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Avian Use of a Bottomland Hardwood Afforestation Site in the Red River Alluvial Valley

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**AVIAN USE OF A BOTTOMLAND HARDWOOD
AFFORESTATION SITE IN THE RED
RIVER ALLUVIAL VALLEY**

by

Colby W. Sharp, B.S.F.

A Thesis Presented in Partial Fulfillment
of the Requirements of the Degree
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River Alluvial Valley**

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ABSTRACT

Bottomland hardwood forests (BHF) cover about 2.8 million hectares of the original 10 million hectares that once existed in the southeastern United States. These losses have led to an emphasis on afforestation of retired agricultural land. Research was needed to evaluate changes in wildlife communities as these afforested stands progress through succession. To assess the avian community at this 25-year-old afforested BHF, I conducted point count surveys at 28 point locations across seven forest types, six times during the 2016–2018 avian breeding seasons. My research objectives were to determine: (1) if avian density and diversity varied among the dominant forest types that have developed in the research site; and (2) how this BHF compared to mature BHF of the southeastern United States that were at least 50 years old. Results indicated that avian density varied among forest types showing five statistical groupings, with ranges in density from 22.836 to 6.634 birds/ha among forest types. Avian diversity analyses indicated no significant difference among the seven forest types. Results of comparative analyses indicated that the research site was 68% similar in avian species composition to mature BHF in the southeastern United States, thus not meeting the goal of 75–85% similarity. My management recommendation is to allow this site to continue on its current path of increasing in similarity as it has shown to have done over the past three breeding seasons, with forest management only taking place if non-native tree species begin to establish in open canopy areas.

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DEDICATION

This thesis is dedicated to my loving wife Christin and my family. This work could have not been done without their prayers, encouraging words, and endless support through the entirety of this research.

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CHAPTER 1

INTRODUCTION

1.1 Background

Bottomland hardwood forests (hereafter BHF) occur in floodplains throughout the southeastern United States (Gosselink et al. 1990). These forests have saturated soils during some parts of the year, with flooding usually occurring during late winter through early spring (Gosselink et al. 1990; Conner and Sharitz 2005). BHF are dominated by a variety of hardwood species, such as river birch (*Betula nigra*), overcup oak (*Quercus lyrata*), and water tupelo (*Nyssa aquatica*; Clark and Benforado 1981). These forests develop via hydrologic factors (e.g., movement, distribution, water quality) and geomorphologic processes (e.g., weathering, erosion, deposition of landforms) associated with frequency and duration of floodwaters in the bottom, and topography of those bottoms (Gosselink et al. 1990). These factors play a critical role in BHF development over time (Gosselink et al. 1990).

The historic range of BHF included approximately 10 million ha of the southeastern United States, with the largest portion found in the Lower Mississippi Alluvial Valley (hereafter LMAV; Fig. 1.1; Stanturf et al. 1998). The earliest documented losses of BHF were during the 1700s when European settlers cleared and drained these sites for agricultural crop production to take advantage of their fertile soils (King et al.

2005). Prior to this, conditions in these early ecosystems were not well documented, but expeditions by European explorers from the mid-1500s to the late 1600s noted an untouched landscape with an abundance of canebrakes near rivers and fertile floodplains with areas of large oaks (King et al. 2005).

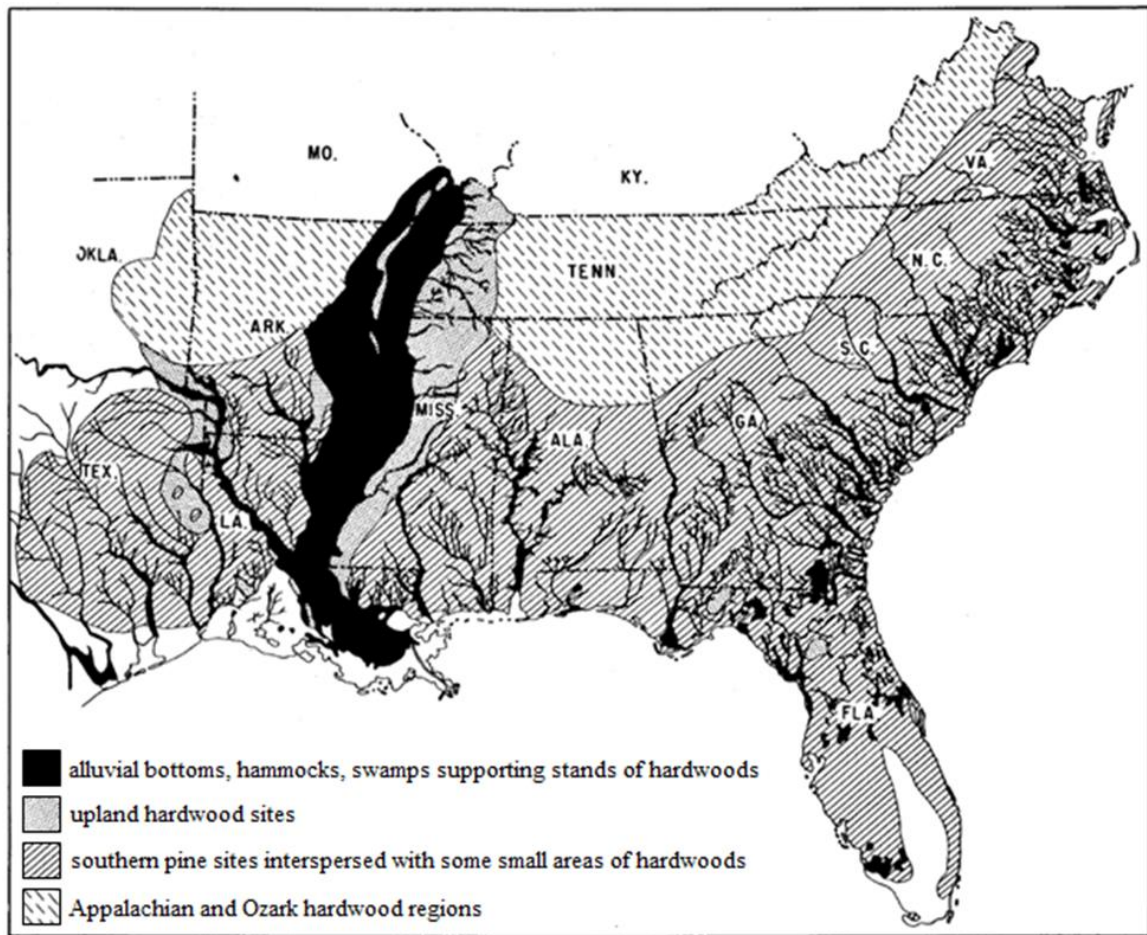


Figure 1.1: Historical extent of bottomland hardwood forests in the southeastern United States (from Putnam et al. 1960).

Over the next 200 years, BHF experienced continuous deforestation and land use conversion (King et al. 2006). By the 1900s, only half of the original BHF were estimated to remain in the LMAV (King et al. 2006). BHF were also lost from 1900–1950 because of changes in hydrologic and geomorphic processes after the construction

of levees, drainage ditches, and channels (Fredrickson 2005; King et al. 2005). These changes reduced flooding in this flood-adapted environment and caused areas to dry out, making it easier for conversion to agriculture (Hupp 2000). Changes in hydrologic processes were evident soon after levee construction, but the lack of geomorphic processes was not noticed until later when lands were not replenished with natural sediments from waterways (Hupp 2000).

During the mid-1940s, clearing of BHF's increased when more efficient vehicles and roads replaced horses and oxen for transporting logs (Williams 2000). These clearing practices were commonly used throughout the southeastern United States, leaving only the most poorly-drained areas forested (Rudis 2001). The extent of clearing and conversion practices was evident in a 1967 Delta survey conducted in Mississippi in which the United States Forest Service documented 170,000 ha of forest land was converted to soybean fields in 10 years (Beltz and Christopher 1967). Currently, the extent of BHF's is approximately 26% of the original range (Hanberry et al. 2012). The greatest losses have been observed in the LMAV and eastern Texas, where only 2.8 million hectares of the original 10 million hectares of BHF's remain (King and Keeland 1999).

The fragmentation and loss of BHF's negatively influenced the distribution and abundance of wildlife adapted to these areas (Fredrickson 2005). As BHF's were cleared and open areas became more contiguous, the use of fencerows (i.e., uncultivated areas around a fence where vegetation is allowed to grow) by landowners declined, thus increasing forest fragmentation. Avian species associated with edge habitat, such as mourning dove (*Zenaida macroura*), loggerhead shrike (*Lanius ludovicianus*), and

northern bobwhite (*Colinus virginianus*), declined rapidly (Fredrickson 2005).

Populations of Louisiana black bear (*Ursus americanus luteolus*), a species once commonly found in BHF, also declined (Davidson et al. 2015). In 1992, the Louisiana black bear was listed as threatened under the Endangered Species Act of 1973 (Davidson et al. 2015). Due to conservation efforts throughout Louisiana, including that of BHF afforestation, the Louisiana black bear was delisted in April 2016 (Davidson et al. 2015). The re-establishment and conservation of existing BHF are crucial because, without them, many wildlife species would become threatened or extinct.

As BHF were cleared, the hydrology changed with the increased use of levees, ditches, and dams (Fredrickson 2005). Altering of hydrologic factors changed timing and extent of flooding, thus altering habitat for flood-adapted species. These flooded habitats offered year-round habitat for waterfowl, like hooded merganser (*Lophodytes cucullatus*) and wood duck (*Aix sponsa*), as well as over-winter habitat for species like the mallard (*Anas platyrhynchos*; Dickson 2001). Altering hydrology in these areas resulted in changes in distribution and habitat use by waterfowl. Though habitat and distribution were altered, conservation efforts in national wildlife refuges and wildlife management areas helped to maintain waterfowl populations in Arkansas, Louisiana, and Mississippi (Dickson 2001).

Avian populations were negatively influenced by BHF losses because of their extreme sensitivity to changes in the ecosystems, such as fragmentation and changes in tree species composition due to hydrology changes. The prothonotary warbler (*Protonotaria citrea*), a songbird that relies on BHF for breeding, is currently defined as a species of conservation concern by the United States Fish and Wildlife Service (U.S.

Fish and Wildlife Service 2008), and has experienced a 34% population decline according to Partners in Flight (Rosenberg et al. 2016). Other BHF species, such as cerulean warbler (*Dendroica cerulea*) and wood thrush (*Hylocichla mustelina*), are also important because they are indicators of habitat type and quality (Maurer 1993; Wilson and Twedt 2005). Cerulean warblers require large extents of BHF for successful breeding, but these areas have been lost to fragmentation (Mueller et al. 1995; Hamel 2000). Both species have been classified as species of conservation concern by the United States Fish and Wildlife Service (U.S. Fish and Wildlife Service 2008), and are both experiencing population declines according to Partners in Flight, with losses of 59% for wood thrush and 73% for cerulean warbler (Rosenberg et al. 2016).

With the loss and fragmentation of BHFs, many other associated bird species are potentially threatened during the breeding season (Hamel et al. 2001). BHF fragmentation, which has led to an increase in amount of forest edge, limits breeding opportunities for forest interior birds and increases nest predation and parasitism (Robinson and Wilcove 1994; Robinson et al. 1995; Hamel et al. 2001). Acadian flycatcher (*Empidonax virens*), for instance, must contend with nest parasitism from brown-headed cowbirds (*Molothrus ater*) in edge habitats (Robinson et al 1995; Twedt and Loesch 1999).

After the passing of the 1985 Farm Bill, which established the Conservation Reserve Program (CRP), the number of afforested BHFs increased due to monetary incentives that were given to farmers that allow land to return to a natural state or that establish vegetative species suitable for the soil types present on their land (Gardiner et al. 2004). As more landowners began to show interest in implementing conservation

practices on their property, effective management practices associated with converting retired agricultural fields to afforested BHF were needed. For instance, many cases of mass failure of afforested stands have occurred when monocultures of hard mast species, such as Nuttall oak (*Quercus texana*), were planted. This was most likely due to long durations of flooding or competition from other flood-adapted vegetation (Stanturf et al. 1998).

Afforested BHF are typically established on land previously leveled for agricultural use (Shankman 1993). This results in long periods of flooding where water is stagnant, potentially causing seedling mortality (Allen 1997). Another factor that contributes to stand failure are site-specific requirements of different tree species as each species may have a specific soil type and moisture level in which it can grow (Shankman 1993).

Researchers and landowners gained a better understanding of the factors that contributed to stand failure or poor quality from these previous plantings. With this understanding, came new research and practices for planting multi-species afforested BHF (Gardiner and Lockhart 2007). Studies show that afforestation is more successful and affordable when tree species that have similar species-site relationships (i.e., interactions between inherent species physiology and floodplain conditions in that area) are used, such as planting sweetgum (*Liquidambar styraciflua*) with overcup oak to promote rapid height growth while developing quality stems (Gardiner and Lockhart 2007; Dey et al. 2010). Gardiner et al. (2004) further suggested planting tree species that encompass rapid growth to establish canopy forest structure for forest birds. Rapid afforestation with developed canopy structure may also increase understory diversity,

which attracts late successional species, such as red-eyed vireo (*Vireo olivaceus*), wood thrush, and Acadian flycatcher (Gardiner et al. 2004). Rapid growth is also associated with an increase in diversity and density of wintering avian species; however, early successional species, such as painted bunting (*Passerina ciris*), indigo bunting (*Passerina cyanea*), and blue grosbeak (*Passerina caerulea*), may be negatively impacted (Hamel 2003).

As multi-species afforestation sites began to develop, researchers noticed that due to variation in growth rates among species, there was more structural diversity than that of earlier monocultural oak stands (Nuttle and Burger 2005). This vegetation and structural diversity creates distinct habitats that can increase avian diversity (Allen et al. 2006). During succession, however, variation in vegetation and structural diversity could influence the associated avian community. Nuttle and Burger (1996; 2005) found that as a BHF develops, the avian community changes from early successional to late successional avian species. For example, canopy closure in an afforested site without rapidly growing species occurs 15–20 years after establishment, thus decreasing sunlight to the forest floor and inhibiting understory growth necessary for associated avian species (e.g., northern cardinal [*Cardinalis cardinalis*], and yellow-billed cuckoo [*Coccyzus americanus*]; Hamel 2003; Nuttle and Burger 2005). These changes in forest conditions were evident in 21 to 27-year-old reforested BHFs which supported 75–85% of the avian community found in mature bottomland hardwoods (Nuttle and Burger 1996).

