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EFFECTS OF SEASON OF FIRE ON RED-COCKADED WOODPECKER *(PICOIDES BOREALIS)* REPRODUCTION AND THE BREEDING BIRD COMMUNITY OF A LONGLEAF PINE ECOSYSTEM

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EFFECTS OF SEASON OF FIRE ON RED-COCKADED WOODPECKER (*PICOIDES BOREALIS*) REPRODUCTION AND THE BREEDING BIRD COMMUNITY OF A LONGLEAF PINE ECOSYSTEM

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by
Sarah Ann Lauerman
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Accepted by:
Dr. Joseph Lanham, Committee Chair
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ABSTRACT

Fire is the most important management tool in restoring and maintaining the longleaf pine ecosystem but the effects of season of burning on fauna are not fully understood. Of particular concern is the community of birds which breed in the longleaf pine forest, several of which are endangered, threatened or species of concern. This study examined the effects of season of fire on the breeding bird community and a population of red-cockaded woodpeckers (RCW) at Brosnan Forest in Dorchester, South Carolina. Fifty-eight RCW territories received dormant or growing season fire over a five-year period from 2001 to 2005. Prior to 2001, all territories had been burned regularly during the dormant season. RCW groups were monitored for reproductive success and breeding bird numbers were determined using 50 meter fixed radius point counts. No difference was found in RCW group size, clutch size or number of fledglings between season of burn treatments. RCW territories treated with growing season burns were also compared before and after treatment. Reproductive measures did not change significantly after the introduction of growing season fire. Mean total abundance of breeding birds and species composition were not different between season of burn treatments; however species richness was greater in growing season burned territories ($P < 0.10$). Bachman's sparrows and indigo buntings were more abundant in dormant season burn territories ($P < 0.10$). Mourning doves, pine warblers and white-eyed vireos were more abundant in growing season burn territories ($P < 0.10$). Analyses of breeding bird data by nesting, foraging, and habitat guilds, showed no significant differences in abundance between treatments, with the exception of tree nesters, which were more abundant in growing season burn territories. Avian Conservation Values (ACV) were calculated for the season of burn treatments by weighting bird abundance values with adjusted Partners In Flight concern scores. ACVs were significantly different between burn treatments when years were blocked ($P = 0.0279$); however yearly variation was large. Overall, this study found season of fire had little influence on the RCW population or the bird community as a whole; however, long-term studies are needed to better understand this relationship.

DEDICATION

I would like to dedicate this thesis to my daughter, Gwendolyn Ann Lauerman. She lived through my graduate school experience and helped shape it in a way no other person could have. She received the adrenaline thrills in utero from my climbs up longleaf pines to band woodpecker nestlings. She weathered the stress I felt as I tried to finish my analysis before her arrival. Her birth taught me about the power of persistence, a lesson I would later apply to the writing process. Her needs defined my work schedule and her natural rhythms set the tempo of my progress towards graduation. She was with me through every step of the writing process, and as the thesis grew, so did she. Her presence in this process has brought me gifts of humor and balance. Thank you Gwen.

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TABLE OF CONTENTS

Page

TITLE PAGE i

ABSTRACT ii

DEDICATION iv

ACKNOWLEDGEMENTS v

LIST OF TABLES x

LIST OF FIGURES xi

CHAPTER

1. INTRODUCTION 1

    History of Fire in the Southeastern United States 1
    Season of Fire in the Southeastern Pine Savannas 2
    Decline of the Longleaf Forest 4
    Birds of the Longleaf Forest 5
    Red-cockaded Woodpecker as a Focal Species 6
        Factors Affecting Red-cockaded Woodpecker Reproductive Success 9
        Fire and Red-cockaded Woodpeckers 13
    Fire, Red-cockaded Woodpecker Management and Other Species of Concern 15
    Fire and Birds in the Southeastern United States 18
        Effects of Fire on Nesting and Foraging Guilds 21
        Effects of Season of Fire on Birds 22
    Study Objectives 24

2. MATERIALS AND METHODS 26

    Study Area 26
    Experimental Design 28
    Red-cockaded Woodpecker Data Collection 30
    Breeding Bird Data Collection 32
    Vegetation Data Collection 33

Table of Contents (Continued)

Page

Data Analysis 33
Red-cockaded Woodpecker Analysis 35
Breeding Bird Analysis... 36

3. RESULTS 40

Red-cockaded Woodpeckers... 40
Breeding Birds 41

4. DISCUSSION.. 52

Red-cockaded Woodpeckers... 52
Breeding Birds 57

5. CONCLUSIONS... 66

Management Recommendations... 66
Further Research 67

APPENDIX.. 69

A: Number of birds observed by species and season of burn
treatment from 2004 to 2005, along with habitat
associations, foraging guilds and nesting guilds
as defined for this study in Dorchester, South Carolina 70

LITERATURE CITED 73

LIST OF TABLES

Table Page

1. Comparison of mean red-cockaded woodpecker reproductive measurements per group by season of burn treatment (years pooled) ± standard deviation 44

2. Randomized block ANOVA (with years as blocks) for mean total abundance, mean species richness and total species richness of bird species per RCW territory 48

3. Mean ± standard deviation species richness and mean ± standard deviation total species richness seen per RCW territory by year and treatment 49

4. Bird species considered indicators for season of burn treatments by the Indicator Species Analysis (ISA) method 51

LIST OF FIGURES

Figure Page

1. Map of the experimental red-cockaded woodpecker territories at Brosnan Forest by season of burn treatment 29

2. Map of red-cockaded woodpecker territories used in the analysis, by season of burn treatment, with areas receiving growing season burns shown 34

3. Mean red-cockaded woodpecker group size per territory by season of burn treatment (years pooled) ± standard deviation at Brosnan Forest, South Carolina 45

4. Red-cockaded woodpecker reproductive success by season of burn treatment and years ± standard deviation as measured by mean clutch size, and number of chicks at pre-fledge checks and post-fledge checks at Brosnan Forest, South Carolina 46

5. Mean group size and mean number of fledglings of red-cockaded woodpecker groups before and after the application of growing season fires at Brosnan Forest, South Carolina 47

6. Nonmetric Multidimensional Scaling (NMS) 2-dimensional ordination graph of bird species composition (mean abundance of species per point within a year) by season of burn treatment 50

CHAPTER 1

INTRODUCTION

History of Fire in the Southeastern United States

The importance of fire in the southeast United States has received increasing attention in an effort to understand its impact on flora and fauna, and how its role can be used to meet land management and habitat conservation goals. The interaction between the natural and cultural fire regimes in the Southeast is complex, but both natural and human ignited fires played a role in the evolution of the ecosystems in the region (Komarek 1968, Jackson 1988, Robbins and Myers 1992, Waldrop et al. 1992, Ware et al. 1993, Porcher and Rayner 2001, Frost 2006). Natural fires predominately occur from lightning strikes during the spring and summer seasons resulting in growing season fires (Jackson 1988, Robbins and Myers 1992, Martin and Boyce 1993, Ware et al. 1993, Frost 2006). Humans migrated into the southeast between 12,000 and 15,000 years ago and used fire as a tool to manipulate the landscape (Waldrop et al. 1992, Delcourt et al. 1993, Porcher and Rayner 2001). When Europeans arrived on the continent they gave accounts of Native Americans use of fire during the dormant season (Robbins and Myers 1992, Ware et al. 1993, Frost 2006) and described a park-like pine savanna with an overstory of mature pine trees, little to no midstory and a diverse herbaceous ground cover (Earley 2004). The forest structure indicated a historical fire regime that was both high frequency and low intensity which maintained the openness of the southern pine forests (Waldrop et al. 1992).

Season of Fire in the Southeastern Pine Savannas

"Growing" and "dormant" are fire season terms used to indicate periods of plant growth and dormancy. The exact months that these seasons cover can vary by region and by study, as a season of fire review by Streng et al. (1993) illustrated. A season of fire review by Robbins and Myers (1992) defined growing season in Florida as mid-March to early-September; conversely, dormant season is approximately late September to early March. Most studies on season of burn use the terms "growing" and "dormant" to describe time periods within the range set forth by Robbins and Myers (1992) but season descriptors such as "early" and "late" can confuse the definition. When needed, specific months are included to clarify seasons.

Season of fire has varying effects on pine trees, hardwoods and understory vegetation in pine savanna habitat. Literature reviews by Robbins and Myers (1992) and Streng et al. (1993) offer helpful summaries of season of burn studies in the Southeast. Both reviews found conflicting conclusions about the effects of season of fire on pine growth and mortality but more consistent results regarding hardwood control and understory vegetation. Robbins and Myers (1992) concluded that late growing season fires (July–September) caused more pine mortality than dormant or early growing season fires (March–June). Streng et al. (1993) found no consistent effect of season of burn on pines. Both reviews supported the findings that early growing season fires helped young longleaf pines (*Pinus palustris*) survive by reducing the incidence of brown spot fungus

(*Mycosphaerella dearnessii*). The impact of season of fire on hardwoods is less contradictory. Growing season burns, especially annual burns, show greater top-kill, complete kill and reduced resprouting of hardwood species than dormant season fires (Robbins and Myers 1992, Streng et al. 1993). Understory vegetation varies in response to seasonal fire. Many grasses, shrubs and forbs increase flowering production as a response to growing season burns (Platt et al. 1988). The composition of the groundcover, as defined by the presence or absence of species, changes very little (Streng et al. 1993, Walker and Silletti 2006, Mudder 2006); however, some species increase or decrease in relative abundance under regimes of different seasons of burning. Herbaceous species, especially grasses are abundant after late dormant season (March-April) or early growing season burns (April-June) whereas woody species are more abundant in sites burned in the dormant season (Waldrop et al. 1992, Sparks et al. 1998, Mudder 2006). Legumes have a varied response to season of fire (Robbins and Myers 1992, Waldrop et al. 1992, Mudder 2006), with many species showing no response to season of burn treatments while other species have shown delayed flowering and more synchronous flowering after summer (June-July) burns (Hiers et al. 2000).

The interplay between fire intensity, frequency and season makes it difficult to discuss one aspect without addressing the others. Fire intensity is the rate at which a fire produces thermal energy or the energy released by fire (Pyne et al. 1996). Both Robbins and Myers (1992) and Streng et al. (1993) point out the importance of fire intensity and Streng et al. (1993) warn that fire intensity could confound observable effects of fire season. Additionally, Robbins and Myers (1992) stated that prescribed fires in Florida pine forests could be conducted in any month of the year as long as fire intensity remained low. Sparks et al. (1999) identified the need to quantify fire intensity when reporting results of fire studies. Their study in west-central Arkansas found late dormant season fires (March-April) were more intense and consequently were more effective in removing woody stem density in the 1-3 meter (m) strata than late growing season burns (September-October). Along with fire intensity, fire frequency may have more influence on sustaining the longleaf pine forest understory than the season of burn (Walker and Silletti 2006). A long-term fire study in South Carolina, assessing periodic summer/winter burns along with annual summer/winter burns found periodic fires, regardless of season, did not remove hardwoods from the understory, whereas growing season annual burns created and maintained an herbaceous groundcover and annual winter burns had more sweet gum (*Liquidambar styraciflua*) and legumes (Waldrop et al. 1992). In summary, the impacts of fire intensity and frequency on flora, especially woody species, can contribute to the effects of season of fire.

Decline of the Longleaf Forest

The most common tree species of the Southeast was once the longleaf pine. Frost (2006) estimated that the longleaf pine ranged across 37 million hectares (ha) of the Southeast before European settlement, 23 million ha of which was dominated by longleaf. As of 2000, only 841,800 ha of naturally regenerated longleaf is estimated to be left, about 2% of the pre-settlement acreage (Frost 2006). The decline of longleaf was due to multiple factors including the introduction of cattle and hogs, the naval stores industry, logging for lumber, agriculture and development, and fire suppression (Ware et al. 1993, Earley 2004, Frost 2006). The loss of the longleaf pine ecosystem has caused the imperilment of fauna whose life history depends on the habitat, including species of amphibians (i.e. flatwoods salamander-*Ambystoma cingulatum*), reptiles (i.e. eastern indigo snake-*Drymarchon corais* and gopher tortoise-*Gopherus polyphemus*), birds (i.e. red-cockaded woodpecker-*Picoides borealis*) and mammals (i.e. fox squirrel-*Sciurus niger*) (Means 2006).

Birds of the Longleaf Forest

Engstrom (1993) compiled a list of 86 bird species, both breeding and winter visitors, associated with the longleaf pine forests in Georgia, North Carolina, Florida and Mississippi, encompassing community types from sandhills, clayhills and flatwoods (also see Mean 2006). Thirty-five of the species were permanent residents, 22 species were winter residents, and 29 were long-distance neotropical migrants or short distance migrants using the longleaf forest for breeding (Engstrom 1993). Three bird species were strongly associated with longleaf pines: red-cockaded woodpecker (see Appendix A for scientific names of this and other species recorded in this study), Bachman's sparrow and brown-headed nuthatch (Engstrom 1993). Not surprisingly, these three species are currently endangered, threatened or declining throughout their range (U. S. Fish and Wildlife Service 2003, Tucker et al. 2004, Sauer et al. 2005, Cox and Slater 2007).

