EFFECTS OF MANAGEMENT PRACTICES ON TERRESTRIAL VERTEBRATE DIVERSITY AND ABUNDANCE IN AN OAK SAVANNA ECOSYSTEM

Gregory Gene Gustafson

A Thesis

Submitted to the Graduate College of Bowling Green
State University in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

May 2018

Committee:

Karen Root, Advisor

Kevin McCluney

Tim Schetter

ABSTRACT

Karen Root, Advisor

Oak savanna and its associated species in the Midwest United States are being depleted and degraded. Oak savanna, a globally rare ecosystem, is dwindling because of hardwood encroachment, agricultural conversion and fire suppression. Disturbance is critical in an oak savanna ecosystem to maintain proper habitat structures for native species. Land management practices like herbicide applications, mechanical vegetation removal, and prescribed fire are all utilized to restore and maintain these early successional and native habitats in Northwest Ohio by subduing tree encroachment. Land management plays a key role in altering the structure of the landscape and subsequently the abundance and diversity of the wildlife in those areas.

To examine these relationships we surveyed 15 savannas in two preserves in Lucas County, Northwest Ohio. Point counts were conducted to observe avian and mammalian species day and night, May to October. We also used camera traps to assess larger wildlife within sites. Management data, provided by land managers, was aggregated per site via GIS. Our analysis, including linear mixed effects models and likelihood ratio tests yielded some significant results. Mixed effects models were run first and top fixed effects included in each of those models were analyzed using a likelihood ratio test to obtain a p-value for the relationship between variables.

Increasing mechanical management instances and duff depth correlated with and increase in total and avian abundance of observations (Likelihood ratio test, p-values<0.05). Increasing mechanical management instances was also correlated to a decrease in vegetation density (Likelihood ratio test, p-value <0.05) Increased Red-headed woodpecker abundance was correlated with increasing snag density (Likelihood ratio test, p-value <0.05). Increasing mammalian abundance of observations models were best predicted by the amount of coarse woody debris. Increasing mechanical management instances and duff depth correlated with and ncrease in total and avian abundance of observations (Likelihood ratio test, p-values<0.05).

Mechanical management repeatedly had relationships with response and environmental variables. Snag density, coarse woody debris, and vegetation density are all important structural features that relate to various vertebrate taxa. These findings contain important information for land managers in oak savanna ecosystems around the Midwest United States and the World.

This master's thesis in a long time coming and a culmination of so many aspects of my upbringing that I feel the need to dedicate it many people and experiences but I will select only a few. This thesis is dedicated to my parents as they have guided and galvanized me to pursue goals and to work hard from a young age. I also dedicated this thesis to my brothers for being my first companions in the wilderness and really laying the essential ground work for me to thrive in the natural world as a biologist.

ACKNOWLEDGMENTS

I would like to thank and acknowledge many people in helping me complete my thesis. I would like to first thank Dr. McCluney for his input on statistical analysis and help with R. I would like to acknowledge Dr. Schetter for being a practical eye reviewing my thesis. I would like to acknowledge Dr. Schetter and Metroparks of the Toledo Area for buying equipment for the study. I need to thank Krystyn Files my undergraduate field assistant for her important help out in the field. I would like to acknowledge the Department of Biological Sciences here at BGSU for admitting me to the program roughly two years ago. I lastly need to acknowledge my advisor Dr. Karen Root for her valuable guidance and patience as I formed and executed my master's thesis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I: EFFECTS OF MANAGEMENT PRACTICES ON TERRESTRIAL VERTEBRATE DIVERSITY AND ABUNDANCE IN AN OAK SAVANNA ECOSYSTEM

Introduction

Structural features in a habitat and in the surrounding landscape have effects on the abundance, diversity and distribution of organisms (Sallabanks *et al.* 2006, Santos & Poquet, 2010). Such structural features in a habitat can play many roles for an organism, with the most obvious roles being to provide shelter from the elements, cover from predators, and fostering more prey items for various species (Edworthy & Martin, 2014, Greenberg *et al.,* 2007). Structural features in an early successional habitat are usually sparse due to the frequent disturbances in this sort of habitat. Fire, flooding, and tornadoes are a few disturbances that affect early successional habitats and alter the structure quickly. In this study structural features are defined as any material like trees, duff, or vegetation height, etc. in the environment that with which organisms interact.

Organisms are influenced by structural features in specific ways, depending on the taxa. Terrestrial vertebrate taxa like amphibians, reptiles, birds, and mammals are the focus of this study. Each of these taxa has unique relationships with structural features. Overall tree density and trees with a diameter at breast height (DBH) of larger than 15 cm were found to foster greater avian abundance (Sallabanks *et al.* 2006, Kumar 2014). Understory vegetation (trees <15 cm DBH) has a significant effect on wood frog and avian abundance (Hossack *et al.* 2009, Sallabanks *et al.* 2006). Bird and amphibian species see benefits from increased tree density. Based on these studies it is important to understand the underlying relationships between these structural features whether they are anthropogenic or not. Increased canopy cover positively affected amphibian abundance according to Behangana *et al.* (2009). The presence of coarse woody debris and duff depth has positive effects on the presence of anurans in Appalachian hardwood forests (Pitt 2013). Smaller structural features like grass height have effects on vertebrate presence as well. Rodent presence was positively correlated with vegetation height, i.e. the taller the vegetation, the more rodents and rodent species were present (Bock *et al.* 2006, Hagenah *et al.* 2009, Yarnell *et al.* 2007).

Early successional habitat is rare for several reasons. Early successional habitat in this study is defined as any habitat that is highly dependent on disturbance to maintain its unique structural features. Prairies, oak savannas, Eurasian meadow, and sand barrens are examples of early successional habitat. Conversion from prairie or savanna into agricultural fields was common in Midwestern states, which were once heavily dominated by rolling tallgrass prairie and oak savanna (Leach & Givnish 1999, Nuzzo 1986, Brewer & Vankat 2004). Together, fire suppression and land-use changes caused these early successional ecosystems to decline in the south-central United States, as well (Holoubek & Jensen 2015). Fragmentation from roads and urban land use also adds to the loss of early successional habitat. Since 2011, the Oak Openings Region has seen an increase in urban and residential land use of 2.3 percent, or roughly 1064 hectares of land (Root & Martin, 2017). This statistic doesn't mean a loss in early successional habitat directly, but urban expansion is still occurring, even at a slow rate. The loss of early successional habitat is a combination of several pressures mostly applied by human actions after European settlement (Leach and Givnish 1996, Nuzzo 1986).

Prescribed fire, herbicide application regimes, and mechanical vegetation removal are ubiquitous practices in the world of wildlife management. These actions have a pronounced effect on the structural features in a habitat targeting plant communities. These actions have immediate effects on the landscape and structure of the habitat, with less obvious effects on wildlife. These management actions are the three types of management types included in my study. Fire, chemical, and mechanical management have varying relationships with structural features. It is important to recognize that structural features are altered by and can alter these management actions.

Fire affects structural features in numerous ways. Fire plays a key role in suppressing hardwood encroachment and maintains the diversity of floral resources for herbivorous organisms (Brewer & Vankat 2004, Hiers *et al.* 2007, Tester 1989). Prescribed fire has been used to stop woody tree growth in early successional habitats (Brewer & Vankat 2004). Snags in these habitats are products of prescribed fire and offer a diverse set of resources to early successional habitat occupants (Zarnoch *et al.* 2014, Adkins 2006).

Herbicide application is a management practice that is used frequently used to eradicate invasive plants and weeds (Wegener *et al.* 2016, Goffnett *et al.* 2016, Fernando *et al.* 2016). Carlson and Gorchov (2004) found that plots sprayed with herbicide targeting garlic mustard (*Alliaria petiolata)* had an increase in the percent cover of spring perennials a year after treatment. Herbicide applications have long-term positive effects on native plant populations by removing unwanted species like invasives (Garcia-Ruiz *et al.,* 2018). Herbicide treatments may alter the composition of floral resources by allowing other invasives to take the place of the previous invasive plant that was eradicated (Ketternring & Adams, 2011). Conversely, the reduction of invasive species allows natives to use those resources that were previously in use by the invasives like sunlight, water, and soil nutrients. These findings are variable and studies analyzing the relationship between herbicide applications and structural features are needed.

