July 30, 2004

To the Graduate School:

This thesis entitled "Effects Of Prescribed Fire And Understory Removal On Bird Communities In A Southern Appalachian Forest" and written by Aimee Livings Tomcho is presented to the Graduate School of Clemson University. I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master Of Science with a major in Forestry And Natural Resources.

J. Drew Lanham, Thesis Advisor

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and recommend its acceptance:

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EFFECTS OF PRESCRIBED FIRE AND UNDERSTORY REMOVAL ON BIRD COMMUNITIES IN A SOUTHERN APPALACHIAN FOREST

A Thesis

Presented to

the Graduate School of

Clemson University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Forestry and Natural Resources

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by

Aimee Livings Tomcho

August 2004

Advisor: Dr. J. Drew Lanham

ABSTRACT

Fire exclusion has contributed to increased fuel loads and potential for catastrophic fires in forested landscapes. In 2000, the National Fire and Fire Surrogate Study was initiated to research the ecological consequences of fuel reduction techniques in several ecosystems across the country. The Green River Game Lands in Polk County, NC, were chosen to represent the Southern Appalachian upland hardwood forest ecosystem. Three treatments (mechanical understory removal, prescribed burns, and mechanical understory removal with prescribed burns) and a control were implemented to reduce fuel loads. Mechanical understory removal treatments were implemented in 2002. All stems of *Rhododendron*, *Kalmia*, and trees >1.8 m tall and <10.2 cm diameter at breast height (DBH) were cut. Prescribed burn treatments implemented in March 2003 produced flames 1-2 meters high with an objective to remove the shrub layer.

Breeding, wintering, and early migrant bird communities were sampled at each treatment area using three 50-meter fixed radius points that were visited three times per season for three years in spring (breeding birds) and during winter 2002-2003 (resident birds) before and during 2003 early migration after the burn treatments were implemented. A total of 2,489 bird detections of 59 species was observed.

No differences were detected among treatment areas in breeding season abundance, species richness, or evenness for any year ($p>0.10$). Species diversity (H) was highest in controls during the 2003 breeding season. Abundance of ground nesters differed among treatments only in 2001 when no treatments had been implemented. Richness of ground nesting species was highest in controls in 2002 and 2003. There were

no treatment differences in breeding season abundance of cavity, shrub or tree nesting species or richness of shrub or tree nesters in 2001, 2002, or 2003. Richness of cavity nesting species differed among treatments in 2001, 2002, and 2003. No treatment differences were detected in abundance or richness of ground or tree foraging species in 2001, 2002, or 2003. Treatment differences were detected in abundance of shrub foraging species in 2001 and 2003, when controls were most abundant. Richness of shrub foraging species was highest in controls in 2003.

Nest success varied by guild and treatment. The three-year success rate averages of 1) cavity nests were 100% in controls, burns, and mechanical understory removal sites; 2) ground nests were 67% in controls and 100% in mechanical understory removal sites; 3) shrub nests were 56% in controls, 38% in burns, and 60% in mechanical understory removal sites; and 4) tree nests were 25% in controls, 33% in burns, and 60% in mechanical understory removal sites. No cavity, ground, or shrub nests were found in sites with mechanical understory removal and prescribed burns combined. Nest substrate characteristics differed in percent nest cover for all nests but did not differ for any variable measured for successful nests.

No changes in abundance, species richness, diversity, or evenness of early migrant bird communities or foraging guilds were detected after the prescribed fire. Post-treatment shrub and ground cover, snag density and litter layer depths differed among treatments.

Initial avian responses to fuel reduction treatments in the Southern Appalachians were minimal and often reflected guild or species responses rather than the responses of an entire community.

ACKNOWLEDGMENTS

First and foremost, I would like to thank my husband, friend and mentor, Joseph Tomcho Jr. He taught me to open my ears to the symphony of the birds. He also bestowed exceptional support to me. For those things, I am forever grateful.

I would like to thank Dr. Cathryn H. Greenberg for presenting me with the opportunity to conduct this research and for providing cooperative feedback. I would like to thank my advisor, Dr. Drew Lanham, for his inspiration to advance the field of wildlife research. I would like to thank Dr. Tom Waldrop for being instrumental in planning and completion of this project, as well as being a model of respect and intelligence to me. I would also like to thank the USDA Forest Service field crews for their commitment to the Fire and Fire Surrogate Study, especially with grid layout and vegetation measurements- you helped make this adventure possible. I would like to thank Bent Creek Experimental Forest for being a project partner and home base, Dr. David Loftis for interest and approval, scientists, technicians and volunteers. I would like to thank the North Carolina Wildlife Resources Commission for land use and Dean Simon's willing cooperation as Fire Boss and general game land consultant. I would like to thank Dr. David Van Lear for educating me about fire ecology. I would like thank Dr. Billy Bridges for his statistical support and encouraging knowledge of SAS.

I would like to thank my family: my Dad for walks in the woods as a child and helping me develop a fascination for many things, my Mom for my first adventure in bird identification (I still remember our first Scarlet Tanager), and my brother Tim for watching over them in my absence.

Finally, I would like to thank fellow graduate students, especially Katie Bruce, Julia Camp, and Julia Murphy for companionship at Clemson.

This is contribution number 49 of the National Fire and Fire Surrogate Research (FFS) Project. This research was funded by the USDA Forest Service through the National Fire Plan and by the Southern Research Station Research Work Units SRS-4101 and SRS-4104. Although the authors received no direct funding for this research from the U.S. Joint Fire Science Program (JFSP), it was greatly facilitated by the JFSP support of existing FFS project sites.

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CHAPTER I

INTRODUCTION

In 2003, the chief of the USDA Forest Service announced that fuel reduction was one of the top four priorities facing America's forests (Bosworth 2003). Concurrent with this prioritization, Congress passed the Healthy Forests Initiative attempting to hasten the legal procedures regarding forest fuels treatments and associated forest restoration. Both of these actions have stemmed from catastrophic wildfires that have ravaged through the nation's forests in recent years. Since the beginning of the last century, fires have been handled through suppression and prevention. However, over time research and management has shown that these methods can create more hazards, especially in the expanding wildland-urban interface, by permitting a buildup of shrub and small tree forest fuels, and by degrading the process and function of some fire-adapted ecosystems.

The National Fire and Fire Surrogate Study (NFFS) was developed in 2000 as a reaction to wildfires across the U.S. It is a product of the Joint Fire Science Program, whose members are Department of Interior's Bureau of Land Management, Bureau of Indian Affairs, Geological Survey, Fish and Wildlife Service, National Park Service, and the Department of Agriculture's Forest Service. The overall goal was to create a large-scale study to quantify the ecological and economic consequences of fire and fire surrogate treatments in several forest types across the United States. Because response variables- such as fire behavior, soil properties, and wildlife- and sampling methodologies are standardized across study locations, the data will be suitable for meta-analysis where common responses (if they exist) can be seen across many ecosystems and forest types. The priorities of NFFS (Executive Summary 2000) as are follows:

1. Quantify the initial effects (first five years) of fire and fire surrogate treatments on a number of specific core response variables within the general groupings of (a) vegetation, (b) fuel and fire behavior, (c) soils and forest floor (including relation to local hydrology), (d) wildlife, (e) entomology, (f) pathology, and (g) treatment costs and utilization economics.

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 FFS 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.

Cooperative relationships together with the desire to study several forest types across the United States led to the following 13 sites nationwide participation in NFFS:

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.

8. Jemez Mountains, Santa Fe National Forest, northern New Mexico, mixed conifer forest dominated by ponderosa pine with southwest white pine, white fir, Douglas fir, and aspen.

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 Lands, Polk County, North Carolina, Appalachian hardwood and hardwood-pine forest.

Often thought of as primarily a western phenomenon, wildfires also threaten communities in the eastern United States. The wildfires of California in 2003 illustrated the dramatic consequences of the increasing wildland-urban interface, defined as 1) lands where structures are directly adjacent to wildlands and 2) lands where structures are scattered throughout a wildland area (Hill 2003). Between April 1990 and April 2000 in the thirteen-state region from Virginia to Texas, the population increased nearly 14% and accounted for nearly 32.5% of the national population total, increasing the wildland-urban interface dramatically in these regions (Macie and Hermansen 2003). Today, nearly 80% of the U.S. population is urban, with approximately 3 million acres of new development added annually (Macie and Hermansen 2003). Further, both naturally and anthropogenically-caused fires have been suppressed nationwide creating heavy fuel loads in many forests. In 2001, the Larman fire near Hot Springs, NC (approximately 105 kilometers from the Green River NFFS study site with a similar forest composition), burned over 1200 hectares at a monetary cost of over 2 million dollars (Ramey 2002).

In general, forest quality in terms of timber production, wildlife diversity, and human-viewed aesthetics has deteriorated during the era of fire exclusion. Most of the thirteen NFFS research sites nationwide can reduce their fuel loads by reducing overstory tree density. At the Appalachian site in North Carolina, most of the fuel loadings are due to a dense understory component, dominated by a thick shrub layer, making it unique among the thirteen NFFS sites.

These dense, more homogenous forests threaten wildlife communities associated with natural disturbance. Currently in the Southern Appalachians, forest management trends favor mechanical and chemical understory removal rather than fire for forest thinning. Because fire has been excluded, natural resource managers do not fully understand the role of fire today and its possible integration into current management practices. The wildlife component of NFFS focuses on assessing the effects of fuel reduction treatments on the songbird, small mammal, and herpetofaunal communities.

The influence of vertical and horizontal vegetation structure on bird communities is well established (MacArthur and MacArthur 1961). Silvicultural disturbance, such as prescribed fire and mechanical thinning, affect habitat structure and, due to increased light levels and primary productivity, may promote a higher density of insects, and increased fruit production (Blake and Hoppes, 1986; Martin and Karr, 1986). Several studies report higher species richness, diversity, and density in silviculturally disturbed sites compared to mature undisturbed forest (Annand and Thompson, 1997; Baker and Lacki, 1997).

There is a lack of literature regarding birds' responses to fire in the southern Appalachians. This study will help to fill that gap. The primary objective was to assess the effects of prescribed fire and understory removal on breeding and non-breeding bird communities. The null hypotheses tested in this study were:

Ho1: Avian community composition (abundance, species richness, diversity, evenness, similarity) does not differ during breeding season, winter, or migration as a result of fuel reduction treatments.

Ho2: Avian community structure (nesting guilds, foraging guilds) does not differ during breeding season, winter, or migration as a result of fuel reduction treatments.

Ho3: Nesting attempts and successes do not differ among fuel reduction treatments.

Ho4: Vegetative structure does not differ among fuel reduction treatments.

CHAPTER II

LITERATURE REVIEW

The only constant in American forests seems to be change. Many regions have experienced ice, drought, floods, wind, and fire and have resulted in forest composition and structures that bear little resemblance to any that have existed in the past (Oak 2002). Disturbances continued with man's settlement through means of anthropogenic fire, agriculture, logging, industrialization, and eventual urbanization. With the spread of humans over the landscape, the adoption of the Clementsian theory of succession and the Great Fires of 1910, fire suppression became a core goal of forest management. Early in the twentieth century, William Greeley, chief of the United States Forest Service announced that fire prevention was the primary job of American foresters (Saveland 1995). The age of the 10 A.M. policy dawned, which mandated control of a fire by 10 A.M. the morning following its report, and the policy would not be seriously reconsidered until the 1940's (Pyne 1997).

Today, fire is often regarded with reserve and conflicting views. A 2000 survey conducted in Texas showed that 52% of respondents strongly agreed that wildfires should be prevented in state parks but 51% strongly believed that fire is necessary for the health of the forests (Rideout et al. 2003). Recent wildfires have been catastrophic due to heavy fuel loads in the forests and have resurfaced the questions regarding fire exclusion policies. As scientists are realizing the importance of mimicking historic disturbance regimes to maintain diversity and other ecological values, methods of fuel reduction are being studied at regional scales to attempt to mitigate years spent lacking fuel removal regimes through mechanical means and use of prescribed fires.

In Southern Appalachian hardwood stands, heavy fuel loading is often due to widespread shrub encroachment and thick understory densities. These forest structures are drawing attention from foresters not only because of threatening fires but due to reduced regeneration of marketable tree species. Van Lear et al. (2002) noted that exclusion of fires in cove forests allowed rhododendron (*Rhododendron maximum*) to occur well beyond its normal streamside ranges. This encroaching ericaceous shrub, along with mountain laurel (*Kalmia latifolia*) has led to gradual changes in understory composition that threaten diversity and productivity.

Numerous studies have been conducted examining the impacts of fire on the understory component and subsequent target tree regeneration. Clinton et al. (1998) found that careful consideration should be given to humus and litter layers when aiming for a prescribed burn identifying a goal of understory removal. Loftis (1990) demonstrated the value, yet high expense, of using herbicides for under- and midstory competition control in oak regeneration. Barnes and Van Lear (1998) found similar results using prescribed burns in oak-shelterwood stands but required several years to do so. In an experiment studying fire effects on the undesirable pin cherry (*Prunus pennsylvanica*) in West Virginia, researchers also noted that repeated fires are necessary to successfully eliminate competing seed germination and quick establishment (McGill et al. 1999). Periodic burning in Table Mountain/Pitch Pine stands at Green River Game Lands in North Carolina revealed that understory tree density continued to decrease in number with successive prescribed dormant season fires. However, percent shrub cover decreased by 59-75% immediately following one burn and did not decrease in three subsequent fires, suggesting that periodic burns maintain but do not further reduce shrub cover (Randles et al. 2002).

Mechanical treatments may also be used to reduce competing forest vegetation. Mechanical removal of shrub layers is a relatively new concept associated with the advent of wildfire and regeneration concerns. It is relatively costly and requires extensive man hours to minimize disturbance to overstory trees. Therefore there have been few studies looking at this level of disturbance in the forest. Foresters often employ various methods, such as clearcuts and shelterwoods, to regenerate desirable tree species. Floral diversity following harvest was studied in Southern Appalachian mixed oak sites; one method utilized in this study by Hammond et al. (1998) was chemical understory control. While more intense treatments resulted in increased vegetation species richness, the herbicide treatment more or less mimicked the control stands with a net gain of only 2 species.

