CHANGES IN AVIAN DIVERSITY AND POTENTIAL INVASIVE SEED DISPERSAL POST-WILDFIRE IN A SOUTHEASTERN DECIDUOUS FOREST; FLIPPER BEND WOODS, SIGNAL MOUNTAIN, TENNESSEE

By

Mary Elizabeth Feely

David A. Aborn
Associate Professor of Environmental Science
(Chair)

DeAnna Beasley
Assistant Professor of Environmental Science
(Committee Member)

Shannon McCarragher
Assistant Professor of Geography, Social, Cultural, and Justice Studies
(Committee Member)

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ABSTRACT

In eastern deciduous forests, fire-disturbance and its ecological implications have not been heavily studied. In Tennessee, a recently burned site (2016) presented a unique opportunity to analyze habitat regrowth two-three years after a major wildfire thought to have been worsened by invasive plants. In order to examine post-fire recovery and invasive plant recolonization, researchers observed the diversity of avian species in a burned and unburned site. Using mist-nets, line-transects, and vegetation analysis, this study found that though the unburned site was higher in avian diversity, the burned site appeared to be suitable habitat for multiple disturbance-dependent avian species. There was no evidence found that birds were contributing to invasive plant colonization of the burned site. This study supports the need for greater fire research in eastern deciduous forests and the results suggest that regular fires could benefit struggling species of disturbance-dependent birds in this region.

DEDICATION

To my Grandmother, Sarah M. C. Feely, who stressed the importance of education and filled her days with the joy of birdsong. Thank you for everything.

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I would like to thank my advisor Dr. David Aborn and committee members Dr. Deanna Beasley and Dr. Shannon McCarragher for their support and guidance. I would also like to thank my family and friends and all the contributors that assisted me during this project. I would also like to thank James Dale, the Assistant District Forester (TN), and Phil Morrissey, State Forest Unit Leader Division of Forestry (TN), for providing information on the fire and maps of the area. Lastly, I would like to sincerely thank Mr. Jordan Sikkema and all of the North Chickamauga Creek Conservancy for all of their help and the gracious access to their land. Without everyone's support, this project would have been impossible.

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CHAPTER I

INTRODUCTION

In Earth's changing climate, large and uncontrolled fires have become more common, thus strengthening the need to observe their influence on ecosystems and fire-biota interactions (Bowman et al., 2009; Freeman, Kobziar, Rose, & Cropper, 2017). Some of these high-intensity fires, referred to as "mega fires," are significantly more intense and destructive due to issues such as fire exclusion policies, drought, fuel accumulation, and climate conditions. Properly managing and planning for them and their aftermath has become crucial for land managers, scientists, and wildlife programs (Adams, 2013; Williams, 2012). One way to examine the aftermath of an unplanned fire is to observe avian diversity post-fire, their impact on recolonization in the successional habitat, and the impact that invasive plant species have.

However, despite the historical occurrence of fires within the southeastern United States and the more frequent use of fire in as a management tool (Aldrich et al., 2014; Flatley et al., 2015; Lafon & Quiring, 2012), fire studies focusing on avian diversity post-fire in the region appear to be sparse. Many of these fire studies have taken place in areas such as the Western and Central United States and Australia (Bagne & Purcell, 2011; DellaSala et al., 2017; Dickens & Allen, 2014; Klinger & Brooks, 2017; Latif et al., 2016; Levine et al., 2016). Those that do occur in the Eastern US tend to be in other habitats such as grasslands (Hovick et al., 2017; Mero et al., 2015). These studies, while informative, cannot be used to directly compare fires in southeastern deciduous forests as the ecosystem is different. One general literature review of the southeastern region found that there was a “critical need for long-term studies” on avian diversity post-fire in eastern deciduous forests in order to understand their interactions (Artman et al., 2005). The lack of studies and the literature review findings point to the importance of a study such as this one and the need for more as fire management and fire occurrence become more frequent. The studies that focused on eastern deciduous fires generally found that fire benefited disturbance-dependent species of birds and they occurred more frequently within the post-burned habitat (Akresh et al., 2015; Artman et al., 2005; Greenberg et al., 2007; Klaus et al., 2010; Rose & Simons, 2016; Rush et al., 2012).

However, while fires can be beneficial, in literature reviews on historical fire regimes it is emphasized that scientists should seek to understand fire-biota interactions depending on the species that the study is focused on. Some avian species may be better adapted to high-intensity fires versus low or vice versa (Adams, 2013; Brawn et al., 2001; Freeman et al., 2017). Further, no one type of fire has been found that can benefit all species in an ecosystem, thus leading to a greater need for more studies (Rose et al., 2016). Additionally, in ecosystems with more invasive species, the outcome could be different than expected as it has been long enough for the ecosystem to be upturned and the species composition to have shifted to flora and fauna that are less adapted to fire regimes (Freeman et al., 2017). Because of this, greater amounts of fire-disturbance studies in the southeast are needed in order to understand their interactions. Thus, my study focused on the avian diversity in burned and unburned sites in Tennessee in order to understand the outcome of a fire disturbance and attempt to help fill in the gaps of the existing literature.

Background

Fire History in Eastern Temperate Forests of North America

Within the Appalachian region, and many of Eastern North American temperate forests, fire historically influenced ecosystem development and created ecosystems that were adapted to fires (Brawn et al., 2001; Flatley et al., 2013; Lorimer, 2001; Nowacki & Abrams, 2008). As far back as 3,900 years ago, frequent fires are thought to have been common occurrences in some areas of Eastern North America (Delcourt & Delcourt, 1997). Fires would have occurred during Native American occupation, Euro-American settlement, and throughout the logging phase that took place at the start of the 20th century (Copenheaver et al., 2017; Flatley et al., 2013).

These fires were primarily low to moderate severity that dominated the Appalachian region and limited fuel accumulation (through burning), thus diminishing the likelihood of severe fires that would cause gross mortality of the standing vegetation (Flatley et al., 2013; Wimberly & Reilly, 2007). Fires typically burned in two to four year intervals, generally during the dormant seasons in areas such as the Great Smoky Mountains (Aldrich et al., 2014; Rose & Simons, 2016). Larger, area-wide fires that burned more than one stand of trees occurred at intervals of 6-13 years (Flatley et al., 2013).

Frequent fires were important in maintaining many disturbance-dependent ecosystems in this region, such as oak-pine and oak-chestnut dominated forests and pine savannas (Adams, 2013; Delcourt & Delcourt, 1997; Flatley et al., 2013; Nowacki & Abrams, 2008). The eastern deciduous forests that were acclimated to fire were generally dominated by fire-dependent xerophytic plants such as several species in *Quercus, Pinaceae,* and *Castanea* (Nowacki & Abrams, 2008). These forests would have been sustained and "rejuvenated" by fire and support the xerophytic plant community that was generally shade-intolerant and fire-dependent (Bond et al., 2005).

However, since the mid-twentieth century, burns (controlled or accidental) have been rare in the Eastern US due to the implementation of fire suppression by the US Forest Service (Flatley et al., 2013). As a result, fire-maintained ecosystems and their associated species have declined (Flatley et al., 2013; Glasgow & Matlack, 2007; Lorimer, 2001). Biotic homogenization has been documented in fire-suppressed habitats, most likely due to low ecological disturbances (Brawn et al., 2001; Flatley et al., 2015; Mero et al., 2015). This has resulted in a species composition shift (for both flora and fauna) within ecosystems previously associated with burns (Fei et al., 2011; Flatley et al., 2015; Glasgow & Matlack, 2007; Nowacki & Abrams, 2008).

In many Eastern forests, due to the lack of disturbance, the species composition of the flora shifted towards mesophytic trees such as species in *Acer*, *Prunus,* and *Tsuga.* These mesophytic trees are shade-tolerant and outcompeted the shade-intolerant and fire adapted species. These changes can lead, and in many habitats have led, to a loss in species richness and structural and compositional changes throughout the ecosystem (Nowacki & Abrams, 2008). For example, across the Eastern United States, eight *Quercus* species have declined within a thirty-year period in part due to competition from more shade-tolerant species (Fei et al., 2011). Other fire-tolerant, xerophytic plants were more abundant when frequent fires occurred and previously made up large stands consisting mainly of species in *Pinus* and *Fagaceae* (Flatley et al., 2015).

Without fire, the new fire-intolerant species could actually continue to deter fire through dense shading and the production of moisture-holding leaf litter and woody debris that are not conducive to burning (Bond et al., 2005). However, when these mesophytic forests do burn, they tend to have years of fuel accumulation built up, the presence of invasive plant species, and fire-intolerant plants (Freeman et al., 2017). This can cause higher-severity fires that will burn hotter and longer and lead to mortality of the standing vegetation, ultimately resulting in an early-successional habitat that will take the place of the former established one (Adams, 2013; Flatley et al., 2015; Williams, 2012).

