AVIAN AND ARTHROPOD RESPONSES TO FUEL REDUCTION TREATMENTS IN THE UPPER PIEDMONT OF SOUTH CAROLINA

A Thesis

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by

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ABSTRACT

Fire exclusion policies over the last 100 years have increased the amount of fuel in many forested ecosystems throughout the United States. Government agencies, forest managers, and landowners agree these fuels must be treated, but the ecological consequences of various methods are unknown. The Clemson Experimental Forest, located in Clemson, South Carolina, is part of a nationwide investigation (National Fire and Fire Surrogate Study (FFSS)) examining the effects of fuel reduction on many aspects of forest health, including wildlife. Avian and arthropod responses to prescribed burns and thinning were examined.

Upland pine and mixed pine-hardwood bird communities were censused with fixed 50-meter radius point counts during the non-breeding and breeding seasons of 2000-2002. Nest searches were also conducted to assess survival in the treated stands. Winter bird abundance and species evenness (J′) did not change significantly between pre- and post-treatment winter surveys. However, species richness (S_1) increased significantly between years ($p=0.0231$). No differences were found between treatments and the controls for spring avian abundance, richness, or evenness. During the spring censuses, foliage-gleaning and canopy-nesting species were detected significantly more often in thinned ($p=0.0098$) stands than burned or control study areas. Seventy-nine nests (thin, n=30; burn, n=27; control, n=22) were monitored over the two-year study period. Forty-nine percent of the overall nests failed with the most failures occurring in the thinned stands (41%).

Assessment of arthropod resource abundance and richness occurred during the months of May, June, and July of 2001 and 2002. Arthropods were captured using a modified sticky trap placed on the boles of pine and hardwood trees within the study areas. Three classes, Arachnida, Diplopoda, and Insecta, and 24 orders were identified during the two-year sampling period. Arthropod abundance was significantly greater in the burned stands than control or thinned stands for both years (p=0.0975). Arthropod richness was not different across treatments.

DEDICATION

I dedicate this work to my brother, Stephen J. Zebehazy (1969-1999). His belief that I could accomplish anything that I put my mind, heart, and soul into helped carry me through difficult times. I know he would be proud.

ACKNOWLEDGEMENTS

First and foremost, I want to extend my heart-felt gratitude to the chair of my thesis committee, Dr. Drew Lanham. His guidance, patience, wisdom, companionship, and sincerity helped me to accomplish everything that is found on these bound pages. I am proud to say that Dr. Lanham was my advisor, and I know that I will continue to call him a mentor and dear friend. Dr. Tom Waldrop and Dr. Roy Hedden were also instrumental in the planning, implementation, and completion of this thesis research. Their advisement over the course of the past two and one-half years smoothed over the rough spots along the way. Dr. Billy Bridges also deserves mention since his skill and talent in the art of statistics and SAS programming contributed tremendously to the completion of my work.

The contributions of the Forest Service employees involved directly with the National Fire and Fire Surrogate study made so much of my thesis research possible. Their hard work, dedication, and diligence in the implementation of this study, like the establishment of the study areas and vegetation measurements, did not go unnoticed. Ross Phillips deserves special mention since he had the patience to endure my countless questions and requests. Also, Michelle Buckner, Austin Jenkins, Lea Gemmel, and Erek Majka need recognition for their collection and recording of bird and insect data during the hot and humid summer months. I will always be indebted to them.

Also, I want to recognize all of the graduate students of 2000-2002 within the Department of Forest Resources for their support and camaraderie during classes, out in the field, and after hours. My memories of Clemson University will always be infused with good times, hearty laughs, and friendly faces.

Last, but not least, my parents' and sister's constant support and belief in my abilities throughout this endeavor helped keep me moving forward. I know with all my heart that I can always depend on their love, faith, and encouragement.

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CHAPTER I

INTRODUCTION

Since the beginning of the last century, wildfires and prescribed fires (controlled burns) have been suppressed due to governmental policy and societal bias. In the 1940s, the American public was introduced to Smokey Bear with support from the United States Forest Service, the National Advertising Council, and state forestry agencies, and the Smokey Bear program became the most effective advertising campaign in the anti-fire effort (Johnson and Hale 2000). Due to this effort and other fire suppression policies, fuel loads in forests across the United States have reached excessive proportions that make catastrophic wildfire almost inevitable in many regions. In the first nine months of 2002 alone, approximately 64,000 fires burned approximately 2.6 million hectares across the United States, exceeding the previous year's total hectares burned by 1.2 million (USDA Forest Service 2002). Additionally, much of the South, in particular the Piedmont physiographic province, experienced moderate to exceptional drought conditions in 2002, exacerbating wildfire hazard (National Drought Mitigation Center 2002). As of September of 2002, a total of 168,995 hectares burned throughout the Southeast. South Carolina had 3, 565 fires and approximately 12,545 hectares burned (USDA Forest Service 2002).

One way to manage wildfire occurrence is to "fight fire with fire." The use of prescribed fire has grown slowly in popularity since World War II as a management tool to reduce fuel loads (Johnson and Hale 2000). Another application that can be used to mitigate wildfire potential is the mechanical removal of understory and diseased or insect-infected trees from the forested area. Thinning appears to mimic prescribed fire in its reduction of fuel loads by physically removing them from forested areas. However, the ecological, economic, or social impacts of using one fuel reduction technique over the other are not fully understood. In 1999, with support from the USDI-USDA Joint Fire Science Program, a group of scientists and land managers developed a national protocol to research the consequences of using alternative methods like prescribed fire and mechanical removal treatments on fuel and fire behavior, vegetation, wildlife, entomology, pathology, soils and hydrology, utilization and economics, and social science (Fire and Fire Surrogate 2000). Thirteen study sites across the United States are taking part in the National Fire and Fire Surrogate Study (FFSS):

1. Mission Creek, North-Central Washington, Wenatchee National Forest, mixed conifer forest dominated by ponderosa pine and Douglas-fir.

2. Hungry Bob, Blue Mountains of Northeast Oregon, Wallowa-Whitman National Forest, mixed-conifer forest dominated by ponderosa pine and Douglas-fir.

3. Lubrecht Forest, University of Montana, Northern Rockies, Western Montana, mixed-conifer forest dominated by ponderosa pine and Douglas-fir.

4. Southern Cascades, Northern California, Klamath National Forest, mixed-conifer forest dominated by ponderosa pine and white fir.

5. Blodgett Forest Research Station, University of California-Berkeley, Central Sierra Nevada, California, mixed-conifer forest dominated by ponderosa pine with sugar pine, white fir, and Douglas-fir.

6. Sequoia National Park, Southern Sierra Nevada, California (satellite to Blodgett Forest Research Station Site), mixed-conifer forest dominated by old growth ponderosa pine, sugar pine, and white fir.

7. Southwest Plateau, Coconino and Kaibab National Forests, Northern Arizona, ponderosa pine forest.

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9. Ohio Hill Country, lands managed by the Ohio Division of Forestry and Mead Paper Corporation, oak-hickory forest.

10. Southeastern Piedmont, Clemson Experimental Forest, Northwestern South Carolina, Piedmont pine and pine-hardwood forest.

11. Southern Coastal Plain, Myakka River State Park, Southwest Florida, longleaf and slash pine forest.

12. Gulf Coastal Plain, Solon Dixon, Andalusta, Alabama, longleaf pine with loblolly and shortleaf pine forest.

13. Southern Appalachian Mountains, Green River Game Management Area, Polk County, North Carolina, Appalachian hardwood and hardwood-pine type forest.

The FFSS developed three types of fire hazard reduction treatments, plus an untreated control, to apply to forested areas in the 13 sites that were at a high risk of wildfire occurrence. These treatments included a mechanical reduction of fuel, prescribed fire, and a combination of mechanical fuel removal and prescribed fire. This thesis deals specifically with a single application of the treatments to the study sites on the Clemson Experimental Forest, thinning and prescribed fire. The combination treatment (thinning and prescribed fire) study sites were not completed in a timely manner to be included in this thesis. The common objectives of the FFSS were to (taken from the Executive Summary in the final study proposal):

1. Quantify the initial effects (first five years) of fire and fire surrogate treatments on a number of specific core response variables (i.e. fuel and fire behavior, vegetation, wildlife, soils and hydrology, entomology, pathology, utilization and economics, and social science).

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 the 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 research 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 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 United States. Develop and validate models of ecosystem structure and function, and successively refine recommendations for ecosystem management.

Specifically, the main objective of the wildlife component of the FFSS is to assess the impacts that fuel reduction has on the small mammal, herpetafauna, and avian communities found on the treated sites. There is a dearth of information on the impacts of fuel reduction on wildlife and their habitats even though most prescribed burns are applied for the main purpose of fuel hazard reduction or silviculture objectives (Brennan et al. 1998). In the southern landscape, many wildlife species have evolved with lightning-induced fires, as well as Native American and early European settler burning for a myriad of purposes from land clearing for agriculture to flushing of wild game for hunting (Johnson and Hale 2000, Brennan et al. 1998, Landers 1987). The primary purpose of this study is to measure the relationship between fuel reduction techniques and songbird communities that use the mixed pine-hardwood forests of the upper Piedmont of South Carolina. In addition to the avian community, arthropod resource abundance was also assessed because food resource availability is a major determinant of survivability, conditioning, and reproductive potential (Martin 1987). The specific objectives of this study were:

1. To determine the effects of prescribed fire and thinning on breeding and non-breeding passerines by evaluating cause-effect relationships of species abundance, richness, evenness, and nest success.

2. To assess the impacts of the treatments on arthropod resource abundance and richness during the months of May, June, and July.

The null hypotheses tested in this study were:

- Ho_1: Vegetative structure and composition does not differ among treatments.

- Ho_2: Avian and arthropod community composition does not differ in relation to forest structure changes incurred by treatment applications.

- Ho_3: Avian community composition (abundance, richness, evenness) does not differ among treatments.

- Ho_4: Survivability of avian nests does not differ among treatments.

- Ho_5: Arthropod resource abundance and richness does not differ among treatments.

CHAPTER II

LITERATURE REVIEW

Fire suppression, or exclusion, can dramatically alter the composition of a forest ecosystem. In southern pine forests, fire suppresses hardwood growth, removes vegetation, creates gaps in the canopy, and exposes bare soil for pine seed germination (Engstrom et al. 1984, Dickson 1981, Wade and Johansen 1986). With the exclusion of fire in pine stands, the density of sapling hardwoods increases, canopy cover increases, and ground cover decreases (Engstrom et al. 1984, Dickson 1981). Areas of planted pine that reach complete canopy closure are generally thought of as being "ecological deserts" for many species of wildlife until some sort of disturbance occurs either naturally, like fire or wind storms, or as some type of mid-rotation management application, like thinning.

Successional changes in plant species can cause a shift in the bird species that use pine stands once shaped by historically frequent fires. During a fifteen year fire exclusion study in a longleaf pine forest, bird species usually found in open habitat disappeared within five years, shrub-scrub habitat bird species were detected until year nine, and as the hardwood understory continued to develop, more mature mesic forest bird species became more common (Engstrom et al. 1984).

Johnston and Odum (1956) found that breeding bird densities in the Georgia Piedmont increased as the hardwood understory developed in older pine forests. The understory chiefly determined bird species composition of the forest rather than the pine overstory (Johnston and Odum 1956). Another study, focusing on avian density and number of species, found increases in both with the change in ecological succession in northwestern Arkansas with most birds occurring in the intermediate stage versus early or climax stages (Shugart and James 1973). However, Dickson and Segelquist (1979) found bird density and species diversity to be lower in middle-aged pine stands that lacked a developed understory. During the winter, pine forests in the uplands of North Carolina supported higher populations of birds than the deciduous forest, but less than the grasslands (Odum 1947, Johnston and Odum 1956).

Most research in southeastern forests has focused on the effects of even-aged management like clearcutting (Sallabanks et al. 2000, Conner et al. 1979, Yahner 2000, Conner and Adkisson 1975, Strelke and Dickson 1980, Thompson et al. 1992) rather than uneven-aged management. In a recent study, three hardwood reduction techniques, prescribed burning, herbicide application, and mechanical felling-girdling, were applied to longleaf forests in Florida (Provencher et al. 2002). Researchers evaluated breeding bird responses, and detected overall positive responses from red-headed (*Melanerpes erythrocephalus*) and red-cockaded woodpeckers (*Picoides borealis*), brown-headed nuthatches (*Sitta pusilla*), and Bachman's sparrows (*Aimophila aestivalis*); however, decreased detections of eastern tufted titmouse (*Baeolophus bicolor*), northern cardinal (*Cardinalis cardinalis*), and Carolina chickadee (*Poecile carolinensis*) were recorded. Generally, hardwood reduction techniques, in particular felling-girdling, appeared to benefit bird species associated with open canopies or early-successional shrub habitats.

Rodewald and Smith (1998), in a study of uneven-aged management (understory removal or understory/selective cutting treatments) on breeding birds in Arkansas oak-hickory forests, found that understory-nesters, like ovenbirds (*Seiurus aurocapillus*), acadian flycatchers (*Empidonax virescens*), and worm-eating warblers (*Helmitheros vermivora*), were more abundant in mature forests that were left untreated. The canopy-nesting guild was most abundant in forests that had either of the uneven-aged treatments applied. Indigo buntings (*Passerina cyanea*), white-breasted nuthatchs (*Sitta carolinensis*), and eastern wood-pewees (*Contopus virens*) were detected more often in the sites with understory removal and selective cuttings. Understory removal appeared beneficial for some species, in particular canopy-nesters; however, it may have negative impacts on ground/understory-nesters, which comprises a majority of neotropical migrants.

A two-age treatment (similar to a low basal area shelterwood cut), which left 37-49 mature hardwoods/hectare after harvest until the next rotation, benefited edge species, shrub nesters, and ground gleaners in the Monongahela National Forest of West Virginia (Duguay et al. 2000). Overall, songbird abundance did not differ among the two-age treatment and clearcuts, unharvested stands not adjacent to cuts, or unharvested stands adjacent to the treatment areas. The researchers concluded that two-age treatments might be a viable conservation alternative to clearcuts in contiguous forested landscapes.

Unlike uneven-aged management, prescribed fire, or burning, has been researched more often in regards to its effects on songbird communities (Bendell 1974, Conner 1981, Dickson 1981, White et al. 1999, Kreisel and Stein 1999, Stoddard 1963), especially in the southeast. However, due to the variability in the effects of burning on vegetation, definite conclusions on songbird responses are difficult to determine (Dickson 1981). There is a dearth of information available which focuses on prescribed fire and the objective of fuel reduction despite the fact that most burning is used for that specific objective (Brennan et al. 1998, Johnson and Hale 2000).

An Alabama Piedmont study assessing the impacts of cool fires (sparse fuel loading due to yearly burns) and hot fires (heavy fuel loads) on songbirds, determined that canopy-, shrub-, and cavity-nesters were more numerous in the cool burned pine-hardwood forests, and ground-nesters and ground foragers were more abundant on the hot burns due to the presence of bare ground (Stribling and Barron 1995). In another study, abundance of birds that nested on the ground or in shrubs was greater in the unburned areas during both years of the study (Aquilani et al. 2000). A study in mature pine stands in Arkansas Ozarks found that ground-nesting neotropical migrants decreased significantly in the burned stands while shrub-, sub-canopy-, and canopy-nesters did not show a significant change (Salveter et al. 1996).

White and others (1999) compared songbird abundance in prescribed burned and unburned mature (>60 years) pine forests in Georgia. They concluded that 21 species preferred burned sites while six species preferred the unburned sites. Overall, mean abundance estimates were low for most species detected, and species richness and evenness were similar for the unburned and burned stands. Total breeding bird abundance was greater in the pine and pine-hardwood stands of Mississippi after mechanical removal of hardwoods and fires were set on a 2 to 3 year rotation during the growing season than in stands that were burned every 3 to 6 years during the dormant season (Burger et al. 1998). Nine species favored the stands that were treated mechanically and burned while only four favored the burn only treatments. Also, seven of the nine species that preferred the dual treatment were known to be declining while all four of the species that preferred the burned area were relatively common forest interior species (Burger et al. 1998). Winter bird species richness and diversity was greatest in mature pine stands that had been burned periodically (4 to 5 year intervals) and contained a dense understory than in pine plantations or mature upland hardwood tracts in the Georgia Piedmont (White et al. 1996). Finally, a study during the winter in the Piedmont of Georgia found that season of burn had little effect on the composition of the winter bird community (King et al. 1998).

Many studies on the effects of timber management focus on relative abundance or density of avian populations, but those parameters may not be sufficient in detailing the viability of bird populations (Sallabanks et al. 2000, Van Horne 1983, Vickery et al. 1992, Martin 1992). In general, about half of open-cup nests of altricial birds fail in the North Temperate Zone (Nice 1957), so understanding the impacts of forest management on nesting birds is of utmost importance.