Whether plant species richness increases, the same species regenerate by sprouting, or low forest cover is reduced, both fires and mechanical manipulation affect spatial structure of vegetation response creating structural heterogeneity (Franklin 1997). Heterogeneity, or patchiness, across a landscape is considered beneficial to wildlife by creating a mosaic of food and cover. The importance of food resources such as arthropods (Van Horne and Bader 1990) and fleshy fruits (McCarty et al. 2002) to wildlife is documented. Nesting studies among bird species are a popular way to document shelter resource needs (Martin 1992, Barber et al. 2001).

Bird communities are considered ecological indicators of forest condition and resource availability. Canterbury et al. (2000) and von Euler (1999) have attempted to create indices of ecosystem integrity based on bird assemblages. Although they are not as widely accepted as the similar Index of Biotic Integrity created by Karr (1991) to measure communities of aquatic organisms, the use of bird communities to reflect changes in forest systems is a viable one. Because individual species don't always respond similarly as indicators (a proposed but often criticized concept), guilds have been developed that group birds into similar life strategies, such as nesting and foraging. Blondel (2003) illustrates the importance of guild classification as relating to location rather than function. Functional groups characterize similarity in function rather than resource sharing which in cases of forest structure manipulation may be less important.

There have been many studies investigating avian responses to various habitat manipulations including such disturbances as fire and mechanical harvests. Aquilani et al. (2000) studied the effects of prescribed surface fires to reduce shade-tolerant understory woody vegetation on ground and shrub nesting Neotropical migratory birds in Indiana oak forests. Within 1-2 years of fire, they found that the abundance of birds in these nesting guilds were greatest in unburned areas and nesting success, determined by the Mayfield method (Mayfield 1961, 1975), was significantly lower in the burned areas as compared to unburned areas. Further, they found that nest sites in burned areas had higher vegetative cover than random points suggesting that birds selected nest sites least affected by fire.

Bird communities in Kentucky were sampled to assess short-term changes in response to silvicultural prescriptions (Baker and Lacki 1997). They found that silvicultural prescription such as low- and high-leave harvest as well as clearcuts had similar effects on bird communities by increasing abundance, diversity, and richness following treatments. Interestingly, hooded warblers (*Wilsonia citrina*) were detected

Practically, forest management could benefit all groups involved. Simon et al. (2002) questioned if clearcuts mimic natural disturbances such as fire. After measuring bird communities in Labrador, Newfoundland, he found that bird densities peaked in 14 year old burns exceeding numbers reported for mature forests in Labrador. Further he found that total bird density was lower in clearcuts suggesting that allowing some forests to burn naturally or prescribing less drastic logging regimes may benefit songbirds.

Prescribed burning and wildfires both allow what Stuart-Smith et al. (2002) describe as a pyrogenic habitat mosaic to develop. Studying songbirds in Alberta, Canada 5-6 years following a fire, they subdivided the burned landscape (9600 hectares) into unburned patches within the fire, burned patches, patches that had been clearcut prior to the burn, and unburned, continuous forest adjacent to the burn. Finding that unburned patches within the fire supported higher abundance and richness than unburned forest adjacent to the burn, they concluded that unburned patches tended to contain more foliage gleaning birds and burns more aerial foragers. Areas that were cut prior to burning supported a lower number of shrub nesters, aerial foragers, and Neotropical migrants in general. Shrub-based arthropod biomass was highest in burned areas and unburned patches within the burn supporting the finding that the patch mosaic created by fire (5-6 year post-burn) supports higher numbers of birds than clearcuts or continuous unburned habitat adjacent to a burned area.

Saab et al. (2003) also found that patchy burns benefit certain species of birds. Fire tends to support cavity nesters due to snag creation, increased insect colonization, and elimination of obstacles such as foliage and in some cases, midstory. In Idaho, species of cavity-nesting birds systematically recolonized due to prey availability and excavating strategies (strong and weak excavators, secondary cavity nesters). Five years after the fire, recolonization by cavity nesters declined. Nesting success by cavity nesters decreased when nest predators began to reenter the burned areas. This didn't occur in larger burned patches until the fourth year after the fire but depended on the patchiness of the burn. Thus burn patchiness may benefit not just birds but small mammalian and reptilian nest predators.

Giese and Cuthbert (2003) also studied cavity nesting birds. Surveying to identify parameters for managers leaving trees during timber harvests, established woodpecker nests were measured for surrounding vegetation and general locations. They found that nest tree, rather than surrounding vegetation, most heavily influenced nest site selection in woodpeckers in the upper Midwest. With varying degrees of clumping and spacing of snags, the most identifiable trend was the mere availability of high quality snags (quality often being defined by density and longevity (Lanham and Guynn 1996)).

Snag densities are often inversely related to thinning intensity (Graves and Fajvan 1999). In contrast, snag production is often increased by the use of fire in management (Van Lear 2000). Kreisel and Stein (1999) found that wintering birds in western coniferous forests had similar numbers in burned and unburned forest but differed in species composition. The stand-replacement fires studied supported higher numbers of trunk and branch foraging species suggesting that relaxing fire suppression policies and initiating prescribed burning programs in forest that once experienced them regularly can help manage for cavity nesting species during both breeding and non-breeding seasons.

Non-breeding seasons are often overlooked when conducting surveys for birds. However, winter may be arguably the most important season and habitat indicating survival of an individual (Arcese et al. 1992, Terbough 1989, Morton 1992). King et al. (1998) compared wintering bird communities in mature pine stands managed by prescribed burning in Georgia. They found that neither growing nor dormant season burns negatively impacted wintering bird abundance or species richness. These results may be directly attributed to no significant changes being reported in basal area, canopy closure, or shrub density between fires prescribed during the growing or dormant seasons.

There have been many studies addressing fire, silvicultural operations, and natural disturbances and their effects on bird communities. The number of fuel reduction studies has increased due to the increasing number of catastrophic wildfires and increasing wildland-urban interface. Ultimately, change in vegetation structure may predict changes in bird communities. However, there is little information regarding fuel reduction techniques that target shrub layer removal with prescribed burns versus mechanical treatments in the Southern Appalachian Mountains. Information on the effects of these treatments on local breeding, wintering, and migrating bird communities is also lacking.

CHAPTER III

METHODS

Study Area

Three study sites were selected within the Green River Game Lands in Polk County, North Carolina (Figure 1). The Green River Game Lands, managed by the North Carolina Wildlife Resources Commission, cover 5,841 hectares of forest and wildlife openings in several noncontiguous blocks. Most parcels were purchased in the early 1950s as a result of the North Carolina's Natural Areas Trust Fund grant. The primary purpose of establishing the game lands was to enhance acquisition and protection of the state's ecological diversity and cultural heritage and to inventory the natural areas of the state (Hunting and fishing maps for NC game lands 2003). Activities on Green River Game Lands include public hunting, trapping, fishing, and various non-consumptive outdoor recreation.

Entirely within the mountainous Blue Ridge Physiographic Province of Western North Carolina, the Game Lands consist of Evard series soils (fine-loamy, oxidic, mesic, Typic Hapludults) which are very deep and well-drained in mountain uplands (USDA Natural Resources Conservation Service 1998). There are also areas of rocky outcrops in steeper terrain. Forest stands are composed mainly of oaks (*Quercus* spp.) and hickories (*Carya* spp.). Shortleaf (*Pinus echinata*) and Virginia (*P. virginiana*) pines are found on ridgetops and white pine (*P. strobus*) occurs in moist coves. Stand ages for the study sites varied from 80 to 120 years (Waldrop 2001). Elevations range from approximately

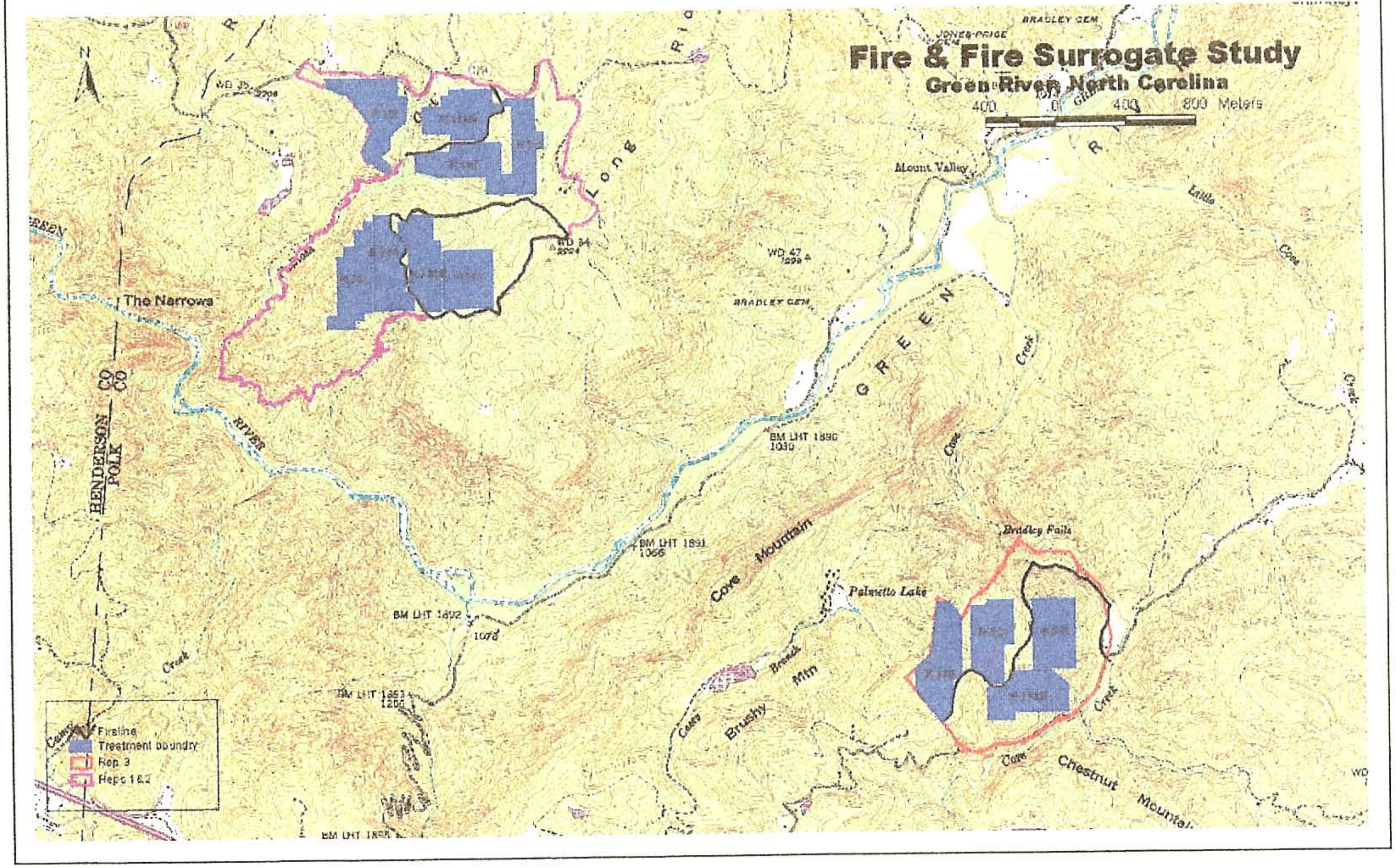

Figure 1. Map of Fire and Fire Surrogate Study sites at Green River Game Lands, Polk County, North Carolina. Map courtesy of Ross Phillips, USDA Forest Service, Clemson, SC.

366-793 m, with the study plots averaging 610 m. First and second order streams border and/or traverse all three replicate blocks.

Study Sites

National Fire and Fire Surrogate study sites were located based upon several main ecological and logistical criteria. The ecological selection criteria were (Executive summary 2000):

1. The site is representative of forests with a historically short-interval (3-5 years), low- to moderate-severity fire regime and a current high risk of uncharacteristically severe fire, and

2. The site is representative of widespread forest conditions (site characteristics, forest type and structure, treatment history) that are in need of, and likely to benefit from, fire or fire surrogate treatments, and in which such treatments are feasible.

The three Southern Appalachian Fire and Fire Surrogate study blocks were chosen based upon stand size, stand age, cover type, and management history. The four treatments were randomly assigned to each of the three complete blocks. Minimum treatment size was 14 hectares to allow for 10 hectare treatment areas and a buffer of 20 meters around each treatment area. Stand age characteristic of oak-hickory forests in the Southern Appalachians ranges from 80-120 years; thus, this range was targeted for this study. Cover types targeted for fuel removal were shrub layers in oak forests, which create the heavy fuel loads in the Southern Appalachian Mountains. None of the sites had been thinned during the past 10 years and none had been burned (wild or prescribed) in at least five years.

Treatments

Three treatments and an untreated control (C) were randomly assigned to each of three study blocks at Green River Game Lands. The three treatments were:

1. Fuel reduction by mechanical understory removal (M),
2. Fuel reduction by prescribed burning (B), and
3. Fuel reduction by mechanical understory removal and prescribed fire (MB).

Mechanical Understory Removal of Fuels

The primary objective of the mechanical treatment was to remove the shrub layer. Mechanical fuel reduction was implemented by contract chainsaw operators in winter 2001-2002 who cut all mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendron* sp.) and all trees over 1.8 meters tall and less than 10.2 cm DBH. No fuels were removed from the site due to the high cost of operating in steep terrain.

Removal of Fuels with Prescribed Fire

Prescribed fires were applied to designated treatment blocks in all three sites in March 2003 by the North Carolina Wildlife Resources Commission with assistance from USDA Forest Service personnel. Fire parameters were developed considering fuel reduction targets, standard silvicultural practices in the Southern Appalachian Mountains, and past experience. Target flame heights of 1-2 meters were achieved by ignition of strip headfires by hand crews in some areas and aerial ignition supplementation of spot fires. The primary objective of prescribed burning was to remove the shrub layer.