A successional habitat is one dominated by pioneer species of plants and animals. These types of species will move in after some form of disturbance has occurred such as a fire (Lorimer, 2001). Early successional communities are comprised of shrubs, young trees, grasses, and forbs. In the Eastern US, a review on successional habitats found that the successional forested communities that occurred after disturbance, such as the one in this study, tended to regenerate relatively quickly (10-20 years depending on the disturbance) (Thompson & Degraaf, 2001). For most ecosystems, there are four stages of development post-major disturbance: stand initiation (an open-enough canopy where seedlings can become established and ground vegetation is supported), stem exclusion (the canopy is closed, increases in height, and is occupied fully by trees; thought of as the end of the successional habitat), understory reinitiation (the understory returns), and old-growth (fully regenerated forest) (Oliver & Larson, 1996; Thompson & Degraaf, 2001).

In habitats previously acclimated to fire, the suppression of burnings has also led to the decline of avian species linked to fire-disturbance (Freeman et al., 2017). Within North America, severe declines in mature or closed canopy forests have been observed (Brawn et al., 2001; Freeman et al., 2017; Kalies, Chambers, & Covington, 2010). In the Great Smoky Mountains, fires historically supported many avian species, such as the Red-cockaded Woodpecker (*Leuconotopicus borealis*), that were adapted to the post-fire plant community (Rose & Simons, 2016).

Successional Habitats Following Fire Disturbance

When an ecosystem is disturbed through various fire-severity ranges, it can create a multi-layered habitat used by diverse groups of animals (Bagne & Purcell, 2011; Doherty et al., 2017; Fontaine & Kennedy, 2012; Kalies et al., 2010). Studies suggest that to have effective conservation efforts, protected habitats should not be spared from historically ecologically significant events such as fires (Brawn et al., 2001; Freeman et al., 2017; Kelly et al., 2015). Decreasing fire management and/or integrating prescribed burns into forest management practices could be beneficial to previously fire-adapted ecosystems that have not had fire-disturbances for an extended period (Bagne & Purcell, 2011; Fontaine & Kennedy, 2012; Tingley et al., 2016).

Fire disturbances have been found to create diverse habitats when reintroduced to areas that were previously acclimated to fires (Brawn et al., 2001; Flatley et al., 2013). Multiple studies on forest management techniques have found that a combination of fire-severity (low-high) is necessary to maintain high diversity and species richness of fire-sensitive taxa (Brawn et al., 2001; Fontaine & Kennedy, 2012; Glasgow & Matlack, 2007).

Multiple ecosystems have been found to benefit from fires, and multiple avian species have been found to thrive post-fire depending on the severity. For example, in California it was found that in areas of fire suppression the structure of avian communities could be aided by low-severity fires (Bagne & Purcell, 2011). In conifer stands, a combination of fire treatments in patch arrangements assisted the overall diversity and density of animals (Kalies et al., 2010). Point count surveys taken three years after a wildfire within a dry conifer forest found a positive relationship between fire severity and secondary cavity nesters, aerial insectivores, bark-drilling birds, and finches as a group (Latif et al., 2016). In freshwater marshes and wetlands, landscape burning raised overall species richness in the following years (Mero et al., 2015). In grasslands, fires increased the diversity and richness of migratory shorebirds (Hovick et al., 2017). In addition, during a species-specific study, it was found that female Red-cockaded Woodpeckers laid larger clutches of eggs the first breeding season after a fire and they preferred habitat that was influenced by burnings (James et al., 1997).

Studies have found that pyrodiversity (varying levels of fire intensity) has been shown to increase disturbance-dependent avian species for a period of time (1-20 years in most cases in eastern deciduous forests (Rose & Simons, 2016)) and that bird communities will slowly shift back to disturbance-intolerant species as the flora of the ecosystem returns (Smucker et al., 2005; Tingley et al., 2016). Studies have also found that the level of severity could be linked to the bird species found after the fire and that avian abundance changed significantly according to the severity type. They also found that time since fire and the level of fire severity were needed to be known in order to manage for certain disturbance-dependent avian communities (Rose & Simons, 2016; Smucker et al., 2005). This suggests that many Eastern fire-adapted landscapes were adapted to various fire severity levels and that avian species adapted to them as well.

In a literature search, studies on disturbance in Eastern US forests focused on mechanisms such as stand thinning (Sheehan et al., 2014; Yahner, 2003) and browsing disturbance regimes (Nuttle et al., 2013). Further searches (using the combined key words "forest and brush fires," "Eastern United States," and "avian," for example) found few avian diversity fire studies within the Eastern US. Those that did occur were generally in different climates and ecosystems than this study took place in. These studies generally found that populations of disturbance-dependent avian species were assisted by fire. For example, one study focused on pine-oak forests post-fire in the Great Smoky Mountain National Park and found that 13 species of birds occurred more frequently within the post-burned habitat (Rose & Simons, 2016). Another looked at the short-term effects of fire on breeding bird populations in southern Appalachia and found that species richness increased by 26% within two years post-fire and rose within the next 3-6 years (Klaus et al., 2010).

However, as previously mentioned, it is emphasized that scientists should seek to understand fire-biota interactions and the state of the ecosystem pre-fire (Adams, 2013; Brawn et al., 2001; Freeman et al., 2017). In ecosystems with more invasive species, the outcome could be different than expected as it has been long enough for the ecosystem to be upturned and the species composition to have shifted to flora and fauna that are less adapted to fire regimes, such as mesophytic vegetative species (Freeman et al., 2017).

The Effect of Invasive Plants on Forest Fires

Invasive plants such as tree-of-heaven (*Ailanthus altissima*) and Japanese honeysuckle (*Lonicera japonica*), are common in the Eastern US and have been found to have a high heat of combustion rates during a fire. Their heat content due to structure and foliage could potentially affect fire behavior and cause more intense fires and longer recovery times (Dibble et al., 2007).

In addition, invasive plants have been shown to slow succession above ground and affect the soil below ground (Dickens & Allen, 2014). In a post-fire environment, Amur honeysuckle (*Lonicera maackii*) was found to benefit after fires by having greater seedling recruitment in burned sites. Their seeds were not germinating due to smoke or heat exposure, but instead were successfully inhabiting post-fire environments after a reduction in competitive species (Guthrie, Crandall, & Knight, 2016). One way the recolonization of these species, and other invasives, could be assisted is through ornithochory (avian dispersal of seeds). Multiple plant species rely on vertebrates to spread their seeds inside of forested habitats, whether through ingestion or attachment to avian feathers or defecation (Richardson et al., 2000).

Seed Dispersal – Movement Patterns and Viability

In general, avian dispersal of seeds has been found to be more prevalent than mammal dispersal (Fleming & Kress, 2011). In a literature review, it was found that the spread of seeds by birds was common within many ecosystems. This review focused on the mutualistic spread of seeds (by intentional fruit consumption) and on fleshy seeds attractive to vertebrates (Gosper et al., 2005). Studies have shown some frugivorous birds increased seed germination percentages and speed (D'Avila et al., 2010; Velez et al., 2017). Our study is specifically interested in the invasive alien plants and how their fleshy fruits are commonly linked to bird dispersal (D'Avila et al., 2010). For many invasive alien plants, generalist native and exotic frugivorous birds have been found to spread their seeds and some native birds can even assist these exotic plant species in becoming invasive in their introduced habitat (Bartuszevige & Gorchov, 2006; Ramaswami et al., 2016).

Seed dispersal of any plant of either exotic or native species is determined by the digestive process of the bird and the species of plant. This can lead to the seed increasing or decreasing in its viability once defecated (Bartuszevige & Gorchov, 2006; Ingold & Craycraft, 1983; Renne et al., 2001). Some researchers have found that some invasive species benefit from their seeds being digested. Researchers found that the invasive Chinese tallow tree (*Sapium sebiferum* (L.) Roxb.) seeds they collected germinated faster if defecated from birds, particularly Northern Flickers (*Colaptes auratus* L.), rather than remaining untouched (Renne et al., 2001).

In New Jersey, one study found that 33% of plants ingested by frugivorous birds were non-native (White & Stiles, 1992). In Ohio, out of 17 bird species seen eating the invasive honeysuckle (*Lonicera maackii),* five of those species produced viable seeds. The American Robin (*Turdus migratorius),* a bird that generally resides on the edges of woodlots and along fencerows, was found to ingest honeysuckle seeds and not inhibit germination, thus potentially leading to the spread of the plant. However, Cedar Waxwings (*Bombycilla cedrorum*) were found to ingest *Lonicera* spp. and usually render the seeds unviable (Bartuszevige & Gorchov, 2006).