Red-cockaded Woodpecker as a Focal Species

The red-cockaded woodpecker (RCW) has been listed as a federally endangered species since October 13, 1970 (Federal Register 35:16047), three years before the passage of the Endangered Species Act in 1973. The U. S. Fish and Wildlife Service estimates the current population of RCWs, as of 2006, to be 12,210 individuals residing in 6,105 active clusters scattered across Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma and Texas (U. S. Fish and Wildlife Service unpublished data). RCWs are non-migratory and live in family groups that include a breeding male and female, zero to four helpers, and offspring from the current breeding season (Ligon 1970, Walters 1990). Family groups defend a territory, which includes the group's cavity trees, called a "cluster", and foraging habitat (Ligon 1970, Hooper et al. 1982, Walters 1990). Average home ranges are roughly 50-150 ha per RCW group, depending on geographic location, habitat quality, season, and population density (Hooper et al. 1982, Porter and Labisky 1986, DeLotelle et al. 1987, Walters 1990, Hardesty et al. 1997a, Engstrom and Sanders 1997, Walters et al. 2002). RCWs live in open pine forests with little or no midstory vegetation and an herbaceous groundcover (Hopkins and Lynn 1971, Van Balen and Doerr 1978, Locke et al. 1983, Hovis and Labisky 1985, James et al. 1997, Hardesty et al. 1997a, Walters et al. 2002). RCWs also require mature, live pine trees for nesting and roosting (Ligon 1970, Jackson et al. 1979). As primary excavators, they choose large, old pine trees, typically 80-150 years old with heartwood thick enough to accommodate a resin-free cavity (Jackson et al.

1979, Hooper et al. 1980, Hovis and Labisky 1985, Jackson and Jackson 1986, DeLotelle and Epting 1988, Rudolph and Conner 1991, Conner and Rudolph 1995, Conner et al. 2004a). They typically select longleaf pines, presumably for their high resin yield and longevity, but will also use other species such as loblolly or shortleaf pines (Conner et al. 2004a). The process of drilling out a cavity can take years (Jackson et al.1979, Conner and Rudolph 1995), thus making them a limited resource (Ligon 1971, Walters et al. 1988 and 1992a, Lennartz et al. 1987, Walters 1991, Conner and Rudolph 1995, Conner et al. 2004a). Additionally, RCWs are not the only species that utilize their cavities. Studies have documented twenty-seven vertebrate species using RCW cavities (Ligon 1970, Dennis 1971, Beckett 1971, Jackson 1978a, Harlow and Lennartz 1983, Loeb 1993, Kappes and Harris 1995, Loeb and Hooper 1997). Kappes (1997) described species that benefit from the usurpation of a cavity at the expense of RCWs as “kleptoparasites”. Red-bellied woodpeckers (*Melanerpes carolinus*) and southern flying squirrels (*Glaucomys volans*) are common kleptoparasites that use RCW cavities for nesting and roosting (Dennis 1971, Jackson 1978a, Harlow and Lennartz 1983, Kappes and Harris 1995, Laves and Loeb1999).

The diet of RCWs includes 41 species of arthropods and is primarily made up of wood cockroaches (*Parcoblatta* sp.) and/or ants (Formicidae) (Ligon 1971, Hess and James 1998, Hanula and Horn 2004). Research by Hanula and Horn (2004) found wood cockroaches made up 54.7% of the diet of nestlings in 4 populations in South Carolina, Georgia, Alabama and Florida. RCWs also fed their nestlings caterpillars (Lepidoptera), spiders (Araneae), ants, centipedes (Scolopendromorpha), wood borer larvae (Cerambycidae), and insect larvae (Insecta) (Hanula and Horn 2004). RCWs forage almost exclusively on live pines but will also feed on recently dead pines (Ligon 1968, Ligon 1970, Hooper and Lennartz 1981, Hardesty et al. 1997a). Males and females exhibit intersexual partitioning of food sources, with females foraging primarily on the lower part of the trunk and males feeding in the upper trunk and branches (Ligon 1968, Hooper and Lennartz 1981, Porter et al. 1985, Engstrom and Sanders 1997, Hardesty et al. 1997a).

Red-cockaded woodpeckers exhibit cooperative breeding, a system found in only 3% of avian species, where helpers assist the breeding pair in incubating eggs, and brooding and feeding nestlings (Ligon 1970, Lennartz and Harlow 1979, Ehrlich et al. 1988). The breeding season begins around mid-April with the breeding female laying 2-5 eggs in the breeding male's cavity (Ligon 1970, 1971, Walters 1990). Incubation is 10-12 days long and begins before the clutch is complete, resulting in asynchronous hatching (Ligon 1970, 1971, Beckett 1971). Nestlings fledge between 26-29 days (Ligon 1970, 1971). Typically, female offspring disperse in search of a mate and male offspring stay with the group to become helpers until a breeding opportunity arises. (Ligon 1970, Lennartz et al. 1987, Walters 1990)

Factors Affecting Red-cockaded Woodpecker Reproductive Success

Many factors can contribute to RCW reproductive fitness, one of which is group size. Ligon (1971), Jackson (1987), Lennartz et al. (1987), Walters (1990), Neal et al. (1993), Heppell et al. (1994), Reed and Walters (1996), James et al. (1997), Schiegg et al. (2002) and Conner et al. (2004b) found that groups with helpers fledged more young. Khan and Walters (2002) reported increased breeder survival with increased group size. Some studies have found no correlation between group size and fledgling production (Hardesty et al. 1997b, Leonard et al. 2004), or even a negative relationship between groups with helpers and number of fledglings (DeLotelle and Epting 1992), however these findings are in the minority.

Breeder age and experience can also influence the number of fledglings (Walters 1990, Walters et al. 1992b, Reed and Walters 1996, Schiegg et al. 2002, Leonard et al. 2004). Younger RCWs had lower reproductive success and higher variability in their reproduction than older birds (Reed and Walters 1996). Schiegg et al. (2002) reported earlier egg laying, which produced more fledglings in experienced females and experienced breeding pairs. Lennartz et al. (1987) and DeLotelle and Epting (1992) found correlation between breeder experience and fledgling success; however other variables, such as group size, confounded results.

Habitat quality influences RCW reproductive fitness in various ways. Several studies have found relationships between pine density, size, and/or basal area and fledgling production (Hardesty et al. 1997a, James et al. 2001) or group size (Rudolph and Conner 1994, Hardesty et al. 1997a, James et al. 2001, Walters et al. 2002). Other studies have linked groundcover conditions to RCW reproduction (James et al. 1997, 2001, Hardesty et al. 1997a, Taylor and Walters 2004). Lennartz et al. (1987) found correlations between fledgling success and habitat quality; however, they indicated other variables, such as group size, may have had a stronger influence on the number of fledglings. Leonard et al. (2004) did not find any difference in habitat quality related to reproductive fitness, but noted that habitat at their study sites was already considered good quality.

The amount of habitat available to RCW groups may affect reproduction. Larger home ranges reflect increased foraging resources (Hooper et al. 1982, Hardesty et al. 1997a), assuming habitat quality is constant. Hardesty et al. (1997a) found that RCW home range size was positively correlated with number of fledglings in one year and group size in the following year and successful breeders had home ranges 46% larger than unsuccessful groups. When habitat quality is not constant, the amount *and* quality of available habitat are important, as seen in several studies. Spadgenske et al. (2004) found a correlation between RCW reproductive fitness and the number of hectares within 800 m of the cluster that were in compliance with U. S. Fish and Wildlife Service (2003) foraging habitat guidelines. Similarly, Walters et al. (2002) found that group size increased with amount of “high” and “medium” quality habitat (as defined for their study area and by criteria from past research). Lennartz et al. (1987) found RCW groups with helpers had bigger home ranges and produced more fledglings; however home range size and reproductive fitness were not directly correlated. The effects of home range size and amount of good quality habitat may only be a factor in suboptimal habitat. For example, Engstrom and Sanders (1997) recorded small average home ranges (63.3 ha) but high population density and reproductive fitness in old growth longleaf (200-400 year old canopy trees) indicating the importance of habitat quality over quantity in this situation.

Habitat structure is very important to RCWs and several studies have linked midstory encroachment to lower fitness. Walters et al. (2002) found group size decreased with increasing height of the hardwood midstory. Hardesty et al. (1997a) found a negative relationship between hardwood structure and group size, clutch size and number of fledglings. Lennartz and Heckel (1987) noted an increase in RCW nest predation in habitat with considerably more hardwood midstory. Also RCW cluster abandonment has been associated with hardwood encroachment (Beckett 1971, Hooper et al. 1980, Jackson 1987, Conner and Rudolph 1989, Loeb et al. 1992, Richardson and Stockie 1995).

Variations in weather can impact reproductive efforts in RCWs. Heavy rainfall reduces nestling provisioning, which may affect reproductive success (Neal et al. 1993, Conner et al 2005). Rainfall can also cause cavity flooding (Beckett 1971, Walters and Kneitel 2004). RCWs construct cavities with upward entrances to protect against weather (Dennis 1971, Jackson 1978a) and most cavity flooding is found in enlarged RCW cavities (Dennis 1971, Jackson 1978a, Loeb 1993), but it can also occur in suitable nest cavities (Beckett 1971, Loeb 1993, Walters and Kneitel 2004). Conversely, drought was suggested as the cause of a record low in RCW reproduction in a Georgia population (Lennartz and Heckel 1987). Additionally, Boughton et al. (2004) suspected drought as the reason for observed cavity tree mortality in a RCW population in Florida. Tree mortality did not adversely effect the RCW population; however artificial cavity inserts were installed to mitigate cavity loss (Boughton et al. 2004).

Nest predation is a direct cause of reproductive loss. The rat snake (*Elaphe spp.*) is capable of climbing trees to prey on eggs and nestlings (Jackson 1974, Lennartz and Heckel 1987, Neal et al. 1993, Richardson and Stockie 1995) and Cole et al. (2004) has shown rat snakes select nest trees. Resin barriers created by RCWs wounding trees around the cavity entrance deter snake predation; however, resin is ineffective against other predators (Ligon 1970, Dennis 1971, Jackson 1974, Jackson 1978b, Conner et al. 2004c). Southern flying squirrels commonly use RCW cavities and destroy RCW nest contents (Lennartz and Heckel 1987, LeBranche and Walters 1994). Red-bellied woodpeckers have also been reported to kill RCW nestlings (Jackson 1978a). LeBranche and Walters (1994) reported almost 13% of RCW nests which experienced whole brood loss had flying squirrels, red-bellied woodpeckers, or red-headed woodpeckers occupying the nest cavity afterwards.

Cavity usurpation has been observed to decrease reproductive fitness. Direct impacts on reproduction can occur from loss of suitable nest sites (Jackson 1978a, Harlow and Lennartz 1983, LeBranche and Walters 1994) or predation of eggs and nestlings (see above). Indirect impacts on reproductive fitness may include energy expenditure on cavity defense (Ligon 1971), increased partial brood loss (Laves and Loeb 1999), reduction of helpers due to cavity loss (Jackson 1987, Laves and Loeb 1999) and increased risks from open roosting (Ligon 1971, Jackson 1987). Further support for the link between cavity kleptoparasitism and decreased reproductive fitness is seen in several experimental studies. Laves and Loeb (1999) reported an increase in the number of fledglings for groups which had southern flying squirrels removed from RCW cavities. Several studies introduced cavities to RCW clusters to reduce competition for the limited resource. Loeb and Hooper (1997) saw increased rates of nest initiation by RCWs and increased fledgling success in groups with nest boxes installed for non-RCW cavity nesters. Anecdotal information from Jackson (1978a) supports the reduced use of natural cavities by non-RCW species after the addition of nest boxes. Carrie et al. (1998) reported increased group size after artificial cavity installations. In contrast, Conner et al. (1996) found no relationship between RCW reproductive fitness and cavity usurpation by southern flying squirrels, but noted that squirrel presence was high everywhere, thereby precluding an assessment of RCW reproduction at varying levels of squirrel abundance.

Fire and Red-cockaded Woodpeckers

The RCW evolved in a fire adapted environment and the benefits of fire to RCWs are well documented. Fire is the natural agent which creates the habitat that RCWs require. Fire removes midstory vegetation which results in greater density of arthropods (Collins et al. 2002) and suitable surroundings for nesting and roosting. The fire regime is also necessary for sustaining the diverse groundcover, which has been associated with RCW reproductive fitness (James et al. 1997, Hardesty et al. 1997a), and the arthropod community (Taylor and Walters 2004).

Relatively little research has been done on the effects of season of fire and RCW reproduction; however the U. S. Fish and Wildlife Service (2003) recommends using early to mid-growing season burns to manage RCW nesting and foraging habitat. Growing season fire is believed to be the natural fire regime in which RCWs evolved. Several studies have linked increased RCW fitness to habitat variables associated with growing season burns (James et al. 1997, 2001, Hardesty et al. 1997a, Walter et al. 2002). Taylor and Walters (2004) advocated growing season burns in RCW management based on the results of Taylor (2003), who found positive correlations between arthropod biomass and the percent of herb and grass cover, and on the findings of James et al. (1997) which positively correlated RCW density and percentage of wiregrass (*Aristida beyrichiana*). Nonetheless, no studies have demonstrated greater RCW fitness directly associated with growing season burns.