Mowing is a widespread practice in savanna and prairie ecosystems to increase diversity of plant life (Davies *et al.* 2012, Brys *et al.* 2004, Bonari *et al.* 2017). Most studies involving management look at the effects of those actions on plant communities; these actions include reducing vegetation height, tree thinning, and complete tree stand removal (Bruegel *et al.* 2015, Coppoletta *et al.* 2016, Luvuno *et al.* 2016) with fewer focusing on wildlife in the state of Ohio. This study was designed to tease out the actual effects of these management actions on wildlife abundance and/or diversity. Work still needs to be done to give confidence to our wildlife managers that these management actions are not causing harm to wildlife.

These management actions have varying effects on wildlife and must be understood to properly manage a community assemblage and not just the plant life. The effects of fire are variable among terrestrial taxa. In Rose *et al.'s* study (2016) they correlated increased fire severity with an increase in Indigo Bunting (*Passerina cyanea*) abundance. The Prairie Warbler *(Setophaga discolor)* and Eastern Wood-pewee (*Contopus virens*) both had positive responses in their abundance to fire several years after a burn (Rose *et al.,* 2016). The Ovenbird (*Seiurus aurocapillus*) and Worm–eating Warbler *(Helmitheros vermivorum)* were both impacted by fire with a reduction in their abundance since those species prefer forest interior habitats (Rose *et al.,* 2016). Avian abundance of species like the Worm-eating Warbler, Hooded Warbler (*Setophaga citrina*), and the Eastern Wood-Pewee all showed significant positive changes in response to fire two years after the area was burned (Greenberg *et al.,* 2007). According to a meta-analysis conducted by Pastro *et al.* (2014), North America was the only continent to see significant changes in vertebrate species assemblages after prescribed fire. These studies show fire has varying effects on wildlife and more research is needed in this area of the country.

Herbicide application affects terrestrial vertebrates in several ways. Herbicide applications are ubiquitous in the wildlife management profession so more studies on their effects should be conducted. Druille *et al.* (2016) concludes that the herbicide glyphosate impacts soil microorganisms and plant root health adversely which leads to a decline in vertebrate herbivore presence. So, some of these herbicide effects may target prey items of the organism and not the organism itself. Some direct effects have been recorded. The common herbicide Roundup affects larval Wood Frogs (*Rana sylvatica*) and American Bullfrogs (*Bufo americanus*) negatively and sometimes results in death (Jones *et al.,* 2010). Ralyea (2009) found equivalent results with Gray Tree Frog (*Hyla versicolor*) and Leopard Frog (*Rana pipiens*) larvae. Amphibian responses to herbicide applications are understudied according to Green *et al.* (2016). Sullivan (1990) showed increase in recruitment of Deer Mice (*Peromyscus maniculatus*) in the years after spraying glyphosate. Sullivan (1990) also showed the Oregon vole (*Microtus oregoni*) female survival increased the summer after treatment compared to controls.

Mechanical management actions have varying relationships with wildlife and can alter structural features in a few ways. Mowing may have negative effects on the presence of small mammals like voles in prairie ecosystems (Horvath 2013). Tree removal in open habitats (e.g. prairie, wetland, savanna ecosystems) prompted weak positive responses by grassland birds and wetland birds six years after removal.

(Thompson *et al.* 2016). Red-backed salamanders (*Plethodon cinereus*) were most abundant in the unharvested forests of West Virginia compared to areas of increased harvest (Homyack *et al.*, 2011). Suzuki & Hayes (2003) suggest that thinning of forest stands did not have significant detrimental effects on any small mammals they studied and only positive effects on several other small mammals. White-footed Mice (*Peromyscus leucopus*) populations in Greenberg *et al.'s* (2006) study showed significant increases in their populations in plots with mechanical removal when compared to controls two years after treatments. Mechanical management is another ubiquitous practice in the land management profession that land-owners use to alter structural features.

Oak (*Quercus)* savannas rely on management to maintain their unique structural features from a closed canopy woodland or a tallgrass prairie (Hutchinson *et al.* 2005, Artman *et al.* 2008). Upland savannas in the Oak Openings Region of Ohio are only 0.8 percent of the total land-area, with only four patches exceeding five hectares (Schetter & Root 2011). Oak savanna worldwide covers about five percent of land area (Defries *et al.* 2004). Noss *et al.* (1995) concluded oak savanna in the Midwest is a critically endangered ecosystem since it has lost greater than 98 percent of its pre-settlement land coverage. According to Brewer and Vankat (2004) oak savanna only covers about one percent of old pre-settlement extent. These values are alarming, as the earth is lacking upland, temperate oak savannas. Not only is the ecosystem important but the Oak Openings Region of Ohio, with a variety of natural ecosystems, is home to 145 state threatened and/or endangered plant and animal species (Brewer & Vankat 2004). It is important to understand the drivers of habitat alteration in this region because it holds remnants of globally rare habitats and is full of threatened and endangered flora and fauna. This study is an attempt to find a relationship between management actions and their effects on this early successional habitat and the organisms that occupy this habitat. The need for this is critical, because oak savanna and early successional habitat, in general, are in decline and studies on the effects of management on wildlife abundance and diversity are scarce locally. In a meta-analysis conducted by Fontaine and Kennedy (2012), no studies conducted on the effects of fire in forests on vertebrates were from the state of Ohio. There are few studies regarding fire effects on prairies and savannas in Ohio (Averett *et al.*, 2004) and most studies weren't looking at wildlife responses. I will attempt to correlate effects of structural features that are influenced by management, on the abundance and diversity of observations of vertebrate taxa in these drastically dwindling oak savanna ecosystems. The findings of this study will be generally beneficial for the ecological research community both within and outside of the Oak Openings Region. This is evident because I am studying fundamental relationships between structural features, organismal abundance and diversity of observations in oak savannas. Similar tree and grass species are also present in other areas across the Midwestern United States and the world. My study revolves around one question: How do management actions relate to structural features and vertebrate taxa in an oak savanna ecosystem?

Methods

Study Plots

Study plots were in oak savannas in Northwest Ohio in two preserves within the Oak Openings Region. Oak savanna is commonly described as having a grass layer dominated by Big Bluestem (*Andropogon gerardii*), Little Bluestem (*Schizachyrium scoparius*), Indian grass (*Sorghastrum nutans*), and sapling oak species with sparse amounts of mature oak species like White *(Q. alba*), Eastern Black (*Q. Velutina),* and pin (*Q. palustris)* (Brewer & Vankat 2004, Tulloss & Cadenasso 2015, Natureserve 2006). There are also forbs present in the understory like Wild Lupine (*Lupinus perennis*), Round headed-bush clover (*Lespdeza capitata*), Rough Blazing Star (*Liatris aspera*) and various species of goldenrod (*Solidago*). Each study plot was 100 by 200 m or roughly two hectares. There were 15 plots dispersed between the two parks. I had 7 plots at Kitty Todd Nature Preserve (KTNP) (Figure 1) and the other 8 plots were located within Oak Openings Preserve (OOP) (Figure 2).

My study has a hierarchical structure consisting of preserves, plots and sub-plots. Preserve is my largest unit of analysis. The next largest units are plots. Nested within plots are sub-plots. Each plot contains five sub plots. There is one sub-plot per corner and one in the middle of each plot (Figure 3). All plots in OOP were initially selected via a GIS landcover map (Schetter & Root 2011) and subsequently ground truthed for confirmation. During ground truthing identification of plant species commonly associated with oak savanna were found and used to confirm the site selection. OOP is managed by the Metroparks of Toledo Area staff. Plots at KTNP were selected based on suggestions by land managers and ground truthed. KTNP is a 400 hectare preserve managed by The Nature Conservancy.

Management Data

Land management data were acquired from Metroparks of the Toledo Area for OOP. Data for KTNP were provided by The Nature Conservancy staff at the preserve

(Ryan Gauger, pers. comm.). These data consisted of the type of management action (e.g., prescribed burn, herbicide application, or mechanical management), the location, and the date. Management variables like number of herbicide applications, prescribed fires, mechanical management instances, and total management instances were tabulated per sub-plot, plot, and preserve as totals in the last 5 years. Arial photos and GIS files were examined to find overlap between my study plots and the denoted management areas provided by the park. If a plot had only part of it managed in a year I still counted it as a full management action on that plot. I quantified management by collating how many instances of prescribed burning, herbicide applications, and mechanical removal/ thinning occurred from 2011 to 2017. I also summed all three into a measure of total management instances per park, plot, and sub-plot.