Another study in Ohio found that out of 26 species, nine consumed and passed *Lonicera* spp. seeds. These included the American Robin and Cedar Waxwing, as well as species different from the previous study; Swainson's thrush (*Catharus ustulatus*), Gray Catbird (*Dumetella carolinensis*), Northern Cardinal (*Cardinalis cardinalis*), Purple Finch (*Carpodacus purpureus*), American Goldfinch (*Carduelis tristis*), and the White-throated Sparrow (*Zonotrichia albicollis*). Birds not captured, but of interest, include the Yellow-rumped Warbler (*Dendroka coronata*), Brown Thrasher (*Toxosoma rufum*), and the Blue Jay (*Cyanocitta cristata*) (Ingold & Craycraft, 1983). These birds are of great interest in this study as many are in this region year-round or during the non-breeding season.

Flipper Bend Fire

In 2016, a fire burned the Flipper Bend region of Signal Mountain in Tennessee that belongs to the North Chickamauga Creek Conservancy. The fire, later deemed arson, began November 5th and was declared over on November 29th, with around 987 acres burned in total. Despite efforts to contain the fire, it ran underground past control lines, through the mineral rich soil and spread across the forest. The fire burned hot enough to cause mortalities to the standing vegetation and caused rare hardwood crown-fires (fire reaching the canopy) (James Dale, Assistant District Forester, Tennessee, personal communication). Invasive plants are thought to have significantly worsened the fire within the site by allowing it to easily spread and to climb up ladders into the crowns of trees. The major plants of interest that could have provided "ladders" are honeysuckle (*Lonicera* spp.) and Chinese privet (*Ligustrum sinense*) (James Dale, Assistant District Forester, Tennessee, personal communication).

The Flipper Bend area presents a unique opportunity to analyze a forest where regrowth has occurred one year on after the fire and portions of the forest were untouched by the fire (see Figure's 1 and 2).

Objectives and Hypotheses

The goal of this study is to examine and evaluate whether a burned eastern deciduous located in the Flipper Bend forest could provide suitable habitat for disturbance prone avian species as compared to a similar unburned eastern deciduous forest. The specific objectives of my thesis project were to assess:

(*1*) The overall avian species diversity, evenness, and richness within the post-burned site and unburned site and

(*2*) Whether invasive plant species recolonization of the forest could be assisted by various species of frugivorous birds.

I hypothesize that, at the successional stage of the land at two years of regrowth when this study began, I will find a greater amount of disturbance-dependent birds within the burned study site such as the Prairie Warbler (*Setophaga discolor*), Field Sparrow (*Spizella pusilla*), American Goldfinch, Common Yellowthroat (*Geothlypis trichas*), Chestnut-sided Warbler (*Setophaga pensylvanica*) and the Yellow-breasted Chat (*Icteria virens*). I expect to find these species either in higher quantities or only within the burned site when compared to the unburned. Furthermore, I expect that I will find that avian ornithochory is contributing to the spread of invasive plants, such as honeysuckle (*Lonicera* spp.) and Chinese privet in the regenerating burned site.

CHAPTER II

METHODOLOGY

Study Area

The study was conducted within Flipper Bend, Tennessee (hereinafter referred to as the burned site) from April 2018 through June 2019 (photos located in Appendix B). The burned study site was located in the "intensely burned" portion (Figure 1 and 2). The unburned study site was farther down the mountain and ran alongside the heavily trafficked North Chickamauga Creek access (hereinafter referred to as the unburned site) (photos located in Appendix C).

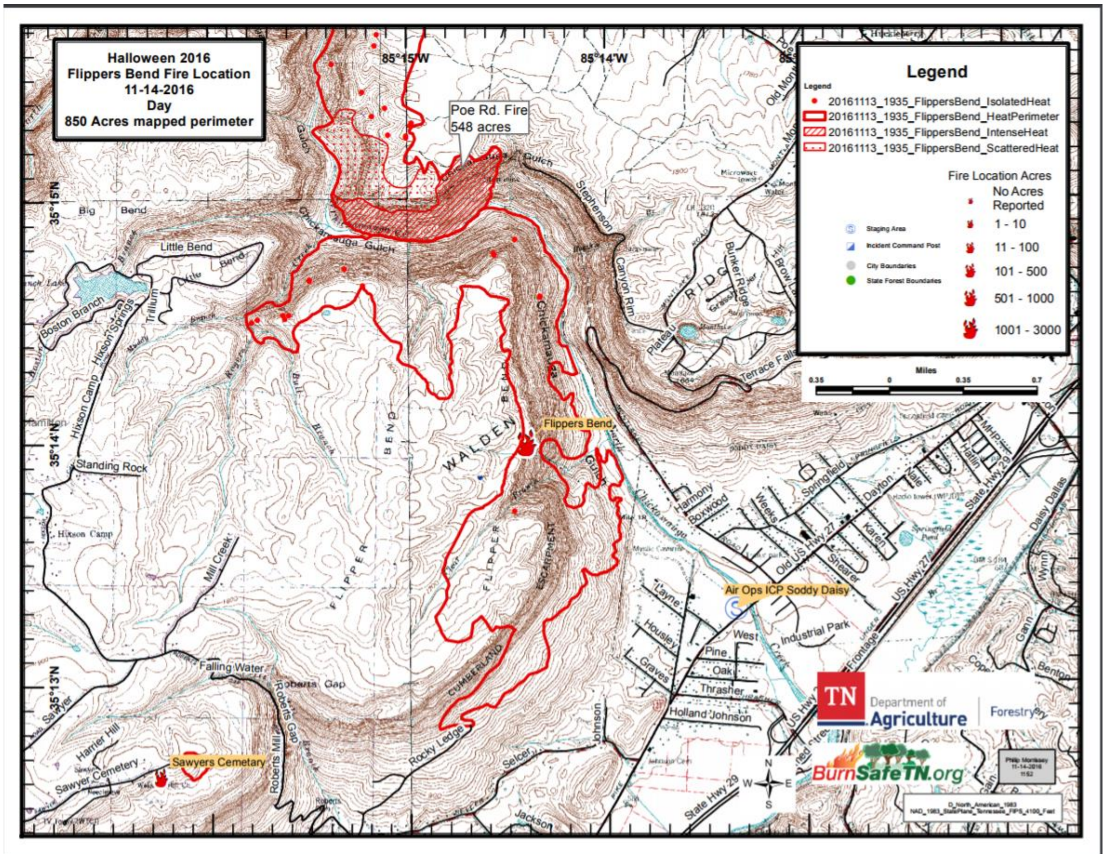

Figure 1 Heat perimeters and fire locations within the Flipper Bend and Walden ridge portions of Signal Mountain, Tennessee. The burned study site was the "intensely burned" section. Map provided by Phil Morrissey; State Forest Unit Leader Division of Forestry

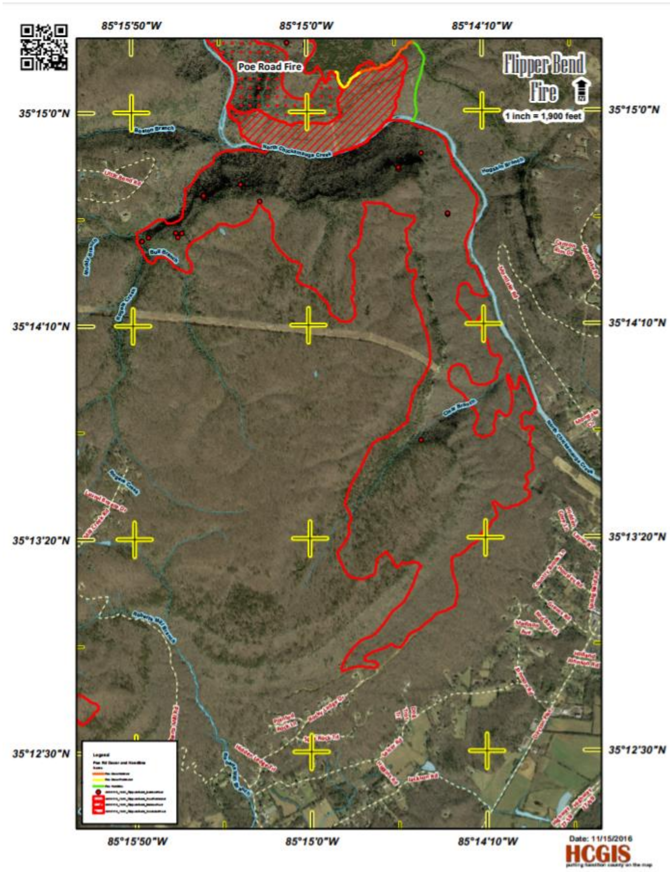

Figure 2 Aerial photos showing heat perimeters and fire locations within the Flipper Bend and Walden ridge portions of Signal Mountain, Tennessee. The burned study site was located in the "intensely burned" section. Map provided by Phil Morrissey; State Forest Unit Leader Division of Forestry. Images were acquired by the US Forest Service and were manipulated using GIS from an incident command center out of Colorado

Mist Netting

In order to obtain fecal samples to discern if birds were bringing in invasive seeds, mist nets (12m X 2.6m, 30mm mesh) were utilized within the intensely burned site. To lower the risk of bias due to ease of accessibility, mist net locations were chosen via GIS analysis of the burned sites and were placed along the highest burned sections (Mero et al., 2015). Six nets were set up and were opened within 30 minutes of local sunrise and checked approximately everything 30 minutes until four hours after local sunrise (Arizaga et al., 2011). Nets were closed when the ambient temperature exceeded 27° C or fell below 40° C, wind speed exceeded 10 km/h, or if more than a light drizzle was falling (Ralph et al., 1993). Mist netting occurred monthly, lasting from one to four days (weather permitting) from March 2018 through May 2019 (IACUC Approval Appendix A).