1.2 Research Objectives and Hypotheses

Research is needed to evaluate habitat quality of immature afforested stands relative to mature BHFs. Also, an assessment technique is needed that can evaluate the functionality

and success of afforested BHF relative to mature BHF. My research goal was to evaluate the effectiveness of a 25-year old afforested BHF in the Red River Alluvial Valley in providing suitable habitat for migratory birds. My specific research objectives were: (1) compare the density and diversity of the breeding bird communities among developed forest types within the 25-year old afforested BHF; (2) compare avian species composition in the 25-year old afforested BHF to that of mature BHF (i.e., ≥ 50 years old) in the southeastern United States based upon published literature; and (3) develop forest management recommendations to maintain and/or improve BHF habitat quality at the research site for birds found in mature BHF. My hypotheses were: (1) avian density and diversity would vary significantly among the developed forest types within the research site; and (2) avian species composition at the research site would be less than 75-85% similar to the composition of a mature BHF. These objectives and hypotheses required data collection and analyses methods that may be duplicated to assess other afforested BHF in the southeastern United States.

CHAPTER 2

AVIAN COMMUNITIES IN DOMINANT FOREST TYPES OF AN AFFORESTED BOTTOMLAND HARDWOOD

2.1 Introduction

Young afforested bottomland hardwood forests (hereafter BHF) of today are a combination of different planting styles, with a mixture of hardwood species such as sweetgum (*Liquidambar styraciflua*) and persimmon (*Diospyros virginiana*), with the exception of a small amount of land that had tree species planted based on soils and flooding potential. Research by Lockhart et al. (2008) and Groninger (2005) suggested that planting tree species in areas where they may be naturally found or closely associated, will allow for better establishment of seedlings and growing conditions than would planting trees in areas they are not adapted too. This planting strategy may increase forest health and be more beneficial for wildlife that require BHF habitat across the southeastern United States.

Many researchers (e.g., Twedt and Portwood 1997; Nuttle and Burger 2005; Lockhart et al. 2008) have evaluated wildlife responses to multi-species plantings and compared them to past research on oak (*Quercus sp.*) monocultures, without much focus on the tree community composition and its effect on the wildlife community, such as

birds. Tree species diversity in a forest will influence what wildlife are present by creating different habitat features (e.g., food abundance, foraging technique opportunities, and vertical structure) for populations of breeding woodland birds (Twedt and Best 2004; Wakeley and Roberts 1996). In the past, research revealed that habitat complexity, including vegetative structure and vegetation density, influence the types of avian species present. Though structural diversity is essential for a diverse bird community, it is important to understand that tree and herbaceous vegetation species composition influence the avian communities (Robinson and Holmes 1982; Gardiner et al. 2004; Twedt and Best 2004).

My research objective was to evaluate how dominant forest types of a BHF in the Red River Alluvial Valley of Louisiana influence the community of breeding woodland birds. My specific research goals were to: (1) determine if the density of breeding woodland birds differed among dominant forest types of the afforested BHF; and (2) determine if the diversity of breeding woodland birds differed among the dominant forest types of the afforested BHF. I hypothesized both avian density and diversity would differ among the forest types. Results and associated recommendations from my research will aid land managers in evaluating and managing afforested BHF's for wildlife associated with mature BHF's habitat across the southeastern United States.

2.2 Literature Review

The avian community present in afforested areas is the result of how, what, and where tree species were planted on site. How tree seedlings and/or seeds are planted may influence the rate trees grow (Dey et al. 2010). For example, if the same species of trees are planted beside each other, they will share nutrients and show fewer signs of

competition, thus slowing growth overall, while different tree species will show more signs of competition by growing faster or taking up significant amounts of nutrients (Dey et al. 2010).

Afforestation has changed over time to more ecologically based techniques where trees are planted in areas that more closely match associated growing conditions. This planting strategy may produce a diverse afforested bottomland hardwood stand as a whole, but can potentially be small groups of monocultures that dominate specific areas because of soil conditions that are more favorable for that species. These small monocultures create dominant forest types that may be observed on many afforested sites (Strozier 2015).

Planting techniques (e.g., different species planted in different areas) used to afforest an area may be a determining factor in what tree species are most prevalent in later years, but hydrology will play a major role in determining if those species will survive (Clark and Benforado 1981; Strozier 2015). In bottomland hardwood systems, associated tree species are tolerant of frequent flooding. Flooding creates different topographic zones throughout the bottoms with transects of levees, swamps, oxbows, and ridges of various elevation, all of which influence tree species diversity (Clark and Benforado 1981). These topographic zones promote the growth of different tree species, with tree species that are tolerant to frequent short duration flooding being closest to the water source and tree species that are adapted to less frequent long duration flooding being further from the water source (Fig. 2.1; Hodges 1997; Hupp 2000). For example, point bars have species such as river birch (*Betula nigra*), black willow (*Salix nigra*), and eastern cottonwood (*Populus deltoides*) growing along them, which are adapted to sandy

soils associated with banks of streams or rivers and can withstand changes in flooding frequency (Hodges 1997; Hupp 2000). Flats may have a variety of species depending on elevation, with wetter flats having water adapted species like overcup oak (*Quercus lyrata*), and well-drained flats having sugarberry (*Celtis laevigata*) and ash (*Fraxinus* spp.; Hodges 1994a; Hupp 2000). Swamps are associated with prolonged periods of flooding which caters to species such as water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*) that have adapted to these growing conditions (Hupp 2000). Ridges may be the most variable in species diversity because they occur at varying elevations through the bottoms (Hodges 1994b; 1997). Low and high ridges can have species typical of upland ecosystems. When afforestation is conducted using these topographic and hydrologic associations, trees may become better established. This diverse planting strategy will allow avian species to inhabit these areas as they would in a natural BHF.

Afforestation of BHF by planting a variety of site-adapted tree species has been shown to help with tree establishment and growth, allowing trees to eventually provide late successional habitat to associated avian species in less time (Dey et al. 2010; Strozier 2015). If afforestation is conducted without this planting strategy and develops a monocultural stand, then decreased growth or seedling mortality can occur. This mortality will slow successional progress by creating openings with early and mid-successional habitat, thus decreasing late successional habitat area and colonization of associated avian species, such as yellow-billed cuckoo (*Coccyzus americanus*) and Acadian flycatcher (*Empidonax virens*; Conner et al. 2004).

A diversity of tree species will create greater vertical structure diversity, which is desired by avian guilds with specific dietary needs, foraging techniques, and nesting requirements. For example, presence of open canopy tree species, like sweet pecan (*Carya illinoensis*) or honey locust (*Gleditsia triacanthos*), allows more sunlight to reach the ground which encourages growth of understory vegetation, such as giant ragweed (*Ambrosia trifida*), purpletop vervain (*Verbena bonariensis*), and black-eyed Susan (*Rudbeckia hirta*). Understory vegetation may favor early and mid-successional granivorous (seed-eating) and insectivorous (insect-eating) birds, such as blue grosbeak

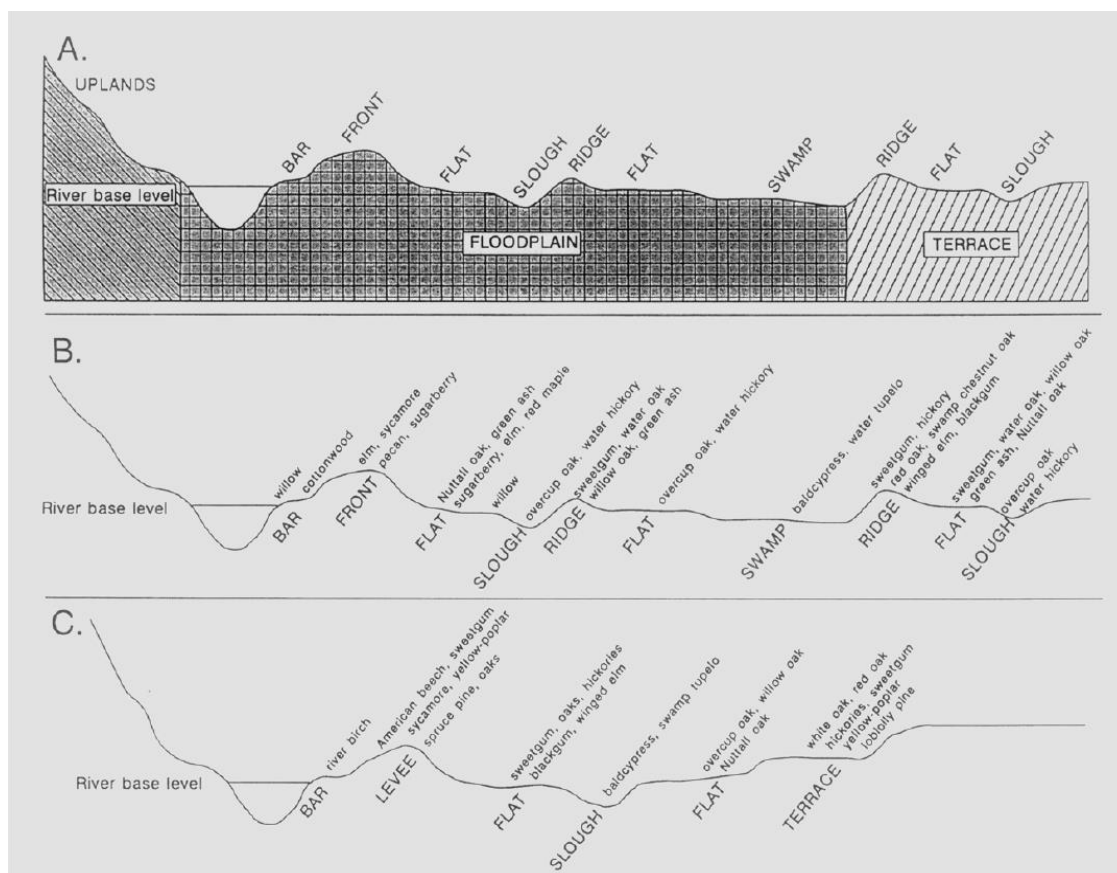


Figure 2.1: Diagrams of major and minor bottoms in Coastal Plains: (A) topographic features are present and where they are found in relation to the river base level, (B) changes in topography and the tree species associated in major bottoms, and (C) topographic changes and trees species associated in minor bottoms (from Hodges 1997).

(*Passerina caerulea*) and white-eyed vireo (*Vireo griseus*). It also creates nesting habitat for species that prefer to nest within shrubby vegetation, such as yellow-breasted chat (*Icteria virens*) and indigo bunting (*Passerina cyanea*).

Open canopy tree species are beneficial to early and mid-successional species, but they may be a hindrance to bird species that are associated with mature forests. For example, the wood thrush (*Hylocichla mustelina*) uses mature forests for breeding and foraging where they search for insects under leaf litter in moist soil areas with an open forest floor. Chettri et al. (2005) found that 14 species of birds in the Yuksom–Dzongri trekking corridor located in Sikkim, India, had a positive relationship with tree density and basal area, potentially due to a greater number of insects in ground litter in more moist conditions of closed canopy forests. Though ground foraging species use closed canopy forest, avian diversity may be increased by having multiple canopy layers along with diverse understory vegetation. When a forest is allowed to have complete canopy closure it will significantly decrease understory regeneration, thus decreasing the mid-story over time (Clements 1916; Bell 1979; Merritt et al. 2010). This decrease of multiple layers below the canopy can potentially reduce nesting habitat for bird species that nest below the canopy and forage resources such as berries, seeds, and insects (Cody 1985; Wakeley and Roberts 1996).

A combination of open and closed canopy can create a more diverse forest, potentially providing more foraging opportunities for birds in multiple foraging and dietary guilds (Kovalenko et al. 2012). For example, gleaning is a foraging technique where insects are picked from the surface of trees, branches, grasses or leaves (Williamson 1971). Gleaning is used by many families of birds, such as titmice and

chickadees (Paridae), warblers (Parulidae), and vireos (Vireonidae), while other families, such as flycatchers (Tyrannidae), commonly use hawking (i.e., catching insects in air and eating midflight) or sallying (i.e., catching insects in air and returning to perch) to retrieve prey (Williamson 1971). Foliage shape and form play an important role in determining if a guild will be successful. Trees with leaves and/or leaflets, such as honey locust, may provide more leaf surface area for insects to hide, while simple two-dimensional leaves, like maples (*Acer* spp.) and oaks, reduce hiding area, allowing birds to be more successful at catching prey (Robinson and Holmes 1982).

Different tree species provide a variety of fruits and seeds to birds while serving as hosts to different insect species, thus simultaneously attracting frugivorous, granivorous, and insectivorous birds (Twedt and Best 2004). Oak and pecan trees, for instance, can be hosts for the same Lepidoptera species, such as luna moths (*Actias luna*) and forest tent caterpillar moths (*Malacosoma disstria*), while ash trees harbor insects like ash sphinx moths (*Sphinx chersis*) and eastern tiger swallowtails (*Papilio glaucus*; Twedt and Best 2004). These insect species create diverse foraging opportunities for different insectivorous avian species. Thus, both vegetative structure and tree species diversity are important for avian diversity by creating diverse foraging and nesting opportunities.

Vegetation structure and tree species diversity are often studied independently where researchers infer one is potentially more important than the other when conducting an afforestation or reforestation project (Tews et al. 2004; Dey et al. 2010; Smith et al. 2014). For example, Gardiner et al. (2004) explained afforestation projects predominantly with tree species that produce hard mast (e.g., oaks) should be interplanted with fast-

growing pioneer species, such as eastern cottonwood, to add structure. Some research has suggested that simply having fast-growing species to provide vertical structure is enough to determine bird diversity in forest ecosystems (August 1983; Twedt and Portwood 1997; Hamel 2003; Tews et al. 2004). Although past research has shown vertical structure influences the bird communities, these studies did not consider using multiple tree species to create the vegetation structure itself (Hamel 2003; Tews et al. 2004; Smith et al. 2014). Tree species diversity allows for a more diverse vegetation structure to occur by way of differences in growth patterns (Twedt and Best 2004). Trees with faster stem elongation, such as the green ash (*Fraxinus pennsylvanica*), promote greater structural diversity in the mid- and understory, as well as providing cover for canopy species, such as red-eyed vireo (Hamel 2003; Dey et al. 2010). This diversity of tree species and habitat structure allows for many potentially nesting and foraging opportunities, thus potentially increasing bird species diversity and density (MacArthur and MacArthur 1961; Twedt and Best 2004).

My objective was to compare the density and diversity of the breeding bird communities among developed forest types within a 25-year old afforested BHF. Results of my research will help land managers understand how dominant forest types within an afforested stand and how the associated bird community differs among these dominant forest types. These results will allow land managers to assess habitat quality of afforested BHF in the southeastern United States in terms of both internal forest type diversity (e.g., tree species, structure) and compared to mature BHF. This will improve our understanding of habitat type and quality in established afforested BHF. Land managers, wildlife biologist, and foresters will be able to better develop and maintain quality BHF

habitat for birds and potentially other wildlife species by using avian diversity and density as an indicator of habitat quality (Maurer 1993; LMVJV 2007).