Wildlife Surveying

I surveyed all terrestrial vertebrate taxa in my study plots. I surveyed at multiple times during the day and into the night. I surveyed all plots the same amount of time over the season and surveyed them in the same way every time. I began surveying in May and finished at the end of September. I avoided days of inclement weather like rain and high winds (winds >40 kph). I did this to avoid irregular activity of the vertebrates in response to these conditions. I surveyed my plots using a transect method in a "Z" pattern through my plots (Figure 4). At each corner and in the middle I conducted point counts for three minutes each for a total of 15 minutes of controlled visual surveying during the day time (dawn to dusk). Survey time at each point-count was reduced to avoid double-counting. Once a vertebrate was counted we made sure to mark where it came to rest to avoid counting it again. I used a 50-meter detection radius for my point counts at each sub-plot.

Trees or other markers were flagged to denote 50 meters from a sub-plot. If a detection was made while walking between plots or walking up to the plot within the 50-meter radius I counted that as an opportunistic sighting and recorded it under the proper sub-plot location. Nocturnal visual surveys were conducted after dusk and before dawn in the same transect pattern used during the day. I used a flashlight to identify wildlife by eye-shine. Once eyes were detected I closed in on the vertebrate and confirmed the species.

I also used passive methods to detect wildlife. I deployed camera traps to track mammals in particular. Due to budget constraints only 17 camera traps were available. I used 5 to 6 cameras per plot and rotated them after two weeks to a separate set of plots. Each plot was monitored twice over the summer for a total of 3.5 weeks. The second rotation was only 1.5 weeks per plot because of time constraints. Cameras were placed on the center line of each plot along a 200 meter transect. Two cameras were always placed in the middle of the plot facing in opposite directions away from the center of the plot. If six cameras were available there would be two on each end pointed inward towards the center of the plot with 120 degrees of separation between them. If only 5 cameras were available, one end of the plot would only have one camera (Figure 5). Unless the difference between individuals within a species was evident, the observation was only counted once. Date, time, and temperature were recorded on the cameras at the time of the photo.

Abundance in my study was defined as the total number of observations of any terrestrial vertebrate taxa. Total abundance was defined as the total of all taxa observations at all scales, preserve, plot and sub-plot, and months. Avian abundance was defined as the total avian observations recorded at each preserve, plot, and sub-plot location. I also calculated abundance of observations per month. Diversity in my study was defined as the diversity of observations per preserve, plot and sub-plot. Diversity was measured using the Shannon's and Simpson's diversity indices as totals by month and over the season per preserve, plot, and sub-plot.

Vegetation Surveying

To characterize the vegetation and structure of each plot, I measured vegetation density, duff depth, canopy cover, small tree density, large tree density, snag abundance, and coarse woody debris (hereafter CWD). I measured duff depth, canopy cover, and vegetation density at each sub-plot location 3 times over the study period for each plot. Plot values for duff depth, canopy cover, and vegetation density are found by averaging sub-plot values. I measured duff depth with a ruler measuring the height of litter and debris on the ground in centimeters from the top of the soil. Canopy cover was recorded with a light meter (Dr. Meter, Model # - LX1330B) in Lumens. I just recorded the number of lumens for each sub-plot. At the plot level I averaged all the sub-plot canopy values. Greater values in lumens indicated less canopy cover and vice versa. I lumped my vegetation density measurement into categories from 0 (no vegetation) to 5 (thick vegetation) by halves (e.g. - 0, 0.5, 1.0, 1.5, etc). Vegetation density was derived from an estimation of percent cover. I estimated the amount of herbaceous plants within a 30x30 cm area in each sub-plot (Table 1).

I measured small tree density, large tree density, snag abundance and CWD once over the study period at each plot. Small and large tree densities were difficult to census in some plots because trees were numerous. So, I measured relative density of small and large trees instead. I selected three points in the plot. All the points are along the center line one at 0 m, 100 m, and 200m. Once I arrived at the designated spot I found the nearest small tree (15cm<x<30cm) and the nearest large tree (x>30cm) then I measured the distance between the nearest small trees and recorded. I did the same for the large trees. I did the same at each point (0 m, 100 m, 200 m) with a total of three measurements from each plot for each class of tree. I measured snag abundance by simply counting any snags (x>15 cm DBH) present on the plot. A snag was any tree with no leaves still upright in the study plot. I measured CWD by walking my normal transect route looking for any log or stone that was greater than 30 cm in length or in diameter. These were tallied and totaled per plot.

Several landscape features were analyzed using ArcGIS (Version 10.2.2). I analyzed habitat types (e.g., landcover types based on Martin and Root 2017: Upland Forest, Upland Savanna, Wet Prairie, etc) in and around each plot to analyze differences between surrounding landscapes for each plot. The landcover map (Root & Martin, 2017) has a resolution of 30 meters. I measured the diversity of landcover types by calculating the total area of each land cover type within 3 different buffers of 50-meter, 100 meter and 500-meter radius around each plot. I also measured the landcover diversity within my plot. I estimated this by finding the area covered by each landcover type found within each buffer and plot. I tabulated those values and used the Habitat Diversity Index first described by Turner (1990) to calculate the diversity of land covers with in certain buffers.

Statistical Analysis

Analysis was run in R (Version 4.3.2). I used a mixed effects models approach like Bolker *et al.* (2009). I chose to use mixed effects models to test relationships among management, environmental and response variables. I used Model selection was based on AIC scores. Models that were within three AIC points of the top model were considered similar. Analysis was conducted at all spatial scales: preserve, plot, and sub-plot. Each spatial scale was then incorporated into the model as a random effect to avoid spatial autocorrelation among sampling points. Model sets were run for several response variables that included: total, avian, and mammalian diversity of observations as well as total, avian, and mammalian abundance of observations.

AIC tables were generated for each response variable. Diversity of observation models used a Gaussian distribution; however, abundance of observation models used a Poisson distribution. Each model set had each fixed effect run singularly against the same response variable. Fixed effects in models that were within three AIC scores of the top model were combined in another model to complete the entire model set for one response variable. Random effects were included in every model. P-values in graphs and tables were derived from a Likelihood ratio test after running the mixed effects models.

