from 9 September 2000 - 9 January 2001 in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Caudata	R1B	R1C	R1T	R1TB	R2B	R2C	R2T	R2TB	R3B	R3C	R3T	R3TB	TOTAL
Ambystoma opacum								1					1
Eurycea cirrigera		2	6	2	1				1	2			14
Gyrinophilus porphyriticus dunni		1	2	2									5
Notophthalmus v. viridescens		9	1		1		2	8					21
Plethodon cholorobryonis		3	1	1				1	2		3	4	15
Plethodon metcalfi		6											6
Plethodon teyahalee	1	9	6	1	1	1		1	3		1	22	46
Psuedotriton ruber schencki		2	1	2	1		1			1	2	2	12
Pseudotriton r. ruber		1											1
Abundance	1	33	17	8	4	1	3	11	6	3	6	28	121
Richness	1	7	6	5	4	1	2	4	3	2	3	3	8
Order Anura													
Acris c. crepitans		1						2	1	6(1)	1		11
Bufo americanus		5				1		1	3	2			12
Bufo fowleri	9	7(1)	10	23(1)	14(2)		10(1)	8	7	3(1)	41	7	139
Bufo sp.									1				1
Gastrophryne carolinensis	1	4	1			1	3	9	3	4	4	1	31
Hyla chrysoscelis		1								3	3		7
Pseudacris c. crucifer		2					1	1	1			5	10
Rana catesbieana		2	1	1		1		4	4(1)	24(3)	1	2	40
Rana clamitans melanota							1	5		47(3)			53
Rana sphenocephala							1			2			3
Rana sp.									1	1			2
Abundance	10	22	12	24	14	3	16	30	21	92	50	15	309
Richness	2	7	3	2	1	3	5	7	6	8	5	4	9
Order Testudines													
Kinosternon s. subrubrum									1				1
Terrapene c. carolina	5	11	1	3(1)	4	1	5	7	4	6	7	6	60
Abundance	5	11	1	3	4	1	5	7	5	6	7	6	61
Richness	1	1	1	1	1	1	1	1	2	1	1	1	2

Table A-1 (continued). Number of captures by species for the overall sampling period from 9 September 2000 - 9 January 2001 in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Squamata Suborder Lacertilia	R1B	R1C	R1T	R1TB	R2B	R2C	R2T	R2TB	R3B	R3C	R3T	R3TB	TOTAL
Anolis carolinensis	1	4	13	26(3)	9	3	6	28	9	2	11	12(1)	124
Cnemidophorus s. sexlineatus					4								4
Eumeces fasciatus	5	2	9	11	7(1)	3	10	10(2)	11	8	12(4)	8	96
Eumeces inexpectatus				1		1	2	1	1	1	2		9
Eumeces laticeps			4	1	1	1	2	1		7	4		21
Eumeces sp.				1	1	1	1		1		2	1	8
Sceloporus undulatus hyacinthinus	24	19	46(4)	49(6)	33(2)	15(1)	21	35(2)	34(3)	17	31(4)	12	336
Scincella lateralis		3	10	7	7	7	2	3	4	2	1	2	48
Abundance	30	28	82	96	62	31	44	78	60	37	63	35	646
Richness	3	4	5	6	6	6	6	6	5	6	6	4	7
Suborder Serpentes													
Carphophis a. amoenus	4	3	1	1	2	3	2	9	2	9	8	3	47
Cemphora c. coccinea							1			1			2
Coluber c. constrictor			2		2		1			2		1	8
Diadophis punctatus			1	1	1		1	1			2	2	9
Elaphe o. obseleta		1	1				1						3
Heterodon platirhinos				1									1
Nerodia sipedon				1						1			2
Opheodrys aestivus	1		1										2
Regina septemvittata								1					1
Storeria dekayi							2					1	3
Storeria occipitomaculata		3	1	1	1	1		1	1		3		12
Tantilla coronata	6	6	7	5	3	6	8	5	15	7	13(1)	3	84
Thamnophis s. sirtalis		1											1
Virginia v. valeriae										3	1	1	5
Abundance	11	14	14	10	9	10	16	17	18	23	27	11	180
Richness	3	5	7	6	5	3	7	5	3	6	5	6	14
Total Abundance	57	108	126	141	93	46	85	143	110	161	153	95	1318
Total Richness	10	24	22	21	17	14	22	23	19	23	20	18	40