Several studies have found season of burn has no effect on RCWs. Engstrom et al. (1996) and King et al. (1998) found no difference in RCW abundance between growing season and dormant season burn treatments. Studies on RCW nests during growing season prescribed burns have not shown any direct effects on nestling survival (Stamps et al. 1983, The Nature Conservancy of Georgia 1994). Hanula and Horn (2004) examined

RCW prey response to season of burn and found decreased abundance of spiders and ants in growing season burns, but no effect on cockroaches, and thus concluded season of burn had minimal overall impact.

Fire induced loss of RCW cavity trees and nests have been well documented (Beckett 1971, Conner and Locke 1979, Conner 1981, Stamps et al. 1983, Conner et al. 1991, LeBranche and Walters 1994, Thurber et al. 2004). One of the primary causes of tree ignition is the resin flow, which RCWs stimulate by chipping the bark around the cavity entrance (Conner and Locke 1979, Engstrom et al. 2005). Increased resin flow, perhaps from increased resin well maintenance in the breeding season or the warmer temperatures of spring and summer, could make fire in the growing season more hazardous to trees (Robbins and Myers 1992). However, these concerns have not been substantiated by data gathered from RCW populations monitored across the southeastern region. The overall loss of active cavity trees, specifically nest trees, has been very low since record keeping was initiated in 1997 (U. S. Fish and Wildlife Service unpublished data 2007). Unfortunately it is difficult to say whether the low nest tree mortality is reflective of minimal growing season fire impact or precautionary measures taken by land managers to protect cavity trees during prescribed fires.

Fire, Red-cockaded Woodpecker Management and Other Species of Concern

Red-cockaded woodpecker recovery has been the primary objective of many longleaf pine restoration efforts but single species management also affects many non-target species (Hunter et al. 1994, Liu et al. 1995, Brennan et al. 1995, Conner et al 2002, Wood et al. 2004). One species of particular concern is the Bachman's sparrow. The sparrow is currently listed as vulnerable or imperiled in several states and the U. S. Fish and Wildlife Service considers it a high priority species of management concern (NatureServe 2007). Bachman's sparrows are particularly sensitive to the conditions of the understory vegetation and need an open forest structure (Dunning and Watts 1990, Plentovich et al. 1998). Tucker et al. (2004) found that a specific fire interval of 2-3 years was most suitable for Bachman's sparrow habitat and recommended growing season burns because of its positive effects on vegetation structure. Similarly, Tucker et al. (2006) found sparrow reproduction declined after the fourth season post-burn suggesting management for this species should include prescribed burning at least every three years. RCW management appears compatible with the needs of this grassland species; however, neotropical migrants, which are experiencing population declines as a whole, have a mixed response to RCW management. Migrants, such as indigo buntings and yellow-breasted chats, benefit from land management practices aimed at RCW habitat improvements (Lucas 1994, Brennan et al. 1995, Wilson et al. 1995, Brunjes 1998, Burger et al. 1998, Hines 1999, White et al. 1999, Masters et al. 2002, Conner et al. 2002, Shurette 2003, Wood et al. 2004), while other species, particularly those dependent on hardwoods, like red-eyed vireo and ovenbird (*Seiurus aurocapillus*), are negatively affected by RCW conservation (Krieger 1997, Hines 1999, Masters et al. 2002, Shurette 2003).

One approach to reducing the conflict between endangered species and non-target species negatively impacted by recovery efforts is the use of a scoring system based on conservation values (Hunter et al. 1994). Partners in Flight (PIF), a partnership program started in 1990 to bring organizations together to conserve North American landbirds, has been involved in an ongoing process to develop a scoring system to rank birds by conservation need (Carter et al. 2000, Beissinger et al. 2000, Panjabi et al. 2005). PIF derives scores from six global or regional factors: population size, population trend, breeding and non-breeding distribution, and threats to breeding and non-breeding (Panjabi et al. 2005). These scores can be used to weight species based on their level of conservation priority, which helps land managers objectively review the effectiveness of management techniques in meeting overall conservation goals (Hunter et al. 1994, Twedt 2005).

Several studies have applied PIF scores to bird communities in the southeastern pine forests. Hunter et al. (1994) examined the management values of pine stands, hardwood stands and pine-hardwood mixed stands on several groups of high priority landbirds to determine if RCW management was in conflict with management for neotropical migrants. By using PIF scores, the importance of pure stands over mixed pine-hardwoods became apparent, thus supporting the need to conserve both mature pine stands and mature hardwood stands but not necessarily at the same location (Hunter et al. 1994). Wood et al. (2004) used an Avian Conservation Value (ACV, see Equation 2, page 39) to objectively evaluate the conservation importance of two management methods. The ACV incorporates PIF conservation scores of individual species along with abundance values to create a cumulative community total. Wood et al. (2004) used ACV to assess RCW managed stands verses stands with longer fire intervals and no hardwood removal and found RCW stands had a 60% greater conservation value. Tucker et al. (2003) also found the application of PIF concern scores helped illuminate the importance of longleaf stands. They compared the bird communities in nine habitat types at Eglin Air Force Base in Florida with and without concern scores and found mature burned longleaf stands had a low rank without the scores but they became the most important habitat for species with the greatest management concern when scores were applied (Tucker et al. 2003).

Fire and Birds in the Southeastern United States

Without fire, the bird community of the longleaf pine forest changes rapidly, resulting in the decline of some species and the increased abundance of others. A 15-year fire exclusion study in Florida showed the disappearance of four open-habitat bird species within 5 years of fire suppression, including the Bachman's sparrow (Engstrom et al. 1984). Canopy species were the least affected by fire removal since the canopy composition was relatively unchanged during the early stages of succession. However, Engstrom et al. (1984) predicted that as the pine forest succeeded to a beech-magnolia hardwood forest under fire exclusion, several bird species would soon disappear, including the brown-headed nuthatch, a species of high conservation concern in the Southeast. Engstrom et al. (1984) also found that bird abundance was greatest in the first five years after fire exclusion, but declined for the next six years to its lowest point and then increased again through year fifteen, when tree density was predominately hardwoods and basal area was equally comprised of pines and hardwoods. The lowest species richness was seen between eight and eleven years post-fire when high density of oaks formed a low subcanopy below the pines (Engstrom et al. 1984). In another fire exclusion study, Conner et al. (2005) reported a decrease in abundance of species associated with open-pine habitat, with a significant decrease seen in Bachman's sparrow abundance over an eight-year period. In contrast, birds affiliated with the woody shrub layer of vegetation, such as northern cardinals, Carolina wrens, hooded warblers and white-eyed vireos, were not reduced by the removal of fire or in some cases showed an increase in abundance (Conner et al. 2005).

The structural changes induced by fire in southern pine forests influence avian diversity in southern pine forests. Species richness tends to increase or remain stable under prescribed fire. Brunjes (1998), Burger et al. (1998), Masters et al. (2002), Conner et al. (2002) and Wood et al. (2004) reported increased species richness in stands managed for RCWs, possibly reflecting the increase in habitat heterogeneity associated with patchy fires (Meyers and Johnson 1978, Dickson 1981). Krieger (1994), Wilson et al. (1995), Hines (1999), White et al. (1999), Provencher et al. (2002b) and Shurette (2003) saw no change in species richness under management that included prescribed fire regimes. Theoretically, fire should increase open-pine and early-successional bird species while decreasing some of the hardwood and shrub species in proportion to the amount of midstory loss (Dickson 1981). Studies looking at avian response to fire regimes support similar conclusions. Lucas (1994), Wilson et al. (1995), Krieger (1997), Burger et al. (1998), Hines (1999), White et al. (1999), Masters et al. (2002), Conner et al. (2002), Provencher et al. (2002a), Shurette (2003) and Tucker et al. (2003) found breeding birds associated with pine savannas, grasslands or forest edge habitat showed increases in abundance while species associated with forest interiors and hardwoods decreased in abundance under the thinning/burning regimes of RCW management. Among the species benefited by fire were northern bobwhite (*Colinus virginianus*), brown-headed nuthatch, red-cockaded woodpecker, white-eyed vireo, yellow-breasted chat, Bachman's sparrow, indigo bunting, eastern wood-pewee, chipping sparrow, common yellowthroat, pine warbler, prairie warbler and eastern towhee. Species that typically declined under management that involved frequent burns were tufted titmouse, black-and-white warbler (*Mniotilta varia*), Acadian flycatcher, hooded warbler, ovenbird, and red-eyed vireo. Some species showed varying responses to fire, including blue-gray gnatcatcher, Carolina wren, Carolina chickadee, great-crested flycatcher, wood thrush, summer tanager and northern cardinal.

Overall, breeding bird abundance increases with burning in the southeastern pine forests. Many studies found RCW management that included prescribed burns, was associated with increased bird abundance (Lucas 1994, Brunjes 1998, Burger et al. 1998, Masters et al. 2002, Conner et al. 2002, Shurette 2003, Wood et al. 2004). Similarly, Wilson et al. (1995) reported highest bird densities in stands in their second growing season post burn and lowest densities in stands without RCW management (no fire or thinning). Hines (1999) also found an increase in bird abundance on RCW managed sites, but the difference was not statistically significant.

Effects of Fire on Nesting and Foraging Guilds

Studies assessing the effects of fire on breeding bird guilds have found patterns in bird abundance based on nesting locations. Ground nesting species associated with hardwood forests, such as black-and-white warblers and ovenbirds, favored unburned sites (Wilson et al. 1995, Hines 1999, Shurette 2003); however ground nesters associated with forest edge, shrubs or pine savanna habitat were more abundant in burned sites (Burger et al. 1998, Hines 1999). Shrub nesting species showed increased abundance in RCW managed sites due to resprouting of shrubs post-burn (Wilson et al. 1995, Burger et al. 1998, Hines 1999). Cavity nesting species remained stable (Wilson et al. 1995, Shurette 2003) or increased (Hines 1999) under a regular fire regime. Likewise, canopy nesting species appeared to be unaffected (Hines 1999) or increased in abundance (Wilson et al. 1995) under RCW management.

Less information is available on how foraging guilds are affected by fire in the southeast. Wilson et al. (1995) and a later study by Brunjes (1998), using guild categories set forth by Wilson et al. (1995), found bird species that forage on the bole, ground/shrubs, or in the canopy were more abundant in burned treatments. Both studies reported no difference in species foraging in the midstory. Wilson et al. (1995) found a greater abundance of aerial foragers in burned sites but Brunjes (1998) found no difference in aerial foraging species between treatments.

Effects of Season of Fire on Birds

Few studies have looked at the effects of the season of fire on breeding birds; however, the timing of burns can affect reproductive efforts, food availability and survivorship (Robbins and Myers 1992, Engstrom et al 2005). Growing season fire can directly destroy nests, with ground and shrub nesters being most vulnerable to nest loss (Robbins and Myers 1992, Engstrom et al 2005). Burns can displace birds from their breeding territories and force them to disperse in search of new suitable habitat (Seaman and Krementz 2000). Fires during the nesting season can extend the breeding period as birds attempt to renest (Shriver et al. 1999, Cox and Slater 2007); however, some species, like the Florida grasshopper sparrow (*Ammodramus savannarum floridanus)*, are sensitive to the timing of fire within the growing season and may not renest after fires in late-June (Shriver et al. 1999). Also, growing season burns are more effective in killing hardwood species and reducing hardwood sprouting (Streng et al. 1993) which could affect the amount of suitable substrate available for nesting for bird species that use the shrub layer and/or hardwoods. Food resources are both positively and negatively impacted by the season of fire (Robbins and Myers 1992, Smith 2000). Over a 43 year study of season and frequency of prescribed burning in pine savannas, Waldrop et al. (1992) found legumes to be most abundant in annual winter burns and *Vaccinium* species to be abundant in all plots except annual summer burns. These findings suggest seed and fruit production can be altered by season of burn and may affect available food sources for birds. Lastly, fire seldom causes direct mortality to adult birds (Smith 2000); however it may lower survivorship by reducing cover and thereby increasing predation (Robbins and Myers 1992). The recovery time for groundcover vegetation is longer after dormant season fires, which could lengthen the time birds are exposed to predators (Robbins and Myers 1992).

Despite the potential hazards of fire, research on season of burns suggests there is only a minor, if any, effect on the overall breeding bird population in the longleaf pine ecosystem. Studies in both the breeding and winter season have found no difference in species richness or bird abundance between season of burn treatments (Engstrom et al. 1996, King et al. 1998). Bird species which nest and/or forage on the ground have received special focus because of their increased vulnerability to fire. Two studies have reported no difference in Bachman's sparrow abundance between dormant season and growing season burn treatments (Engstrom et al. 1996, Tucker et al. 2004) and Tucker et al. (2006) found no difference in Bachman's sparrow reproduction between season of burn treatments. Research by Seaman and Krementz (2000), on Bachman's sparrow movement and survival in direct response to growing season fires in South Carolina, found the most notable impact on this species. Seaman and Krementz (2000) reported no adult mortality from May and June fires and their survival rates were not different between burned sites and the control, although two nests were lost. In the same study, Bachman's sparrows with transmitters were tracked before, during, and after prescribed fires. The birds dispersed from the burn sites within a few days and sparrow density remained low for 50 to 100 days post-fire (Seaman and Krementz 2000). A study on Henslow's sparrow (*Ammodramus henslowii*) survival rates found the effects of season of fire was far less important than the time since burning occurred (Thatcher et al. 2006). A season of fire study comparing nest box use by great-created flycatchers found no preference between dormant and growing season burn sites (White and Seginak 2000). Flycatcher clutch sizes were larger in growing season burns, but fledgling success was greater in dormant season burn sites (White and Seginak 2000).

