AN EVALUATION OF RED-COCKADED WOODPECKER RESTORATION EFFORTS IN THE OCALA NATIONAL FOREST

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my fiancé Ben

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TABLE OF CONTENTS

APPENDIX

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
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The relationship between red-cockaded woodpeckers (*Picoides borealis*) and their habitat in sandhill of Ocala National Forest (ONF) is not well understood. This unique region is the largest continuous forest of sand pine (*Pinus clausa*) scrub ecosystem with islands of longleaf pine (*P. palustris*) wiregrass (*Aristida stricta*) sandhills. While red-cockaded woodpeckers (RCWs) avoid sand pines, the longleaf pine habitat is ideal for RCWs when managed properly. This study indicated a positive response in woodpecker reproduction from management implementations such as 1-2 year rotation fire regime to minimize the midstory density, annual translocation of single and paired birds to help bolster small populations, continuous treatment of hardwoods through mechanical and chemical applications to reduce midstory heights and installing artificial cavities away from scrub ecotones but close to other establish RCWs. The most successful translocations were those conducted with paired, unrelated birds in close proximity to resident RCWs. Future prospects include expanding the ONF RCW population westward through habitat restoration and translocations. The expansion area has vegetation conditions very different from those that occur where the current RCW

populations exist in ONF, so other national forests in Florida were explored through Geographical Information System data layers to find suitable and similar habitat that could estimate the carrying capacity of ONF's future expansion. I estimated this region of ONF could sustain 32 clusters if the habitat was managed properly. Results of this research should aid in prioritizing the type and location of future management actions that will most benefit RCWs in ONF.

CHAPTER 1
GENERAL INTRODUCTION

The Ocala National Forest (ONF) has over 154,000 hectares (ha) of forested land. The diversity of the forest can be seen in the many ecosystems ranging from sand pine scrub to longleaf pine sandhill, natural flatwoods, live oak hammocks, and swamps (Whitney et al. 2004). These ecosystems contain a variety of animals including several threatened and endangered species. One key species is the red-cockaded woodpecker (RCW) which lives in longleaf pine ecosystems. Currently, there are two separate healthy populations of RCWs in well maintained ONF habitats. A third vacant area once served as habitat for RCWs but is now unsuitable and has not had a potential breeding group since 1989. In addition, nearby lands managed by other agencies has the potential to be restored for RCW habitat.

Though there are many species that could be considered when designing restoration plans, the RCWs can be viewed as an umbrella species. Animals that would benefit from efforts to restore habitat for RCWs include southeastern American kestrels (*Falco sparverius paulus*) (Gault et al. 2004), Bachman's sparrows (*Aimophila aestivalis)* (Conner et al. 2002), pocket gophers *(Thomomys talpoides),* Sherman's fox squirrel (*Sciurus niger shermani*) and gopher tortoises (*Gopherus polyphemus)* (Myers and Ewel 1990). Restoring habitat for RCWs could create large areas that also provide improved habitat for these other species.

The long term success of RCW clusters is dependent upon many variables including the distance to other clusters. The farther apart clusters are from each other, the less stable the population is (Letcher et al. 1998, Schiegg et al. 2002a). With several close clusters to emigrate to, the birds have the ability to search for new vacancies. If other clusters are too far, then the clusters are at risk of becoming inactive (Engstrom and Mikusinski 1998). Additionally, translocating individual or paired birds from other public lands to vacant clusters in ONF can aid in the long term success of the species in ONF but is an expensive alternative for bolstering isolated populations.

Red-cockaded woodpeckers face many threats that may lead to a decline in their numbers. For instance, cavities can be usurped by other animals such as flying squirrels (*Glaucomys sabrinus)*, snakes, eleven species of birds, several types of bees and the broad-headed skink (*Eumeces laticeps)* (Whitney et al. 2004). A southern pine beetle (*Dendroctonus frontalis*) epidemic can have catastrophic damage on an entire forest including wiping out half the nesting trees as seen on the Sam Houston National Forest (NF) (Conner et al. 1991). In order to secure RCW populations and their habitats, these threats should be assessed and managed whenever possible.

Preferred Habitat

Red-cockaded woodpeckers prefer pine stands that have park-like characteristics. These include older slash or longleaf pine stands of at least 60 years of age that have trees with heart rot fungus, understory with little or no hardwood encroachment, and that experience frequent low intensity fires. Fire is an essential component because it enhances the reproduction, growth, and maintenance of longleaf pine and native ground cover species while reducing hardwoods in the understory (Saenz et al. 2001). The condition of the ground cover influences the abundance of prey (arthropods) for RCWs found on pine trees (Hanula and Franzreb 1998).

These birds are unique in a sense that they are the only woodpeckers in Florida that nest in live trees (Whitney et al. 2004). As trees age, they may eventually become exposed to heart rot which softens and decays the center of the tree. This makes excavating a cavity easier for the birds (Hooper et al. 1991). Cavities can take six months to several years to complete (Whitney et al. 2004). Artificial cavities can aid RCWs by reducing time spent excavating new cavities and increasing time spent foraging for food. Franzreb (2006) suggests the foraging area for RCW clusters are around 60 ha. Their diet includes spiders, ants, roaches, centipedes, and insect eggs that they find by foraging on tree bark (Whitney et al. 2004).

The United States Fish and Wildlife Service (USFWS) wrote the second recovery plan for RCWs in 1985 which stated, "The survival of the red-cockaded woodpecker ultimately depends on halting the loss of nesting habitat and providing adequate acreage in old-growth pines in perpetuity. Merely protecting existing clusters will delay extinction but not prevent it. A continuing supply of old- growth habitats is required to replace clusters lost or abandoned and to provide for population expansion" (USFWS 1985). One recommendation to achieve this goal is to use a combination of site analysis, historic background from the project site, and information from nearby reference sites (Walker and Silletti 2006). Examples of current restoration treatments are mowing, chopping, thinning, installing artificial cavity inserts, planting pine seedlings, seeding groundcover, chemical applications, and most importantly, prescribed burning. The most common treatment with longleaf pine restoration is the removal of hardwoods. Hardwood reduction can be accomplished with repeated fire and mechanical treatments such as mowing or roller chopping, a chemical application such as herbicides, or the combination of all three. Restoration has to be considered at multiple levels in the forest, including the canopy of pines and the ground level vegetation (Walker and Silletti 2006).

Study Area Description

This study was conducted in Ocala National Forest which is located in Lake, Marion and Putman counties in central Florida. The ONF has two distinct sub-populations of red-cockaded woodpeckers (Study areas B and C, Figure 1-1) and is planning to establish another RCW population in a third region (Study area A, Figure 1-1). The United States Forest Service's (USFS) Global Positioning System (GPS) database shows historical RCW nesting trees in study area A. Unfortunately, there has not been an active potential breeding group there since 1989 and reasons for abandonment are uncertain. Generally, reasons for RCW abandonment are harvesting of old trees, years of fire suppression, failure to establish longleaf pine seedlings, and converting native species of pine to more fast-growing timber. Stand records in ONF show historical RCW stands were replanted with mostly longleaf pines and some areas with slash pines in the 1920s. Fire suppression and over harvesting are likely causes of abandonment in the western region of Ocala National Forest.

Study area A (Figure 1-1) covers roughly 20,500 ha and is located on the west side of the ONF. It is located west of Highway 314A and covers land both north and south of State Road 40. Figure 1-1 shows the location of historical trees with black dots in study area A. Study area B contains active red-cockaded woodpecker clusters (black dots) in approximately 6,200 ha of forested sandhills located in the northern region of the forest around Lake Kerr, also known as Riverside Island. The southernmost active clusters are in approximately 5,300 ha of forested sandhills knows as the Paisley Woods (study area C). According to the Ocala National Forest's daily records, this forest receives about 155 ±32 centimeters (cm) ($\bar{X}$ ± SD) of rainfall annually and about 40% of that falls during the summer months of May, June, and July (60 ± 17 cm). These are the months when RCWs most commonly raise young in nest trees. The forest's daily temperature averaged between 59 ± 1 Fahrenheit (ºF) and 84 ± ºF but during the summer months averaged between 68 ± 1 ºF and 92 ± 1 ºF.

Objectives

The goal of this multi-faceted study was to assess the efficacy of past management actions and anticipated future RCW restoration regimes for the ONF. I determined which habitat features and management actions have the greatest effect on RCW nest success. In addition, I investigated data collected over a ten year period in study areas B and C to assess the benefits of translocations. I also evaluated the potential of the western area to serve as additional habitat for this endangered species. The models I developed help identify the most beneficial restoration regime for study area A to create a third sub-population and build a sustainable population of RCWs. Results of this study have the potential to inform future management decisions on ONF, by investigating which management actions have had the greatest positive influence on RCW productivity the past 10 years, and identifying locations most suitable for RCWs in the region of the ONF that RCWs have abandoned. This research has the potential to aid in prioritizing the type and location of future management actions that will most benefit RCWs.

There were three specific research questions: (1) Which habitat characteristics and management activities have historically provided high habitat quality for RCWs in the Ocala National Forest? (2) How beneficial have the translocations of RCWs in Ocala National Forest been to the resident populations? (3) Can information on RCW habitat selection from other National Forests in Florida be used to prioritize the location of restoration efforts in Ocala National Forest?

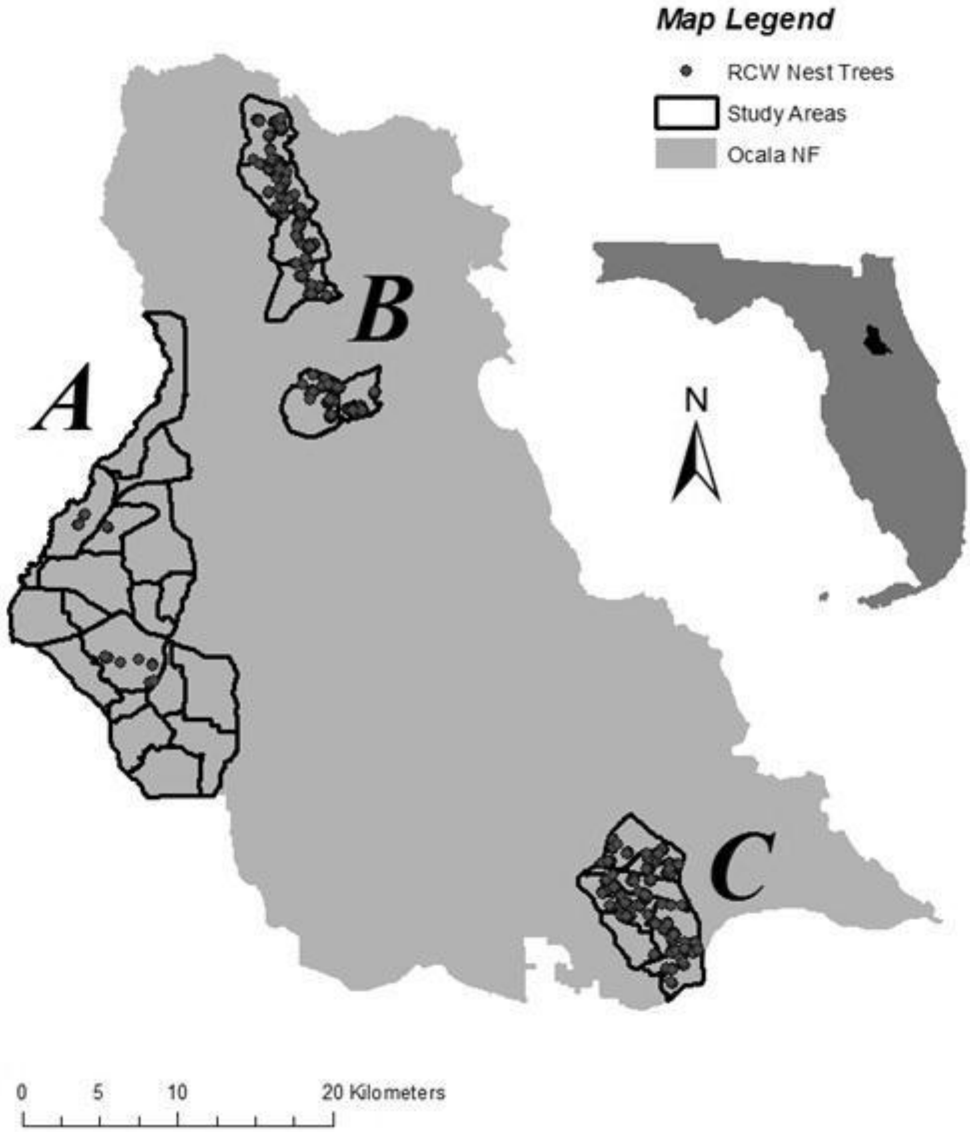


Figure 1-1. Study areas within the Ocala National Forest include the historic RCW clusters in Church Lake region (study area A) on the west side of the forest, current RCW clusters in Riverside Island (study area B) located in the north and current RCW clusters located in Paisley Woods in the south (study area C).

CHAPTER 2
SITE SELECTION AND REPRODUCTIVE SUCCESS OF RED-COCKADED WOODPECKERS IN OCALA NATIONAL FOREST

Introduction

The red-cockaded woodpecker's (RCW) range currently spans from southeast Oklahoma to Virginia and from the Gulf Coast of Texas to South Florida (Ligon et al. 1986) with isolated pockets of potential breeding groups (PBGs). In 2000, an estimated 14,000 birds, or about 5,600 groups, occurred across this range, which is approximately 3% of their original abundance (Chadwick 2004). The recovery plan provides recommendations on habitat management, but this information is based on range-wide averages across the 11 states in the Southeast (USFWS 1985). At the edge of the species range, birds may behave differently, and with global climate change these individuals at the edge of the range are of vital importance due to behavioral changes that could affect fledgling success (Schiegg et al. 2002b). This study provides insight into the biology of RCW at the edge of the species range, in Ocala National Forest (ONF).

The recovery plan is an excellent source for habitat management, but this information is not tailored to the Ocala National Forest. I undertook this study to determine which habitat characteristics and management procedures contribute most to woodpecker productivity in ONF. In particular, I evaluated landscape-scale features, stand-scale features, management practices, and spatial characteristics affecting the social behavior and reproductive success of the birds.

I developed two objectives to determine which factors were most influential in determining the productivity of red-cockaded woodpeckers in the ONF.

- Objective 1: To determine which vegetation conditions provide high quality habitat for red-cockaded woodpeckers in the Ocala National Forest during 2010.
- Objective 2: To Evaluate Relationships Between Various Habitat Conditions Available on Record Over the Past Ten Years and RCW Productivity.

Methods

Objective 1: To Determine Which Vegetation Conditions Provide High Quality Habitat for Red-Cockaded Woodpeckers in the Ocala National Forest During 2010

Ninety-one active and inactive clusters were recorded on the Ocala National Forest in 2010. In ArcMAP (v 9.3.1, 2009), I drew a buffer with a radius of 0.4 kilometers (km) around the centroid of each of these clusters to create an area totaling approximately 50 hectares (ha) to characterize foraging habitat for each cluster (USFWS 1985). For each of the active clusters, the nest tree was considered the centroid point. For the inactive clusters, the centroid points were centered on either a previously active tree or if there were no previously active trees, a suitable tree with a cavity was selected at random. Buffers were uniquely identified by forest compartment and cluster number (i.e., 260-1). I selected 48 of these clusters with a stratified random selection to capture a wide range in RCW productivity and fire frequency (described below).

Historical productivity was estimated for each of the 91 clusters by calculating the number of fledglings recorded divided by the number of years a cluster was monitored. I used data for each of the seven available years between 2001 and 2010 (2006, 2008, and 2009 were excluded due to missing data). All clusters with a score of zero for fledglings received a “low” ranking and the remaining were divided in half, giving the higher scores “high” ranks. This provided a ranking of “high”, “medium” or “low” historical productivity for each cluster.

The fire frequency inside each of the 91 buffers over the last ten years was determined in ArcMAP by drawing polygons around all fires every year from 1990 to 2009. Using the “intersect” function in Hawth’s Analysis Tools (v 3.27, 2007), I calculated the proportion of each buffer burned in a given year. If ≥30% of a buffer was burned in a given year, regardless of season, I considered the buffer to be burned that year. Buffers were placed into three categories: buffer burned ≤3 times, buffer burned 4 times, and buffer burned ≥5 times.

After RCW productivity and fire frequency was calculated, I selected 48 clusters, 16 from each of the high, medium, and low historical productivity categories and from 12 to 21 clusters in each fire frequency category so that each productivity x fire frequency combination was represented by 2 to 8 clusters. Some categories were limited in the number of clusters and therefore all available clusters were used. Other categories had an abundance of clusters to choose from so a random selection was drawn. This stratified random selection ensured that I evaluated clusters subjected to a wide range of fire frequencies, and that experienced a wide range in productivity.

Stand-scale features

I measured 10 stand-scale habitat features to characterize vegetation for each cluster. Using the random point generator in Hawth’s Analysis Tools for ArcMAP, I created 10 random points within each buffer with ≥15 m spacing between points. Points were loaded into a Trimble Geo XT 2008 so I could locate each Global Positioning System (GPS) coordinate to 3 meters (m) accuracy in the field. At each point I measured stand level variables to represent the over-story, mid-story, and ground cover characteristics of the forest stand.

For the over-story data, I used a variable radius plot with an imperial prism with basal factor 10 (10 $feet^2$/acre). For each tree, I recorded DBH to 0.25 centimeters (cm) accuracy and species. Trees per acre were derived for any *Pinus elliottii* and *P. palustris* trees that were ≥35 cm.

Mid-story vegetation data were collected using fixed area plots of 1/125 ha (5 m radius). All stems 5–12 cm in diameter were counted by species while any oak stems <5 cm were ignored since their density changes from year to year due to frequent fire regimes. Oak basal area was combined from the overstory and understory data to give a total basal area for oak species. Each buffer's mid-story was categorized as dominated by either oak or pine or neither, based on the findings using fixed area plots (FAP).

Finally, ground cover was measured using 1 m x 1 m quadrats at locations 5 m to the north, south, east, and west of the central point and then averaged. In each quadrat I recorded percent cover of six ground cover categories: wiregrass, herbaceous, shrubs <1.5 m in height, shrubs >1.5 m in height, pine litter, and bare ground.

Landscape-scale features

I measured three landscape-scale variables: patch size, proportion of interior foraging buffer vs edge, and heterogeneity of the vegetative community in the foraging buffer. Patch size was calculated based on the area of each isolated sandhill island within the sand pine scrub ecosystem using the United States Forest Service (USFS) Geographical Information System (GIS) layer, "Ecosystems." Next, I created a 0.4 km ecotone buffer along the inside edge of each patch's ecotone to differentiate between interior (>0.4 km from scrub edge) and edge (≤0.4 km from scrub edge) (Figure 2-1). Within each RCW cluster's buffer, I used the "Intersect" tool and "Calculate Geometry" in ArcMAP to calculate the proportion of each cluster buffer’s interior vs edge. To evaluate the heterogeneity of the vegetative community around each cluster, I “Intersected” the foraging buffers with the ecosystem layer to determine the proportion of acres of non-sandhill habitat to the total acres.