(#) = number of recaptures

Table A-2. Number of captures by species for the total post-treatment sampling period from 11 April 2001 - 9 January 2002 in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Caudata	R1B	R1C	R1T	R1TB	R2B	R2C	R2T	R2TB	R3B	R3C	R3T	R3TB	TOTAL
Ambystoma opacum								1					1
Eurycea cirrigera		1	6	1									8
Gyrinophilus porphyriticus dunni				1									1
Notophthalmus v. viridescens		6	1		1		2	8					18
Plethodon chlorobryonis		3	1	1				1	2		1	3	12
Plethodon metcalfi		5											5
Plethodon teyahalee	1	8	5	1	1			1	3		1	15	36
Psuedotriton ruber schencki		1	1	2	1		1				2	1	9
Pseudotriton r. ruber		1											1
Abundance	1	25	14	6	3	0	3	11	5	0	4	19	91
Richness	1	6	5	5	3	0	3	4	2	0	3	3	8
Order Anura													
Acris c. crepitans								2	1	6	1		10
Bufo americanus		3				1		1		2			7
Bufo fowleri	8	6	10	23	13		10	8	6	3	41	7	135
Bufo sp.									1				1
Gastrophryne carolinensis	1	4	1			1	4	9	2	4	4	1	31
Hyla chrysoscelis		1								3	3		7
Pseudacris c. crucifer		1					1	1	1			2	6
Rana catesbieana		2	1	1		1		4	4	24		2	39
Rana clamitans melanota							1	5		47			53
Rana sphenocephala							1			2			3
Rana sp.									1	1			2
Abundance	9	17	12	24	13	3	17	30	16	92	49	12	294
Richness	2	6	3	2	1	3	5	7	5	8	4	4	9
Order Testudines													
Kinosternon s. subrubrum									1				1
Terrapene c. carolina	3	7	1	2	4	1	5	7	3	5	6	6	50
Abundance	3	7	1	2	4	1	5	7	4	5	6	6	51
Richness	1	1	1	1	1	1	1	1	2	1	1	1	2

Table A-2 (continued). Number of captures by species for the total post-treatment sampling period from 11 April 2001 - 9 January 2002 in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Squamata **Suborder Lacertilia**	**R1B**	**R1C**	**R1T**	**R1TB**	**R2B**	**R2C**	**R2T**	**R2TB**	**R3B**	**R3C**	**R3T**	**R3TB**	**TOTAL**
Anolis carolinensis	1	2	12	24	8	3	2	20	6	1	8	9	96
Cnemidophorus s. sexlineatus					4								4
Eumeces fasciatus	4	2	13	11	6	3	10	10	11	8	12	8	98
Eumeces inexpectatus				1			2	1	1	1	2		8
Eumeces laticeps				1	1	1	2	1		7	4		17
Eumeces sp.				1		1	1		1		2	1	7
Sceloporus undulatus hyacinthinus	16	16	39	39	25	13	21	34	27	15	23	11	279
Scincella lateralis		3	9	6	5	6	2	1	3	1		2	38
Abundance	21	23	73	83	49	27	40	67	49	33	51	31	547
Richness	3	4	4	6	6	5	6	6	5	6	5	4	7
Suborder Serpentes													
Carphophis a. amoenus	1	3	1	1	1	3	2	9	2	8	7	3	41
Cemphora c. coccinea							1			1			2
Coluber c. constrictor			1		2		1			1		1	6
Diadophis punctatus			1	1	1		1	1			2	2	9
Elaphe o. obseleta		1	1										2
Heterodon platirhinos				1									1
Nerodia sipedon				1						1			2
Opheodrys aestivus	1		1										2
Regina septemvittata								1					1
Storeria dekayi							2					1	3
Storeria occipitomaculata		3	1	1		1					3		9
Tantilla coronata	5	4	7	5	1	6	8	5	15	7	13	3	79
Thamnophis s. sirtalis		1											1
Virginia v. valeriae										3	1	1	5
Abundance	7	12	13	10	5	10	15	16	17	21	26	11	163
Richness	3	5	7	6	4	3	6	4	2	6	5	6	14
Total Abundance	41	84	113	125	74	41	80	131	91	151	136	79	1146
Total Richness	10	22	20	20	15	12	20	22	16	21	18	18	40

Table A-3. Total captures for the pretreatment protocol sampling period in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Caudata	R1B	R1C	R1T	R1TB	R2B	R2C	R2T	R2TB	R3B	R3C	R3T	R3TB	Total
Ambystoma opacum													
Eurycea cirrigera		1											1
Gyrinophilus porphyriticus dunni													
Notophthalmus v. viridescens		3											3
Plethodon chlorobryonis											1		1
Plethodon metcalfi													
Plethodon teyahalee													
Psuedotriton ruber schencki													
Pseudotriton r. ruber													
Abundance		4									1		5
Richness		2									1		2
Order Anura													
Acris c. crepitans													
Bufo americanus													
Bufo fowleri													
Bufo sp.													
Gastrophryne carolinensis													
Hyla chrysoscelis													
Pseudacris c. crucifer													
Rana catesbieana													
Rana clamitans melanota													
Rana sphenocephala													
Rana sp.													
Abundance													
Richness													
Order Testudines													
Kinosternon s. subrubrum													
Terrapene c. carolina	2	2		1									5
Abundance	2	2		1									5
Richness	1	1		1									1