The fires were implemented the winter following mechanical fuel reduction to allow drying and some decomposition of slash. Replication 3 was burned on March 12, 2003 while replications 1 and 2 were burned the next day. Replication 3 was ignited by a hand crew using a strip-headfire technique. Fire intensity was moderate to high. Flame lengths of 1 to 2 meters occurred throughout the burn unit but flames reached as high as 5 meters in localized spots where topography or intersecting flame fronts contributed to erratic fire behavior. Temperatures measured by heat tiles 1 meter above ground were generally below 120^0C but reached as high as 788^0C in one location. Replications 1 and 2 were burned as a single unit. Backing fires were set along fire lines by hand followed by spot fires set by helicopter using a plastic sphere dispenser. Fire intensity was low to moderate with flame lengths of 1 to 2 meters. Measured temperatures were generally below 93^0C but exceeded 982^0C in one location.

Avian Community Assessment

The diversity and abundance of birds of this study were assessed using point count censuses (Ralph et al. 1993). Three points were established within each treatment area, spaced at 200 meter intervals. All points within treatment areas were surveyed for 10 minutes each (preceded by a 3-5 minute settling period to minimize disturbance) during three separate visits during each of the 2001, 2002, and 2003 breeding seasons (May 11– June 30) and during winter 2002-2003 before prescribed burns (December-January) and early migrations (March) after prescribed burns. All birds detected by sight or sound within a 50 meter radius were recorded. Point counts were conducted within 4 hours of sunrise (0600-1000 hours in spring, 0700-1100 hours in winter) on days with minimal or no wind or precipitation. The times of point count station visitation was varied to avoid time-of-day biases. No flyovers were included in analyses.

Point Count Analyses

Mean abundance and species richness (S) was calculated for each treatment by summing three points averaged from three visits. Species diversity was also calculated using the Shannon diversity index (H):

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

where pi is the proportion of S made up of the i^{th} species. Evenness was also calculated using Shannon's equitability index (E):

$$E= H / \ln S.$$

Species were categorized by nesting (spring) and/or foraging guilds (spring, winter, and migrant) (Appendix A-2) (Hamel et al. 1992). Nesting guilds included ground, shrub, tree, and cavity categories. Foraging guilds included ground, shrub, and tree foraging location categories. Nesting and foraging group data were examined to assess any habitat utilization differences across treatments using life-history traits and vertical forest structure.

The means for abundance, richness (entire survey and by guild), diversity, and evenness were used as the dependent variables in a two-way repeated measures analysis of variance (ANOVA) (PROC GLM, SAS Institute 1996). ANOVAs were also used to determine whether individual species presence varied by treatment. An alpha level of $p<0.10$ was used to determine significance. Pairwise t-tests distinguished differences among treatments, blocks, and years.

Community similarity was calculated using the Sorenson Index (C_s):

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

where a is the number of species present in community 1, b is the number of species present in community 2, and j is the number of species that are in common to both communities. C_s index ranks communities from 0-1 (0=dissimilar, 1=similar).

Nest Searching and Monitoring

Nest productivity within treatments was measured using standardized methods (Ralph 1993, Martin and Geupel, 1993, Martin et al. 1997, etc). Only two of three replicate blocks were used to assess treatment differences. Search methods were systematic following established grid points and were supplemented by behavioral cues, such as carrying of nest material observations. Nests were monitored every 3-4 days. A mirror on a telescoping pole was used for monitoring higher nests. Non-invasive visual checks were completed before 3 days of the estimated fledge date to prevent premature fledging. Nests were again checked at estimated fledging date to verify fledge or failure status. If no birds were in the nest (often accompanied by signs that fledglings were nearby), nests were considered successful. Equal search times were applied among treatments all three years but more total time was invested in 2003 search and monitoring efforts (40 hours/treatment type). Chi-square analyses were performed to determine if nesting attempts differed among treatments using an alpha level of $p<0.10$. Microhabitat measurements were made at nest sites after nesting activity was completed using 11.3 meter radius circular plots. Measurements reported include nest substrate [height of the shrub or tree holding the nest (m), DBH of the shrub or tree holding the nest (cm)] and nest characteristics [height of the nest above ground (m), cover (%)]. Percent cover was determined by recording the percent of nest obscured by vegetation or other obstructions (i.e. the trunk of the snag for cavity nesters). A 25 cm diameter sphere was imagined as surrounding the nest site to estimate how much was filled with cover. ANOVAs were used to determine treatment differences in nest substrate and nest characteristics of nest attempts (fledged and failed) and fledged nests.

Vegetation Sampling

As part of the cooperative NFFS agreement, vegetation sampling was conducted by a team of USDA Forest Service technicians. Permanent grid points were established at a 50 meter spacing interval at each treatment. The 50-meter distances were adjusted for slope using a hypsometer. Based on the grid layer established, ten 0.1 ha (20x50 m) rectangular sample plots were placed every fourth grid point (Figure 2.) Ten x ten meter subplots, developed within the 20x50 m sample plots, were used to measure vegetation. All trees 10 centimeters (cm) DBH or larger were measured in 5 of the 10 subplots. For each tree, the tree number, species, DBH, status, total height, height to live crown, height to dead crown, and crown condition were recorded. Status included: standing live, standing dead, dead and down, and harvested. Crown condition was an estimate of percent cover. Increment cores were extracted from 3 randomly selected trees to establish product age. Saplings (trees >1.4 m tall and < 10 cm DBH), shrubs, and larger trees were measured on the same five 10 x 10 meter subplots. Saplings were recorded by species, status, and DBH class. Status included live, top-killed, 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 area covered by shrubs' crowns (Waldrop 2001). Total snags ≥12 cm were averaged for both pre- and post-treatment data. ANOVAs were generated to determine treatment differences in trees (mean DBH, % crown cover, snag

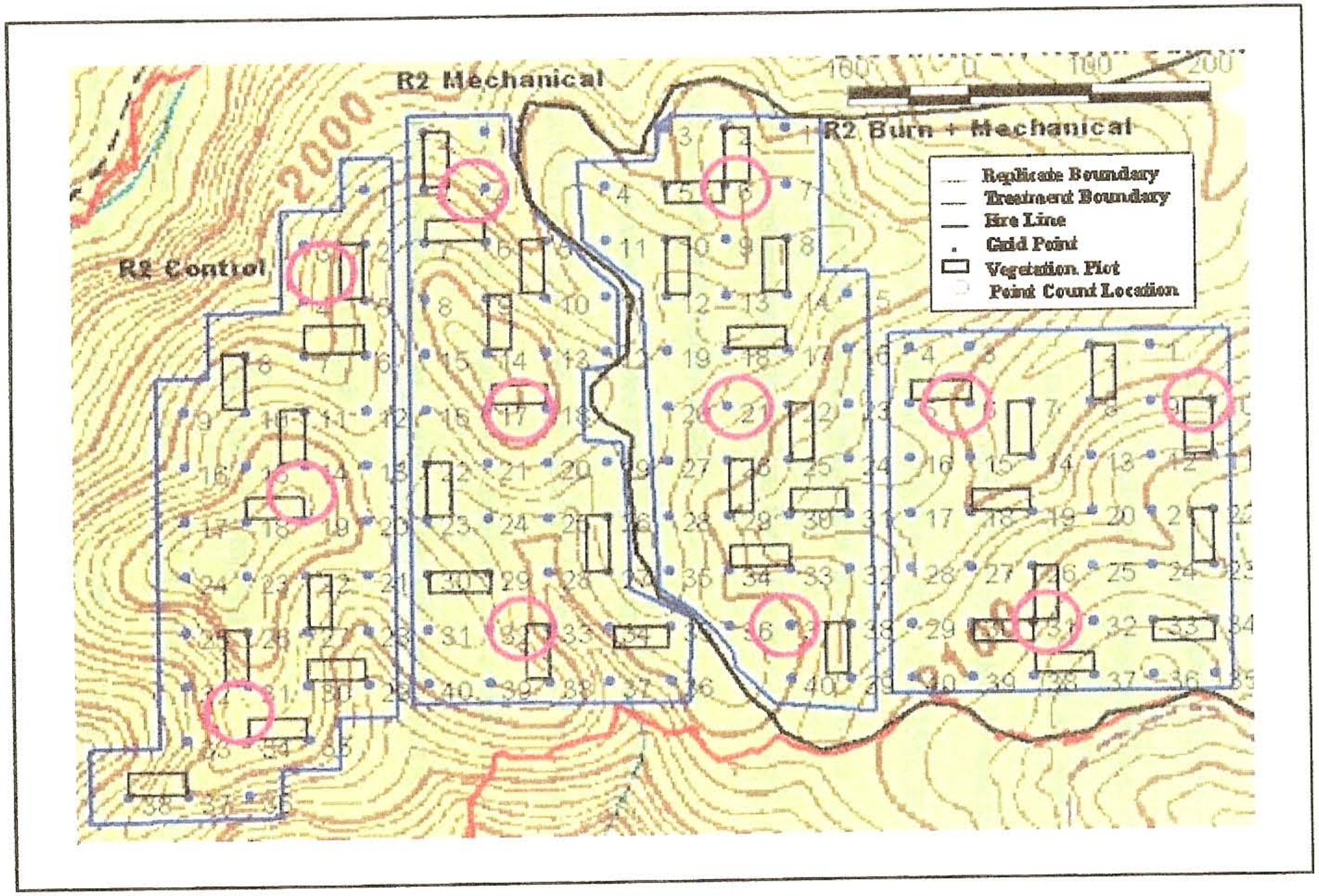

Figure 2. Map of Replicate 2 at Green River Game Lands, Polk County, NC.

density) and shrubs (% cover). An alpha level of $p<0.10$ was used to determine significance.

A total of twenty 1m^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 x 10 m subplot. All trees < 1.4 m tall were recorded by origin and height class categories. Origin categories included first-year seedling, established seedling, or sprout. Height classes included < 10 cm, 10 to 50 cm, and 50 to 139 cm. Shrubs (<1.4 m tall) and all herbaceous species were recorded by species, cover class, and origin class. Cover classes included <1%, 1 to 10%, 11 to 25%, 26 to 50%, 51 to 75%, and > 75%. Origin class included germinant, established plant, or sprout (Waldrop 2001). An ANOVA was generated to analyze forbs (% ground cover). An alpha level of $p<0.10$ was used to determine significance.

Vegetation measurements were taken in 2001 and 2003 from June-August yielding pre-treatment and post-treatment data for all twelve of the study plots. The measurements most relevant to songbird composition, including average DBH, crown cover, snag density, shrub cover, and ground cover, will be presented for each of three treatments implemented and a control.

Litter Layer Sampling

Samples were randomly selected in areas that represent the full range of forest floor depth on the each treatment area. Therefore, one litter sample was collected at each of 40 grid points per treatment. An additional 10 samples were collected from just outside each vegetation sample plot. A wooden frame was used along with a cutter to collect each sample. After careful removal of the frame, leaf layer was measured in the center of each side of the square foot sample. The four depths measured were then averaged by layer for that particular sample (Waldrop 2001). Litter layer depths were averaged from post-treatment measurements. An ANOVA was generated to analyze litter layer depths. An alpha level of $p<0.10$ was used to determine significance. Pairwise t-tests distinguished differences among treatments, blocks, and years.

CHAPTER IV

RESULTS

Avian Community Assessment

A total of 2489 birds was detected. Over 3 years (3 seasons), 59 species were detected (Table 1).

Table 1. Point count surveys abundance and species richness 2001-2003, Green River Game Lands, NC.

Season[1]	Treatment[2]	# individuals	species richness	∑ individuals/ ∑ richness
Spring 2001	C	145	19	582 / 31
	B	131	24	
	M	137	19	
	MB	169	25	
Spring 2002	C	206	29	842 / 37
	B	210	30	
	M	207	30	
	MB	219	30	
Winter 2002	C	66	16	277 / 27
	B	86	23	
	M	60	14	
	MB	65	16	
Migrant 2003	C	100	24	384 / 37
	B	98	23	
	M	93	23	
	MB	93	18	
Spring 2003	C	122	27	404 / 42
	B	99	25	
	M	82	21	
	MB	101	29	
Totals		2489	59	

[1] Spring 2001, no treatments in place; Spring 2002 and Winter 2002, mechanical treatments in place; Migrant 2003 and Spring 2003, all treatments in place.

[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.

Breeding Bird Surveys

No differences were detected in breeding season abundance during the 2001 pretreatment surveys (p=0.6949), 2002 M and C surveys (p=0.9952), or 2003 post-treatment surveys comparing B, M, MB, and C (p=0.1001). There were differences in abundance among years (p<0.0001) (Table 2). No differences were detected in breeding season species richness during 2001 pretreatment surveys (p=0.3681), 2002 M and C surveys (p=0.9495), or 2003 post-treatment surveys (p=0.1081). However, there were richness differences across years (p<0.0001) (Table 3).

Species diversity (H) differed among treatments during the 2003 breeding season (p=0.0796). Controls were more diverse than burn treatments (both mechanical treatments grouped together with diversity levels between controls and burns) and ranged from 2.47-2.69. Treatment evenness (E) remained constant throughout all surveys ranging from 0.942-0.991.

Abundance of ground nesters differed among treatments only in 2001 when no treatments had been implemented (p=0.0816) (M had highest abundance, other treatment plots grouped together with lower abundance) (Table 2). Abundance of ground nesters decreased in 2003 (p=0.0026). Richness of ground nesting species differed among treatments in 2002 (p=0.0701) and 2003 (p=0.0289). (Controls had consistently higher richness). Yearly differences in total abundance and richness of ground nesting were detected (p=0.0026, p=0.0965) (Table 2 and 3).

There were no treatment differences in breeding season abundance or richness of shrub nesting species in 2001, 2002, or 2003. No treatment differences were detected in abundance or richness of tree nesting species in 2001, 2002, or 2003 (Tables 2 and 3).

Table 2. Comparisons of breeding bird abundance per 10 hectares, Green River Game Lands, NC.