Study Objectives

The focus of this study was to evaluate the effects of season of burn on a RCW population and on the breeding bird community in a mature longleaf pine ecosystem in South Carolina after four years of growing season burning in a site with a history of dormant season burning. Specifically, the objectives of this study were:

1) To monitor and measure nesting efforts and reproductive success of an intensively managed population of RCWs at Brosnan Forest to determine if season of burn affected group size, clutch size, or number of fledglings in the 2004 and 2005 breeding season.
2) To census the breeding bird population at Brosnan Forest to determine if total bird abundance, species richness, species composition, or abundance of individual species was different between growing season and dormant season burn treatments. Additionally,

differences in burn treatment were examined by bird guilds and conservation value to highlight any impact season of burn may have on the breeding bird community.

CHAPTER 2

MATERIALS AND METHODS

Study Area

Research was conducted at Brosnan Forest, located in Dorchester, South Carolina in the physiographic region of the Coastal Plain Province (N33 09’03.34”, W80 26’55.28”). This 5,966 ha property is owned by Norfolk Southern Railway (NSR) and currently managed as a hunting and recreational facility for NSR employees and clients. Research on RCWs at Brosnan Forest began in 1997 in partnership with the U.S. Fish and Wildlife Service, Clemson University, and Milliken Forestry Company, Inc. The fieldwork for this study was conducted between April 2004 and August 2005.

Brosnan Forest was once part of a larger tract of land purchased by the railroad company for timber harvesting. By the early 1900’s the forests had been clear cut and left fallow. In the 1920’s and 1930’s the remaining parcel of property was converted into a demonstration forest for pulpwood production and experimental forestry management techniques. In the 1950’s, the railroad’s vice president, D. W. Brosnan, envisioned the property as a corporate retreat and implemented a 12-year project to build 386 km of roads and an extensive drainage ditch system throughout the property. Under Brosnan, some low intensity, dormant season prescribed fires were used to promote quail hunting and manage timber in a few blocks, but it was not until the 1980’s that a more complete prescribed fire regime was implemented. In 1981, Milliken Forestry Company, Inc. became the forestry consulting firm for the property. The new management goals were to improve quail habitat by removing the densely stocked understory planted slash pine (*Pinus elliotii*), and convert poor quality longleaf sites to loblolly pine (*P. taeda*) stands, primarily on the southern portion of the forest. Most of the property (except bottomlands) was burned annually between December and March. Some April burns were used to control sweet gum but were later discontinued to avoid disruptions to quail and turkey nesting. Management at Brosnan Forest today includes prescribed burning in dormant and growing seasons at 2-3 year intervals, selective logging, and herbicide treatment for hardwood midstory removal. The timber management goal is to keep the longleaf pine stands at a basal area of 11.5 sq m/ha and encourage natural regeneration of longleaf pine.

Brosnan Forest currently has extensive stands of longleaf pine which reseeded naturally after the clear cuts in the early 1900's. As a result, the property includes 2,560 ha of nearly 100 year old mature longleaf with longleaf seedlings in various stages of regeneration. The ground layer vegetation in these stands is primarily wiregrass, bracken fern (*Pteridium aquilinum*) and variety of woody shrub and legume species (Mudder 2006). Mature loblolly pines dominate 878 ha, along with 46 ha and 1310 ha of planted longleaf and loblolly pines, respectively. Over 350 spring and winter wildlife food plots are distributed throughout the property to collectively comprise 448 ha. Spring food plots are planted with a rotation of sorghum, millet, soy beans, iron pea, clay pea, and buckwheat. In the fall, winter plots are sown with a mixture of rye, wheat, oats, Austrian winter pea, crimson clover, and arrowleaf clover. There are also 491 ha of hardwoods, several lakes/ponds (84 ha) and wet areas (33 ha).

In 1998, Brosnan Forest entered into a voluntary safe harbor agreement with the U. S. Fish and Wildlife Service. This type of agreement allows non-federal landowners the ability to conserve threatened and endangered species without increased Endangered Species Act restrictions on their land use (Costa and Kennedy 1997, Costa et al. 2001). Brosnan Forest started safe harbor with a baseline of 68 active RCW clusters (62 of which were potential breeding groups). Researchers from Clemson University began monitoring these groups in 1998 and banded the majority of adults and offspring on the property. The discovery of new clusters along with the addition of recruitment clusters has brought the total number of clusters to 79, with 70 and 65 potential breeding groups in 2004 and 2005, respectively. The adult RCW population census for 2004 and 2005 tallied 185 and 194 birds, respectively.

Experimental Design

The experimental units for this study were RCW territories, which included the cluster of cavity trees and foraging habitat of each RCW group. The RCW clusters at Brosnan Forest were defined and mapped by Sanders (2000) and the foraging habitat was defined as the area within a 0.8 km radius from the cluster center (U.S. Fish and Wildlife Service 2003; Figure 1). The design for the study was a randomized complete block design with 60 active RCW territories randomly selected to receive a prescribed fire treatment and

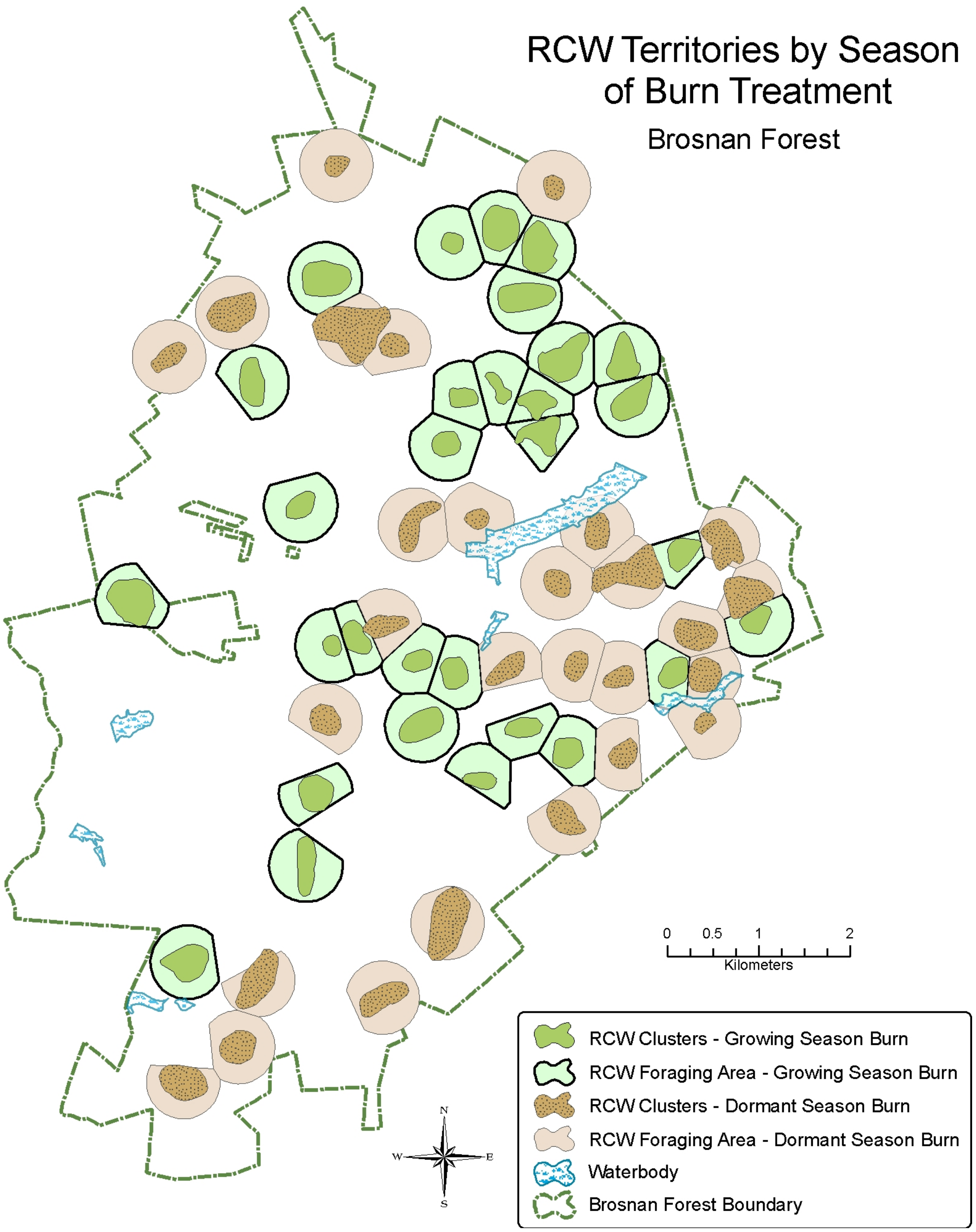

Figure 1: Map of the experimental red-cockaded woodpecker territories at Brosnan Forest by season of burn treatment

breeding years (2004/2005) treated as the block. Each year, RCW groups were monitored for reproductive efforts and group size, and breeding birds were sampled across RCW territories.

All RCW territories had similar histories of dormant season prescribed burns every 1-2 years. Thirty territories were assigned a growing season (April-August) burn regime and the remaining territories continued to receive dormant season (December- March) burns. This study defined burn periods as “dormant” and “growing” based on typical seasonal patterns of vegetative growth in the southeast. The growing season in Dorchester, South Carolina generally begins mid-March, however the entire month of March was categorized as “dormant” season since no prescribed burning occurred in the last two weeks of March. Prescribed burns were conducted on the level of burn units, which were delimited by fire breaks such as roads, ditches and plow lines. Burn units varied in size from approximately 4.5 to 50 ha and sometimes several burn units were needed to cover the area of a single RCW territory. The burns were scheduled every other year, for a total of three experimental burns between 2001 and 2005.

Red-cockaded Woodpecker Data Collection

The red-cockaded woodpecker population at Brosnan Forest was monitored during the 2004 and 2005 breeding seasons to locate active nest cavities, band nestlings, determine fledgling success and document group size. Nest searching began each year in mid-April. Clusters were checked weekly to inspect active cavity trees for evidence of a nest or nesting behavior. Active cavities were determined by fresh chipping on the bark of the tree and recent resin flow (Hooper et al. 1980). Evidence of nesting included fresh wood chips lining the bottom of the cavity or the presence of eggs or nestlings. Nest searching was primarily conducted using a TreeTop Peeper II ™ video probe system (by Christensen Designs) on a 15 m extending pole, which allowed remote visual inspection inside the cavity. When a nest was located, it was visited weekly to determine clutch size, and age of chicks. Banding was scheduled when chicks were 7-10 days old. Swedish climbing ladders were used to access cavity nests and chicks were extracted using a noose made of pliable tubing fitted with monofilament loops (Jackson 1982). Chicks were banded with a U.S. Geological Survey aluminum band and a unique color band combination to allow later identification with a spotting scope. Nests were revisited when chicks were approximately 21 days old to determine sex of nestlings (pre-fledge checks). RCW groups were followed post-fledging to obtain data on group composition and determine the number of chicks successfully fledged (post-fledge checks). All animal handling procedures were approved under Clemson University Research Protocol #50063.

In the event of a nest predation or a complete hatch failure, nest searching resumed until the birds re-nested or until July 1. If a nest was not found in an active cluster, the group was followed to determine group composition and verify the absence of nestlings or fledglings.

Breeding Bird Data Collection

Breeding birds were surveyed from mid-April to early June of 2004 and 2005 using 50 m fixed-radius point counts (Hutto et al. 1986). Counts were conducted using standard avian monitoring protocols described in Ralph et al. (1993) and Hamel et al. (1996). Points were selected from an existing grid of sampling stations laid out in 100 m intervals across the 60 RCW territories. Two points per territory were selected based on the criteria of being at least 250 m distance from each other and when possible, 150 m from the territory boundary. Counts were visited within the first 4 hours of sunrise and points within the same territory were surveyed on the same day. Each point was visited twice per season with 3-4 weeks between visits. The majority of the points on the study site were within close proximity to neighboring points and would have been conducive to 5-minute (min) count durations, but a 10-min duration was chosen for this study to compensate for the few remote points that had travel distances greater than 15 min (Ralph et al. 1993, Hamel et al. 1996). Data were recorded on bull's eye datasheets with three distance bands (0-25 m, 25-50 m, > 50 m) (Hamel et al. 1996) and bird detections were separated by time intervals (0-3 min, 4-5 min, 6-10 min). All birds detected visually or aurally were recorded, but detections > 100 m and flyovers were excluded from the analysis. The site, visit, date, weather and time were recorded at each point. Weather Bureau codes and the Beaufort scale were used for sky and wind conditions (USGS Patuxent Wildlife Research Center 2007). Data were not collected in moderate or heavy rain, or in winds greater than 30.6 km/h. Point counts continued in light fog or misting rain if the observer felt that bird detection within the fixed radius was not compromised. Points were sampled by a single observer in both years.