2.3 Methods

2.3.1 Study Area

I collected data at an 809-ha afforested BHF owned by NRG Energy, Inc, in Desoto Parish, Louisiana (Fig. 2.2). The stand was planted with bottomland hardwoods during the winters of 1994–95 and 1995–96 by U.S. Fish and Wildlife Service specifically for wildlife. Strozier (2015) identified seven forest types at the site that differ in dominant bottomland hardwood species: (1) green ash, (2) honey locust, (3) Nuttall oak (*Quercus texana*), (4) sugarberry – persimmon, (5) sweet pecan, (6) sweetgum, and (7) willow oak (*Quercus phellos*; Fig. 2.3). Strozier (2015) identified these dominant forest types using species importance value measurements, such as sum of relative basal area (i.e., average amount of an area occupied by tree stems) and relative density of each hardwood species in the area. These measurements were used to create a cluster dendrogram that identified relationships between similar sets of data. The cluster analysis identified the seven dominant forest types (Strozier 2015).

Formation of these forest types was primarily due to how the site was planted, which was with multiple seed and seedling mixes with some that consisted of species with similar site requirements (Strozier 2015). These mixes were planted in specific areas of the study site. For example, the south end of the study site has an intermittent stream (i.e., flowing water during the wet season, but dry during hot summers) and a higher flood potential than the northern parts of the site. Though dry-adapted, wet-adapted, and cypress-Nuttall-tupelo mixes were planted, ecological conditions have selected wet-

adapted species with other mixes only persisting in areas of higher elevation (Strozier 2015). Another factor that could have contributed to the formation of these forest types is timing and duration of flooding across the NRG site. Some areas on the site are more susceptible to flooding during rain events due to this site being dominated by Armistead clay (39.64%) and Buxin clay (44%; Strozier 2015). Armistead clay is a somewhat poorly drained soil found on natural levees and is considered prime farmland soil. Buxin clay is a poorly drained soil found on floodplain steps and has frequent ponding during wet periods, thus allowing more flood tolerant species, such as willow oak and Nuttall oak, to become dominant rather than other species present in seedling mixes (Strozier 2015).

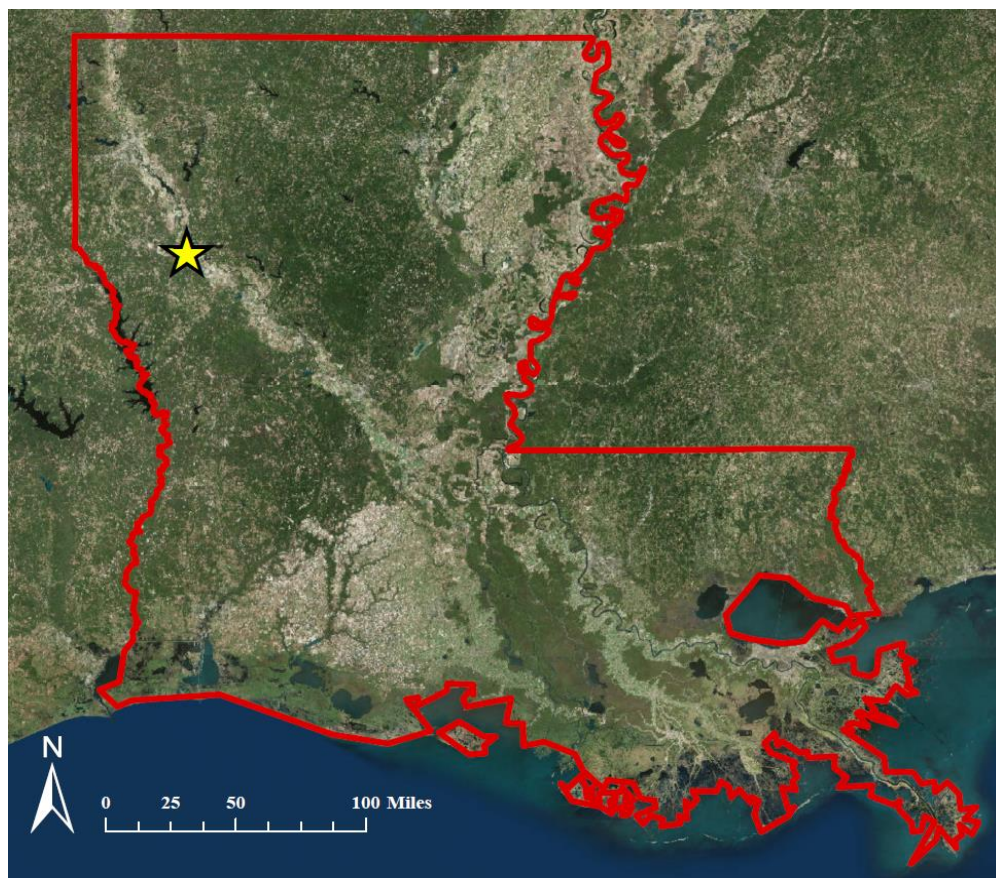


Figure 2.2: The location of the 809-ha afforested bottomland hardwood forest owned by NRG Electric, Inc. in Desoto Parish, Louisiana.

2.3.2 Avian Point Counts

Avian point count surveys were used to estimate avian density and diversity at the study site. This allows diversity at the study site to be compared among forest types during analyses. Strozier (2015) established 184 points at the study site that were 80–210 m apart (\bar{x} = 166 m). From these points, 28 points (4 points/forest type) that were at least 350 meters apart, were randomly selected using Microsoft Excel's random number generator (Fig. 2.3). This minimum distance prevents double-counting birds among points (Hamel et al. 1996). Point counts were conducted during the avian breeding season (June–August) of three consecutive years (2016–2018) by two observers (C. W. Sharp and H. L. Adams). Points were visited at least five times during each breeding season on mornings with no precipitation and wind speeds less than 12.9 km/hour from half an hour before sunrise to four hours after sunrise (Robbins 1981a; b).

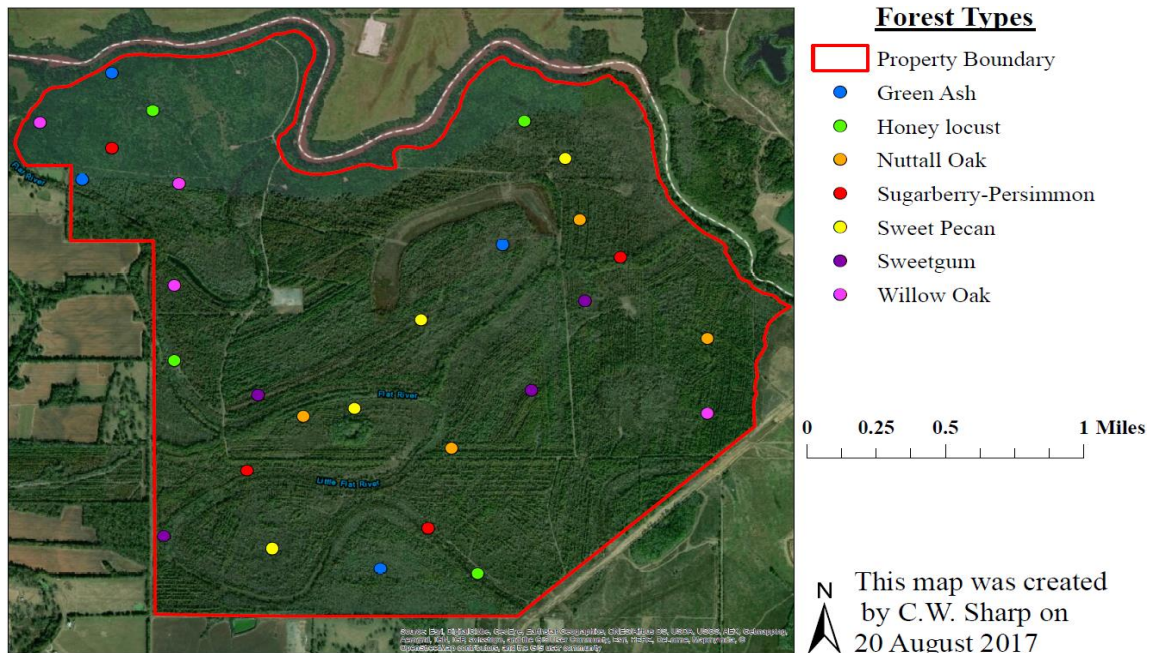


Figure 2.3: Point locations at the afforested bottomland hardwood forest owned by NRG Electric, Inc. in Desoto Parish, Louisiana where avian point count surveys were conducted June–August, 2016–2018.

Before conducting each point count, the observer had a calming period (i.e., 5–10 minutes for wildlife to proceed with normal activity) due to the disturbance associated with reaching the point. During point counts, a single observer documented all avian species seen and/or heard during a 10-minute time frame (Hamel et al. 1996). To further ensure that double-counting did not occur, the observer used auditory and visual cues to ensure only unique individuals are documented. Point location (forest type and ID number), date, start time, wind speed, temperature, bird species, distance from observer (using aerial maps with marked distance intervals [i.e., 10, 25, 50, and 75 meters from point]), number of individuals (if in a group), and specific information to indicate unique individuals (e.g., nests, fledglings, age, sex, etc.) were also recorded (Hamel et al. 1996).

2.3.3 Data Analyses

To estimate avian density, I used Program DISTANCE 7.0 to estimate detection functions (i.e., probability of detecting a bird given its distance from an observer) and associated avian densities for forest type by year (Buckland et al. 2001; Thomas et al. 2010). Estimation accuracy was increased by removing observation outliers using an *a priori* right-truncation of 15% of all NRG observation data (Buckland et al. 2001). This truncation resulted in the exclusion of avian observations ≥ 100 m from an observer. I used appropriate key functions (i.e., half-normal or hazard-rate) with possible series expansions (i.e., cosine or simple polynomial), and 0 to 3 adjustment terms to generate models of each forest type by year observation dataset (Buckland et al. 2001). I used corrected Akaike's Information Criterion (AIC_c), detection probability, and goodness-of-fit to select the best model. To compare avian density by forest type and/or by year, I used 95% confidence intervals to indicate significant differences.

To avoid data bias in situations where all points could not be visited five times per data collection season (e.g., poor weather conditions, flooding, high concentration of feral hogs in the area), I standardized avian point count data across forest type by year using number of individuals detected/ha for all detected species. I then calculated forest type by year avian diversity indices using Shannon's Index (H'), which is calculated as:

$$H' = -\sum (P_i * \ln P_i)$$

where P_i is the proportion of the entire population composed of the i^{th} species (Shannon and Weaver 1963). I then calculated the maximum Shannon's Index possible (H_{\max}) for each forest type by year, which is calculated as:

$$H_{\max} = H' / \ln S$$

where S is the total number of species in the entire population (Shannon and Weaver 1963). Finally, I calculated equitability (J') for each forest type by year, which is calculated as:

$$J' = H' / H_{\max}$$

I used a general linear model in SAS PROC MIXED (SAS Institute, Inc. 2014) to determine if there were significant differences in avian equitability among forest types using $\alpha = 0.05$. I used chi-square analyses to determine if there were significant differences in avian equitability for the entire study site among the three breeding seasons (2016, 2017, 2018) using $\alpha = 0.05$.

2.4 Results

During the breeding seasons (June–August) of 2016, 2017, and 2018, 2,995 individual avian detections were made that represented 52 bird species among the seven forest types (Tables 2.1 and 2.2). The three most commonly detected species were

northern cardinal (*Cardinalis cardinalis*; $n_{2016} = 57$, $n_{2017} = 187$, $n_{2018} = 244$), yellow-billed cuckoo ($n_{2016} = 36$, $n_{2017} = 91$, $n_{2018} = 104$), and indigo bunting ($n_{2016} = 29$, $n_{2017} = 90$, $n_{2018} = 114$).

Table 2.1: Avian species detected at the NRG study site in Desoto Parish, Louisiana during the 2016–2018 breeding seasons.

Common Name	Alpha Code	Scientific Name
Acadian Flycatcher	ACFL	<i>Empidonax virescens</i>
American Bittern	AMBI	<i>Botaurus lentiginosus</i>
American Coot	AMCO	<i>Fulica americana</i>
American Crow	AMCR	<i>Corvus brachyrhynchos</i>
American Robin	AMRO	<i>Turdus migratorius</i>
Barred Owl	BAOW	<i>Strix varia</i>
Belted Kingfisher	BEKI	<i>Megaceryle alcyon</i>
Blue Grosbeak	BLGR	<i>Passerina caerulea</i>
Blue Jay	BLJA	<i>Cyanocitta cristata</i>
Blue-gray Gnatcatcher	BGGN	<i>Poliophtila caerulea</i>
Brown-headed Cowbird	BHCO	<i>Molothrus ater</i>
Carolina Chickadee	CACH	<i>Poecile carolinensis</i>
Carolina Wren	CAWR	<i>Thryothorus ludovicianus</i>
Cerulean Warbler	CEWA	<i>Setophaga cerulea</i>
Common Gallinule	COGA	<i>Gallinula galeata</i>
Common Grackle	COGR	<i>Quiscalus quiscula</i>
Downy Woodpecker	DOWO	<i>Picoides pubescens</i>
Eastern Bluebird	EABL	<i>Sialia sialis</i>
Eastern Meadowlark	EAME	<i>Sturnella magna</i>
Eastern Towhee	EATO	<i>Pipilo erythrophthalmus</i>
Eastern Wood-Pewee	EAWP	<i>Contopus virens</i>
Fish Crow	FICR	<i>Corvus ossifragus</i>
Gray Catbird	GRCA	<i>Dumetella carolinensis</i>
Great Blue Heron	GRBH	<i>Ardea herodias</i>
Great Crested Flycatcher	GCFL	<i>Myiarchus crinitus</i>
Great Egret	GREG	<i>Ardea alba</i>
Green Heron	GRHE	<i>Butorides virescens</i>
Hairy Woodpecker	HAWO	<i>Leuconotopicus villosus</i>
Hooded Warbler	HOWA	<i>Setophaga citrina</i>
Indigo Bunting	INBU	<i>Passerina cyanea</i>
Kentucky Warbler	KEWA	<i>Oporornis formosus</i>
Louisiana Waterthrush	LOWA	<i>Parkesia motacilla</i>
Mourning Dove	MODO	<i>Zenaida macroura</i>
Northern Cardinal	NOCA	<i>Cardinalis cardinalis</i>