Guild	Year[1]	Abundance Treatment[2] C	M	MB	B	Total	P-value Treatment Year	P-value
All Species	2001	23.06±3.74	22.99±3.60	29.42±8.27	21.49±2.53	96.96B[3]	0.6949	<0.0001
	2002	33.81±6.78	32.48±2.68	32.48±5.24	32.95±4.27	131.72A	0.9952	
	2003	19.77±2.76	14.12±0.54	16.47±3.08	15.85±3.15	66.21C	0.1001	
Ground Nesting	2001	6.43±1.55ab[4]	10.12±0.61a	3.84±1.65b	4.47±1.54b	24.86A	**0.0816**	0.0026
	2002	7.92±0.44	8.39±0.44	5.26±1.31	7.43±1.81	29.00A	0.1813	
	2003	5.49±1.55	4.71±1.25	1.41±0.00	2.82±0.82	14.43B	0.3285	
Shrub Nesting	2001	8.08±1.93	6.67±1.71	12.08±3.90	6.67±1.71	33.50B	0.2128	0.0066
	2002	10.83±2.32	10.12±2.48	9.18±1.57	10.12±2.52	40.12A	0.9506	
	2003	7.77±2.12	5.65±1.87	5.57±2.21	8.39±0.34	27.38C	0.3047	
Tree Nesting	2001	10.98±1.97	9.34±1.91	16.24±5.25	11.81±2.18	48.37A	0.4583	0.0003
	2002	10.59±2.37	13.41±1.03	12.24±2.05	13.49±2.61	49.73A	0.6533	
	2003	7.22±1.66	6.51±1.73	8.63±1.41	7.61±2.11	29.97B	0.6259	
Cavity Nesting	2001	6.75±1.02	7.77±3.18	4.71±0.47	9.26±1.11	28.49B	0.4986	0.0836
	2002	9.41±1.60	9.41±2.49	13.81±3.11	6.75±0.16	39.38A	0.2718	
	2003	6.67±1.98	5.41±0.85	8.16±0.55	8.24±0.85	28.48B	0.3879	
Ground Foraging	2001	5.81±1.57	8.00±2.01	5.49±2.21	4.71±1.70	24.01B	0.6329	0.0076
	2002	8.39±1.63	9.41±0.72	7.14±0.77	9.34±1.57	34.28A	0.5043	
	2003	5.49±1.19	4.63±0.77	4.39±1.93	5.41±0.62	19.92B	0.8990	
Shrub Foraging	2001	6.75±2.08ab	5.02±1.63bc	7.92±2.25a	3.77±2.35c	23.46B	**0.0811**	0.0054
	2002	8.16±0.77	8.94±1.44	6.90±2.11	6.12±1.03	30.12A	0.6034	
	2003	7.92±2.18a	4.00±0.24b	1.41±0.00b	3.53±0.41b	16.86C	**0.0850**	
Tree Foraging	2001	16.79±3.51	16.63±3.42	20.63±6.22	16.16±2.47	70.21B	0.8721	0.0001
	2002	23.61±5.10	21.65±2.17	22.75±4.12	22.12±3.29	90.13A	0.9893	
	2003	13.65±3.40	11.14±0.68	11.85±0.34	11.85±3.11	48.49C	0.8210	

[1] 2001=no treatments implemented, 2002= mechanical treatments implemented, 2003=all treatments implemented.
[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[3] Means followed by the same upper case letter within a column and guild are not significantly different at the 0.1 level.
[4] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Table 3. Comparisons of breeding bird species richness per 10 hectares, Green River Game Lands, NC.

Guild	Year[1]	Treatment[2] C	M	MB	B	Total	P-value Treatment	P-value Year
			Species Richness					
All Species	2001	20.24±1.25	20.24±1.25	24.47±2.62	21.65±0.47	86.60B[3]	0.3681	<0.0001
	2002	30.12±2.86	30.59±3.29	28.24±2.94	30.12±1.70	119.07A	0.9495	
	2003	22.59±2.16	18.36±1.41	18.36±2.94	19.30±0.47	78.61C	0.1081	
Ground Nesting	2001	4.71±0.47	3.77±0.47	3.77±0.47	3.77±1.16	16.02AB	0.7300	0.0965
	2002	6.12±0.44a[4]	3.77±0.44b	3.29±1.31b	4.71±1.81ab	17.89A	**0.0701**	
	2003	5.18±1.55a	3.77±1.25ab	2.12±0.00c	2.35±0.82bc	13.42B	**0.0289**	
Shrub Nesting	2001	4.24±0.82	4.24±0.82	8.00±1.89	5.18±0.47	21.66B	0.1399	<0.0001
	2002	7.06±0.82	5.65±1.41	9.88±1.63	6.12±0.94	28.71A	0.2200	
	2003	6.59±0.94	4.71±1.25	4.71±2.05	5.65±0.82	21.66B	0.6993	
Tree Nesting	2001	8.00±0.94	8.00±0.94	8.94±2.05	8.47±1.88	33.41	0.9726	0.1247
	2002	8.00±0.82	9.88±0.94	8.94±2.16	9.41±0.82	36.23	0.8587	
	2003	6.59±2.05	8.00±1.25	8.00±1.70	7.53±1.25	30.12	0.8733	
Cavity Nesting	2001	4.24±0.00bc	5.18±0.47ab	3.77±0.47c	5.65±0.00a	18.84C	**0.0342**	<0.0001
	2002	8.47±0.00b	10.35±1.25a	7.06±0.82b	8.47±0.00b	34.35A	**0.0661**	
	2003	6.12±1.25b	3.77±0.47b	8.94±1.25a	4.24±0.00b	23.07B	**0.0271**	
Ground Foraging	2001	3.77±0.47	4.71±1.25	5.65±0.82	4.71±0.94	18.84B	0.2108	0.0220
	2002	6.59±1.25	6.59±1.25	6.59±0.47	4.71±0.47	24.48A	0.2512	
	2003	5.18±0.47	4.71±0.94	4.71±2.05	4.71±0.47	19.31B	0.9849	
Shrub Foraging	2001	3.29±0.47	2.35±0.47	4.71±0.94	3.29±0.94	13.64B	0.2325	0.0039
	2002	6.12±0.47	5.18±1.25	6.12±0.94	4.24±0.82	21.66A	0.5240	
	2003	6.12±0.94a	3.77±0.47b	2.12±0.71c	2.82±0.00bc	14.83B	**0.0070**	
Tree Foraging	2001	12.71±1.41	13.65±0.47	12.71±2.16	14.59±0.47	53.66B	0.7780	0.0020
	2002	18.36±0.82	18.83±2.35	16.47±1.88	17.89±1.25	71.55A	0.8160	
	2003	13.18±2.86	14.12±1.63	16.00±0.94	12.24±0.47	55.54B	0.2910	

[1] 2001=no treatments implemented, 2002= mechanical treatments implemented, 2003=all treatments implemented.
[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn
[3] Means followed by the same upper case letter within a column and guild are not significantly different at the 0.1 level.
[4] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Abundance of cavity nesters did not differ among treatments in 2001, 2002, or 2003 (Table 2). Richness of cavity nesting species differed among treatments in all three years: 2001 pretreatment ($p=0.0342$) (B richest- no treatment), 2002 ($p=0.0661$) (M richest), and 2003 when all treatments were in place ($p=0.0271$) (MB richest). Yearly differences in total abundance and richness of cavity nesting were detected ($p=0.0836$, $p<0.0001$); 2002 was more abundant and rich (Table 2 and 3).

No treatment differences were detected in the abundance or richness of ground or tree foraging species in 2001, 2002, or 2003 (Tables 2 and 3). Differences were detected in the abundance of shrub foraging species in 2001 pretreatment surveys ($p=0.0811$) (MB: highest abundance) and 2003 post treatment surveys ($p=0.0850$) (C: highest abundance). Yearly differences were detected ($p=0.0054$) (Table 2). Richness of shrub foraging species differed among treatments in 2003 ($p=0.0070$) (C richest, MB least rich) (Table 3).

During breeding season 2001 pretreatment surveys, abundance of 3 species differed among treatment plots: American crows (*Corvus brachyrhynchos*) ($p=0.0436$) and eastern phoebes (*Sayornis phoebe*) ($p=0.0701$) were most abundant in MB, and white-breasted nuthatches (*Sitta carolinensis*) ($p=0.0077$) were most abundant in B plots (Table 4).

During breeding season 2002 C and M surveys, abundance of yellow-shafted flickers (*Colaptes auratus*) differed among treatments ($p=0.0701$) (M: most abundant) (Table 5).

Five species differed in abundance among treatments during breeding season 2003: hooded warblers (*Wilsonia citrina*) ($p=0.0401$), northern cardinals (*Cardinalis cardinalis*) ($p=0.0701$) and red-eyed vireos (*Vireo olivaceous*) ($p=0.0590$) were most

Table 4. 2001 Mean (±SE) abundance (per 10 ha) of breeding birds in pretreatment stands, Green River Game Lands, NC.

Species Common Name (*Scientific Name*)	Treatment[1] C	B	M	MB	P-value
Acadian flycatcher (*Empidonax virescens*)	0.00±0.00	0.10±0.10	0.00±0.00	0.00±0.00	0.4547
American crow (*Corvus brachyrhynchos*)	0.00±0.00b[2]	0.10±0.10b	0.05±0.05b	0.26±0.10a	**0.0436**
American goldfinch (*Carduelis tristis*)	0.00±0.00	0.00±0.00	0.00±0.00	0.16±0.09	0.1170
American robin (*Turdus migratorius*)	0.00±0.00	0.10±0.10	0.00±0.00	0.00±0.00	0.4547
Black-and-white warbler (*Mniotilta varia*)	0.21±0.14	0.16±0.09	0.31±0.09	0.31±0.09	0.7119
Black-throated green warbler (*Dendroica virens*)	0.47±0.16	0.37±0.29	0.42±0.19	0.63±0.42	0.8903
Blue-gray gnatcatcher (*Polioptila caerulea*)	0.26±0.26	0.05±0.05	0.00±0.00	0.42±0.42	0.6673
Blue-headed vireo (*Vireo solitarius*)	0.73±0.43	0.89±0.60	0.42±0.23	0.68±0.45	0.4049
Blue jay (*Cyanocitta cristata*)	0.10±0.05	0.20±0.14	0.05±0.05	0.05±0.05	0.6014
Broad-winged hawk (*Buteo platypterus*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Carolina chickadee (*Poecile carolinensis*)	0.31±0.00	0.47±0.09	0.68±0.45	0.00±0.00	0.3283
Carolina wren (*Thryothorus ludovicianus*)	0.31±0.24	0.00±0.00	0.16±0.16	0.10±0.10	0.5573
Eastern phoebe (*Sayornis phoebe*)	0.00±0.00b	0.00±0.00b	0.00±0.00b	0.10±0.05a	**0.0701**
Eastern towhee (*Pipilo erythrophthalmus*)	0.10±0.10	0.10±0.05	0.00±0.00	0.10±0.10	0.5376
Eastern tufted titmouse (*Baeolophus bicolor*)	0.41±0.19	0.37±0.14	0.52±0.37	0.26±0.05	0.8821
Hooded warbler (*Wilsonia citrina*)	1.15±0.52	0.42±0.19	0.94±0.24	1.10±0.31	0.1935
Indigo bunting (*Passerina cyanea*)	0.00±0.00	0.00±0.00	0.00±0.00	0.36±0.23	0.1492
Northern cardinal (*Cardinalis cardinalis*)	0.00±0.00	0.00±0.00	0.00±0.00	0.16±0.09	0.1170
Ovenbird (*Seiurus aurocapillus*)	0.37±0.14	0.35±0.19	0.78±0.09	0.21±0.14	0.1714
Red-eyed vireo (*Vireo olivaceus*)	1.15±0.41	1.08±0.53	1.05±0.29	1.26±0.24	0.9860
Ruby-throated hummingbird (*Archilochus colubris*)	0.37±0.23	0.05±0.05	0.47±0.18	0.31±0.24	0.5402
Scarlet tanager (*Piranga olivacea*)	0.26±0.10	0.42±0.26	0.26±0.05	0.73±0.41	0.5122
White-breasted nuthatch (*Sitta carolinensis*)	0.00±0.00b	0.31±0.00a	0.10±0.05b	0.10±0.05b	**0.0077**
Wild turkey (*Meleagris gallopavo*)	0.05±0.05	0.05±0.05	0.00±0.00	0.00±0.00	0.6542
Wood thrush (*Hylocichla mustelina*)	0.00±0.00	0.16±0.09	0.05±0.05	0.58±0.50	0.4547
Worm-eating warbler (*Helmitheros vermivorus*)	0.58±0.26	0.05±0.05	0.31±0.18	0.26±0.19	0.1618
Yellow-billed cuckoo (*Coccyzus americanus*)	0.05±0.05	0.00±0.00	0.05±0.05	0.00±0.00	0.6542
Yellow-throated warbler (*Dendroica dominica*)	0.00±0.00	0.05±0.05	0.00±0.00	0.10±0.10	0.4547

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[2] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Table 5. 2002 Mean (±SE) abundance (per 10 ha) of breeding birds, Green River Game Lands, NC. Mechanical treatments implemented.