Management practices

I assessed five variables pertaining to habitat management practices near each cluster: number of prescribed fires during the previous 10 years, number of years since the last prescribed fire, number of years since a mowing or oak removal, number of artificial cavities installed, and the ratio of artificial cavities to natural cavities. The USFS prescribed fire history is collected in polygon form for each fire. To count the number of fires in each cluster’s foraging area buffer over the last ten years with ≥ 30% of a buffer burned, I used Hawth’s Analysis Tools “Intersect” to combine each fire polygon with the buffer polygon and used excel to calculate whether ≥30% or 15 ha was burned in each event. In addition, I used these data to find the year the buffer was last burned. Forest Service records were used to determine the year of the last mow or hardwood removal treatment. Hardwood treatment included mechanical removal of hardwoods using chainsaws, roller chopping or herbicide application. The artificial cavity data are maintained in the attributes table of the USFS RCW layer in ArcMAP. The count and proportion of cavities was calculated in excel.

Spatial characteristics affecting social behavior

I determined four variables pertinent to the spatial characteristics affecting the social behavior of the birds: distance to the nearest active or inactive cluster, number of active or inactive clusters with overlapping foraging areas, percent of foraging area overlapped by others, and occurrence of translocation. To find the distance to the nearest neighbor, I used centroids and Hawth's Analysis Tools "nearest neighbor analyst." Next, using the "Polygon in Polygon Analysis" feature in Hawth's Analysis Tools, I counted the number of overlapping buffers and proportion of overlap for each buffer. Finally, I counted the presence or absence of the translocations in new clusters during the winter before the 2010 breeding season. Translocation is an opportunity to bolster small populations by relocating surplus birds from large populations to smaller declining population.

Productivity

The 2010 breeding status and productivity of RCWs were used as the response variables in logistic regression. I analyzed the data three separate ways: (1) to identify variables differentiating clusters with potential breeding groups from those without; (2) to identify variables that differentiated successful clusters from unsuccessful clusters; and (3) to identify variables that differentiated clusters that produced one fledgling from those that produced two. The first assessment identified variables most strongly associated with the presence or absence of potential breeding groups in the 48 selected clusters. The second assessment included only the 35 clusters with potential breeding groups, and identified variables most strongly associated with the presence or absence of fledglings. The final assessment included data from only those 19 clusters that were successful in 2010 (successful clusters are those that produced an offspring that survived at least 26 days). The response variable for the third assessment, the fledgling count, showed a 1 or 2 representing the number of successful fledglings in the nesting season.

Logistic regression

All data were analyzed with SAS (v 9.2, 2008). I conducted logistic regression using the variable selection technique recommended by Hosmer and Lemeshow (2000). I first noted all variables with p-values < 0.25 when examined in a univariate context (each variable was independently regressed on the dependent variable). Variables with p-values < 0.25 were considered candidates for model inclusion. Second, to eliminate the possibility of including redundant metrics in the same model, I determined which variables were highly correlated (Pearson's correlation ≥0.60) and therefore should not occur in the same model. Third I performed a backward selection in logistic regression with all remaining variables until the model contained only variables with P≤0.10. Additionally, I evaluated the goodness of fit of the final model using Hosmer and Lemshow (2000) goodness-of-fit tests, and Cox and Snell pseudo R square index to assess model fit (Cox and Snell 1989).

Objective 2: To Evaluate Relationships between Various Habitat Conditions Available on Record Over the Past Ten Years and RCW Productivity

The second part of the analysis used the data collected over the past 10 years among all clusters (*n* = 91). The stand scale features were not available over the ten year period and were therefore not considered for this analysis. The landscape variables were the same as described for the analysis of 2010 data: patch size, proportion of foraging buffer within 400 m of the edge of the ecosystem, and the proportion of the buffer containing ecosystems other than sandhills (heterogeneity of the vegetative community). This information was derived from GIS polygons created by the Forest Service GIS Specialist, Kathy Bronson. Management practices were also similar to those described in the analysis of 2010 data: the number of years since last burn in

≥30% of each 0.4 km buffer surrounding a cluster and the number of times ≥30% of a buffer was burned in the previous 10 years. Spatial characteristics affecting social behavior were the same as the analysis of 2010 data: distance in meters to the nearest cluster (active or inactive), number of buffers within 0.4 km of each cluster, the percent of each buffer that overlapped with other buffers, the occurrence of a translocation, and the count of translocations per cluster per year. In addition, I assessed annual and summer rainfall. Precipitation data were gathered on a daily basis at a weather station at the Forest Service central location, from which I obtained measurements from January 2001 to December 2010. I calculated two precipitation characteristics: average daily precipitation (a single average was used to represent each year) and average daily precipitation during the breeding season (May – July) (again, a single average was used to represent each breeding season).

The breeding status and productivity of RCWs from 2001 to 2010 (2006, 2007, and 2009 were unavailable) were used as the response variable in the generalized linear mixed models (Glimmix). As described in objective one, I analyzed the data three separate ways: (1) to identify variables differentiating clusters with potential breeding groups from those without; (2) to identify variables that differentiated successful clusters from unsuccessful clusters; and (3) to identify variables that differentiated clusters that produced one fledgling from those that produced more than one.

All data were analyzed with SAS (v 9.2, 2008). I conducted the analysis with Glimmix using the variable selection technique recommended by the College of Agriculture and Life Sciences (CALS) statistician James Colee. The Glimmix procedure uses the Kenward-Roger Degree of Freedom method which accounts for repeated measures. I first noted all variables with p-values < 0.25 when examined in a univariate context (each variable was independently regressed on the dependent variable). Variables with p-values < 0.25 were considered candidates for model inclusion. Second, I reviewed continuous variables with large ranges with lsmeans to find ways of organizing data into a small number of biologically meaningful categories. Third, to eliminate the possibility of including redundant metrics in the same model, I determined which variables were highly correlated (Pearson's correlation ≥0.60) and therefore should not occur in the same model. Finally, I performed a manual backward selection in Glimmix with all remaining variables by entering all variables and removing the variable with the highest p-value and repeating until all remaining variables had $P \leq 0.10$.

Results

Objective 1: To Determine Which Vegetation Conditions Provide High Quality Habitat for Red-Cockaded Woodpeckers in the Ocala National Forest During 2010

In the first assessment, differentiating clusters with potential breeding groups from clusters without potential breeding groups ($n = 48$), the Hosmer and Lemeshow (2000) goodness of fit test indicated adequate model fit ($\chi^2 = 6.39$, df = 8, $P = 0.6032$) and the Cox and Snell $R^2 = 0.36$. There were three features that were most useful in the final model: hardwood basal area (ft^2/ac) ($P = 0.0026$), % cover of bareground ($P = 0.0578$), and % cover of shrubs >1.5 m ($P = 0.0119$), (Table 2-1). Results indicate that higher hardwood basal area and % bareground were associated with a lower likelihood of having an active cluster. On the other hand, higher % cover of shrubs >1.5 m was associated with a higher likelihood of having an active cluster.

In the second assessment ($n = 35$), no variables were able to differentiate successful clusters from unsuccessful clusters.

The third assessment, differentiating clusters with one fledgling from clusters with two or more fledglings (*n = 19*), the Hosmer and Lemeshow (2000) goodness of fit test indicated the model fit the data (χ^2 = 9.06, df = 8, *P* = 0.3375) and the Cox and Snell R^2 = 0.45. There were two features in the final model: % cover of shrubs <1.5 m (*P* = 0.0912) and distance to nearest neighbor (*P* = 0.0340) (Table 2-1). Farther distances from the nearest cluster were associated with higher likelihoods of a cluster producing more than one fledgling. Also, higher % cover of shrubs <1.5 m were associated with a greater likelihood that a cluster will produce more than one fledgling.

Objective 2: To Evaluate Relationships between Various Habitat Conditions Available on Record Over the Past Ten Years and RCW Productivity

The Pearson correlation test found strong correlations between proportion of non-sandhill ecosystems (non-sandhill) and proportion of interior sandhill ecosystems (interior). The proportion of interior was selected for model inclusion due to its known biological relevance to RCW reproduction (Carl Petrick, personal communication).

In the first assessment, differentiating clusters with potential breeding groups from those without (*n* = 91), the close proximity of the generalized chi-square statistic to 1(χ^2 = 1.02) indicates the variability in the data was properly modeled. The model found four features helpful in differentiating these clusters: interior (*P* = 0.0641), annual rainfall (*P* = 0.0138), number of prescribed fires (*P* = 0.0151), and number of translocations (*P* = 0.0573) (Table 2-2). Results show that increasing the proportion of interior habitat and increasing the number of prescribed fires over a ten year period was associated with an increased likelihood of having a PBG. For every 10% increase in the proportion of the buffer that was interior rather than edge, there was a 9% increase in the odds of having a PBG. Buffers where prescribed fire was applied 4-5 times per decade were almost twice as likely to have a PBG than those burned only 1-3 times per decade, and were more than twice as likely to have a PBG when compared to those with more than 6 prescribed fires per decade. The model also showed that high annual rainfall was associated with a decreased likelihood of finding a PBG. Lastly, the odds of having a PBG were five times greater when a single bird was translocated to a resident bird than when paired birds were translocated. There was no significant difference in the likelihood of having a PBG in areas where a single bird was released and areas were no translocations occurred.

The second assessment, comparing clusters successful at raising fledglings with clusters that failed to produce fledglings (*n* = 66), the close proximity of the generalized chi-square statistic to 1(χ^2 = 1.02) indicates the variability in the data was properly modeled. Two features were significant in the final model: interior (*P* = 0.0062) and number of years since the last prescribed hardwood treatment (*P* = 0.0751) (Table 2-2). Results show increasing the proportion of interior habitat and the number of years since the last hardwood treatment was associated with an increased likelihood of having a successful PBG. For every 10% increase in the proportion of the buffer that was interior rather than edge, there was a 14% increase in the odds of having a successful PBG. The trend for hardwood treatment is small: the relative odds of a potential breeding group being successful increased by only 6% with every year since the last hardwood treatment. The final assessment, differentiating between clusters with 1 fledgling and clusters with more than 1 fledgling (*n* = 53), found no significant variables.

Discussion

Objective 1: To Determine Which Vegetation Conditions Provide High Quality Habitat for Red-Cockaded Woodpeckers in the Ocala National Forest During 2010

The features that differentiated clusters with potential breeding groups from those that were inactive were hardwood basal area, % cover of bare ground and % cover of shrubs >1.5 m. Increasing the % cover of bare ground and hardwood basal area was associated with decreased odds of having a potential breeding group in a cluster. This corresponds to the well-known relationships between RCW success and frequent fire (Ligon 1970, Robbins and Myers 1992, Costa 1995). Frequent fires help to develop native groundcover, create open canopies, reduce midstory oak and other hardwood species, and promote longleaf pine dominated overstory (Allen et al. 2006). High percentage of bare ground can disconnect the ground fuels and cause a mosaic burn pattern, leaving opportunity for hardwoods to encroach. During fire suppression, plant succession will allow hardwoods to choke out longleaf and other groundcover species (Loeb et al. 1992, James et al. 1997). The shorter the interval between fires, the less chance hardwoods have to reach a size and density that becomes problematic to RCWs. The RCW requires a low density of trees in the mid story (Loeb et al. 1992), which provides the birds the ability to protect their cavities from predators by giving them a clear view of potential danger. On the other hand, my result indicating that increasing the percent cover of shrubs >1.5 m was associated with an increase in the odds of having a potential breeding group is in congruence with some but not all prior studies. Loeb et al. (1992) found midstory height was higher among active clusters vs inactive clusters while basal area and stem/ac were both lower. The recovery plan states that nesting cavities should have about 15 m of clearance around each cavity tree and that midstory heights should stay below 4 m (USFWS 1985). Clusters in ONF had a very limited range in percent cover of shrubs >1.5 m: 0 – 20% (Appendix A). Therefore, my result may illustrate how birds may tolerate taller shrubs but only at low stem densities. Another study found that hardwood midstory heights greater than 4 m had a profound negative effect on use by RCWs (Walters et al. 2002). My analysis only reviewed shrubs in the ground cover layer, most of the ground cover species in ONF do not grow in excess of 2-4 m, and I did not include trees with diameters over 5 cm as they would be captured in the midstory layer. Therefore, I cannot make inferences about the effects of the height of the midstory on RCWs in ONF.

The features that differentiated those clusters that were successful at producing two RCW fledglings from those that produced only one were distance to nearest neighbor and % cover of shrubs <1.5 m. Increasing the distance to the nearest neighbor was associated with an increase in the odds of having two rather than one fledgling. This suggests that competition may affect the success of the survival of offspring. Ligon (1970) found similar results while extensively monitoring several pairs of RCWs near Gainesville, Florida. In addition, this could suggest that more successful clusters have a larger home range size as well. A similar study found that successful RCW groups used larger home ranges than unsuccessful groups (Hardesty et al. 1997). Increasing the percent cover of shrubs < 1.5 m also was associated with increased odds of having two rather than one fledgling. Other studies have reported similar patterns. Davenport et al. (2000) found highest RCW productivity in clusters with understory below 1.89 m and lowest productivity in clusters with understory above 3.26 m. Hardesty et al. (1997) also found that smaller and shorter hardwoods increased the success rate of groups.

However, another study found hardwood encroachment lead to higher fledgling predation (Lennartz and Heckel 1987). Further research should be conducted on how height and density of oak species in the groundcover layer effect the habitat RCWs select or avoid.

Objective 2: To Evaluate Relationships between Various Habitat Conditions Available on Record Over the Past Ten Years and RCW Productivity

The features that differentiated clusters with potential breeding groups from those that were inactive over the last ten years were the proportion of interior habitat, annual rainfall, number of prescribed fires over the past ten years and the number of birds translocated to a cluster per year. Increased proportion of interior habitat per cluster was associated with an increase in the odds of having a potential breeding group. Increasing the amount of annual rainfall was associated with a decrease in the odds of having a potential breeding group. The translocation of 1 bird per year was associated with an increase in the likelihood of having a potential breeding group compared to translocating 2 birds per year but was similar to not translocating at all. Prescribed fires had a positive impact; an increase in the number of fires within the past decade was associated with an increase in the odds of having a potential breeding group.

The landscape variable that was found to be significant was proportion of interior. Results indicate that PBGs were associated with sandhill habitat devoid of sand pine scrub. This is likely because sandhills typically have an open canopy with widely spaced pines and little to no midstory, whereas sand pine scrub has closed canopy and dense midstory, making it unsuitable habitat for nesting or foraging (Myers and Ewel 1990, Walters et al. 2002). The selection of interior habitat over edge indicates that birds preferred sites where foraging buffers would contain no scrub. Eglin Air Force base has seen similar patterns in RCW territories that are located on the edge of habitat boundaries; these edge clusters switch more frequently between status of active and inactive than do those clusters with several groups surrounding them and away from the edge (2010, personal communication with Carl Petrick). Similarly, active clusters were surrounded by less total edge habitat and more uniform forest cover than inactive clusters in the Red Hills RCW population located on private land in north Florida and south Georgia (Cox 2001).

The environmental variable that was found to be significant was annual rainfall. Heavy rainfall is detrimental to productivity because it restricts the parents from flight and reduces the amount of feeding time, which is especially detrimental in the month of May when rainfall can have the most negative impact on parents with young (Conner et al. 2005). In Arkansas, helpers (other RCWs) were able to offset this negative impact of rainfall on nestlings (Neal et al. 1993), but comparable data are not available to examine these social patterns in more detail on the ONF. Other forests in Florida have seen similar declines in fledge success during summers with heavy rain such as the Osceola National Forest in Lake City (2011, personal communication with Sarah Lauerman). It is worth noting that the trend I found may not be biologically meaningful because precipitation data was not available from multiple locations throughout each of the study areas.

The management variable that was found to be significant was the number of times a foraging buffer was burned over the last ten years. I found that burning areas 4-5 times over ten years was better than burning only 1-3 times, and burning more than 6 times was most beneficial. This represents an average of 1 – 3 year burn regime.

Previous research has found habitat areas with fire suppression were avoided by RCWs (Provencher et al. 2002, Allen et al. 2006). It may be the case that birds selected more frequently burned areas because an increase in fire frequency leads to more successful clusters by increasing the arboreal arthropod density on the boles of trees and reducing the basal area of hardwoods (Taylor and Walters 2004) providing higher food availability and ideal habitat structure.

The social variable that was found to be significant was number of birds translocated into a cluster per year. The benefits of translocations demonstrated in other regions include expanding small populations, reducing potential adverse genetic consequences of small population sizes, and aiding in recovery after a catastrophic event (Franzreb 2004). The results show that PBGs were more likely to be associated with translocations of an individual bird to a local solitary bird that already has an established territory than to translocations of an unrelated pair. These results are similar to those reported in other studies (Edwards and Costa 2004, Walters et al. 2004). However, this result may be spurious for several reasons. First, RCWs that were translocated singly were paired with a resident bird, which gave them a higher chance of creating a potential breeding group in that same location shortly thereafter, whereas birds released as a pair into a vacant area were less likely to both be detected the following year. In addition, the Glimmix model only considered those birds that formed a potential breeding group within the breeding season directly following translocation. Therefore, the model is limited by the fact that in some cases of paired releases clusters retained a single translocated bird and formed a potential breeding group after the breeding season directly following translocation.

In the second part of this analysis, the features that differentiated clusters that successfully produced one fledgling from those that failed to produce a fledgling over the last ten years were the proportion of interior habitat vs edge and the number of years since the last hardwood treatment. Similar to the previous findings, the odds of having at least one fledgling produced in a cluster was associated with an increase in the proportion of interior habitat. Surprisingly, the odds of having at least one fledgling produced in a cluster increased as the number of years since the last hardwood treatment increased. A limited number of hardwood treatments (n = 20) were completed within active and inactive clusters during the study period. Therefore, the data had a large number of non-treated areas which may have driven the results to a negative response when comparing successful vs unsuccessful clusters. Upon closer inspection of the data, I found that 47% of all active clusters that received hardwood removal treatments (7 of 15) showed an improvement in productivity within 8 years of application, of which 4 clusters showed improvement within one year of treatment. This suggests that the way I chose to analyze the data may have been the reason for the unexpected result. Additionally, research on the effects of hardwood treatment over time on RCW productivity is suggested.

Management Implications

To provide quality habitat for potential breeding groups of RCWs, managers should strive to reduce hardwood basal area and reduce coverage of bare ground, implement prescribed fires on a 1-2 year rotation, and consider translocations of single birds to resident birds in interior sandhills habitat. To improve the success of potential breeding groups, active management to promote RCW habitat should be focused in areas that will minimize the amount of scrub ecotone and provide the maximum distance between active neighbors, and utilize hardwood treatment in areas where fire may be inappropriate to maintain shrubs below 1.5 m. RCW habitats in study areas B and C on the ONF have been consistently burned on a 1 – 2 year rotation, effectively controlling midstory basal area. An alternative to fire is hardwood treatment when areas have long been devoid of fire, which provides a controlled approach to reducing hardwood basal area and density but is significantly more expensive. Translocation has had a successful reputation in the Southeast and has shown to be successful in ONF. My research suggests that the translocation of a single bird to a resident bird is more productive than the introduction of a pair or none.