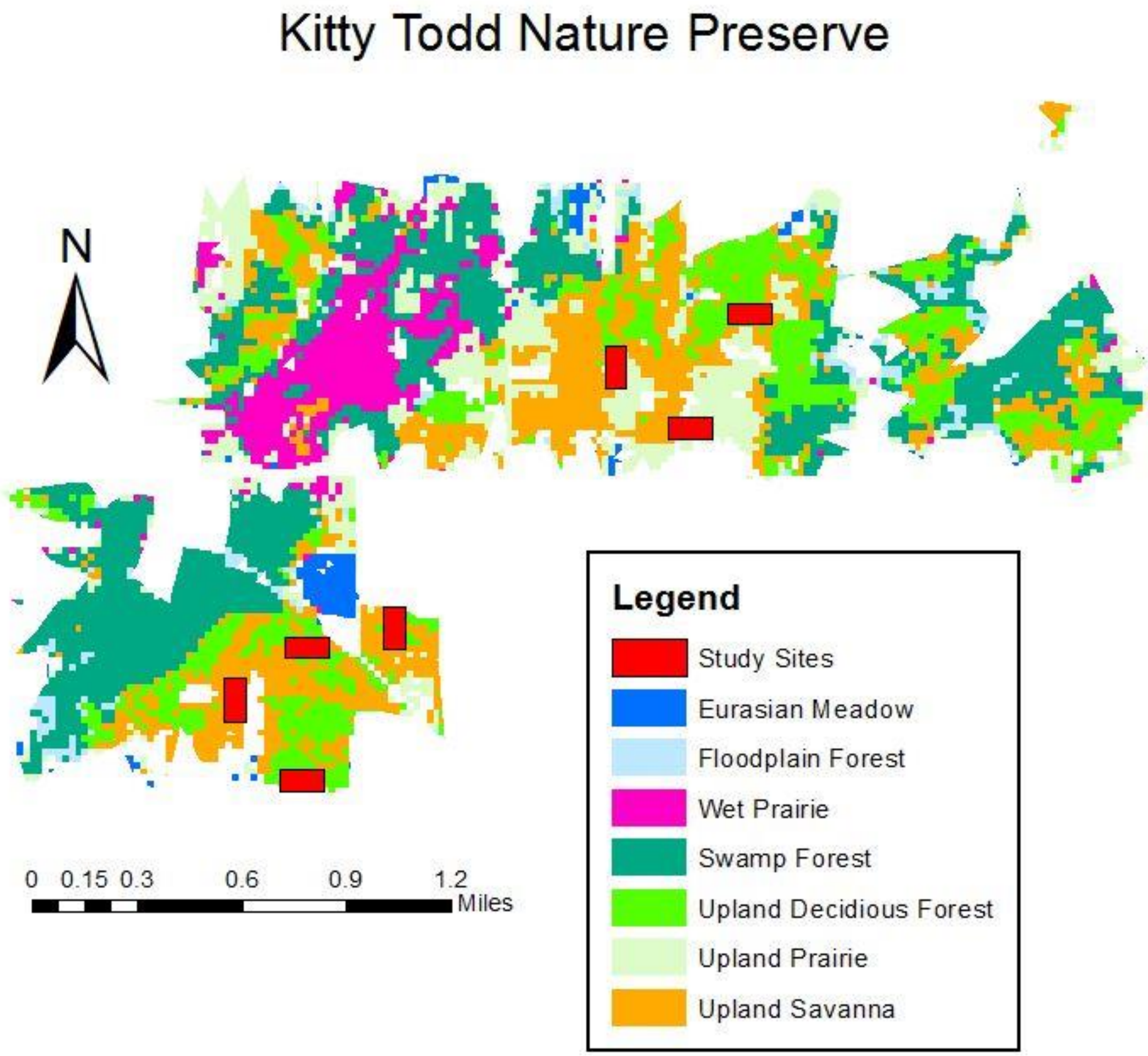


Figure 1: Kitty Todd Nature Preserve, Lucas County, Ohio. Managed by The Nature Conservancy. GIS data provided by Ryan Gauger of The Nature Conservancy. Land cover map produced by Amanda Martin and Dr. Karen Root (2017).

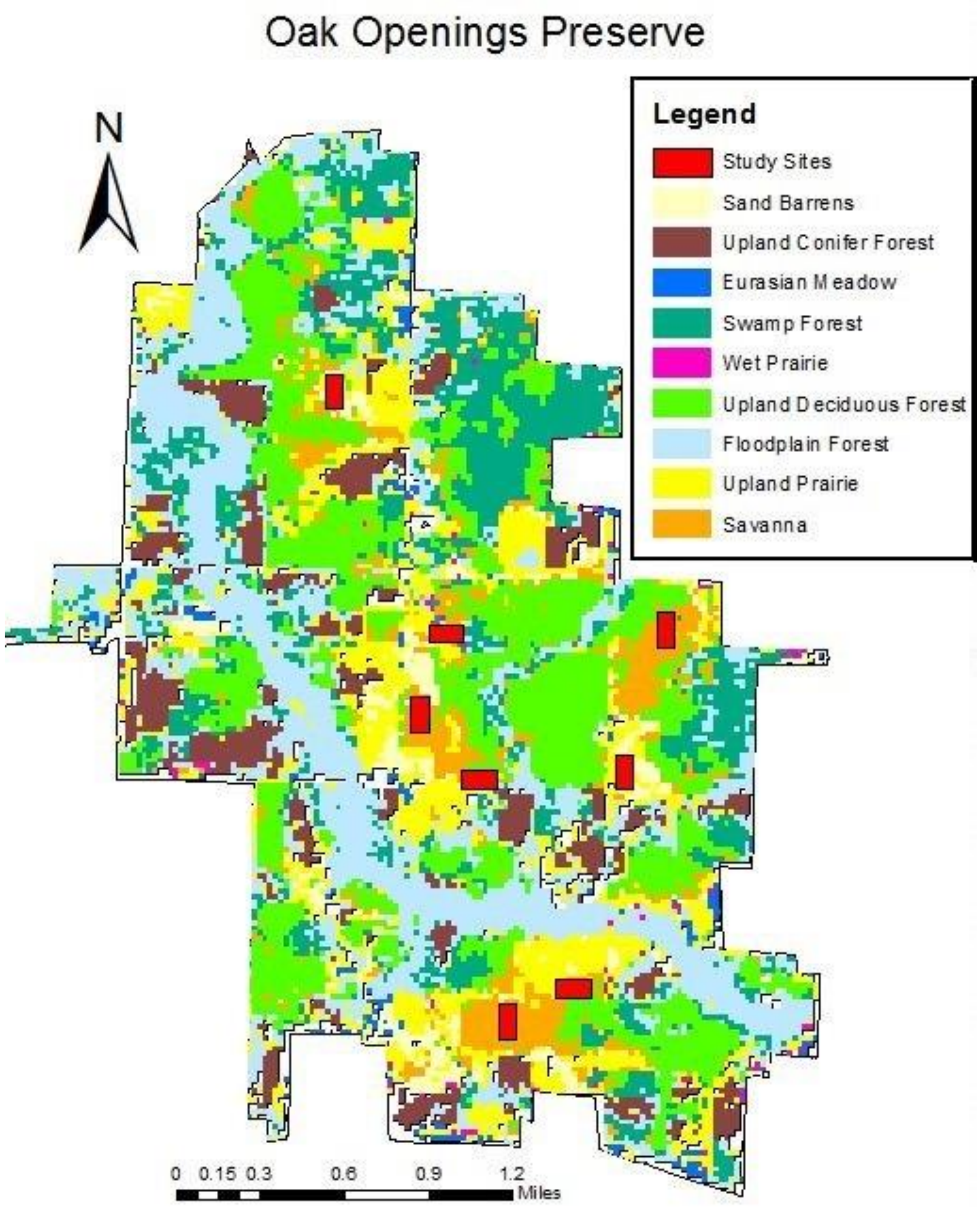


Figure 2: Oak Openings Preserve, Lucas County, Ohio. The preserve is managed by Metroparks of the Toledo Area. GIS data provided by Dr. Karen Root, and Amanda Martin (2017).

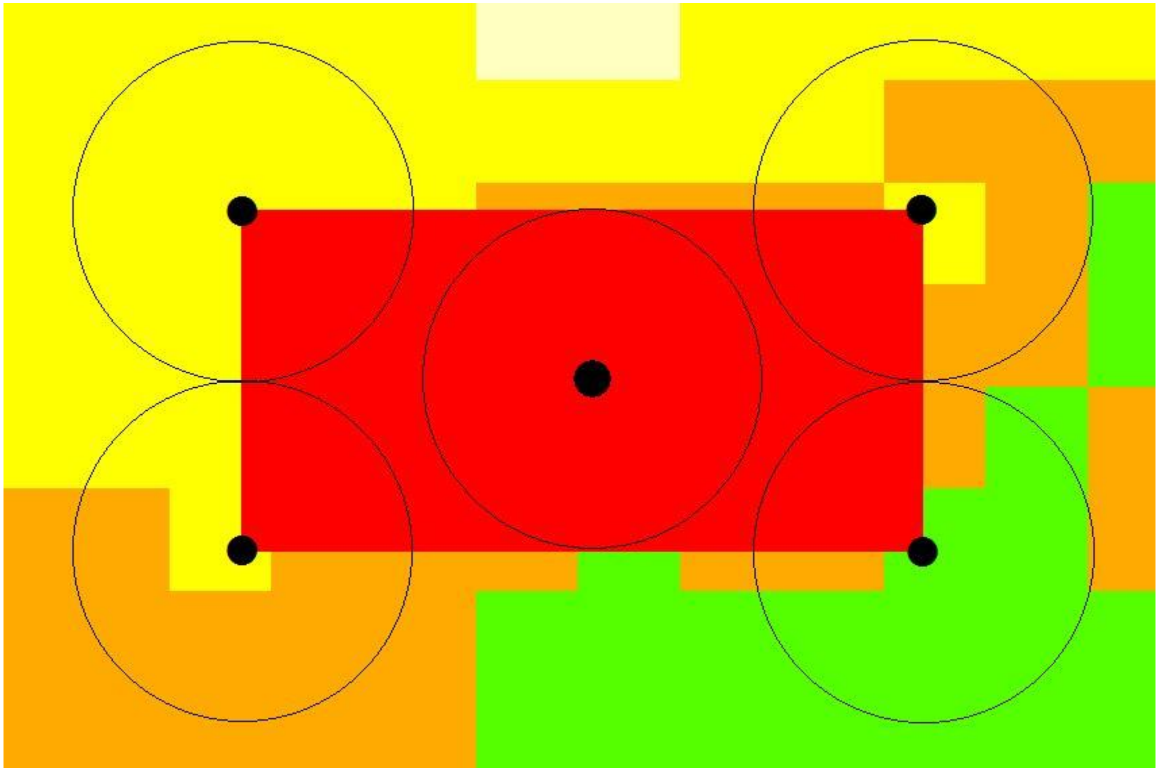


Figure 3: Diagram of a study plot (red rectangle) and the five sub-plot (black dots) locations within each plot. Black circles around each sub-plot location represent the 50 m search radius at each sub-plot.