Species Common Name (*Scientific Name*)	Treatment[1] C	B	M	MB	P-value
Acadian flycatcher (*Empidonax virescens*)	0.26±0.05	0.42±0.21	0.05±0.05	0.26±0.26	0.5263
American crow (*Corvus brachyrhynchos*)	0.10±0.10	0.16±0.16	0.21±0.05	0.31±0.18	0.7710
American goldfinch (*Carduelis tristis*)	0.37±0.19	0.31±0.09	0.21±0.10	0.31±0.09	0.4547
Black-and-white warbler (*Mniotilta varia*)	0.47±0.09	0.31±0.18	0.21±0.21	0.16±0.16	0.6670
Black-throated green warbler (*Dendroica virens*)	0.37±0.19	0.31±0.24	0.63±0.24	0.31±0.24	0.1170
Blue-gray gnatcatcher (*Polioptila caerulea*)	0.10±0.10	0.16±0.16	0.10±0.05	0.21±0.21	0.9453
Blue-headed vireo (*Vireo solitarius*)	0.94±0.33	0.99±0.69	1.36±0.50	0.78±0.33	0.7406
Blue jay (*Cyanocitta cristata*)	0.21±0.10	0.42±0.28	0.16±0.09	0.10±0.10	0.4267
Carolina chickadee (*Poecile carolinensis*)	0.84±0.32	0.16±0.09	0.47±0.18	0.94±0.00	0.1211
Carolina wren (*Thryothorus ludovicianus*)	0.52±0.14	0.16±0.00	0.37±0.14	0.52±0.26	0.3486
Chimney swift (*Chaetura pelagica*)	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.05	0.4547
Downy woodpecker (*Picoides pubescens*)	0.16±0.09	0.10±0.05	0.21±0.14	0.05±0.05	0.7033
Eastern phoebe (*Sayornis phoebe*)	0.00±0.00	0.10±0.10	0.05±0.05	0.00±0.00	0.4547
Eastern towhee (*Pipilo erythrophthalmus*)	0.10±0.05	0.00±0.00	0.05±0.05	0.05±0.05	0.4547
Eastern tufted titmouse (*Baeolophus bicolor*)	0.58±0.05	0.63±0.24	0.78±0.36	0.94±0.36	0.8040
Hairy woodpecker (*Picoides villosus*)	0.10±0.10	0.16±0.00	0.10±0.05	0.05±0.05	0.7138
Hooded warbler (*Wilsonia citrina*)	1.36±0.24	1.10±0.24	0.58±0.14	0.78±0.27	0.1585
Indigo bunting (*Passerina cyanea*)	0.10±0.05	0.05±0.05	0.21±0.21	0.26±0.19	0.7659
Kentucky warbler (*Oporornis formosus*)	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.4547
Mourning dove (*Zenaida macroura*)	0.00±0.00	0.00±0.00	0.00±0.00	0.21±0.14	0.1788
Northern cardinal (*Cardinalis cardinalis*)	0.05±0.05	0.00±0.00	0.05±0.05	0.10±0.05	0.4547
Ovenbird (*Seiurus aurocapillus*)	0.73±0.19	0.94±0.36	1.20±0.26	0.89±0.45	0.3570
Pileated woodpecker (*Dryocopus pileatus*)	0.47±0.18	0.31±0.09	0.21±0.05	0.26±0.10	0.5427
Red-bellied woodpecker (*Melanerpes carolinus*)	0.16±0.09	0.00±0.00	0.10±0.05	0.00±0.00	0.1170
Red-eyed vireo (*Vireo olivaceus*)	0.84±0.19	0.94±0.09	0.78±0.33	1.26±0.47	0.4661
Ruby-throated hummingbird (*Archilochus colubris*)	0.00±0.00	0.10±0.10	0.00±0.00	0.10±0.05	0.3776
Scarlet tanager (*Piranga olivacea*)	0.37±0.23	0.73±0.23	0.78±0.05	0.58±0.23	0.3731
Veery (*Catharus fuscescens*)	0.05±0.05	0.05±0.05	0.00±0.00	0.00±0.00	0.4547

Table 5. (Continued)

Species Common Name (*Scientific Name*)	Treatment C	B	M	MB	P-value
Whip-poor-will (*Caprimulgus vociferus*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
White-breasted nuthatch (*Sitta carolinensis*)	0.26±0.10	0.31±0.16	0.52±0.38	0.63±0.24	0.6063
Wood thrush (*Hylocichla mustelina*)	0.21±0.14	0.52±0.32	0.16±0.16	0.10±0.05	0.5436
Worm-eating warbler (*Helmitheros vermivorus*)	0.47±0.16	0.47±0.24	0.42±0.05	0.31±0.09	0.8532
Yellow-billed cuckoo (*Coccyzus americanus*)	0.00±0.00	0.05±0.05	0.05±0.05	0.00±0.00	0.4547
Yellow-shafted flicker (*Colaptes auratus*)	0.00±0.00b[2]	0.00±0.00b	0.10±0.05a	0.00±0.00b	**0.0701**
Yellow-throated warbler (*Dendroica dominica*)	0.00±0.00	0.10±0.10	0.00±0.00	0.16±0.16	0.4547

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.

[2] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Table 6. 2003 Mean (±SE) abundance (per 10 ha) of breeding birds, Green River Game Lands, NC. All treatments implemented.

Species Common Name (*Scientific Name*)	Treatment[1] C	B	M	MB	P-value
Acadian flycatcher (*Empidonax virescens*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
American crow (*Corvus brachyrhynchos*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
American goldfinch (*Carduelis tristis*)	0.16±0.09	0.37±0.23	0.10±0.10	0.37±0.23	0.2533
American robin (*Turdus migratorius*)	0.00±0.00	0.00±0.00	0.05±0.05	0.00±0.00	0.4547
Black-and-white warbler (*Mniotilta varia*)	0.26±0.05	0.05±0.05	0.10±0.10	0.05±0.05	0.2617
Black-throated green warbler (*Dendroica virens*)	0.10±0.10	0.16±0.16	0.26±0.26	0.10±0.10	0.4547
Blue-gray gnatcatcher (*Polioptila caerulea*)	0.26±0.14	0.37±0.29	0.21±0.14	0.10±0.10	0.6930
Blue-headed vireo (*Vireo solitarius*)	0.31±0.09	0.37±0.19	0.42±0.19	0.21±0.14	0.8064
Blue jay (*Cyanocitta cristata*)	0.00±0.00	0.26±0.14	0.21±0.05	0.21±0.10	0.2398
Broad-winged hawk (*Buteo platypterus*)	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.4547
Carolina chickadee (*Poecile carolinensis*)	0.05±0.05	0.05±0.05	0.10±0.10	0.10±0.05	0.9194
Carolina wren (*Thryothorus ludovicianus*)	0.21±0.14	0.00±0.00	0.00±0.00	0.00±0.00	0.1788
Chimney swift (*Chaetura pelagica*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Chipping sparrow (*Spizella passerina*)	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.05	0.4547
Downy woodpecker (*Picoides pubescens*)	0.21±0.14	0.10±0.05	0.00±0.00	0.16±0.09	0.5137
Eastern bluebird (*Sialia sialis*)	0.00±0.00	0.00±0.00	0.00±0.00	0.42±0.42	0.4547
Eastern phoebe (*Sayornis phoebe*)	0.00±0.00	0.00±0.00	0.00±0.00	0.16±0.16	0.4547
Eastern towhee (*Pipilo erythrophthalmus*)	0.10±0.10	0.00±0.00	0.05±0.05	0.00±0.00	0.4547
Eastern tufted titmouse (*Baeolophus bicolor*)	0.42±0.23	0.47±0.24	0.16±0.16	0.42±0.10	0.6344
Eastern wood- pewee (*Contopus virens*)	0.00±0.00	0.00±0.00	0.00±0.00	0.26±0.19	0.2271
Great-crested flycatcher (*Myiarchus crinitus*)	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.4547
Hairy woodpecker (*Picoides villosus*)	0.05±0.05	0.00±0.00	0.10±0.05	0.10±0.05	0.1889
Hooded warbler (*Wilsonia citrina*)	1.36±0.55a[2]	0.21±0.21b	0.31±0.09b	0.00±0.00b	**0.0401**
Indigo bunting (*Passerina cyanea*)	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.05	0.4547
Mourning dove (*Zenaida macroura*)	0.00±0.00	0.16±0.16	0.00±0.00	0.10±0.10	0.4547
Northern cardinal (*Cardinalis cardinalis*)	0.10±0.05a	0.00±0.00b	0.00±0.00b	0.00±0.00b	**0.0701**
Ovenbird (*Seiurus aurocapillus*)	0.37±0.29	0.05±0.05	0.42±0.19	0.05±0.05	0.4414
Pileated woodpecker (*Dryocopus pileatus*)	0.16±0.09	0.16±0.09	0.00±0.00	0.16±0.09	0.2473
Pine warbler (*Dendroica pinus*)	0.00±0.00	0.05±0.05	0.05±0.05	0.31±0.18	0.2089
Red-bellied woodpecker (*Melanerpes carolinus*)	0.05±0.05	0.00±0.00	0.00±0.00	0.10±0.05	0.3376

Table 6. (Continued)

Species Common Name (*Scientific Name*)	Treatment C	B	M	MB	P-value
Red-eyed vireo (*Vireo olivaceus*)	0.94±0.09a	0.05±0.23b	0.37±0.14b	0.47±0.09b	**0.0590**
Ruby-throated hummingbird (*Archilochus colubris*)	0.16±0.09	0.16±0.09	0.05±0.05	0.05±0.05	0.5187
Scarlet tanager (*Piranga olivacea*)	0.05±0.05	0.16±0.16	0.42±0.19	0.26±0.14	0.3984
White-breasted nuthatch (*Sitta carolinensis*)	0.00±0.00	0.42±0.21	0.42±0.14	0.37±0.10	0.2332
Wild turkey (*Meleagris gallopavo*)	0.00±0.00	0.05±0.05	0.00±0.00	0.05±0.05	0.4547
Wood thrush (*Hylocichla mustelina*)	0.05±0.05bc	0.26±0.05a	0.00±0.00c	0.10±0.05b	**0.0072**
Worm-eating warbler (*Helmitheros vermivorus*)	0.31±0.09a	0.21±0.14a	0.31±0.09a	0.00±0.00b	**0.0541**
Yellow-billed cuckoo (*Coccyzus americanus*)	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.4547
Yellow-shafted flicker (*Colaptes auratus*)	0.00±0.00	0.00±0.00	0.05±0.05	0.05±0.05	0.6542

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[2] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

abundant in C, worm-eating warblers (*Helmitheros vermivorus*) ($p=0.0541$) were least abundant in MB, and wood thrushes (*Hylocichla mustelina*) ($p=0.0072$) were most abundant in B treatments (Table 6).

Avian communities were relatively similar throughout pretreatment, 2002, and post-treatment surveys (Table 7).

Nest Surveys

In 2001, four nests of four species were found including wood thrush, yellow-billed cuckoo, blue-headed vireo, and hooded warbler (Table 8). In 2002, 11 nests were found (7 in "C" and 4 in M. Wood thrush, black-and-white warbler, Carolina wren, ovenbird and blue jay nests were found in controls while worm-eating warbler, Carolina wren, blue-headed vireo, and eastern tufted titmouse nests were found in mechanical plots. Thus Carolina wrens were the only species in 2002 that nested in more than one treatment type. More nests were found in 2003 due to greater search effort. Hooded warblers, hairy woodpeckers, worm-eating warblers, and black-and-white warblers were detected only in C, blue jays were detected only in B, and ruby-throated hummingbirds and whip-poor-wills were found only in M.

In 2003, nesting attempts were relatively equal in all treatments ($n=31$) except MB where no nests were found (Table 9). Among nesting attempts in 2003, 8 (62%) were successful ($\geq$ 1 fledgling produced) in C, 5 (45%) were successful in B, and 6 (75%) were successful in M.

In 2003, nesting attempt distributions by various guilds did not differ among treatments ($p=0.4821$) (Table 10). Among 2003 nesting attempts, 6 (14%) were ground nesters, 17 (40%) were shrub nesters, 12 (29%) were tree nesters, and 7 (17%) were

Table 7. Breeding avian species community similarity (C_s) among treatments, Green River Game Lands, NC.

C_s	B+C[1]	B+M	B+MB	C+M	C+MB	M+MB
Spring 2001[2]	0.780	0.780	0.596	0.833	0.476	0.762
Spring 2002	0.842	0.828	0.897	0.912	0.877	0.862
Spring 2003	0.640	0.714	0.538	0.682	0.630	0.700

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[2] 2001: no treatments implemented, 2002: only mechanical treatments implemented 2003: all treatments implemented.

Table 8. Nesting summary, Green River Game Lands, NC. Bird species and nest success (*). Search effort was not equal in 2001, 2002, and 2003. See Table A-1 for scientific names of bird species.

	2001[1]	2002	2003
C[2]	n/a	Wood thrush *Black-and-white warbler *Carolina wren	*Hooded warbler *Hairy woodpecker *Downy woodpecker *Eastern tufted titmouse Ovenbird Worm-eating warbler *Black-and-white warbler *Wood thrush Blue-headed vireo *Black-and-white warbler *Downy woodpecker Blue-headed vireo Wood thrush
B	*Wood thrush	Ovenbird Blue jay Wood thrush Ovenbird	Wood thrush Blue jay *Blue jay *Downy woodpecker Blue-headed vireo Blue-headed vireo *Wood thrush Wood thrush *Blue-headed vireo Blue-headed vireo *Wood thrush
M	n/a	*Worm-eating warbler *Blue-headed vireo	*Whip-poor-will *Blue-headed vireo *Blue-headed vireo *Pileated woodpecker Ruby-throated hummingbird Blue-headed vireo *Ovenbird *Eastern tufted titmouse
MB	*Yellow-billed cuckoo Blue-headed vireo *Hooded warbler	*Carolina wren *Eastern tufted titmouse	n/a

* Nest success was defined by production of $\geq$ 1 fledgling.
[1] 2001=no treatments, 2002=only mechanical treatments, 2003=all treatments.
[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.

Table 9. Nest success summary by year, Green River Game Lands, NC.

	2001[1]	2002	2003	3-year average
C[2]	n/a	2 (67%)[3]	8 (62%)	10 (71%)
B	1 (100%)	n/a	5 (45%)	6 (38%)
M	n/a	2 (100%)	6 (75%)	8 (80%)
MB	2 (67%)	2 (100%)	n/a	4 (80%)

[1] 2001=no treatments, 2002=only mechanical treatments, 2003=all treatments.
[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[3] Nest success was defined by production of ≥ 1 fledgling.

Table 10. 2003 nesting frequency by guild and treatment, Green River Game Lands, NC. p=0.4821.

Frequency	Cavity	Ground	Shrub	Tree	Total
B[1]	1	0	8	6	15
C	4	4	5	2	15
M	2	2	4	4	12
MB	0	0	0	0	0
Total	7	6	17	12	42

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.

cavity nesters. Of those nesting attempts in 2003 by respective nesting guilds, 4 (67%) of ground nesters were successful, 7 (41%) shrub nesters were successful, 4 (33%) of tree nesters were successful, and 7 (100%) cavity nesters were successful. (Note: blue-headed vireo nesting ratios were applied to both shrub and tree analysis.) This analysis is unlike the analysis using point count data to analyze nesting guild because point count data were more complete and included substantial pretreatment population status.