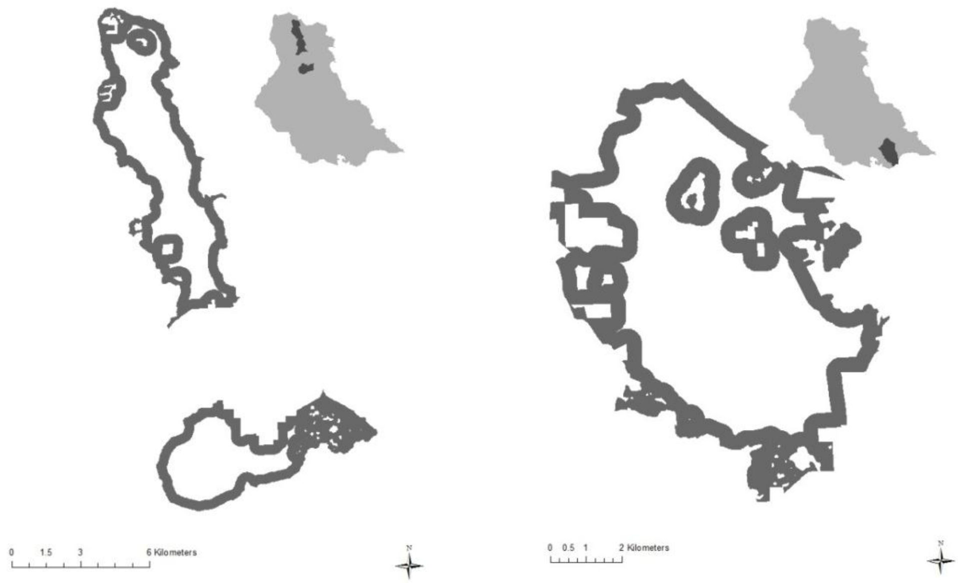
This study explored several RCW habitat characteristics; some which can be managed for while others are dependent on the behavior of the birds. Many of the stand scale features significant in my analyses of RCW site selection and productivity in 2010 in the Ocala National Forest aligned with the RCW recovery plan's habitat guidelines. The ONF has a healthy and productive, albeit isolated, habitat that is managed primarily for RCWs. Intensive management practices (annual translocation, frequent prescribed fires, and cluster augmentation that avoid scrub ecotones) over time have helped maintain the population.

Table 2-1. Parameter estimates ± standard error (SE), and adjusted odds ratios with 95% confidence intervals (CI) from the best fit models using backward logistic regression in predicting probability of a cluster having a potential breeding group (PBG) or not in the first assessment and predicting the probability of producing one or more than one fledgling in the second assessment within the 2010 breeding season

Year 2010 assessment	Parameter	Parameter estimate ± SE	Adjusted odds ratio		
			Estimate	95% CI	*P*
PBG vs non PBG	Hardwood basal area (ft^2/ac)	-0.41 ± 0.14	0.66	0.51–0.87	0.0026
	% cover bareground	-0.09 ± 0.05	0.92	0.84–1.00	0.0578
	% cover shrubs >1.5 m	0.67 ± 0.27	1.95	1.16–3.28	0.0119
1 fledgling vs >1 fledgling	Distance to nearest neighbor (m)	0.01 ± 0.01	1.01	1.00-1.03	0.0340
	% cover shrubs < 1.5 m	0.33 ± 0.19	1.39	0.95–2.03	0.0912

Table 2-2. Parameter estimates ± SE, and adjusted odds ratios with 95% confidence intervals from the best fit models using backward logistic regression in predicting probability of a cluster having a potential breeding group (PBG) or not, and the RCW productivity having at least one fledgling vs none within the 2001-2010 breeding seasons

10 year assessment	Parameter value	Parameter estimate ± SE	Adjusted odds ratio		
			Estimate	95% CI	*P*
PBG vs Non PBG	Interior	0.90 ± 0.48	2.46	0.95–6.37	0.0641
	Annual Rainfall	-5.51 ± 2.23	0.00	<0.001–0.32	0.0138
	Rx fire count ≥6	0.79 ± 0.36	2.19	1.07–4.48	0.0311
	Rx fire count 4–5	0.57 ± 0.21	1.77	1.18–2.65	0.0060
	Rx fire count 1–3	.	.	.	.
	Translocate0	-0.74 ± 0.58	0.48	0.15–1.48	0.1992
	Translocate2	-1.53 ± 0.69	0.22	0.06–0.84	0.0267
	Translocate1	.	.	.	.
PBG success vs failure	Interior	1.37 ± 0.49	3.93	1.49–10.38	0.0062
	Hardwood Trtmnt	0.06 ± 0.03	1.06	0.99–1.13	0.0751



A B

Figure 2-1. Map showing a 0.4 km foraging buffer along the inside edge of each sandhill patch’s ecotone to differentiate between interior (>0.4 km from scrub edge) and edge (≤0.4 km from scrub edge). A) Riverside Island. B) Paisley Woods.

CHAPTER 3
EFFECTS OF TRANSLOCATIONS ON THE RESIDENT POPULATION OF RED-COCKADED WOODPECKERS IN THE OCALA NATIONAL FOREST

Introduction

The red-cockaded woodpecker (RCW) is a federally listed endangered species in forests of the southern Unites States. Longleaf pine savannah habitat for this species was harvested in the 1800s and early 1900s and reduced to about 1% of its original range, resulting in a reduced population of RCWs of 3% or about 5,600 groups (Chadwick 2004). One of the management practices listed in the Red-cockaded Woodpecker Recovery Plan is to increase the number of potential breeding groups through translocations (USFWS 1985). There are four reasons the recovery plan recommends translocations: (1) augmenting small populations below the critical threshold of 30 potential breeding groups (PBG), (2) growing current populations to reduce isolation of groups, (3) releasing birds to suitable habitat within historic ranges, and (4) management of genetic resources (USFWS 1985). Translocations have been very successful at increasing population sizes by increasing potential breeding groups at recipient sites while having minimal effects on the donor populations (Saenz et al. 2002, Herbez et al. 2011).

Although augmenting individual birds from a densely populated area to a sparsely populated group is an important management strategy to help stabilize small populations, it is an expensive strategy. The estimated cost of transporting a pair of birds, according to the supervisory biologist on the Ocala National Forest (ONF), Carrie Sekerak (2010), is around $4500. This cost estimate includes installation of 8 artificial cavities or 2 clusters designated for the pair; man hours to scope out fledgling success, gender, and the individuals’ roosting tree; transportation from the donor population to the recipient location; and monitoring fledge success. Given the high cost of this management activity, it is important to measure the impact on the recipient populations to determine if the cost is justifiable.

The Ocala National Forest currently has two distinct populations of red-cockaded woodpeckers. The largest population of birds is located in the northern region of the forest known as Riverside Island and the other population (Paisley Woods) is located in the south (Figure 1-1). In an effort to continue increasing the number of potential breeding groups, juvenile red-cockaded woodpeckers are translocated from public lands with a surplus of birds to unoccupied territories on other public lands that are below the critical threshold of 30 potential breeding groups. Every year since 1987, the Ocala National Forest has been receiving birds from different public lands such as Camp Blanding near Starke, Florida; Fort Stewart, Georgia; and Francis Marion National Forest, McClellanville, South Carolina. In 1993, records show a total of 7 potential breeding groups between Riverside Island's and Paisley Woods' population. ONF was supplemented with a total of 81 translocated individuals over 13 years with the goal of reaching above the critical threshold of 30 PBGs per subpopulation.

Previous research suggests translocated birds respond differently according to gender, number of birds released per cluster, and varying habitat sizes (USFWS 1985, Carrie et. 1999). The ONF is unique in that it has the world's largest scrub ecosystem that in many areas completely surrounds high quality sandhill habitat, and it has two distinct subpopulations of RCWs. I undertook the study to determine which translocation techniques were most successful at contributing to the resident populations, and to examine differences between the two subpopulations. Success was measured by the number of new PBG formed, the ability of a group to successfully fledge offspring, and detection of translocated birds during the next breeding season at the cluster or within the RCW managed areas (fidelity). Specific factors that were evaluated included number of birds released at a site, which region of the forest the birds were released, and gender of the released birds. I also examined information on the last known status of the bird and the age of the birds at first reproduction.

The goal of this study was to determine whether translocations have had substantial positive impacts on resident red-cockaded woodpeckers in the Ocala National Forest.

- Objective 1: To compare the productivity of clusters and number of potential breeding groups in the vicinity of translocations before vs after translocation events.
- Objective 2: To determine cluster-site fidelity and regional-site fidelity of translocated birds.
- Objective 3: To compare productivity between birds released singly vs birds released as pairs, between males vs females, and between regions.

Methods

Objective 1: To Compare the Productivity of Clusters and Number of Potential Breeding Groups in the Vicinity of Translocations before vs after Translocation Events

I conducted four paired t-tests to evaluate whether translocations caused changes in the local number of PBGs and fledglings at two spatial scales: (1) within a 2.1 kilometers (km) buffer surrounding each receiving cluster, and (2) at the 4 clusters closest to the receiving cluster. I chose these two spatial scales because each is biologically relevant to red-cockaded woodpeckers.

Conner et al. (1997) suggests that movements among dispersing birds range from 1.8 km to 5.4 km depending on age and gender. With the proximity distances between clusters and the limited spatial arrangement of the habitat “islands” in ONF, I chose a 2.1 km radius, which captures a maximum of 14 clusters with an average of 8.6 ± 3.7 clusters. In ArcMAP (v 9.3.1, 2009), I drew a 2.1 km buffer around each receiving cluster to represent the average dispersal distance for females. I recorded the number of fledglings produced by each cluster within each buffer and whether there was a potential breeding group present for two years before the translocation and two years after. For example, when a translocation occurred in the winter of 2003, I averaged productivity of all clusters in the buffer from years 2001 and 2002 to characterize productivity prior to the translocation and averaged productivity for these clusters during years 2003 and 2004 to characterize productivity after the translocation.

The recovery plan states that dispersal movement of fledglings ranges from 1 to 4 clusters from the natal cluster (USFWS 1985). Therefore, I also recorded the number of fledglings produced by each of the four nearest clusters around each receiving cluster, and whether there was a potential breeding groups present for two years before the translocation and two years after for these same four nearest clusters to each receiving cluster.

I compared productivity of nearby clusters before and after translocations, and compared the number of potential breeding groups nearby translocation sites before and after translocations, at both spatial scales, using paired t-tests. I used the translocation data from 2003, 2004, 2006, and 2007 (n=16) along with the available data on fledglings and potential breeding groups from 2001 through 2008 to analyze whether there was a significant difference ($P \leq 0.10$) in the productivity of birds in the area surrounding each recipient cluster when comparing the two years prior to translocation to the two years after. For each cluster, the data were averaged together over the four years for which they were available.

Objective 2: To Determine Cluster-Site Fidelity and Regional-Site Fidelity of Translocated Red-Cockaded Woodpeckers

The second set of analyses determined cluster-site fidelity and regional-site fidelity of translocated individuals by gender, region and release type (paired or single). I calculated the cluster-site fidelity by determining the ratio of the number of translocated birds that remained at the release site during the next breeding season over the total number of recipient birds. Similarly, I measured regional-site fidelity by determining the ratio of the number of individual birds that stayed within the boundaries of Riverside Island or Paisley Woods, respectively, during the next breeding season over the total number of birds that were received for each region. In addition, I measured the post-release distance traveled by each translocated bird from their release site to their new territory. These measurements were entered into an Analysis of Variance (ANOVA) to test for difference of means ($P \leq 0.10$) between genders, regions (Riverside Island or Paisley Woods), and release types (paired or single).

Objective 3: To Compare Productivity among Birds by Translocation Type (Released Singly or as Pairs), Gender, and Regions

The third analysis compared the effectiveness of releasing a single RCW to a resident RCW vs translocating two unrelated RCWs as a pair to an unoccupied area. The response variables reviewed were a) the number of birds that settled into a cluster; b) the number of birds that formed a PBG; c) the number of birds that successfully contributed to the population with fledglings; and d) the number of fledglings produced during the first 4 years after translocation. These four components were reviewed against translocation type (paired release vs single release) and gender of the translocated birds. Logistic regression was used to identify which factors (type, gender, and region of release) differentiated translocated birds that produced fledglings from those that did not.

Results

Objective 1: To Compare the Productivity of Clusters and Number of Potential Breeding Groups in the Vicinity of Translocations before vs after Translocation Events

The first paired t-test assessment of the translocation data revealed there was no difference in fledgling success among clusters within a 2.1 km buffer of the release sites before vs after birds were moved (P = 0.636). In contrast, the second paired t-test found the number of potential breeding groups in 2.1 km proximity to the release site increased slightly (P = 0.091) (Table 3-1).

The third and fourth assessments tested for differences in fledgling success and the number of potential breeding groups in the four closest clusters to each release site respectively. There were no differences in either fledgling success (P = 0.280) or number of potential breeding groups (P = 0.418) (Table 3-1).

Objective 2: To Determine Cluster-Site Fidelity and Regional-Site Fidelity of Translocated Red-Cockaded Woodpeckers

The analysis of records collected from 1993 through 2005 revealed 50 clusters were augmented with 81 birds (44 Males, 37 Females) with 38 (47%) successfully remaining in the forest. Forest wide, translocation was moderately successful at retaining birds within a cluster (14 birds, 17%) and had greater success retaining birds within a region (Riverside Island and Paisley Woods; 24 birds, 30%). Overall dispersal distance among RCWs was 1.9 ± 0.3 km (Table 3-2) with 42% of birds (16 out of 38) dispersing >2.1 km.

Monitoring for gender across the forest during all available years found 22 Males (out of 44, 50%; 10 within the cluster and 12 within the region) and 16 Females (out of 37, 43%; 4 within the cluster and 12 within the region) settling into a new territory (Table 3-2). Monitoring within subpopulations found 24 birds in Riverside Island (51%; 13 within the cluster and 11 within the region) and 14 in Paisley Woods (41%; 1 within the cluster and 13 within the region) settling into a new territory (Table 3-2). Status of these birds was classified into four categories: mated with another translocated individual (Paired); claimed a territory alone (Solitary); mated with a resident bird (Local Mate); and undetected or lost (Missing). Of these, 4 Males settled in solitary (2 within the cluster and 2 within the region) vs 3 Females (1 within the cluster and 2 within the region) (Figure 3-1). In addition, 11 Males formed a PBG with a local mate (5 within the cluster and 6 within the region) vs 8 Females (1 within the cluster and 7 within the region). There were 6 male birds that paired with another translocated bird (3 within the cluster and 3 within the region) compared to 4 females (2 within the cluster and 2 within the region) (Figure 3-1). There were 43 translocated birds that were never detected after their release (53%; 23 in Riverside Island and 20 in Paisley Woods) (Figure 3-1).

A three-way analysis of variance of dispersal distances indicated a significant main effect for the region of translocation, $F_{1,37} = 17.42$, $P = 0.0002$, with the average distance birds traveled when translocated to Paisley Woods significantly greater ($\overline{X}$ = 3.3 ± 0.5 km) than birds translocated to Riverside Island ($\overline{X}$ = 1.1 ± 0.3 km). The main effects of gender and type and all interactions were non-significant (Table 3-3).

Objective 3: To Compare Productivity among Birds by Translocation Type (Released Singly or as Pairs), Gender, and Regions

Reviewing the cluster success, in the first breeding season after a translocation, 9 recipient clusters (18%) formed a PBG by retaining at least one of the translocated individuals. Six of these new pairs successfully produced 9 fledglings. In the second year after a translocation, 17 recipient clusters formed PBGs (34%) with 11 PBGs producing 15 fledglings. In the third year after a translocation there were 18 recipient clusters with PBGs (36%) with 13 PBGs producing 13 fledglings. Finally, in the fourth year, 22 recipient clusters had PBGs (44%) with 16 PBGs producing 13 fledglings (Figure 3-2).

Translocation types included 58 birds released as pairs (29 Males, 29 Females) to inactive clusters and 23 single birds released (15 Males, 8 Females) in the vicinity of a resident bird. Of the birds released as a pair, 27 (47%) settled into a territory. There were 20 (34%) birds that formed PBGs and 17 (29%) were successful at producing 37 fledglings within 4 years of release and starting breeding at the average age of 2.2 yr. Of the single bird translocations, 11 (48%) remained with a resident bird or settled elsewhere. There were 9 (39%) new PBGs formed with 4 (17%) producing 13 fledglings within 4 years of release and starting breeding at age 2.5 years. Reviewing patterns in gender revealed 22 (50%; out of 44) males settled in clusters with 17 (39%) forming PBGs. Twelve (27%) males contributed fledglings starting at the average age of 2 years. There were 16 (43%; out of 37) females that remained at clusters with 12 (32%) forming PBGs. There were 9 (24%) successful females contributing offspring starting at the average age of 2.5 years (Table 3-4). Over the course of 13 years, there were 102 fledglings contributed to the population by 21 translocated birds (Figure 3-3). Logistic regression indicated the factors that differentiated translocated birds that produced fledglings from those that did not was region (P = 0.0404), but not type of translocation (P = 0.0762) or gender (P = 0.9713). Birds translocated to Riverside Island were five times more likely to produce fledglings than birds translocated to Paisley Woods.

The status of translocated birds by type of release showed 14 paired males (4 paired, 3 solitary, and 7 with a local mate), 8 single males (2 paired, 2 solitary, and 4 with a local mate), 13 paired females (4 paired, 4 solitary, and 5 with a local mate), and 3 single females (3 with a local mate) (Figure 3-4).

Discussion

Objective 1: To Compare the Productivity of Clusters and Number of Potential Breeding Groups in the Vicinity of Translocations before vs after Translocation Events

Red-cockaded woodpecker offspring usually disperse within one year of fledging (Walters et al. 1988). During this time frame, biologists utilize the opportunity to translocate surplus individuals to another population that will not be able to reach the critical threshold of 30 potential breeding groups independently. The statistical results show that the 16 translocations that were selected for analysis produced no significant changes in the local number of fledglings during the first two years after translocation release or at either spatial scale investigated. These translocations only slightly increased the number of potential breeding groups formed within a 2.1 km radius of the receiving cluster, and had no effect within the 4 closest clusters. This may in part be explained by the age of the donor birds. These donor birds averaged about 6 months old; both males and females are highly susceptible to nest failure or no nest attempt in the first 2 years (Daniels and Walters 2000). Previous research has shown that translocated females nested later in the season and with smaller clutches compared to native females but these effects were not permanent and within a few years revealed no differences among the two groups (Levesque et al. 2004). The fact that the number of potential breeding groups increased slightly as a result of translocations within a 2.1 km buffer around translocations provides support for the idea that translocated birds may make positive contributions to resident populations over a longer period of time than the period I analyzed in both creating PBGs and potential fledglings. Additional research should examine longer time periods to assess whether productivity of translocated individuals increases as time since release increases.

Objective 2: To Determine Cluster-Site Fidelity and Regional-Site Fidelity of Translocated Red-Cockaded Woodpeckers

In the second assessment, I analyzed the historical records from 1993-2005 to review cluster-site fidelity and regional-site fidelity among translocated birds and then compared region and gender effects on translocation. This analysis was not limited by time or space as in the previous test. The proportion of undetected translocated birds in both subpopulations was about 53% over 13 years. The high proportion of undetected birds in ONF could be due to detection error which is often associated with small population size, individuals that are difficult to sample, or limited sampling efforts (Gu and Swihart 2004). Alternatively, it could be from birds emigrating out of the population beyond monitored areas or from predation. Other studies show RCW translocations with similar to better success. Hagan and Costa (2001) monitored two translocation events in Florida. Fifty percent of translocated birds were lost in the 1st year of translocation and 30% the 2nd year. Saenz et al. (2002) studied a large scale translocation across Texas, Louisiana, Arkansas and Oklahoma with 29% failure in retaining translocated individuals. Similarly, Carrie et al. (1999) also found 29% failure in Texas. ONF is unique in its vegetation community heterogeneity. For instance, Riverside Island is completely surrounded by scrub (Figure 3-5). The width of high quality habitat (sandhill) ranges between only 2 km–4 km and the RCW population is clustered towards the center and away from the bordering scrub ecosystem. There is a high potential for birds to explore into the scrub and become undetected. While Paisley Woods isn't completely surrounded by scrub (Figure 3-6), it's bordered by a variety of habitat described by the RCW Recovery Plan (USFWS 1985) as unsuitable. Limited size of available habitat might also influence the RCW success rate in ONF. Walters et al. (2004) had a higher success rate (74%) than ONF in a larger habitat range – 188,000+ha in Eglin Air Force Base vs 5000+ha in ONF. In addition to size, ONF has a large amount of edge that birds tend to avoid and during the beginning efforts of translocations, there were low densities of resident PBGs. Translocation success may be negatively correlated to distances between neighboring resident birds (Allen et al. 1993). The limited amount of habitat areas in ONF with its large amount of edge, make it plausible there are birds seeking shelter in neighboring ecosystems that are not monitored for RCWs.