Table 2.1: Continued

Common Name	Alpha Code	Scientific Name
Northern Flicker	NOFL	<i>Colaptes auratus</i>
Painted Bunting	PABU	<i>Passerina ciris</i>
Pileated Woodpecker	PIWO	<i>Hylatomus pileatus</i>
Red-bellied Woodpecker	RBWO	<i>Melanerpes carolinus</i>
Red-eyed Vireo	REVI	<i>Vireo olivaceus</i>
Red-shouldered Hawk	RSHA	<i>Buteo lineatus</i>
Red-tailed Hawk	RTHA	<i>Buteo jamaicensis</i>
Red-winged Blackbird	RWBL	<i>Agelaius phoeniceus</i>
Ruby-throated Hummingbird	RTHU	<i>Archilochus colubris</i>
Summer Tanager	SUTA	<i>Piranga rubra</i>
Tufted Titmouse	TUTI	<i>Baeolophus bicolor</i>
White-breasted Nuthatch	WBNU	<i>Sitta carolinensis</i>
White-eyed Vireo	WEVI	<i>Vireo griseus</i>
Wood Thrush	WOTH	<i>Hylocichla mustelina</i>
Yellow Warbler	YEWA	<i>Setophaga petechia</i>
Yellow-billed Cuckoo	YBCU	<i>Coccyzus americanus</i>
Yellow-breasted Chat	YBCH	<i>Icteria virens</i>
Yellow-throated Vireo	YTVI	<i>Vireo flavifrons</i>

Table 2.2: Bird species with an average number of detections per visit in the seven dominant forest types for 2016, 2017, and 2018 breeding seasons at the NRG site in Desoto Parish, Louisiana. Common and scientific names as seen in Table 2.1

Alpha Code	Year	Green Ash	Honey Locust	Nuttall Oak	Sweet Pecan	Sugarberry-Persimmon	Sweetgum	Willow Oak
ACFL	2016	–	–	0.200	0.333	0.167	0.250	–
	2017	0.308	0.143	0.538	0.500	0.200	0.375	0.231
	2018	0.100	0.250	0.150	0.474	0.450	0.579	0.150
AMBI	2016	–	–	–	–	–	–	–
	2017	–	0.071	–	–	–	–	–
	2018	–	–	–	–	–	–	–
AMCO	2016	–	–	–	–	–	–	–
	2017	–	–	–	–	–	–	–
	2018	–	–	–	–	–	–	0.050
AMCR	2016	0.333	0.333	0.400	–	–	0.250	0.167
	2017	0.385	0.500	0.077	0.083	0.067	0.188	0.154
	2018	0.100	0.150	0.200	0.105	0.150	0.158	0.100
AMRO	2016	0.167	–	–	0.167	–	–	–
	2017	–	–	–	–	–	–	0.154
	2018	0.050	–	–	–	–	–	–
BAOW	2016	–	0.167	–	–	–	–	–
	2017	–	0.071	–	–	–	–	–
	2018	–	–	–	–	–	–	–
BEKI	2016	–	–	–	–	–	–	–
	2017	–	–	–	–	–	–	–
	2018	–	–	–	–	–	–	0.050
BLGR	2016	–	–	–	0.333	–	–	–
	2017	–	–	–	–	–	–	–
	2018	–	–	–	–	–	–	–
BLJA	2016	0.333	–	–	–	0.333	–	0.167
	2017	0.077	0.143	0.615	0.417	0.133	0.188	0.154
	2018	0.150	0.300	0.200	0.105	0.200	0.421	0.450
BGGN	2016	0.167	0.500	0.200	0.167	0.167	–	0.167
	2017	0.077	0.071	0.231	0.333	0.200	–	–
	2018	0.100	0.200	0.050	0.158	0.150	0.053	0.150
BHCO	2016	–	–	–	–	–	0.250	–
	2017	–	0.071	–	–	–	–	–
	2018	0.050	–	–	–	0.050	–	–
CACH	2016	0.333	1.000	0.400	0.667	0.833	–	0.333
	2017	0.077	0.500	0.308	0.167	0.467	0.250	0.231
	2018	0.350	0.400	0.200	0.368	0.200	0.316	0.300

Table 2.2: Continued

Alpha Code	Year	Green Ash	Honey Locust	Nuttall Oak	Sweet Pecan	Sugarberry-Persimmon	Sweetgum	Willow Oak
CAWR	2016	0.667	0.333	0.400	1.667	0.833	0.500	0.333
	2017	0.385	0.714	0.385	0.500	0.333	0.563	0.769
	2018	0.500	0.700	0.750	0.316	0.450	0.474	0.750
CEWA	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	0.067	—	—
	2018	—	—	—	—	0.050	—	—
COGA	2016	—	—	—	—	—	—	—
	2017	0.077	—	—	—	—	—	—
	2018	0.050	—	0.050	—	—	—	—
COGR	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	—	—	—
	2018	0.100	—	—	—	—	—	—
DOWO	2016	—	0.167	—	—	—	—	—
	2017	—	—	—	—	—	—	—
	2018	0.050	0.050	—	—	0.050	—	—
EABL	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	—	—	0.077
	2018	—	—	—	—	0.050	0.053	—
EAME	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	—	—	—
	2018	—	0.100	—	—	0.550	—	—
EATO	2016	1.000	0.167	0.600	0.333	0.167	0.750	0.167
	2017	0.769	0.143	0.692	1.250	0.333	0.688	0.462
	2018	0.300	0.500	0.600	0.579	—	0.684	0.500
EAWP	2016	—	—	—	—	—	—	—
	2017	—	—	0.154	—	—	0.063	0.308
	2018	—	—	—	0.053	—	—	—
FICR	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	—	0.188	—
	2018	—	—	—	—	—	—	—
GRCA	2016	—	—	0.200	—	—	—	0.167
	2017	—	—	0.077	—	0.067	—	0.077
	2018	—	—	—	—	—	—	—
GRBH	2016	—	—	—	0.167	—	—	—
	2017	—	—	—	—	—	—	—
	2018	—	0.100	—	—	—	—	0.050
GCFL	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	—	0.063	0.077
	2018	—	—	0.050	0.053	—	—	—

Table 2.2: Continued

Alpha Code	Year	Green Ash	Honey Locust	Nuttall Oak	Sweet Pecan	Sugarberry-Persimmon	Sweetgum	Willow Oak
GREG	2016	–	–	–	–	0.167	–	–
	2017	–	–	–	0.167	–	–	0.077
	2018	–	–	–	–	–	–	–
GRHE	2016	–	–	–	–	–	–	–
	2017	0.077	–	0.077	–	–	–	–
	2018	0.050	–	0.100	–	–	–	–
HAWO	2016	–	–	–	–	–	–	–
	2017	0.077	–	–	–	0.067	0.125	0.231
	2018	0.050	–	–	–	0.050	0.053	–
HOWA	2016	–	0.333	–	–	0.167	–	0.167
	2017	–	–	–	0.167	–	–	0.077
	2018	0.050	0.050	0.150	0.158	–	0.368	0.050
INBU	2016	0.833	0.500	1.000	0.500	0.667	1.250	0.667
	2017	1.615	1.357	0.769	0.667	0.733	0.625	0.846
	2018	1.050	0.850	0.600	0.632	0.700	0.789	1.150
KEWA	2016	–	–	–	0.167	–	–	–
	2017	–	–	0.077	0.250	0.067	0.125	–
	2018	–	0.100	0.100	0.158	0.100	0.263	–
LOWA	2016	–	–	–	–	–	–	–
	2017	–	–	–	–	–	–	–
	2018	–	–	–	–	0.050	–	–
MODO	2016	0.167	0.667	–	–	0.500	–	0.167
	2017	0.231	0.286	0.154	–	–	–	–
	2018	0.050	0.050	0.050	–	–	–	–
NOCA	2016	1.667	1.833	1.400	1.167	1.333	2.000	1.000
	2017	2.231	1.929	1.000	1.833	2.867	1.563	2.154
	2018	1.850	1.900	1.750	1.947	1.650	1.474	1.800
NOFL	2016	–	–	–	–	–	0.250	–
	2017	–	–	–	–	–	–	–
	2018	–	–	–	–	–	–	–
PABU	2016	0.167	0.167	–	–	–	–	0.167
	2017	0.385	0.643	0.308	0.333	0.133	–	0.308
	2018	0.150	0.100	0.050	–	–	–	0.050
PIWO	2016	–	–	–	–	–	–	–
	2017	–	–	–	0.083	–	0.125	0.077
	2018	–	–	–	–	–	–	–
RBWO	2016	0.167	0.333	–	0.500	0.167	0.750	–
	2017	0.154	0.214	0.154	0.083	0.200	0.188	0.154
	2018	0.350	0.150	0.100	0.158	0.050	0.158	0.100

Table 2.2: Continued

Alpha Code	Year	Green Ash	Honey Locust	Nuttall Oak	Sweet Pecan	Sugarberry-Persimmon	Sweetgum	Willow Oak
REVI	2016	—	—	—	0.167	0.167	—	—
	2017	0.154	0.143	0.077	—	0.267	0.188	—
	2018	0.150	0.050	0.100	0.105	0.300	0.474	0.100
RSHA	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	—	—	—
	2018	—	0.050	—	—	0.050	0.053	—
RTHA	2016	—	—	—	—	—	—	—
	2017	0.077	0.071	—	—	0.067	0.063	—
	2018	—	—	—	—	—	0.053	—
RWBL	2016	—	—	—	—	—	—	—
	2017	0.154	0.143	—	0.167	0.133	—	—
	2018	0.250	—	0.150	—	0.050	—	—
RTHU	2016	—	—	—	0.333	—	—	—
	2017	—	—	0.077	—	0.067	0.063	0.077
	2018	0.050	0.050	—	—	—	—	—
SUTA	2016	—	—	—	—	0.167	—	0.167
	2017	0.077	0.071	—	0.167	—	—	—
	2018	0.050	—	0.050	—	—	0.053	—
TUTI	2016	0.333	0.667	0.800	0.333	0.833	1.250	0.333
	2017	0.385	0.571	0.308	0.417	0.467	0.375	0.538
	2018	0.450	0.500	0.250	0.263	0.500	0.421	0.350
WBNU	2016	—	—	—	—	—	—	—
	2017	—	—	—	—	0.067	—	—
	2018	—	—	—	—	—	—	—
WEVI	2016	—	0.333	0.200	0.500	—	0.500	—
	2017	0.077	0.286	—	0.500	0.267	0.438	0.231
	2018	0.200	0.450	0.550	0.474	0.550	0.368	0.400
WOTH	2016	—	—	—	0.167	—	—	—
	2017	—	—	0.846	—	—	—	—
	2018	—	—	0.050	0.105	0.050	—	—
YEWA	2016	—	0.167	—	—	—	—	—
	2017	—	—	—	—	—	—	—
	2018	—	0.050	—	—	—	—	—
YBCU	2016	0.333	1.167	0.800	0.833	0.667	2.000	1.000
	2017	0.923	1.071	0.923	0.667	1.067	1.063	0.846
	2018	0.600	0.600	0.800	0.632	1.100	0.895	0.650

Table 2.2: Continued

Alpha Code	Year	Green Ash	Honey Locust	Nuttall Oak	Sweet Pecan	Sugarberry-Persimmon	Sweetgum	Willow Oak
YBCH	2016	0.333	–	0.600	1.167	0.333	1.500	–
	2017	0.615	0.786	1.077	1.083	0.667	0.313	0.692
	2018	0.300	0.600	1.050	0.842	0.800	0.474	0.350
YTVI	2016	–	–	–	–	–	–	0.167
	2017	–	–	–	–	–	–	–
	2018	–	–	–	–	0.050	–	–

Avian density results from Program DISTANCE 7.0 analyses indicated a difference in avian density among the seven dominant forest types. Based on the 95% confidence intervals generated by Program DISTANCE 7.0, honey locust ($22.836 [18.9 \leq x \leq 27.6]$ birds/ha), sugarberry-persimmon ($16.368 [13.0 \leq x \leq 20.6]$ birds/ha), and sweet pecan ($14.217 [10.2 \leq x \leq 19.8]$ birds/ha) forest types had significantly greater avian densities compared to the green ash ($7.622 [5.8 \leq x \leq 10.1]$ birds/ha) and willow oak ($6.634 [5.1 \leq x \leq 8.6]$ birds/ha; Fig. 2.4) forest types.

Avian density differed across the entire study site among the three breeding seasons surveyed (2016–2018; Fig. 2.5). Avian densities in 2017 ($17.661 [15.1 \leq x \leq 20.7]$ birds/ha) and 2018 ($15.563 [14.0 \leq x \leq 17.3]$ birds/ha) were significantly greater than avian densities in 2016 ($6.660 [5.5 \leq x \leq 8.1]$ birds/ha).

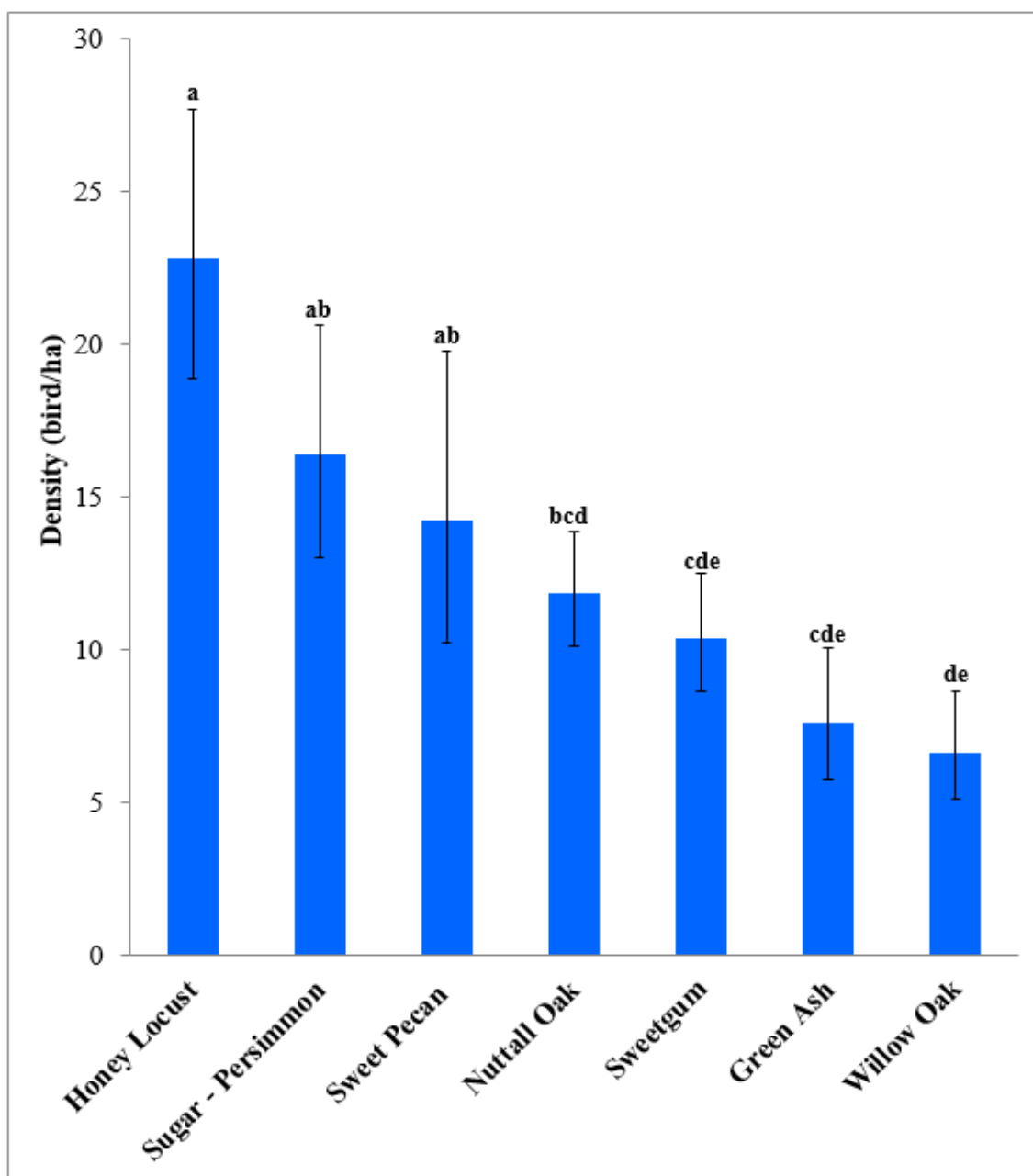


Figure 2.4: Results Program DISTANCE 7.0 to determine if there were significant differences in avian density (birds per hectare) among seven dominant forest types during the 2016–2018 breeding seasons at the NRG site in Desoto Parish, Louisiana. Error bars indicate 95% confidence intervals for birds/ha among forest types.