Nest success varied by guild and treatment (Table 11). The three year average of cavity nests reflected 100% (n=5) success rates in C, 100% (n=1) success rates in B, and 100% (n=4) success rates in M. No cavity nests were found in MB. The three year average of ground nests reflected 67% (n=6) success rates in C and 100% (n=4) success rates in M. No ground nests were found in B or MB. The three year average of shrub nests found reflected 56% (n=9) success rates in C, 38% (n=8) success rates in B, and 60% (n=5) success rates in M. No shrub nests were found in MB. The three year average of tree nests found reflected 25% (n=4) success rates in C, 33% (n=6) success rates in B, and 60% (n=5) success rates in M. No tree nests were monitored in MB (although blue jay and blue-headed vireo nests were observed).

Substrate height (p=0.2524), substrate DBH (p=0.7169), and nest height (p=0.6797) did not differ among treatments for nest attempts. Nest cover (p=0.0507) differed among treatments, and was highest in C (Table 12). Nests that successfully produced fledglings, regardless of treatment or type of nest, did not differ in nest substrate or nest characteristics compared to those nests where no fledglings were produced (failures).

Winter Bird Surveys

No differences were detected in abundance or species richness in C versus M treatments in December/January 2002-2003 (Tables 13 and 14). Neither species diversity nor evenness differed among treatments in winter 2002-2003.

Table 11. Nest success summary by guild, Green River Game Lands, NC. C=cavity, G=ground, S=shrub, T=tree.

	2001	2002	2003	3-year average*
C[1]	C-n/a	C-1 (100%)	C-4 (100%)	C-5 (100%)
	G-n/a	G-2 (100%)	G-2 (50%)	G-4 (67%)
	S-n/a	S-n/a	S-2 (40%)	S-5 (56%)
	T-n/a	T-n/a	T-n/a	T-1 (25%)
B	C-n/a	C-n/a	C-1 (100%)	C-1 (100%)
	G-n/a	G-n/a	G-n/a	G-n/a
	S-1 (100%)	S-n/a	S-3 (38%)	S-3 (38%)
	T-n/a	T-n/a	T-2 (33%)	T-2 (33%)
M	C-n/a	C-n/a	C-2 (100%)	C-4 (100%)
	G-n/a	G-1 (100%)	G-2 (100%)	G-4 (100%)
	S-n/a	S-1 (100%)	S-2 (50%)	S-3 (60%)
	T-n/a	T-1 (100%)	T-2 (50%)	T-3 (60%)
MB	C-n/a	C-2 (100%)	C-n/a	C-n/a
	G-n/a	G-1 (100%)	G-n/a	G-n/a
	S-1 (50%)	S-n/a	S-n/a	S-n/a
	T-1 (50%)	T-n/a	T-n/a	T-n/a

* Adjustments were made according to time of treatment implementation.
[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.

No C or M treatment differences in abundance or richness of ground, shrub, or tree foraging species were detected in winter 2002-2003 (Tables 13 and 14).

During the December 2002-January 2003 C and M surveys, abundance of red-bellied woodpeckers ($p=0.0087$) and eastern tufted titmice ($p=0.0869$) differed among treatments (Table 15).

Migrant Bird Surveys

No post-treatment differences were detected in abundance or species richness in March 2003 (Tables 13 and 14). Neither species diversity nor evenness was different among treatments in March 2003.

No post-treatment differences in abundance or richness of ground, shrub, or tree foraging species were detected among treatments in March 2003 (Tables 13 and 14). However, total abundance of tree foraging species and richness of ground and tree foraging species increased in 2003 surveys.

Ovenbirds ($p=0.0701$) (C: most abundant) and yellow-shafted flickers ($p=0.0590$) (MB: most abundant) differed in abundance among treatments during March 2003 surveys (Tables 15 and 16).

Avian communities were similar throughout December 2002-January 2003 C and M winter surveys and March 2003 post-treatment winter surveys (Table 17).

Table 12. 2003 nest substrate vegetation measurements,* Green River Game Lands, NC.

	C[1] All/Successful[3]	B All/Successful	M All/Successful	MB[2] All/Successful	P-value All/Successful
Substrate height (m)	9.16/9.46	13.96/10.75	15.18/15.45	.	0.2524/0.7901
Substrate DBH (cm)	16.52/20.03	21.06/13.40	20.23/23.53	.	0.7169/0.7883
Nest height (m)	5.95/5.61	6.01/5.12	8.28/7.65	.	0.6797/0.9651
Nest cover (%)	70.64a[4]/73.22	39.50b/41.25	54.25ab/56.50	.	**0.0507**/0.6994

* Ground nesters were not included in nest substrate height, DBH, or nest height averages.

1 C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.

2 No nests found in MB in 2003 surveys.

3 Nest success was defined by production of $\geq$ 1 fledgling.

4 Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Table 13. Comparisons of winter and early migrant bird abundance per 10 hectares, Green River Game Lands, NC.

Guild	Year[1]	Treatment[2] C	Abundance M	MB	B	Total	P-value Treatment	P-value Year
All Species	2002	13.96±2.44	11.92±2.47	12.63±4.01	13.81±1.75	52.32	0.9544	0.1203
	2003	16.71±4.13	17.41±3.92	18.67±2.66	17.41±2.05	70.20	0.9742	
Ground Foraging	2002	1.41±0.00	4.24±0.47	2.82±0.00	3.29±0.82	11.76	0.2228	0.1827
	2003	4.32±1.41	4.94±0.94	8.47±1.25	4.47±0.94	22.20	0.2816	
Shrub Foraging	2002	2.12±0.71	1.41±0.00	2.82±0.00	2.35±0.47	8.70	0.2918	0.1107
	2003	2.84±0.47	3.45±0.94	6.00±0.00	5.65±1.41	17.94	0.2660	
Tree Foraging	2002	8.02±1.70	7.85±1.03	6.90±3.29	9.41±2.59	32.18B[3]	0.9196	0.0080
	2003	13.93±2.98	14.04±2.93	16.40±1.72	16.71±3.96	61.08A	0.8536	

[1] 2002= winter surveys with mechanical treatments implemented, 2003= early migrant surveys with all treatments implemented.
[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[3] Means followed by the same upper case letter within a column and guild are not significantly different at the 0.1 level.

Table 14. Comparisons of winter and early migrant bird species richness per 10 hectares, Green River Game Lands, NC.

Guild	Year[1]	Treatment[2] C	Species Richness M	MB	B	Total	P-value Treatment	P-value Year
All Species	2002	12.24±0.47	12.24±2.05	13.18±3.85	18.83±1.70	56.49B[3]	0.1951	0.0971
	2003	19.30±4.71	18.83±4.10	18.83±2.35	17.41±1.70	74.37A	0.9742	
Ground Foraging	2002	1.41±0.00	1.88±1.63	1.41±0.00	2.82±0.82	7.52B	0.3613	0.0643
	2003	5.65±1.41	3.29±0.94	4.71±1.25	3.29±0.94	16.94A	0.1912	
Shrub Foraging	2002	1.41±0.00	1.41±0.00	2.82±0.00	1.88±0.47	7.52	0.2670	0.1055
	2003	2.35±0.47	3.29±0.94	2.82±0.00	2.82±0.00	11.28	0.5884	
Tree Foraging	2002	7.06±0.82	6.59±1.25	8.00±2.62	9.88±2.16	31.53B	0.5407	0.0153
	2003	14.12±3.55	13.65±3.68	15.06±1.25	13.65±2.62	56.48A	0.9814	

[1] 2002= winter surveys with mechanical treatments implemented, 2003= early migrant surveys with all treatments implemented.
[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[3] Means followed by the same upper case letter within a column and guild are not significantly different at the 0.1 level.

Table 15. 2002 Mean (±SE) abundance (per 10 ha) of wintering birds, Green River Game Lands, NC. Mechanical treatments implemented.

Species Common Name (*Scientific Name*)	Year/Treatment C	B	M	MB	P-value
American crow (*Corvus brachyrhynchos*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
American goldfinch (*Carduelis tristis*)	0.10±0.10	0.10±0.05	0.10±0.10	0.16±0.16	0.9756
American robin (*Turdus migratorius*)	0.00±0.00	0.05±0.05	0.05±0.05	0.00±0.00	0.6542
Blue jay (*Cyanocitta cristata*)	0.00±0.00	0.05±0.05	0.00±0.00	0.10±0.05	0.1889
Brown creeper (*Certhia americana*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Carolina chickadee (*Poecile carolinensis*)	0.37±0.14	0.21±0.14	0.47±0.24	0.42±0.34	0.7583
Carolina wren (*Thryothorus ludovicianus*)	0.21±0.21	0.10±0.05	0.05±0.05	0.16±0.09	0.7420
Cedar waxwing (*Bombycilla cedrorum*)	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.05	0.4547
Cooper's hawk (*Accipiter cooperii*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Dark-eyed junco (*Junco hyemalis*)	0.05±0.05	0.31±0.24	0.37±0.23	0.21±0.21	0.3973
Downy woodpecker (*Picoides pubescens*)	0.16±0.09	0.31±0.18	0.05±0.05	0.05±0.05	0.3396
Eastern phoebe (*Sayornis phoebe*)	0.05±0.05	0.05±0.05	0.05±0.05	0.16±0.09	0.4547
Eastern towhee (*Pipilo erythrophthalmus*)	0.00±0.00	0.00±0.00	0.05±0.05	0.00±0.00	0.4547
Eastern tufted titmouse (*Baeolophus bicolor*)	3.69±0.28a[2]	3.45±0.42a	2.29±0.53b	2.17±0.14b	**0.0869**
Golden-crowned kinglet (*Regulus satrapa*)	0.10±0.10	0.31±0.09	0.16±0.09	0.10±0.05	0.4547
Hairy woodpecker (*Picoides villosus*)	0.16±0.16	0.31±0.18	0.10±0.05	0.26±0.18	0.3241
Northern cardinal (*Cardinalis cardinalis*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Pileated woodpecker (*Dryocopus pileatus*)	0.16±0.09	0.10±0.05	0.10±0.05	0.16±0.09	0.9394
Red-bellied woodpecker (*Melanerpes carolinus*)	0.10±0.05b	0.31±0.09a	0.00±0.00b	0.05±0.05b	**0.0087**
Turkey vulture (*Cathartes aura*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
White-breasted nuthatch (*Sitta carolinensis*)	0.68±0.28	0.58±0.28	0.73±0.43	0.21±0.14	0.6401
Winter wren (*Troglodytes troglodytes*)	0.05±0.05	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Yellow-bellied sapsucker (*Sphyrapicus varius*)	0.00±0.00	0.10±0.10	0.00±0.00	0.10±0.05	0.4547
Yellow-shafted flicker (*Colaptes auratus*)	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.3776

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[2] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Table 16. 2003 Mean (±SE) abundance (per 10 ha) of winter and early migrant birds (*), Green River Game Lands, NC. All treatments implemented.

Species Common Name (*Scientific Name*)	Year/Treatment C	B	M	MB	P-value
American crow (*Corvus brachyrhynchos*)	0.00±0.00	0.21±0.21	0.00±0.00	0.00±0.00	0.4547
American goldfinch (*Carduelis tristis*)	0.05±0.05	0.00±0.00	0.16±0.16	0.00±0.00	0.4547
American robin (*Turdus migratorius*)	0.16±0.09	0.21±0.10	0.16±0.09	0.26±0.14	0.8951
Barred owl (*Strix varia*)	0.00±0.00	0.00±0.00	0.05±0.05	0.00±0.00	0.4547
Black-and-white warbler (*Mniotilta varia*) *	0.10±0.10	0.00±0.00	0.00±0.00	0.00±0.00	0.4547
Black-throated green warbler (*Dendroica virens*) *	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.4547
Blue-headed vireo (*Vireo solitarius*) *	0.68±0.32	0.58±0.21	0.83±0.10	0.68±0.28	0.8185
Blue jay (*Cyanocitta cristata*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Brown creeper (*Certhia americana*)	0.00±0.00	0.05±0.05	0.05±0.05	0.00±0.00	0.6542
Carolina chickadee (*Poecile carolinensis*)	0.84±0.19	0.78±0.48	0.58±0.34	0.42±0.19	0.7270
Carolina wren (*Thryothorus ludovicianus*)	0.00±0.00	0.05±0.05	0.16±0.09	0.00±0.00	0.2853
Chipping sparrow (*Spizella passerina*)	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.05	0.4547
Cooper's hawk (*Accipiter cooperii*)	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547
Dark-eyed junco (*Junco hyemalis*)	0.05±0.05	0.05±0.05	0.00±0.00	0.00±0.00	0.6542
Downy woodpecker (*Picoides pubescens*)	0.16±0.00	0.37±0.19	0.31±0.16	0.26±0.19	0.7444
Eastern bluebird (*Sialia sialis*)	0.10±0.10	0.00±0.00	0.10±0.10	0.21±0.21	0.4547
Eastern phoebe (*Sayornis phoebe*)	0.05±0.05	0.10±0.05	0.21±0.19	0.26±0.05	0.3241
Eastern towhee (*Pipilo erythrophthalmus*)	0.00±0.00	0.00±0.00	0.05±0.05	0.00±0.00	0.4547
Eastern tufted titmouse (*Baeolophus bicolor*)	0.89±0.28	0.99±0.50	0.42±0.05	0.31±0.18	0.4045
Golden-crowned kinglet (*Regulus satrapa*)	0.21±0.14	0.16±0.09	0.05±0.05	0.00±0.00	0.4547
Hairy woodpecker (*Picoides villosus*)	0.21±0.10	0.00±0.00	0.05±0.05	0.16±0.09	0.3241
Mourning dove (*Zenaida macroura*)	0.00±0.00	0.00±0.00	0.00±0.00	0.16±0.16	0.4547
Myrtle warbler (*Dendroica coronata*)	0.00±0.00	0.16±0.16	0.31±0.31	0.29±0.10	0.5346
Ovenbird (*Seiurus aurocapillus*) *	0.10±0.05a[2]	0.00±0.00b	0.00±0.00b	0.00±0.00b	**0.0701**
Pileated woodpecker (*Dryocopus pileatus*)	0.26±0.14	0.21±0.14	0.16±0.09	0.47±0.33	0.6977
Pine warbler (*Dendroica pinus*)	0.26±0.14	0.21±0.21	0.37±0.19	0.31±0.18	0.8286
Red-bellied woodpecker (*Melanerpes carolinus*)	0.05±0.05	0.05±0.05	0.16±0.09	0.31±0.09	0.1672
Red-tailed hawk (*Buteo jamaicensis*)	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.4547

Table 16. (Continued)

Species Common Name (*Scientific Name*)	Year/Treatment C	B	M	MB	P-value
Ruby-crowned kinglet (*Regulus calendula*)	0.00±0.00	0.00±0.00	0.05±0.05	0.00±0.00	0.4547
White-breasted nuthatch (*Sitta carolinensis*)	0.37±0.05	0.47±0.18	0.16±0.09	0.26±0.10	0.3942
Wild turkey (*Meleagris gallopavo*)	0.05±0.05	0.05±0.05	0.00±0.00	0.00±0.00	0.6542
Winter wren (*Troglodytes troglodytes*)	0.05±0.05	0.00±0.00	0.05±0.05	0.00±0.00	0.6542
Yellow-bellied sapsucker (*Sphyrapicus varius*)	0.05±0.05	0.10±0.05	0.10±0.05	0.21±0.05	0.3161
Yellow-shafted flicker (*Colaptes auratus*)	0.05±0.05b	0.10±0.10ab	0.00±0.00b	0.21±0.05a	**0.0590**
Yellow-throated warbler (*Dendroica dominica*) *	0.05±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.4547

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[2] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Table 17. Winter and migrant avian species community similarity (C_s) among treatments, Green River Game Lands, NC.