Regional-site fidelity was higher than cluster-site fidelity suggesting that birds were more likely to stay within the region than within close proximity to release sites. There were also differences in retention between the two regions. Paisley Woods retained less translocated individuals at their release site compared to Riverside Island. Paisley Woods had a high number of available territories, low density of established PBGs near the release sites and had an average distance between clusters of 1.3 km (± 0.7) resulting in low cluster-site fidelity but higher regional-site fidelity (Figure 3-1). Pasinelli and Walters (2002) found the probability of fledgling dispersal was positively related to the number of unoccupied territories where the higher number of available territories, the farther the birds traveled. In contrast, Riverside Island had a lower availability of territories, a higher density of resident PBGs and had an average distance between clusters of 0.8 km (± 0.3) resulting in very little difference between cluster and regional fidelity though both were fairly high (Figure 3-2). Carrie et al. (1999) observed a beneficial social interaction when releasing individuals in close proximity to resident birds. A similar response was found in Riverside Island where there was a higher success with higher density of PBGs near the release sites.

The overall average dispersal distance among males and females was 1.9 km (± 0.3). This is smaller than a study by Carrie et al. (1999) who found an average dispersal distance of 2.8 km. Walters et al. (1988) found a significant difference in dispersal distances between males (4.5 km) and females (3.2 km). In ONF, males and females dispersed similar distances (1.8 km and 2.0 km respectively) (Table 3-2). Of the 38 translocated birds later detected, 24 settled outside the release site with 16 (42%) traveling farther than 2.1 km. The average starting age for reproduction was 2.3 years. This suggests that the results of objective 1 may be misleading: 42% of the translocated birds flew outside of the analyzed areas and on average didn't produce offspring until after the 2 year timeframe the analysis reviewed. Further research should be conducted to determine if there is a significant benefit to the population from birds dispersing beyond the 2.1 km distance and 2 year time frame I evaluated with objective 1.

Objective 3: To Compare Productivity among Birds by Translocation Type (Released Singly or as Pairs), Gender, and Regions

Across both regions of ONF, the number of new PBGs and successful PBGs increased each year for 4 years following translocation events. The number of fledglings produced by the new PBGs varied among years. Of the birds that established a territory, Riverside Island (51%) and Paisley Woods (41%) retained a lower percentage than Carrie et al. (1999) reported (71%), but Riverside Island (13 out of 24) had a higher cluster-site fidelity than Carrie et al. (1999) reported (3 out of 12) and Paisley Woods (1 out of 14). The overall success rate of translocations on the ONF (47%) is less than Franzreb (1999) and Allen et al. (1993) reported (63.2 % and 69% respectively).

Retention of translocated birds was similar between types of translocation, gender and region. Paired birds released to inactive clusters resulted in 47% retention and single birds released to a resident bird resulted in 48%. Translocated males showed 50% retention and females 43% (Table 3-4). Nest success was similar between types of translocation and gender but differed in regions. Riverside Island's nest success was five times higher than Paisley Woods. The paired release method was almost twice as successful (29%) compared to the single bird release technique (17%). Males were found with 27% nest success vs females with 24%. Average age to reproduction was lowest among paired and male birds. A study by Allen et al. (1993) found that translocations were most successful in South Carolina when matching an experienced, adult female (3 out of 3 nested) or male (6 out 8 nested) with a resident bird. They had little success translocating paired or single birds (4 out of 12 nested) into inactive clusters.

Investigation of the status of translocated birds found the majority of them settling with a local resident (Local Mate); this outcome was twice as common as any other status. All single females were found in this status. Paired females were almost equal in all categories of status (paired, solitary, or with a local mate). Further research on translocated birds, both male and female, should test whether translocating older birds results in a higher success rate than I found with translocating first year hatchlings.

Management Implications

The positive effects of translocation are evident in both Riverside Island and Paisley Woods in the ONF. Translocations have resulted in the formation of new potential breeding groups, provided solitary males the opportunity to mate with a new female and created new solitary males for resident females. These events have also resulted in a large number of offspring from the translocated birds, multiplying the success into future generations. Over a 13 year period (1993–2005), translocations have helped increase the population from 7 to 39 PBGs (Figure 3-3).

Not all events of translocation were successful. The lack of neighboring birds could have led to higher failures in early years. Future translocations should be completed with paired, unrelated individuals within close proximity to other resident birds. Significance of translocation within a 2.1 km radius of release sites was minimal to the resident population during the first two years. Additional research should be conducted at a wider range over longer time periods to determine if there is a greater impact beyond the spatial and temporal scales I investigated.

The habitat structure and size of resident populations might give insight to the response of translocated birds. Riverside Island is completed surrounded by scrub ecotone, has a narrower habitat structure and a denser resident population compared to Paisley Woods, and had greater success in productivity and higher cluster site fidelity. The larger resident population could have aided in the survival of the young birds. The scrub ecotone surrounding the island is avoided by RCWs (chapter 2) and affected the distance birds traveled. Future translocations should be in areas avoiding scrub ecotones.

The success of RCWs on the Ocala National has exceeded the 5% annual increase required by the recovery plan. On average, ONF's population increased by 16% per year (range from -11 to 32%), with an average of 6.2 birds translocated forest-wide per year (range from 1 to 12 birds). Survival of fledglings on ONF was 47% overall during the 13 years, which was similar to survival of birds translocated to sandhills in North Carolina. The ONF's population grew over 450% in 13 years from 7 potential breeding groups to 39. It appears that the translocation program had a positive impact on overall population growth.

Table 3-1. Effects of translocation efforts on productivity of surrounding red-cockaded woodpecker (RCW) clusters at two spatial scales. Comparisons were of number of fledglings and number of potential breeding groups (PBG) during the two years before vs two years after translocations using paired t-tests.

Dispersal ranges	Metric	$\overline{X} \pm SE$	*P*	95% CI
2.1 km max (n=16)	Fledglings	-0.03 ± 0.06	0.636	-0.16–0.01
	PBG	0.05 ± 0.03	0.091	-0.01–1.00
Closest 4 (n=16)	Fledglings	-0.12 ± 0.10	0.280	-0.32–0.09
	PBG	0.04 ± 0.05	0.418	-0.06–0.15

Table 3-2. Number of translocated RCWs (1993 to 2005) by region, gender and type that settled at their release site (cluster-site fidelity) or beyond their release site but within the region (regional-site fidelity), total number of birds found after translocation (total fidelity), the average dispersal distance traveled in kilometers (km) ± standard error (SE) and dispersal range

Translocation type	Cluster-site fidelity	Regional-site fidelity	Total fidelity	Dispersal distance in km ($\overline{X} \pm SE$)	Range (km)
Riverside (*n*=47)	13 (28%)	11 (23%)	24 (51%)	1.1 ± 0.3	0–5.8
Paisley (*n*=34)	1 (3%)	13 (38%)	14 (41%)	3.3 ± 0.5	0–7.1
Female (*n*=37)	4 (11%)	12 (32%)	16 (43%)	2.0 ± 0.5	0–3.9
Male (*n*=44)	10 (23%)	12 (28%)	22 (50%)	1.8 ± 0.3	0–7.1
Paired (*n* = 58)	9 (16%)	18 (31%)	27 (47%)	1.9 ± 0.3	0–5.8
Single (*n*= 23)	5 (22%)	6 (26%)	11 (48%)	1.8 ± 0.7	0–7.1
Forest Wide (*n* = 81)	14 (17%)	24 (30%)	38 (47%)	1.9 ± 0.3	0–7.1

Table 3-3. Analysis of variance summary for variables describing distance traveled by translocated RCWs. Difference were considered significant if $P<0.05$.

Source of variation	df	SS	MS	F-value	P-value
Type	1	2.22	2.22	0.90	0.3507
Gender	1	0.68	0.68	0.28	0.6029
Region	1	43.07	43.07	17.42	0.0002
Type x gender	1	0.28	0.28	0.11	0.7369
Type x region	1	6.13	6.13	2.48	0.1258
Gender x region	1	2.53	2.53	1.03	0.3194
Type x gender x region	1	0.89	0.89	0.36	0.5538
Error	30	74.17	2.47		
Total	37	133.48			

Table 3-4. Status of translocated RCWs based on type of translocation (paired vs single), gender of birds and region released

	Settled	PBG	Produced fledgling	Age to reproduction in years ($\bar{X} \pm$ SE)
Riverside (*n* = 47)	24 (51%)	20 (43%)	16 (34%)	2.3 ± 0.4
Paisley (*n* = 34)	14 (41%)	9 (26%)	5 (15%)	2.4 ± 0.7
Paired (*n*=58)	27 (47%)	20 (34%)	17 (29%)	2.2 ± 0.4
Single (*n*=23)	11 (48%)	9 (39%)	4 (17%)	2.5 ± 0.7
Male (*n*=44)	22 (50%)	17 (39%)	12 (27%)	2.1 ± 0.4
Female (*n*=37)	16 (43%)	12 (32%)	9 (24%)	2.6 ± 0.5
Forest Wide (n = 81)	38 (47%)	29 (36%)	21 (26%)	2.3 ± 0.3

Table 3-5. Parameter estimates ± SE, and adjusted odds ratios with 95% confidence intervals from the best fit models using backward logistic regression in predicting probability of producing an RCW fledgling

		Adjusted odds ratio		
Parameter value	Parameter estimate ± SE	Estimate	95% CI	*P*
Type	0.73 ± 0.41	4.30	0.86–21.60	0.0762
Region	-0.79 ± 0.39	0.21	0.05–0.93	0.0404
Gender	0.01 ± 0.37	1.02	0.24–4.40	0.9802

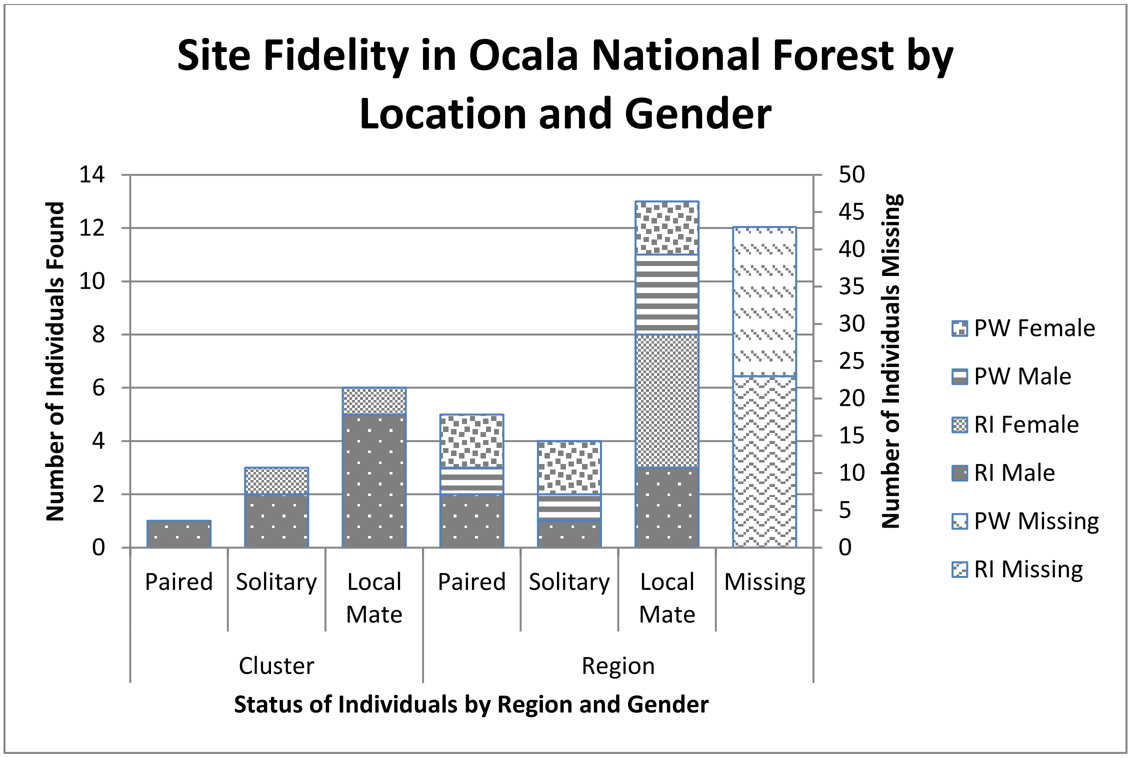


Figure 3-1. Count of red-cockaded woodpeckers (RCWs) surviving from 1993 – 2005 after translocation to the Ocala National Forest (ONF), Florida, by location and gender. Counts of birds that remained in the cluster to which they were translocated (Cluster), and count found in Riverside Island (RI) and Paisley Woods (PW) (Region) are shown with counts of birds found without a mate (Solitary), and found paired with a local resident (Local Mate). The count birds that disappeared (Missing) are represented by the second y-axis. Translocation types were paired males with paired females brought to newly constructed clusters (n = 17 each gender), males brought to solitary females (Single Males, n = 8) and females brought to solitary males (Single Females, n = 5).

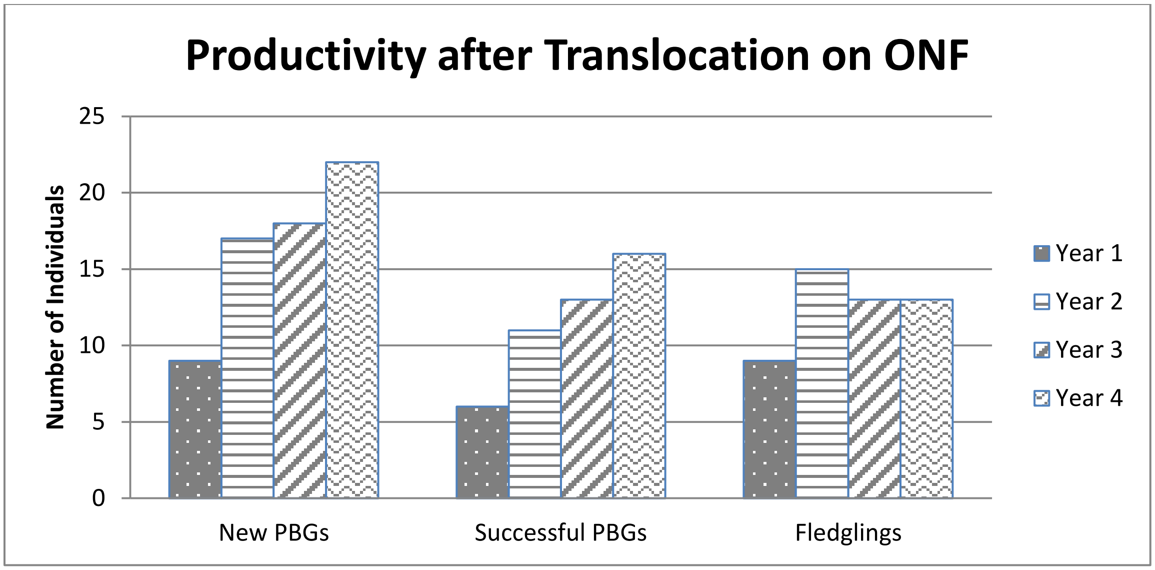


Figure 3-2. Productivity of RCW potential breeding group's activity after translocations on the ONF, Florida, measured as counts of birds over four years after each translocation. Metrics include new potential breeding groups created within Riverside Island and Paisley Woods (New PBGs), PBGs successfully raising young to fledgling stage (Successful PBGs), and number of young surviving to fledgling stage (Fledglings).

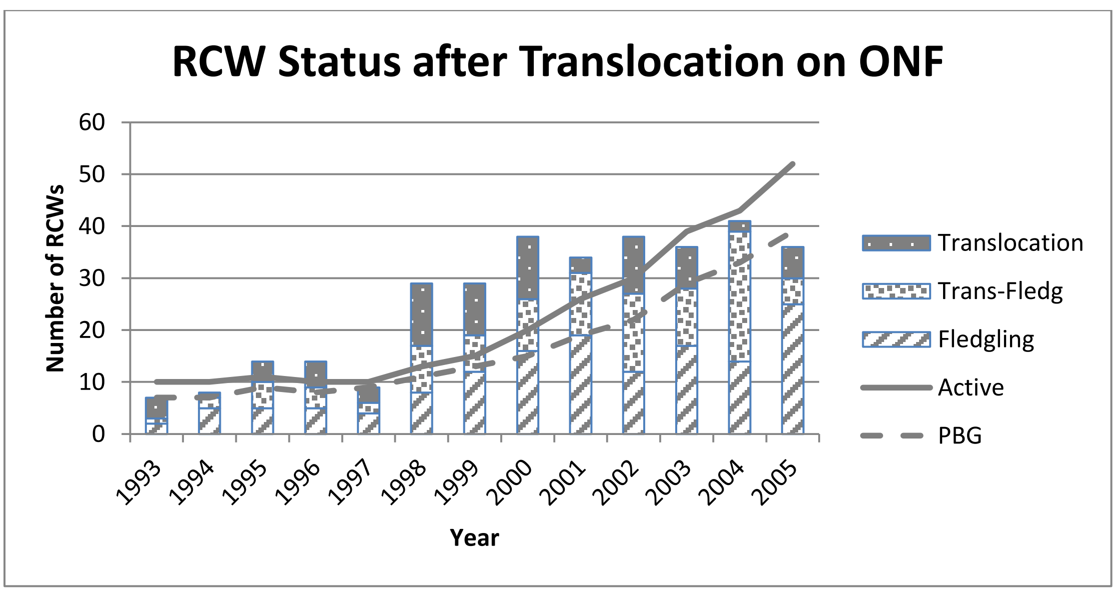


Figure 3-3. Cumulative number of RCWs in the ONF introduced by translocation events, fledglings added by translocated birds (Trans-Fledg), and fledglings produced by resident birds (Fledgling). The solid line depicts the change in number of active clusters (Active) and the dashed line shows the change in number of potential breeding groups (PBG).