Barber and others (2001) examined nesting success, nest predation and cowbird parasitism within regenerating (3-6 years old), mid-rotation (12-15 years old), and thinned (17-23 years old) pine plantations, single-tree selection, and late-rotation pine-hardwood stands in Arkansas. They observed that predation rates were highest in thinned plantations possibly due to a higher proportion of shrub-nesting species, which generally experience higher nest predation (Martin 1993). Bird nests in the thinned plantations probably suffered greater predation rates due to the increased structural diversity, which created more habitat for a greater number of predators such as American crows (*Corvus brachyrhynchos*) and blue jays (*Cyanocitta cristata*) (Barber et al. 2001). Another study found that daily nest survival rates were greatest in unharvested stands than in two-age treatment stands, and that a decrease in daily nest survival rates in the two-age stands may be linked to increased predator activity (Duguay et al. 2000).

In oak stands that were burned in Indiana, nest success was significantly lower in burned stands for ground- and shrub-nesting species, and in all cases but one, nest failure was attributed to predators (Aquilani et al. 2000). Productivity estimates were also lower overall in burned pine forests in Georgia, however the burned stands were preferred for nesting over the unburned sites (White et al. 1999). Predation was cited as the most probable cause of nest failure (White et al. 1999).

Food resource availability is another important issue silvicultural research has ignored. Very little information is available that evaluates the impacts of different treatment applications on arthropod resource abundance (Dickson 1981). Food resource availability is critical in determining wintering bird survivability and reproductive potential for the following breeding season (Anderson et al. 1983, Fretwell 1972), but it can be just as limiting for breeding birds before, during, and after nesting attempts (Martin 1987).

Insects comprise 10% or more of the diet of 44% of the 640 bird species that breed in North America (Jackson 1979a). Arthropod abundance may influence habitat and nest-site selection. In southern Ontario, ovenbirds chose territories in areas of forest with significantly higher prey biomass than what occurred randomly (Burke and Nol 1998). In another study, northern cardinal nest success, fledgling success, and number of young were positively correlated to arthropod biomass within territories (Conner et al. 1986).

Little information exists on the impact of harvest techniques on arthropod abundance, richness, or biomass; however, some studies have shown that silviculture techniques have little to no significant impact (Schowalter 1995, Greenberg and McGrane 1996). Mean total invertebrate biomass and litter-dwelling invertebrates were greater in unharvested stands than clearcuts, and that greater biomass may have been attributable to a more diverse forest structure in the unharvested stands in a study in West Virginia (Duguay et al. 2000). However, Collins et al. (2002) found that arthropod density was greatest in stands of pine that had the hardwood midstory removed.

Unlike mechanical silvicultural techniques, more research exists on prescribed fire effects on arthropods, and most of it has occurred in conjunction with red-cockaded woodpecker management and restoration of longleaf forest ecosystems (Hanula and Franzreb 1998, New and Hanula 1998, Hanula et al. 2000). In general, fire has a short-term effect on arthropod abundance as long as enough time exists between burns for recolonization and to allow vegetation to respond to the burn since many arthropods depend on plants as a food source (Harper et al. 2000, New and Hanula 1998).

CHAPTER III

METHODS

Study Area

Nine study sites were selected within the Clemson Experimental Forest (CEF) in the upper Piedmont of South Carolina. The CEF, originally 12,000 hectares, was purchased in the 1930s under the provisions of the Bankhead-Jones Farm Tenant Act to demonstrate to local landowners and farmers how to manage their lands sustainably after years of abuse (Sorrells 1984). In 1939, the CEF was deeded to Clemson College, so that the natural resources could continue to be maintained, protected, and developed (Sorrels 1984). Presently, 7,100 hectares remain within three South Carolina counties, Anderson, Oconee, and Pickens, in a nearly complete block dissected only by the city of Clemson, Lake Hartwell, and Lake Issaqueena (Figure 1). The CEF's northern parcel resides within the Lower Foothills of the Piedmont Foothills region which have clayey soils that are moderately deep to thin and well-drained (Meyers et al. 1986). The southern portion of the CEF is located in the Interior Plateau of the Midlands Plateau region, and the soils are usually relatively thin and composed mostly of clay (Meyers et al. 1986). The nine sites selected for this study are composed mainly of naturally regenerated and planted pine stands. Pine species include loblolly (*Pinus taeda*), shortleaf (*Pinus echinata*), and Virginia (*Pinus virginiana*) pines. The hardwood component, mainly found in the under- and mid-story, is comprised mostly of various oak species (i. e. *Quercus nigra*, *Q. falcata*, *Q. coccina*, *Q. alba*, *Q. stellata*), sweetgum

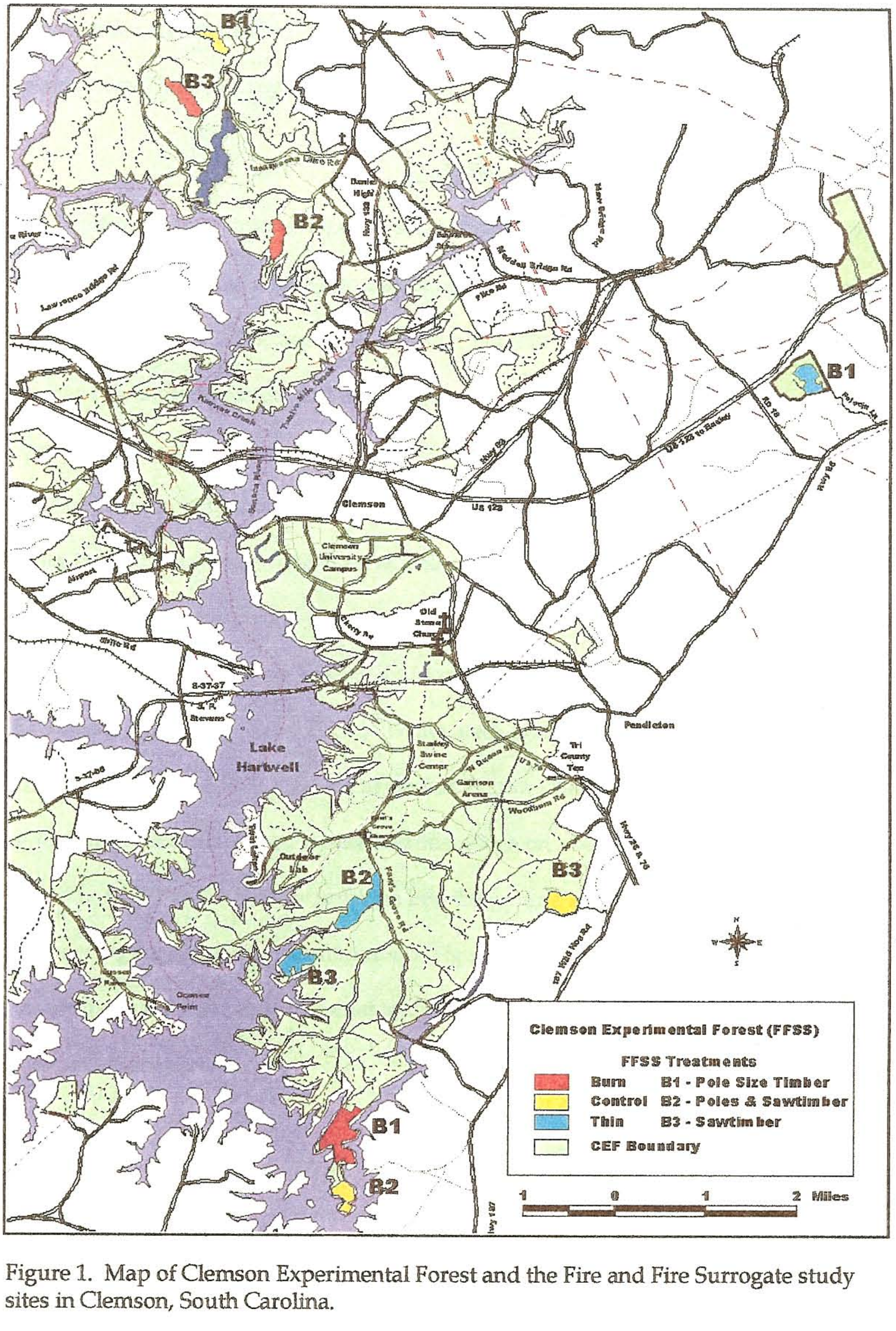

Figure 1. Map of Clemson Experimental Forest and the Fire and Fire Surrogate study sites in Clemson, South Carolina.

(*Liquidambar styrraciflua*), tulip popular (*Liridendron tulipefera*), holly (*Ilex opaca*), persimmon (*Diospyros virginiana*), and blackgum (*Nyssa sylvatica*).

Study Sites

Based upon National Fire and Fire Surrogate protocol (Fire and Fire Surrogate 2000), sites were selected based on size, stand age, and management history. Each site was a minimum of 14 hectares, and comprised of a 10-hectare sample area with a buffer of approximately 20 meters and was judged to be in danger of uncharacteristically severe wildfire due to heavy fuel loads. None of the nine sites had been thinned during the last 10 years or burned (wild or prescribed) in at least 5 years. Stand ages varied from 15 to 60 years so age was used as a blocking factor to reduce variability. Block 1 was comprised of pulpwood-sized trees (dbh (diameter at breast height) 15-25 cm), Block 2 had a mixture of pulpwood- and sawtimber-sized trees, and Block 3 contained sawtimber-sized trees (dbh >25 cm). Within each block, two treatments, prescribe fire or thinning, were randomly assigned as well as an untreated control. Forty permanent grid points were established in each treatment area on a 50-m spacing along cardinal directions. A 1-meter rebar was driven into the ground and affixed with an aluminum number tag for subsequent identification (Figure 2). Grid points were numbered beginning in the northeastern corner and followed a zigzag pattern traveling east and west on alternate rows.

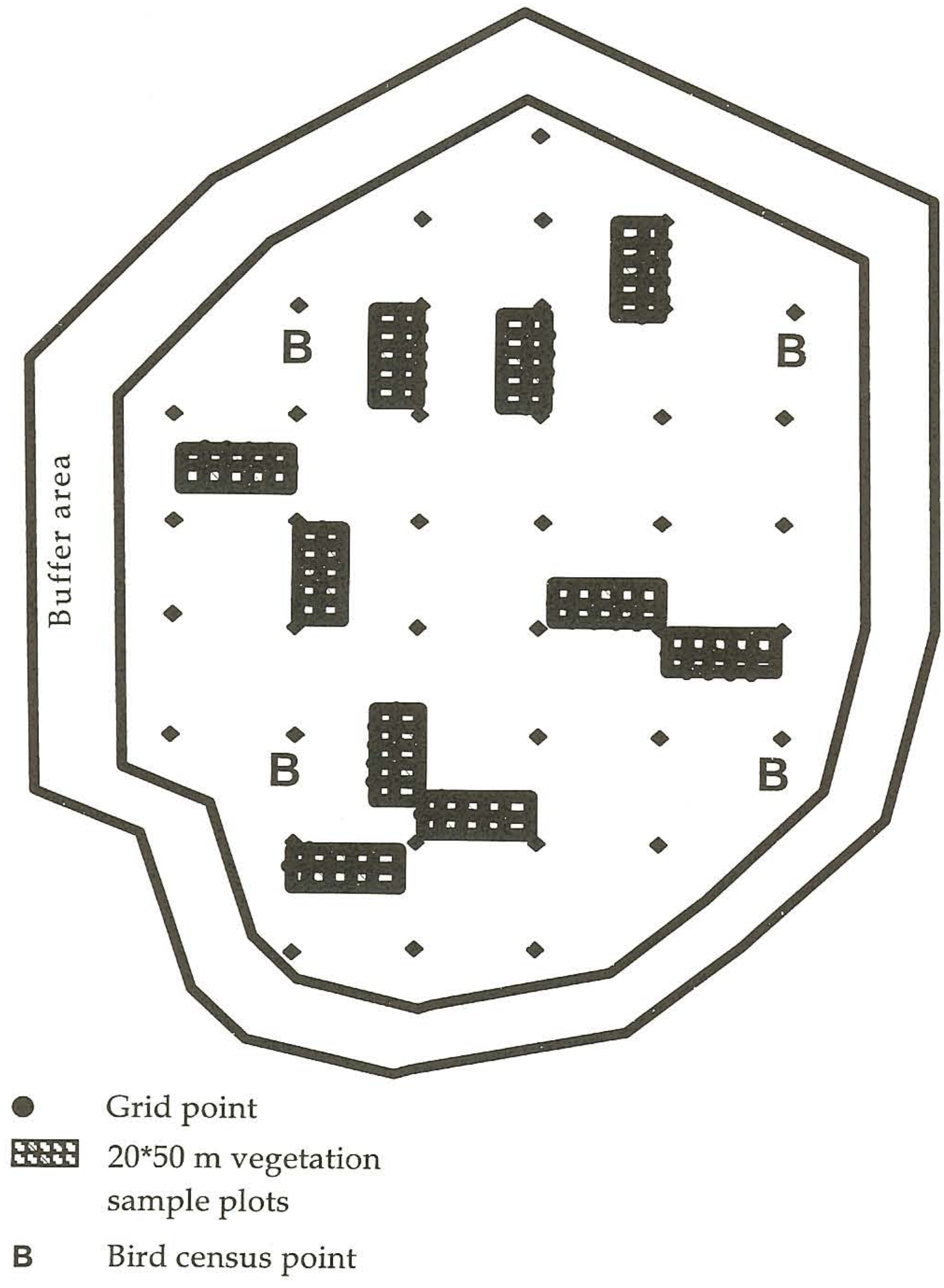

Figure 2. Typical treatment area layout for bird census stations and vegetation data collection on the Fire and Fire Surrogate study sites, Clemson, South Carolina.

Treatments

Prescribed Fire

Prescribed fires were applied to three sites during the spring of 2001. The fires were set and monitored by employees of the Department of Forest Resources at Clemson University, USDA Forest Service (USFS) personnel, and graduate research assistants.

For the burn only treatment, each treatment area was burned as a separate burn unit in April 2001. Block 1 was burned on April 10. 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 hrs along the northeast side to burn into a southwesterly wind. Strip headfires were set in parallel lines approximately 3 to 5 meters apart.

Relative humidity was 51% at the time the fire started and dropped to a low of 42% at 1520 hrs. Temperatures ranged from 22 degrees Celsius (C) at 1230 hrs to 30 degrees C at 1520 hrs. Eye-level wind speeds ranged from 5 to 8 km/hr and were mainly from the southwest. Forest floor samples were collected at 1030 hrs; moisture content was found to be 91% for the duff and 17% for the litter layer (Table 1). Moisture content of 10-hr timelag fuels was 13% at 1030 hrs.

Table 1. Percent moisture content of various fuel components collected one hour prior to ignition in each burn-only treatment area (data provided by the USFS Fire and Fire Surrogate Study crew).

	Block 1	Block 2	Block 3	All Blocks (Average)
Litter	16.55	16.76	12.91	15.45
Duff	91.47	58.77	70.30	73.58
1-hr fuels	12.40	14.29	12.76	13.12
10-hr fuels	12.85	14.83	12.05	13.20
100-hr fuels	27.92	26.73	27.41	27.37
Forbs	197.83	188.55	447.22	307.20
Grasses	59.46	88.07	76.93	69.67
Shrubs	153.79	141.68	105.47	135.32
Vines	94.47	119.71	97.13	100.83

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

Block 3 was burned on April 11, 2001. 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 hrs along the north side to burn into a southerly wind. Flanking fires were set perpendicular to the backing fire; each was approximately 10 meters long. Spot fires were used throughout the burn unit to burn areas not covered by the flanking fires.

Relative humidity was 46% at the time the fire started and remained at that level much of the afternoon. Temperatures ranged from 24 degrees C at 1230 hrs to 29 degrees C at 1515 hrs. Eye-level wind speeds ranged from 4 to 9 km/hr and were mainly from the south. Forest floor samples were collected at 1030 hrs; 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 hrs.

Fire intensity was moderate with flame heights generally between 1 and 2 meters. Heat-sensitive paints showed temperatures ranging from 100 to 200 degrees 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 degrees C. Flames covered the entire burn unit and all burning was completed by 1900 hrs.

Block 2 was burned on April 12, 2001. 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 hrs along the northern side to burn into a southerly wind. Strip headfires were set in parallel lines approximately 3 to 5 meters apart.

Relative humidity was 56% at the time the fire started and dropped to a low of 45% at 1600 hrs. Temperatures ranged from 23 degrees C at 1230 hrs to 29 degrees C at 1545 hrs. Eye-level wind speeds ranged from 5 to 10 km/hr and were mainly from the south. Forest floor samples were collected at 1000 hrs; 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 hrs.

Fire intensity was generally low with flame heights below 1 m. Heat-sensitive paints showed temperatures generally below 150 degrees 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 meter above ground reached as high as 300 degrees C. Flames covered the entire burn unit and all burning was completed by 1600 hrs.

Thinning

Contract loggers conducted thinning between December 2000 and April 2001. Small (<10 cm dbh), merchantable-sized trees and diseased or insect-infected trees were selected first, and further trees were removed to accomplish the objective of reducing basal area to 18 m^2/ha (Table 2). However, Block 1 Thin (B1T) was thinned by rows with operator selection between rows.