Fecal Collection

When a bird was caught in the mist net, a cloth bag was held underneath it as it was extracted to catch any defecation that occurred. The bird was then placed into the bag and taken to a banding location. Birds were banded with aluminum US Geological Survey leg bands, had their unflattened wing chords measured, were weighted using an electronic balance, and then released. Once the bird was released, the bag was examined. If defecated in, an index card with the date, band number, and species was placed inside (Ralph et al., 1985). Once I returned from the field, any bags with feces were stored in a freezer until examination for seed identification (Parrish et al., 1994).

Seed Identification

Fecal samples were placed on dissection trays and viewed under dissecting scopes. Needles and tweezers were used to separate the intact seeds from the fecal matrix. Alcohol and water were used to wash the seeds as needed. Seeds were identified using literature and guidance from Dr. Joey Shaw, the University of Tennessee, Knoxville seed database, and the *Seed Identification Manual* (Martin & Barkley, 1973).

Line Transects

To evaluate overall avian diversity, line transects were performed up to five times per season. One transect was located within an intensely burned area, and for comparison a second transect was established in the unburned, which was outside of any burn zones. The burned transect was 1 km long and the unburned transect was 690m. Transects were walked at a 30-minute pace, and all birds seen and heard within 50 m on either side of the transect were recorded.

Vegetation Analysis

Vegetation analysis took place in May 2019. The burned and unburned avian transects were walked for the vegetation analysis. At the start of the transect, and then at each 100m interval, vegetation density, canopy cover, canopy height, and percent of ground cover data were collected on each side of the transect. To examine foliage density, I used a vegetation profile board similar to that described by Nudds (1977). The profile board consisted of a 0.50 m X 1.22 m board painted in five alternating segments of black and white (35 cm each) with a total height of 1.75 m. Two samples were taken at each sampling point, 20 m from the edge on either side of the trail. Foliage was visually estimated by the percent of each board segment covered by vegetation to the nearest 5%. Readings were taken with eye level at a height of one meter starting with the bottom segment and moving to the top (see Mitchell & Hughes, 1995). Canopy cover was estimated using a densiometer, and canopy height was visually estimated. Ground cover was estimated using a 1 X 1 meter quadrant, which was laid down 20 m from the edge on either side of the trail.

Data Analysis

Data were split into the four seasons; March, April, May, and Early June were considered Spring; late June, July, and August as Summer; September, October, and November as Fall; and December, January, and February as Winter. The Shannon-Weiner Diversity Index was used to analyze the richness and evenness differences between the four seasons and compare the burned and unburned regions of the forest. A Jaccard’s Index was used to calculate community similarity between the burned and unburned sites for each season. Two-way ANOVA’s were run, with site and season as the main effects, and Holm-Sidak post-hoc tests were used if there were any significant differences. Analysis were completed using Excel for the Shannon Index and Jaccard’s and SPSS was used for the two-way ANOVA.

CHAPTER III

RESULTS

Vegetation Analysis

The burned site had a higher density of vegetation and a higher percentage of vegetation coverage. The unburned had greater canopy height and coverage (Table 1).

Table 1 The average density, canopy height, canopy coverage, and vegetation coverage for the burned and unburned. The unburned had 16 plots averaged and the burned had 20

	Density	**Canopy Height (m)**	**Canopy Coverage (%)**	**Vegetation Coverage (%)**
Unburned	20.75	15.37	83.43	56.31
Burned	22.75	3.55	18.75	94

*Hypothesis I***:** I hypothesized that, at the state of the land at two years of regrowth when this study began, I would find an increase of disturbance-dependent birds within the burned study site such as the Prairie Warbler, Field Sparrow, American Goldfinch, and the Yellow-breasted Chat. *Result***:** My results indicate that disturbance-dependent birds did utilize the burned site either in greater numbers or exclusively as compared to the unburned.

Shannon Diversity Index

Burned

All transects from the burned site 2018 and 2019 (excluding Spring 2018) were analyzed for each season and the average Shannon Diversity Indexes, average *H*-max, evenness, richness, and individual count averages are shown in Table 2. Fall had the highest individual count average, Summer had the highest richness, evenness, Shannon average, and *H*-max. Winter was the lowest in all categories except for individual count average.

Table 2 Average Shannon Diversity, *H*-max, evenness, richness, and individual count for Winter, Fall, Summer, and Spring of the 2018 and 2019 burned region of Flipper Bend, Signal Mountain, TN. Bold indicates significance

Season	Shannon Average	*H*-max	Evenness	Richness	Individual Count Average
Winter	2.12	2.64	0.81	14.00	69.00
Fall	2.44	2.85	0.86	17.60	88.20
Summer	**3.00**	3.24	**0.93**	**25.67**	60.67
Spring 2018	2.95	3.22	0.91	24.80	64.60
Spring 2019	2.60	2.95	0.88	19.60	54.40

Unburned

All transects from the unburned 2018 (excluding Spring 2018) were analyzed for each season and the average Shannon Diversity averages, average *H*-max, evenness, richness, and individual count average are shown in Table 3. I was unable to sample the unburned in the spring of 2018 because the area was closed. Summer 2018 had the highest Shannon Diversity index, but Spring 2019 was closer to its *H*-max, as evidenced by its high evenness. Winter had the highest evenness and species count, whereas summer had the highest richness.

Table 3 Average Shannon Diversities, *H*-max, evenness, richness, and individual species count average for Winter (transect=2), Fall (transects=3), and Summer 2018 (transects=2), and Spring 2019 (transects=4) of the unburned region of North Chickamauga Creek, Signal Mountain, TN. Bold indicates significance

	Average Shannon	***H*-max**	**Evenness**	**Richness**	**Individual Count Average**
Winter	2.84	3.05	0.93	21.5	110.5
Fall	2.80	3.04	0.92	22.0	75.0
Summer	**2.89**	3.19	0.90	**24.5**	87.5
Spring 2019	2.06	2.17	**0.95**	9.0	16

ANOVA Results

A two-way ANOVA was run to compare the Shannon Diversity Indexes of each site to each other for the seasons of Summer 2018, Fall 2018, Winter 2018/19. As I was unable to sample the unburned in Spring 2018, I am unable to compare it with the burned in Spring 2018. For Shannon Diversity comparisons, sites were found to differ regardless of season (p=0.019), regardless of site (p=0.024), and there was no significant interaction found between site and season (p=0.055). The unburned site was found to have the highest diversity overall with a mean of 2.844 versus the burned site's mean of 2.521. In general, Summer also had the higher average diversity than fall and winter (p<0.05). There was no significant difference found between the site, seasons, or 'site x season' for the H-max. A t-test was performed on the burned and unburned Spring 2019 data, they were not significantly different (p=0.067).

Jaccard's Index

The 2018 summer season had the highest percent similar at 33% and the spring of 2019 had the lowest percent similar at 23%. The full results are shown in Table 4.

Table 4 Jaccard's index data, species data, and count data for North Chickamauga (Unburned) and Flippers Bend (Burned) for Winter (transects=3), Fall (transects=8), and Summer of 2018 (transects=5), and Spring 2019 (transects=9)

	Winter 2018	**Fall 2018**	**Summer 2018**	**Spring 2019**
Jaccard's	0.25	0.28	0.33	0.23
Percentage	25	28	33	23
Total Species	40	78	66	73
Same Species	21	22	22	17
Burned Count	14	32	37	49
Unburned Count	26	46	29	24

Seasonal Community Composition

Summer 2018:

In the burned region during the summer, 37 species of birds were noted during the transect data collection (transect=3) and out of those, 13 were not found in the unburned. In the unburned region during the summer, 29 species were found during the transect data collection (transect=2) and out of those 29, seven species were unique to the unburned. Full results are shown in Table 5.