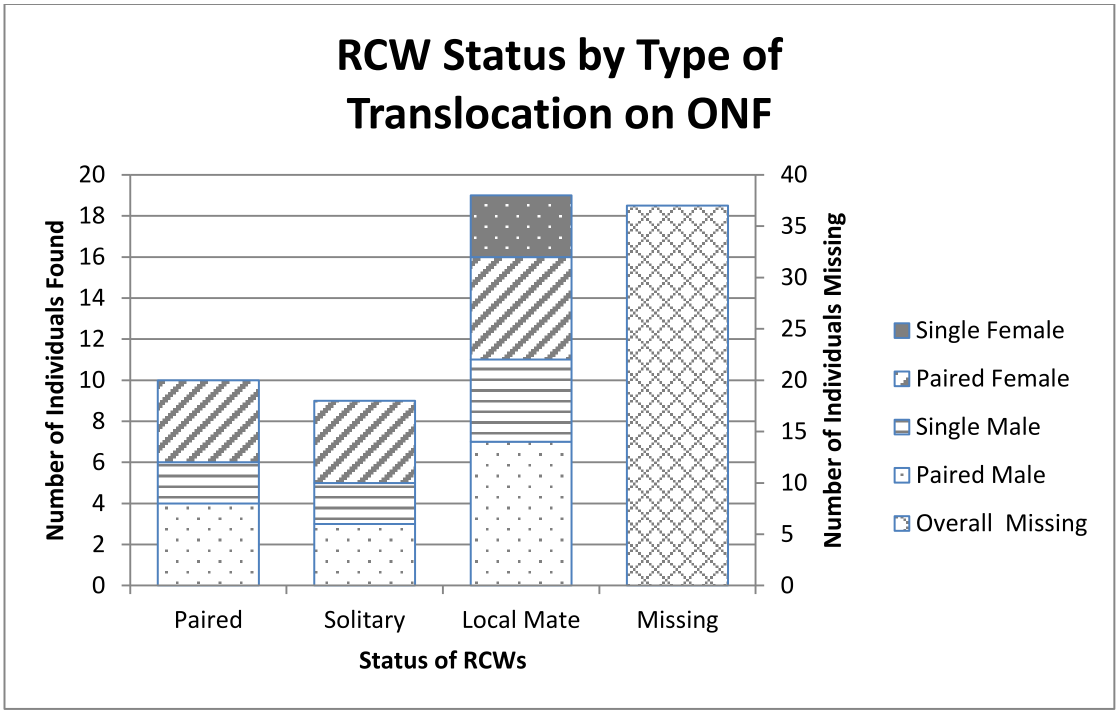


Figure 3-4. Number of RCWs surviving from 1993 – 2005 after translocation to the ONF, Florida, by gender and type of translocation (paired or single). The number of birds that disappeared (Missing) is indicated on the second y-axis.

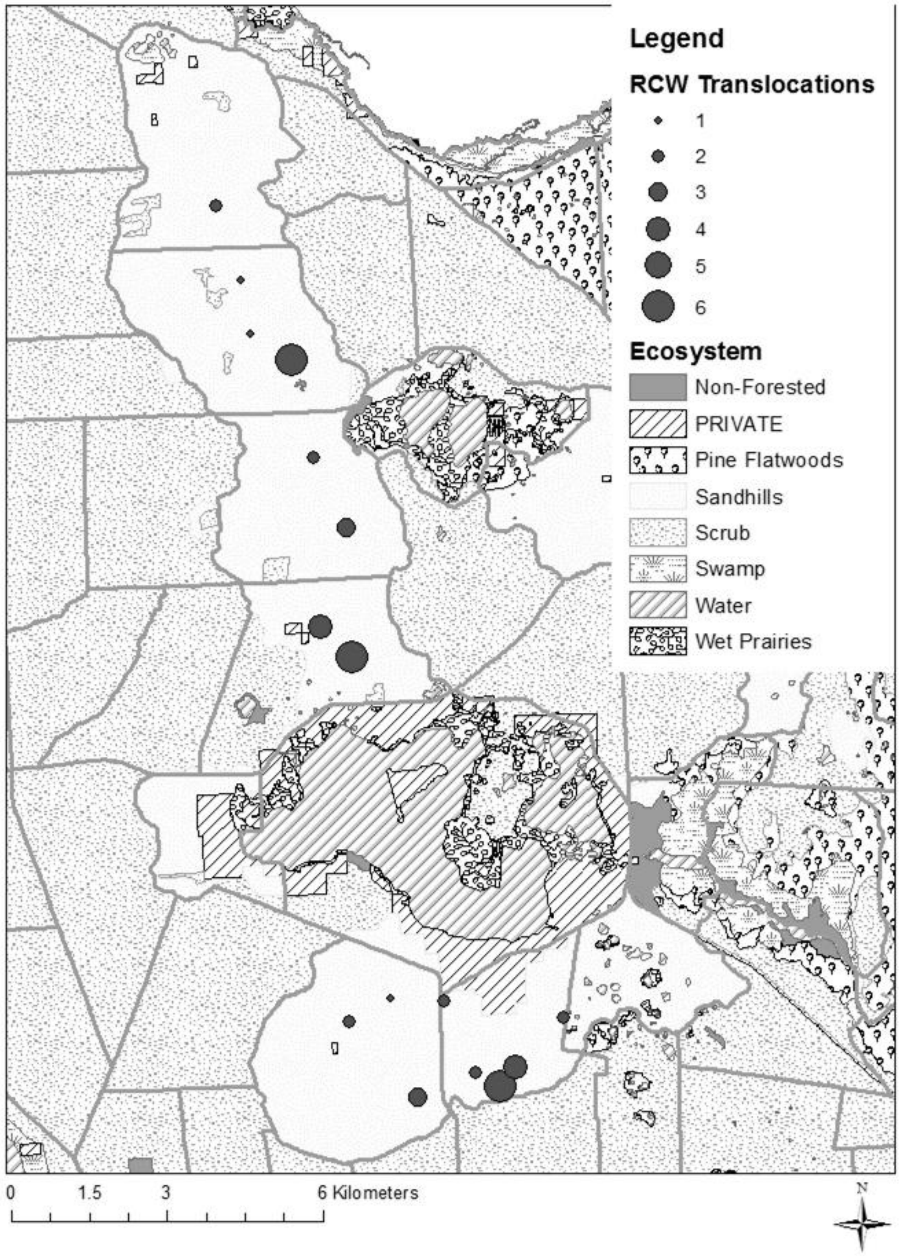


Figure 3-5. Ecosystems in Riverside Island in the northern region of the ONF. Forty-seven red-cockaded woodpeckers were translocated in 16 newly created artificial clusters from 1993 to 2004.

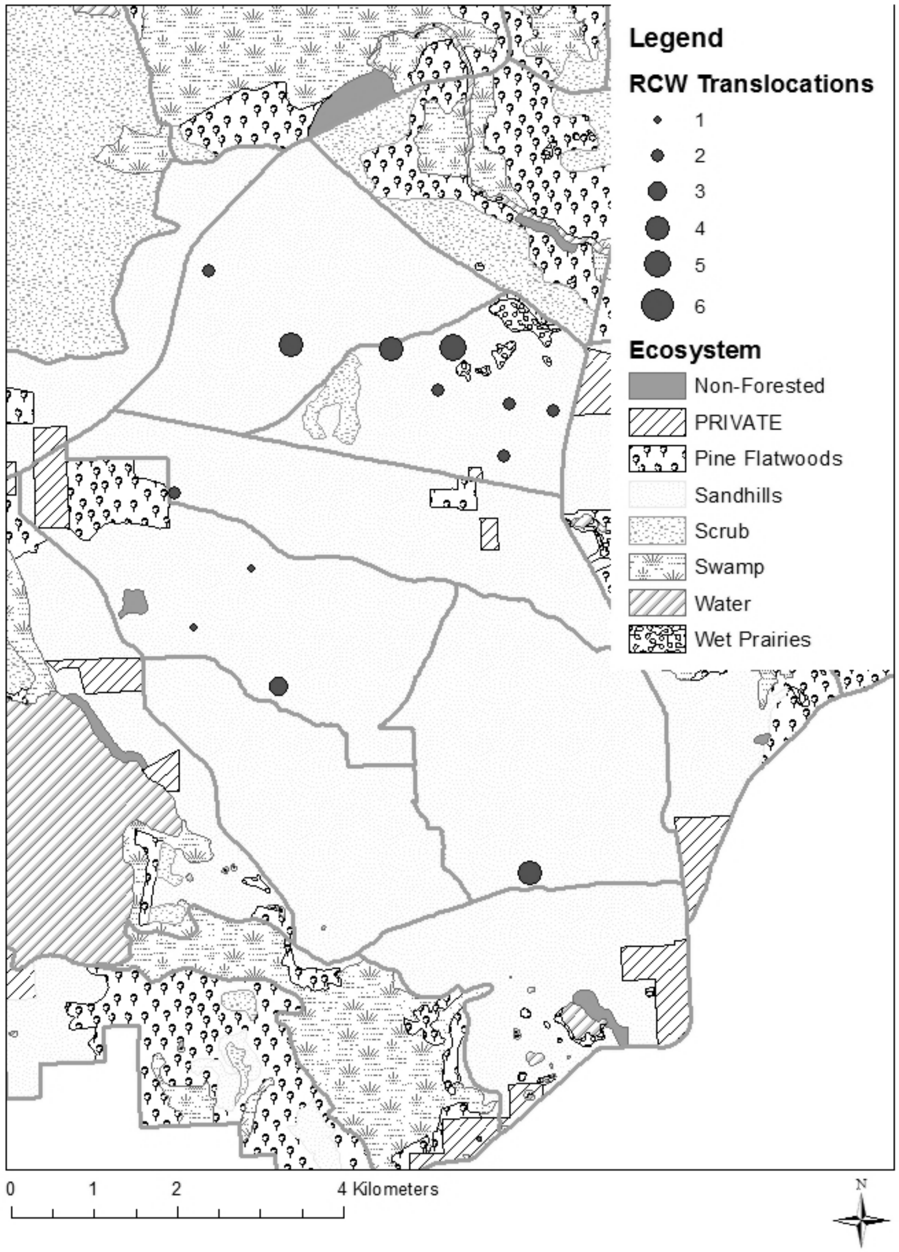


Figure 3-6. Ecosystems in Paisley Woods in the southern region of the ONF. Thirty-four RCWs were translocated in 13 newly created artificial clusters from 1995 to 2005.

CHAPTER 4
USING DATA ON RED-COCKADED WOODPECKER HABITAT SELECTION FROM OTHER NATIONAL FORESTS IN FLORIDA TO MAKE INFERENCES ABOUT HABITAT RESTORATION AND SUITABILITY ON OCALA NATIONAL FOREST

Introduction

The red-cockaded woodpecker's (RCW) range spans across 11 states of the southeastern United States (Ligon et al. 1986). Although many researchers believe that RCW's are most closely adapted to longleaf pine (*Pinus palustris*) ecosystems (Conner et al. 2001), which now is one of the most important endangered ecosystems in the nation (Simberloff 1993, Ware et al. 1993), remnant populations can be found in habitats with varying vegetative structure and species composition (USFWS 1985). Some of these habitats include shortleaf (*P. echinata*) and loblolly pine (*P. taeda*) forests (Wood et al. 2008), hydric slash pine (*P. elliottii*) flatwoods (Beever and Dryden 1992, Smith and Martin 1995), and pond pine (*P. serotina*) communities (USFWS 1985). Despite the variety of habitats they occupy, RCWs select similar vegetation features throughout their range. They prefer stands of large, old growth pines (>60 years), with minimal hardwood midstory, maintained by frequent growing season fires (USFWS 1985, Hooper and Harlow 1986, Jones and Hunt 1996, Zwicker and Walters 1999). In addition, their home range size can vary dramatically across geographic regions from 14 to 225 hectares (ha) (Wood et al. 2008) and has been found to be negatively related to the availability of high quality habitat (Davenport et al. 2000).

The largest RCW population in the southeastern US occurs in northern Florida in the Apalachicola National Forest (ANF) containing approximately 650 active clusters (James 1991, Petrick and Krusac 2012). The clusters are located in areas composed predominantly of longleaf pine flatwoods and slash pine plantations (Hovis and Labisky

1985) with small areas of sandhills (Petrick and Krusac 2012). The Osceola National Forest (OsNF) is estimated to have over 400 active clusters with 140 potential breeding groups. According to the United States Forest Service (USFS) forest type Geographical Information System (GIS) layer, the major components of their habitat consist of 40% slash pine forests and 20% bald cypress water tupelo mix; the Florida Fish and Wildlife Conservation Commission (FWC) (FWC Metadata 2004) vegetation and land cover data indicates swamp and wetland areas cover 40% of the OsNF and pinelands cover 35%. In contrast, the Ocala National Forest (ONF) contains only 75 potential breeding groups (Petrick and Krusac 2012). The ONF supports two very contrasting vegetative communities often separated by sharp boundaries. The first community, longleaf pine-wiregrass, occurs in isolated islands within a matrix of the second community, sand-pine scrub (Kalisz and Stone 1984). Longleaf pine-wiregrass communities are dominated by open stands of longleaf pine trees as well as other pine species, deciduous oaks, and a wiregrass ground cover; while sand-pine scrub communities are dominated by a closed canopy of sand pine (*P. clausa*) with a scrub oak understory and little herbaceous ground cover or bare ground (Myers 1985). Although RCWs' preference and adaptation to the longleaf pine ecosystem has been well documented (Conner et al. 2001), how RCWs interact with sand-pine scrub communities is poorly understood and could be a subject of future investigation.

In the 1900s fire suppression and unfavorable silvicultural practices had negative effects on the red-cockaded woodpecker status and the ecosystems on which they depend (Ligon et al. 1986, 1991; Frost 1993; Ware et al. 1993; Landers et al. 1995; Conner et al. 2001). Loss of habitat and fragmentation of existing habitat are major threats to this species. RCWs do not display movements across large geographic distances within metapopulations, and therefore require within-population genetic variation (Stith et al. 1996). In cases where populations of RCW's have been extirpated from an area, translocation of individuals to new recruitment stands may be the only option for re-establishing breeding groups within historically occupied areas, and may also help bolster small existing populations (Carrie et al. 1999). Rudolph et al. (1992) recommended releasing multiple pairs of RCWs when attempting to reintroduce birds into a previously occupied habitat. Carrie et al. (1999) reported that releasing multiple pairs of RCWs in close proximity to each other and to resident groups facilitated social contact and allowed individuals to settle and obtain mates in the area.

The purpose of this study is to evaluate the suitability of potential habitat for RCWs in the area of ONF where birds have been extirpated (study area A; Figure 1-1). Due to the stark contrast between habitat types in this area in comparison to the sandhills currently in use by RCW populations in ONF (study areas B and C; Figure 1-1), I examined habitat selection patterns of RCWs in other national forests in Florida to develop predictions for the geographic areas most deserving of future restoration efforts and translocations in ONF.

- Objective 1: To examine habitat selection by RCWs in all 3 national forests in Florida.
- Objective 2: To map the location of habitat features selected by RCWs in other national forests in Florida to the region abandoned by RCWs in ONF.

Methods

Objective 1: To Examine Habitat Selection by RCWs in All 3 National Forests in Florida

I obtained GIS layers from the United States Forest Service (USFS) data base and FWC vegetation class. These layers included three categories: RCW trees (three national forests), FWC forest type (statewide), stand data (forest type and stand initiation dates; three national forests), and soils (statewide). In addition, I obtained the Florida Natural Areas Inventory's (FNAI) natural community categories, the Florida Land Use, Land Cover Classification System (FLUCCS) land cover categories and the Cooperative Research in Forest Fertilization (CRIFF) forest soil classification (Jokela and Long 1999).

The recovery plan describes the average territory size of RCWs for different regional areas including central Florida, northwest Florida and Coastal Georgia, (129 ha, 109 ha and 80 ha respectively; USFWS 1985). I chose the largest average size, 129 ha, to represent the typical RCW territory size for all three national forests in Florida to guarantee capture of the birds' territory. This represents a radius of approximately 0.64 kilometers (km).

I reduced the RCW tree layer to centroids of all active and inactive trees to provide a representation of areas occupied by woodpeckers both currently and historically. I created buffers around each centroid in each of the three national forests.

Once the buffers were created, I wanted to differentiate between areas currently/historically in use from areas of available habitat. To ensure there was no overlap in these areas, I doubled the buffers around each centroid (1.28 km radius) and used the 'erase' tool in ArcMAP (v 10, 2010) to delete these areas from the forest boundary layer. This resulted in two separate regions: buffers around current/historical nest trees (i.e., used habitat) and available habitat.

I took a simple random selection of buffers around current/historical nest trees (used habitat) in each of the three forests to sample 20% of the current RCW population of each forest. This provided a total of 30 points in Ocala National Forest, 50 points in Osceola National Forest and 160 points in Apalachicola National Forest. Then I ran a random sample point generator in the available habitat region of each national forest to obtain the same number of points in available areas per forest. Each data layer was intersected with the buffers from the sampling points to generate data for a logistic regression model to test which factors differentiated between used and available habitat.

The FWC Global Information System (GIS) data on forest type was originally in a raster form. In order to intersect the data with the sample buffers, I converted the raster into a shape file in ArcMAP and then dissolved and projected it to make it more pliable. The data created from intersecting buffers and the raster were formatted in Excel to prepare for SAS import. Due to the large ratio of variables relative to sample points collected (373 variables / 480 sample points) and the limited number of variables suggested per sample points for logistic regression (5–10 sample points per variable) (Peduzzi et al. 1996, Vittinghoff and McCulloch 2006), I used a hierarchical approach. First, to derive a coarse assessment of RCW habitat selection, I collapsed the FWC and USFS forest types vegetative descriptions into the 8 FNAI categories. I used the CRIFF forest soil classification to reduce the soil layers from 149 categories to 22. Finally, I grouped age year of stands into 10 year increments, reducing the number of stand variables from 124 to 15. In SAS, I completed a univariate test on each variable to find which had a p-value < 0.250. Next, I ran a correlation test to determine which vegetative descriptions were always found together in a buffer per forest (P>0.600). Using logistic regression in SAS, I first tested uncorrelated variables (Appendix B) using the FNAI, stand initiation classifications, and CRIFF to provide a coarse scale estimate of significant variables (P > 0.100). Next, I tested uncorrelated variables using the FWC, USFS forest type, stand initiation classifications, and USFS soil types to provide a fine scale estimate of significant variables (P > 0.100).

Weighted overlay analysis in ArcMAP requires variables to be scaled based on suitability. I used 8 categories of habitat use: very strongly avoided, strongly avoided, moderately avoided, slightly avoided, slightly preferred, moderately preferred, strongly preferred, and very strongly preferred. These categories were determined by using the inverse of those odds ratios between 0 and 1 to standardize the results (Chen et al. 2010) and then order them from smallest (most avoided) to largest (most preferred). To represent weighted overlay scales (WOS), I scaled the results from 1 to 8 based on each variable's standardized odds ratio: <-4.72 = very strongly avoided (WOS 1); -4.72 to -2.75 = strongly avoided (WOS 2); -2.74 to -1.53 = moderately avoided (WOS 3); -1.52 to 0 = slightly avoided (WOS 4); 0 to1.52 = slightly preferred (WOS 5); 1.53 to 2.74 = moderately preferred (WOS 6); 2.75 to 4.72 = strongly preferred (WOS 7); and >4.72 = very strongly preferred (WOS 8).

Objective 2: To Map the Location of Habitat Features Selected by RCWs in Other National Forests in Florida to the Region Abandoned by RCWs in ONF

I mapped the regions in the area of ONF RCWs have abandoned (study area A) to identify the most suitable locations for RCW reintroductions. I used the ecosystem layer

(USFS GIS Layer) to exclude areas that will never have a chance of being managed for RCW habitat. These areas included six categories: non-forested, private lands, scrub, swamp, wetlands, and water. The remaining potential habitat areas were sandhills and pine flatwoods. The results from the logistic regression conducted in objective one were reclassified in GIS on a scale from 1 to 8 reflecting the standardized odds ratios. Additionally, correlated variables not entered into the logistic regression were reclassified and all variables were entered into a weighted overlay analysis in ArcMAP. The results were mapped within the potential habitat boundaries to highlight preferred and avoided areas. The weighted overlay analysis utilized preferred and avoided habitat areas from objective one within different layers and identified the most suitable habitat for RCWs. Correlated variables not used in the logistic regression were added to the weighted overlay analysis for additional support of suitable variables. Soils were removed from the analysis due to the lack of occurrence of significant soil variables in Church Lake.