Breeding Bird Sampling

Breeding birds were surveyed from 15 April to 15 June 2001 and 2002 using a 50-meter fixed-radius point count method (Ralph et al. 1993). Each treatment area contained three to four point count stations depending on the shape of the treatment area. Points were at least 200 meters apart and at least 100 meters from the treatment boundary. A ten-minute survey was conducted in which every bird heard or seen within a 50-m radius of the census point was recorded. A one to two minute settling period preceded every ten-minute survey in order to limit disturbance before beginning the actual count. Each point was surveyed three times during the 2001 and 2002 breeding seasons. Surveys were conducted in the morning between sunrise and 1000 EST on days with no precipitation and minimal wind velocity (<20 kph) (Ralph et al. 1993). Point count stations and treatment areas were randomly visited and then rotated for subsequent counts to minimize time biases. Birds flying over the canopy were not included in the analysis.

Mean species abundance was calculated for each replicate and treatment as the sum of all birds recorded divided by the number of point count visits, in this case three visits per stand. Species were categorized by foraging and nesting guild assemblages (Appendix 1) (Hamel et al. 1982). Foraging guild assemblages were categorized as follows: a) ground-gleaning, b) foliage-gleaning, c) bark-gleaning, d) hawking, and e) carnivore. Categorization of nesting strategies was as follows: 1) ground/shrub, 2) canopy, and 3) cavity. Both of these guild assemblages represent important life-history traits that clarify habitat utilization for breeding birds.

Species richness indices (S_1; Margalef 1958) were calculated for each replicate and treatment as the sum of species recorded in each replicate and treatment. S_1 is defined by the equation:

$$S_1 = S - 1/\log N$$

where S is the total species count and N is the total number of individuals sampled for each replicate and treatment.

Species evenness (J'; Pielou 1969) was calculated to determine the uniformity of species distribution across replicates and treatments and is defined by the following equation:

$$J' = H'/H'max$$

where H' (Shannon and Wiener 1949) and H' max are:

$$H' = -\sum p_i \ln p_i$$

$$H' max = \log S$$

where p_i is the proportional abundance of the *i*th species and S is the total species count.

Species similarity (C_S; Sorenson 1948) was calculated using Sorenson quantitative C_S index. C_S was calculated for the comparisons burn v. thin, burn v. control, and thin v. control. The Sorenson species similarity index reflects the equitability between two communities in regard to species presence between those communities. C_S is defined by the equation:

$$C_S = 2j/a+b$$

where j is the number of species common to both sites, a is the number of species in site A, and b is the number of species in site B.

Analysis of variance (ANOVA) (PROC GLM; SAS Institute 1996) was used to detect significant differences in variance for avian species abundance, richness, evenness, and foraging and nesting guilds across blocks and treatments. Differences were deemed significant at the p-value of 0.10 for all statistical analyses. An alpha level of 0.10 was used to reduce the probability of committing a Type II error when evaluating relationships between fuel reduction and various response variables. The model statements for ANOVA included some combination of treatment, block, and year. Pairwise t-tests distinguished differences in treatments and blocks and year and treatments. Assumptions of normality and equal variance were carefully assessed, and if log transformations of the data gave the same results as the untransformed data, the untransformed analysis was reported. The Shapiro-Wilk W statistic was used to test for normality and to evaluate unequal variance issues; Levene's Test for Homogeneity of Variance was also performed.

Winter Bird Sampling

Birds were surveyed during the winters of 2000 and 2001 to assess community composition of overwintering individuals. The surveys used the same methodology as the breeding season surveys except each point was visited twice instead of three times. This difference was due to the initiation of thinning during the second round of surveys in the winter of 2000, and two point count stations in Block 2 Thin (B2T) were lost due to their proximity to the thinning operation. All counts were conducted between 15 November and 15 January both years from 0700 to 1100 EST. Winter bird sampling data were calculated using the same analyses as the breeding bird sampling; however, only the foraging guild assemblage was used to categorize the birds detected.

Nest Searching and Monitoring

Monitoring natural nests can help determine the breeding productivity (quality) of a particular habitat unlike counts of bird densities within the same habitat (Van Horne 1983). Nest searches and monitoring took place on the nine study sites from the first week of April until the first week of July during the breeding seasons of 2001 and 2002. Searches were alternated between plots with a maximum of three days between plot visits (Martin and Geupel 1993). The study site area was systematically searched by walking the permanent grid points to determine areas of high bird activity and to observe behavioral cues of parental activity in the form of carrying nesting material or food or visiting a specific area repeatedly (Martin and Geupel 1993, Ralph et al. 1993). Active nests were monitored every 2 to 3 days to record pertinent data like species, location, nesting stage (building, laying, incubation, and nestling), number of eggs or young, and fate of nest. Numbers of eggs or young were only determined on active open-cup nests that were within 4 meters in height using either a compass mirror or a mirror attached to an aluminum pole. Cavity nest contents were not determined since the heights of the entrance of these nests were often too high for searchers to observe. The stage of the cavity nests was determined through binoculars, and as long as there were adults visiting or using the cavity, the nest was considered active (Martin 1992, Jackson 1977). Nest searchers tried to minimize disturbance at nests by observing nests for short periods of time, by approaching the nest from different directions on subsequent visits, flagging nests from a minimum distance of 6 meters, and by leaving no dead end trails at the nest site (Martin and Geupel 1993, Ralph et al. 1993).

Nest success, or survivability, was determined for blocks and treatments by year and between years. Percent of nests fledged or failed was calculated as the sum of successful or failed nests divided by total number of nests by species. Nesting species were categorized by nest substrate assemblage guild: ground- or shrub-nester, canopy-nester, or cavity-nester. Ground- and shrub-nesters were combined due to the minimal number of ground nests found and monitored. To evaluate significant differences between fate of nests and treatments, a count frequency procedure (PROC FREQ; SAS Institute 1996) categorized the data, and then was statistically analyzed using Chi-square analysis.

Vegetation Sampling

In late summer of 2001 and 2002, vegetation sampling was conducted at each nest site and a corresponding random non-use site within after the termination of nest searching and monitoring. Samples were not collected until the termination of the nesting period to minimize disturbance to nesting pairs. When sampling, an 11.3-m radius plot was centered on the nest. The nest substrate species, height (m), dbh (cm), and health (live or dead) were recorded. Actual nest measurements included nest height (m), orientation (degrees), and nest cover (percent). Nest cover was determined by estimating the percent of the nest concealed within a 25-cm sphere. The number and species of shrubs and trees (greater than 1.3 meters in height) was recorded by size class within the 11.3-m radius plot. Individuals were placed in one of 3 size categories: <8 cm dbh, 8-23 cm dbh, or >23 cm dbh. Snags were also identified to species if possible and placed in either a <12 cm or >12 cm size class. Non-use sites were determined by locating the same nest substrate species within 30 meters of the original nest site along the same topographic line. The substrate selected had to resemble the nest substrate as closely as possible in height, dbh, and health. The same methodology for vegetation sampling at the nest site was then conducted around the selected substrate.

PROC FREQ and chi-square were used to compare use and non-use sites by treatment for three species of bird, northern cardinal, blue-gray gnatcatcher (*Polioptila caerulea*), and summer tanager (*Piranga olivacea*), for which the most nests were found.

Collection of vegetation measurements in each of the nine study plots occurred before and after treatment application by USFS employees. All vegetation variables were measured on all, or a portion of, ten 0.1 ha sample plots located systematically throughout each treatment area (Figure 2). Sample plots were established at grid points 2, 6, 10, 14, 18, 22, 26, 30, 34, and 38. Each plot was 50 by 20 meters 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 meters in size.

All trees 10-cm dbh or larger were measured in 5 of the 10 subplots. 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 millimeter. 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. 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 meter 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 an estimate of the percentage of the area covered by shrubs' crowns.

A total of 20, 1-m^2 quadrats 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-meter subplot. All trees <1.4 meter 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 meters 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. The above description of study site vegetation measurements was taken from the Southeastern Piedmont Study Plan with permission from the author (Waldrop 2000).

Arthropod Sampling

Arthropod abundance within each study site was determined with the following technique. Every fourth grid point (#4, 8, 12, 16, 20, 24, 28, 32, 36, and 40) within each treatment area was selected for insect trap sites. The type of tree to be sampled at each site was then determined by pine to hardwood ratios generated from tree data collected by the USFS crew working on the vegetation-sampling component of the national study (Table 3). The pine to hardwood ratios were determined by the number of trees tallied for each tree type in each of the 10 vegetation measurement plots within each treatment area. All size classes were included in the tree type tally. At each randomly selected tree, type of tree (pine or hardwood) and dbh was recorded. The dbh of the trap tree determined the number of sticky traps that would be affixed (1 trap, 7.6-17.8 cm dbh; 2 traps, 17.9-33 cm dbh; 3 traps, >33 cm dbh). The largest trap tree had a dbh of 46 cm. Trap sites were prepared by shaving the bark ridges on the surface of the bole to a width of approximately 25 cm to reduce the chances of insects by-passing the trap by traveling underneath. Modified non-pheromone yellow corn rootworm (*Diabrotica spp.*) sticky traps (28 cm x 23 cm) purchased from Great Lakes IPM were attached using a staple gun and left on the trees for a total of 7 days during each of the months of May, June, and

July of 2001 and 2002. When traps were collected, they were covered with wax paper and kept indoors at room temperature.

Arthropods were identified to taxonomic class for Diplopoda and to taxonomic order in the class Insecta and Arachnida. A micrometer was used to measure length of the arthropods and to place them into one of six size categories: <1 mm, 1-3 mm, 3-5 mm, 5-10 mm, 10-20 mm, or >20 mm. The traps had a 63 square grid (23 cm x 18 cm) embedded into the sticky surface, which was utilized to randomly sample 10 percent of the area to expedite identification. A random number generator was used to determine which square within the grid to sample. Final arthropod numbers were standardized by dividing the number of arthropods captured by the number of traps per trap site. Analyses of arthropod abundance and richness (S_1) were calculated and analyzed statistically using the same indices and analyses as the breeding and winter bird sampling.

Chapter IV

RESULTS

Study Site Vegetation

In general, seedlings, vines, mosses, and ferns decreased in number after burning. Herbs, grasses, shrubs, mosses, ferns, and sedges decreased after thinning. Most of the eight lifeforms (vine, herb, grass, shrub, moss, fern, and sedge) increased in number in the untreated areas (Table 4) (Kilpatrick 2002). Average basal area in the burned study areas was reduced from 24.8 m^2/ha to 18.6 m^2/ha, and basal area was reduced to 21.3 m^2/ha in the thinned study areas (Table 2). The untreated areas experienced a slight reduction in basal area between pre-treatment vegetation sampling in the spring of 2000 and subsequent sampling in the spring of 2001.

Breeding Bird Sampling

Point Count Data

During the spring point counts, 61 species representing 2,746 individuals were detected (Tables 5 & 6). Breeding bird species abundance, richness, and evenness were not significantly different among treatments or blocks for both spring sampling periods combined (Table 7). Between year differences were detected for species abundance ($p=0.0253$) and species richness ($p=0.0965$) (Table 8). Species abundance and species richness generally increased in the burned and control stands between spring 2001 and 2002, however, species abundance stayed the same and species richness decreased slightly in the thinned stands between years.

Table 4. Total number of occurrences of eight vegetation lifeforms per 200 1-m^2 subplots averaged for each treatment at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

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

Table 5. Frequency of occurrence (+/- standard deviation) of individuals detected during the spring of 2001 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	R1B	R1C	R1T	R2B	R2C	R2T	R3B	R3C	R3T	TOTAL
Sharp-shinned hawk *Accipiter striatus*		1.0 (0.0)								1
Northern bobwhite *Colinus virginianus*								1.3 (0.6)		1.3
Wild turkey *Meleagris gallopavo*	0.7 (0.0)	0.7 (0.0)								1.4
Mourning dove *Zenaida macroura*	1.3 (0.6)	0.3 (na)			0.3 (na)	2.7 (0.5)	1.7 (0.5)			6.3
Yellow-billed cuckoo *Coccyzus americanus*	0.3 (na)	1.3 (0.0)	0.3 (na)	0.7 (na)	1.0 (0.0)				1.0 (0.0)	4.6
Red-bellied woodpecker *Melanerpes carolinus*	3.0 (0.5)	1.3 (0.0)		0.7 (0.0)	3.7 (0.5)	2.3 (0.6)	2.3 (0.0)	1.0 (0.0)	5.3 (0.5)	19.6
Downy woodpecker *Picoides pubescens*	0.3 (na)	1.0 (0.0)	1.3 (0.0)	1.0 (0.0)	1.3 (0.6)	1.0 (0.0)			0.7 (0.0)	6.6
Hairy woodpecker *Picoides villosus*	0.3 (na)	0.7 (na)		0.7 (0.0)	0.3 (na)	0.7 (0.0)	1.3 (0.6)	0.7 (0.0)	0.3 (na)	5
Northern flicker *Colaptes auratus*						0.3 (na)	0.3 (na)	0.3 (na)		0.9
Pileated woodpecker *Dryocopus pileatus*			0.3 (na)	0.7 (na)			0.3 (na)	0.3 (na)	2.3 (0.6)	3.9
Eastern wood-pewee *Contopus virens*									0.3 (na)	0.3
Acadian flycatcher *Empidonax virescens*		0.3 (na)								0.3
Great crested flycatcher *Myiarchus crinitus*	1.0 (0.0)	0.7 (0.0)		0.3 (na)	1.3 (0.6)	1.0 (0.7)		0.3 (na)	3.0 (0.5)	7.6
Red-eyed vireo *Vireo olivaceus*	3.7 (0.7)	5.0 (0.5)	6.0 (0.7)	4.3 (0.5)	1.0 (0.0)	3.7 (0.7)	2.7 (0.4)	4.7 (0.7)	7.0 (1.2)	37.8
White-eyed vireo *Vireo griseus*			0.7 (0.0)							0.7
Yellow-throated vireo *Vireo flavifrons*		0.3 (na)	0.3 (na)			0.3 (na)	0.3 (na)			1.2
Blue-headed vireo *Vireo solitarius*	0.3 (na)	0.3 (na)	1.0 (0.7)	1.3 (0.0)		2.0 (0.5)	1.0 (0.7)	1.7 (0.0)	3.7 (0.5)	11.3
Blue jay *Cyanocitta cristata*	1.7 (0.5)	1.3 (0.0)	2.0 (1.0)		9.3 (1.5)	2.0 (0.5)	1.0 (0.7)	2.7 (0.9)	2.7 (0.9)	22.7
American crow *Corvus brachyrhynchos*	2.0 (1.0)	1.3 (0.6)	2.3 (1.0)	1.0 (0.0)	1.0 (0.0)	2.0 (0.6)	0.7 (na)	0.7 (0.0)	0.7 (0.0)	12.7
Eastern tufted titmouse *Baeolophus bicolor*	5.3 (0.8)	2.7 (1.4)	6.0 (1.0)	3.0 (0.5)	8.7 (2.0)	3.7 (0.5)	1.7 (0.0)	3.3 (0.8)	3.7 (0.7)	38.1
Carolina chickadee *Poecile carolinensis*	2.3 (1.0)	2.0 (0.0)	1.0 (0.0)	1.0 (na)	3.7 (1.0)	0.7 (0.0)	2.0 (1.0)	1.3 (0.6)		14
White-breasted nuthatch *Sitta carolinensis*					0.7 (0.0)					0.7
Carolina wren *Thryothorus ludovicianus*	0.7 (na)	0.3 (na)	1.3 (0.0)		2.0 (0.0)	1.3 (0.6)	1.3 (0.0)	2.0 (0.0)	0.3 (na)	9.2
Ruby-crowned kinglet *Regulus calendula*			0.3 (na)							0.3
Blue-gray gnatcatcher *Polioptila caerulea*		1.7 (1.2)	2.0 (0.6)	0.7 (0.0)		1.3 (0.6)	1.0 (0.7)	1.7 (1.2)	0.7 (0.0)	9.1
American robin *Turdus migratorius*	1.0 (0.7)	0.3 (na)	0.3 (na)			0.7 (0.0)				2.3
Wood thrush *Hylocichla mustelina*								0.3 (na)		0.3
Veery *Catharus fuscescens*								0.3 (na)		0.3
Brown thrasher *Toxostoma rufum*	0.7 (0.0)	0.3 (na)	0.7 (0.0)				0.3 (na)			2
Northern parula *Parula americana*			0.7 (na)	0.7 (0.0)						1.4
Cape May warbler *Dendroica tigrina*									0.3 (na)	0.3
Yellow-rumped warbler *Dendroica coronata*									0.7 (na)	0.7
Prairie warbler *Dendroica discolor*			0.3 (na)				2.3 (0.4)			2.6
Pine warbler *Dendroica pinus*	9.7 (1.3)	4.3 (0.7)	1.7 (0.6)	7.3 (0.9)	10.0 (0.8)	13.3 (2.0)	10.0 (1.6)	9.0 (1.3)	9.7 (1.1)	75
Worm-eating warbler *Helmitheros vermivorus*		1.0 (0.0)								1
Ovenbird *Seiurus aurocapillus*						0.7 (0.0)		0.7 (0.0)		1.4

Table 5. Frequency of occurrence (+/- standard deviation) of individuals detected during the spring of 2001 at the Fire and Fire Surrogate study sites, Clemson, South Carolina (Continued).