Table A-3 (continued). Total captures for the pretreatment protocol sampling period in the Piedmont Site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Squamata												
Suborder Lacertilia												
Anolis carolinensis				1	1	3	7	1	1		1	15
Cnemidophorus s. sexlineatus												
Eumeces fasciatus	1											1
Eumeces inexpectatus												
Eumeces laticeps												
Eumeces sp.												
Sceloporus undulatus hyacinthinus	5	2	3	3	3			1	2	2		21
Scincella lateralis							1	1	1			3
Abundance	6	2	3	4	4	3	8	3	4	2	1	40
Richness	2	1	1	2	2	1	2	3	3	1	1	4
Suborder Serpentes												
Carphophis a. amoenus	3								1			4
Cemphora c. coccinea												
Coluber c. constrictor			1						1			2
Diadophis punctatus												
Elaphe o. obseleta						1						1
Heterodon platirhinos												
Nerodia sipedon												
Opheodrys aestivus												
Regina septemvittata												
Storeria dekayi												
Storeria occipitomaculata					1							1
Tantilla coronata		1			1							2
Thamnophis s. sirtalis												
Virginia v. valeriae												
Abundance	3	1	1		2	1			2			10
Richness	1	1	1		2	1			2			5
Total Abundance	11	9	4	5	6	4	8	3	6	3	1	60
Total Richness	4	5	2	3	4	2	2	3	5	2	1	13

Table A-4. Total captures of species for the post-treatment protocol sampling period in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Caudata	R1B	R1C	R1T	R1TB	R2B	R2C	R2T	R2TB	R3B	R3C	R3T	R3TB	Total
Ambystoma opacum													
Eurycea cirrigera			2										2
Gyrinophilus porphyriticus dunni													
Notophthalmus v. viridescens		1											1
Plethodon chlorobryonis													
Plethodon metcalfi													
Plethodon teyahalee			1										1
Psuedotriton ruber schencki													
Pseudotriton r. ruber													
Abundance		1	3										4
Richness		1	2										2
Order Anura													
Acris c. crepitans													
Bufo americanus													
Bufo fowleri													
Bufo sp.													
Gastrophryne carolinensis													
Hyla chrysoscelis													
Pseudacris c. crucifer													
Rana catesbieana													
Rana clamitans melanota													
Rana sphenocephala													
Rana sp.													
Abundance													
Richness													
Order Testudines													
Kinosternon s. subrubrum													
Terrapene c. carolina													
Abundance													
Richness													

Table A-4 (continued). Total captures of species for the post-treatment protocol sampling period in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Squamata													
Suborder Lacertilia													
Anolis carolinensis		1					1	2					4
Cnemidophorus s. sexlineatus													
Eumeces fasciatus													
Eumeces inexpectatus													
Eumeces laticeps													
Eumeces sp.													
Sceloporus undulatus hyacinthinus	1		3					1					5
Scincella lateralis			1										1
Abundance	1	1	4				1	3					10
Richness	1	1	2				1	2					3
Suborder Serpentes													
Carphophis a. amoenus													
Cemphora c. coccinea													
Coluber c. constrictor													
Diadophis punctatus													
Elaphe o. obseleta													
Heterodon platirhinos													
Nerodia sipedon													
Opheodrys aestivus													
Regina septemvittata													
Storeria dekayi													
Storeria occipitomaculata		1											1
Tantilla coronata													
Thamnophis s. sirtalis													
Virginia v. valeriae													
Abundance		1											
Richness		1											
Total Abundance	1	3	7				1	3					15
Total Richness													7

Table A-5. Total captures for array, hand, modified, and unmodified trap types in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