Table 5 Species found at unburned (transects=2) and burned (transects=3) during the Summer of 2018. 'X' means they were present; a blank cell means they were absent

Species	Unburned	Burned
American Crow (*Corvus brachyrhynchos)*	X	X
American Goldfinch		X
American Robin	X	X
Barn Swallow (*Hirundo rustica*)		X
Belted Kingfisher (*Megaceryle alcyon*)	X	
Black-and-white Warbler (*Mniotilta varia*)	X	X
Blue Jay	X	X
Blue-gray Gnatcatcher (*Polioptila caerulea*)	X	X
Broad-winged Hawk (*Buteo platypterus*)		X
Brown-headed Cowbird (*Molothrus ater*)	X	
Carolina Chickadee (*Poecile carolinensis*)	X	X
Carolina Wren (*Thryothorus ludovicianus*)	X	X
Chimney Swift (*Chaetura pelagica*)	X	X
Downy Woodpecker (*Dryobates pubescens*)	X	X
Eastern Bluebird (*Sialia sialis*)		X
Eastern Phoebe (*Sayornis phoebe*)		X
Eastern Towhee (*Pipilo erythropthalmus*)	X	X
Eastern Wood-Pewee (*Contopus virens*)	X	
Field Sparrow		X
Gray Catbird	X	
Hairy Woodpecker (*Leuconotopicus villosus*)		X
Hooded Warbler (*Setophaga citrina*)	X	X
Indigo Bunting		X
Mourning Dove (*Zenaida macroura*)		X
Northern Cardinal	X	X
Northern Flicker		X
Ovenbird (*Seiurus aurocapillaI*)	X	X
Pileated Woodpecker (*Dryocopus pileatus*)	X	X
Prairie Warbler		X
Red-bellied Woodpecker (*Melanerpes carolinus*)	X	X
Red-eyed Vireo (*Vireo olivaceus*)	X	X
Red-headed Woodpecker (*Melanerpes erythrocephalus*)		X
Red-shouldered Hawk (*Buteo lineatus*)	X	
Ruby-throated Hummingbird (*Archilochus colubris*)	X	X
Scarlet Tanager (*Piranga olivacea*)	X	X
Summer Tanager (*Piranga rubra*)	X	
Tufted Titmouse (*Baeolophus bicolor*)	X	X
White-breasted Nuthatch (*Sitta carolinensis*)	X	X
White-eyed Vireo (*Vireo griseus*)	X	X
Wood Thrush (*Hylocichla mustelina*)	X	
Yellow-billed Cuckoo (*Coccyzus americanus*)	X	X
Yellow-breasted Chat		X
Yellow-throated Vireo (*Vireo flavifrons*)		X

Fall 2018:

In the burned region during the fall, 32 species were found during the transect data collection and out of those 31, eight species were unique to the burned. In the unburned region during the fall, 46 species were found during the transect data collection (transect=3) and out of those 46, 19 species were unique to the unburned (Table 6).

Table 6 Species found at the unburned (transects=3) and burned (transects=5) during the Fall of 2018. ‘X’ means they were present; a blank cell means they were absent

FALL	**Unburned**	**Burned**
American Crow	X	X
American Goldfinch		X
American Kestrel (*Falco sparverius*)		X
American Redstart (*Setophaga ruticilla*)	X	
American Robin	X	X
Belted Kingfisher	X	
Black-and-white Warbler	X	
Black-throated Green Warbler (*Setophaga virens*)	X	
Blue Jay	X	X
Blue-gray Gnatcatcher	X	
Brown Thrasher	X	
Brown-headed Cowbird	X	X
Brown-headed Nuthatch (*Sitta pusilla*)		X
Canada Warbler (*Cardellina canadensis*)	X	
Carolina Chickadee	X	X
Carolina Wren	X	X
Cedar Waxwing	X	X
Chimney Swift	X	
Cooper's Hawk (*Accipiter cooperii*)	X	X
Downy Woodpecker	X	X
Eastern Bluebird		X
Eastern Phoebe	X	X
Eastern Towhee	X	X
Eastern Wood-Pewee	X	
Golden-crowned Kinglet (*Regulus satrapa*)	X	X
Gray Catbird	X	
Great Crested Flycatcher (*Myiarchus crinitus*)	X	
Hairy Woodpecker		X
Hermit Thrush (*Catharus guttatus*)	X	X
Hooded Warbler	X	
Kentucky Warbler (*Geothlypis formosa*)	X	
Magnolia Warbler (*Setophaga magnolia*)	X	
Mourning Dove	X	
Northern Cardinal	X	X
Northern Flicker		X
Ovenbird	X	
Pileated Woodpecker	X	X
Pine Warbler (*Setophaga pinus*)	X	X
Red-bellied Woodpecker	X	X
Red-eyed Vireo	X	
Red-headed Woodpecker		X
Red-tailed Hawk (*Buteo jamaicensis*)	X	
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	X	X
Ruby-crowned Kinglet (*Regulus calendula*)	X	X
Ruby-throated Hummingbird	X	
Swainson's Thrush	X	
Tennessee Warbler (*Leiothlypis perigrina*)	X	
Tufted Titmouse	X	X
White-breasted Nuthatch	X	
White-eyed Vireo	X	X
White-throated Sparrow	X	X
Winter Wren (*Troglodyte hiemalis*)		X
Wood Thrush	X	
Yellow-rumped Warbler	X	
Yellow-throated Vireo	X	

Winter 2018:

In the burned region during the winter, 14 species were found during the transect data collection (transect=1) and out of those, four species were unique to the burned. In the unburned during the winter, 26 species were found during the transect data collection (transect=2) and out of those, 16 were not found in the burned. This is shown in Table 7.

Table 7 Species found at the unburned (transects=2) and burned (transects=1) during the Winter of 2018/2019. 'X' means they were present; a blank cell means they were absent

Species	Unburned	Burned
American Crow	X	
American Goldfinch	X	X
American Robin	X	X
Belted Kingfisher	X	
Blue Jay	X	X
Brown Thrasher	X	
Carolina Chickadee	X	X
Carolina Wren	X	
Common Grackle (*Quiscalus quiscula*)	X	
Cooper's Hawk		X
Dark-eyed Junco (*Junco hyemalis*)	X	X
Downy Woodpecker	X	
Eastern Bluebird	X	X
Eastern Phoebe	X	
Eastern Towhee	X	
Golden-crowned Kinglet	X	X
Hairy Woodpecker		X
Hermit Thrush	X	
Mourning Dove		X
Northern Cardinal	X	X
Pileated Woodpecker	X	
Pine Warbler	X	
Red-bellied Woodpecker	X	
Red-shouldered Hawk		X
Ruby-crowned Kinglet	X	X
Tufted Titmouse	X	X
White-breasted Nuthatch	X	X
White-throated Sparrow	X	
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	X	
Yellow-rumped Warbler	X	

Spring 2019:

In the burned region during the spring, 49 species were found during the transect data collection (transect=7) and out of those, 31 species were unique to the burned. In the unburned during the spring, 24 species were found during the transect data collection (transect=4) and out of those, 7 were not found in the burned. This is shown in Table 8.

Table 8 Species found at the unburned (transects=4) and burned (transects=7) during the Spring of 2019. 'X' means they were present; a blank cell means they were absent

Species	Unburned	Burned
Acadian Flycatcher (*Empidonax virescens*)	X	
American Crow	X	X
American Goldfinch		X
American Robin		X
Bald Eagle (*Haliaeetus leucocephalus*)	X	
Black-and-white Warbler		X
Black-throated Green Warbler	X	X
Blue Grosbeak (*Passerina caerulea*)		X
Blue Jay	X	X
Blue-gray Gnatcatcher		X
Broad-winged Hawk	X	
Brown Thrasher		X
Carolina Chickadee	X	X
Carolina Wren	X	X
Cedar Waxwing		X
Chimney Swift		X
Chipping Sparrow (*Spizella passerine*)		X
Common Grackle		X
Cooper's Hawk		X
Dark-eyed Junco		X
Downy Woodpecker	X	X
Eastern Bluebird		X
Eastern Phoebe	X	X
Eastern Towhee	X	X
Eastern Wood-Pewee		X
Field Sparrow		X
Golden-crowned Kinglet		X
Gray Catbird		X
Hairy Woodpecker	X	X
Hooded Warbler	X	X
House Wren (*Troglodytes aedon*)		X
Indigo Bunting		X
Louisiana Waterthrush (*Parkesia motacilla*)	X	
Mourning Dove	X	X
Northern Cardinal	X	X
Northern Flicker		X
Pileated Woodpecker		X
Pine Warbler		X
Prairie Warbler		X
Red-bellied Woodpecker	X	
Red-breasted Nuthatch		X
Red-eyed Vireo	X	X
Red-headed Woodpecker		X
Ruby-crowned Kinglet	X	X
Ruby-throated Hummingbird		X
Scarlet Tanager	X	
Tufted Titmouse	X	X
White-breasted Nuthatch		X
White-eyed Vireo		X
White-throated Sparrow		X
Wood Thrush	X	
Yellow-billed Cuckoo	X	X
Yellow-breasted Chat		X
Yellow-rumped Warbler		X
Yellow-throated Vireo	X	X

Common Disturbance-dependent Species

The burned site was found to have many species of disturbance prone birds. Five that only occurred at that site and are of particular interest due to fluctuating or declining populations are the Prairie Warbler, Yellow-breasted Chat, Indigo Bunting, Field Sparrow, and Red-headed Woodpecker (Sauer et al., 2017).