	R1B	R1C	R1T	R2B	R2C	R2T	R3B	R3C	R3T	TOTAL
Common yellowthroat *Geothlypis trichas*			0.3 (na)							0.3
Hooded warbler *Wilsonia citrina*			0.3 (na)					1.3 (0.6)		1.6
Yellow-breasted chat *Icteria virens*							1.7 (0.5)	0.3 (na)		2
Summer tanager *Piranga rubra*		0.7 (0.0)			1.3 (0.0)	1.3 (0.6)	2.0 (0.6)		3.0 (0.8)	8.3
Scarlet tanager *Piranga olivacea*		0.3 (na)		1.3 (0.0)	0.7 (0.0)	0.7 (0.0)	0.3 (na)	0.7 (0.0)	1.7 (0.0)	5.7
Northern cardinal *Cardinalis cardinalis*	3.0 (0.8)	2.3 (0.6)	5.7 (1.1)	1.3 (0.0)	1.0 (0.0)	2.7 (0.6)	2.0 (0.0)	5.3 (0.8)	0.7 (0.0)	24
Indigo bunting *Passerina cyanea*	0.3 (na)		1.3 (0.6)			0.7 (0.0)	2.7 (0.8)	0.3 (na)	0.3 (na)	5.6
Eastern towhee *Pipilo erythrophthalmus*			2.0 (0.5)				1.7 (0.0)	0.3 (na)	0.3 (na)	4.3
Field sparrow *Spizella pusilla*			0.3 (na)							0.3
Brown-headed cowbird *Molothrus ater*	2.0 (0.5)	2.3 (1.0)	1.7 (0.7)	1.0 (0.0)	0.7 (0.0)	0.7 (0.0)	3.0 (0.6)	2.0 (0.6)	3.7 (1.0)	17.1
Common grackle *Quiscalus quiscula*	0.3 (na)		0.7 (0.0)		0.3 (na)			0.3 (na)		1.6
American goldfinch *Carduelis tristis*	0.7 (0.0)		1.0 (0.7)	0.7 (na)		2.3 (1.5)	1.3 (0.6)			6
Total number of individuals by site	40.7 (1.0)	34.0 (0.7)	42.0 (0.8)	27.7 (0.7)	48.3 (1.2)	48.0 (1.1)	45.0 (0.9)	43.0 (0.9)	52.0 (0.8)	329.8
Total number of species by site	22	26	28	18	19	24	25	26	23	48

Table 6. Frequency of occurrence (+/- standard deviation) of individuals detected during the spring of 2002 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	R1B	R1C	R1T	R2B	R2C	R2T	R3B	R3C	R3T	TOTAL
Sharp-shinned hawk *Accipiter striatus*				0.7 (na)						0.7
Red-shouldered hawk *Buteo lineatus*		0.3 (na)								0.3
Red-tailed hawk *Buteo jamaicensis*					0.7 (0.0)					0.7
Northern bobwhite *Colinus virginianus*				0.3 (na)				3.3 (0.5)		3.6
Wild turkey *Meleagris gallopavo*			0.3 (na)				0.7 (0.0)			1
Mourning dove *Zenaida macroura*	0.7 (0.0)	0.3 (na)		0.3 (na)	3.0 (0.8)	1.3 (0.0)	4.7 (1.2)		0.7 (0.0)	11
Yellow-billed cuckoo *Coccyzus americanus*	0.3 (na)	0.7 (0.0)		0.7 (0.0)	1.0 (0.7)	0.3 (na)	0.3 (na)	0.3 (na)	0.3 (na)	3.9
Great horned owl *Bubo virginianus*							0.3 (na)			0.3
Ruby-throated hummingbird *Archilochus colubris*						0.3 (na)		0.3 (na)		0.6
Red-bellied woodpecker *Melanerpes carolinus*	1.3 (0.6)	1.0 (0.7)		1.0 (0.0)	5.0 (0.5)	2.3 (0.4)	1.3 (0.6)	1.0 (0.0)	0.7 (0.0)	13.6
Downy woodpecker *Picoides pubescens*	1.3 (0.0)	1.0 (0.7)	1.0 (0.0)	2.7 (0.6)	1.0 (0.0)	0.7 (0.0)	1.0 (0.0)	2.3 (0.6)	1.3 (0.0)	12.3
Hairy woodpecker *Picoides villosus*	1.3 (0.6)	0.3 (na)			0.3 (na)	0.7 (na)	1.3 (0.0)	0.3 (na)	0.7 (0.0)	4.9
Northern flicker *Colaptes auratus*			0.3 (na)	0.7 (0.0)		1.0 (0.7)	0.3 (na)			2.3
Pileated woodpecker *Dryocopus pileatus*	0.3 (na)	0.3 (na)			0.3 (na)	2.0 (1.0)	0.7 (0.0)	1.7 (0.5)	1.0 (0.0)	6.3
Eastern wood-pewee *Contopus virens*			0.3 (na)						0.3 (na)	0.6
Acadian flycatcher *Empidonax virescens*		0.3 (na)								0.3
Eastern phoebe *Syornis phoebe*	0.3 (na)				0.3 (na)					0.6
Great crested flycatcher *Myiarchus crinitus*	3.0 (0.5)	1.3 (0.0)		1.3 (0.0)	2.3 (0.6)	2.7 (0.8)	1.0 (0.0)	0.3 (na)		11.9
Red-eyed vireo *Vireo olivaceus*	1.3 (0.6)	6.7 (0.8)	8.3 (1.5)	3.0 (0.8)	2.7 (0.5)	4.3 (0.7)	2.0 (0.5)	4.7 (0.7)	7 7 (0.8)	40.7
White-eyed vireo *Vireo griseus*		0.3 (na)								0.3
Yellow-throated vireo *Vireo flavifrons*		0.7 (0.0)								0.7
Blue-headed vireo *Vireo solitarius*		0.7 (0.0)		1.3 (0.6)		2.3 (1.5)	1.0 (0.0)	1.0 (0.0)	0.7 (0.0)	7
Blue jay *Cyanocitta cristata*	3.0 (1.0)	2.3 (0.5)	1.7 (0.6)	2.7 (1.4)	7.3 (1.8)	0.7 (na)	2.3 (1.0)	3.7 (0.8)	4.3 (1.8)	28
American crow *Corvus brachyrhynchos*	6.3 (1.7)	1.7 (2.1)	1.3 (0.6)	0.7 (0.0)	0.3 (na)	1.0 (0.7)	4.3 (4.9)	0.7 (na)	1.3 (0.0)	17.6
Eastern tufted titmouse *Baeolophus bicolor*	5.0 (2.1)	4.7 (0.7)	2.3 (1.0)	4.0 (0.9)	5.7 (1.2)	3.0 (1.2)	1.3 (0.0)	7.3 (0.9)	5.0 (1.2)	38.3
Carolina chickadee *Poecile carolinensis*	4.3 (1.0)	4.3 (0.9)	2.0 (0.0)	4.3 (1.1)	3.7 (1.0)	1.3 (1.4)	2.3 (0.6)	1.3 (0.6)	1.0 (0.7)	24.5
White-breasted nuthatch *Sitta carolinensis*					0.3 (na)				0.3 (na)	0.6
Brown-headed nuthatch *Sitta pusilla*						0.7 (0.0)	2.0 (1.0)			2.7
Carolina wren *Thryothorus ludovicianus*	5.0 (0.8)		4.0 (1.1)	1.7 (1.2)	2.3 (0.6)	4.3 (0.7)	1.0 (0.0)	1.7 (0.0)	6.0 (1.2)	26
Ruby-crowned kinglet *Regulus calendula*							0.3 (na)			0.3
Blue-gray gnatcatcher *Polioptila caerulea*	1.7 (0.7)	1.3 (0.6)	5.7 (0.8)	3.3 (1.0)	0.3 (na)	1.7 (0.6)	6.3 (1.3)	0.3 (na)	1.0 (na)	21.6
Eastern bluebird *Sialia sialis*				1.0 (0.7)			1.3 (0.6)			2.3
American robin *Turdus migratorius*	0.3 (na)	0.3 (na)	0.3 (na)							0.9
Wood thrush *Hylocichla mustelina*						0.3 (na)				0.3
Brown thrasher *Toxostoma rufum*	0.3 (na)		0.7 (na)	0.3 (na)						1.3
Cedar waxwing *Bombycilla cedrorum*			19.3 (15 .2)					0.3 (na)		19.6

Table 6. Frequency of occurrence (+/- standard deviation) of individuals detected during the spring of 2002 at the Fire and Fire Surrogate study sites, Clemson, South Carolina (Continued).

	R1B	R1C	R1T	R2B	R2C	R2T	R3B	R3C	R3T	TOTAL
Northern parula *Parula americana*			0.7 (0.0)	1.0 (0.0)				0.3 (na)		2
Yellow-rumped warbler *Dendroica coronata*	0.7 (na)				1.0 (0.7)			0.3 (na)		2
Prairie warbler *Dendroica discolor*							3.7 (0.8)			3.7
Pine warbler *Dendroica pinus*	13.0 (1.1)	5.0 (0.8)	2.3 (1.0)	6.7 (0.8)	10.3 (1.1)	18.7 (2.0)	9.3 (0.9)	12.7 (1.5)	13.3 (1.5)	93.3
Yellow-throated warbler *Dendroica dominica*		0.3 (na)			0.3 (na)					0.6
Worm-eating warbler *Helmitheros vermivorus*		0.3 (na)	0.3 (na)							0.6
American redstart *Setophaga ruticilla*						0.7 (0.0)				0.7
Ovenbird *Seiurus aurocapillus*						0.3 (na)				0.3
Hooded warbler *Wilsonia citrina*			0.3 (na)					2.3 (0.4)		2.6
Yellow-breasted chat *Icteria virens*	0.3 (na)						1.0 (0.0)			1.3
Summer tanager *Piranga rubra*	0.3 (na)	1.7 (0.5)		1.0 (0.0)	3.3 (0.5)	1.0 (0.0)	1.0 (0.0)		1.7 (0.6)	10
Scarlet tanager *Piranga olivacea*		0.3 (na)	0.3 (na)				0.3 (na)	0.7 (0.0)	0.3 (na)	1.9
Northern cardinal *Cardinalis cardinalis*	2.7 (0.8)	4.7 (0.7)	5.7 (0.8)	2.7 (1.4)	4.0 (1.3)	3.0 (0.6)	5.0 (1.1)	8.3 (1.4)	3.0 (0.5)	39.1
Rose-breasted grosbeak *Pheucticus ludovicianus*		2.3 (na)								2.3
Indigo bunting *Passerina cyanea*	3.0 (0.4)		1.7 (0.0)	3.0 (0.8)			2.0 (1.0)	0.7 (0.0)	0.7 (0.0)	11.1
Eastern towhee *Pipilo erythrophthalmus*	2.7 (0.4)		2.0 (0.5)				3.0 (0.8)	0.3 (na)		8
Field sparrow *Spizella pusilla*							2.7 (1.3)			2.7
Chipping sparrow *Spizella passerina*	0.3 (na)	0.7 (0.0)			0.7 (0.0)	0.3 (na)	0.3 (na)	1.7 (0.6)	0.7 (0.0)	4.7
Brown-headed cowbird *Molothrus ater*	2.3 (0.5)	1.0 (0.0)	1.0 (0.0)	0.3 (na)	0.3 (na)	4.7 (0.7)	4.0 (0.8)	6.7 (0.8)	2.3 (1.5)	22.6
House finch *Carpodacus mexicanus*							0.3 (na)			0.3
American goldfinch *Carduelis tristis*	0.7 (na)		1.3 (1.4)	2.3 (1.5)		2.7 (0.6)	2.0 (1.0)	0.7 (na)	3.0 (1.0)	12.7
Total number of individuals by site	62.0 (1.3)	45.0 (1.0)	68.3 (4.1)	47.0 (0.9)	56.7 (1.0)	62.3 (1.4)	70.7 (1.2)	65.3 (1.2)	57.3 (1.2)	468
Total number of species by site	27	28	24	25	24	27	34	28	24	57

Table 7. Breeding bird species abundance, richness (S_1), and evenness (J') means and ANOVA p-values for all treatments and blocks for both post-treatment years combined at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Treatments			
	Burn	Control	Thin	p-value
Species abundance	25.16	25.16	25.00	0.9965
Species richness (S_1)	11.17	11.23	10.87	0.9328
Species evenness (J')	2.01	1.94	1.91	0.2451

	Blocks			
	Block 1	Block 2	Block 3	p-value
Species abundance	25.83	22.83	26.66	0.3216
Species richness (S_1)	11.57	10.12	11.56	0.3642
Species evenness (J')	1.95	1.95	1.96	0.9688

Table 8. Comparisons of spring avian species abundance and richness (S_1) means between years at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Treatments		
Species abundance	Burn	Control	Thin
2001	21.66b	23.66b	25.00a
2002	28.66a	26.66a	25.00a
Treatment p-value	0.0029	0.0499	1.0000

	Treatments		
Species richness	Burn	Control	Thin
2001	10.06b	10.87a	11.18a
2002	12.27a	11.58a	10.56a
Treatment p-value	0.0228	0.3112	0.3690

*Values with different letters down columns are significantly different ($p \leq 0.10$).

Foraging and Nesting Guilds

No differences were detected for the bark-gleaners, hawkers, and carnivores within or between years across treatments. Ground-foragers (p=0.0016) and foliage-gleaners (p=0.0139) significantly increased between years. Significant increases were identified for ground-foragers in burned (p=0.0232), control (p=0.0032) and thinned (p=0.0326) stands between years (Table 9). A significant block-treatment interaction existed for ground foragers (p=0.0061) (Table 10). Foliage-gleaners increased significantly in burned (p=0.0460) and control (p=0.0699) stands but not in thinned (p=0.1268) stands. Although not significant, more foliage-gleaners were detected in the thinned stands.

Canopy-nesters were recorded significantly more often in thinned stands than in the control or burned stands (p=0.0143) (Table 11). There were also significantly more canopy-nesters in the spring of 2002 than the spring of 2001 (2001, $\bar{x}$ = 194.67; 2002, $\bar{x}$ = 252.33; p=0.0559). Ground/shrub-nesters demonstrated a significant increase in abundance between the spring of 2001 and 2002 (2001, $\bar{x}$ = 70.667; 2002, $\bar{x}$ = 126.00; p=0.0032). There was no difference between treatments for ground/shrub-nesters although the burned and thinned stands had more individuals than the control stands. No differences were detected for cavity-nesters within or between years across all treatments.

Table 9. Comparisons between spring 2001 and 2002 by treatment for mean number of ground-foragers at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Treatments		
Ground foragers	Burn	Control	Thin
2001	93.0b	77.0b	83.0b
2002	132.0a	146.0a	118.0a
Treatment p-value	0.0232	0.0032	0.0326

*Values with different letters down columns are significantly different ($p \leq 0.10$).

Table 10. Comparisons of mean number of ground-foragers across blocks and treatments for two post-treatment spring sampling periods at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Treatments		
	Burn	Control	Thin
B1	136.50a	130.50a	78.00b
B2	115.50a	48.00b	69.00b
B3	85.50b	156.00a	154.00a

*Values with different letters across rows are significantly different ($p \leq 0.10$).

Table 11. Comparisons of mean number of canopy-nesters among treatments for both post-treatment years combined at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	2001 & 2002 means
Burn	191.50b
Control	211.50b
Thin	267.50a

*Values with different letters down columns are significantly different ($p \leq 0.10$).

When foraging and nesting guilds were combined, birds categorized as foliage-gleaners and canopy-nesters were found significantly more often in thinned stands ($\bar{x}$ = 249.50) then burned ($\bar{x}$ = 169.50) or control ($\bar{x}$ = 196.50) stands (p=0.0098). Foliage-gleaners and canopy-nesters were also significantly more abundant in the spring of 2002 than 2001 (2001, $\bar{x}$ = 177.30; 2002, $\bar{x}$ = 233.00; p=0.0607). For ground-foragers and foliage-gleaners that nest either on the ground or in shrubs there were significantly more individuals detected in the spring of 2002 in both cases (respectively, p=0.0057 and p=0.0175).

Pine warblers, red-eyed vireos, northern cardinals, eastern tufted titmice, and blue jays were the most abundant species recorded during the spring point counts. There was no significant increase or decrease of any of these species between the two spring sample periods.

The thinned and burned stands were most similar in the spring of 2001 (C_S =0.8450) while in the spring of 2002, the most similar stands in species composition became the thinned and control stands (C_S =0.7848) (Table 12).