Lastly, I dissolved coarse scale WOSs 5-8 (slightly to very strongly preferred) from the selected areas to calculate acreage of large connected areas of selected habitat. The recovery plan (USFWS 1985) states that high quality forested areas should provide at least 49 ha per cluster and low quality areas 80 – 120 ha. Each of the dissolved layers produced after identifying habitat features selected by RCWs in ANF and OsNF were divided by low and high quality home range size estimates to suggest the possible carrying capacity of study area A.

Results

Objective 1: To Examine Habitat Selection by RCWs in All 3 National Forests in Florida

Coarse scale analysis

The logistic regression identified variables that differentiated used from available habitat at the coarse scale using FNAI natural communities combined with the FLUCCS land cover, stand initiation age class, and CRIFF forest soil classification (Table 4-1). FNAI classes RCWs avoided were freshwater forested wetlands (*P* = <0.0001) (WOS4), and hardwood forested uplands (*P* = 0.0200) (WOS 4), whereas they selected for high pine scrub (*P* <0.0028) (WOS 5) and pine flatwoods/dry prairie (*P* = <0.0001) (WOS 5). Stand initiation age classes RCW selected for were 1899-1908 (*P* = 0.0036) (WOS 5), 1909-1918 (*P* = <0.0001) (WOS 5), 1919-1928 (*P* = <0.0001) (WOS 5), and 1929-1938 (*P* =<0.0001) (WOS 5). CRIFF soil classes selected by RCWs were BCD-Savannas/Flatwoods (*P* = <0.0001) (WOS 5), BD-Savannas/Flatwoods (*P* = 0.0010) (WOS 5), C-flatwoods (*P* = 0.0131) (WOS 5), and E-uplands (*P* = 0.0102) (WOS 6). The FNAI class results show the more freshwater forested wetlands and hardwood forested uplands, the less likely there will be a cluster in the area. These were both considered slightly avoided for the weighted overlay scale. In contrast, as high pine scrub and pine flatwoods/dry prairie increases, the likelihood of finding a cluster in an area increases. These were slightly preferred. The stand initiation age class results indicate the more trees older than 70 years, the more likely there will be a cluster in the area. All stand initiation age classes were scaled as slightly preferred. Increasing BCD-Savannas/Flatwoods, BD-Savannas/Flatwoods, C-flatwoods, or E-uplands increased the likelihood of finding an RCW cluster. CRIFF series E was considered moderately preferred for the weighted overlay scale whereas all others were slightly preferred.

Fine scale analysis

The second logistic regression analysis identified variables that differentiated used from available habitat at the fine scale level, using FWC forest cover classes, USFS forest types, stand initiation age class, and USFS soil types. FWC vegetation classes RCWs avoided were hardwood swamp (P = 0.0054) (WOS 4) and mixed wetland forest (P = 0.0002) (WOS 4), while pinelands (P = <0.0001) (WOS 5) and sandhills (P = <0.0001) (WOS 5) were selected for. The USFS forest type RCWs selected for was longleaf pine (P = <0.0001) (WOS 5), pond cypress (P = 0.0036) (WOS 5) and slash pine (P = 0.0954) (WOS 5) while bottomland hardwood/yellow pine mix (P = 0.0285) (WOS 4), slash pine hardwood (P = 0.0159) (WOS 4) and forest type–unknown (P = 0.0024) (WOS 4) were avoided. Stand initiation age classes RCWs selected for were 1909-1918 (P = 0.0033) (WOS 5), 1919-1928 (P = <0.0001) (WOS 5), and 1929-1938 (P = <0.0001) (WOS 5). Lastly, soil classes avoided by RCWs were B-Rutlege and Plummer (P = 0.0383) (WOS 4), G-Foxworthy (P = 0.0628) (WOS 4), and unknown-Hosford (P = 0.0017) (WOS 1), whereas BCD-Plummer, Sapelo, and Pottsburg (P = <0.0001) (WOS 5) and E-Goldsboro (P = 0.0285) (WOS 7) were selected for. The FWC vegetation results show that the greater the area with hardwood swamp or mixed wetland forest, the less likely there will be an RCW cluster. These variables were considered slightly avoided for the weighted overlay scale. In contrast, the greater the area with pinelands and sandhills the more likely there will be a cluster in the area. There were considered slightly preferred. The USFS forest type results indicate that increasing the amount of longleaf pine, slash pine and pond cypress increased the likelihood of having an RCW cluster (slightly preferred), whereas increased amounts of bottomland hardwood/yellow pine and unknown (slightly avoided) decreased the likelihood. The stand initiation age class results indicate the more trees older than 70 years, the more likely there will be a cluster in the area. All stand initiation age classes were scaled at slightly preferred. Finally, increasing the amount of BCD-Plummer, Sapelo, and Pottsburg (slightly preferred) and E-Goldsboro (strongly preferred) soils increased the likelihood there will be an RCW cluster. In contrast, increasing the amount of areas of B-Rutlege and Plummer (slightly avoided), G-Foxworthy (slightly avoided), and unknown-Hosford (very strongly avoided) decreased the likelihood of finding an RCW cluster.

Objective 2: To Map the Location of Habitat Features Selected by RCWs in Other National Forests in Florida to the Region Abandoned by RCWs in ONF

The region where the current populations of RCWs reside (study areas B and C) are 6,200 ha and 5,300 ha respectively, and approximately 90% sandhills. In contrast, the area RCWs abandoned (study area A) is 20,500 ha with 7,400 ha of flatwoods and sandhills (the vegetation types suitable for potential RCW management) (Figure 4-2). Study area A has a mixture of 38% private lands, along with a mosaic pattern of non-forest, private lands, pine flatwoods, sandhills, scrub, swamp, water and wet prairies (Table 4-3). Variables that differentiated used vs available habitat at both coarse scale and fine scales in objective one were standardized based on their odd ratio estimates and entered into a weighted overlay analysis in ArcMAP to identify areas most suitable for future RCW introductions. These results were mapped onto study area A (Figures 4-3 and 4-4).

To estimate the carrying capacity of potential breeding groups in study area A, I utilized the recovery plan's (USFWS 1985) estimation for carrying capacity according to varying qualities of habitats. Areas that are considered high quality require at least 49 ha per cluster and areas that are considered low quality need 80 – 120 ha. The coarse scale weighted overlay analysis identified 3,361 ha of potential habitat in study area A and the fine scale analysis found 2,780 ha. At both scales, I isolated contiguous areas that were at least 49 ha in size to calculate the potential carrying capacity if all acres met high quality standards (Figures 4-5 and 4-6). In the coarse scale, there was 2,654 ha existing in contiguous regions at least 49 ha per polygon, which would potentially provide habitat for 54 clusters if this were high quality habitat (Table 4-4). At the fine scale level, there was 1,934 ha existing in contiguous regions, allowing for 39 clusters if this were high quality habitat. Next, I isolated contiguous areas with at least 80-120 ha and found 1,737 to 2,314 ha available at the coarse scale, which would provide for 14-28 clusters and 1,016 to 1,530 ha available at the fine scale which would provide for 8-19 clusters if this were low quality habitat (Table 4-4).

Discussion

Objective 1: To Examine Habitat Selection by RCWs in All 3 National Forests in Florida

Coarse scale analysis

Two FNAI natural communities were selected for: high pine/scrub and pine flatwoods/dry prairie. FNAI describes high pine/scrub as hills with mesic or xeric woodlands or shrublands, and pine flatwoods/dry prairie as mesic or hydric pine woodland or mesic shrublands on flat sandy or limestone substrates. These natural communities contain fine-scale habitat feature described in the FWC and USFS vegetation layers that were selected for and others that were avoided according to the univariate test. Two FNAI natural communities were avoided: freshwater forested wetlands and hardwood forested uplands. These four variables were only slightly preferred or avoided on the weighted overlay scale. Other studies have observed swamps, savannas and clearcuts as avoided habitat areas when they were a part of RCW home ranges (Porter and Labisky 1986). Areas that have more than 10% of canopy trees with hardwoods have also been reportedly avoided (Jones and Hunt 1996). In contrast, RCWs foraging predominately on pines annually and throughout the breeding season have been observed foraging on hardwoods during the non-breeding season (Wood et al. 2005). In general, RCWs preferred high pines in Florida and in some areas, may use small hardwood areas for foraging.

The red-cockaded woodpeckers normally select habitat containing old growth pine trees (Jones and Hunt 1996, Zwicker and Walters 1999, Wood et al. 2005). The results found RCWs in Florida selected stands that were greater than 70 years old. These four age classes over 70 years old were found slightly preferred for the weighted overlay scale. RCWs are well known for nesting in habitats that are >80 yrs and foraging during the non-breeding season in trees stands that are <60 yrs (Zwicker and Walters 1999).

RCWs selected for CRIFF soil classes BCD – savannas/flatwoods, BD – savannas/flatwoods, C – flatwoods and E – uplands. These results correspond to RCWs well-known preference for pine ecosystems. CRIFF series uplands was moderately preferred while all others were slightly preferred. The large variety of soil types selected is likely indicative of the large area of ANF which contains many varying soil types. With the largest number of RCW clusters, it is expected that birds in ANF are adaptable to different soil types. In ONF, RCWs are found primarily in areas with the CRIFF soil class G. Because this soil class has a high correlation with the FNAI category high pine scrub (*P* >0.60), this soil class was not entered in the final model.

Fine scale analysis

At the fine scale level, RCWs avoided areas that included mixed wetland forests and hardwood swamps, and selected for areas with sandhills and pinelands. These four variables were only slightly preferred or avoided for the weighted overlay scale. It is no surprise that RCWs selected sandhills since much of their habitat is within the sandhill habitat islands in ONF, and also in ANF. The OsNF is dominated by large areas of pinelands used by their resident RCW population.

The Forest Service delineates forest types at the stand level describing the dominant tree species to represent the stand. The USFS forest types selected for by RCWs were longleaf pine, pond cypress and slash pine. These variables were slightly preferred in the weighted overlay scale. Longleaf pine is correlated with FNAI's category of high pine scrub (Appendix B) and is well understood to be a higly selected component of foraging habitat for RCWs (Nesbitt et al. 1978, DeLotelle et al. 1987, Shackelford and Conner 1997, Conner et al. 1998). One study found that longleaf pine stands were selected during foraging 90% of the time over cypress domes 10% of the time (DeLotelle et al. 1987). On the other hand, flatwoods associated with longleaf, slash, and pond pines, were found to be used 82% of time (Nesbitt et al. 1978). Other studies monitored used of varying pine species and found that longleaf pines were selected over slash pine 72% of the time vs 22% (Porter and Labisky 1986). The USFS forest types avoided by RCWs were bottomland hardwoods/yellow pine mix, slash pine/hardwoods mix and forest type unknown. These were all slightly avoided for the weighted overlay scale. The first two variables are associated with higher percentage of hardwoods than what is tolerated by RCWs while the other, forest type unknown, is most commonly associated with areas of open water. RCWs again selected for stands greater than 70 years old.

The USFS soil classes avoided were B-Rutlege and Plummer, G-Foxworthy, and unknown CRIFF series-Hosford, whereas soil classes selected were BCD – Plummer, Sapelo, and Pottsburg, and E-Goldsboro. E-Goldsboro was strongly preferred, Hosford was very strongly avoided and all others were only slightly preferred or avoided. These soil selection patterns are similar to those found with the coarse scale analysis where BCD and E represent a mix of savannas with flatwoods and uplands. The B CRIFF series is native to areas with depressions, stream terraces and broad wet flats which would not house suitable habitat for RCWs and were found avoided in the FWC results (hardwood swamps and mixed wetland forests). The G CRIFF series is associated with sandhills mixed with longleaf pines or sand pines; it is surprising that G-Foxworthy was avoided. In ONF, almost all sandhill forests are the CRIFF G series, but RCWs are only found on the Astatula sand soil type. All soil types selected and avoided in the final fine scale model were found only in ANF. The ANF has the largest representation of RCW populations and is the only recovered population. The samples taken for this analysis represented a 20% sample of all forests, giving the heaviest weight to the most successful forest. Therefore, it is not surprising that the results are in favor of soils found only in ANF.

Objective 2: To Map the Location of Habitat Features Selected by RCWs in Other National Forests in Florida to the Region Abandoned by RCWs in ONF

The vegetation in the Church Lake unit of ONF is extremely diverse (Figure 4-2, Table 4-3) compared to Riverside Island and Paisley Woods (study areas B and C). While the region used by the current population of RCWs consists of 90% sandhills, the Church Lake unit only has 11% in sandhills. Cluster locations for translocations cannot be based on the habitat conditions currently used by RCWs in study areas B and C and therefore I considered the habitat characteristics of areas used by RCWs in other national forests in Florida.

The Church Lake unit has 7,400 ha of sandhills and flatwoods ecosystems. The weighted overlay analysis categorized all variables on a scale from low to high preferences based on suitability of the variables determined in objective one and this was then mapped over that portion of the Church Lake area that may potentially be managed for RCWS (sandhills and flatwoods).

The weighted overlay scale represented how RCW selected habitat features in a range from very strongly avoided to very strongly preferred. The results from the first objective consistently found variables to be slightly preferred or slightly avoided, rather than more extreme options such as moderately, strongly, and very strongly preferred or avoided. The lack of strong preferences or avoidances may have been caused by the variation in habitat selection of RCWs from one national forest to another. ANF has the largest population of RCWs and the only forest with a recovered population and therefore had the most influence in the analysis (67%; 320 sample points out of 480). OsNF was given the second most influence with 100 sample point (21%) and Ocala last with 60 sample points (13%).

When the results were mapped onto study area A (figures 4-3 and 4-5), it becomes clear that a large portion of the study area could be considered as habitat for translocations. Depending on the quality of the habitat and its connectivity, a range of 8-54 clusters could be managed for. The recovery plan (USFWS 1985) for RCWs describes the quality of habitat based on a number of variables: pine and hardwood basal area and stems per hectares; the stems per hectare and basal area of large pines; the percent of ground cover species including wiregrass and herbs; the density of hardwoods found in the midstory; and the species found in the overstory. Areas of lower quality habitat would require larger habitat range per cluster than areas of higher quality habitat to ensure proper amount foraging areas. Given the current condition of vegetation in the Church Lake area, this region would probably be considered low quality habitat, and therefore capable of providing habitat for 8-32 clusters.

Management Implications

Consideration for the expansion of red-cockaded woodpecker habitat in the Church Lake management unit of the Ocala National Forest (Figure 1-1; study area A) should take into account vegetative communities selected by RCWs on other National Forests in Florida. With the completion of future plans for RCW habitat restoration in Church Lake, there is a potential for the introduction of 32 clusters into the area. The restoration should be based on maintenance of old growth longleaf pines >70 years old found in sandhills and pineland habitats. Hardwood swamps and mixed wetland forest should be avoided when planning recruitment cluster locations. Future research should explore other variables significant to RCW habitat selection. Additionally, distance to avoided habitat in respect to ecotone tolerance was not studied here and could affect management decisions for placement of recruitment clusters. Further research should review areas of transitional zones between avoided and selected areas to test the tolerance of RCWs for ecotones.

Table 4-1. Variables that differentiated between used and available habitat for red-cockaded woodpeckers (RCWs) from all national forests in Florida at a coarse scale using data from Florida Natural Areas Inventory (FNAI), Cooperative Research in Forest Fertilization (CRIFF), and stand initiation dates. Parameter estimate ± standard error (SE), and odds ratios with 95% confidence intervals (CI)

			Adjusted odds ratio		
Coarse scale	Parameter value	Parameter estimate ± SE	Estimate	95% CI	*P*
FNAI class	Freshwater forested wetlands	-0.09 ± 0.01	0.92	0.89–0.95	<0.0001
	High pine/scrub	0.02 ± 0.01	1.02	1.01–1.04	0.0028
	Hardwood forested uplands	-0.32 ± 0.14	0.73	0.55–0.95	0.0200
	Pine flatwoods/dry prairie	0.04 ± 0.01	1.04	1.02–1.05	<0.0001
Stand initiation	1899–1908	0.06 ± 0.02	1.06	1.02–1.11	0.0036
	1909–1918	0.07 ± 0.01	1.07	1.04–1.09	<0.0001
	1919–1928	0.06 ± 0.01	1.06	1.04–1.08	<0.0001
	1928–1938	0.04 ± 0.01	1.04	1.02–1.05	<0.0001
CRIFF	BCD-Savannas/flatwoods**	0.09 ± 0.02	1.09	1.06–1.13	<0.0001
	BD-Savannas/flatwoods**	0.19 ± 0.06	1.21	1.08–1.35	0.0010
	C-Flatwoods**	0.02 ± 0.01	1.02	1.00–1.03	0.0131
	E-Uplands**	0.63 ± 0.25	1.88	1.16–3.04	0.0102

**Variables included in the logistic regression but not entered in the weighted overlay analysis.

Table 4-2. Variables that differentiated between used and available habitat for RCWs from all national forests in Florida at a fine scale using Florida Fish and Wildlife Conservation Commission (FWC) forest type, United States Forest Service (USFS) forest type, stand initiation dates and USFS soil type. Parameter estimate ± standard error (SE), and odds ratios with 95% confidence intervals (CI)

Fine Scale	Parameter value	Parameter estimate ± SE	Adjusted odds ratio Estimate	95% CI	*P*
FWC forest type	Hardwood swamp	-0.17 ± 0.06	0.85	0.75–0.95	0.0054
	Mixed wetland forest	-0.17 ± 0.04	0.85	0.78–0.92	0.0002
	Pinelands	0.05 ± 0.01	1.05	1.03–1.08	<0.0001
	Sandhills*	0.07 ± 0.02	1.07	1.04–1.11	<0.0001
USFS forest type	FT46 – Bottomland hardwood/yellow pine	-0.10 ± 0.04	0.91	0.83–0.99	0.0285
	FT21 – Longleaf pine	0.07 ± 0.01	1.07	1.05–1.10	<0.0001
	FT23 – Pond cypress	0.10 ± 0.04	1.11	1.03–1.19	0.0036
	FT22 – Slash pine*	0.02 ± 0.01	1.02	1.00–1.04	0.0954
	FT14 – Slash pine/hardwoods	-0.07 ± 0.03	0.93	0.88–0.99	0.0159
	FT0 – Unknown	-0.10 ± 0.03	0.91	0.85–0.97	0.0024
Stand initiation	1909–1918	0.05 ± 0.02	1.06	1.02–1.09	0.0033
	1919–1928	0.06 ± 0.01	1.06	1.04–1.09	<0.0001
	1929–1938	0.05 ± 0.01	1.05	1.03–1.07	<0.0001
USFS soil type	B – Rutlege and Plummer**	-0.04 ± 0.02	0.96	0.93–1.00	0.0383
	BCD – Plummer, Sapelo, and Pottsburg**	0.23 ± 0.05	1.26	1.13–1.40	<0.0001
	E – Goldsboro**	1.20 ± 0.49	3.31	1.27–8.65	0.0145
	G – Foxworthy**	-0.06 ± 0.03	0.94	0.88–1.00	0.0628
	Unknown – Hosford**	-2.83 ± 0.90	0.06	0.01–0.35	0.0017

*Correlated variables not included in the logistic regression but entered in the weighted overlay analysis. **Variables included in the logistic regression but not entered in the weighted overlay analysis.