Prairie Warblers were found frequently with an average of 5 individuals per transect out of 65.5 individuals for Spring 2019 (transect=4), Spring 2018 had 5.5 out of 81 individuals (transect=4), and Summer 2018 was an average of 1.3 individuals of 66.3 (transect=3). Yellow-breasted Chat were found with an average of 4.75 individuals per transect out of 65.5 individuals for Spring 2019 (transect=4), Spring 2018 had 9.5 out of 81 individuals (transect=4), and Summer 2018 was an average of 4 individuals of 66.3 (transect=3). Indigo Bunting were found with an average of 2.75 individuals per transect out of 65.5 individuals for Spring 2019 (transect=4), Spring 2018 had 6.25 out of 81 individuals (transect=4), and Summer 2018 was an average of 4.6 individuals of 66.3 (transect=3). Red-headed Woodpeckers were found with an average of 1.6 individuals per transect out of 60.8 individuals for Spring 2019 (transect=5), Spring 2018 had 0 out of 81 individuals (transect=4), and Summer 2018 was an average of 2 individuals of 66.3 (transect=3). Field Sparrows were found with an average of 3.4 individuals per transect out of 60.8 individuals for Spring 2019 (transect=5), Spring 2018 had 3.8 out of 81 individuals (transect=4), and Summer 2018 had an average of 3.33 individuals of 66.3 (transect=3).

Seed Analysis

Hypothesis II: I also hypothesized that I would find that avian ornithochory is contributing to the spread of invasive plants, such as honeysuckle (*Lonicera* spp.) and Chinese privet (*Ligustrum sinense*) in the regenerating burned site.

Result: I did not find any evidence that ornithochory was contributing to the spread of invasive plants.

Out of 58 samples spanning from May 2018 to November 2018, only 15 contained seeds. The 15 that did contain seeds were all native blackberry seeds (*Rubus* spp.). No evidence of invasive species was found within the samples. The birds who were found with seeds in their samples were the Eastern Phoebe (n=4), Eastern Towhee (n=2), Yellow-breasted Chat (n=6), Scarlet Tanager (n=1), Tufted Titmouse (n=1), and Carolina Chickadee (n=1).

CHAPTER IV

DISCUSSION

Avian Diversity and Presence

During the Spring of 2018 and the Spring and Summer of 2019, the burned region was found to have the largest number of disturbance-dependent species of birds. This is concurrent with studies that compared successional communities of birds in multiple types of disturbed and undisturbed habitat (Akresh et al., 2015; Allen et al., 2006; King et al., 2011; Roberts & King, 2017; Sheehan et al., 2014; Thompson & Degraaf, 2001; Yahner, 2003). While these studies are similar to mine in methodology, most were focused on thinning, clearcutting, and other similar disturbances, instead of fire. Regardless, they found many of the same disturbance-dependent species of birds that my study did. This comparison suggests that multiple disturbance types can assist disturbance-dependent species of birds. Fire studies in the Southeast are less common than other disturbance studies and my results validate the need for more types of fire-disturbance studies in this area in order to understand the impact of fires on these ecosystems.

In addition to focusing on the overall composition of the avian community, my study examined individual species during the transect data and found that several species of disturbance-dependent birds were commonly detected during the transects. During a previous study comparing a burned forest to an unburned (ranging from 1986-2014), researchers found that the level of severity and the length of time since the fire could predict which species of birds would occur (Rose & Simons, 2016). Their models showed that Prairie Warblers, noted frequently and only at my burned site, were found at sites after high-severity fires opened up the canopy through standing vegetation mortality. They also found that they had greater detection of Prairie Warblers depending on the length of time since the fire. For example, high severity fires could leave suitable habitat for up to 25 years. For low to medium-severity fires, Prairie Warblers were less likely to be observed 10 years after the medium-severity fire and generally disappeared less than 5 years after a low-severity fire. My site experienced a high-intensity fire that opened the canopy significantly two to three years prior to the start of this research. This supports my findings, as the canopy coverage was low (18.75%) and there was greater ground vegetation coverage indicative of a more open canopy (94%).

In a southern fire-disturbance study in north Georgia, Prairie Warblers were detected at higher numbers with increasing disturbance (Klaus et al., 2010). However, Prairie Warblers were not found in the site that had the most recent fire, suggesting that they are more adapted to later growth (after one year) (Barrioz et al., 2013; Klaus et al., 2010). Both of these studies support my findings as the Prairie Warblers were captured and counted two and three years after the major fire and significant, shrubby regrowth had occurred. Prairie Warblers were also observed feeding, nesting, and courting in the area.

Yellow-breasted Chats had a similar observation level. However, they were less likely to be seen at a low-severity fire until two to three years afterwards. Yellow-breasted Chats appeared to prefer habitat that was heavily burned and in the high-severity fires areas were found up to 25 years afterwards (Rose et al., 2016). My study found them only at the burned site and observed activities such as feeding, nesting, and courting within the site both two- and three-years post-fire. Another disturbance species, Indigo Bunting, has been found to be more abundant in various levels of disturbed plots as compared to the undisturbed (Annand & Thompson, 1997). Indigo

Buntings have been found to be associated with grass cover in a habitat, which corresponds with my study as the burned site had an average 94% ground vegetation coverage (Barrioz et al. 2013).

Many disturbance-dependent avian species observed in this study, such as the Prairie Warbler, Field Sparrow, American Goldfinch, and Yellow-breasted Chat, are associated with low and medium vegetation heights, low overstory height, and low residual basal area that occur in an early successional forest (Burger et al., 2016; Sheehan et al., 2014). Several birds found, such as the Prairie Warbler and American Goldfinch, are also associated with low, dense woody understory and few overstory trees that are indicative of more open habitats (King, 2011). My findings are in agreement with those studies as I only found Prairie Warblers, Field Sparrows, and Yellow-breasted Chats within the burned region where the average canopy height was 3.55 meters with an average canopy coverage of 18.75%. When comparing the average canopy coverage to other studies on woodlands, prairies, and savannas, the cover of 18.75% fell into the average range of "savanna" that other researchers have documented (Burger et al., 2016). This suggests that this level of fire disrupted the ecosystem enough to provide a different kind of habitat than the intact forest that surrounds it.

The unburned/undisturbed site was found to be significantly higher in diversity when using the Shannon index to compare between the sites. This was surprising as other studies have found that disturbed sites had a higher amount of richness overall from pre- to post-disturbance (Annand & Thompson, 1997; Klaus et al., 2010; Yahner, 2003). However, these results could be attributed to site dependency, as the opposite was found in a Southeastern Longleaf Pine (*Pinus palustris*) study that focused specifically on fire (Allen et al., 2006). Differences between my study and previous studies could stem from a lack of opportunity to study the site before it burned. If I was able to study bird diversity pre-fire, I would have been able to examine whether the site gained or lost avian diversity after this disturbance.

Within the unburned site, many birds that are associated with a non-disturbed area with higher canopy coverage and height were found, such as the Black-throated Green Warbler, Ovenbird, Eastern Wood-pewee, and the Wood Thrush (Klaus et al., 2010; Sheehan et al., 2014). Wood Thrush, in particular, has been reported in mature sites and fire-suppressed habitats in higher abundance in other studies (Allen et al., 2006; Annand & Thompson, 1997). These studies support my findings as the unburned site had high canopy coverage (83.43%) and canopy height (15.37 m), indicative of a forested habitat that generally has 80-100 percent canopy coverage (Burger et al., 2016).

Depending on the season, multiple species of birds were also found to occur in both sites. Some of the more common ones were the American Robin, Tufted Titmouse, and Blue-gray Gnatcatcher. This finding is similar to others, which also found that Tufted Titmice and Blue-gray Gnatcatchers were not affected by the level of disturbance at the sites, given they were recorded or observed across multiple habitat types regardless of vegetation cover (Barrioz et al., 2013). Furthermore, other studies have found that the abundance of Tufted Titmice, Blue-gray Gnatcatchers, American Crows, Blue Jays, Pine Warblers, Red-bellied Woodpeckers, and Black-and-White Warblers have been identified in the literature as habitat generalists, given that their abundance is not a significantly impacted by the level of disturbance (Allen et al., 2006; Annand & Thompson, 1997). This could explain their presence across both the burned and unburned study sites, in this study, as all species were found simultaneously within most or all of the seasons. On the other hand, some species were only found during a single season during the year. For example, the American Goldfinch was found within the burned site for Spring, Summer, and

Fall and was only noted within the unburned during the Winter. Studies have found that the American Goldfinch occurred at different levels within fire disturbed and undisturbed habitat but was more likely to occur four years after the fire (Klaus et al., 2010). This suggests that the burned site was ideal for that species during those seasons.