Nest Success

Seventy-nine nests were discovered and monitored during the springs of 2001 and 2002 (Table 13) (Appendix 2). Out of the 79 nests, 44.3% were successful in fledging young, 49.3% failed due to predation, abandonment, or weather, and 6.4% of the nests' fates were undetermined (Table 14). Fate of nests was not determined by treatment application for either 2001 or 2002 (2001, χ^2=0.4888; 2002, χ^2=0.7703). The thinned areas had more nests discovered in 2001 (14 nests out of 20 total), and more nests were found in the burned areas (25 nests out of 59 total) in 2002. Nests were divided by

Table 12. Comparisons of species similarity (C_S) by sampling period and treatment on the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Treatments		
	Burn v. Thin	Burn v. Control	Control v. Thin
2000 Winter season	0.8421	0.6666	0.7692
2001 Winter season	0.8275	0.7719	0.8000
2001 Breeding season	0.8450	0.8285	0.7532
2002 Breeding season	0.7594	0.7317	0.7848

Table 13. Combined total number of monitored nests and nest survivorship by nesting guild and species in 2001 and 2002 for the Fire and Fire Surrogate study sites, Clemson, South Carolina.

Ground/Shrub nesters	Total #	Completed	Failed	Unknown
Northern cardinal	17	4	11	2
Chuck-wills-widow	3	1	1	1
Wild turkey	4	1	3	0
Indigo bunting	4	3	1	0
Mourning dove	4	0	4	0
Carolina wren	1	0	1	0
	33	27%	64%	9%

Canopy nesters	Total #	Completed	Failed	Unknown
Pine warbler	3	1	2	0
Summer tanager	8	2	4	2
Blue-gray gnatcatcher	11	9	2	0
Blue-headed vireo	3	0	3	0
Sharp-shinned hawk	1	1	0	0
Yellow-billed cuckoo	1	1	0	0
Blue jay	2	1	1	0
Red-eyed vireo	3	1	2	0
Northern parula	1	1	0	0
	33	52%	42%	6%

Cavity nesters	Total #	Completed	Failed	Unknown
Northern flicker	2	0	2	0
Pileated woodpecker	2	2	0	0
Red-bellied woodpecker	3	1	2	0
Hairy woodpecker	2	2	0	0
Eastern tufted titmouse	2	2	0	0
Downy woodpecker	2	2	0	0
	13	69%	31%	0%

Table 14. Number of nests and nest survivorship for treatments by year at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

2001 **Treatments**	Successful	Failed	Unknown	Total
Burn	0	2	0	2
Control	2	1	1	4
Thin	4	6	4	14
Total # of nests	6	9	5	20
Percent	30%	45%	25%	

2002 **Treatments**	Successful	Failed	Unknown	Total
Burn	14	10	1	25
Control	8	9	1	18
Thin	7	9	0	16
Total # of nests	29	28	1	59
Percent	49%	48%	3%	

Table 15. Nest survivorship by nesting guild and species for 2001 and 2002 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

2001

Ground/Shrub nesters

	Total #	Completed	Failed	Unknown
Northern cardinal	5	1	3	1
Chuck-wills-widow	1	0	0	1
Wild turkey	2	0	2	0
	8	25%	50%	25%

Canopy nesters

	Total #	Completed	Failed	Unknown
Pine warbler	1	0	0	1
Summer tanager	3	1	1	1
Blue-gray gnatcatcher	1	0	1	0
Blue-headed vireo	1	0	1	0
Sharp-shinned hawk	1	1	0	0
Yellow-billed cuckoo	1	1	0	0
	8	38%	38%	25%

Cavity nesters

	Total #	Completed	Failed	Unknown
Northern flicker	1	0	1	0
Pileated woodpecker	1	1	0	0
Red-bellied woodpecker	2	0	1	1
	4	25%	50%	25%

Table 15. Nest survivorship by nesting guild and species for 2001 and 2002 at the Fire and Fire Surrogate study sites, Clemson, South Carolina (Continued).

2002

Ground/Shrub nesters

	Total #	Completed	Failed	Unknown
Chuck-wills-widow	2	1	1	0
Indigo bunting	4	3	1	0
Northern cardinal	12	2	9	1
Mourning dove	4	0	4	0
Carolina wren	1	0	1	0
Wild turkey	2	1	1	0
	25	27%	69%	4%

Canopy nesters

	Total #	Completed	Failed	Unknown
Blue jay	2	1	1	0
Blue-headed vireo	2	0	2	0
Blue-gray gnatcatcher	10	9	1	0
Red-eyed vireo	3	1	2	0
Northern parula	1	1	0	0
Summer tanager	5	1	3	1
Pine warbler	2	1	1	0
	25	56%	40%	4%

Cavity nesters

	Total #	Completed	Failed	Unknown
Hairy woodpecker	2	2	0	0
Eastern tufted titmouse	2	2	0	0
Downy woodpecker	2	2	0	0
Northern flicker	1	0	1	0
Pileated woodpecker	1	1	0	0
Red-bellied woodpecker	1	1	0	0
	9	89%	11%	0%

nesting guild to determine nest survivorship. In 2001, canopy-nesters were less successful than ground/shrub- and cavity-nesters (Table 15). In 2002 and overall, cavity-nesters were more successful in completing a nesting attempt than canopy- or ground/shrub-nesters (Table 13 & 15). Except in the spring of 2001, ground/shrub-nesters experienced more failures than the other nesting types.

Northern cardinal, blue-gray gnatcatcher, and summer tanager nests were used to evaluate nest site vegetation differences between random non-use sites by treatment. Northern cardinal nest sites were significantly different from random non-use sites in all treatment types (n= 15; burn, p=0.0003; control, p≤0.0001; thin, p=0.0004). The nests located in the burned plots were found in areas with significantly fewer medium-sized trees (p=0.0850) and small snags (p=0.0042), but with significantly more large snags (p=0.0001). In the thinned stands, northern cardinals located their nests in areas with significantly fewer medium-sized trees (p=0.0176) and large snags (p=0.0160), but with significantly more small snags (p=0.0093). Significantly more of smaller diameter trees and shrubs (p≤0.0001) and significantly fewer smaller diameter snags (p≤0.0001) were located around nests in the control stands than was randomly available.

Blue-gray gnatcatcher nest sites were only significantly different from the non-use sites in the burned stands (n=10; p=0.0178). In the burned stands, blue-gray gnatcatcher nest locations were in areas with more small trees and shrubs (p=0.0051) and small snags (p=0.0148), but with fewer large trees (p=0.0537) than the random non-use sites. In the thinned stands, the only significant difference was that nests were located in areas with more small diameter snags (p=0.0195) than was randomly available. No significant differences were detected in any of the size classes for live or dead trees between nest sites and non-use sites in the control areas.

Summer tanager nest site vegetation was different from the non-use sites in control and thinned stands (n=8; respectively, p≤0.0001 and p=0.0480). No differences were detected in any of the size classes for live or dead trees between nest sites and non-use sites on the burned sites for the summer tanager. However, summer tanager nests were found in areas with significantly more smaller diameter trees and shrubs (p=0.0055) and less medium-sized trees (p=0.0173) than randomly available in the thinned sites. In the control areas, nests were located in areas with significantly more small trees and shrubs (p=0.0002) and less small or large snags (respectively, p=0.0792 and p≤0.0001) than the non-use sites.

In the thinned stands, northern cardinal successful nest vegetation characteristics were significantly different from nests that failed (p=0.0004). Also, blue-gray gnatcatcher successful nests were significantly different in vegetation composition than failed nests in thinned stands (p=0.0387). Summer tanager nest sites were the only ones found with a significant difference in vegetation between failed and successful nests in control stands (p≤0.0001). However, both summer tanager and blue-gray gnatcatcher successful nest sites were significantly different from failed nest sites in the burned stands (respectively, p=0.0007 and p≤0.0001).

Table 16. Frequency of occurrence (+/- standard deviation) of individuals detected during the winter of 2000 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	R1B	R1C	R1T	R2B	R2C	R2T	R3B	R3C	R3T	TOTAL
Belted kingfisher *Ceryle alcyon*					0.5 (na)					0.5
Red-bellied woodpecker *Melanerpes carolinus*	0.5 (na)	1.0 (0.0)	2.0 (0.0)	1.0 (0.0)	0.5 (na)		0.5 (na)	1.5 (0.0)		7
Yellow-bellied sapsucker *Sphyrapicus varius*					0.5 (na)			1.0 (na)	0.5 (na)	2
Downy woodpecker *Picoides pubescens*	0.5 (na)	1.0 (0.0)		0.5 (na)	0.5 (na)			2.0 (0.6)	0.5 (na)	5
Hairy woodpecker *Picoides villosus*		3.5 (0.9)								3.5
Northern flicker *Colaptes auratus*					0.5 (na)					0.5
Pileated woodpecker *Dryocopus pileatus*	0.5 (na)								2.0 (0.0)	2.5
Eastern phoebe *Syornis phoebe*						0.5 (na)	1.0 (0.0)		2.0 (0.6)	3.5
Blue-headed vireo *Vireo solitarius*				1.0 (0.0)						1
Blue jay *Cyanocitta cristata*		2.0 (na)	0.5 (na)	0.5 (na)				1.0 (na)		4
American crow *Corvus brachyrhynchos*	1.0 (0.0)	2.0 (1.4)	0.5 (na)	5.0 (2.5)	1.0 (na)	0.5 (na)	2.0 (0.0)	3.0 (1.3)	5.0 (1.0)	20
Eastern tufted titmouse *Baeolophus bicolor*	1.5 (0.7)	3.0 (0.6)	2.0 (0.6)	1.0 (na)	3.5 (1.0)	1.0 (na)	2.0 (1.4)	3.5 (1.5)	2.5 (na)	20
Carolina chickadee *Poecile carolinensis*	3.0 (1.0)	3.0 (1.0)		6.5 (2.1)	6.0 (1.7)	2.0 (na)	2.0 (1.4)	2.0 (1.4)		24.5
Brown creeper *Certhia americana*	0.5 (na)									0.5
Carolina wren *Thryothorus ludovicianus*	0.5 (na)	0.5 (na)	1.5 (0.0)		1.5 (na)	0.5 (na)	1.5 (0.0)	1.0 (na)		7
Winter wren *Troglodytes troglodytes*	0.5 (na)								0.5 (na)	1
Golden-crowned kinglet *Regulus satrapa*	4.0 (1.4)	13.0 (2.5)	15.5 (3.9)	9.5 (1.8)	6.0 (2.0)	9.0 (1.7)	8.5 (1.1)	15.0 (2.9)	18.0 (4.7)	98.5
Ruby-crowned kinglet *Regulus calendula*	3.0 (0.0)	1.0 (0.0)	1.5 (0.7)	8.0 (1.4)	3.5 (0.5)	2.0 (1.4)	1.5 (0.0)	6.5 (2.2)	1.5 (0.7)	28.5
American robin *Turdus migratorius*		3.0 (0.6)	1.5 (0.7)	3.5 (2.1)	1.0 (0.0)	1.0 (na)	2.0 (na)	4.5 (0.5)	0.5 (na)	17
Hermit thrush *Catharus guttatus*	2.5 (1.2)	0.5 (na)	3.0 (0.5)	5.0 (1.3)			1.0 (0.0)	1.0 (na)		13
Cedar waxwing *Bombycilla cedrorum*		0.5 (na)								0.5
Yellow-rumped warbler *Dendroica coronata*								1.5 (na)		1.5
Pine warbler *Dendroica pinus*		0.5 (na)	1.5 (0.0)		1.0 (0.0)			3.0 (0.6)	0.5 (na)	6.5
Northern cardinal *Cardinalis cardinalis*	0.5 (na)	4.0 (1.2)	1.5 (0.0)		0.5 (na)		2.5 (0.7)	2.0 (0.6)		11
Eastern towhee *Pipilo erythrophthalmus*						0.5 (na)				0.5
American goldfinch *Carduelis tristis*					0.5 (na)		0.5 (na)	0.5 (na)	0.5 (na)	2
Total number of individuals by site	18.5 (2.5)	38.5 (1.5)	31.0 (2.35)	41.5 (1.7)	27.0 (1.3)	17.0 (1.9)	25.0 (1.2)	49.0 (1.9)	34.0 (2.8)	252
Total number of species by site	13	15	11	11	15	9	12	16	12	26

Table 17. Frequency of occurrence (+/- standard deviation) of individuals detected during the winter of 2001 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	R1B	R1C	R1T	R2B	R2C	R2T	R3B	R3C	R3T	TOTAL
Turkey vulture *Cathartes aura*							2.0 (na)			2
Sharp-shinned hawk *Accipiter striatus*									0.5 (na)	0.5
Red-shouldered hawk *Buteo lineatus*			0.5 (na)							0.5
Red-tailed hawk *Buteo jamaicensis*				0.5 (na)						0.5
Mourning dove *Zenaida macroura*			0.5 (na)							0.5
Red-bellied woodpecker *Melanerpes carolinus*	2.0 (0.6)	3.0 (0.6)	0.5 (na)	1.0 (na)	2.0 (0.0)	4.5 (0.8)	1.5 (0.0)	1.0 (0.0)	3.0 (0.5)	18.5
Yellow-bellied sapsucker *Sphyrapicus varius*					0.5 (na)					0.5
Downy woodpecker *Picoides pubescens*	1.0 (0.0)	1.5 (1.0)	3.5 (1.0)	2.5 (0.5)	1.0 (0.0)	2.0 (0.6)	4.5 (0.6)	0.5 (na)	2.0 (0.6)	18.5
Hairy woodpecker *Picoides villosus*							1.0 (0.0)			1
Northern flicker *Colaptes auratus*	0.5 (na)	0.5 (na)	1.0 (0.0)			3.0 (0.6)	1.5 (0.7)	0.5 (na)		7
Pileated woodpecker *Dryocopus pileatus*	0.5 (na)		0.5 (na)			0.5 (na)		0.5 (na)	1.5 (0.0)	3.5
Eastern phoebe *Syornis phoebe*		2.0 (0.6)		0.5 (na)	1.0 (0.0)	2.0 (0.0)	3.0 (1.0)		0.5 (na)	9
Blue-headed vireo *Vireo solitarius*		0.5 (na)				2.0 (0.6)	0.5 (na)			3
Blue jay *Cyanocitta cristata*	0.5 (na)		1.0 (0.0)	1.5 (0.7)		0.5 (na)		2.0 (0.6)	1.5 (0.7)	7
American crow *Corvus brachyrhynchos*	4.5 (2.1)	1.0 (0.0)	1.0 (na)	1.0 (na)		1.5 (0.7)	3.5 (1.5)	3.5 (1.3)	1.5 (0.7)	17.5
Eastern tufted titmouse *Baeolophus bicolor*	3.0 (1.1)	2.0 (1.4)	4.0 (1.5)	1.0 (0.0)	3.0 (0.0)	8.0 (1.2)	2.0 (0.0)	3.5 (1.0)	2.5 (1.3)	29
Carolina chickadee *Poecile carolinensis*	5.5 (1.0)	6.0 (2.7)		1.5 (0.7)	4.0 (1.8)	3.0 (0.8)	1.5 (na)	4.5 (1.1)	1.5 (na)	27.5
Red-breasted nuthatch *Sitta canadensis*		0.5 (na)				1.0 (na)				1.5
White-breasted nuthatch *Sitta carolinensis*	0.5 (na)						1.0 (0.0)	1.0 (0.0)		2.5
Brown-headed nuthatch *Sitta pusilla*						1.0 (na)	0.5 (na)			1.5
Brown creeper *Certhia americana*		0.5 (na)								0.5
Carolina wren *Thryothorus ludovicianus*	4.0 (0.9)	1.0 (na)	1.5 (0.0)	2.5 (1.2)	2.5 (1.2)	5.5 (0.8)	2.0 (0.6)	2.0 (0.6)	6.0 (1.0)	27
Winter wren *Troglodytes troglodytes*			0.5 (na)				1.5 (0.0)		1.0 (0.0)	3
Golden-crowned kinglet *Regulus satrapa*	6.5 (1.8)	8.5 (1.1)	7.0 (2.2)	6.0 (0.8)	12.5 (2.6)	12.0 (1.9)	1.5 (1.0)	14.0 (0.8)	10.5 (1.4)	78.5
Ruby-crowned kinglet *Regulus calendula*	3.5 (0.5)	0.5 (na)	1.5 (0.0)	0.5 (na)	3.0 (1.0)	7.5 (1.6)	2.0 (0.8)	5.5 (0.8)	2.5 (0.5)	26.5
Eastern bluebird *Sialia sialis*		0.5 (na)	0.5 (na)				1.0 (na)	0.5 (na)		2.5
American robin *Turdus migratorius*		0.5 (na)	0.5 (na)	0.5 (na)		1.0 (0.0)	4.5 (1.3)	6.5 (3.0)	0.5 (na)	14
Hermit thrush *Catharus guttatus*	2.5 (1.2)	2.5 (1.2)	2.5 (0.6)	2.0 (1.4)	1.0 (na)	9.0 (1.5)	1.5 (na)	3.5 (1.2)	0.5 (na)	25
Cedar waxwing *Bombycilla cedrorum*	0.5 (na)							1.0 (na)	0.5 (na)	2
Yellow-rumped warbler *Dendroica coronata*		1.0 (na)								1
Pine warbler *Dendroica pinus*	1.5 (0.7)	2.5 (0.6)	2.0 (0.8)	0.5 (na)	3.0 (1.0)	14.5 (1.5)	7.0 (1.5)	6.5 (1.4)	5.5 (1.1)	43
Northern cardinal *Cardinalis cardinalis*	0.5 (na)		1.0 (0.0)			0.5 (na)	0.5 (na)	3.0 (0.8)		5.5
Eastern towhee *Pipilo erythrophthalmus*	0.5 (na)		1.0 (na)	0.5 (na)			0.5 (na)	1.0 (na)		3.5
Savannah sparrow *Passerculus sandwichensis*	2.5 (na)									2.5
White-throated sparrow *Zonotrichia albicollis*							0.5 (na)			0.5
Dark-eyed junco *Junco hyemalis*	6.0 (3.6)		1.0 (na)	0.5 (na)		10.0 (7.4)	5.0 (na)			22.5

Table 17. Frequency of occurrence (+/- standard deviation) of individuals detected during the winter of 2001 at the Fire and Fire Surrogate study sites, Clemson, South Carolina (Continued).