Table 4-3. Percent coverage of each ecosystem across all three study areas in Ocala National Forest (ONF) in hectares (ha)

Ecosystems	Riverside	Paisley	Church Lake
Non-forested	15 (0%)	22.6 (0%)	140.3 (1%)
Pine flatwoods	0 (0%)	112.5 (2%)	5043.4 (25%)
Private	150.3 (2%)	125.5 (2%)	7791.1 (38%)
Sandhills	5520.8 (89%)	4944.2 (93%)	2309.3 (11%)
Scrub	436.4 (7%)	39.6 (1%)	781.8 (4%)
Swamp	16.3 (0%)	0.0 (0%)	2059.0 (10%)
Water	32.2 (1%)	19.2 (0%)	1158.5 (6%)
Wet Prairies	0 (0%)	39.6 (1%)	1215.3 (6%)
Total	6171.0	5303.2	20498.8

Table 4-4. Number of RCW clusters that could be supported in Church Lake using the variables selected in the coarse and fine scale analyses and the recovery plan's description of size of home ranges based on quality of habitat

Scale	Habitat quality	Area containing selected habitat features (ha)	Potential number of clusters supported
Coarse	High (requires 49 ha)	2654	54
	Low (requires 80–120 ha)	1737–2314	28–32
Fine	High (requires 49 ha)	1934	39
	Low (requires 80–120 ha)	1016–1530	8–19

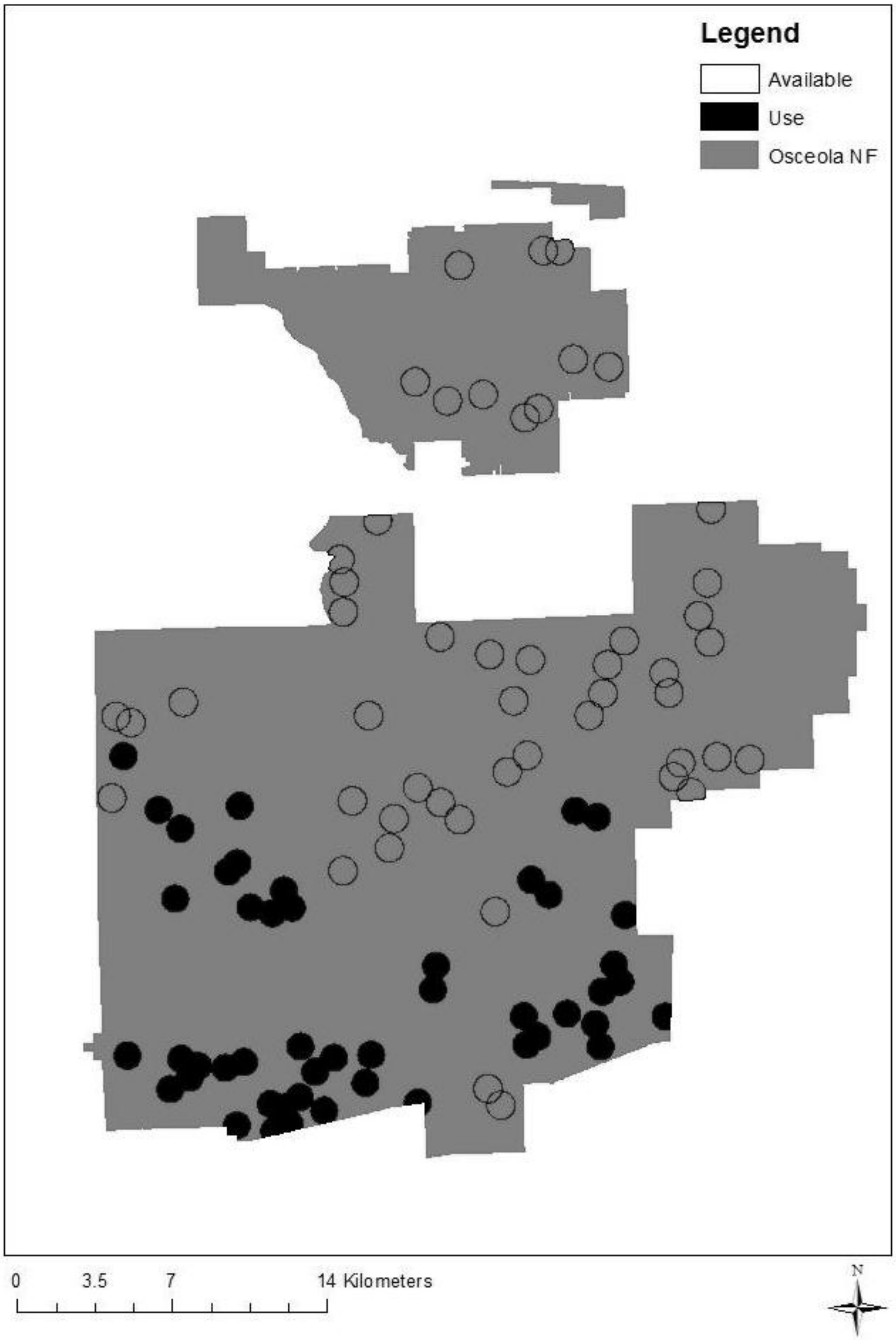


Figure 4-1. Map of the Osceola National Forest (OsNF) with black circles representing buffers around current and historical red-cockaded woodpecker (RCW) sites (used areas), and empty circles representing randomly selected sites (available areas).

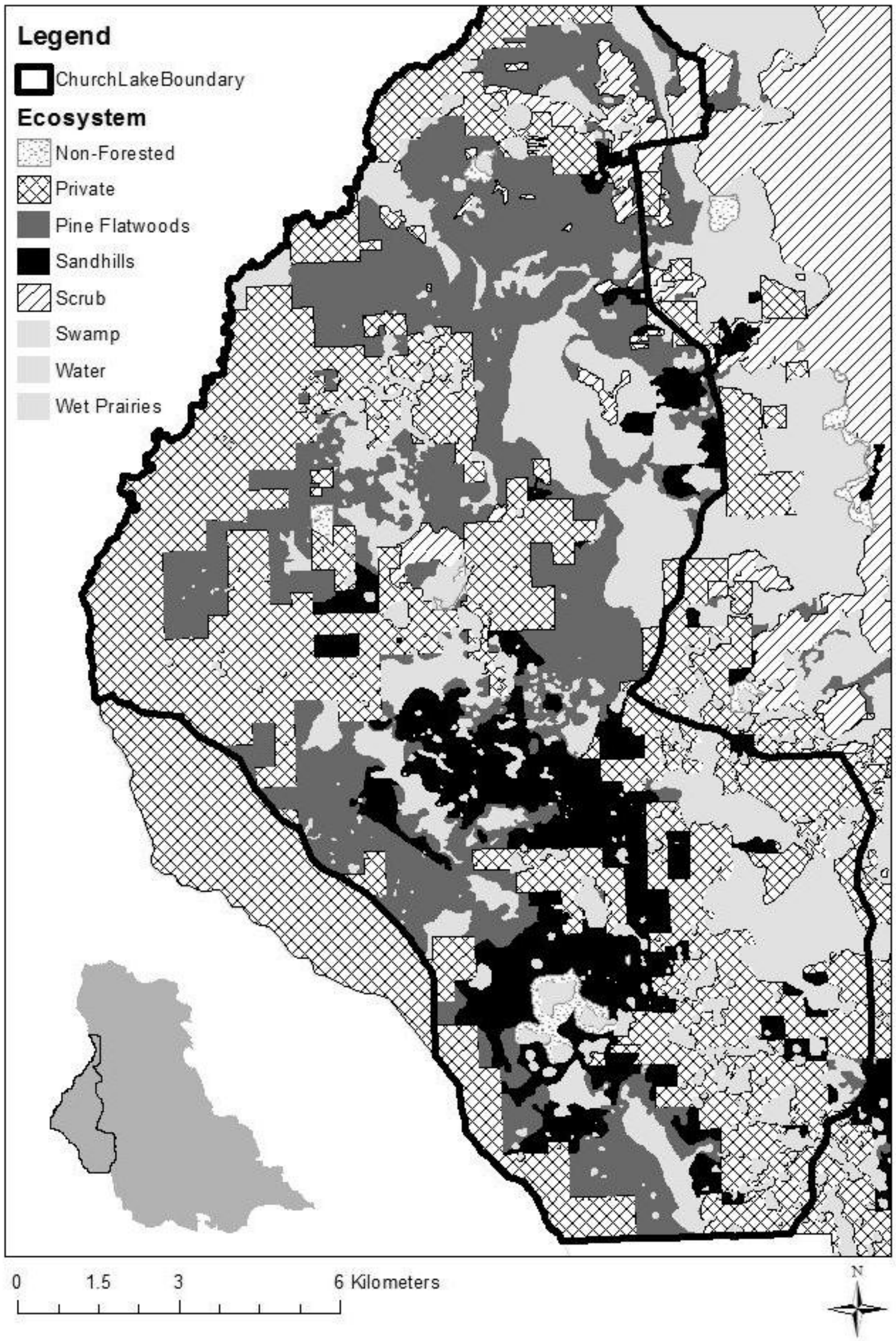


Figure 4-2. Ecosystem distribution of Church Lake management unit (study area A) in the western region of the Ocala National Forest (ONF).

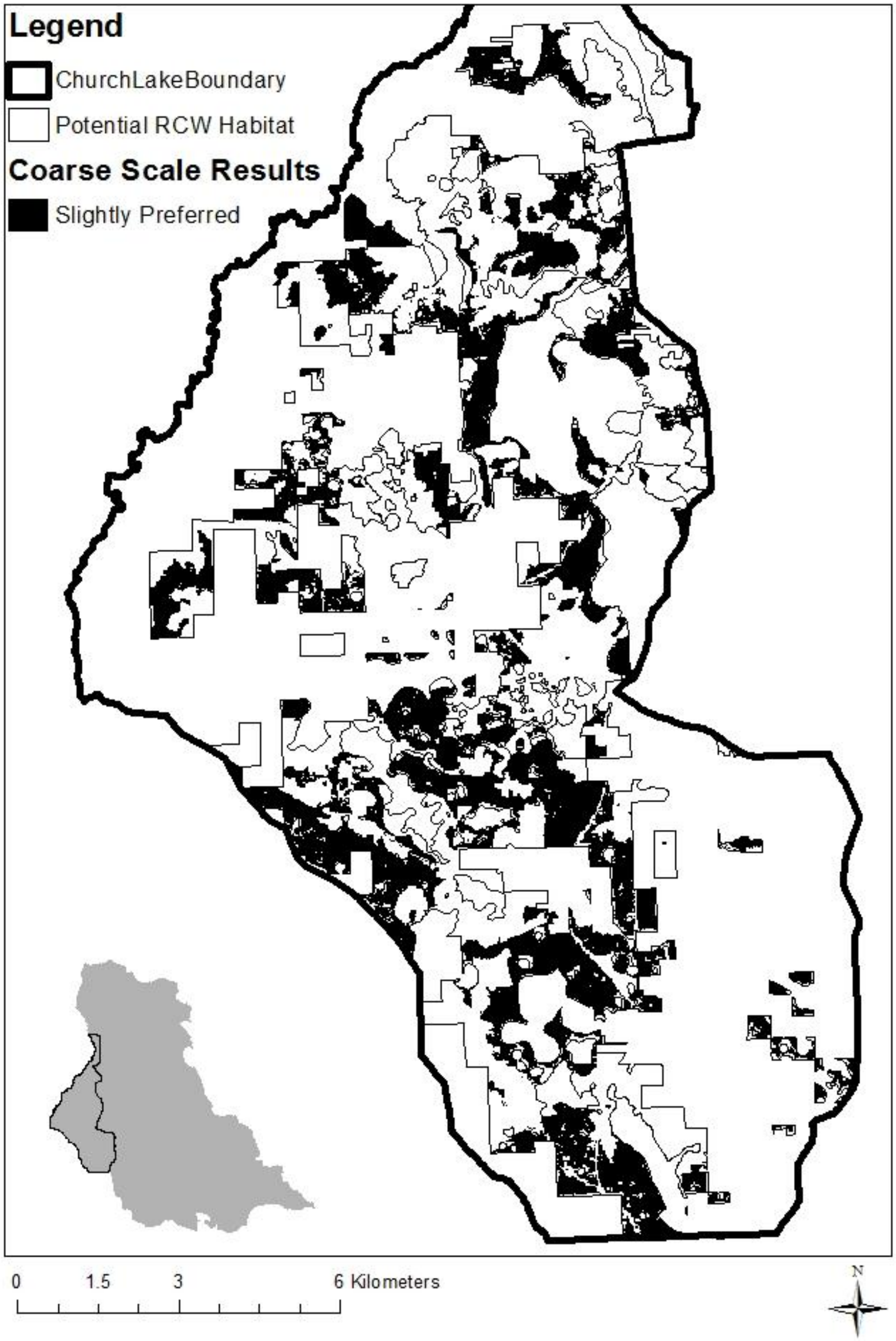


Figure 4-3. Weighted overlay coarse scale results of RCW habitat use mapped onto potential RCW habitat areas in study area A (Church Lake boundary). Potential RCW habitat areas are sandhill and pine flatwoods ecosystems.

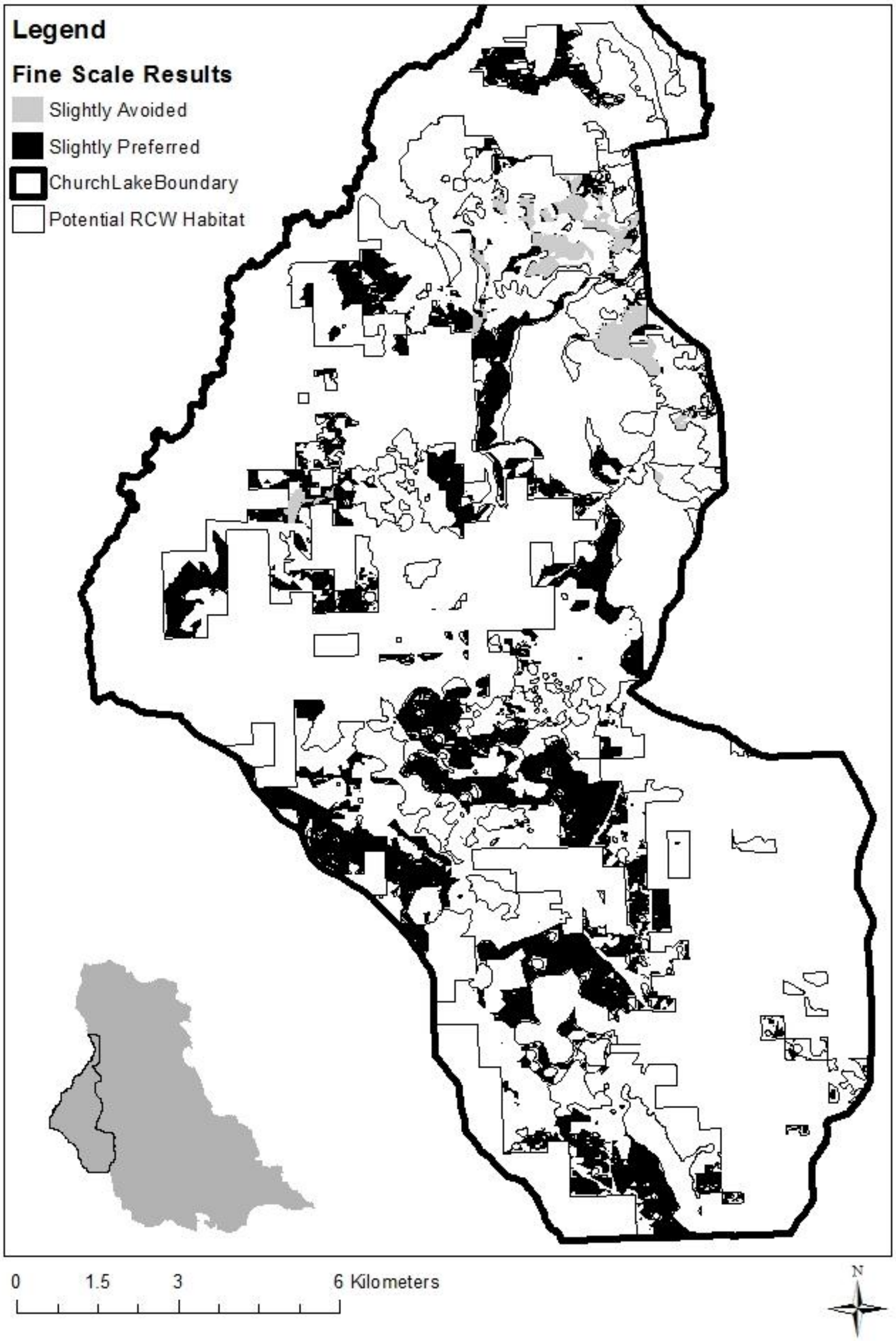


Figure 4-4. Weighted overlay fine scale results of RCW habitat use mapped onto potential RCW habitat areas in study area A (Church Lake boundary). Potential RCW habitat areas are sandhill and pine flatwoods ecosystems.

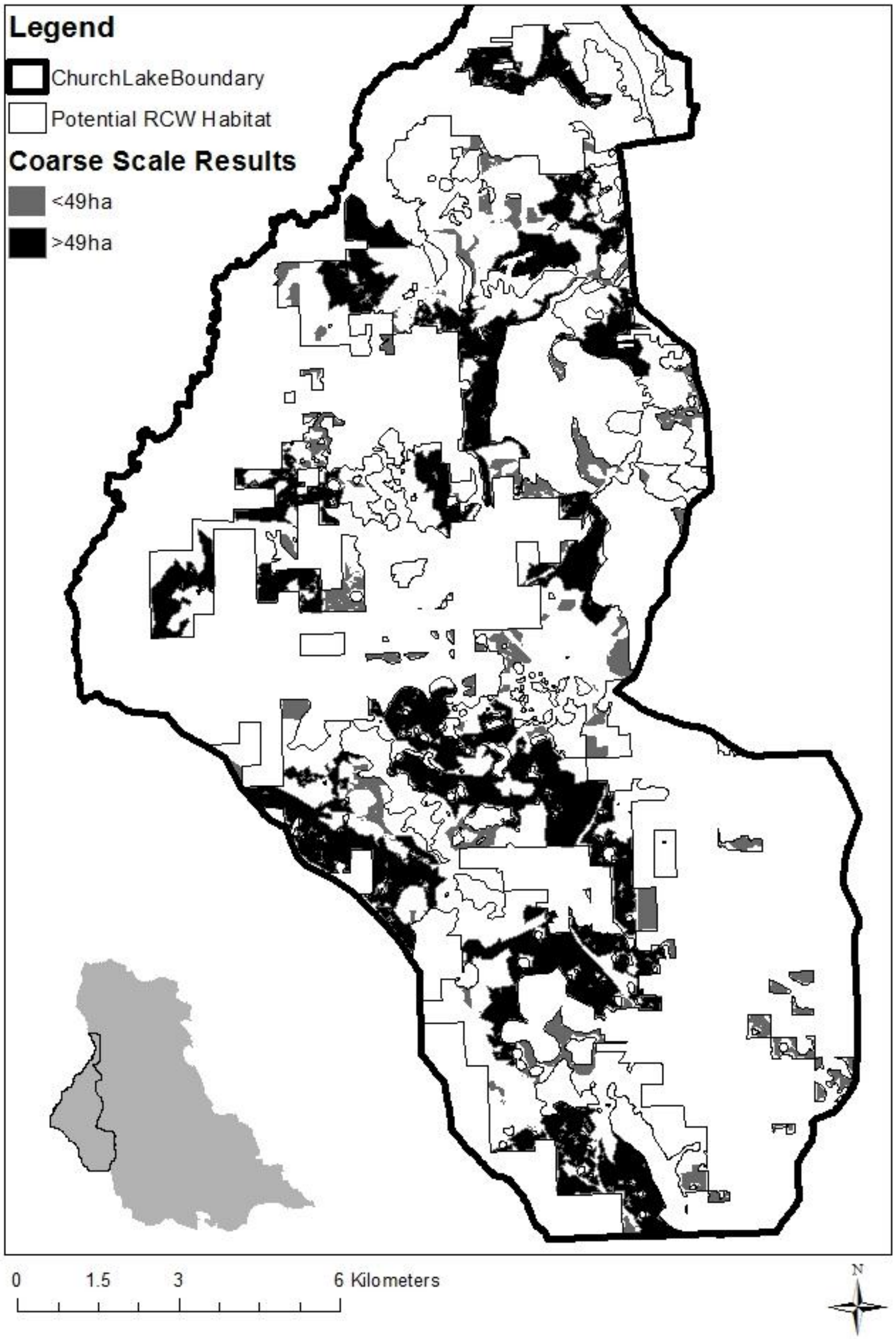


Figure 4-5. Coarse scale results of RCW habitat use from weighted overlay analysis mapped onto study area A and dissolved to identify large contiguous blocks of potential habitat area. Connected areas >49 ha (highlighted in black) are recommended for consideration as future nesting areas.