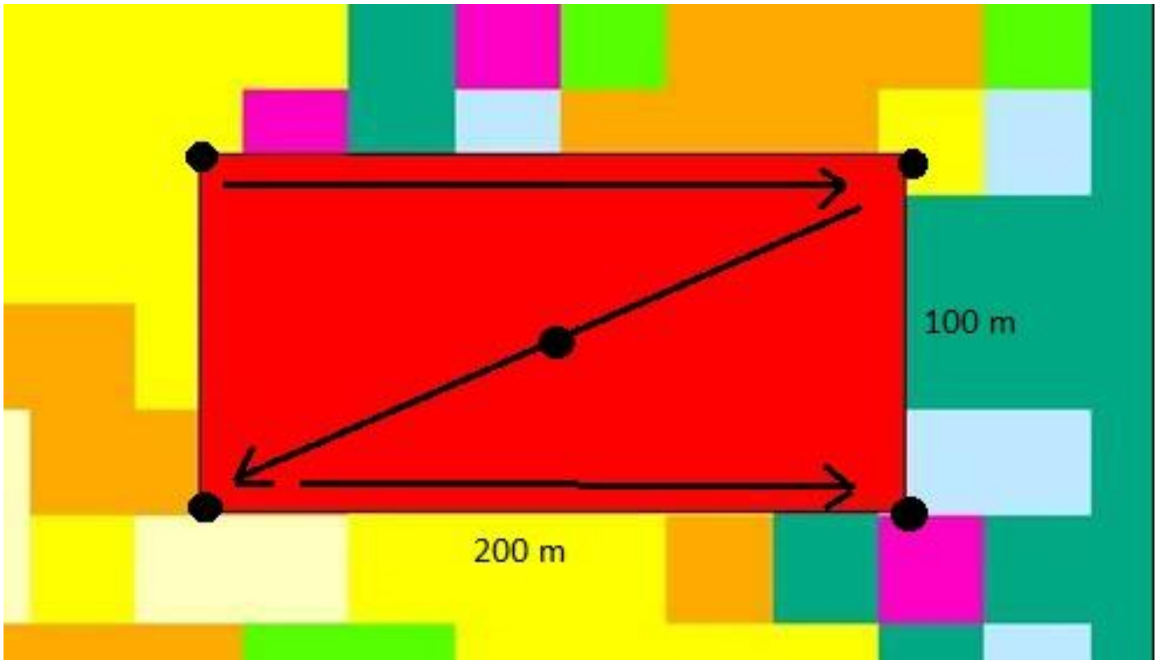


Figure 4: Diagram of one example study plot with the sampling plot designated as the red rectangle. Lines represent the 'Z' transect and the black dots represent sub-plot locations.

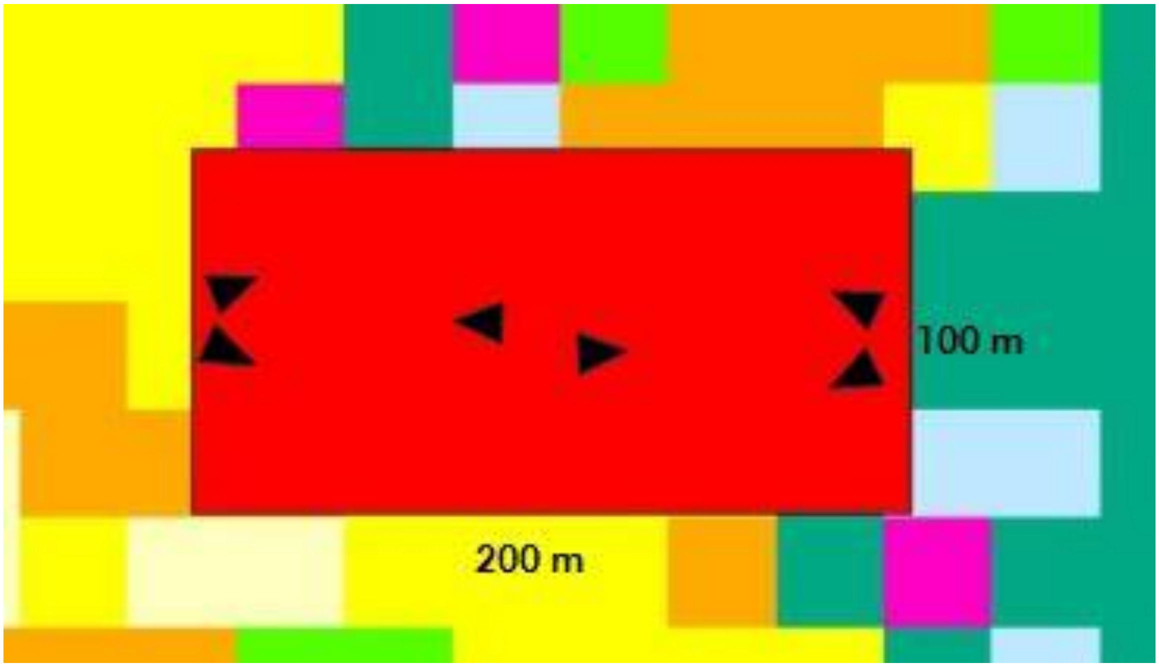


Figure 5: Camera trap layout within a plot (red rectangle) at a study plot. Cameras are represented by the black triangles. Narrow end of triangle represents the direction the camera is facing.

Table 1: Left column shows the percent range assigned to the specific scale value. This measurement is referred to as vegetation density.

Percent cover (%)	Scale Value
0	0
1--10	0.5
11--20	1
21--30	1.5
31-40	2
41-50	2.5
51-60	3
61-70	3.5
71-80	4
81-90	4.5
91-100	5

Results

I recorded a total of 1770 observations over the study period. A minute number of reptiles and amphibians were recorded and subsequently removed from further analysis. I recorded 1342 avian observations (76 %) and 428 mammalian observations (24 %) (Table 2). I removed any avian observations I couldn't identify to species from my analysis. All mammalian observations were identified to species. Overall 65 species were identified with 13 (20%) being mammalian and 52 (80 %) being avian. Of the 1770 observations 634 (35%) were in KTNP and 1136 (65%) were in OOP (Figure 6). Plot 2 in OOP had the most total observations at 254 and most species detected at 37 over the study period. The most avian observations were recorded at Plot 5 in OOP and the most mammalian detections were at plot 8 in OOP as well. The highest diversities were also found in OOP's plots. The most mammalian species detected was at plot 1 in OOP at 9 species. The most avian species observed at a plot was plot 2 in OOP. I attempted capturing and recording amphibians and reptiles but too few were found to conduct any statistical analysis.

A few correlations were found between parks among my measurements. Snag density was different between KTNP and OOP (Likelihood ratio test, p-value=0.05). Amount of mechanical management instances and total management instances were also different between preserves (likelihood ratio test, p-values<.001, and .008, respectively). It is worth noting I detected a marginally significant difference in total abundance of observations between parks (Likelihood ratio test, p-value=0.107). No other variables were different between the preserves.

Relationship between Management Actions and Structural Features

At the sub-plot scale increasing mechanical management instances correlated with a decrease in vegetation density (Likelihood ratio test, p-value=0.0053) (Figure 7). This relationship was also seen at the plot scale (Likelihood ratio test, p-value= 0.0471). Increasing mechanical management was correlated with an increase in CWD at the plot scale only (Likelihood ratio test, p-value <0.001). Increasing chemical applications was correlated with a decrease in snag density at the plot level (Likelihood ratio test, p-value<0.001).

Relationship between Structural Features and Response Variables

At the sub-plot scale my top model to predict total abundance of observations included total mechanical management instances and duff depth (Table 3). Mechanical management and duff depth also best predicted avian abundance of observations at the sub-plot scale. No combination or singular fixed effect was more effective at predicting total, avian, and mammalian diversity of observations at the sub-plot scale than the null model. The null model was the top performing model for mammalian abundance of observations at the sub-plot scale as well.