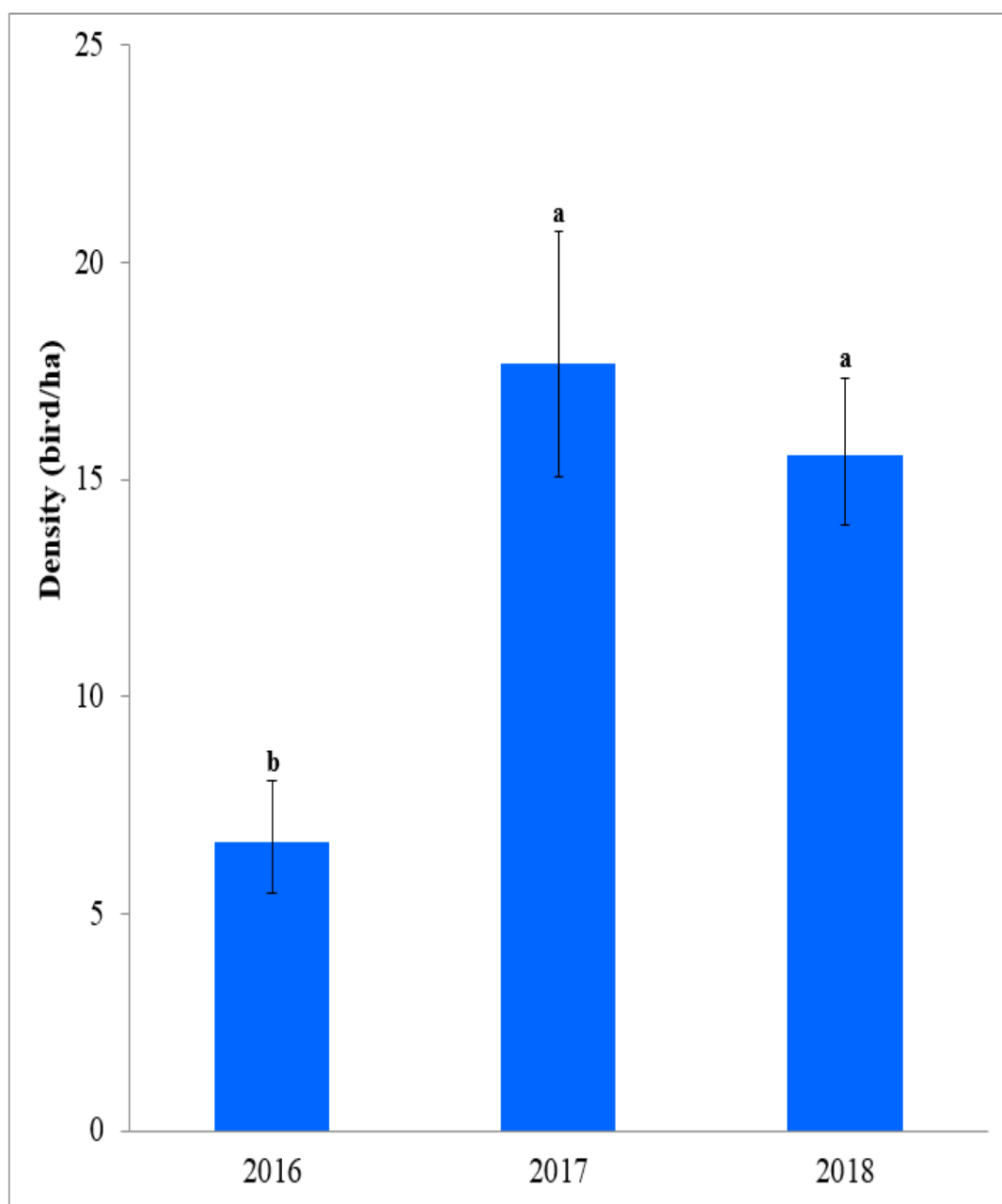


Figure 2.5: Results Program DISTANCE 7.0 to determine if there were significant differences in avian density between years at the NRG site in Desoto Parish, Louisiana. Error bars indicate 95% confidence intervals for birds/ha among breeding seasons.

Equitability analyses for diversity indicated forest type by year ranged from a low in 2017 of 78.838 in sugarberry-persimmon to a high in 2016 of 92.591 in the Nuttall oak forest type (Table 2.3). Results from data analyses indicated there was no significant difference in avian diversity among the seven dominant forest types present at the NRG site (Table 2.4). Results from the chi-square analysis indicated that diversity of birds across the study site was not significantly different among the three breeding seasons ($p = 0.516$; $\chi^2 = 1.322$; $DF = 2$; Table 2.5)

Table 2.3: Shannon's Equitability estimates for seven dominant forest types for 2016, 2017, and 2018 breeding seasons at the NRG site in Desoto Parish, Louisiana.

Forest Type	2016	2017	2018
Green Ash	89.060	80.996	81.42
Honey Locust	89.946	84.722	88.66
Nuttall Oak	92.591	89.172	86.07
Sugarberry-Persimmon	90.680	78.838	88.02
Sweet Pecan	90.659	88.527	83.53
Sweetgum	90.380	87.057	93.37
Willow Oak	89.829	84.481	82.75

Table 2.4: Differences in avian diversity among seven dominant forest types during 2016, 2017, and 2018 breeding seasons at the NRG site in Desoto Parish, Louisiana.

Forest Type	Estimate	Standard Error Prediction	t Value	Pr > t
Green Ash	-0.01303	0.01133	-1.15	0.2723
Honey Locust	0.00232	0.01133	0.20	0.8411
Nuttall Oak	0.00815	0.01133	0.72	0.4855
Sugarberry-Persimmon	-0.00518	0.01133	-0.46	0.6556
Sweet Pecan	0.00153	0.01133	0.14	0.8947
Sweetgum	0.01201	0.01133	1.06	0.3098
Willow Oak	-0.00580	0.01133	-0.51	0.6178

Table 2.5: Chi-square test of the number of avian species among 2016, 2017, and 2018 breeding seasons at the NRG site in Desoto Parish, Louisiana.

Year	Observed Number of Species	Expected Number of Species	$\frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$
2016	33	38.333	0.742
2017	39	38.333	0.012
2018	43	38.333	0.568
χ^2			1.322
$\chi^2_{0.05,2}$			5.991

2.5 Discussion

2.5.1 Density among Forest Types

Avian density at the NRG site was found to be highly variable, showing five statistical groupings (a, ab, bcd, cde, de) among the seven dominant forest types, where groups that do not have a letter in common are statistically different. For example, the ab group which includes the sugarberry-persimmon and sweet pecan forest types is statistically different from the cde group that includes green ash and willow oak. This variability may be due to the differences in habitat and food availability that are present because of different amounts of understory and canopy structure. Previous research by Strozier (2015) found that forest types had different amounts of understory cover, which correlated with overstory cover. Results of my research indicate the honey locust forest type had the greatest density of bird/ha, potentially because of abundance and diversity of herbaceous and woody plant species in the understory that was associated with these areas, which allows for an abundance of food resources for multiple foraging guilds, especially insectivorous and granivorous bird species (Wakeley and Roberts 1996; Twedt and Best 2004). Strozier (2015) found forest types at the NRG research site with a dominant honey locust component had the lowest percentages of overstory, and the

highest percentages of understory, thus explaining the changes in food resource abundance and cover availability among forest types. The forest type with the least birds/ha was willow oak. This forest type typically had closely spaced trees with complete canopy closure, thus allowing for little understory and an oak monoculture habitat that only provided canopy during growing season and food during years with good acorn production. These results are consistent with results from Swifts et al. (1984) who found that there was an increase in the prevalence of shrubby vegetation 1-3 meters tall, which are common in the honey locust forest type, and that there breeding bird density followed the same increasing trend. The results from this research indicated that my hypothesis was correct in that avian density would vary significantly among the developed forest types within the research site. The developed forest types at the research site do have an effect on the density of birds present, but the exact causes of the differences are not completely understood because of the multiple factors (leaf and canopy structure, fruiting bodies present etc.) that play a role in a bird's presence in a forest type.

2.5.2 Density Differences across Breeding Seasons

There was a significant difference in avian density, showing two statistical groupings (a, b) among the three breeding seasons. The season that had the lowest density was the 2016 breeding season (6.660 birds bird/ha), with the 2017 season (17.661 bird/ha) having 2.5 times more birds per hectare and 2018 (15.563 bird/ha) seasons having approximately two times more birds per hectare. The first season was used to collect avian community data, as well as to locate and set up the point count survey locations which caused points to be visited fewer times and could have allowed from

more observer error because of the lack of familiarity with the research site. The difference seen between the first breeding seasons was expected and was the reason for two additional breeding season surveys. Differences in the 2017 and 2018 seasons were also expected because of changes in weather conditions between the two years, with 2017 having a large amount of precipitation and 2018 having a drought for much of the breeding season. Significant differences found between breeding seasons may have been caused by a combination of observer error and drastic weather changes from year to year and would need to be further researched to determine which of these factors contributed the most to differences seen in the first year.

2.5.3 Diversity among Forest Types

There was no significant difference in avian diversity among the seven forest types at the NRG site. Lack of differences in diversity is potentially due to differences in bird species that are found among the seven forest types. In other words, diversity equitability of forest types depended on the how many different bird species were present compared to what that forest type is capable of, rather than what specific bird species are present in that forest type. This allows species to vary among forest types but yet still show similar diversity equitability values. For example, the sweet pecan and willow oak forest types had a total of 20 bird species detected in 2018 but had different species such as painted bunting (*Passerina ciris*) in willow oak and Kentucky warbler (*Oporornis formosus*) in sweet pecan. The same trend was seen in the honey locust and Nuttall oak forest types, where 25 total bird species were detected in 2018, but had different species such as ruby-throated hummingbird (*Archilochus colubris*) in honey locust, and summer tanager (*Piranga rubra*) in Nuttall oak. The difference in avian species composition for

each forest type was potentially due to differences in habitat and food availability (Cody 1985; Wakeley and Roberts 1996). For example, honey locust areas typically have an open canopy and are similar to early and intermediate stages of succession, while Nuttall oak forest type typically had a closed canopy that is similar to late successional stages. Lack of significant differences among forest types at the NRG site was surprising because of potential changes in food variety and abundance that are typically associated with differences in tree species. Though unexpected, these results are consistent with research by Wakely and Roberts (1996) that found avian species richness was similar across forest zones during the breeding season.

There were forest types (i.e., green ash, sugarberry-persimmon, willow oak) that may have had a negative effect on the differences in diversity among the forest types at the NRG site. These forest types may have detections that are biased toward some species over others, making them less even in number of individuals per species across a particular forest type. For example, during the 2017 breeding season, the sugarberry-persimmon forest type had 135 detections, with approximately 52% of them being the three most frequently detected species at the NRG site (northern cardinal, $n = 43$; yellow-billed cuckoo, $n = 16$; indigo bunting, $n = 11$). The same trend was seen during the 2018 breeding season in the green ash forest type, where 46% of the total detections in that forest type were the same three common species (northern cardinal, $n = 37$; indigo bunting, $n = 21$; yellow-billed cuckoo, $n = 12$). The unevenness associated with these three forest types may have caused the seven forest types to appear more similar in diversity than in actuality.

2.5.4 Diversity among Breeding Seasons

The NRG site had no significant difference in avian diversity among the three breeding seasons. Though there is not a statistical difference in avian diversity, this site did trend toward an increase in avian species detected each year (2016, $n = 33$; 2017, $n = 39$; 2018, $n = 43$). This increase in total avian species as the forest ages is consistent with research by Buffington et al. (1997) who found that avian diversity was generally greater in bottomland hardwood areas that were in later stages of succession.

CHAPTER 3

AVIAN COMMUNITY ASSESSMENT OF A 25-YEAR OLD BOTTOMLAND HARDWOOD FOREST

3.1 Introduction

The difference between young and mature bottomland hardwood forests (hereafter BHF) can be seen in the vegetative structure and wildlife species in the area. A young BHF has an open canopy with large amounts of early successional vegetation, and thus has wildlife species associated with these habitat characteristics. A mature BHF has a closed canopy with very little herbaceous vegetation in the understory, but may have more vertical structure than young forests because of a diverse mid-story.

The difference in vegetation among young and mature BHF is not only influenced by canopy cover, but also the flooding regime associated with these successional stages. A young BHF will be found in areas close to a water source because of frequent disturbance by flooding (Hodges 1997). As forests age, sediments deposited by flooding may change the elevation, which in turn, decreases flood potential, allowing soils to mature (>100 years), and permits establishment of climax bottomland hardwood species such as cherrybark oak (*Quercus pagoda*; Hosner and Minckler 1963; Bell 1974; Hodges 1994a). Previous studies indicate that these two stages of succession (i.e., early

and late) cater to vegetation and wildlife species that are specialists for those environmental types while allowing for little overlap of successional species (Naiman and Decamps 1997).

There has been extensive research conducted on the early and late stages of BHF's throughout the United States, but research on intermediate stages when the forest is transitioning from one successional stage to the next is needed. Lack of research during intermediate stages makes it difficult to assess where a forest is in regard to site objectives and if management is required to put the forest on the desired trajectory. My research will help bridge this research gap in an afforested BHF's progress through the intermediate stages of succession by assessing the composition of the avian community and determining if the species composition is 75–85% similar to that of a mature BHF (Nuttle and Burger 1996). Based on results of this research, I will develop management recommendations to either maintain current conditions or to improve habitat quality through silvicultural practices such as planting and thinning.