	R1B	R1C	R1T	R2B	R2C	R2T	R3B	R3C	R3T	TOTAL
House finch *Carpodacus mexicanus*		0.5 (na)								0.5
American goldfinch *Carduelis tristis*	0.5 (na)					0.5 (na)	1.0 (na)	1.0 (0.0)		3
Total number of individuals by site	46.5 (1.6)	35.0 (1.3)	31.5 (1.2)	22.5 (0.9)	33.5 (1.7)	89.5 (2.1)	51.5 (1.5)	61.5 (1.5)	41.5 (1.0)	340.5
Total number of species by site	20	19	20	16	11	21	24	20	17	38

Table 18. Comparisons of mean avian species abundance, richness (S_1), and evenness (J') by treatment for pre- and post-treatment winters at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Treatments		
	Burn	Control	Thin
Winter season			
2000-Pre-treatment			
Species abundance	56.60a	77.00a	54.60a
Species richness (S_1)	6.46ab	7.66a	5.60b
Species evenness (J')	2.14a	1.93a	1.64b
2001-Post-treatment			
Species abundance	79.60a	86.60a	108.30a
Species richness (S_1)	10.10a	8.13a	9.26a
Species evenness (J')	2.05a	1.91a	1.98a

*Values with different letters are significant across rows ($p \leq 0.10$).

Winter Bird Sampling

Point Count Data

A total of 39 species and 1,399 individuals was detected during the winter point counts (Tables 16 & 17). Winter bird species abundance was not significantly different within or between winters across treatments. However, species richness (p=0.0955) and species evenness (p=0.0344) were significantly different among treatments in the pre-treatment winter and not in post-treatment winter (Table 18). Between year differences were detected for species richness (p=0.0231) but not for species evenness (p=0.2408) (Table 19).

Foraging Guilds

There was no significant difference in abundance between treatments in pre-treatment or post-treatment winters for any of the foraging guilds except bark-gleaners who were significantly more abundant (p=0.0994) in the control stands before treatments were applied. A significant increase in bark-gleaners (p=0.0510) was detected in the thinned stands after treatment.

Golden-crowned kinglets, ruby-crowned kinglets, Carolina chickadees, eastern tufted titmice, and American crows were the most abundant species detected during the pre-treatment winter point counts. In the post-treatment winter point counts the most abundant species shifted to include pine warblers and Carolina wrens. Golden-crowned kinglets decreased significantly between 2000 and 2001 (p=0.0003) while Carolina wrens and pine warblers increased significantly (respectively, p=0.0028 and p≤0.0001) (Figure 3).

Table 19. Comparisons of mean avian species richness (S_1) and evenness (J') between pre- and post-treatment winters at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Treatments		
Species richness	Burn	Control	Thin
Pre-treatment	6.46b	7.66a	5.60b
Post-treatment	10.10a	8.13a	9.26a

	Treatments		
Species evenness	Burn	Control	Thin
Pre-treatment	2.14a	1.93a	1.64b
Post-treatment	2.05a	1.91a	1.98a

*Values with different letters down columns are significantly different ($p \leq 0.10$).

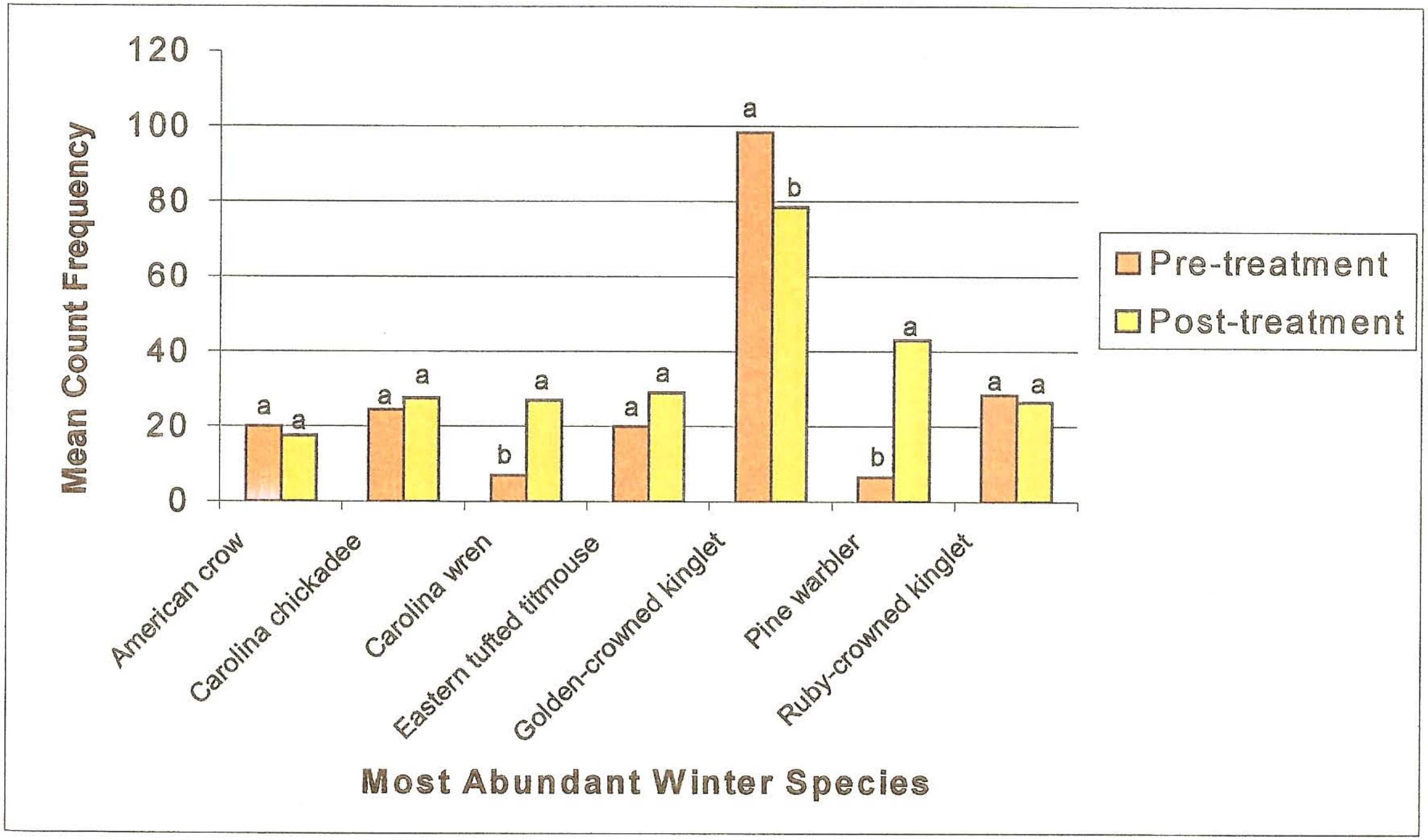

Figure 3. Comparisons between pre-treatment and post-treatment winters of the most abundant species detected at the Fire and Fire Surrogate study sites, Clemson, South Carolina. Columns with different letters for each species grouping are significantly different ($p \leq 0.10$).

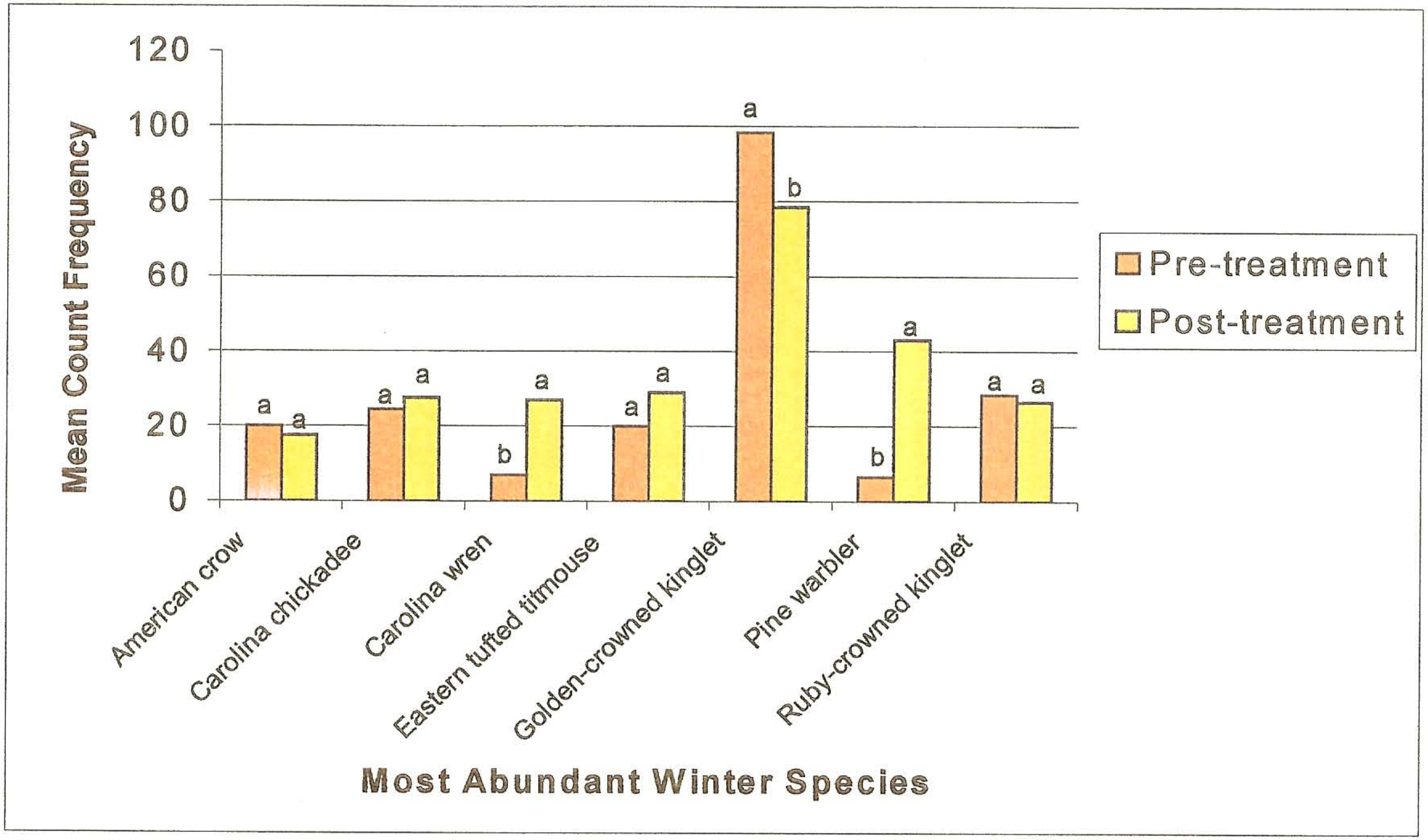

Figure 3. Comparisons between pre-treatment and post-treatment winters of the most abundant species detected at the Fire and Fire Surrogate study sites, Clemson, South Carolina. Columns with different letters for each species grouping are significantly different ($p \leq 0.10$).

In the winter before treatments were applied, the stands selected for burning and thinning were the most similar (S =0.8421) in composition while the burn and control stands were the most dissimilar (S =0.6666). These remained the cases after treatment application with the burned and thinned stands most similar (S =0.8421) and the burned and control stands the least similar (S =0.7719) (Table 12).

Arthropod Sampling

Three classes, Arachnida, Diplopoda, and Insecta, and 24 orders were identified during the two-year sampling period (Table 20). Coleoptera, Collembola, Diptera, Homoptera, Hymenoptera, and Thysanoptera were the most abundant orders (Table 21). Arthropod abundance (total number of arthropods/number of traps) was significantly greater in the burned ($\bar{x}$ = 803.22) stands than control ($\bar{x}$ = 283.06) or thinned ($\bar{x}$ = 441.05) stands for both years (p=0.0975). Abundance was greater in the spring of 2001 versus 2002 (2001, $\bar{x}$ = 615.57; 2002, $\bar{x}$ = 402.65; p=0.0111). In July of 2001, arthropod abundance decreased significantly from the numbers captured in May (p=0.0594) and June (p=0.0549). Significantly less arthropods were captured in May (p=0.0119) and June (p=0.0399) of 2002 than the same months the previous year (Table 22). There were no differences detected across treatments between the months of May, June, and July (p=0.2226).

Arthropod richness was not different across treatments within years (Table 23) or for combined years (p=0.2154). Significant differences were detected across months between the years of 2001 and 2002 (p=0.0003) (Table 22). For the month of May, arthropod richness increased significantly between 2001 and 2002 (2001, $\bar{x}$ = 2.16; 2002, $\bar{x}$ = 3.45; p=0.0005), however arthropod richness decreased significantly between years for the month of July (2001, $\bar{x}$ = 3.86; 2002, $\bar{x}$ = 2.87; p=0.0044).

Table 20. Standardized (total number of arthropods/number of traps) arthropod abundance by order across treatments for 2001 and 2002 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	2001			**Total for**	2002			**Total for**
Order	Burn	Control	Thin	**2001**	Burn	Control	Thin	**2002**
Araneae	13.26	38.96	29.95	82.17	24.10	19.13	23.83	67.06
Acari	4.00	13.63	10.10	27.73	0.00	0.00	0.00	0.00
Phalangida	0.00	0.50	0.00	0.50	1.00	1.80	3.50	6.30
Diplopoda (class)	0.50	1.00	0.00	1.50	0.00	3.00	1.50	4.50
Anoplura	0.00	0.00	0.00	0.00	4.00	6.20	2.10	12.30
Coleoptera	350.61	272.51	284.80	907.92	239.02	222.66	184.39	646.07
Collembola	29.16	24.83	80.30	134.29	603.33	46.85	678.43	1328.61
Dermaptera	0.00	0.00	0.50	0.50	0.50	0.50	0.00	1.00
Diptera	8370.05	2147.45	3420.99	13938.49	1003.6	880.29	1036.23	2920.12
Ephemeroptera	2.00	2.46	4.50	8.96	0.50	0.00	0.00	0.50
Hemiptera	2.80	2.00	2.00	6.80	0.00	1.00	1.50	2.50
Homoptera	115.56	28.66	48.52	192.74	195.55	133.55	165.82	494.92
Hymenoptera	176.36	214.41	180.56	571.33	197.53	201.70	187.90	587.13
Isoptera	0.50	7.50	6.30	14.30	10.10	1.50	3.83	15.43
Lepidoptera	0.00	0.00	0.50	0.50	0.50	0.50	1.00	2.00
Mallophaga	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00
Mecoptera	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
Neuroptera	9.16	23.78	7.83	40.77	0.50	1.00	1.00	2.50
Orthoptera	7.50	3.63	8.63	19.76	4.00	3.40	2.00	9.40
Plecoptera	2.50	0.83	4.00	7.33	0.00	0.00	0.00	0.00
Psocoptera	1.30	1.80	3.83	6.93	0.00	0.00	0.00	0.00
Siphonaptera	0.00	0.30	0.00	0.30	0.00	0.00	0.00	0.00
Thysanura	1.00	1.50	0.50	3.00	0.00	0.50	0.00	0.50
Thysanoptera	597.50	42.30	0.00	639.80	2482.10	739.14	1549.49	4770.73
Trichoptera	5.50	2.10	3.12	10.72	1.00	0.00	0.00	1.00
	9690.3	2831.2	4096.9	16618.3	4767.3	2262.7	3843.5	10873.6

Table 21. Arthropod taxa sampled from the boles of pines and hardwoods during the summer of 2001 and 2002 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

Class	Order	Common name
Archnida	Araneae	Spiders
	Acari	Mites
	Phalangida	Daddy-long-legs
Diplopoda		Millipedes
Insecta	Anoplura	Sucking lice
	Coleoptera	Beetles
	Collembola	Springtails
	Dermaptera	Earwigs
	Diptera	Flies
	Ephemeroptera	Mayflies
	Hemiptera	True bugs
	Homoptera	Cicadas, hoppers, and aphids
	Hymenoptera	Ants, bees, and wasps
	Isoptera	Termites
	Lepidoptera	Butterflies and moths
	Mallophaga	Chewing lice
	Mecoptera	Scorpianflies
	Neuroptera	Net-winged insects
	Orthoptera	Grasshoppers and roaches
	Plecoptera	Stoneflies
	Psocoptera	Barklice
	Siphonaptera	Fleas
	Thysanura	Silverfish
	Thysanoptera	Thrips
	Trichoptera	Caddisflies

Table 22. Comparison of mean arthropod abundance and richness (S_1) across months sampled between 2001 and 2002 at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

Arthropod abundance	May	June	July
2001	706.85a	701.57a	438.28a
2002	417.38b	337.12b	453.45a

Arthropod richness	May	June	July
2001	2.16b	3.12a	3.86a
2002	3.45a	2.95a	2.87b

*Values with different letters down columns are significantly different ($p \leq 0.10$).