Several relationships were seen at the plot scale. Total prescribed fire instances singularly best predicted total, and avian abundance of observations at the plot scale (Table 4 & 5 respectively). Avian diversity of observations was best predicted by mechanical management and canopy cover. Increasing abundance of Red-headed Woodpeckers observations (*Melanerpes erythrocephalus*) was correlated with an increase in snag density (Likelihood ratio test, p-value <0 .001) (Figure 8 and Table 6). This was the only relationship that was found between a single species and another variable. Abundance of White-tailed deer observations was unrelated to management and environmental variables. A decrease in abundance of mammalian observations was found to be correlated with an increase in CWD at the plot scale (likelihood ratio test, p-value=0.0017) (Figure 9).

Table 2: This table represents each study plot and the number of birds, mammals, and total observations. Totals for each preserve and over the study season are listed on the right side of the table.

Park	**OOP**								
Plot #	1	2	3	4	5	6	7	8	**Totals**
Total Birds	97	158	95	85	184	116	36	55	**826**
Total Mammals	50	52	43	32	17	17	32	67	**310**
Total per plot	147	210	138	117	201	133	68	122	**1136**
Park	**KTNP**								
Plot #		1	2	3	4	5	6	7	
Total Birds		65	71	107	42	92	82	57	**516**
Total Mammals		21	4	28	28	14	10	13	**118**
Total per plot		86	75	135	70	106	92	70	**634**
Overall total									**1770**

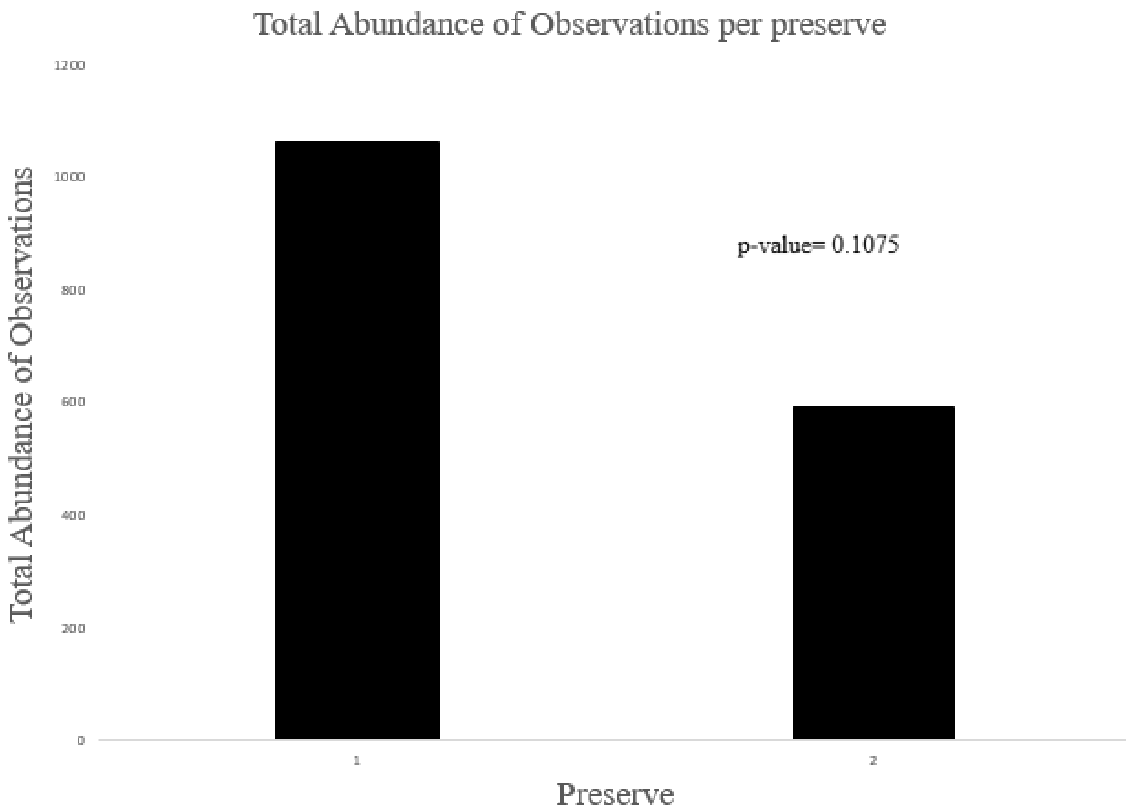


Figure 6- Relationship between total abundance of observations between preserves. Preserve 1 is OOP and preserve 2 in KTNP. I used a likelihood ratio test to find significance.

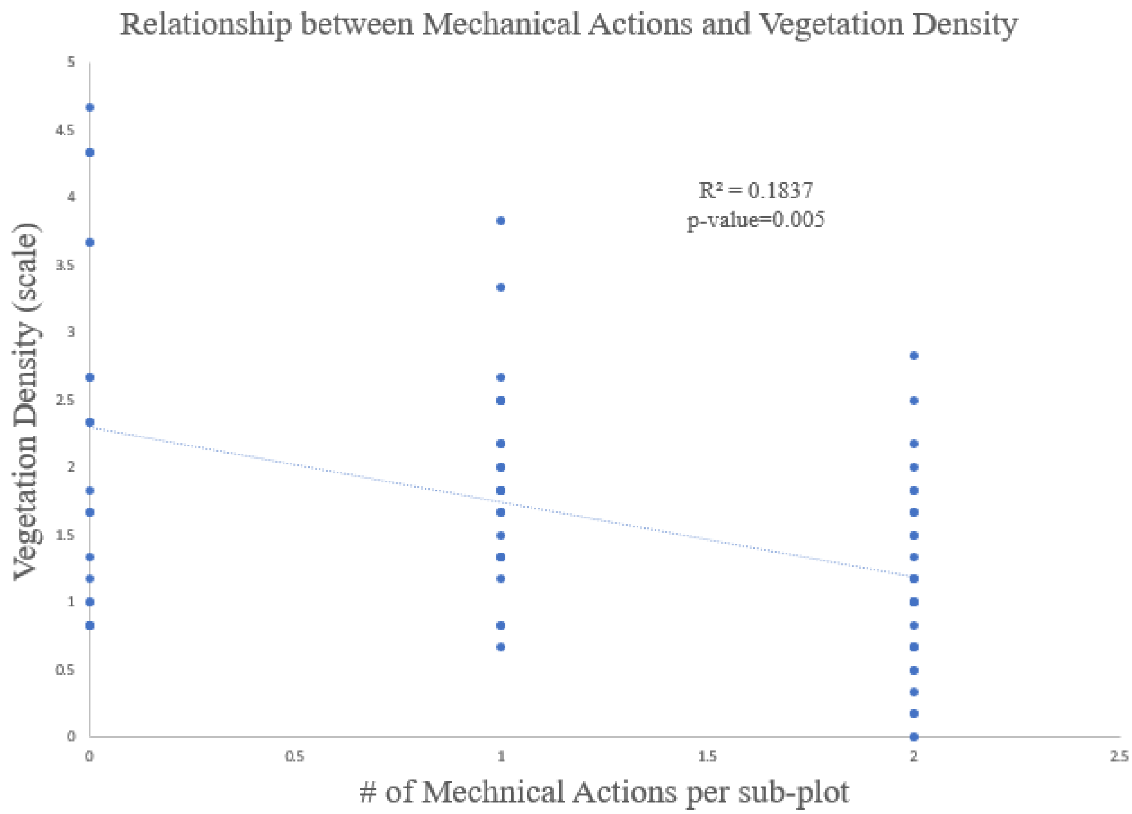


Figure 7- Relationship between the number of mechanical actions and vegetation density per sub-plot. I used a likelihood ratio test to find significance in this relationship (p=0.005).

Table 3- Shown are the results for all models for total abundance of observations per sub-plot. Mechanical actions and duff depth in combination produce the best model. K= number of parameters per model, LL-log likelihood, Delta_AICc= change in AIC score from the top model and Cum.Wt= model weights.