Vegetation Data Collection

Post-treatment data on vegetation was collected from May-August 2005. Ten to twelve points were sampled in each RCW territory. At each point, a 5×5 m plot was sampled for vegetation composition and number of woody stems ≥ 1 m in height. Four subplots were established within the sampling plot for ground cover estimates in nine categories: wiregrass, other graminoids, cane, ferns, herbaceous, legumes, woody species > 1 m tall, litter and bare ground. A more extensive description of the vegetation data collection is given in Mudder (2006).

Data Analysis

Two territories were dropped from the study, leaving 30 growing season and 28 dormant season treatments. Uneven application of prescribed fire resulted in the removal of 25 of the remaining 58 RCW territories from the breeding bird and woodpecker analysis. Two of the excluded territories did not receive any treatment until the spring of 2005. The other 23 territories had less than 75% of the vegetation points treated by the desired fire treatment due to patchiness of the burn or mixed season burning. Thirty-three territories remained in the analysis (Figure 2). Of the territories used for analyses, five received burns in months outside the designated season and needed to be reclassified. Three growing season territories were reclassified as dormant season to reflect actual fire

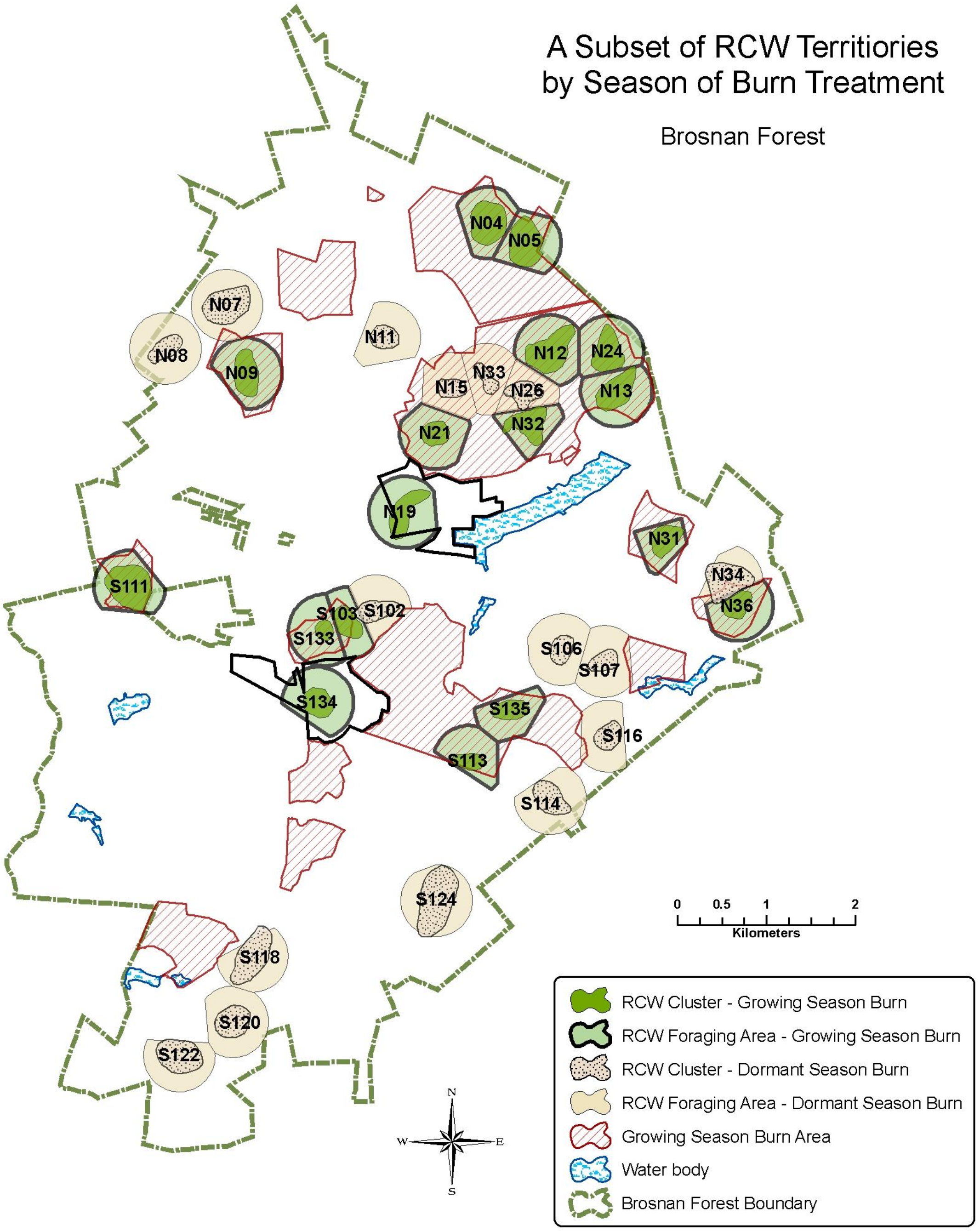

Figure 2: Map of red-cockaded woodpecker territories used in the analysis, by season of burn treatment, with areas receiving growing season burns shown. (Note: three growing season burn territories were reclassified as dormant season burn due to March burns instead of April burns: N15, N33, and N26; two dormant season burn territories, N19 and S134, were reclassified as growing season burn due to mixed season fires; burned area outlined with a solid black line.). Territory labels starting with "N" and "S" signify their location in the north or south side of the property, respectively.

application (burns were conducted in March instead of April). Two dormant season territories received mixed season burns and were reclassified as growing season treatment. After reclassification, there were 16 dormant season burn and 17 growing season burn territories.

A significance value of $\alpha = 0.10$, rather than the conventional $\alpha = 0.05$, was chosen as the rejection criteria for the two-tailed tests. Although this higher significance level increases the risk of a type I error (which rejects the null hypothesis when it is true) it reduces the chances of making a more serious type II error (Quinn and Keough 2002). In this particular case, a "false alarm" which declares a difference in breeding bird abundance or endangered woodpecker reproduction when there is none, has less environmental cost than a "defective alarm" which fails to show a difference in burn season when, in fact, there is an effect on the birds (Gonick and Smith 1993, Quinn and Keough 2002).

Due to the yearly variation, analyses were run with years blocked. When differences in years were not significant at a $P = 0.10$ level, results were presented by burn treatment, with the years pooled, to better capture trends.

Red-cockaded Woodpecker Analysis

Differences in RCW reproductive fitness were tested between growing and dormant season burn treatments using clutch size, numbers of nestlings seen at pre-fledge checks, numbers of fledglings seen at post-fledge checks and group size (number of adults). Data did not meet the assumption of normality, therefore a one-way analysis of variance (ANOVA) test for non-parametric data was run using “PROC NPAR1WAY” (SAS Institute Inc. 2002-2003) to produce a Kruskal-Wallis test with years pooled. Reproductive measures were also compared using data from Sanders (2000) and Jordan (2002) to conduct a matched-pair test of the 17 growing season burn territories, in which mean group size and mean number of fledglings per group before the first growing season burns were compared to post-treatment averages. Data for the comparison were collected from 1998 to 2005, with most pre-treatment data collection occurring from 1998 to 2002 and most post-treatment data collection occurring from 2003 to 2005. Fledgling numbers were derived from pre-fledge checks when available, but post-fledgling numbers were substituted in 1998. A matched-paired t-test was conducted in SAS software using “PROC TTEST” (SAS Institute Inc. 2002-2003).

Breeding Bird Analysis

Point count data were summarized by RCW territories for each year. Mean total abundance was calculated for each territory by totaling the average number of individuals seen across visits and points. Mean species richness was determined by adding the number of species observed across visits, then averaging species by points within each territory. Total species richness was the sum of species across visits and points per territory. The mean total abundance per territory, mean species richness per territory, and total species richness per territory were tested for differences in burn treatment with years blocked and tested for differences between years and the interaction (years × treatments) using a two-way ANOVA test. All tests were conducted with the procedure “PROC GLM” for an unbalanced design using SAS software (SAS Institute Inc. 2002-2003) and a priori, pair-wise comparisons were made using the Least Squares Means for the year × treatment effect.

Mean abundance of species per territory was also tested by categorizing species into habitat groups, foraging guilds and nesting guilds. Data did not meet the assumption of normality, therefore a one-way ANOVA for non-parametric data (Kruskal-Wallis test) was performed with year pooled using the “PROC NPAR1WAY” procedure (SAS Institute Inc. 2002-2003).

A multivariate analysis using ordination was conducted to look for patterns in the composition of bird assemblages, and to relate any patterns to burn treatment if possible. Ordination of community data produces a graphical display of the data, such that the distance between units indicates the degree of similarity, with similar units clustering together and dissimilar units spreading apart in ordination space (McCune and Grace 2002). Nonmetric Multidimensional Scaling (NMS), using PC ORD software, Version 5 (McCune and Mefford 1999), was used to analyze the sample point × bird species abundance matrix, with cell values equaling mean abundance per species per point per year. NMS analyses were run in “autopilot” mode with a thoroughness setting of “slow and thorough”, using the recommended Sorensen distance measurement (McCune and

Grace 2002, McCune and Mefford 1999). Random starting coordinates were initially used to determine the best configuration for the final run. Autopilot used 6 dimensions and 250 runs with real and randomized data. The PC ORD software selected a three-dimensional solution and reran the data using the run with the lowest stress in the chosen dimension as the starting configuration (Monte Carlo test, 250 randomized runs, mean stress = 25.5, $P = 0.004$). The final stress of the test after 500 iterations was 25.4, which is considered a poor fit for the data (McCune and Grace 2002), so interpretation of the test was done with caution. Final instability was 0.00187, which indicates a stable solution (McCune and Grace 2002).

Indicator Species Analysis was conducted with PC ORD software to identify any species occurring more frequently and abundantly in a burn treatment compared to randomly distributed data. A matrix of mean abundance of 55 species within a territory for each year was used to identify indicators. A Monte Carlo test with 1000 randomizations was run to determine indicator values of significance. Species with indicator values of $p \leq 0.10$ were retested for differences between treatments in SAS software. One-way ANOVA tests, using “PROC NPAR1WAY”, were run with years both separated and pooled (SAS Institute Inc. 2002-2003).

Finally, mean bird abundance per territory was weighted with conservation values for each species to create an adjusted mean total abundance. “Concern Ratings” (CR) were derived from Partners in Flight (PIF) concern scores using their regional combined scores in the breeding season (Panjabi et al. 2005). These scores range from 5 to 25, with 25 representing a species with the highest regional threats and therefore of greatest conservation concern (Panjabi et al. 2005). These PIF scores were transformed into CRs using Equation 1 from Twedt (2005). This equation rescales the PIF scoring system into an exponential curve that places greater weight on higher priority species.

$$\text{CR=LOG GAMMA(PIF concern score)}^2 \qquad \text{[Equation 1]}$$

Individual species abundance were multiplied by their CR and then used to calculate mean total abundance per territory using a modified version of the Avian Conservation Value (AVC) equation from Wood et al. (2004):

$$\mathbf{ACV}_l = \sum_{k=1}^{S} (\bar{x}_{kl} \times \text{CR}_k) \qquad \text{[Equation 2]}$$

where ACV is the avian conservation value at territory l; S is the total number of species seen at territory l; k is an individual bird species; $\bar{x}_{kl}$ is the mean abundance of species k at territory l; and CR_k is the concern rating of species k. The ACV was calculated by territory and compared by treatment with years blocked using “PROC GLM” (SAS Institute Inc. 2002-2003).

CHAPTER 3

RESULTS

The 2004 and 2005 breeding seasons were considerably different in average monthly temperature and rainfall. After a record drought from 1998 to 2002, South Carolina received rain in 2003 but the relief was short lived (SCDNR 2007). In the spring of 2004, average precipitation was below normal from March to May and average monthly temperatures were above normal for most of the spring and summer resulting in a hot, dry spring (SCDNR 2007). The number of RCW fledglings at Brosnan Forest in 2004 was the largest recruitment since the monitoring program began in 1998. However, there were 17% fewer breeding birds recorded in 2004 (n = 5530) point counts than in 2005 (n = 6473). The spring of 2005 was much cooler, with temperatures below normal from March to June and precipitation at normal to above normal levels from February to August (SCDNR 2007). The cooler, wetter conditions of spring 2005 may have negatively impacted RCW reproductive efforts because fledgling recruitment was the lowest since 1998. On the other hand, overall breeding bird totals were higher on 2005 point counts.

Red-cockaded Woodpeckers

Red-cockaded woodpecker reproductive fitness showed no difference in season of burn treatments (Table 1). RCW group size was slightly higher in growing season burn territories (2.7 birds per group) verses dormant season burned territories (2.4 birds per group) both years, however, the difference was not statistically significant (*P* = 0.1399;

Figure 3; Table 1). Clutch size ($P = 0.7941$), and number of chicks at pre-fledge checks ($P = 0.9339$) and post-fledge checks ($P = 0.8082$) showed no difference between treatments (Figure 4; Table 1). The matched-pair tests on growing season burn territories before and after treatment showed slight increases in mean group size and mean number of fledglings after the implementation of growing season prescribed fire, however, the difference was not significant (DF = 16, t = -0.49, $P_{groupsize} = 0.6336$; DF = 16, t = -0.49, $P_{fledglings} = 0.6836$; Figure 5).