	Array B1	Array B2	Array B3	Array B4	Array B1-B4	Hand	Modified	Unmodified	Total
Order Caudata									
Ambystoma opacum							1		1
Eurycea cirrigera	1			3	4		9	1	14
Gyrinophilus porphyriticus dunni							2	3	5
Notophthalmus v. viridescens	7	1	7		15		5	1	21
Plethodon chlorobryonis	3	1		3	7		6	2	15
Plethodon metcalfi							4	2	6
Plethodon teyahalee	8	4	1	11	24		12	10	46
Psuedotriton ruber schencki	2	2	1	4	9		3		12
Pseudotriton r. ruber		1			1				1
Abundance	21	9	9	21	60		42	19	121
Richness	5	5	3	4	5		8	6	8
Order Anura									
Acris c. crepitans				1	1	5	4	1	11
Bufo americanus			1	3	4		7	1	12
Bufo fowleri	3	2	4	19	28	35	59	17	139
Bufo sp.				1	1				1
Gastrophryne carolinensis	2	3	2	11	18		8	5	31
Hyla chrysoscelis						7			7
Pseudacris c. crucifer						9	1		10
Rana catesbieana	3	3	7	8	21		11	8	40
Rana clamitans melanota	4	2	1	20	27		13	13	53
Rana sphenocephala				2	2		1		3
Rana sp.				1	1		1		2
Abundance	12	10	15	66	103	56	105	45	309
Richness	4	4	5	7	7	4	8	6	9
Order Testudines									
Kinosternon s. subrubrum				1	1				1
Terrapene c. carolina			3	3	6	39	11	4	60
Abundance			3	4	7	39	11	4	61
Richness			1	2	2	1	1	1	2

Table A-5. Total captures for array, hand, modified, and unmodified trap types in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Caudata	Array B1	Array B2	Array B3	Array B4	Array B1-B4	Hand	Modified	Unmodified	Total
Ambystoma opacum							1		1
Eurycea cirrigera	1			3	4		9	1	14
Gyrinophilus porphyriticus dunni							2	3	5
Notophthalmus v. viridescens	7	1	7		15		5	1	21
Plethodon chlorobryonis	3	1		3	7		6	2	15
Plethodon metcalfi							4	2	6
Plethodon teyahalee	8	4	1	11	24		12	10	46
Psuedotriton ruber schencki	2	2	1	4	9		3		12
Pseudotriton r. ruber		1			1				1
Abundance	21	9	9	21	60		42	19	121
Richness	5	5	3	4	5		8	6	8
Order Anura									
Acris c. crepitans				1	1	5	4	1	11
Bufo americanus			1	3	4		7	1	12
Bufo fowleri	3	2	4	19	28	35	59	17	139
Bufo sp.				1	1				1
Gastrophryne carolinensis	2	3	2	11	18		8	5	31
Hyla chrysoscelis						7			7
Pseudacris c. crucifer						9	1		10
Rana catesbieana	3	3	7	8	21		11	8	40
Rana clamitans melanota	4	2	1	20	27		13	13	53
Rana sphenocephala				2	2		1		3
Rana sp.				1	1		1		2
Abundance	12	10	15	66	103	56	105	45	309
Richness	4	4	5	7	7	4	8	6	9
Order Testudines									
Kinosternon s. subrubrum				1	1				1
Terrapene c. carolina			3	3	6	39	11	4	60
Abundance			3	4	7	39	11	4	61
Richness			1	2	2	1	1	1	2

Table A-5 (continued). Total captures for array, hand, modified, and unmodified trap types in the Piedmont site of the National Fire and Fire Surrogate Study, Anderson, Oconee, and Pickens Counties, South Carolina.

Order Squamata **Suborder Lacertilia**	Array B1	Array B2	Array B3	Array B4	Array B1-B4	Hand	Modified	Unmodified	Total
Anolis carolinensis	9	6	6	10	31	21	33	39	124
Cnemidophorus s. sexlineatus						1		3	4
Eumeces fasciatus	12	13	10	17	52	1	25	18	96
Eumeces inexpectatus			1	1	2	1	3	3	9
Eumeces laticeps	3	1	2	8	14		6	1	21
Eumeces sp.	1		1	1	3	3	1	1	8
Sceloporus undulatus hyacinthinus	8	8	12	21	49	86	126	75	336
Scincella lateralis	2	3	1	2	8	14	10	16	48
Abundance	35	31	33	60	159	127	204	156	646
Richness	5	5	6	6	6	6	6	7	7
Suborder Serpentes									
Carphophis a. amoenus	9	7	12	6	34	1	3	9	47
Cemphora c. coccinea		2			2				2
Coluber c. constrictor						7	1		8
Diadophis punctatus	2	2	1	1	6		3		9
Elaphe o. obseleta						3			3
Heterodon platirhinos						1			1
Nerodia sipedon				1	1		1		2
Opheodrys aestivus	2				2				2
Regina septemvittata								1	1
Storeria dekayi	2				2			1	3
Storeria occipitomaculata	2			3	5	1	3	3	12
Tantilla coronata	7	12	15	7	41	1	27	15	84
Thamnophis s. sirtalis						1			1
Virginia v. valeriae	1	2	1		4		1		5
Abundance	25	25	29	18	97	15	39	29	180
Richness	7	5	4	5	9	7	7	5	14
Total Abundance	93	75	89	169	426	237	401	253	1317
Total Richness	21	18	19	24	27	18	30	25	40

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