C_s	B+C[2]	B+M	B+MB	C+M	C+MB	M+MB
Winter 2002[1]	0.737	0.929	0.769	0.800	0.839	0.774
Migrant 2003	0.652	0.667	0.700	0.711	0.700	0.718

[1] 2002= winter surveys with mechanical treatments implemented, 2003= early migrant surveys with all treatments implemented.
[2] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.

Study Site Vegetation and Litter Layer

No pre-treatment vegetation measurements (tree DBH, percent crown cover, snag density, percent shrub or ground cover, litter layer) differed among treatments (Table 18). Post-treatment tree DBH did not differ among treatments (p=0.7245). Post-treatment percent crown cover did not differ among treatments (p=0.1640).

Several post-treatment vegetation measurements differed among treatments. Snag density (p=0.0464) increased in MB following March prescribed burns and differed from other treatments and control.

Shrub cover differed among treatments (p=0.0968) and was highest in controls (26.7%) and lowest in MB (8.6%).

Ground cover differed among treatments (p=0.0168). M had highest percent ground cover (25.4%) while B had lowest percent ground cover (15.5%). *Vaccinium* species represented a large percentage of total ground cover and included *Vaccinium atrococcum*, *V. constablaei*, *V. fuscatum*, *V. pallidum*, and *V. stamineum*.

Litter layer depths were lower in both burn treatments following March prescribed fires (p<0.0001).

Table 18. Summary of vegetation results pre- and post-treatment implementation, Green River Game Lands, NC.

		C[1]	B	M	MB	P-value
Tree DBH (cm)	Pre-Treatment	22.39	22.02	21.56	21.85	0.6792
	Post-Treatment	22.47	21.87	21.89	21.50	0.7245
Tree Crown Cover (%)	Pre-Treatment	63.60	47.01	59.67	47.70	0.2786
	Post-Treatment	71.77	69.30	61.13	62.13	0.1640
Tree Snags/10ha	Pre-Treatment	132	116	92	124	0.6318
	Post-Treatment	120b[2]	104b	88b	232a	**0.0464**
Shrub Cover (%)	Pre-Treatment	14.49	8.00	15.35	9.94	0.5277
	Post-Treatment	26.66a	16.82ab	9.55b	8.58b	**0.0968**
Ground Cover (%)	Pre-Treatment	26.43	22.93	25.40	31.08	0.4158
	Post-Treatment	17.20bc	15.50c	25.52a	20.25b	**0.0168**
Litter Depth (cm)	Pre-Treatment	5.1	4.8	5.1	5.1	0.8587
	Post-Treatment	4.3b	1.0c	5.6a	0.5c	**0.0001**

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[2] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

Table 18. Summary of vegetation results pre- and post-treatment implementation, Green River Game Lands, NC.

		C[1]	B	M	MB	P-value
Tree DBH (cm)	Pre-Treatment	22.39	22.02	21.56	21.85	0.6792
	Post-Treatment	22.47	21.87	21.89	21.50	0.7245
Tree Crown Cover (%)	Pre-Treatment	63.60	47.01	59.67	47.70	0.2786
	Post-Treatment	71.77	69.30	61.13	62.13	0.1640
Tree Snags/10ha	Pre-Treatment	132	116	92	124	0.6318
	Post-Treatment	120b[2]	104b	88b	232a	**0.0464**
Shrub Cover (%)	Pre-Treatment	14.49	8.00	15.35	9.94	0.5277
	Post-Treatment	26.66a	16.82ab	9.55b	8.58b	**0.0968**
Ground Cover (%)	Pre-Treatment	26.43	22.93	25.40	31.08	0.4158
	Post-Treatment	17.20bc	15.50c	25.52a	20.25b	**0.0168**
Litter Depth (cm)	Pre-Treatment	5.1	4.8	5.1	5.1	0.8587
	Post-Treatment	4.3b	1.0c	5.6a	0.5c	**0.0001**

[1] C-Control, B- Prescribed burn, M-Mechanical understory removal, MB- Mechanical understory removal followed by prescribed burn.
[2] Means followed by the same lower case letter within a row are not significantly different at the 0.1 level.

CHAPTER V

DISCUSSION

Breeding Birds

In 2003, breeding season abundance estimates were lower and reflected nearly significant treatment differences (p=0.1001). Although not significant at the alpha level chosen, it is important to recognize the change in bird density to accurately assess treatment responses. Abundance estimates were lower by nearly 50% (13 birds) in MB plots from 2001 to 2003 surveys. Interestingly, birds were most abundant in MB (after controls). In 2003, breeding season species richness had nearly significant treatment differences (p=0.1081). Richness means were lower by 2-6 species per 10 hectares in the three treatments while controls increased by a 2 species per 10 hectares. However, observations revealed 5 additional species in 2003, 4 of which were most frequently observed in burned areas (bluebirds, chipping sparrows, great-crested flycatchers, pine warblers). Shifts in bird abundance estimates are commonly observed following forest disturbances due to shifts in vegetation structure (Mauer et al. 1981). Although there were shifts in some vegetation structure following treatment implementation, no significant shifts in treatment abundance or richness estimates may suggest that treatment size was too small or surveys were conducted too soon to reflect significant changes in bird communities.

The only significant differences detected in abundance and species richness occurred across years rather than among treatments. Using a half century of survey comparisons, Haney et al. (2000) found no significant declines in songbirds for the Blue

Ridge Province as a whole. With only three survey years, the increase in bird abundance in 2002 relative to 2001 and 2003 would be difficult to attribute to any effect following treatment implementation.

Breeding season diversity differed among treatments in 2003. Controls had the highest diversity while MB had the second highest diversity estimates. There have been numerous studies that compare diversity levels of undisturbed habitat and early successional habitat, such as clearcuts or rights of way (Annand and Thompson 1997, Simon et al. 2002, Lanham 1997). Opening the forest canopy can provide islands of differing light penetration and successional stages in the forest increasing heterogeneity across the landscape (Weakland et al. 2002). Although not significant when vegetation measurements were taken in August 2003, perhaps an immediate opening of the forest floor following treatment in March enhanced bird diversity estimates taken in May and June.

Previous studies of nesting (Wilcove 1985) and foraging (Hejl and Verner 1990) guilds associated with bird communities detected acute responses to habitat pressures. Rodewald (1998) found that understory removal in an Arkansas oak-hickory forest adversely affected ground and shrub nesters. Following treatment (2002-2003), richness of ground nesting species differed among treatments, possibly due to a reduction in ground cover or litter layer.

When individual species were analyzed, different results were reflected. This suggests that changes may occur at the species level rather than at the guild level. For example, worm-eating warblers, which nest on the ground and use leaves for nest material and camouflage, disappeared from MB treatments surveys in 2003. Litter layer depth was greatly reduced in MB in 2003. Hooded warblers use shrubs, such as mountain laurel, as nesting substrate, which was targeted for removal in all three treatments. They were over four times more abundant in controls and were not observed in MB in 2003; both also nested only in controls. Blue-headed vireos are mid-story nesters, but showed no responses to treatments, as only some of their nesting trees were affected. Red-eyed vireos, which are overstory nesters, were significantly more abundant in controls. The reason for this is unknown, although they are considered area-sensitive species often associated with generally contiguous, undisturbed habitats (Robbins et al. 1989). Finally, cavity nesters, such as the eastern bluebird, were detected in point counts only in MB treatments in 2003 (observed outside of surveys in B). Although this was not statistically significant, it may suggest that they respond positively to burning as a management tool that results in snag density increase. Higher species richness was observed in MB which may continue in the future with increased snag production attracting more primary and secondary cavity nesters to the area. Hence, species-specific responses may be important when examining the effects of fuel reduction treatments. Consideration at these levels may be productive when managing for endangered or threatened species, although none were detected in our surveys.

Analysis of foraging guilds was done on a structural level rather than a functional level (tree forager versus bark or foliage forager) to attempt to pinpoint relevance to targeted to fuel reduction changes in forest strata. Maurer (1981) found that many ground foragers increased within 1 year of clearcuts in West Virginia. However, some mature forest ground foragers, such as wood thrushes and ovenbirds did not increase until 3 years following clearcutting. At the Green River study sites, neither the abundance nor richness of ground foraging species decreased following treatment implementation. This may indicate that the structure was changed enough to adversely affect nesting sites but not prey base. Furthermore, the flush of new foliage following disturbance can lead to an increase in the biomass of both insects (Greenberg and McGrane 1996, Greenberg and Forrest 2003) and fruit (Greenberg and Levey, in press), especially at ground levels. Changes in ground cover percentages may also reflect abundant resprouting of cut shrubs following treatment implementation.

Although the shrub layer was targeted for removal, shrub nesting species did not differ among treatments. Stability may be due to versatility of shrub nesters. Martin (1993) reasons that shrub nesters experiencing higher predation rates commonly attempt frequent renests following nest failures. Lack of abundance or richness shifts in shrub nesting species may also be due to adequate structure of cut shrubs that were left on site. However, treatment differences were observed in shrub forager species richness. A trend of increasing abundance and species richness from MB to control plots was enough to produce significant differences in both abundance and species richness of shrub foragers. Whether this trend will hold may depend on the frequency of treatment implementation in future years.

Shrub cover was lowest in MB treatments and highest in controls. Some shrub foragers may rely on live, intact vegetation to provide needed resources such as insects and berries. An initial decrease of blueberries following fire treatments may account for the major shift. Birds rely on soft, fleshy fruits, as important food resources during summer (Perry et al. 1999). Blueberries can recover within a year of burning (Randles et al. 2002) and may represent less hazardous fuels than other shrub species such as mountain laurel and rhododendrons. They may also provide up to 23% of mean total dry edible fruit biomass in upland hardwood ecosystems (Greenberg 2001, unpublished data). The decrease in abundance and species richness numbers in shrub foragers was negligible and somewhat predictable. Due to the immediate nature of these responses, negative effects may be variable in foraging guilds of songbirds in these communities.

Some ground nesting and shrub foraging species decreased in treated areas. Significantly more black-and-white warblers, hooded warblers, northern cardinals and red-eyed vireos were found in controls than in treatments. Only these 5 species (in controls) and wood thrushes (in burns) were present significantly more of the time in a particular treatment during 2003 breeding season counts. These abundance estimates, similarity indices, and evenness indices corroborate that there was little treatment effect on bird communities.

Bird abundance and richness estimates were comparable to others in southern Appalachian oak forests. For unharvested oak stands in West Virginia, Weakland et al. (2002) found similar densities of several species, including black-throated green warblers and scarlet tanagers. Greenberg and Lanham (2001) also found similar densities of cavity, ground, and tree nesting species in xeric upland oak forests of the southern Appalachians. Although no threatened or endangered species were detected, numerous species of concern were identified. A prioritization list has been established by Partners in Flight (PIF), a cooperative partnership among conservation entities ranging from state and federal government to private agencies, which identifies breeding bird species in need of conservation attention. The priority list, specific to physiographic regions, ranks species by importance and also provides a breakdown of species priority by species suite, such as mature forest. In hardwood forests of the Southern Blue Ridge region, several species of high conservation concern were detected in Green River surveys: Acadian flycatchers, wood thrushes, Kentucky warblers, and hooded warblers.

Nest success was determined from a relatively small amount of data and focused on ground and shrub nesters. Nest success rates were relatively high. In Indiana oak forests, Aquilani (2000) reported the probability of ground and shrub nesting success rates in burned areas was 13% while in unburned areas it averaged 29%. The differences may be due to higher brown-headed cowbird (*Molothrus ater*) pressures as noted in the Ohio study. At Green River Game Lands, very few brown-headed cowbirds were detected (2 observations of black-throated green warbler parasitism). Prior to fire, Artman and Dettmers (2003) reported ground and shrub nesting success probabilities ranging from 25-32% in an Ohio mixed oak forest. This contrasts with the high nest success of ground nesters (75%) and shrub nesters (55%) predicted in an Arkansas upland hardwood forest (Martin 1993). NFFS estimates are similar to the latter study.

The nest vegetation measurements also indicate that nest site selection did not differ greatly in microsite characteristics among treatments. Nest cover was higher in controls (71%) than treated sites (40-54%). No measured microsite characteristics differed among treatments when analyzing 2003 nest successes from failures to examine microsite, indicating that nest site selection was not a function of treatment but general selection for vegetation and site qualities across a landscape setting. The nesting outcomes in 2003 did not reflect negative impacts from fuel reduction treatments.

Wintering and Migrating Birds

Considering that post-treatment effects were measured within two weeks of the prescribed fire, seeing relatively little treatment effect is remarkable. Overall species numbers increased significantly in March following treatment. However, that increase may be due primarily to the influx of certain species of migrants (blue-headed vireos, ovenbirds, etc.). Species richness was similar in all four treatments, with an average increase of about 2 species per hectare from pervious estimates which may be due to yearly fluctuations. There was no treatment effect detected before or after the burns, suggesting that even though counts were not done prior to the implementation of all treatments (2001), prescribed burning had little effect on winter bird communities in the short-term.