Table 23. Comparisons of mean arthropod richness (S_1) across treatments and years at the Fire and Fire Surrogate study sites, Clemson, South Carolina.

	Burn	Control	Thin	Treatment p-value
2001	2.72	3.40	3.00	0.2875
2002	2.94	3.41	2.93	0.4334

CHAPTER V

DISCUSSION

Breeding Birds

Point Counts

The increase in breeding bird abundance in the burned stands in 2002 may be attributed to the diversification of the forest structure over time. In the spring of 2001, point counts occurred in less than two weeks after the burns were applied. The burned stands experienced a major reduction of the understory and a thinning of the midstory, so those stands were very open underneath with very little understory vegetation present. By the spring of 2002, many of the plants in the understory responded to the fire by initiating stump sprouts, which increased the density of vegetation one year following the fires. The increase in abundance in the control sites may be attributed to either natural fluctuations in populations or to southern pine beetle, which altered the layers of vegetation by decreasing canopy cover from overstory pines. No change in abundance occurred between years for the thinned stands, which may be because the vegetation response to the thin treatment was not as dramatic as to the prescribed fire.

Not surprisingly, when abundance was low in the burned stands so was species richness. Between the spring of 2001 and 2002, species richness increased significantly in the burned plots, which may, again, be attributed to the diversification of the habitat. There were slight changes in richness for both the control and thin stands with a minimal increase in the control sites and an insignificant decrease in the thinned stands.

Stands were blocked by tree age, and there was a significant interaction between blocks and treatments for species abundance, richness, and evenness. The nuances of the interaction are hard to tease out with values for all indices changing depending on age of trees and treatment type. The inconsistencies detected may contribute to the reason that treatment effect for all three indices proved insignificant.

Foraging and Nesting Guilds

Ground-foragers, including brown thrashers, Carolina wrens, eastern towhees, mourning doves, northern cardinals, wild turkeys, and others, increased in all treatment types and in the untreated stands between 2001 and 2002. In the burned sites, bare ground appeared to increase and the thick shrub layer was reduced but not completely eliminated. This diversification created more foraging areas plus retained important cover from predators. The thinned stands also had some bare ground present along skid trails and landings, and coarse woody debris from the thinning operation was usually dispersed across the stands with intermittent piles of logging slash left near landings (Waldrop 2000 and personal observation). Coarse woody debris acts as cover and as foraging sites for birds like the Carolina wren (Haggerty and Morton 1995). Significant interactions were detected between tree density and treatments for ground-foragers. Ground-foragers were consistently more abundant in the burn treatments in the pole-sized (Block 1) and intermediate-sized (Block 2) timber blocks, but in the sawtimber-sized (Block 3) tree stands abundance shifted to be greatest in the thin and control sites.

Abundances of foliage-gleaners like blue-gray gnatcatchers, blue-headed vireos, Carolina chickadees, eastern tufted titmice, indigo buntings, pine warblers, and summer tanagers, increased significantly between 2001 and 2002. Significant increases occurred in the burned and control stands, but not in the thinned stands. Overall, foliage-gleaners were more abundant in the thinned areas, but the less dramatic response of the vegetation to the thinning application may explain the stability in abundance between the two springs. The increase in the burned stands probably is related to vegetation responses, and the increase in the control areas may again be attributed to population fluctuations and southern pine beetle impacts.

Surprisingly, bark-gleaners or hawkers (species that fly out from perches to capture prey) did not show any significant changes over the two-year study. Both the burn and thin treatments decreased the overstory canopy creating more open areas for hawkers to forage. It is known that burning forests can reduce snag density if fires burn too hot, but, in general, burning increases snag densities even if only short-term (Conner 1981). We expected a positive response by bark-gleaners due to the presumed increase in snags, but an undetectable change in abundance only indicates that thinning and burning did not impact their foraging substrate in this particular study.

Canopy-nesters, like blue-gray gnatcatchers, summer tanagers, and yellow-billed cuckoos, increased between years, and they were found more often in the thinned stands. There was not a significant response detected in the burned areas, which agrees with Salveter and others (1996). The increase in abundance for canopy-nesters can be attributed to the opening of the canopy and vegetation response to the thinning operation. Ground/shrub-nesters (i.e. brown thrasher, eastern towhee, hooded warbler, and prairie warbler) also increased between years, but no significant differences were detected across the treatments. There was a significant interaction between blocks and treatments for ground/shrub-nesters. The thin treatments of Block 1 and Block 2 supported greater numbers than the burns or controls, but, in Block 3, the burned stand supported the most ground/shrub-nesters. Stribling and Barron (1995) found that ground-nesters were more abundant in forests with open ground due to the effects of prescribed fires that burned hot and destroyed much of the under- and mid-story. Vegetation in Block 3 Burn responded vigorously to the burn treatment with accelerated stump sprout growth as well as retaining bare patches of ground, but, also, the stand itself was adjacent to a cutover area that may have contributed to its colonization by ground/shrub-nesters. Cavity-nesters were not affected which may indicate that they were not limited in nesting sites by the treatments.

Bird species categorized as foliage-gleaners and canopy-nesters (i.e. summer tanager, red-eyed vireo, pine warbler, and northern parula) increased over time and were found more often in the thinned plots, which may be attributed to the diversification of the forest canopy due to the removal of some trees. Ground-foragers and foliage-gleaners that nest either on the ground or in shrubs increased between the spring of 2001 and 2002; however, there was no significant response to the treatments. The lack of a response to treatments may be due to an interaction between blocks and treatments. No specific trends were revealed for foliage-gleaners, but in general, more ground-foragers were found in the thin treatments of Block 1 and 2, and, conversely, more were detected in Block 3 Control. Block 3 Control has dense areas of shrubs intermixed with patches of bare ground, which may attract a larger component of ground-foragers that nest in shrubs. Block 3 Thin differs from the other thin treatments due to the general lack of shrubs found throughout the stand. A response to the thin may take longer in this stand due to the fact that mature hardwoods prior to the treatment heavily shaded the stand.

No significant increases or decreases occurred for the most abundant species detected such as pine warbler, red-eyed vireo, northern cardinal, eastern tufted titmouse, or blue jay, and this possibly could be attributed to the fact that these species are generalists in their life-history traits and appear to be more adaptable to disturbance.

Breeding Bird Species Similarity

In the breeding season of 2001, the burned and thinned stands were most similar in species composition, which was expected due to the habitat manipulation incurred. The species similarity shifted in 2002 so that the thinned stands and the untreated areas were most similar. This may have occurred due to the slower response of the vegetation to the thinning operation. Prescribed fire tends to stimulate growth and flowering in plants by recycling nutrients, reducing vertical and horizontal competition, and preparing seed beds (Pyne 1984). The breeding bird species similarity between the thinned and untreated areas may have been due to the incidence of southern pine beetle in the untreated areas, which can mimic thinning operations by reducing overstory pine canopy cover.

Nest Success

Most of the nests monitored over the two-year study were discovered during the second spring (2001=20 nests, 2002=59 nests). This discrepancy in nest numbers over years may be attributed to the experience of the technicians, the general absence of nests found on any of the burned sites directly after fire application in 2001, the amount of ground that had to be covered in a limited amount of time, general elusiveness of birds, and difficulty in searching the control sites due to vegetation density. Out of the 79 nests, 44.3% were successful and 49.3% failed due to predation, weather, or abandonment, and the remaining 6.4% failures could not be determined. It is probable that most of the nests failed due to predation, which has been found to account for 80% of nest losses in other studies (Martin 1992, Martin 1993b), however without remote cameras placed at the nests, it is difficult to determine fates by nest remains (Lariviere 1999). Another indication that predators may have been the most common reason for nest failure is that most failures occurred when the young would have been only two to three days old; too young to fledge. A large suite of potential predators are found within the Clemson Experimental Forest (personal observation) including: red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), opossum (*Didelphis virginiana*), eastern chipmunk (*Tamias striatus*), gray squirrel (*Sciurus carolinensis*), American crow, blue jay, black rat snake (*Elaphe obsolete*), black racer (*Coluber constrictor*), and other small mammals. Habitat manipulation may create more and better habitat for birds, but it may do the same for potential predators (Duguay et al. 2000, Barber et al. 2001).

Ground/shrub-nesters experienced more failed nesting attempts than canopy- and cavity-nesters overall. Shrub-nesters have been found to experience higher incidences of nest failure due to their generalized selection of nest sites and lower nest heights in other studies (Best and Stauffer 1980, Martin 1993b). The fact that cavity-nesters had the most successful nesting attempts agrees with other studies (Martin and Li 1992, Nice 1957), however cavity-nesters are more limited by the availability of appropriate nest substrates than open-cup nesters (Nice 1957, Martin and Li 1992, Shackleford and Conner 1997, Welsh et al. 1992).

Northern cardinals placed their nests in areas with greater densities of smaller diameter trees and shrubs. This agrees with other studies and descriptions of nest site microhabitat for cardinals (Halkin and Linville 1999, Conner et al. 1986). The trend that nests in the thinned and burned stands were not placed in areas of greater density of smaller diameter trees and shrubs than what was randomly available demonstrates a possible increase in overall shrub density in the treated stands one year after application. In the control plots, northern cardinals chose areas with greater shrub density than what was randomly available.

Blue-gray gnatcatchers appear to select nest sites with criteria that this study's nest vegetation sampling did not measure. Blue-gray gnatcatchers usually place their nests in the top third of tall trees, and the vegetation measurements did not measure the vertical diversification above the ground. Therefore, the results showing that their nest sites did not usually differ from what was randomly available in the treatment areas should be viewed with caution. A study in Vermont did show that blue-gray gnatcatchers had a non-significant tendency to select sites with lower basal area and tree density than what was available (Ellison 1992).

Summer tanagers seemed to place nests in smaller diameter trees that towered over the underlying vegetation affording the female an unhampered view of the surrounding area (personal observation), which agrees with other observations of nest site selection (Robinson 1996). From the nest site vegetation data collected, summer tanagers placed their nests in areas with an increased density of shrubs and small trees. Little research is available on nest site microhabitat selection by summer tanagers to compare their nest site selection on the Fire and Fire Surrogate study with (Robinson 1996). However, its habitat preferences include areas near gaps or edges with more open canopy cover, shorter tree heights, and few tree species (Robinson 1996).

Winter Birds

Point Counts

Winter bird abundance, within and between the pre-treatment winter surveys and the post-treatment winter surveys, did not change significantly across treatments, which concurred with King and others (1998). Winter birds occur more randomly on the landscape in the non-breeding season due to the fact they travel greater distances to forage (Fretwell 1972). They are also less vocal in the winter, which may result in fewer detections. Species richness and evenness were significantly different in the pre-treatment winter; however, this may have been a relict of natural population fluctuations. After treatments were applied in the spring of 2001, species richness did increase significantly in the treated stands and not in the controls. The diversification of the forest structure probably created alternative foraging sites for a greater range of bird species than the controls. Species evenness, after its pre-treatment differences across treatment types, was uniformly distributed across treatment types in the winter of 2001.

Foraging Guilds

Birds foraging in the winter become general in their habits since food is more limited (Martin 1987). This may explain why none of the foraging guilds, except bark-gleaners, experienced a significant change between the winter of 2000 and 2001 across any of the treatments. A significant decline was noted in golden-crowned kinglets between the winter of 2000 and 2001. Golden-crowned kinglets are considered hardier than ruby-crowned kinglets in relation to temperature extremes, however reductions in breeding densities have been shown to occur in burned and logged areas or habitats with open canopies (Ingold and Galati 1997). Carolina wrens increased significantly.

This increase in abundance may be due to an increase in coarse woody debris on the thin sites, which offers cover and foraging sites. Pine warblers also increased after treatment applications, and this may be because they have a propensity to winter in pine forests with low-growing or sparse understory (Rodewald et al. 1999). The thin and burn treatments probably attracted more pine warblers since those treatments had reduced understories yet a developed overstory pine component.

Winter Species Similarity

Even before treatments were in place on the study sites, the sites randomly selected for the burn and thin treatments were most similar in species composition, and this remained the case after treatment application in the winter of 2001. This similarity would be expected since both treatments involved the removal or reduction of understory and midstory trees and shrubs.

Arthropods

Arthropod populations fluctuate dramatically from generation to generation in response to normal environmental variables (Jackson 1979), so any dramatic change in the landscape or climate would seem to have an impact on arthropod abundance. The variance in arthropod numbers may be linked to any one or multiple reasons. The Piedmont of South Carolina has been experiencing a moderate to severe drought for the last five years, and this alone may have a significant impact on arthropods. After treatment applications, arthropod abundance was markedly greater in the burn treatments over both springs. This may be due in part to the fact that some platypezid and empidid smoke flies and some cerambycid and buprestid beetles appear to be attracted to smoke from fires (Evans 1972). Unlike the breeding bird abundance, arthropod abundance decreased significantly between 2001 and 2002. Again, this may be attributable to many variables like the drought. Other studies on fire have found that the impact of fire on arthropods is usually short-term as long as recolonization is possible and the frequency of fire allows the vegetation to recover (Harper et al. 2000, New and Hanula 1998). In the case of thinning, no significant changes occurred for species abundance or richness, however Collins and others (2002) detected a significant increase in arthropod density after the hardwood midstory was removed from a pine stand.

Arthropod richness fluctuated across months within and between years. Interestingly, in July of 2001, arthropod abundance was significantly less than in May or June, but arthropod richness was significantly greater. While arthropod abundance decreased significantly between May 2001 and 2002, arthropod richness increased significantly in May 2002. At the scale investigated, it is nearly impossible to detect differences for arthropod responses to the treatments. Another confounding factor is the catastrophic southern pine beetle outbreak that occurred in the treatment areas (Table 24). Coleoptera were one of the six most abundant orders sampled in the study plots, however determining the impacts of southern pine beetle was not possible within the scope of this study.

Table 24. Area of southern pine beetle infestations in each of the nine treatment areas on the Fire and Fire Surrogate study sites, Clemson, South Carolina (Boyle 2002).

Block	Treatment	2000 Infestation (ha)	2001 Infestation (ha)
1	Burn	0.00	0.29
1	Control	4.73	4.24
1	Thin	0.00	4.81
2	Burn	2.06	3.31
2	Control	0.00	0.78
2	Thin	0.00	0.49
3	Burn	0.64	1.31
3	Control	0.00	0.38
3	Thin	0.00	0.22

CHAPTER VI

CONCLUSIONS

Initial response data on the effects of prescribed fire and thinning as fuel reduction treatments on breeding and winter bird communities appears to enhance certain aspects of bird community composition. In the case of winter bird species richness, treatments appear to improve the forest structure in such a way as to support a broader range of bird species during the winter months. This may contribute to breeding bird reproductive success in the subsequent season. Breeding bird abundance and richness changed between years, which may perhaps be due to the change in vegetation composition over time. The lack of response across treatment types by breeding birds may be due to southern pine beetle impacts, or there may be some other confounding environmental variable that was not measured. The application of prescribed fire and thinning increased abundance of certain foraging and nesting guilds like foliage-gleaners and ground/shrub-nesters. Both of these guild types include birds that are either or both neotropical migrants and early-successional species, both of which have shown declines over the years due to various variables including human disturbance or the lack thereof.

The application of fuel reduction techniques, such as prescribed fire and thinning, to pine and mixed pine-hardwood stands will need to be left up to the individual landowner and forest manager. Other concerns like smoke management, economic costs, and site characteristics will play a major role in the implication of either treatment application. Management objectives will need to be re-examined to determine the best tool to use to reduce fuel loads and the chance of catastrophic wildfire in naturally regenerated and planted pine stands of the southeastern Piedmont.

Continued research, during this long-term study under the National Fire and Fire Surrogate Study Plan, will probably continue to show some response by avian species to treatment application over the next two to three years because the vegetation will continue to respond to increased light levels and decreased competition. However, as succession progresses and fuel loads accumulate, the bird community will probably return to pre-treatment composition.

Arthropod populations fluctuate dramatically under normal environmental variables, so the results from this thesis research should be looked upon with some caution. The impacts of the southern pine beetle infestation and the long-term drought probably played key roles in the results detected for arthropod abundance and richness. However, future research should evaluate the relationship between arthropod biomass and habitat selection by birds. Prior studies have already demonstrated that there is a positive correlation between nest success and site selection and arthropod biomass and abundance (Conner et al 1986, Burke and Nol 1998).

Further research endeavors need to continue to evaluate the effects of fuel reduction on seasonal bird communities, as well as nest productivity and survivability. Little research exists in the southeastern United States that contributes to sound management decisions concerning bird use of pine forests that are actively managed for timber and other objectives.