3.2 Literature Review

Vegetation in young forests is considerably different from mature forests, with more shade intolerant tree species such as black willow (*Salix nigra*) and eastern cottonwood (*Populus deltoides*) being dominant in a forest's early development (Clements 1916; Hodges 1994b). As forests age, pioneer species will begin dying off due to their relatively short lifespan with most not living past 60 years. This opening of the canopy allows for release of mid-story shade-tolerant species, such as elm (*Ulmus* spp.), ash (*Fraxinus* spp.), and sugarberry (*Celtis laevigata*), to grow into openings and begin the next intermediate stage of succession. A mature forest is considered to be in the latest

stage of succession if cherrybark oak and hickories (*Carya* spp.) are dominant in the canopy. This stage will begin to take form when flooding and deposition of sediments have nearly ceased (Putnam et al. 1960; Hodges 1994b, 1997). These oak-hickory forests are considered to be the climax BHF and will persist for hundreds of years if there is a lack of disturbance (Fig. 3.1; Hodges 1994a; 1997).

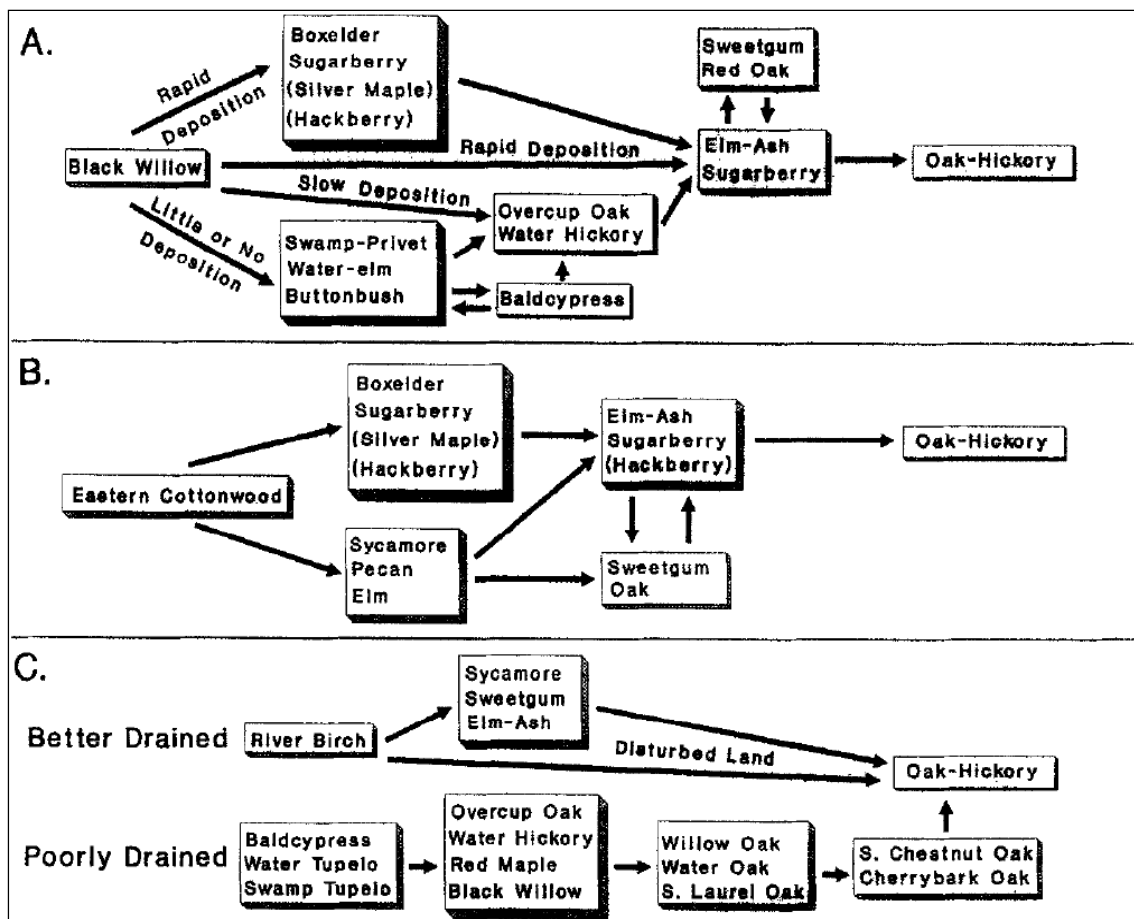


Figure 3.1: Three successional patterns of BHF based on deposition of sediments and soil drainage for (A) poorly drained sites in major bottoms, (B) better-drained ridges in major bottoms, and (C) succession based on drainage in minor bottoms. Identified by Hodges (1994a).

Succession of tree species in BHF's is a direct effect of hydrologic and geomorphic processes that created them (Clements 1916; Hupp 2000). As sediments are deposited by flooding and/or natural flow of the water body, new land is made over time (Putnam 1960; Hosner and Minckler 1963). This new land is where primary succession begins, thus continuing the process that Hodges (1994a) identified, where succession of tree species in both major and minor bottoms depends on soil drainage and the speed and amount of sediment deposition. As new land is inhabited by pioneer species, soils and trees that are no longer adjacent to the water body continue to age and are only affected when flooding occurs (Putnam 1960; Hodges 1997).

Differences between young and mature BHF's extends into the understory with changes in species abundance and diversity as the forest ages. Bell (1979) found distribution and seasonal growth of understory vegetation is determined by both overstory canopy and characteristics of the growing environment, such as soil characteristics (i.e., texture, pH, and moisture content), topographic change, and flooding regime. Young BHF lack of canopy cover, thus allowing the growing environment to determine understory vegetation density and diversity (Bell 1979; Merritt et al. 2010).

The environmental factor with the greatest effect on understory vegetation is the flooding regime (Bell 1979; Hardin and Wistendahl 1983). Flooding creates disturbance by removing and/or depositing sediments randomly across the forest floor creating microtopographic changes, such as mounding and gilgai formations (i.e., basins caused by shrinking of clay texture soils) in the soil. These small differences in topography allow different annual and perennial vegetative species to grow, thus potentially increasing understory diversity with flood specialist species and generalist vegetative species that

are able to persist during disturbance (Hardin and Wistendahl 1983; Naiman and Decamps 1997; Merritt et al. 2010). Frequency of flooding in these areas will determine if succession of the understory will move forward or backward. When flooding is more frequent, there is an increase in soil disturbance which inhibits the germination of species such as peppervine (*Ampelopsis arborea*) and Indian woodoats (*Chasmanthium latifolium*), which are not adapted to these flood-prone areas (Naiman and Decamps 1997; Lichvar et al. 2016). If flooding is less frequent, soil is allowed to mature and succession moves forward with differences in resource uptake and plant tolerance driving species abundance and distribution (Lyon and Sager 1998).

Recently disturbed areas are in the earliest stages of succession. This community is dominated by annual herbaceous species, such as common ragweed (*Ambrosia artemisiifolia*) and black-eyed Susan (*Rudbeckia hirta*), which provide nesting cover and habitat for insects, such as butterflies (Lepidoptera) and honey bees (*Apis mellifera*; Swanson et al. 2010). The diversity and abundance of insects and seeds provide food resources for avian species, such as blue grosbeak (*Passerina caerulea*) and eastern meadowlarks (*Sturnella magna*). These areas are also inhabited by small mammals, like hispid cotton rats (*Sigmodon hispidus*) and meadow voles (*Microtus pennsylvanicus*), that are adapted to dense herbaceous cover and seed abundance these grassland-like habitats offer. This diversity of insects, birds, and small mammals allows for predators, such as red-tailed hawks (*Buteo jamaicensis*), gray fox (*Urocyon cinereoargenteus*), and coyote (*Canis latrans*), to use these areas for hunting. These areas are also used for nesting, foraging, and cover by many different types of wildlife, but are most crucial for early

successional habitat specialists, such as field sparrows (*Spizella pusilla*; Harper 2007; Swanson et al. 2010).

As BHF age, sediment deposition increases elevation and creates new land along banks of the water body. These geomorphic changes decrease flooding risk. During this intermediate stage of succession, the understory will persist with annual herbaceous growth cycles. At this stage, established tree species cause changes in canopy cover, which begin to favor intermediate shade tolerant understory herbaceous and woody shrub species, such as parsley hawthorn (*Crataegus marshallii*) and Virginia wildrye (*Elymus virginicus*; Lichvar et al. 2016). This intermediate stage of succession may present itself in different ways depending on the time since disturbance and vegetative growth rate, with younger slow-growing areas having shrub-scrub habitat, while other faster-growing areas having a combination of both shrubby vegetation and young canopy trees. Herbaceous and woody vegetation of the understory may potentially be at its most diverse at this point in succession because of the combination of flood specialist species that have persisted, species that quickly adapt to flooding, and potential establishment of upland species (Clements 1916; Naiman and Decamps 1997).

Intermediate areas of succession are inhabited by habitat generalists and specialists from earlier or later stages of succession (Yahner 1995; Dickson 2001). Since these areas have a diversity of successional stages, with some areas still in earlier shrubby stages and others having more canopy structure, they are able to sustain shrub-scrub avian species, such as yellow-breasted chat (*Icteria virens*), as well as yellow-billed cuckoo (*Coccyzus americanus*) which are found in mature closed-canopy forests (Pashley and Barrow 1993; Sallabanks et al. 2000). The greater amount of cover and diversity of

food resources that come with a young forest provides habitat for eastern cottontail (*Sylvilagus floridanus*), fox squirrel (*Sciurus niger*), and white-tailed deer (*Odocoileus virginianus*; Yahner 1995). These wildlife species have the advantage of being able to use these areas throughout the year because intermediate forests provide herbaceous forage and soft mast during the warm season, such as blackberry (*Rubus* sp.), and hard mast during the cold season, such as Nuttall oak (*Quercus texana*) acorns (Yahner 1995; Dickson 2001; McComb 2015).

As succession continues, dominant trees create a completely closed canopy and forests are regarded as mature. At this stage of succession, less sunlight reaches the forest floor, thus decreasing understory vegetation abundance and diversity (Hodges 1994b; Naiman and Decamps 1997; McComb 2015). Understory vegetation is dominated by woody shade-tolerant species with herbaceous vegetation occupying areas of open canopy creating greater vegetative structural diversity. Late successional forests can persist for years and are only disturbed by naturally occurring events, such as tornadoes, hurricanes, or disease outbreak. Flooding only occurs in these areas during extreme precipitation events, thus allowing forest soils to mature and continue to be dominated by long-lived species (Clements 1916; Hodges 1997; Naiman and Decamps 1997).

The decrease in herbaceous vegetation as succession progresses may inhibit wildlife species relying on them, but overall wildlife diversity has been shown to increase, due to the presence of specific habitat features such as dead or hollow trees for cavity-nesting or denning species like the pileated woodpecker (*Hylatomus pileatus*) and American black bear (*Ursus americanus*; Yahner 1995; McComb 2015). Late successional forests allow for many specialists to inhabit specific niches present because

of the vertical and horizontal structural diversity. Diaz et al. (2005) found on Chiloe´ Island, Chile, old-growth forests had the highest number of avian species observed ($n = 21$), while mid-successional forests had the lowest ($n = 14$). This study also found the density of birds was higher in old-growth forests because of the greater amount of canopy trees, dead trees, forest floor logs, and understory cover (Diaz et al. 2005). Late successional forests are crucial for many types of wildlife because of the habitat they provide, but because of the decrease in BHF's many species associated with late-successional ecosystems, such as wood thrush (*Hylocichla mustelina*), follow the same decreasing trend (Gardiner et al. 2004; McKelvey 2015). Uneven-aged structure and multiple successional stages in BHF's create multiple habitat types, thus allowing many different wildlife species to inhabit these areas.

The decrease in prevalence of wildlife species associated with late-successional forests, along with the high diversity associated with early and late successional stages, has led to an emphasis of research on these two successional stages (McKelvey 2015). This has led to a lack of research focusing on forests in intermediate stages of succession, which makes it difficult to assess afforested sites at intermediate stages of succession. To determine if an afforestation site is meeting the goal of providing habitat for late-successional wildlife species, research was needed to evaluate the effectiveness of these developing afforestation sites.

My research objective was to compare avian species composition in a 25-year old afforested BHF to mature BHF's (50 to >200 years old) in the southeastern United States based upon published literature. In other words, I evaluated the progress of an afforested bottomland hardwood stand in the Red River Alluvial Valley to determine if the avian

community was 75–85% similar to the avian community found in mature bottomland hardwoods (Nuttle and Burger 1996). These methods will allow land managers to specifically assess habitat quality of other afforested BHF in the southeastern United States compared to mature BHF in terms of percent similarity in the avian community. These methods also may be used as an assessment technique for researchers and land managers, who are looking at bird species as an indicator of habitat type and quality in reforestation and other types of afforestation projects in other areas in North America. This will improve our understanding of habitat quality in established afforested BHF and afforestation techniques for future projects. Land managers, wildlife biologists, and foresters will be able to better develop and maintain quality BHF habitat for birds and potentially other wildlife species using the avian community's similarity to a mature BHF as an indicator of successional development and habitat quality (Maurer 1993; Nuttle and Burger 1996).

3.3 Methods

3.3.1 Study Area

Refer to Chapter 2 “Avian Community Response to Dominant Forest Types within an Afforested Stand,” section 2.3.1 for study area description.

3.3.2 Avian Point Counts

Refer to Chapter 2 “Avian Community Response to Dominant Forest Types within an Afforested Stand,” section 2.3.2 for avian point count description.

3.3.3 Review of Published Literature

To compare avian species composition at the study site to mature BHF in the southeastern United States, I conducted a review of published literature on breeding avian

communities in mature southeastern BHF's using Google Scholar, JSTOR, and available hard copies of published literature. The six keyword searches that were used in Google Scholar and JSTOR were "bottomland hardwoods," "bottomland hardwood forests," "southeastern bottomlands," "forested wetlands," "southeastern floodplains," and "southern riparian forests." Criteria for published literature included; (1) studies conducted in one of ten southeastern states (i.e., Louisiana, eastern Texas, Arkansas, Mississippi, Alabama, Georgia, South Carolina, southern North Carolina, eastern Tennessee, or the western panhandle of Florida); (2) the studied BHF had to be ≥ 50 years old (Nuttle and Burger 1996, 2005); and (3) an avian species list and described dominant forest types had to be provided. For each publication I found that met these criteria, I documented what avian species were detected and the dominant hardwood species present. A second stage of the literature review was done to identify foraging classification and substrate guilds of avian species associated with mature BHF's in the southeastern United States, as well as for avian species detected at the research site (De Graaf et al. 1985; Hamel 1992; Hunter et al. 1993). This second stage was done to determine if there were trends in avian community composition that would not be seen without foraging classification and substrate guilds being identified.