Similarity index analyses were compared to reflect any individual species displaying treatment preference during the wintering season. A tree gleaner, the yellow-shafted flicker was more abundant in MB treatments. Research indicates that snags are produced following a forest disturbance such as fire (Van Lear 2000). In this study, snag density in MB nearly doubled following treatment. In southwest Virginia, Connor (1974) found that woodpeckers use mature stands with snags over clearcuts or other silvicultural treatments lacking snags.

Ovenbird numbers also differed among treatments but were not taken into serious consideration in winter analyses because they are early migrants. Only these 2 species reflected treatment differences during 2002-2003 wintering and migrating season counts.

CHAPTER VI

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The Southern Appalachians serve as a refuge for forest interior birds in the eastern United States (Haney et al. 2001). These mountains provide a major flyway for migrant songbirds and hawks. Upland forests are one of two major forest types in the mountain region of North Carolina (other: boreal forests) designated as significant contributors to Audubon's Important Bird Area (IBA) Program. There are 19 IBAs, sites providing essential habitat for one or more breeding or non-breeding species, in North Carolina's mountain region including several within 50 km of the NFFS study site (Blue Ridge Escarpment Gorges, Hickory Nut Gorge, Pisgah National Forest). Management of birds in these areas must be monitored to avoid adverse effects on breeding and wintering resources to maintain bird community stability.

Initial assessments of mechanical understory removal and prescribed fire in this study indicate few negative effects on songbirds in Southern Appalachian hardwood forests. Although songbird numbers were typically higher in control plots during the breeding seasons, little difference was detected among the three types of treatments used at the Green River Game Lands. Nesting guild investigations and individual species analyses revealed that individual species often responded differently to different treatments. Individual responses do not seem to have an effect on overall community structure. In 2003, both Sorenson's community similarity and Shannon's evenness indices suggested similar community composition following treatment implementation.

The fuel reduction treatments implemented did impact vegetation structure and composition but impacts were not reflected in the composition of bird communities.

Fuel loading in Southern Appalachian hardwood stands can be attributed heavily to understory encroachment of ericaceous species (*Rhododendron, Kalmia*). Rhododendron began to move upslope from streamsides after three significant events: 1) loss of American chestnut (*Castanea dentata*) trees, 2) 1880-1930 logging efforts, and 3) fire exclusion and suppression. The loss of the American chestnut may have opened the forest canopy by as much as 40 percent (Van Lear et al. 2002). With intense regeneration uncontrolled by fire, forests became thick and regrowth competitive. Following the Inhibition Pathway Model, ericaceous species modified their environment such that other species were inhibited from early and late successional growth (Connel and Slatyer 1977).

Topography and evergreen understory in Southern Appalachian canopy gaps are the primary determinants of spatial and temporal heterogeneity in understory microclimate (Clinton 2003). Van Lear et al. (2002) noted that total species richness in the regeneration layer of cove forests was inversely related to percent rhododendron cover. Rhododendron poses a threat to sustained diversity and productivity of many Southern Appalachian hardwood forests.

In addition to increased fire hazards, the threat of ericaceous species encroachment in the understory may leave oaks and other hardwoods in the Southern Appalachians vulnerable in other ways. *Rhododendron* and *Kalmia* are vectors of sudden oak death, a disease threatening oaks across the United States, most recently transported east of the Mississippi River. Although the debate concerning fire history and its reintroduction to Southern Appalachian hardwoods has not been resolved, a hands-off approach may not be viable.

Controlling hardwood encroachment in the understory is commonly used as a silvicultural tool for southern pine management. However, it can also be a useful tool in hardwood management for hazardous fuel reduction and oak regeneration (Van Lear and Waldrop 1989). Determining frequency and extent of fire use and/or tree cutting as methods of fuel reduction will likely depend on other factors, such smoke management. Whatever method is chosen, it is important to continue to study the effects of fuels in forests. With the expanding wildland-urban interface, potential wildland forest fire damage cannot be prevented by fire suppression alone. It is only with analyses such as these that agencies and the public can make informed decisions regarding fuel reduction treatments.

Wildfires do occur in eastern deciduous forests and present an increasing challenge with expanding urban influences. Studies that determine the ecological impacts of various fuel management methods in these forests are few. At the spatial scale of the Green River NFFS study, because no significant impact on bird communities was detected in surveys, the management implications are that any of these treatments could be applied without consequence. However, the size of the study sites and subsequent avian responses must be considered if application of these treatments was to be done on a larger scale. Because the time frame of this study was short, generalizations are limited. Neither long-term nor large-scale responses of Southern Appalachian bird communities have been determined with this study. Further research is needed to determine fire and other fuel reduction methods' effects on songbird communities.

APPENDICES

A-1. Presence (x) of species by year, season, and treatment, Green River Game Lands, NC.

Species	Year				Season		Treatment			
Common Name (*Scientific Name*)	2001	2002	2003		S	W	C	B	M	MB
Acadian flycatcher (*Empidonax virescens*)	x	x	x		x		x	x	x	
American crow (*Corvus brachyrhynchos*)	x	x	x		x	x	x	x	x	
American goldfinch (*Carduelis tristis*)	x	x	x		x	x	x	x	x	x
American robin (*Turdus migratorius*)	x	x	x		x	x	x	x	x	x
Barred owl (*Strix varia*)			x		x	x			x	
Black-and-white warbler (*Mniotilta varia*)	x	x	x		x	x	x	x	x	x
Black-throated green warbler (*Dendroica virens*)	x	x	x		x	x	x	x	x	x
Blue-gray gnatcatcher (*Polioptila caerulea*)	x	x	x		x		x	x	x	x
Blue-headed vireo (*Vireo solitarius*)	x	x	x		x	x	x	x	x	x
Blue jay (*Cyanocitta cristata*)	x	x	x		x	x	x	x	x	x
Broad-winged hawk (*Buteo platypterus*)	x		x		x		x			
Brown creeper (*Certhia americana*)		x	x			x		x	x	
Carolina chickadee (*Poecile carolinensis*)	x	x	x		x	x	x	x	x	x
Carolina wren (*Thryothorus ludovicianus*)	x	x	x		x	x	x	x	x	
Cedar waxwing (*Bombycilla cedrorum*)		x				x			x	
Chimney swift (*Chaetura pelagica*)	x	x		x			x	x		
Chipping sparrow (*Spizella passerina*)			x		x	x				x
Cooper's hawk (*Accipiter cooperii*)		x	x			x		x		
Dark-eyed junco (*Junco hyemalis*)		x	x			x	x	x	x	
Downy woodpecker (*Picoides pubescens*)		x	x		x	x	x	x	x	x
Eastern bluebird (*Sialia sialis*)			x		x	x	x		x	x
Eastern phoebe (*Sayornis phoebe*)	x	x	x		x	x	x	x	x	x
Eastern towhee (*Pipilo erythrophthalmus*)	x	x	x		x	x	x		x	
Eastern tufted titmouse (*Baeolophus bicolor*)	x	x	x		x	x	x	x	x	x

A-1. (Continued).

Species Common Name (*Scientific Name*)	Year 2001	 2002	 2003	Season S	 W	Treatment C	 B	 M	 MB
Eastern wood- pewee (*Contopus virens*)			x	x					x
Golden-crowned kinglet (*Regulus satrapa*)		x	x		x	x	x	x	
Great-crested flycatcher (*Myiarchus crinitus*)			x	x		x			
Hairy woodpecker (*Picoides villosus*)		x	x	x	x	x		x	x
Hooded warbler (*Wilsonia citrina*)	x	x	x	x		x	x	x	
Indigo bunting (*Passerina cyanea*)	x	x	x	x		x		x	x
Kentucky warbler (*Oporornis formosus*)		x		x		x			
Mourning dove (*Zenaida macroura*)		x	x	x	x		x		x
Myrtle warbler (*Dendroica coronata*)			x		x		x	x	x
Northern cardinal (*Cardinalis cardinalis*)	x	x	x	x	x	x		x	
Ovenbird (*Seiurus aurocapillus*)	x	x	x	x	x	x	x	x	x
Pileated woodpecker (*Dryocopus pileatus*)		x	x	x	x	x	x	x	x
Pine warbler (*Dendroica pinus*)			x	x	x	x	x	x	x
Red-bellied woodpecker (*Melanerpes carolinus*)		x	x	x	x	x	x	x	x
Red-eyed vireo (*Vireo olivaceus*)	x	x	x	x		x	x	x	x
Red-tailed hawk (*Buteo jamaicensis*)			x		x	x			
Ruby-crowned kinglet (*Regulus calendula*)			x		x			x	
Ruby-throated hummingbird (*Archilochus colubris*)	x	x	x	x		x	x	x	x
Scarlet tanager (*Piranga olivacea*)	x	x	x	x		x	x	x	x
Turkey vulture (*Cathartes aura*)		x			x	x			
Veery (*Catharus fuscescens*)		x		x		x			
Whip-poor-will (*Caprimulgus vociferus*)		x		x		x			
White-breasted nuthatch (*Sitta carolinensis*)	x	x	x	x	x	x	x	x	x
Worm-eating warbler (*Helmitheros vermivorus*)	x	x	x	x		x	x	x	x

A-1. (Continued)

Species Common Name (*Scientific Name*)	Year 2001	 2002	 2003	Season S	 W	Treatment C	 B	 M	 MB
Wild turkey (*Meleagris gallopavo*)	x		x	x		x	x		x
Winter wren (*Troglodytes troglodytes*)			x		x	x		x	
Wood thrush (*Hylocichla mustelina*)	x	x	x	x		x	x	x	x
Yellow-billed cuckoo (*Coccyzus americanus*)	x	x	x	x		x		x	
Yellow-bellied sapsucker (*Sphyrapicus varius*)		x			x	x	x	x	x
Yellow-shafted flicker (*Colaptes auratus*)		x	x	x	x	x	x	x	x
Yellow-throated warbler (*Dendroica dominica*)	x	x		x	x	x	x		

A-2. Nesting and foraging guild classifications*. Nesting location: G=ground, S=shrub, T=tree, c=cavity, L=ledge. Foraging location: G=ground, S=shrub, T=tree, V=various.

Species Common Name (*Scientific Name*)	Guild Nesting	 Foraging
Acadian flycatcher (*Empidonax virescens*)	T	T
American crow (*Corvus brachyrhynchos*)	T	G
American goldfinch (*Carduelis tristis*)	S	V
American robin (*Turdus migratorius*)	S	G/S/T
Barred owl (*Strix varia*)	C	V
Black-and-white warbler (*Mniotilta varia*)	G	T
Black-throated green warbler (*Dendroica virens*)	T	T
Blue-gray gnatcatcher (*Polioptila caerulea*)	T	T
Blue-headed vireo (*Vireo solitarius*)	S/T	T
Blue jay (*Cyanocitta cristata*)	T	T
Broad-winged hawk (*Buteo platypterus*)	T	V
Brown creeper (*Certhia americana*)	C	T
Carolina chickadee (*Poecile carolinensis*)	C	T
Carolina wren (*Thryothorus ludovicianus*)	C/G/L	G/S
Cedar waxwing (*Bombycilla cedrorum*)	T	S/T
Chimney swift (*Chaetura pelagica*)	C	T
Chipping sparrow (*Spizella passerina*)	S/T	G
Cooper's hawk (*Accipiter cooperii*)	T	V
Dark-eyed junco (*Junco hyemalis*)	G	G
Downy woodpecker (*Picoides pubescens*)	C	S/T
Eastern bluebird (*Sialia sialis*)	C	G
Eastern phoebe (*Sayornis phoebe*)	L	V
Eastern towhee (*Pipilo erythrophthalmus*)	S/G/L	G/S
Eastern tufted titmouse (*Baeolophus bicolor*)	C	T
Eastern wood- pewee (*Contopus virens*)	T	T
Golden-crowned kinglet (*Regulus satrapa*)	T	T
Great-crested flycatcher (*Myiarchus crinitus*)	C	T
Hairy woodpecker (*Picoides villosus*)	C	T
Hooded warbler (*Wilsonia citrina*)	S	S/T
Indigo bunting (*Passerina cyanea*)	S	S
Kentucky warbler (*Oporornis formosus*)	G	G
Mourning dove (*Zenaida macroura*)	S	G
Myrtle warbler (*Dendroica coronata*)	T	T
Northern cardinal (*Cardinalis cardinalis*)	S	G/S
Ovenbird (*Seiurus aurocapillus*)	G	G
Pileated woodpecker (*Dryocopus pileatus*)	C	T

A-2. (Continued).

Species Common Name (*Scientific Name*)	Guild Nesting	Foraging
Pine warbler (*Dendroica pinus*)	T	G(winter)/T
Red-bellied woodpecker (*Melanerpes carolinus*)	C	T
Red-eyed vireo (*Vireo olivaceus*)	T	T
Red-tailed hawk (*Buteo jamaicensis*)	T	G
Ruby-crowned kinglet (*Regulus calendula*)	S/T	S/T
Ruby-throated hummingbird (*Archilochus colubris*)	S/T	T
Scarlet tanager (*Piranga olivacea*)	T	T
Turkey vulture (*Cathartes aura*)	G/C	V
Veery (*Catharus fuscescens*)	G	G
Whip-poor-will (*Caprimulgus vociferus*)	G	V
White-breasted nuthatch (*Sitta carolinensis*)	C	T
Worm-eating warbler (*Helmitheros vermivorus*)	G	G/S
Wild turkey (*Meleagris gallopavo*)	G	G
Winter wren (*Troglodytes troglodytes*)	G	G
Wood thrush (*Hylocichla mustelina*)	S	G/S
Yellow-billed cuckoo (*Coccyzus americanus*)	T	T
Yellow-bellied sapsucker (*Sphyrapicus varius*)	C	T
Yellow-shafted flicker (*Colaptes auratus*)	C	G/T
Yellow-throated warbler (*Dendroica dominica*)	T	T

* Adapted from Hamel 1992.

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