Modnames	K	AICc	Delta_AICc	ModelLik	AICcWt	LL	Cum.Wt
Mechanical & Duff depth	5	593.2262	0.000000	1.000000000	0.709716063	-291.1783	0.7097161
Duff Depth	4	596.3314	3.105177	0.211699331	0.150246416	-293.8800	0.8599625
Mechanical	4	597.2333	4.007139	0.134853088	0.095707403	-294.3309	0.9556699
NULL	3	601.7155	8.489313	0.014340656	0.010177794	-297.6887	0.9658477
CWD	4	601.9334	8.707180	0.012860562	0.009127348	-296.6810	0.9749750
Snag Density	4	603.0671	9.840889	0.007295886	0.005178007	-297.2478	0.9801530
Canopy cover	4	603.2955	10.069367	0.006508257	0.004619014	-297.3621	0.9847720
Ground cover	4	603.3996	10.173450	0.006178220	0.004384782	-297.4141	0.9891568
Chemical	4	603.6250	10.398785	0.005519916	0.003917573	-297.5268	0.9930744
Total Management	4	603.8706	10.644425	0.004881940	0.003464791	-297.6496	0.9965392
Prescribed Fire	4	603.8729	10.646726	0.004876328	0.003460808	-297.6507	1.0000000

Table 4- Shown are the results for all models for abundance of avian observations per plot. Number of prescribed fires is the best model. K= number of parameters per model, LL-log likelihood, Delta_AICc= change in AIC score from the top model and Cum.Wt= model weights.

Modnames	K	AICc	Delta_AICc	ModelLik	AICcWt	LL	Cum.Wt
Prescribed Fire	3	239.4664	0.00000	1.000000e+00	9.997637e-01	-115.6423	0.9997637
Total Management	3	256.4880	17.02156	2.012865e-04	2.012389e-04	-124.1531	0.9999649
Mechanical	3	260.2249	20.75849	3.107072e-05	3.106338e-05	-126.0215	0.9999960
Canopy cover	3	264.4049	24.93852	3.842984e-06	3.842076e-06	-128.1116	0.9999998
CWD	3	270.5281	31.06168	1.799048e-07	1.798623e-07	-131.1731	1.0000000
Snag Density	3	291.3566	51.89017	5.397496e-12	5.396221e-12	-141.5874	1.0000000
Chemical	3	294.9802	55.51374	8.817464e-13	8.815380e-13	-143.3992	1.0000000
Ground cover	3	295.1651	55.69868	8.038685e-13	8.036786e-13	-143.4916	1.0000000
NULL	2	295.9301	56.46370	5.483559e-13	5.482263e-13	-145.4651	1.0000000
Duff Depth	3	298.8164	59.34994	1.295161e-13	1.294855e-13	-145.3173	1.0000000

Table 5- Shown are the results for all models for avian abundance of observations per plot. Number of prescribed fires is the best model. K= number of parameters per model, LL-log likelihood, Delta_AICc= change in AIC score from the top model and Cum.Wt= model weights.

Modnames	K	AICc	Delta_AICc	ModelLik	AICcWt	LL	Cum.Wt
Prescribed Fire	3	262.0949	0.000000	1.000000e+00	9.173835e-01	-126.9566	0.9173835
Total Management	3	267.3285	5.233604	7.303607e-02	6.700208e-02	-129.5734	0.9843855
Mechanical	3	270.2701	8.175202	1.677944e-02	1.539318e-02	-131.0442	0.9997787
CWD	3	278.7548	16.659826	2.411930e-04	2.212665e-04	-135.2865	1.0000000
Canopy cover	3	298.2446	36.149693	1.413168e-08	1.296417e-08	-145.0314	1.0000000
Chemical	3	309.9234	47.828408	4.113326e-11	3.773497e-11	-150.8708	1.0000000
Snag Density	3	314.1357	52.040763	5.006011e-12	4.592432e-12	-152.9769	1.0000000
NULL	2	314.2003	52.105315	4.847019e-12	4.446575e-12	-154.6001	1.0000000
Ground cover	3	317.1380	55.043093	1.115692e-12	1.023517e-12	-154.4781	1.0000000
Duff Depth	3	317.1561	55.061180	1.105647e-12	1.014303e-12	-154.4872	1.0000000

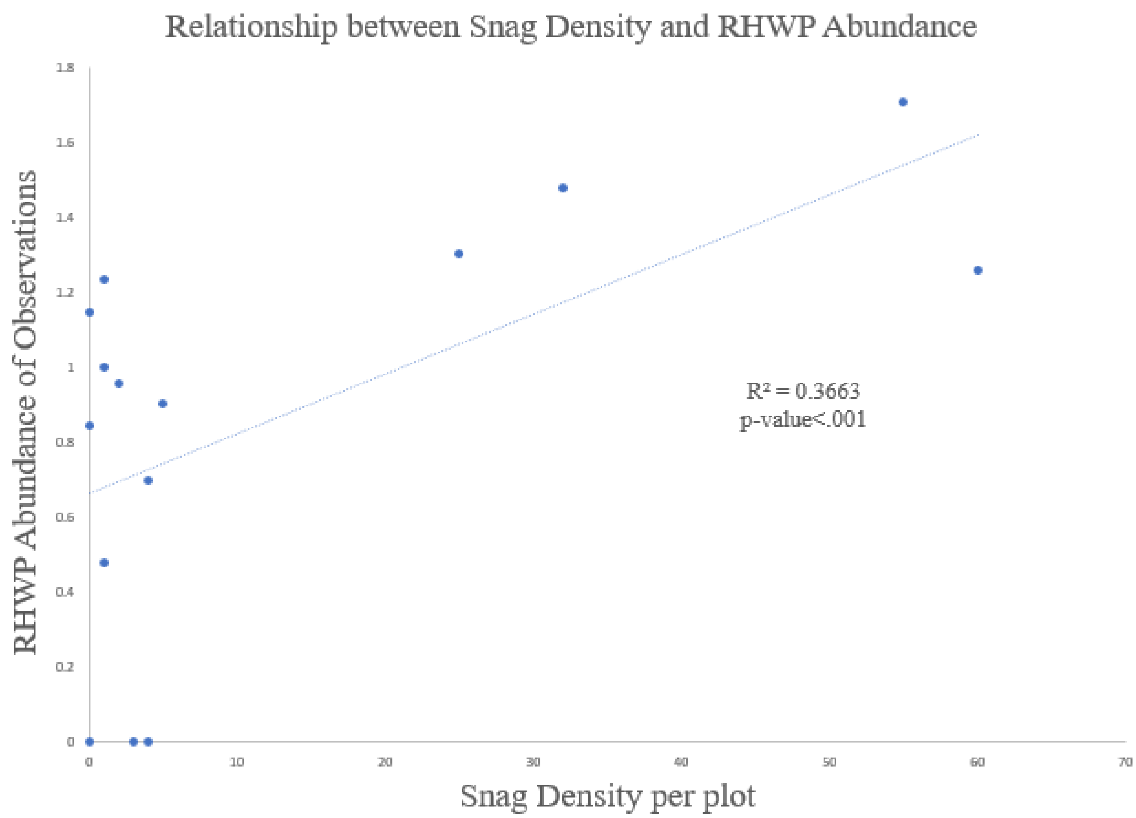
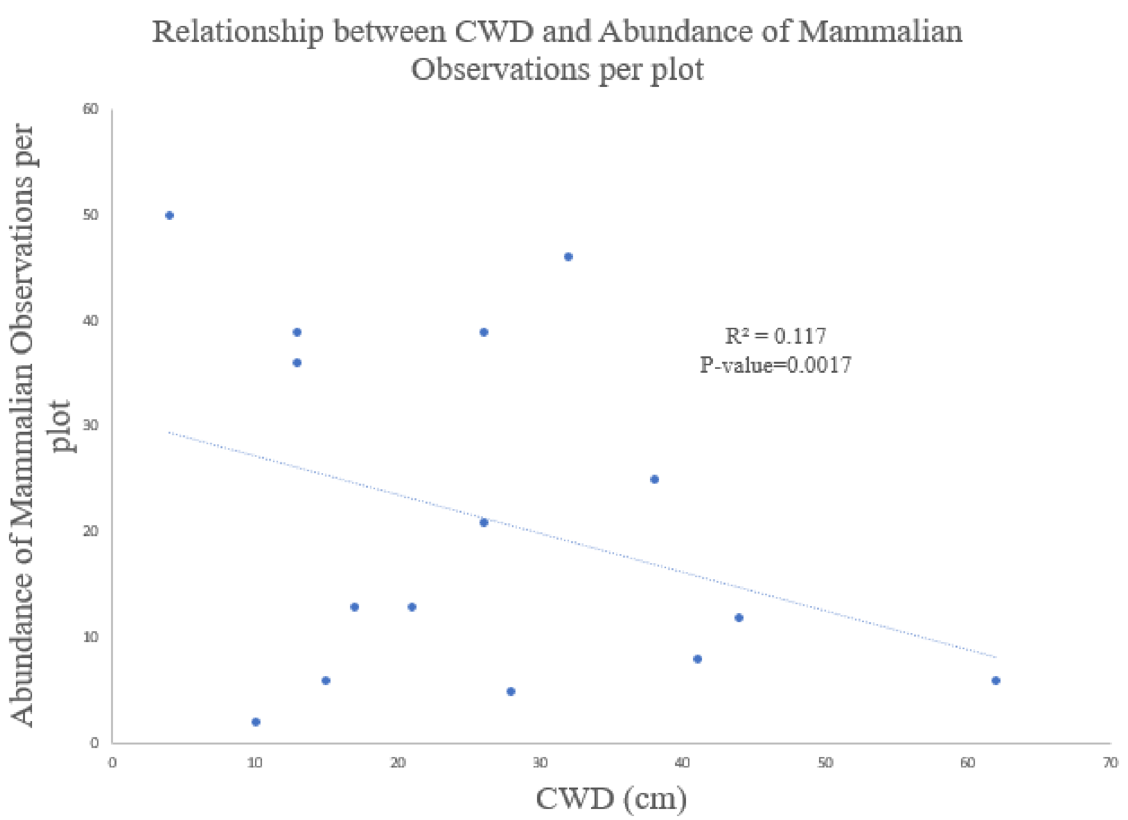