3.3.4 Data Analyses

Avian species diversity did not vary by forest type at the NRG site (as seen in results of Ch. 2), but avian species detected were different among forest types. Thus, I compared avian species across the entire NRG site and among the seven dominant forest types to the species composition of mature BHF's identified by published literature. I also compared seasons to assess differences across the three breeding seasons I collected data.

I performed the comparisons using Sorensen's Similarity Index (Sorensen 1948), which is calculated as:

$$SSI = (2 * C) / (A + B)$$

where *A* is the number of species detected across the NRG site or in a given forest type at the site, *B* is the number of species detected in mature BHF stands, and *C* is the number of species detected in both the study area and mature stands. If BHF habitat at the NRG site was going to provide quality habitat in the future, it must have been 75–85% similar in avian species composition to birds frequently associated with mature BHFs in the southeastern United States (Nuttall and Burger 1996).

3.4 Results

3.4.1 Avian Community in Mature BHFs vs. NRG Site

I found 14 papers from seven different states consisting of multiple dominant forest types and avian community descriptions during my literature review (Tables 3.1–3.2). I found 45 avian species making up five different foraging guilds (i.e., carnivorous, frugivore, granivore, insectivore, omnivore) that were associated with mature BHFs (Table 3.3; De Graaf 1985; Hamel 1992; Hunter et al. 1993).

Table 3.1: Avian species commonly associated with mature bottomland hardwood forests in the southeastern United States with supporting references.

Common name	Scientific name	Publication*
Acadian Flycatcher	<i>Empidonax virescens</i>	C,E,F,G,I,J,K,L,M,N
American Crow	<i>Corvus brachyrhynchos</i>	A,F,M
American Redstart	<i>Setophaga ruticilla</i>	E,K,N
Bachman's Warbler	<i>Vermivora bachmanii</i>	I
Barred Owl	<i>Strix varia</i>	F
Blue Jay	<i>Cyanocitta cristata</i>	A,E,F,J,M,N
Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	C,E,F,G,J,K,M,N
Brown Thrasher	<i>Toxostoma rufum</i>	A,E
Brown-headed Cowbird	<i>Molothrus ater</i>	A,E,J,M
Carolina Chickadee	<i>Poecile carolinensis</i>	A,E,F,G,I,J,K,L,M,N
Carolina Wren	<i>Thryothorus ludovicianus</i>	E,F,G,H,J,K,L,M,N
Cerulean Warbler	<i>Setophaga cerulea</i>	B,I,M
Common Yellowthroat	<i>Geothlypis trichas</i>	E,F,G,H,J,K,L,N
Downy Woodpecker	<i>Picoides pubescens</i>	D,E,F,G,J,K,L,M,N
Eastern Towhee	<i>Contopus virens</i>	A,D,M
Eastern Wood-Pewee	<i>Pipilo erythrophthalmus</i>	C,I,J,K,L,M,N
Great Crested Flycatcher	<i>Myiarchus crinitus</i>	C,E,F,G,J,K,L,M,N
Hairy Woodpecker	<i>Leuconotopicus villosus</i>	E,G,M,N
Hooded Warbler	<i>Setophaga citrina</i>	A,C,D,E,F,G,H,I,L,M,N
Indigo Bunting	<i>Passerina cyanea</i>	D,J,K,M,N
Kentucky Warbler	<i>Oporornis formosus</i>	A,C,E,F,G,H,I,J,L,M,N
Louisiana Waterthrush	<i>Parkesia motacilla</i>	C,F,I,L
Mourning Dove	<i>Zenaida macroura</i>	F,J,M
Ovenbird	<i>Seiurus aurocapilla</i>	H,N
Northern Cardinal	<i>Cardinalis cardinalis</i>	A,D,E,F,G,J,K,L,M
Northern Parula	<i>Setophaga americana</i>	C,E,F,G,I,K,L,M
Orchard Oriole	<i>Icterus spurius</i>	D,I,M
Pileated Woodpecker	<i>Hylatomus pileatus</i>	A,E,F,G,J,K,L,M,N
Prothonotary Warbler	<i>Protonotaria citrea</i>	C,D,E,F,I,J,K,L,M,N
Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	A,D,E,F,G,J,K,L,M,N
Red-eyed Vireo	<i>Vireo olivaceus</i>	C,D,E,F,G,H,J,K,L,M,N
Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>	A,G,I,J,M
Red-shouldered Hawk	<i>Buteo lineatus</i>	E,J

Table 3.1: Continued

Common name	Scientific name	Publication*
Ruby-throated Hummingbird	<i>Archilochus colubris</i>	C,F,G,J,M,N
Summer Tanager	<i>Piranga rubra</i>	C,D,E,F,G,J,K,M,N
Swainson's Warbler	<i>Limnothlypis swainsonii</i>	C,E,H,I,M,N
Tufted Titmouse	<i>Baeolophus bicolor</i>	A,D,E,F,G,H,J,K,L,M,N
White-breasted Nuthatch	<i>Sitta carolinensis</i>	G,K,L,N
White-eyed Vireo	<i>Vireo griseus</i>	A,C,E,G,H,I,J,L,M,N
Wood Thrush	<i>Hylocichla mustelina</i>	C,D,E,F,I,K,L,M,N
Worm-eating Warbler	<i>Helmitheros vermivorum</i>	E,H
Yellow-billed Cuckoo	<i>Coccyzus americanus</i>	C,D,E,F,G,I,J,K,M,N
Yellow-breasted Chat	<i>Icteria virens</i>	H,I,M
Yellow-throated Vireo	<i>Vireo flavifrons</i>	C,D,F,G,I,K,L,M,N
Yellow-throated Warbler	<i>Setophaga dominica</i>	C,E,F,I,J,N

* See Table 3.2 for publication descriptions

Table 3.2: Published literature on mature BHF's in the southeastern United States referencing commonly associated avian species.

Publications Reviewed	Dominant Forest Types	Location
A Dickson and Noble 1978	oak	LA
B Hamel 2000	mature deciduous forest	AR,MO,TN,NC
C Hodges and Krementz 1996	willow oak, overcup oak-water hickory, bald cypress-water tupelo	GA
D Hurst and Bourland 1996	sweetgum-Nuttall-willow oak	MS
E Kennedy et al. 1977	sweetgum-hackberry-water oak;cottonwood-willow-sycamore and cypress-tupelo	LA
F Kilgo et al. 1998	sweetgum, swamp tupelo, red maple, water oak, laurel oak, overcup oak, and cherrybark oak	SC
G Moorman and Guynn 2001	laurel oak, cherrybark oak, and sweetgum	SC
H Moorman et al. 2007	laurel oak, cherrybark oak, and sweetgum	SC
I Mueller et al. 1999	sweetgum, swamp tupelo, oak;	LA,AR,MO,MS

Table 3.2: Continued

	Publications Reviewed	Dominant Forest Types	Location
J	Nuttle and Burger 1996	overcup oak, bitter pecan, sugarberry - American elm, sweetgum-Nuttall-willow oak	MS
K	Sallabanks et al. 2000	water tupelo - bald cypress, sycamore, American elm, green ash sugarberry, boxelder, water hickory, and sweetgum	NC
L	Smith et al. 2001	oak-sweetgum-cypress	AR
M	Twedt et al. 1999	oak-sweetgum-cypress- sugarberry-American elm, sweetgum-Nuttall-willow oak	LA
N	Wakeley and Roberts 1996	water tupelo, bald-cypress, overcup oak, water hickory, and green ash; Nuttall oak, willow oak, sweetgum, water oak, and pignut hickory	AR

Table 3.3: Foraging and habitat substrate guilds of avian species commonly associated with bottomland hardwood forests in the southeastern United States based on published literature.

Common Name	Scientific Name	Guild ^{a,b,c}
Acadian Flycatcher	<i>Empidonax virescens</i>	Insec: ASA
American Crow	<i>Corvus brachyrhynchos</i>	Omni: GF
American Redstart	<i>Setophaga ruticilla</i>	Insec: ASA, LCG
Bachman's Warbler	<i>Vermivora bachmanii</i>	Omni: GF
Barred Owl	<i>Strix varia</i>	Carn: GH
Blue Jay	<i>Cyanocitta cristata</i>	Omni: GF, UCF
Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	Insec: UPG
Brown Thrasher	<i>Toxostoma rufum</i>	Omni: GF
Brown-headed Cowbird	<i>Molothrus ater</i>	Gran: GG, Omni: GF
Carolina Chickadee	<i>Poecile carolinensis</i>	Insec: LC, Omni: LCF
Carolina Wren	<i>Thryothorus ludovicianus</i>	Insec: LCG
Cerulean Warbler	<i>Setophaga cerulea</i>	Insec: UCG
Common Yellowthroat	<i>Geothlypis trichas</i>	Insec: LCG
Downy Woodpecker	<i>Picoides pubescens</i>	Frug: LCG ;Insec: BG
Eastern Towhee	<i>Contopus virens</i>	Omni: GF
Eastern Wood-Pewee	<i>Pipilo erythrophthalmus</i>	Insec: AS
Great Crested Flycatcher	<i>Myiarchus crinitus</i>	Frug: LCG
Hairy Woodpecker	<i>Leuconotopicus villosus</i>	Frug: LCG ;Insec: BG
Hooded Warbler	<i>Setophaga citrina</i>	Insec: ASA, LCG
Indigo Bunting	<i>Passerina cyanea</i>	Omni: LCF
Kentucky Warbler	<i>Oporornis formosus</i>	Insec: GG
Louisiana Waterthrush	<i>Parkesia motacilla</i>	Insec: ShG
Mourning Dove	<i>Zenaida macroura</i>	Gran: GG
Ovenbird	<i>Seiurus aurocapilla</i>	Omni: GF, Insec:GG
Northern Cardinal	<i>Cardinalis cardinalis</i>	Omni: GF
Northern Parula	<i>Setophaga americana</i>	Insec:UCG
Orchard Oriole	<i>Icterus spurius</i>	Insec:UCG
Pileated Woodpecker	<i>Hylatomus pileatus</i>	Insec: BE, Omni: LCF
Prothonotary Warbler	<i>Protonotaria citrea</i>	Insec:LCG, BG
Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	Insec: BG, Omni: GF
Red-eyed Vireo	<i>Vireo olivaceus</i>	Insec: UCG
Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>	Insec: ASA,BG

Table 3.3: Continued.

Common Name	Scientific Name	Guild^{a,b,c}
Red-shouldered Hawk	<i>Buteo lineatus</i>	Carn: GH
Ruby-throated Hummingbird	<i>Archilochus colubris</i>	Omni: FHG
Summer Tanager	<i>Piranga rubra</i>	Insec: UCG
Swainson's Warbler	<i>Limnothlypis swainsonii</i>	Insec: LCG
Tufted Titmouse	<i>Baeolophus bicolor</i>	Insec: LCG, Omni: LCF
White-breasted Nuthatch	<i>Sitta carolinensis</i>	Gran: UCG, Insec: BG
White-eyed Vireo	<i>Vireo griseus</i>	Insec: LCG, Omni: LCF
Wood Thrush	<i>Hylocichla mustelina</i>	Omni: GF
Worm-eating Warbler	<i>Helmitheros vermivorum</i>	Insec: GG
Yellow-billed Cuckoo	<i>Coccyzus americanus</i>	Insec: LCG
Yellow-breasted Chat	<i>Icteria virens</i>	Omni: LCF
Yellow-throated Vireo	<i>Vireo flavifrons</i>	Insec: UCG
Yellow-throated Warbler	<i>Setophaga dominica</i>	Insec: UCG, BG

^a De Graaf et al. 1985, Hamel 1992

^b Forage Classification: Carn–carnivorous, Crust–crustaceovore, Frug–frugivore, Gran–granivore, Insec–insectivore, Omni–omnivore, Pisc–piscivore

^c Forage Substrate: ASA–air sallier, ASC–air screener, BE–bark excavator, GH–ground hawker, WA–water ambusher; BG–bark gleaner, FHG–floral hover-gleaner, GG–ground gleaner, LCG–lower -canopy gleaner, UCG–upper-canopy gleaner, ShG–shoreline gleaner; FMF–fresh-marsh forager, GF–ground forager, LCF–lower-canopy forager, ShF–shoreline forager, UCF–upper-canopy forager; GS–ground, scavenger, ShS– shoreline scavenger

At the study site, I detected 52 avian species making up seven foraging guilds (i.e., carnivorous, crustaceovore, frugivore, granivore, insectivore, omnivore, piscivore), across multiple foraging substrate guilds (e.g., ground gleaners, canopy foragers, and ground scavengers; Table 3.4). The most common foraging guilds were insectivores (n = 26) and omnivores (n = 25), some species being both.

Table 3.4: Avian species detected at a privately-owned bottomland hardwood forest near Coushatta, Louisiana, 2016–2018, along with their associated foraging and substrate guilds based on published literature.