Across the seasons, the sites were never more than 30.33% similar when compared using the Jaccard's Evenness index. Spring 2019 was overall the lowest in similarity at 23.33%. Though the seasons were not statistically significantly different, p=0.055, the value does approach significance and the heavy presence of disturbance-dependent birds in the burned coupled with the low Jaccard's index suggests that the results for Spring 2019 could still be biologically meaningful. This difference in species composition is likely due to the different types of vegetation and canopy structure that occur at each site (Burger et al., 2016).

Seed Dispersal

My study lacked seed samples in the fall and winter of 2018 when the invasive plant species of interest (*Lonicera maacki*, *Lonicera japonica*, and *Ligustrum* spp.) would have been in fruit. Instead, the majority of the samples were obtained in the Spring, Summer, and early Fall. This is due to less birds captured in the late-Fall and Winter or birds not providing samples. This was surprising as there was generally activity on the days the researchers had the mist nets open during the fruiting season.

However, birds that could have ingested and defecated viable seeds of *Lonicera* spp. were noticed during the Fall and Winter such as the American Robin and potentially Cedar Waxwing (Bartuszevige & Gorchov, 2006). Other species observed in the Fall and/or Winter of the burned site that could have spread viable seeds were the American Goldfinch, Blue Jay, Northern Cardinal, and White-throated Sparrow (Ingold & Craycraft, 1983).

Conservation Implications

It is important to note that studies on introducing fires into ecosystems have been unable to find a single pattern of burning that benefits all species of birds (Rose & Simons, 2016). As such, it is crucial to research patterns that benefit disturbance-dependent bird species that have low or struggling populations.

My study found many disturbance-dependent species of birds that only existed within the burned site and are known to have fluctuating or declining populations as found using data from the Breeding Bird Survey (Sauer et al., 2017). Prairie Warblers, Yellow-breasted Chats, Indigo Buntings, Field Sparrows, and Red-headed Woodpeckers were focused on for conservation suggestions from my results as they were found in larger numbers, have struggling populations, and/or evidence of breeding was noted by the researchers.

Area sensitive species such as Prairie Warblers and Indigo Buntings are more likely to occur in larger patches of disturbed habitat that reach at least up to 1.1ha (Akresh et al., 2015; Roberts & King, 2017). Research has shown that Prairie Warblers have been found to have an average territory size of 0.97 hectares (Akresh et al., 2015). In comparison, the entirety of the North Chickamauga Creek Conservancy (that both burned and unburned were located in) is roughly 2,832 hectares and the high intensity burned section was roughly 33 hectares within that. Despite the smaller size of the burned site, both species of bird were found only within the burned site for Spring 2019 and Spring and Summer of 2018.

Evidence of breeding was also observed for the Prairie Warbler (such as nest building). This knowledge could benefit forest managers who do not have large plots of land to burn. My study shows that small patches of burned habitat still benefited some area sensitive species with struggling populations (Figure 3 and 4) (Sauer et al., 2017).

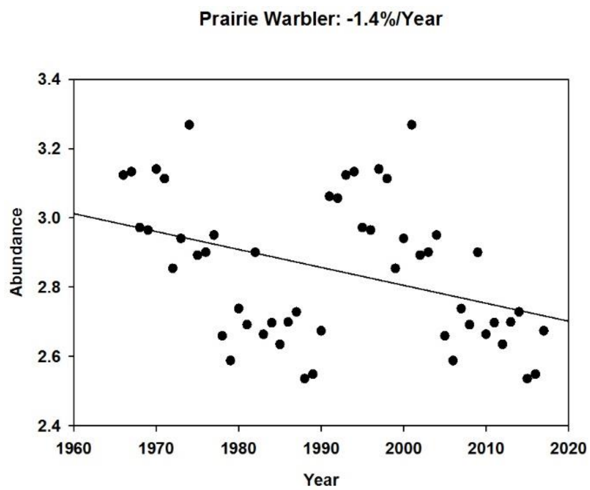

Figure 3 Prairie Warbler population trend via the Breeding Bird Survey (Sauer et al., 2017)

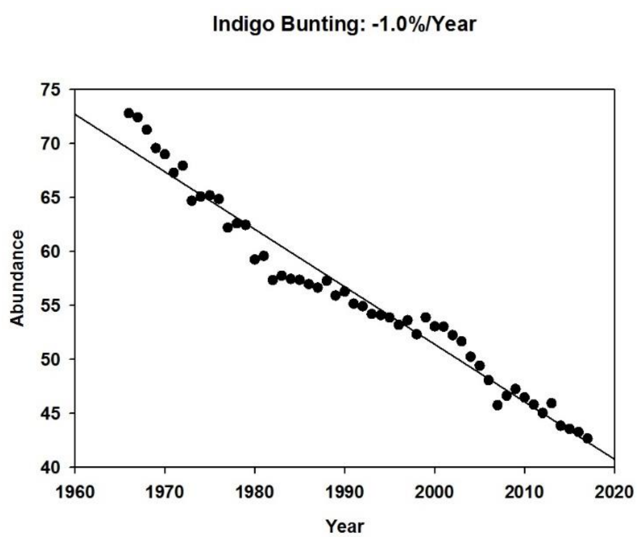

Figure 4 Indigo Bunting population trend via the Breeding Bird Survey (Sauer et al., 2017)

In several studies, Prairie Warblers were found to significantly increase after thinning or burning (Akresh et al., 2015; Allen et al., 2006; King et al., 2011). However, Prairie Warblers were found to decline in numbers four years after the thinning occurred and 4-5 years after disturbance (Akresh et al., 2015; King et al., 2011; Rose & Simons, 2016). My study found Prairie Warblers exclusively within the burned site two years after the fire, during the Spring and Summer (2018), and three years after the fire, in Spring (2019). This suggests that consistent management would be ideal to boost the populations of those species (Figure 3). Some researchers have found that the "periodic creation" of disturbance in managed plots had a positive influence on the successional bird community and diversity overall (Yahner, 2003). For Prairie Warblers, it is suggested to treat areas adjacent to breeding populations with burning, mowing, and other treatments in order to support their population (Akresh et al., 2015). This type of regular disturbance could also benefit the Yellow-breasted Chat and Red-headed Woodpecker as they were also found to decline several years after a disturbance (Barrioz et al., 2013; Rose & Simons, 2016). Thus, regular fires could be beneficial to this region for those species' populations. Indigo Buntings, Eastern Towhees, and Field Sparrows were also found to increase during regular disturbance and could benefit from regular fires (King et al., 2011; Yahner, 2003).

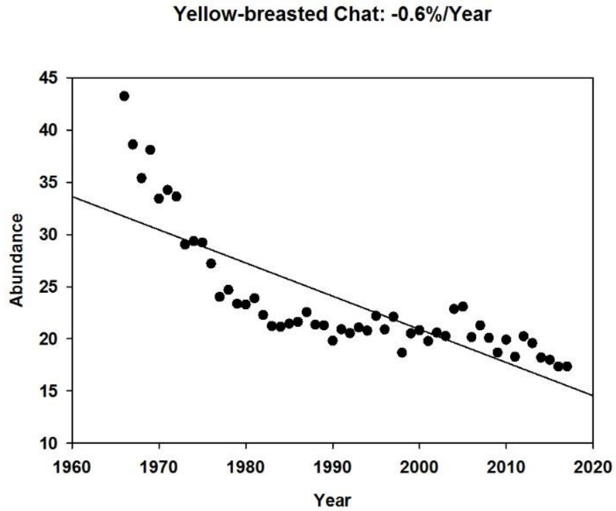

Figure 5 Yellow-breasted Chat population trend via the Breeding Bird Survey (Sauer et al., 2017)

Red-headed Woodpeckers are also a disturbance-dependent species. However, their population does appear to be increasing within Tennessee and several other southern states (Figure 6). Despite that, their overall population has been found to be decreasing by 2.1% a year (Sauer et al., 2017). As this species has been shown to be assisted by fire in other ecosystems (Allen et al., 2006; Rose & Simons, 2016), it is likely that it benefited from the fire as they were only found within the burned region and never in the suppressed, unburned area. Though they were found at low numbers, their presence suggests that regular fire could benefit their population through management.