Breeding Birds

Over the two-year study, 464 point counts were conducted on the property and a total of 82 species were recorded. Of those point counts, 264 counts were on sites receiving the treatments of interest. Several bird species were removed from the data. All migrant birds were removed to focus data analysis on breeding bird species. Game birds, including northern bobwhite, wild turkey and ring-necked pheasant were also excluded because captive-raised birds were regularly released at Brosnan Forest and wild individuals could not be distinguished from the introduced population. A total of 4,420 individual birds, and 55 species, remained in the analysis. A total of 1,768 birds representing 50 species were recorded in 2004, and 2,652 birds representing 50 species were recorded in 2005. Sampling efforts were the same for both years.

Average species richness and total species richness per RCW territory were greater in growing season territories than dormant season territories ($P_{Ave\ SR} = 0.0577$, $P_{Total\ SR} =$

0.0839) (Table 2). Yearly differences were seen in mean species richness ($P < 0.0001$) and total species richness ($P < 0.0001$) (Table 2). There was a notable increase in the number of species per territory seen in 2005, with an average of 5 more species recorded, per territory, in the second year. When years were tested separately, average species richness was not different between treatments and total species richness was different in 2004 only ($P = 0.0605$) (Table 3).

Mean total abundance per territory was different between years ($P < 0.0001$) but not between season of burn treatments ($P = 0.5922$) (Table 2). Similar results were found for guilds. None of the foraging guilds or habitat association guilds showed differences between treatments and only one nesting guild showed significant differences. Tree nesting birds were more abundant in growing season burn sites than dormant season burn treatments ($P = 0.0624$) for years pooled.

Nonmetric Multidimensional Scaling (NMS) showed no separation of the bird abundance assemblages by season of burn (Figure 6). Secondary habitat variables, such as time since the last burn, frequency of burns, number of growing season burns, and the presence or absence of selective logging within the years of the study were also reviewed for possible patterns in the data. Points from both treatments under all variables were scattered evenly across the axes with no discernible clustering.

Indicator Species Analysis (ISA) specified five bird species as indicators for season of burn territories (Table 4). Bachman's sparrow (IV = 51, $P = 0.0780$) and indigo bunting (IV = 56, $P = 0.0510$) occurred more frequently and abundantly in territories receiving dormant season burns. Mourning dove (IV = 50, $P = 0.0150$), pine warbler (IV = 61, $P = 0.0030$), and white-eyed vireo (IV = 53, $P = 0.0020$) were indicators for growing season burn territories. ANOVA tests with years separated showed pine warbler ($P_{2004} = 0.0792$; $P_{2005} = 0.0294$) and white-eyed vireo ($P_{2004} = 0.0507$; $P_{2005} = 0.0137$) were more abundant in growing season burns in both years. Indigo bunting abundance was not significantly different in either year when years were separated ($P_{2004} = 0.1546$; $P_{2005} = 0.1761$). Bachman's sparrow ($P_{2004} = 0.6449$; $P_{2005} = 0.0421$) and mourning dove ($P_{2004} = 0.1581$; $P_{2005} = 0.0398$) were significantly more abundant in dormant and growing season burn treatments, respectively, in 2005 only.

Avian Conservation Values (ACV) for territories in the dormant season burn treatment were greater than for territories in growing season burn treatments ($ACV_{DSB} = 382$, $ACV_{GSB} = 371$, $P = 0.0279$) when years were blocked. When years were compared separately there was no difference between treatments ($P_{2004} = 0.6772$, $P_{2005} = 0.6495$). ACVs were significantly different between years ($P < 0.0001$).

Table 1: Comparison of mean red-cockaded woodpecker reproductive measurements per group by season of burn treatment (years pooled) ± standard deviation. Sample sizes given in parentheses.

Variables	**DSB** [a]	**GSB** [a]	χ^2	***P*-value** [b]
Group Size	2.38±1.0 (32)	2.71±1.1 (34)	2.1787	0.1399
Clutch Size	2.65±1.5 (26)	2.52±1.7 (31)	0.0681	0.7941
Nestlings at pre-fledge check	1.65±1.2 (26)	1.65±1.2 (31)	0.0069	0.9339
Fledglings at post-fledge check	1.38±1.2 (26)	1.28±1.1 (32)	0.0589	0.8082

[a] DSB = dormant season burn; GSB = growing season burn

[b] Kruskal-Wallis test, DF = 1

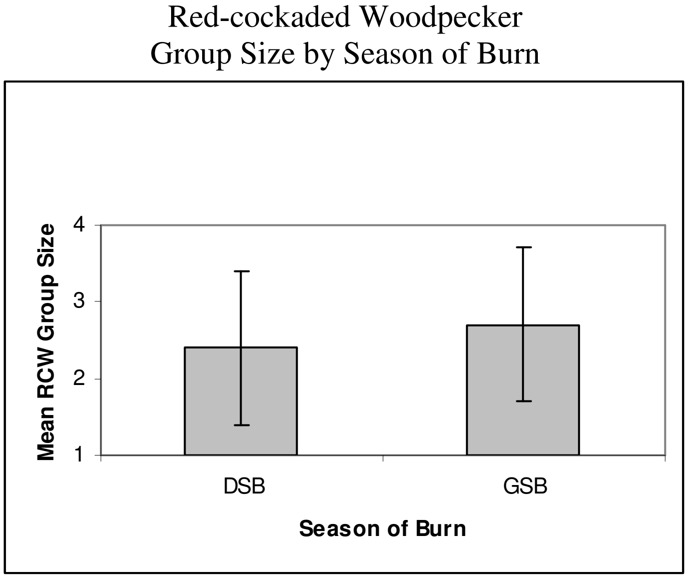

Figure 3: Mean red-cockaded woodpecker group size per territory by season of burn treatment (years pooled) ± standard deviation at Brosnan Forest, South Carolina (*N* = 66); DSB=dormant season burns, GSB=growing season burns.

Red-cockaded Woodpecker Reproductive
Measurements by Year and Season of Burn

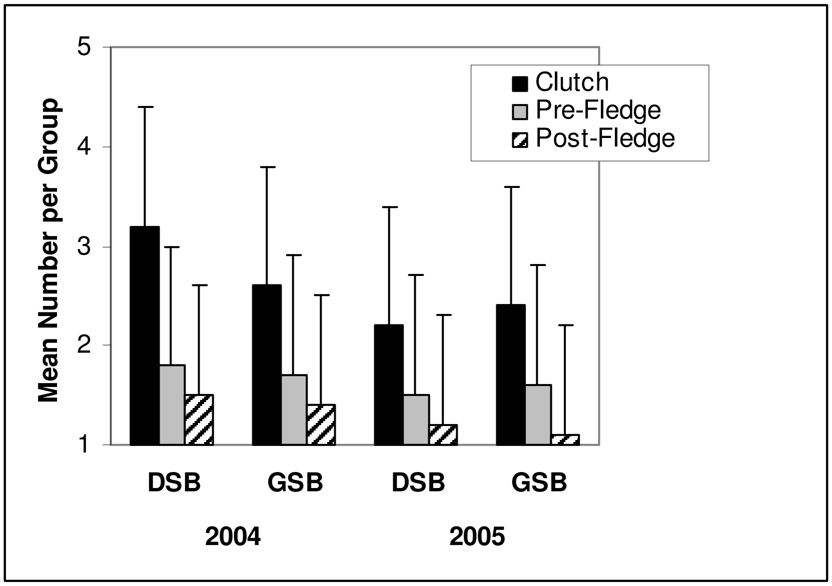

Figure 4: Red-cockaded woodpecker reproductive success by season of burn treatment and years ± standard deviation as measured by mean clutch size (*N* = 57), and number of chicks at pre-fledge checks (*N* = 57) and post-fledge checks (*N* = 58) at Brosnan Forest, South Carolina; DSB = dormant season burns, GSB = growing season burns.

Red-cockaded Woodpecker Fitness Measurements
Before and After Growing Season Fire

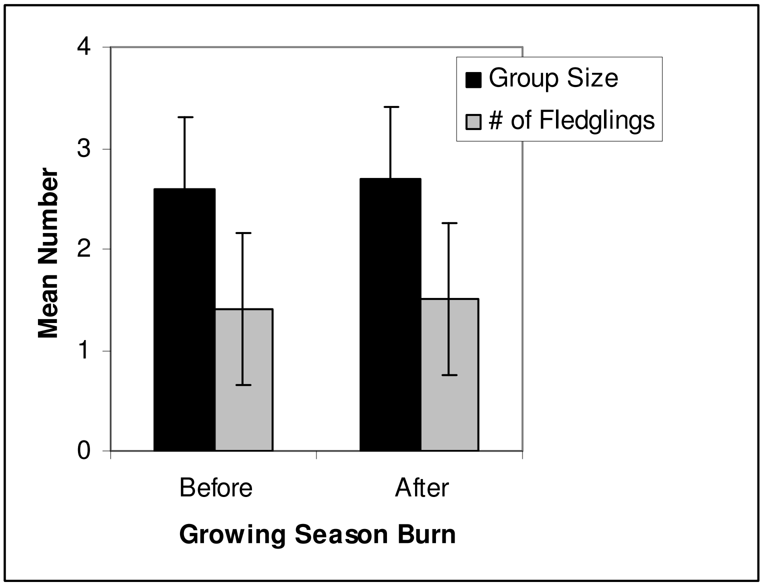

Figure 5: Mean group size and mean number of fledglings of red-cockaded woodpecker groups before and after the application of growing season fires (*N* = 17) at Brosnan Forest, South Carolina.

Table 2: Randomized Block ANOVA (with years as blocks) for mean total abundance, mean species richness and total species richness of bird species per RCW territory. Treatments = dormant season burns, growing season burns; years = 2004, 2005.

Variable	**Source**	**Degrees of Freedom**	**Mean Square**	**F-ratio**	***P*-value**
Mean Total Abundance	Treatment	1	0.211	0.56	0.5922
	Year	1	750.069	83.86	**<0.0001**
	Treatment×Year / Error A[a]	1	0.379	0.04	0.8376
	Error B[b]	62	554.558		
Mean Species Richness	Treatment	1	11.330	121.0	**0.0577**
	Year	1	414.245	93.44	**<0.0001**
	Treatment×Year / Error A[a]	1	0.094	0.02	0.8849
	Error B[b]	62	274.864		
Total Species Richness	Treatment	1	43.432	56.96	**0.0839**
	Year	1	428.338	56.23	**<0.0001**
	Treatment×Year / Error A[a]	1	0.763	0.10	0.7528
	Error B[b]	62	7.618		

[a] Error used for testing treatment effects

[b] Error used for testing year effects and treatment × year interaction

Table 3: Mean ± standard deviation species richness and mean ± standard deviation total species richness seen per RCW territory by year and treatment.

Variable	**Year** **(Sample Size)**	**Treatment[a]** DSB	 GSB	***P*-value[b]**
Mean Species Richness (# of species)	2004 (33)	13.2±2.0	13.9±1.6	0.3081
	2005 (33)	18.1±2.6	19.0±2.2	0.2222
Total Species Richness (# of species)	2004 (33)	18.8±2.6	20.6±2.2	**0.0605**
	2005 (33)	24.1±3.0	25.5±3.2	0.1481

[a] DSB = dormant season burn; GSB = growing season burn

[b] *P*-values from a Least Squares Means test for a priori comparisons of treatment × year (see Table 2 for ANOVA results)

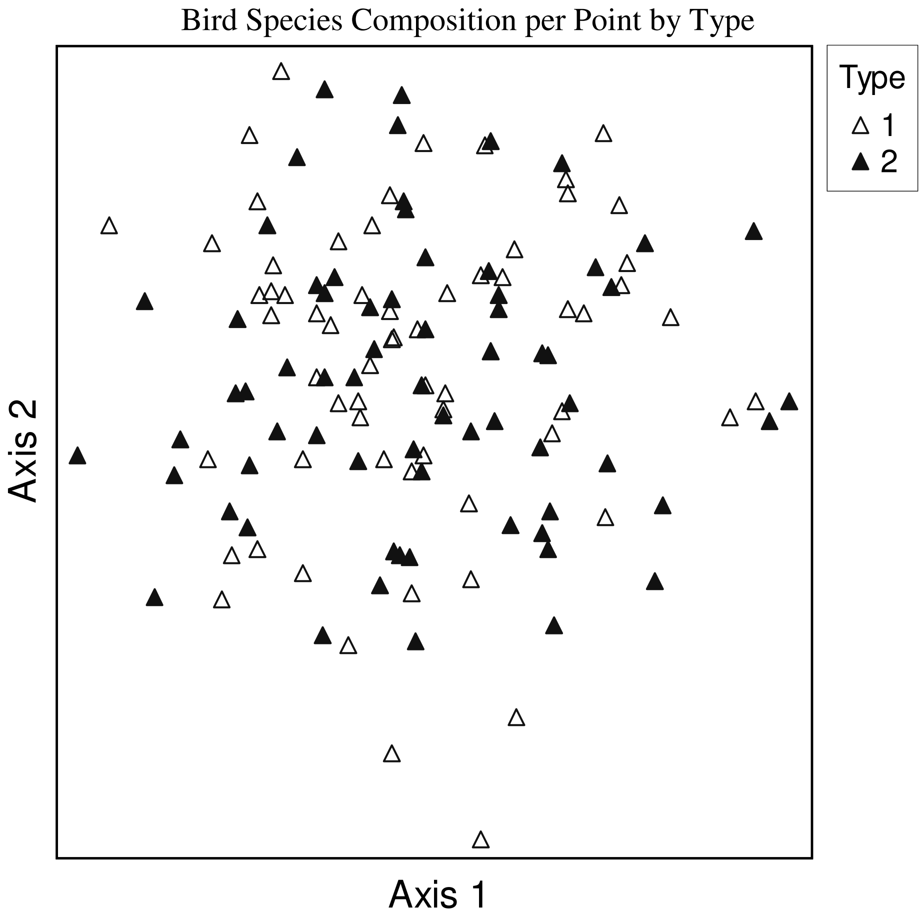

Figure 6: Nonmetric Multidimensional Scaling (NMS) 2-dimensional ordination graph of bird species composition (mean abundance of species per point within a year) by the variable "Type" (Type 1 = dormant season burn; Type 2 = growing season burn)

Table 4: Bird species considered indicators for season of burn treatments by the Indicator Species Analysis (ISA) method. Only indicator values (IV) of significance ($P \leq 0.10$) are listed.