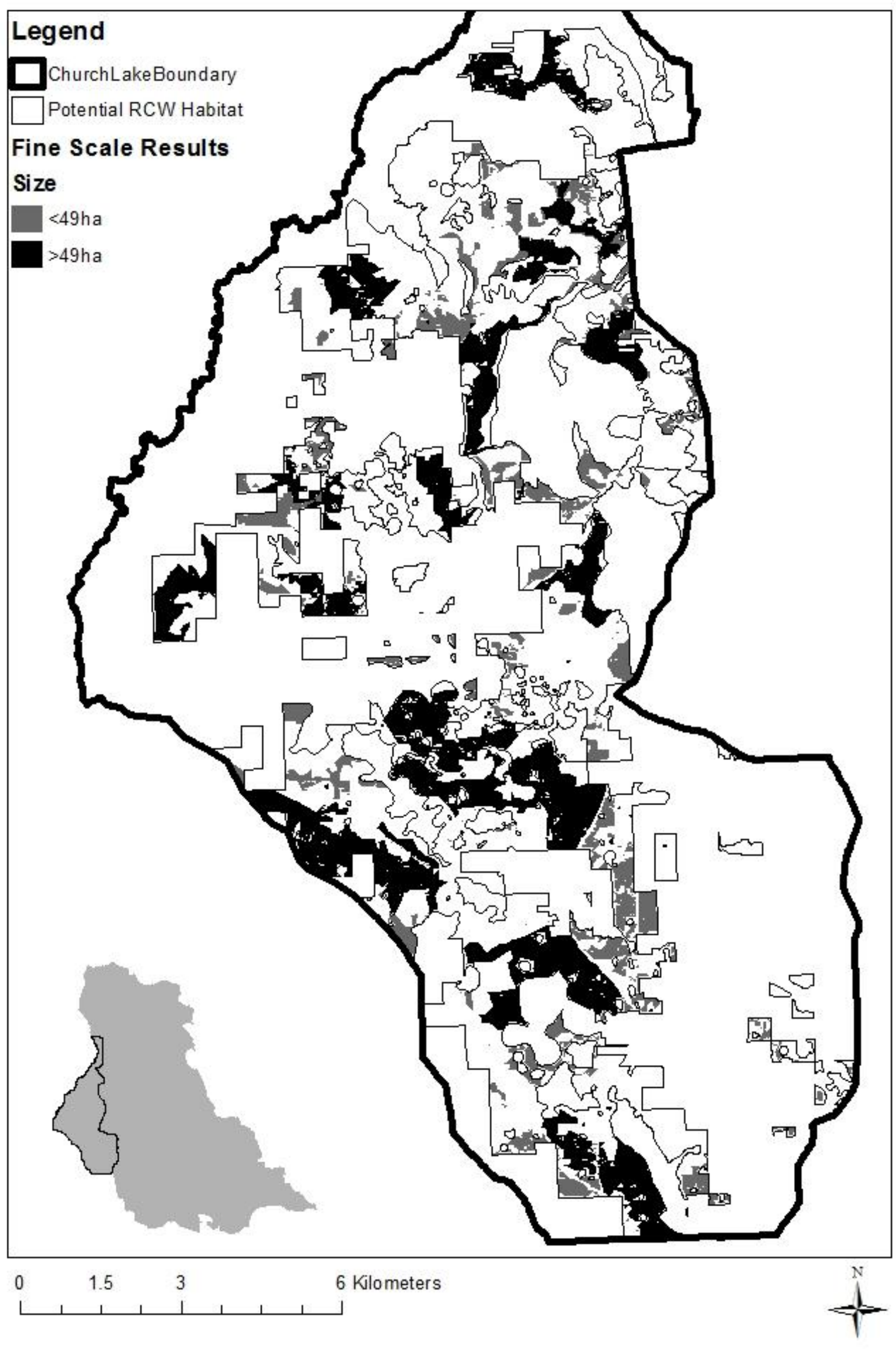


Figure 4-6. Fine scale results of RCW habitat use from weighted overlay analysis mapped onto study area A and dissolved to identify large contiguous blocks of potential habitat area. Connected areas >49 ha (highlighted in black) are recommended for consideration as future nesting areas.

CHAPTER 5
GENERAL CONCLUSION

The red-cockaded woodpecker's range currently spans the southeastern United States with isolated pockets of potential breeding habitat. I initiated this study to gain a better understanding of the biology of these birds near the southern edge of the species range, in the Ocala National Forest (ONF). I developed two objectives to determine the influential factors driving productivity of red-cockaded woodpeckers (RCWs) in the ONF: (1) examine the relationship between the 2010 breeding season and the current habitat conditions and (2) compare relationships across a ten year period (2001 – 2010) between RCW productivity and various habitat conditions. In the first objective, I used 48 active and inactive clusters out of 91 available based on a stratified random selection of RCW productivity and fire frequency. Variables tested within each cluster included stand-scale features, landscape-scale features, management practices, spatial characteristics and productivity which was used as the response variable. Productivity was evaluated three ways: active vs inactive clusters, active clusters successfully produced fledglings vs unsuccessful nest attempt, and active clusters successfully fledging one vs more than one offspring. Logistic regression in SAS (v 9.2, 2008) was used to test all variables. Results demonstrated that decreasing the percent bareground and hardwood basal area increased the odds of having a potential breeding group. Increasing the cover of shrubs >1.5 meter (m) also increased the odds. None of the variables investigated were successful in distinguishing between active clusters successfully producing fledglings vs unsuccessful nest attempts. Increasing the distance to the nearest neighbor and the percent cover of shrubs <1.5 m increased the odds of having two rather than one fledgling. Further research should be conducted on how height and density of oak species in the groundcover layer effect the habitat RCWs select or avoid. The second objective used data from all available clusters. Variables tested included landscape-scale features, management practices, spatial characteristics, precipitation and productivity as the response variable. Productivity was split in the same manner as above and tested using generalized linear mixed models (Glimmix) in SAS (v 9.2, 2008) which allows for repeated measures over time. Results showed that increasing the proportion of interior habitat or decreasing the proportion of non-sandhill habitat (correlated variables) and translocating a single bird to a single resident bird increased the odds of having a potential breeding group. Increased annual rainfall decreased the odds but this variable represents the forest as a whole and would be a stronger predictor if more regions of the forest were sampled. The odds of having at least one fledgling produced in a cluster increased as the proportion of interior habitat increased, and also as the number of years since last hardwood treatment increased. Additionally, research on the effects of hardwood treatment over time on RCW productivity is suggested.

In conclusion, habitat features of the ONF area similar to habitat described as ideal for RCWs in the recovery plan (USFWS 1985) except for one unique feature of ONF that is influencing habitat selection not mentioned in the recovery plan. The largest sand pine scrub ecosystem located in ONF is completely surrounding an active population of RCWs while the other population is surrounded by other unsuitable habitat. Within the interior of the habitat, birds are responding normally by increasing the number of potential breeding group over 5% annually and successfully fledgling offspring. These birds are avoiding the ecotone between unsuitable habitat and longleaf pine sandhills creating marginal habitat on the forest's edge.

The Ocala National Forest had only 7 potential breeding groups of red-cockaded woodpeckers in 1993. Intensive translocations were implemented to bolster an unstable subpopulation where 81 RCWs were translocated to 50 clusters from 1993 to 2005 with a 47% success over 13 years. The first objective of this portion of my study was to examine changes in productivity in fledgling success or potential breeding groups in the vicinity of the translocation at two spatial scales: 2.1 kilometers (km) or 4 nearest neighbors. The paired t-tests revealed the 16 selected translocations had no effect on improving fledgling productivity within two years but had a slight effect on increasing the number of potential breeding groups (PBGs) at the 2.1 km distance. Neither was improved at the 4 nearest neighbor range. Additional research should examine longer time periods to assess whether productivity of translocated individuals increases as time since release increases. The second objective investigated the influence of gender, age and type of translocation of the newly released birds on their site fidelity. Site fidelity seemed dependent on number of available territories and resident PBGs near the release site, with birds showing higher fidelity in the region with fewer available territories and more resident PBGs nearby. Success of retaining translocated birds was similar among gender and type with some difference in region. RCWs on average dispersed 1.9 km from the release site and had successful nest attempts after the age of 2. The type of translocation and region was important when comparing nest success: birds released in pairs had a 29% success rate compared to single bird releases with a 17% success rate and 34% of birds in Riverside Island produced offspring compared to

15% in Paisley Woods. Because of the social characteristics of this species, it is recommended to continue translocation through paired releases near other resident birds. Further research should be conducted to determine if there is a significant benefit to the population from birds dispersing beyond the 2.1 km distance and 2 year time frame I evaluated with objective 1. Additionally, research on translocated birds, both male and female, should test whether translocating older birds results in a higher success rate than I found with translocating first year hatchlings.

The Ocala National Forest is considering the expansion of red-cockaded woodpecker habitat in the Church Lake management unit (Figure 1-1; study area A). Doing so will provide three sub-populations in ONF and help drive future habitat restoration activities to support this endangered species. The history of the Church Lake area shows a historical population of RCWs extirpated in 1989. Reasons for loss are unknown but are assumed from a decline in quality habitat as areas were managed for timber harvesting. The current habitat is a mosaic pattern of varying ecosystems including non-forest, private lands, pine flatwoods, sandhills, scrub, swamp, water and wet prairies (Figure 4-2). RCW management is limited to pine flatwoods and sandhills which exists in only 7,400 ha of varying qualities of habitat in this region. I determined which habitat variables distinguish between used and available areas in other national forests in Florida to determine the best method for selecting suitable habitat areas for future translocations in Church Lake. Forty-five percent of Church Lake's potential RCW habitat area was selected for according to RCW selection criteria determined though my analyses. This potentially could result in over 50 new potential groups in the third subpopulation on Ocala National Forest. Further research should review areas of transitional zones between avoided and selected areas to test the tolerance of RCWs for ecotones.

APPENDIX A
VARIABLES TESTED AGAINST RED-COCKADED WOODPECKER PRODUCTIVITY IN 2010

Table A-1. Means with standard deviation and range of each variable tested in Chapter 2 objective 1. Data collected in 2010. Model 1 tested the presence of active potential breeding groups (PBGs) in a cluster. Model 2 tested for nest success among active PBGs. Model 3 tested the scale of nest success from Model 2.

	Model 1		Model 2		Model 3	
Variables	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Fledglings produced (Count)	0.4 (0.5)	0–1	0.5 (0.5)	0–1	1.0 (0)	1–2
Stand scale features						
Pine basal area (ft^2/ac)	42.4 (15.5)	0–71	43.1 (16.6)	0–71	42.9 (19.6)	0–71
Hardwood basal area (ft^2/ac)	4.6 (4.8)	0–25	3.7 (4.7)	0–25	3.1 (3.4)	0–14
Pine trees per acre	14.5 (6.8)	0–28	15.8 (6.2)	3–28	15.7 (6.7)	8–28
Dominant midstory	0.5 (0.8)	0–2	0.5 (0.8)	0–2	0.3 (0.7)	0–2
Wiregrass (%)	0.2 (0.1)	0.1–0.6	0.3 (0.1)	0.1–0.6	0.3 (0.1)	0.1–0.6
Herb (%)	0.2 (0.1)	0.0–0.3	0.1 (0.1)	0.0–0.3	0.1 (0.1)	0.1–0.3
Shrub <1.5 m (%)	0.2 (0.1)	0.1–0.4	0.2 (0.1)	0.1–0.4	0.2 (0.1)	0.1–0.3
Shrub >1.5 m (%)	0.0 (0.0)	0.0–0.2	0.0 (0.0)	0.0–0.2	0.0 (0.0)	0.0–0.1
Pine litter (%)	0.4 (0.1)	0.1–0.6	0.4 (0.1)	0.1–0.6	0.4 (0.1)	0.2–0.6
Bareground (%)	0.2 (0.1)	0.0–0.4	0.1 (0.1)	0.0–0.4	0.1 (0.1)	0.0–0.3
Landscape scale features						
Size of islands (ha)	4493.1 (1399.5)	2386.4–6055.3	4467.1 (1360.5)	2386.4–6055.3	4730.1 (1039.9)	3957.0–6055.3
Interior (%)	0.7 (0.3)	0.1–1.0	0.8 (0.3)	0.1–1.0	0.8 (0.3)	0.1–1.0
Non sandhill (%)	0 (0.1)	0–0.3	0 (0.1)	0–0.3	0 (0.1)	0–0.3

Table A-1. Continued

Variables	Model 1 Mean (SD)	Range	Model 2 Mean (SD)	Range	Model 3 Mean (SD)	Range
Management practices						
Prescribed fires (count)	4.3 (1.2)	3–8	4.0 (0.8)	3–6	4.2 (1)	3–6
Year since last Rx fire (count)	1.3 (0.4)	1–2	1.3 (0.5)	1–2	1.3 (0.5)	1–2
Hardwood trtmnts (count)	0.2 (0.4)	0–1	0.2 (0.4)	0–1	0.3 (0.5)	0–1
Years since last hardwood trtmnt (count)	13.1 (4.0)	1–15	13.0 (3.9)	1–15	12.5 (4.5)	1–15
Artificial cavities (count)	5.6 (2.9)	1–19	6.0 (3.2)	1–19	5.1 (1.7)	1–7
Ratio of artificial cavities to naturals (%)	0.7 (0.2)	0.1–1	0.7 (0.2)	0.1–1	0.7 (0.3)	0.1–1
Spatial characteristics						
Nearest neighbor (m)	0.7 (0.2)	0.4–1.4	0.7 (0.2)	0.4–1.3	0.7 (0.2)	0.4–1.2
Overlapping neighbors (count)	1.1 (0.8)	0–3	1.2 (0.9)	0–3	1.2 (0.9)	0–3
Overlapping neighbors (%)	0.1 (0.2)	0–0.7	0.2 (0.2)	0–0.5	0.2 (0.2)	0–0.5
Translocations (count)	0 .0 (0.1)	0–1	0.0 (0)	0–0	0.0 (0)	0–0

APPENDIX B
NATIONAL FORESTS OF FLORIDA – VEGETATIVE DESCRIPTION

Table B-1. Vegetative description from Florida Natural Areas Inventory (FNAI), Florida Land Use, Land Cover Classification System (FLUCCS), Florida Fish and Wildlife Conservation Commission (FWC) 2003, and the United States Forest Service's (USFS) Forest Type

FNAI	FWC	USFS forest type	
Freshwater forested wetlands	Bay swamp	68	Sweetbay/swamp tupelo/red maple
Freshwater forested wetlands	Bottomland hardwood forest	46	Bottomland hardwood/yellow pine
Freshwater forested wetlands	Bottomland hardwood forest	61	Swamp chestnut oak/cherry bark oak
Freshwater forested wetlands	Bottomland hardwood forest	65	Overcup oak water hickory
Freshwater forested wetlands	Cypress swamp	23	Pond cypress
Freshwater forested wetlands	Cypress swamp	24	Baldcypress
Freshwater forested wetlands	Cypress swamp	67	Baldcypress/water tupelo
Freshwater forested wetlands	Cypress swamp	79	Slash pine/cypress
Freshwater forested wetlands	Hardwood swamp		
Freshwater forested wetlands	Mixed wetland forest		
Freshwater non–forested wetlands	Freshwater marsh/wet prairie	98	Undrained flatwoods
Freshwater non–forested wetlands	Open water		
Freshwater non–forested wetlands	Shrub/brushland	99	Brush species
Freshwater non–forested wetlands	Shrub swamp		
Hardwood forested uplands	Hardwood hammocks and forest	47	White oak/black oak/yellow pine
Hardwood forested uplands	Hardwood hammocks and forest	53	White oak/northern red oak/hickory
Hardwood forested uplands	Hardwood hammocks and forest	58	Sweetgum/yellow poplar
Hardwood forested uplands	Hardwood hammocks and forest	62	Sweet gum/oak
Hardwood forested uplands	Hardwood hammocks and forest	77	Oak hammock
Hardwood forested uplands	Hardwood hammocks and forest	97	Live oak
Hardwood forested uplands	Mixed pine/hardwood forest	14	Slash pine/hardwood

Table B-1. Continued

FNAI	FWC	USFS forest type	
Hardwood forested uplands	Mixed pine/hardwood forest	18	Pond pine hardwood
Hardwood forested uplands	Mixed pine/hardwood forest	19	Sand pine hardwood
Hardwood forested uplands	Mixed pine/hardwood forest	26	Longleaf pine/hardwood
Hardwood forested uplands	Mixed pine/hardwood forest	40	Hardwood/pond pine
Hardwood forested uplands	Mixed pine/hardwood forest	44	Southern red oak/yellow pine
Hardwood forested uplands	Mixed pine/hardwood forest	48	Northern red oak/hickory-yellow pine
Hardwood forested uplands	Mixed pine/hardwood forest	64	Laurel oak willow oak
High pine/scrub	Xeric oak scrub	57	Scrub oak
High pine/scrub	Sand pine scrub	34	Sand pine
High pine/scrub	Sand pine scrub	49	Bear-oak/southern scrub oak/yellow pine
High Pine/Scrub	Sandhills	21	Longleaf pine
Pine flatwoods/dry prairie	Dry prairie		
Pine flatwoods/dry prairie	Pinelands	22	Slash pine
Pine flatwoods/dry prairie	Pinelands	25	Yellow pine
Pine flatwoods/dry prairie	Pinelands	31	Loblolly pine
Pine flatwoods/dry prairie	Pinelands	36	Pond pine
Ag (FLUCCS)	Improved pasture		
Ag (FLUCCS)	Row/field crops		
Urban (FLUCCS)	Extractive		
Urban (FLUCCS)	High impact urban		
Urban (FLUCCS)	Low impact urban		
Barren (FLUCCS)	Bare soil/clearcut		
Barren (FLUCCS)	Sand/beach		

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BIOGRAPHICAL SKETCH

Elizabeth's life as a student has been a long and prosperous journey. As an forestry-undergraduate student, she has had the pleasure of traveling around the country during professional conferences, exploring forests and gaining a new perspective. Originally from Florida, she never knew it smelled like Christmas all year long in a Douglas-fir forest and enjoyed light snow fall while wearing light clothing because of the difference in relative humidity. As a wildlife-graduate student, her mentality changed to a more independent, research oriented and task focused mind set. Still in Florida, she realized the importance of habitat to threatened and endangered wildlife species. She developed her education to broaden her horizon of habitat restoration and management. Elizabeth applied her thesis work to the current red-cockaded woodpecker program on Ocala National and then beyond the boundaries of her study area to connect with other agencies and continued building on the mission of conservation.