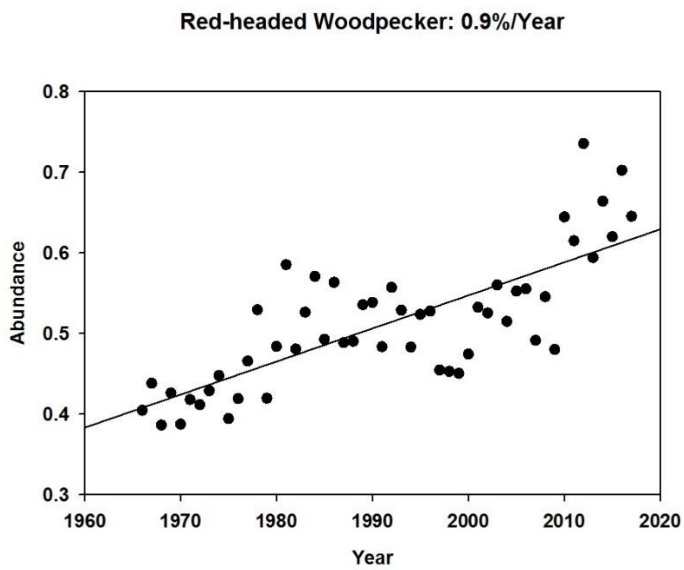

Figure 6 Red-headed Woodpecker population trend via the Breeding Bird Survey (Sauer et al., 2017)

Field Sparrows are another species found to be declining significantly in population (Figure 7) (Sauer et al., 2017). They have been found to be either absent or rare in forests prior to thinning and then increasing afterwards (King et al., 2011). Another study found that Field Sparrows didn't occur after a low or medium fire and only arrive 3-6 years after an intense fire (Klaus et al., 2010). They were found solely in the burned sections (which was described as an intense fire) and evidence of breeding and nesting was noted during the spring. This suggests that this fire also benefited their populations.

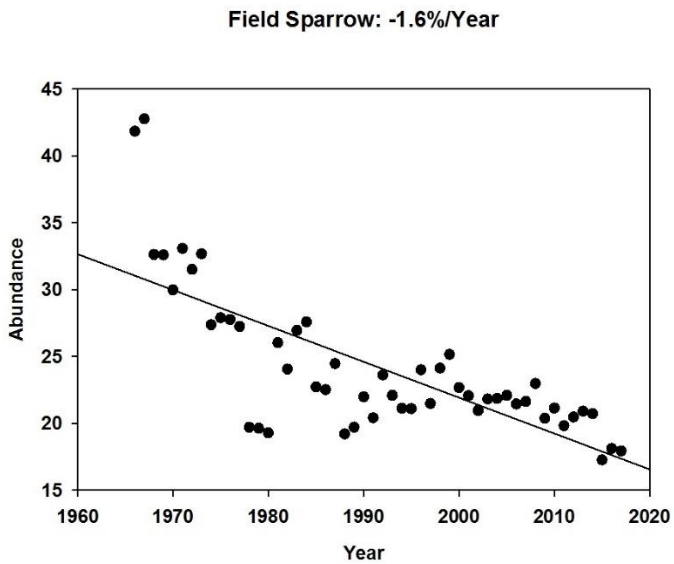

Figure 7 Field Sparrow population trend via the Breeding Bird Survey (Sauer et al., 2017)

Limitations and Future Considerations

One issue that arose was that during Spring 2018 the unburned section of the forest was inaccessible. This caused a lapse in data collection for that time. Another issue involved access to the site via departmental vehicle availability, scheduling conflicts, and inclement weather causing field days to be canceled. These data limitations were mostly confined to the months of January and February 2019.

For future studies, increasing the number of times a transect is walked during each season could boost results as detectability of birds can rise and fall across the breeding season (King et al., 2011). As this study did not find whether ornithochory was contributing to the spread of invasive plants, it is also suggested that researchers should check mist nets more frequently (multiple weeks a month), open a greater number of nets, and sample over the course of multiple years. This could provide a more accurate evaluation of ornithochory in burned eastern deciduous forests of this region.

Furthermore, having multiple severity type burned areas would be ideal to compare the differences in species composition between the level of fire. Some studies have found that certain species of birds are only assisted through high-severity fires (Rush et al., 2012). Through analyzing forests that burned with low, medium, and high fire intensity levels with a fire excluded plot for control, more thorough models could be created that would assist researchers and forest managers working in southeastern deciduous forests.

Another future consideration would be to examine the burned and unburned forests and compare the differences across several years. This could assist managers in managing the changes in avian diversity across time as the ecosystem grows and the canopy begins to return. Differences in diversity and their similarities across two, five, and ten years for a long-term project would greatly enhance our knowledge on southeastern forest fires. Other studies have found success with this technique in more northern eastern deciduous forests such as Massachusetts and Pennsylvania (Akresh et al., 2015; Yahner, 2003). Having a greater number of fire-disturbance studies on forests would increase the information available and potentially assist the struggling populations of bird species dependent on these disturbances. My study shows that even in small burned areas, disturbance-dependent species of birds benefit and could continue to benefit with proper management.

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APPENDIX A

IACUC APPROVAL LETTER

THE UNIVERSITY of TENNESSEE UT CHATTANOOGA

Institutional Animal Care and Use Committee
Dept. 4915
615 McCallie Avenue
Chattanooga, TN 37403-2598
Phone: (423) 425-5867
Fax: (423) 425-4052
iacucpro@utc.edu
http://www.utc.edu/iacuc

MEMORANDUM

TO: Dr. David Aborn

FROM: Dr. Ethan Carver, IACUC Chair
Lindsay Pardue, Director of Research Integrity

DATE: April 12, 2018

SUBJECT: **IACUC #: 18-02: Evaluating Avian Seed Dispersal as a Mechanism for Invasive Plant Regeneration**

The UTC Institutional Animal Care and Use Committee has reviewed and approved your application and assigned you the IACUC number listed above.

Reminder: Approved protocols must be reviewed at least annually. It is the responsibility of the principal investigator to submit an Application for Protocol Annual Continuation form to the IACUC before the anniversary date of the approved protocol. However, the Office of Research Integrity shall make every effort to send reminders 30 days prior to the anniversary date. The annual review form must be completed and submitted to the IACUC Committee before the first day of the anniversary month. New protocols must be submitted and approved every three years.

Please remember to submit a Protocol Modification Form if significant changes occur in your research design or in any instruments used in conducting the study. You should also contact the IACUC immediately if you encounter any adverse effects during your protocol.

For additional information, please consult our webpage http://www.utc.edu/iacuc or email iacucpro@utc.edu.

Best wishes for a successful research project.

APPENDIX B

IMAGES FROM THE FLIPPER BEND SITE (BURNED)

Image of the burned site in March 2018. Standing vegetation mortality was evident with burned trees still standing one and a half years after the fire. Photo Credit: Mary Elizabeth Feely.

Image of the thick growth that occurred due to a lack of canopy in the burned site. Image was taken in June 2018. Photo Credit: Mary Elizabeth Feely.

Wider view of the vegetation growth due to a lack of canopy after the fire. Image was taken in July 2018. Photo Credit: Mary Elizabeth Feely.

APPENDIX C

IMAGES FROM THE NORTH CHICKAMAUGA SITE (UNBURNED)

Image showing the high canopy height and lack of a thick understory at the unburned site. Image was taken in Summer 2019. Photo Credit: Mary Elizabeth Feely.

Image showing the low amount of ground vegetation due to a fairly closed canopy at the unburned site in Summer 2019. Photo Credit: Mary Elizabeth Feely.

VITA

Mary Elizabeth Feely was born in Knoxville, TN to Maria and Michael Feely, she has one sister, Sarah, who is two years younger. She attended Center for Creative Arts for middle and high school and graduated in 2011 before continuing her education at Maryville College in Maryville, TN. In her time there, she joined the American Chemical Society, found her passion for studying wildlife, helped establish TriBeta, and became scuba-certified through a class that spent a week studying coral reef health on the island of Bonaire. Through the tutorage of her advisor, Dr. David Unger, Mary pursued an undergraduate thesis that took her to the Manistee National Forest in Michigan for three months in order to study the prey base of the American marten (*Martes americana*). After graduating in May 2015 with a Bachelor of Science in Biology and a minor in Chemistry, Mary focused on her other passion of writing and worked at the Chattanooga Zoo as an educational assistant. In Fall 2017, Mary began teaching Biology 2 as a teaching assistant and pursued a Master of Science at the University of Tennessee, Chattanooga. She completed a thesis under the guidance of her advisor, Dr. David Aborn, in December 2019. After graduation, Mary continues her passions through teaching biology at Chattanooga State, working on her many novels, and working as an editorial assistant to Dr. David B. Sachsman of the West Chair of Excellence where she helps edit an international journal and the soon-to-be published *Routledge Handbook of Environmental Journalism*.