Species[a]	**Indicator Value (%)**	***P*-value**[b]	**Treatment**[c]
Bachman's sparrow	51	0.0780	DSB
Indigo bunting	56	0.0510	DSB
Mourning dove	50	0.0150	GSB
Pine warbler	61	0.0030	GSB
White-eyed vireo	53	0.0020	GSB

[a] Common names of bird species from the American Ornithologists' Union Check-list of North American Birds, Seventh Edition. (See appendix A for scientific names of species)

[b] *P*-values obtained from the Monte Carlo test of significance for observed verse randomized IV

[c] DSB = dormant season burn; GSB = growing season burn

CHAPTER 4

DISCUSSION

Red-cockaded Woodpeckers

The importance of frequent, low intensity fires to RCWs is well known but the seasonal effect of fire on these birds is not well understood. Although season of fire did affect the vegetation at Brosnan Forest (Mudder 2006), in this study no differences were observed in RCW group size, clutch size or number of fledglings between territories burned in the dormant season verses growing season. Possible explanations for why differences in RCW reproduction were not seen include: 1) the relationship between RCWs and the understory, 2) variables influencing reproductive success, 3) confounding variables of the fire regime and 4) length of the study.

The understory is the most obvious stratum of the longleaf forest affected by fire and recent literature has highlighted the importance of groundcover in RCW management. Season of burn can affect the relative abundance of groundcover species and Mudder (2006) found growing season burn territories at Brosnan Forest had more wiregrass (*Aristida beyrichiana*), legumes, cane, other graminoids, and herbs. Furthermore, James et al. (1997) found wiregrass to be positively correlated with RCW fitness variables and explained 27% of the variability in the density of active territories. However, wiregrass may only positively affect RCWs at a certain threshold. Mudder (2006) reported wiregrass abundance of less than 5% cover in both season of burn treatments, whereas James et al. (1997) found wiregrass ranged from 0 – 78% cover on their study site. At this point in time the territories at Brosnan Forest may not have sufficient wiregrass abundance to affect RCW fitness regardless of the season of burn. Additionally, James et al. (1997) hypothesized that the fire regime, RCWs, and the understory are indirectly linked through the arthropod community. Taylor (2003) found a positive correlation between groundcover and arthropod biomass; however, this relationship does not seem to be affected by the season of burn (Hanula and Horn 2004). Additionally, Davenport et al. (2000) found understory height to be an important variable in determining RCW group fitness. Groups with poor fitness had territories with understory heights twice as tall as the habitat of groups with good fitness (Davenport et al. 2000). At Brosnan Forest, dormant season burn territories had significantly more woody stems and woody species ≥ 1 m tall (Mudder 2006), which should suggest decreased fitness for RCW groups under this burn treatment, but this study did not find a difference between treatments. The reason may be related to a confounding variable-time since the last burn. With each growing season post-burning, we would expect to see the understory vegetation increase in height until the next fire. Not surprisingly, Mudder (2006) found time since the last burn to be a significant co-variable in his analysis of vegetation structure. Therefore, the time since the last burn may be more important in determining understory height than the season of burn. Despite this co-variable, the short fire interval at Brosnan Forest allows only a small variation in the time since the last burn, which may not create understory heights different enough to affect RCW reproduction.

RCW reproductive fitness can be influenced by many factors, making differences based on season of burn difficult to detect. As previously discussed, group size is known to influence reproductive success. This study tested territories by burn treatment for differences in group size and found none, thus reducing any undue influence from this variable. Weather likely also influences reproductive efforts, although its impact has not been well studied in this species. Since years 2004 and 2005 were very different in temperature and precipitation, analyses were run with years separated to account for any yearly differences. This study did not account for several variables known to impact reproduction. Age of breeders can influence reproduction, with birds increasing reproductive fitness up to age five (Walters et al. 1992b). Although the birds at Brosnan Forest are individually marked and monitored yearly, breeder histories were not factored into the analyses of this research. Kleptoparasites and nest predators were present at Brosnan Forest and affected some nests monitored during the study. Several groups lost whole broods with nestling ages ranging from 7 to 20 days old, presumably to predators. Both rat snakes and southern flying squirrels were found in previously active RCW nests. Rates of nest predation were not tested for differences between treatments. Several habitat characteristics, such as fragmentation and number of suitable cavities per cluster, were not assessed in this study and may not have been similar between all territories. Notably, Jordan (2002) found some RCW groups at Brosnan Forest were aggregated based on rates of hatching failure and indicated habitat quality as a possible explanation. Additionally, the north side of the property has a denser population of RCW territories, which have a higher percentage of breeding groups than the south side and this could also be a reflection of differences in habitat quality. The south side has more loblolly pine plantations, less mature longleaf pine habitat and more food plots. The experiment was originally designed to evenly distribute treatments between the north and south side of the property; however, after modifications were made (see Methods) territories used in the analysis did not equally represent both sides of the property. Out of 17 growing season burn territories, eleven (65%) were in the north side of the forest, whereas only 7 (44%) of the 16 dormant season burn territories were in the north. This unintentional location bias may have introduced uncontrolled habitat quality effects on the results. Groups in growing season territories did have larger mean group size, which could have been the influence of location (groups in the north are larger), but the difference even with the bias was not statistically significant. Clutch size and number of fledglings were often slightly greater for groups in the dormant season burn territories, which suggest location did not play a part in these results. The number of suitable cavities was assumed equal among territories but was not evaluated. Brosnan Forest installs artificial cavity inserts in clusters that do not meet a minimum of four suitable cavities per cluster (U.S. Fish and Wildlife Service 2003). Nonetheless, some clusters may have been short on cavities or had pressure from cavity usurpers, which prevented or delayed reproduction.

The pre- and post-growing season burn analysis may have mitigated some of the influences of the confounding reproductive variables. Habitat quality, and perhaps to a lesser extent, breeder experience and number of cavities, remained relatively constant in these groups between pre- and post-treatment years. Results for the pre- and post-burn analysis were the same as the dormant verses growing season burn analyses, thus supporting the conclusion that RCW reproduction is not affected by season of burn in the short term, despite confounding variables.

Season is just one aspect of fire that influences how fire affects the landscape and RCWs, but other fire variables are involved which can be difficult to hold constant. Fire frequency is important to RCW management because of its influence on midstory structure. The U.S. Fish and Wildlife Service (2003) recommends a 1 to 5 year fire interval to maintain the desired habitat for RCWs. Although the burn regime at Brosnan Forest was within these guidelines, there was variation between territories in the time since the last burn. Fire intensity in the longleaf pine ecosystem is generally low due to a fire frequency that reduces fuel loads; however, daily weather conditions can change the amount of available fuels and affect fire behavior. Prescribed fires were not conducted at Brosnan Forest unless the forecast met certain criteria for temperature, humidity and winds; however, prescription conditions sometimes changed during a burn. Intensity is particularly important because of the potential damage hot fires can have on RCW nests and cavity trees. At Brosnan Forest, fire crews remove litter from the bases of active RCW trees before prescribed burning in order to reduce tree mortality. Despite these management actions, one nest tree was lost in 2005 when a fire grew in intensity and ignited the resin.

This experiment was originally designed as a four-year study with growing season burns introduced into a landscape with a traditionally dormant season burn regime. Growing season burns began in 2001 and data collection for this segment of the study occurred during the breeding season of 2004 and 2005. Information obtained from territories receiving dormant season burns reflect long-term conditions but growing season burn territories could only produce, at most, four years of post-treatment data. Some territories did not receive treatment until the second or third year of the experiment; therefore some data collection on RCW breeding only captured the first or second breeding season post-burn. The short interval between treatment and final data collection may not have been long enough to see a difference in RCW reproduction. Although results were not statistically significant, this study found larger group sizes in growing season burn treatments verses dormant season burn treatments, along with increased group size and number of fledglings after growing season fire when growing season burn territories were compared before and after treatment. It is possible these results capture an emerging trend of higher RCW fitness under growing season fire regimes, but further research on season of burn with long-term RCW monitoring is needed to determine if this trend becomes significant over time periods longer than four years.

Breeding Birds

This study found no differences in total breeding bird abundance between the season of burn treatments, which supports the findings of Engstrom et al. (1996). King et al. (1998) reported equivalent results for wintering birds in Georgia. Additionally, no difference in bird composition between burn treatments was seen at Brosnan Forest. Species richness was greater in growing season burn treatments, and this difference was statistically significant when years were blocked; however when data were analyzed by year, differences were not as pronounced (Table 3). The actual species difference between treatments in either year was less than 2 species, which may not be biologically significant.

Avian Conservation Values were higher in dormant season burn treatments (with years blocked). Higher ACV in dormant season burn treatments may be a reflection of the greater abundance of Bachman's sparrows. This species has a high PIF score (21 out of 25) and therefore its corresponding concern rating adds even greater weight to the ACV equation than a common species. Values were approximately 10 points different between treatments; however ACV fluctuated 135 points from 2004 to 2005. In light of these yearly differences, treatment differences may not be meaningful to overall avian conservation.

In Robbins and Myers (1992) review of seasonal effects of fire, they predicted growing season burns would be more favorable to open woodland and grassland bird species whereas dormant season burns would be more likely to attract birds associated with shrubs and understory hardwoods. This study found only five species distributed non-randomly with respect to season of burn treatment. Mourning doves, pine warblers and white-eyed vireos were all more abundant in growing season burns whereas Bachman's sparrows and indigo buntings were more abundant in dormant season prescribed burns. By Robbins and Myers' predictions, mourning doves, pine warblers and indigo buntings at Brosnan Forest seem to be correlated with the appropriate habitat characteristics. On the other hand, the behavior of Bachman's sparrows and white-eyed vireos seems to be counterintuitive. Other variables unaccounted for in this study may be influencing these species to favor one burn regime over the other.

It is somewhat surprising to see mourning doves show a preference for a season of burn treatment since they are an adaptable species capable of living in a wide range of habitats and nesting in various locations. Growing season fire treatments may be attracting these seedeaters by providing a more abundant food source. Mudder (2006) reported a greater abundance of grasses and other herbaceous vegetation in the growing season burns in Brosnan Forest and growing season fires can increase the flowering and fruiting of many plant species (Platt et al. 1988, Streng et al. 1993) so it is possible there was a greater seed crop in growing season treatments, although this was not evaluated. It is also plausible that mourning doves were selecting habitat characteristics unrelated to season of burn. Elmore et al. (2007) found mourning dove abundance was positively correlated with percentage of agricultural cover surrounding call-count routes. At Brosnan Forest, the presence of numerous food plots may have influenced mourning dove abundance more than burn treatment.

Wilson et al. (1995) found that pine warblers preferred burned treatments over unburned stands; however a season of fire study by Engstrom et al. (1996) found no difference in pine warbler abundance between burn treatments. This would suggest that pine warblers respond to the application of fire but not to the subtleties of season of fire. Since hardwood encroachment in the upper one-third of the pine canopy decreases habitat suitability for pine warblers (Schroeder 1982) and frequent fire, regardless of season, removes hardwood midstory (Waldrop et al. 1992), we should expect pine warbler response to support the findings of Wilson et al (1995) and Engstrom et al. (1996). However, in this study pine warblers were more abundant in the growing season burn treatments. One possible explanation for this finding may be the difference in canopy cover between territories. Mudder (2006) found growing season burn units in Brosnan Forest had greater pine basal area as well as total basal area, and speculated that these characteristics were unlikely to be from the burn treatment and might have been pre-existing site differences. Basal area has a positive, linear relationship with canopy cover in ponderosa pines (*P. ponderosa*) when canopy cover is below 60% (Mitchell and Popovich 1997), and if this relationship holds true for longleaf pine basal area, the abundance of pine warblers in growing season burn treatments may simply be a reflection of higher canopy cover.