APPENDICES

A-1. List of species detected in each treatment type by point count during the winter and spring sampling periods 2000-2002 and their corresponding foraging and nesting guild associations.

	Season[1]	Burn	Control	Thin	Foraging guild	Nesting guild[2]
Turkey vulture *Cathartes aura*	W	X			Carnivore	.
Sharp-shinned hawk *Accipiter striatus*	S/W	X	X	X	Carnivore	Canopy
Red-shouldered hawk *Buteo lineatus*	S/W		X	X	Carnivore	Canopy
Red-tailed hawk *Buteo jamaicensis*	S/W	X	X		Carnivore	Canopy
Wild turkey *Meleagris gallopavo*	S	X	X	X	Ground	Ground/Shrub
Northern bobwhite *Colinus virginianus*	S	X	X		Ground	Ground/Shrub
Mourning dove *Zenaida macroura*	S/W	X	X	X	Ground	Ground/Shrub
Yellow-billed cuckoo *Coccyzus americanus*	S	X	X	X	Foliage	Ground/Shrub
Great horned owl *Bubo virginianus*	S	X			Carnivore	Canopy
Ruby-throated hummingbird *Archilochus colubris*	S		X	X	Other	Canopy
Belted kingfisher *Ceryle alcyon*	W		X		Carnivore	.
Red-bellied woodpecker *Melanerpes carolinus*	S/W	X	X	X	Bark	Cavity
Yellow-bellied sapsucker *Sphyrapicus varius*	W		X	X	Bark	.
Downy woodpecker *Picoides pubescens*	S/W	X	X	X	Bark	Cavity
Hairy woodpecker *Picoides villosus*	S/W	X	X	X	Bark	Cavity
Northern flicker *Colaptes auratus*	S/W	X	X	X	Bark	Cavity
Pileated woodpecker *Dryocopus pileatus*	S/W	X	X	X	Bark	Cavity
Eastern wood-pewee *Contopus virens*	S			X	Hawker	Canopy
Acadian flycatcher *Empidonax virescens*	S		X		Hawker	Canopy
Eastern phoebe *Syornis phoebe*	S/W	X	X	X	Hawker	Other
Great crested flycatcher *Myiarchus crinitus*	S	X	X	X	Hawker	Cavity
White-eyed vireo *Vireo griseus*	S		X	X	Foliage	Ground/Shrub
Yellow-throated vireo *Vireo flavifrons*	S	X	X	X	Foliage	Canopy

A-1. List of species detected in each treatment type by point count during the winter and spring sampling periods 2000-2002 and their corresponding foraging and nesting guild associations (Continued).

	Season[1]	Burn	Control	Thin	Foraging guild	Nesting guild[2]
Blue-headed vireo *Vireo solitarius*	S/W	X	X	X	Foliage	Canopy
Red-eyed vireo *Vireo olivaceus*	S	X	X	X	Foliage	Canopy
Blue jay *Cyanocitta cristata*	S/W	X	X	X	Foliage	Canopy
American crow *Corvus brachyrhynchos*	S/W	X	X	X	Ground	Canopy
Carolina chickadee *Poecile carolinensis*	S/W	X	X	X	Foliage	Cavity
Eastern tufted titmouse *Baeolophus bicolor*	S/W	X	X	X	Foliage	Cavity
Red-breasted nuthatch *Sitta canadensis*	W		X	X	Bark	.
White-breasted nuthatch *Sitta carolinensis*	S/W	X	X	X	Bark	Cavity
Brown-headed nuthatch *Sitta pusilla*	S/W	X		X	Bark	Cavity
Brown creeper *Certhia americana*	W	X	X		Bark	.
Carolina wren *Thryothorus ludovicianus*	S/W	X	X	X	Ground	Ground/Shrub
Winter wren *Troglodytes troglodytes*	W	X		X	Ground	.
Golden-crowned kinglet *Regulus satrapa*	W	X	X	X	Foliage	.
Ruby-crowned kinglet *Regulus calendula*	S/W	X	X	X	Foliage	.
Blue-gray gnatcatcher *Polioptila caerulea*	S	X	X	X	Foliage	Canopy
Eastern bluebird *Sialia sialis*	S/W	X	X	X	Ground	Cavity
Veery *Catharus fuscescens*	S		X		Ground	Migrant
Hermit thrush *Catharus guttatus*	W	X	X	X	Ground	.
Wood thrush *Hylocichla mustelina*	S		X	X	Ground	Ground/Shrub
American robin *Turdus migratorius*	S/W	X	X	X	Ground	Canopy
Brown thrasher *Toxostoma rufum*	S	X	X	X	Ground	Ground/Shrub
Cedar waxwing *Bombycilla cedrorum*	S/W	X	X	X	Foliage	Canopy
Northern parula *Parula americana*	S	X	X	X	Foliage	Canopy

A-1. List of species detected in each treatment type by point count during the winter and spring sampling periods 2000-2002 and their corresponding foraging and nesting guild associations (Continued).

	Season[1]	Burn	Control	Thin	Foraging guild	Nesting guild[2]
Cape May warbler *Dendroica tigrina*	S			X	Foliage	Migrant
Yellow-rumped warbler *Dendroica coronata*	S/W	X	X	X	Foliage	Migrant
Yellow-throated warbler *Dendroica dominica*	S		X		Foliage	Canopy
Pine warbler *Dendroica pinus*	S/W	X	X	X	Foliage	Canopy
Prairie warbler *Dendroica discolor*	S	X		X	Foliage	Ground/Shrub
American redstart *Setophaga ruticilla*	S			X	Foliage	Canopy
Worm-eating warbler *Helmitheros vermivorus*	S		X	X	Ground	Ground/Shrub
Ovenbird *Seiurus aurocapillus*	S		X	X	Ground	Ground/Shrub
Common yellowthroat *Geothlypis trichas*	S			X	Foliage	Ground/Shrub
Hooded warbler *Wilsonia citrina*	S		X	X	Foliage	Ground/Shrub
Yellow-breasted chat *Icteria virens*	S	X	X		Foliage	Ground/Shrub
Summer tanager *Piranga rubra*	S	X	X	X	Foliage	Canopy
Scarlet tanager *Piranga olivacea*	S	X	X	X	Foliage	Canopy
Eastern towhee *Pipilo erythrophthalmus*	S/W	X	X	X	Ground	Ground/Shrub
Chipping sparrow *Spizella passerina*	S	X	X	X	Foliage	Canopy
Field sparrow *Spizella pusilla*	S	X		X	Foliage	Ground/Shrub
Savannah sparrow *Passerculus sandwichensis*	W	X			Ground	.
White-throated sparrow *Zonotrichia albicollis*	W	X			Ground	.
Dark-eyed junco *Junco hyemalis*	W	X		X	Ground	.
Northern cardinal *Cardinalis cardinalis*	S/W	X	X	X	Ground	Ground/Shrub
Rose-breasted grosbeak *Pheucticus ludovicianus*	S		X		Foliage	Migrant
Indigo bunting *Passerina cyanea*	S	X	X	X	Foliage	Ground/Shrub
Common grackle *Quiscalus quiscula*	S	X	X	X	Ground	Canopy

A-1. List of species detected in each treatment type by point count during the winter and spring sampling periods 2000-2002 and their corresponding foraging and nesting guild associations (Continued).

	Season[1]	**Burn**	**Control**	**Thin**	**Foraging guild**	**Nesting guild**[2]
Brown-headed cowbird *Molothrus ater*	S	X	X	X	Ground	.
House finch *Carpodacus mexicanus*	S/W	X	X		Foliage	Ground/Shrub
American goldfinch *Carduelis tristis*	S/W	X	X	X	Foliage	Ground/Shrub

[1]: W-detected during winter point counts; S-detected during spring point counts; S/W- detected during both seasons

[2]: "." indicates species either nests in other areas or, in the case of brown-headed cowbird, parasitizes other species' nests

A-2. List of nesting species found in 2001 and 2002 and their associated nest characteristics for the Fire and Fire Surrogate Study.

Species	Year	Treatment	Fate[1]	Nest substrate	Nest sub. Height (m)	Nest height (m)	DBH (cm)	Nest cover (%)	Orientation (degrees)	Health
Blue-gray gnatcatcher	2001	Thin	F/A	*Liriodendron tulipifera*	18.5	12.5	38	30	42 /NNE	LIVE
	2002	Burn	S	*Ulmus alata*	14.8	11.2	25	45	50/NEE	LIVE
	2002	Control	S	*Cornus florida*	6.7	6.1	9	20	90/E	DEAD
	2002	Control	S	*Liriodendron tulipifera*	43.2	32.2	75	30	170/SES	LIVE
	2002	Thin	S	*Liquidambar styraciflua*	9.8	6.9	11	40	270/W	LIVE
	2002	Thin	S	*Quercus nigra*	25.3	20.8	45	35	56/NEE	LIVE
	2002	Thin	S	*Liquidambar styraciflua*	11.4	10.2	10	25	172/SES	LIVE
	2002	Burn	S	*Cornus florida*	12.3	3.1		90	230/SWW	LIVE
	2002	Burn	S	*Liquidambar styraciflua*	26	13.4	26	15	55/NEE	LIVE
	2002	Burn	F/A	*Quercus falcata*	15.7	11.1	28	30	198/ESE	LIVE
Blue-headed vireo	2001	Burn	F/A	*Quercus falcata*	10.6	7.6	17	30	236/SWW	LIVE
	2002	Burn	F/A	*Pinus virginiana*	6.9	5.3	9	5	144/SES	DEAD
	2002	Thin	F/A	*Pinus virginiana*	14.2	10.7	38	<5	346/NWN	LIVE
Blue jay	2002	Control	F/A	*Quercus alba*	23.3	15	46	45	356/NWN	LIVE
	2002	Burn	S	*Pinus virginiana*						Dead
Carolina wren	2002	Thin	F/A	*Liquidambar styraciflua*	2.1	0.5	<2.5	80	90/S	LIVE
Chuck-wills-widow	2002	Burn	F/A	Ground	-	-	-	0	-	-
	2002	Control	S	Ground	-	-	-	0	-	-
Downy woodpecker	2002	Control	S	*Quercus sp.*	40	25	50	90	206/SSW	DEAD
	2002	Control	S	*Pinus taeda*	17.1	12.6	23	95	200/SSW	DEAD
Eastern tufted titmouse	2002	Burn	S	*Oxydendrum arboreum*	8.2	2.5	13	80	280/WNW	LIVE
	2002	Burn	S	*Oxydendrum arboreum*	11.1	2.6	21	80	40/NNE	LIVE
Hairy woodpecker	2002	Burn	S	*Pinus echinata*	20.7	15.3	21	95	164/SES	DEAD
	2002	Control	S	*Quercus sp.*	14	11.4	33	90	230/SWW	DEAD
Indigo bunting	2002	Burn	F/A	RHGL/LITU[a]	1.22	0.91	<2.5	50	346/NWN	LIVE
	2002	Burn	S	*Oxydendrum arboreum*	1.5	0.61	<2.5	75	194/SSW	LIVE
	2002	Burn	S	*Quercus falcata*	1.2	0.45	<2.5	55	180/S	LIVE
	2002	Burn	S	*Quercus falcata*	1.1	0.61	<2.5	70	20/NNE	LIVE
Mourning dove	2002	Burn	F/A	ILOP/PIEC[b]	3.4	2.4	20	5	10/NNE	DEAD
	2002	Burn	F/A	*Oxydendrum arboreum*	11.3	7.2	11	60	312/WNW	LIVE
	2002	Thin	F/A	*Pinus echinata*	2.1	1.98	5	55	122/ESE	LIVE
Northern flicker	2002	Thin	F/A	*Pinus sp.*	18	10.7	38	95	360/N	DEAD

A-2. List of nesting species found in 2001 and 2002 and their associated nest characteristics for the Fire and Fire Surrogate Study (Continued).

Species	Year	Treatment	Fate[1]	Nest substrate	Nest sub. Height (m)	Nest height (m)	DBH (cm)	Nest cover (%)	Orientation (degrees)	Health
Northern cardinal	2001	Control	F/A	*Kalmia latifolia*	6	4.3	8	60	18/NNE	LIVE
	2001	Thin	F/A	*Liquidambar styraciflua*	6	4.6	5	70	999	LIVE
	2001	Thin	S	*Liquidambar styraciflua*	6	4.3	8	50	42/NNE	LIVE
	2001	Thin	S	*Vaccinium sp.*	2.6	2.3	<2.5	60	288/WNW	LIVE
	2001	Control	U	*Acer rubrum*	2.6	2.6	2.5	55	240/SWW	LIVE
	2002	Burn	F/A	*Vitis rotundifolia*	1.8	0.6	<2.5	60	176/SES	LIVE
	2002	Control	F/A	*Vaccinium sp.*	3	2.1	3.3	15	202/SSW	LIVE
	2002	Thin	S	*Vaccinium sp.*	2.4	1.2	<2.5	15	72/NEE	LIVE
	2002	Thin	F/A	clump of dead trees	3.1	1.5	<2.5	40	334/NWN	DEAD
	2002	Thin	F/A	*Quercus nigra*	2	1.8	3	50	320/NWN	LIVE
	2002	Thin	S	*Quercus nigra*	2.1	1.4	3	50	240/SWW	LIVE
	2002	Control	F/A	*Carya tomentosa*	3.1	2.4	3.3	60	66/NEE	LIVE
	2002	Control	F/A	*Vaccinium sp.*	2	1.4	<2.5	5	332/NWN	LIVE
	2002	Control	F/A	*Diospyros virginiana*	3.6	2.8	8	50	82/NEE	LIVE
	2002	Control	F/A	*Nyssa sylvatica*	3.1	1.8	2.8	20	0/N	LIVE
	2002	Control	F/A	*Nyssa sylvatica*	3.4	2.1	7	25	114/ESE	LIVE
Northern parula	2002	Burn	S	*Robinia pseudo-acocia*	18	13.5	30	60	140/SES	LIVE
Pileated woodpecker	2002	Thin	S	*Pinus taeda*	18.9	12.6	34	90	200/SSW	DEAD
Pine warbler	2001	Burn	U	*Pinus taeda*	26.3	22.3	33	25	326/NWN	LIVE
	2002	Burn	S	*Pinus taeda*	20.4	16.2	21	25	350/NWN	LIVE
	2002	Control	F/A	*Pinus echinata*	18.7	15.8	32	5	270/W	LIVE
Red-bellied woodpecker	2001	Burn	U	*Pinus taeda*	10	9.6	33	95	347/NWN	DEAD
	2001	Thin	F/A	*Pinus taeda*	9	8.8	23	98	186/SSW	DEAD
	2002	Thin	S	*Pinus sp.*	18	16.8	38	95	225/SW	DEAD
Red-eyed vireo	2002	Thin	F/A	*Liquidambar styraciflua*	6.2	4.2	8	30	26/NNE	LIVE
	2002	Burn	S	*Cornus florida*	4.3	4	4.3	50	150/SES	LIVE
	2002	Burn	F/A	*Cornus florida*	6.1	2.7	10	30	320/NWN	LIVE
Sharp-shinned hawk	2001	Control	S	*Pinus taeda*	18	13	23	45	200/SSW	LIVE
Summer tanager	2001	Thin	F/A	*Vaccinium sp.*	3.3	2	2.5	25	280/WNW	LIVE
	2001	Thin	F/A	*Acer rubrum*	7	6.3	10	50	250/SWW	LIVE
	2001	Thin	S	*Quercus stellata*	6	5.3	8	50	256/SWW	LIVE
	2002	Burn	U	*Cornus florida*	8.5	7.3	13	85	179/SES	LIVE
	2002	Control	S	*Oxydendrum arboreum*	8.7	7.4	11	55	288/WNW	LIVE
	2002	Control	F/A	*Cornus florida*	8.9	7.4	13	45	235/SWW	LIVE
	2002	Burn	F/A	*Quercus alba*	20.8	13.7	23	55	108/ESE	LIVE

A-2. List of nesting species found in 2001 and 2002 and their associated nest characteristics for the Fire and Fire Surrogate Study (Continued).

Species	Year	Treatment	Fate[1]	Nest substrate	Nest sub. Height (m)	Nest height (m)	DBH (cm)	Nest cover (%)	Orientation (degrees)	Health
Summer tanager	2002	Thin	F/A	*Carya tomentosa*	2	1.5	6	45	202/SSW	LIVE
Wild turkey	2001	Thin	F/A	Ground	-	-	-	0	296/WNW	-
	2001	Thin	F/A	Ground	-	-	-	30	107/ESE	-
	2002	Control	F/A	Ground	-	-	-	10	90/E	-
	2002	Control	S	Ground	-	-	-	5	-	-
Yellow-billed cuckoo	2001	Control	S	*Quercus alba*	6.1	6.1	8	60	160/SES	LIVE

[a]RHGL/LITU= *Rhus glabra/Liriodendron tulipifera*

[b]ILOP/PIEC= *Ilex opaca/Pinus echinata*

[1]Fate codes

S=successful
F/A=failed/abandoned
U=unknown

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