Common Name	Scientific Name	Guild ^{a,b,c}
Acadian Flycatcher	<i>Empidonax virescens</i>	Insec: ASA
American Bittern	<i>Botaurus lentiginosus</i>	Insec, Carn, Crust: WA
American Crow	<i>Corvus brachyrhynchos</i>	Omni: GF
American Robin	<i>Turdus migratorius</i>	Omni: GF, LCF
Barred Owl	<i>Strix varia</i>	Carn: GH
Blue Grosbeak	<i>Passerina caerulea</i>	Omni: GF
Blue Jay	<i>Cyanocitta cristata</i>	Omni: GF, UCF
Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	Insec: UPG
Brown-headed Cowbird	<i>Molothrus ater</i>	Gran: GG, Omni: GF
Carolina Chickadee	<i>Poecile carolinensis</i>	Insec: LC, Omni: LCF
Carolina Wren	<i>Thryothorus ludovicianus</i>	Insec: LCG
Cattle Egret	<i>Bubulcus ibis</i>	Insec: GG
Cerulean Warbler	<i>Setophaga cerulea</i>	Insec: UCG
Common Gallinule	<i>Gallinula galeata</i>	Omni: FMF
Downy Woodpecker	<i>Picoides pubescens</i>	Frug: LCG ;Insec: BG
Eastern Bluebird	<i>Sialia sialis</i>	Frug: LCG, Insec: GG Omni: GF, LCF
Eastern Meadowlark	<i>Sturnella magna</i>	Insec: GG, Omni: GF
Eastern Towhee	<i>Pipilo erythrophthalmus</i>	Omni: GF
Eastern Wood-Pewee	<i>Contopus virens</i>	Insec: AS
Fish Crow	<i>Corvus ossifragus</i>	Omni: ShF
Gray Catbird	<i>Dumetella carolinensis</i>	Omni: GF, LCF
Great Blue Heron	<i>Ardea herodias</i>	Pisc: WA
Great Crested Flycatcher	<i>Myiarchus crinitus</i>	Frug: LCG
Great Egret	<i>Ardea alba</i>	Carn, Crust: WA
Green Heron	<i>Butorides virescens</i>	Crust: WA
Hairy Woodpecker	<i>Leuconotopicus villosus</i>	Frug: LCG
Hooded Warbler	<i>Setophaga citrina</i>	Insec: ASA, LCG
Indigo Bunting	<i>Passerina cyanea</i>	Omni: LCF

Table 3.4: Continued

Common Name	Scientific Name	Guild^{a,b,c}
Kentucky Warbler	<i>Oporornis formosus</i>	Insec: GG
Louisiana Waterthrush	<i>Parkesia motacilla</i>	Insec: ShG
Mourning Dove	<i>Zenaida macroura</i>	Gran: GG
Northern Cardinal	<i>Cardinalis cardinalis</i>	Omni: GF
Northern Flicker	<i>Colaptes auratus</i>	Insec:GG,Omni:GF,LCF

^a De Graaf et al. 1985, Hamel 1992

^b Forage Classification: Carn–carnivorous, Crust–crustaceovore, Frug–frugivore, Gran–granivore, Insec–insectivore, Omni–omnivore, Pisc–piscivore

^c Forage Substrate: ASA–air sallier, ASC–air screener, BE–bark excavator, GH–ground hawker, WA–water ambusher; BG–bark gleaner, FHG–floral hover-gleaner, GG–ground gleaner, LCG–lower -canopy gleaner, UCG–upper-canopy gleaner, ShG–shoreline gleaner; FMF–fresh-marsh forager, GF–ground forager, LCF–lower-canopy forager, ShF–shoreline forager, UCF–upper-canopy forager; GS–ground scavenger, ShS– shoreline scavenger

3.4.2 Avian Community of Afforested BHF's vs. Mature BHF's

Results of Sorenson's similarity analysis indicated that the avian community at the NRG site was 68% similar to mature BHF's. Over the three breeding seasons, there was an increase in similarity (2016, 64.1%; 2017, 66.7%; 2018, 68.2%). During avian point count surveys at the NRG site, nine of the detected 52 avian species were members of the aquatic habitat guild and were not associated with BHF's, according to published literature. Thus, I performed a Sorenson's similarity analysis excluding these species. Results from this analysis indicated that the study site was 75% similar to mature BHF's. Comparison analyses still indicated an increase in similarity over the three breeding seasons (2016, 65.8%; 2017, 71.8%; 2018, 72.3%). When I compared similarity among breeding seasons, analyses indicated the 2017 and 2018 seasons were the most similar at 78%. The 2016 breeding season was 72.2% similar to 2017 and 73.7% similar to the 2018 seasons.

I performed Sorenson's similarity analyses, with the aquatic guild included, to compare the seven forest types to mature BHF's for the three breeding seasons (2016–2018; Table 3.5). Results from forest type comparison indicated the sugarberry-persimmon forest type was the most similar to mature BHF's in regards to avian species composition for the 2016 (51.6%) and 2018 (67.6%) breeding seasons. During the 2017 season, the forest type that was most similar to mature BHF's was the sweetgum (*Liquidambar styraciflua*) forest type (59.7%).

Table 3.5: Sorensen's similarity indices for avian species detected in seven dominant forest types at NRG site during 2016, 2017, and 2018 breeding seasons compared to mature bottomland hardwood forests in the southeast United States.

Forest Type	2016	2017	2018
Green Ash	43.3	52.9	60.3
Honey Locust	48.4	55.9	60.0
Nuttall Oak	41.4	56.7	60.0
Sugar-Persimmon	51.6	58.0	67.6
Sweet Pecan	50.0	54.5	61.5
Sweetgum	41.4	59.7	59.7
Willow Oak	45.9	55.1	50.0

3.5 Discussion

3.5.1 Afforested BHF's vs. Mature BHF's

The 25-year old NRG site does not meet the goal of the avian community being 75–85% similar to mature BHF's in the southeastern United States. Results of this study are in contrast to results of Nuttle and Burger (1996), who found that reforested BHF's 21–27 years old supported 75–85% of the avian community found in mature bottomland hardwoods. The likely reason for this is the NRG site has BHF-associated species, like Carolina chickadee (*Poecile carolinensis*), generalist species like northern cardinal (*Cardinalis cardinalis*), and 17 bird species that are not associated with mature BHF's

(Table 3.6). Avian species not associated with mature BHF are from early successional stages and/or are associated with wetland habitat, creating a lower similarity between the research site and mature BHF.

Table 3.6: List of bird species and total found and/or detected in mature BHF and detected at the NRG site during 2016, 2017, and 2018 breeding seasons, with species found in both to assist with comparison. Common and scientific names as seen in Table 2.1

Birds in Mature BHF	Birds in Both	Birds at NRG
ACFL	ACFL	ACFL
		AMBI
		AMCO
AMCR	AMCR	AMCR
AMRE		
BAWA		
		AMRO
BAOW	BAOW	BAOW
		BEKI
BGGN	BGGN	BGGN
BHCO	BHCO	BHCO
		BLGR
BLJA	BLJA	BLJA
BRTH		
CACH	CACH	CACH
CAWR	CAWR	CAWR
CEWA	CEWA	CEWA
		COGA
		COGR
COYE		
DOWO	DOWO	DOWO
		EABL
		EAME
EATO	EATO	EATO
EAWP	EAWP	EAWP
		FICR
		GBHE
GCFL	GCFL	GCFL
		GRCA
		GREG
		GRHE

Table 3.6: Continued

Birds in Mature BHF	Birds in Both	Birds at NRG
HAWO	HAWO	HAWO
HOWA	HOWA	HOWA
INBU	INBU	INBU
KEWA	KEWA	KEWA
LOWA	LOWA	LOWA
MODO	MODO	MODO
NOCA	NOCA	NOCA
NOPA		
OROR		
OVEN		NOFL
		PABU
PIWO	PIWO	PIWO
PRWA		
RBWO	RBWO	RBWO
REVI	REVI	REVI
RSHA	RSHA	RSHA
RHOW		
		RTHA
RTHU	RTHU	RTHU
		RWBL
SUTA	SUTA	SUTA
SWWA		
TUTI	TUTI	TUTI
WBNU	WBNU	WBNU
WEVI	WEVI	WEVI
WOTH	WOTH	WOTH
WEWA		
YBCH	YBCH	YBCH
YBCU	YBCU	YBCU
		Yewa
YTVI	YTVI	YTVI
YTWA		
Total	45	52

There are early successional areas at the NRG site with a low density of trees, and/or have tree species, such as honey locust (*Gleditsia triacanthos*), with little canopy cover, thus allowing sunlight to reach the forest floor and increase growth of understory vegetation. This lack of canopy cover and increased understory caters to early successional species that are not associated with BHF. For example, areas with shrub-scrub habitat features provide habitat for bird species, such as yellow-breasted chat, which is among the most detected species at the site. The study site is also broken up by small openings of early succession due to mortality during early stand development and anthropogenic factors (e.g., roads, old drilling site, pipelines, mowed small fields). These areas provide multiple stages of succession for species like mourning dove (*Zenaida macroura*) and edge associated species like indigo bunting (*Passerina cyanea*). Though some of these birds are associated with mature BHFs, they are an indicator of the prevalence of other stages of succession at this site. These areas of early succession may explain why this site has not reached the goal of being 75–85% similar to mature BHFs in the southeastern United States.

There were areas at this site more similar to late successional stages. For example, the Nuttall oak and sweetgum forest types were frequently had less understory and more canopy closure. These areas provide habitat for BHF-associated species, like Acadian flycatcher and yellow-billed cuckoo, which were both detected at this site. There were also nine bird species from the aquatic habitat guild, such as great blue heron (*Ardea herodias*), great egret (*Ardea alba*), and common gallinule (*Gallinula galeata*), that were present at this site because of an abundance of hydrological features that included an oxbow and a large creek that flows southwest to northeast through the site. This

abundance of water-adapted species further decreased this site's similarity to mature BHF's because aquatic habitat species were not found in reviewed published literature.

This site has habitat features similar to mature BHF's, but there are 12 avian species frequently associated with mature BHF's that were not detected at this site (Table 3.6). Absence of these species is potentially due to the absence of habitat features, such as Spanish moss (*Tillandsia usneoides*) availability for bird species like the northern parula (*Setophaga americana*), which requires it for nesting. Another species not detected was the prothonotary warbler (*Protonotaria citrea*), most likely due to lack of cavity trees in permanently flooded areas.

Though this site does not meet the similarity goal, there was an increase in the avian community's similarity to mature BHF's over the past three breeding seasons, with the 2018 breeding season showing the greatest similarity to mature BHF's. This greater similarity may be due to the natural progression of this forest through succession. These results are consistent with research by Buffington et al. (1997) and Wilson and Twedt (2005) who found that as succession progresses, avian species richness increases with structural complexity of the forest. This afforested site had adequate time to meet the 75–85% similarity goal with it being approximately four years older than some sites studied by Nuttle and Burger (1996). It is, however, still below 75–85% similarity (68%) unless aquatic habitat species are excluded from analyses (75%), which I did to get an idea of how much these species affect results. The NRG site is also potentially behind because of mortality of tree seedlings during site development and continued disturbance by natural (e.g., drought, flooding, windthrow, disease) and anthropogenic factors, causing more heterogeneity across the site. Though habitat heterogeneity is known to increase species

diversity (Twedt et al. 1999; Wilson and Twedt 2005), the objective of this site was to provide habitat for late-successional wildlife species, rather than to maximize species diversity. After evaluating this site, I believe the objective of this property should be changed from late-successional habitat specific to a general wildlife diversity objective of providing habitat to multiple stages of succession as this research site is doing and could potentially continue to do for many years to come.

CHAPTER 4

MANAGEMENT RECOMMENDATIONS

The avian community at the NRG site had a density that was highly variable among forest types. Avian diversity was not significantly different among forest types, but indicated differences in species assemblage between forest types. Sorenson's similarity analyses indicated that the avian community at the site was 68% similar to mature BHF, thus not meeting the goal of 75–85% similarity, but did show an increasing trend in similarity over the three breeding seasons' data was collected (Nuttall and Burger 1996). The NRG site has an avian community that resembles a forest that in the intermediate stage of succession with multiple bird species that are associated with multiple stages of succession, rather than species from a later successional stage.

4.1 Recommendations for Future Afforestation

After observing the layout of the NRG site and what tree species were found by previous research by Strozier (2015) to be dominant after 25 years, there are some techniques I recommend future afforestation projects do differently that was done at this site and others that I would keep the same. First, this site was planted with multiple tree species mixes, as well as mixtures of seeds and seedlings, which has done well over the past 25 years. With that being said, future afforestation projects should focus more attention on ensuring these seeds and seedlings are planted in soils for which they are

best adapted. There are areas at this site identified by Strozier (2015) with large amounts of mortality primarily due to flooding of tree species not well-adapted for flooding. Another issue with the NRG site is that planted seeds and seedlings were not mixed enough in regards to the ratios of species at this site. These uneven ratios have created multiple small monoculture stands in many areas, rather than a mixture of many species requiring similar growing conditions. Future afforested projects should plant tree species with a more even ratio across the site than was done at the NRGs site and should attempt to plant species randomly rather than making rows or blocks of single species. An issue not present at the NRG site—but one to keep in mind with other afforestation projects—is the shape of the property being planted. It is important to attempt to plant sites not irregularly shaped. Irregularity at the site may cause increased edge effects and increased nest parasitism in the bird community. The NRG site is on the right track for becoming a success, in terms of providing late-successional habitat for wildlife, and issues I observed at this site will help with better establishment of these afforested BHF's in the future.

4.2 NRG Management Recommendations

The first management option to increase late-successional habitat over a shorter time period is to plant tree species such as sweetgum (*Liquidambar styraciflua*), sugarberry (*Celtis laevigata*), and common persimmon (*Diospyros virginiana*) in areas with a high abundance of early successional avian species. These forest types had the greatest similarity to mature BHF's during the three breeding seasons. Fast-growing sweetgum will allow for canopy closure and vertical structure to develop in a shorter time period, while shade tolerant sugarberry and common persimmon have time to grow and produce soft mast in the future for wildlife. Sugarberry is well equipped to grow in areas

with high soil moisture and experience frequent flooding, while common persimmon is well suited for areas with dry soils and infrequent flooding. This management option is similar to recommendations by Wilson and Twedt (2005) on young reforestation sites, but has recommended tree species adapted to inhabit BHF.

My recommendation, however, is to not do any forest management practices at the site, unless invasive tree and shrub species, such as Chinese tallowtree (*Triadica sebifera*) and Chinese privet (*Ligustrum sinense*), need to be controlled. The absence of management will allow the NRG site to continue on its current path of increasing avian community similarity as it has over the past three years. Allowing this site to continue on its current course will provide habitat for bird species from multiple stages of succession. Lack of management causes this stand to naturally form multiple age structures throughout the site and for only the most well-adapted tree species to establish in open areas. This management option will take longer to reach the goal of late succession, as compared a planting recommendation, but it will ultimately resemble a natural bottomland hardwood stand when the objective is met.

I also recommend a forest stand evaluation every five years to ensure the establishment of native species is occurring in open areas rather than non-native species, such as Chinese tallowtree. Chinese tallowtree is fast growing, adapted to a wide variety of soil conditions, and is able to reproduce at three years old with as many as 100,000 seeds per year (Lemus 2018). These characteristics allow Chinese tallowtree to dominate open areas, which prevents establishment of preferred bottomland hardwood species and decreases habitat quality.

Forest stand evaluation will allow managers to determine if there are potential changes in hydrology at the NRG site. Currently, it is apparent that mining on the adjacent property to the south may have affected frequency of flooding. During construction on the adjacent property, water flow was altered from a natural creek flow to a constrained two culvert system under a new road. This constraining of the creek on the southern end could potentially decrease flooding during times of low precipitation because it holds water on the adjacent property until it reaches the culverts, which are at a higher elevation. Constraining the natural flow may also cause flooding to last for longer durations during times of high precipitation because the original floodplain has been broken up, from originally extending across the NRG property line to now stopping at the new road. The available flooded area has been reduced on the adjacent property, thus allowing for more water to flow through the culverts and flood the NRG site during wet periods.

Continued forest evaluation at the NRG site will help determine if a problem with forest health develops due to disease or insect infestation, such as the non-native emerald ash borer (EAB; *Agilus planipennis*). The forest has the potential to be altered in the future by the EAB because green ash is a dominant forest type at the NRG site. If EAB infests the NRG site, the green ash forest type will be quickly eliminated, thus creating more open areas that cater to early successional species. This increase in area of early successional habitat will negatively impact this site's similarity to mature BHF's because of increase in avian species associated with the early successional habitat.

These management recommendations are based on the current status of the forest at the NRG site and on the current primary objective of providing late successional

habitat for mature BHF-associated wildlife. Recommendations are subject to change if primary objectives of the site change or if the site is altered by either of the previously mentioned potential future forest issues (i.e., hydrology change, EAB infestation).

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