White-eyed vireos were more abundant in growing season burn treatments, which concurs with Burger et al. (1998). They concluded that white-eyed vireos were more abundant in RCW managed sites (frequent growing season fires) compared to traditionally managed sites (longer dormant season fire return interval). Unfortunately the results of Burger et al. (1998) are confounded by fire frequency, which is an important aspect to a bird species that uses early successional (shrub-scrub) habitat. Based on the findings of Mudder (2006), which characterized the dormant season burn treatments of this study site as more abundant in woody vegetation, both above and below 1 m, we would expect to see greater abundance of white-eyed vireos in the dormant season burns. This study did not examine the effects of fire frequency or time since the last burn on this species but these variables may be influencing the results. Additionally, white-eyed vireos are associated with riparian areas, therefore distance to pocosins, creeks or other water sources is an important habitat feature (Krieger 1997, Allen et al. 2006) that this study did not address. Brosnan Forest has an extensive network of drainage ditches that could provide this species with patches of suitable habitat unrelated to burn treatment.

Previous studies on Bachman's sparrows show no significant difference in either sparrow abundance or reproduction based on season of burn treatments (Engstrom et al. 1996, Tucker et al. 2004, Tucker et al. 2006), but this study found Bachman's sparrows to be more abundant in dormant season burns. Wiregrass and other nonwoody species were more abundant in the understory of growing season burn treatments (Mudder 2006), which fits habitat descriptions for Bachman's sparrows by Dunning and Watts (1990), Krieger (1997), Plentovich et al. (1998), and Tucker et al. (2004). The vegetative differences between the treatments at Brosnan Forest would suggest greater abundance of

Bachman's sparrows in the growing season burn treatments. Also, studies have shown Bachman's sparrows are sensitive to fire frequency. Seaman and Krementz's (2000) work on Bachman's sparrows fitted with transmitters showed a complete dispersal from their territories immediately after summer burns with recolonization occurring 50 to 100 days post-fire. Additionally, Tucker et al. (2004) reported that Bachman sparrow densities peaked two years after a fire and then decreased quickly after three years post-fire. Clearly, the time since the last burn is important to this species and could influence the results of this study since this variable was not controlled. A post hoc review of the fire history for 2004/2005 showed a relatively even number of point counts between treatments were conducted within a 50-day post-fire period (where we might expect to see low sparrow abundance). Therefore, temporary bird dispersal should not be affecting the results. Reviewing the fire history also found twice as many growing season burn point counts were conducted in their second year after burning (which might represent peak sparrow abundance). If time since the last fire was showing an affect on the data, it would favor greater Bachman's sparrow abundance in the growing season burn treatments. Therefore, other unaccounted for variables must be involved. One potential explanation for observing greater sparrow abundance in the dormant season burn treatments is the patchy nature of fire. Hotter, growing season fires may burn more uniformly making the whole burn unit unsuitable until the vegetation recovers. Conversely, cooler dormant season fires may be incomplete and result in patches of suitable habitat which would cause less decline in sparrow abundance during the first post-fire breeding season.

Indigo buntings were found in greater abundance in dormant season burn treatments where a larger understory woody component was seen. This finding supports known information about indigo bunting habitat preference for shrubby, open forests (Ehrlich et al. 1988). It also supports the predictions of Robbins and Myers (1992), which stated dormant season burns would be preferable to shrub species over growing season burn treatments.

This study found little difference in bird guilds between burn treatments. The tree nesting guild, which was more abundant in growing season burns, was the only guild that showed differences between treatments. This result is most likely an indication of the greater total tree basal area in this treatment (Mudder 2006), which is probably unrelated to the season of fire. Of all the guilds, ground foraging and ground nesting guilds should have been the most affected by changes in the fire regime due to the direct impacts of fire on their food supply and nesting substrate. Ground nesting/foraging guilds were only marginally more abundant in the dormant season burns. Two ground foraging species (Bachman's sparrow and mourning dove), showed differences between burn treatments but did not favor the same treatment. The length of this study may not have been long enough to capture guild responses to shifts in food supplies or reproductive fitness over just a few breeding seasons. Additionally, the overall differences in vegetation found from introducing growing season burning to a traditionally dormant season fire landscape were not substantial enough to influence bird guilds. In other words, even though some vegetation characteristics were statistically different between treatments (Mudder 2006), it does not necessarily make them biologically significant to the bird community.

It is important to note that burn treatments for this study were conducted at the scale of a RCW territory, which was defined as habitat within a 0.8 km radius of a RCW cluster center, or approximately 200 ha; however, some of the territories were smaller due to overlapping habitat with neighboring groups. This scale may not have been appropriate for capturing the response to burn treatment for all bird species since some species may have home ranges larger than 200 ha. For example, red-tailed hawks have home ranges between 130 ha and 520 ha (Dewey and Arnold 2002) which means they may be using habitat outside the burn treatment of interest. Many bird species do not have known home ranges with which to compare to RCW territories but avian territory size is positively correlated with body weight (Schoener 1968). Therefore species similar in size or smaller than RCWs are likely to have home ranges comparable or smaller then 200 ha. Bachman’s sparrows, for example, have an average home range of 2.95 ha during the breeding season (Stober and Krementz 2006). Additionally, the RCW home range of 200 ha is based on year-round territory size; however, RCWs have been recorded foraging in smaller areas during the breeding season (Skorupa and McFarlane 1976, Bradshaw 1995, Jones and Hunt 1996). This reduction in home range during periods of the breeding season has been seen in other bird species as well (Odum and Kuenzler 1955, Schoener 1968) therefore, burn treatments conducted at the scale of RCW year-round territories is probably sufficient to cover most breeding bird home ranges in this study.

CHAPTER 5

CONCLUSIONS

Management Recommendations

A number of studies have reported that the presence of fire in the longleaf pine forest has a notable impact on the bird community. However, this study and others (Engstrom et al. 1996, King et al. 1998, White and Seginak 2000, Tucker et al. 2004) have found most species do not show a significant preference for a season of burn. Therefore, land managers should regard both dormant and growing season fires as appropriate tools for achieving land management goals. However, our knowledge about season of fire and the longleaf bird community is still evolving. Separating the effects of other fire variables, like frequency, from season of fire would enhance our understanding. Additionally, timing within season of burns may be important even if season of fire is not. Therefore, a cautious approach is needed for species of management concern, like RCWs and Bachman's sparrows. For example, land managers should follow U.S. Fish and Wildlife (2003) guidelines for protecting active red-cockaded trees to reduce the loss of cavities. Additionally, conducting fires with some patchiness will allow a mosaic of successional habitat to form and help birds displaced by fire, especially ground nesters like Bachman's sparrows, find suitable habitat. Using a combination of both dormant and growing season fires will allow more opportunities for land managers to burn and facilitate the short fire rotation needed to maintain the longleaf pine forest ecosystem.

Further Research

The limitations of this study indicate a need for further research. Short-term studies on fire regimes are inherently restricted in what they can tell us about long-term effects. Season of fire seems to have little influence on RCWs or the breeding birds in longleaf pine, but bird response to vegetation changes may take more time to manifest itself than this study allowed. For example, the relationship between season of fire, RCW fitness and wiregrass needs to be explored further to see if a growing season burn regime continues to increase wiregrass percent cover and in turn leads to increased RCW reproduction. Long-term research on the effects of season of fire on the breeding bird community is also needed, with careful consideration given to a study design that addresses some important covariables. Factors such as fire frequency and the time since the last burn must be accounted for. When possible, fire intensity should be held constant and patchiness of burning measured. Also, variations in the timing of burns within each season may be significant to birds and worth investigating. The designation of either "dormant" or "growing" season fire using traditional "cut-off dates" (in March/April and September/October) may not be capturing the ambiguity of these transitional months, a time when birds are also in transition from one cycle of their life to another. Lastly, short-term studies are often vexed with the problem of significant year effect due to changes in weather conditions from one year to the next. Although long-term studies alleviate this problem, they are not always economically and logistically feasible. Therefore it would be helpful to have a better understanding of how weather affects the bird community of the longleaf pine ecosystem, especially as it might apply to the recovery of the RCW.

APPENDIX

Appendix A: Number of birds observed by species and season of burn treatment from 2004 to 2005, along with habitat associations, foraging guilds and nesting guilds as defined for this study in Dorchester, South Carolina. (DSB = dormant season burn; GSB = growing season burn)

Species[a] (continued)	**Scientific Name[a]**	**Abundance DSB/ GSB**	**Habitat[bc]**	**Forage[bd]**	**Nest[be]**
Acadian flycatcher	*Empidonax virescens*	1/2	FI	A	T
American crow	*Corvus brachyrhynchos*	8/13	E	G	T
American robin	*Turdus migratorius*	0/4	M	G	T
Bachman's sparrow	*Aimophila aestivalis*	120/83	P	G	G
Black vulture	*Coragyps atratus*	0/2	E	O	T
Blue-gray gnatcatcher	*Polioptila caerulea*	131/177	M	F	T
Blue grosbeak	*Passerina caerulea*	29/40	OW	G	S
Blue jay	*Cyanocitta cristata*	34/44	OW	G	T
Brown-headed cowbird	*Molothrus ater*	63/65	E	G	T
Brown-headed nuthatch	*Sitta pusilla*	97/79	P	B	C
Brown thrasher	*Toxostoma rufum*	14/6	E	G	S
Carolina chickadee	*Poecile carolinensis*	30/33	FI	F	C
Carolina wren	*Thryothorus ludovicianus*	131/111	E	G	C
Chimney swift	*Chaetura pelagica*	1/0	OW	A	T
Chipping sparrow	*Spizella passerina*	66/63	OW	G	T
Common grackle	*Quiscalus quiscula*	5/3	OW	G	T
Common nighthawk	*Chordeiles minor*	7/3	M	A	G
Common yellowthroat	*Geothlypis trichas*	142/143	E	F	S
Downy woodpecker	*Picoides pubescens*	18/36	FI	B	C
Eastern bluebird	*Sialia sialis*	36/23	E	A	C
Eastern towhee	*Pipilo erythrophthalmus*	152/160	E	G	G
Eastern wood-pewee	*Contopus virens*	64/62	E	A	T
Field sparrow	*Spizella pusilla*	0/2	E	G	G
Fish crow	*Corvus ossifragus*	2/1	M	G	T

Species[a] (continued)	**Scientific Name[a]**	**Abundance DSB/ GSB**	**Habitat[bc]**	**Forage[bd]**	**Nest[be]**
Gray catbird	*Dumetella carolinensis*	20/14	E	G	S
Great-created flycatcher	*Myiarchus crinitus*	172/154	E	A	C
Hooded warbler	*Wilsonia citrina*	0/1	FI	F	S
Indigo bunting	*Passerina cyanea*	141/109	OW	F	S
Mourning dove	*Zenaida macroura*	30/64	E	G	T
Northern cardinal	*Cardinalis cardinalis*	76/104	E	G	S
Northern flicker	*Colaptes auratus*	8/11	OW	G	C
Northern mockingbird	*Mimus polyglottos*	4/3	E	G	S
Northern parula	*Parula americana*	9/4	FI	F	T
Orchard oriole	*Icterus spurius*	18/10	OW	F	T
Pileated woodpecker	*Dryocopus pileatus*	4/4	FI	B	C
Pine warbler	*Dendroica pinus*	113/190	P	B	T
Prairie warbler	*Dendroica discolor*	0/1	E	F	S
Red-bellied woodpecker	*Melanerpes carolinus*	49/55	FI	B	C
Red-cockaded woodpecker	*Picoides borealis*	56/56	P	B	C
Red-eyed vireo	*Vireo olivaceus*	3/5	FI	F	S
Red-headed woodpecker	*Melanerpes erythrocephalus*	31/20	OW	A	C
Red-shouldered hawk	*Buteo lineatus*	2/0	FI	O	T
Red-tailed hawk	*Buteo jamaicensis*	1/2	M	O	T
Ruby-throated hummingbird	*Archilochus colubris*	0/1	OW	A	T
Summer tanager	*Piranga rubra*	64/72	FI	F	T
Tufted titmouse	*Baeolophus bicolor*	78/79	FI	F	C
Turkey vulture	*Cathartes aura*	2/1	E	O	T
White-breasted nuthatch	*Sitta carolinensis*	41/41	OW	B	C
White-eyed vireo	*Vireo griseus*	18/48	M	F	S
Wood duck	*Aix sponsa*	0/2	FI	O	C
Wood thrush	*Hylocichla mustelina*	2/1	FI	G	T

Species[a] (continued)	**Scientific Name[a]**	**Abundance DSB/ GSB**	**Habitat[bc]**	**Forage[bd]**	**Nest[be]**
Yellow-breasted chat	*Icteria virens*	35/57	E	F	S
Yellow-billed cuckoo	*Coccyzus americanus*	3/6	OW	F	T
Yellow-throated vireo	*Vireo flavifrons*	4/8	E	F	T
Yellow-throated warbler	*Dendroica dominica*	5/2	M	B	T
Total individuals		2140/2280			
Total species richness		48/53			

[a] Common and scientific names of bird species from the American Ornithologists' Union Check-list of North American Birds, Seventh Edition.

[b] Primary source for classifications was Ehrlich et al. 1988; additional clarifications made with Sibley 2000 and Elphick et al. 2001

[c] Habitat Types: FI= Forest Interior, E=Edge, OW=Open Woodland, M= Mixed, P= Pine savanna

[d] Forage Types: G=Ground, A=Aerial, B=Bole, F=Foliage, O=Other

[e] Nest Types: G=Ground, T=Tree, C=Cavity, S=Shrub

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