Figure 8- Shown is the relationship between the abundance of Red-headed woodpeckers (RHWP) observations and snag density per plot. Significance was found using a likelihood ratio test (p-value<.001).

Table 6- Shown are the results for all models for abundance of Red-headed woodpecker observations per plot. The model including only snag density was the best fit. K= number of parameters per model, LL-log likelihood, Delta_AICc= change in AIC score from the top model and Cum.Wt= model weights.

Modnames	K	AICc	Delta_AICc	ModelLik	AICcWt	LL	Cum.Wt
Snag Density	3	182.0573	0.000000	1.000000e+00	9.320273e-01	-86.93774	0.9320273
Prescribed Fire	3	187.2938	5.236513	7.292990e-02	6.797266e-02	-89.55600	1.0000000
Mechanical	3	262.0708	80.013488	4.219799e-18	3.932968e-18	-126.94448	1.0000000
Duff Depth	3	263.5940	81.536668	1.970324e-18	1.836395e-18	-127.70607	1.0000000
Total Management	3	266.3205	84.263199	5.040560e-19	4.697940e-19	-129.06934	1.0000000
Ground cover	3	266.9249	84.867572	3.725984e-19	3.472719e-19	-129.37153	1.0000000
Canopy cover	3	279.2107	97.153385	8.005907e-22	7.461724e-22	-135.51443	1.0000000
NULL	2	280.0142	97.956880	5.357148e-22	4.993009e-22	-137.50709	1.0000000
Chemical	3	281.3268	99.269485	2.779107e-22	2.590203e-22	-136.57248	1.0000000
CWD	3	281.8946	99.837319	2.092193e-22	1.949981e-22	-136.85640	1.0000000

Figure 9- Shown is the relationship between abundance of mammalian observations and CWD at the plot scale. P-value resulted from a Likelihood ratio test, (p-value=0.0017)



Discussion

Given the importance of structure on the function of oak savannas and other early successional habitats, there is a need to understand the effects of changing the structure of a habitat. This is true regardless if the change occurred naturally or by human intervention. In this study I set out to correlate management actions to structural habitat features. I also correlated those structural features to the total abundance of observations. The goal in this study was to inform management of the relationship between wildlife and structure after a management action. I found few significant relationships among variables. Mechanical actions were related to the amount of CWD at the sub-plot scale and to vegetation density at the plot scale. Snag density and duff depth were correlated with total and avian abundance of observations. The number of prescribed fires and mechanical actions were related to total and avian abundance of observations.

KTNP only accounted for 35 percent of the total observations for the survey period due to a few factors. KTNP is a much smaller preserve (~400 hectares) in comparison to OOP (~1500 hectares) and, as I saw with the White-tailed deer in surrounding habitat up to 500 meters away, this smaller size may have an adverse effect on wildlife abundance. KTNP is smaller and more fragmented and borders more farming and residential areas. These natural habitats rarely extend more than 500 meters from human impacted land, so having fewer detections seems likely at KTNP. OOP, on the other hand, has large contiguous expanses of land in comparison to KTNP of relatively undisturbed habitat beyond a few trails. Similar trends were found in other studies for fragmented areas. Certain bird species suffer negative effects from agricultural conversion and fragmentation of natural habitat (Jones *et al..,* 2017). Crooks (2002) found that several mammal species suffered when the landscape became more fragmented. Keep in mind that rare species were sparsely detected during this study and these interpretations largely depend on data from common species. Amphibians and reptiles went relatively undetected and may change these interpretations.

The Nature Conservancy and the Metroparks of the Toledo Area manage their preserves in a similarly. The only differences detected in my study between parks were with total mechanical actions, total management actions, and snag density. Remember only abundance was marginally different between preserves. Since there were detected differences between parks it was necessary to run mixed effects models. I needed to include those random effects of preserve, plot, and sub-plot because they may have had an effect on my results.

Relationship between Management Actions and Structural Features

Mechanical management was an important variable correlated with CWD. Metroparks of the Toledo Area and TNC land management staff remove downed logs after timber thinning or removal operations (Pers comm. Dr. Tim Schetter and Tim Galleher of Metroparks of the Toledo Area and Ryan Gauger of TNC). A decrease in CWD left on the ground in these same areas is expected due to the specific way management practices are carried out at KTNP and OOP.

Increased mechanical management was also correlated with a reduction in vegetation density at both plot and sub-plot scales. Mowing has immediate effects like grass height reduction and latent effects like increased litter accumulation (McCoy *et al.*

2001). Mowing can have different effects over large temporal scales of years as Gusewell, *et al.* (2009) found. They found immediate differences in plant biomass just after mowing (within 4 years of action) (Gusewell, *et al.* 2009). However, they also found these immediate effects weren't evident in the long term or13-14 years later (Gusewell, *et al.* 2009). Even though I detected a decrease in vegetation density that may affect some wildlife negatively, Gusewell *et al.'s* (2009) study points out that these vegetation differences may not persist in the future.

Relationship between Structural Features and Response Variables

The best avian diversity of observation model included canopy cover and mechanical management instances. As both mechanical and canopy cover values increased so did the diversity of avian observations. A study found a link between thinned tree stands and an increase in avian species diversity (DeGraaf *et al.* 1991). Another study found that as canopy cover and canopy height increased so did avian diversity (Hinsley *et al.* 2009). Twedta *et al.* (1999) found a positive relationship between increasing canopy cover and increasing bird species diversity. Tree thinning changes avian species composition in upland savannas (Connor & Dickson 1997). Key characteristics associated with upland forests are sparse trees with a developed grass species assemblage. So mechanical management is one way to remove trees from these ecosystems and would make sense if you were trying to attract savanna species and increase diversity.

Total and avian abundance of observation models were best predicted by the number of prescribed fires at the plot scale. Fires have been correlated with increases in species abundance and diversity (Greenberg *et al.* 2007, Greenberg *et al.* 2007, Greenberg *et al.* 2006). These increases in abundance of observations may be related to snag density. Snags form from fire because the outer bark and layers of tissue in the tree become scarred from the heat of the fire. This allows fungal spores and various arthropods to breach the inner cambium and cause increased rate of decay (Adkins 2006). Prescribed fire has increased snag abundance in other studies (Zarnoch *et al.* 2014). Snags also provide habitat and food for many species since they house many insects within and around themselves (Greenberg *et al.* 2007).

My only species-specific correlation was between abundance of Red-headed woodpecker observations and snag density. In my study as snag density increased so did abundance of Red-headed woodpeckers. Various insects use snags as shelter and are food items which attract woodpeckers and other birds. Avian species abundance has been correlated significantly with the number of snags (Sallabanks *et al.,* 2006). Another study found that snag density and overall tree density positively affects the abundance of woodpecker species (Greenberg 2007). Snags provide both food and shelter for cavity nesting birds and small mammals. Fox squirrels (*Sciurus nayaritensis*) were seen during the study and are known to use snags for shelter and predator evasion on multiple occasions (Edworthy & Martin, 2014), but no direct correlation between the abundance of mammalian observations was found in my study. Snags are critical resources for many woodpecker species as well. Snags contain insects and soft wood to bore shelters for bird nests.

Duff depth was an important factor in building the best total and avian abundance of observation models at the sub-plot scale. Thicker duff has multiple effects on prey abundance and plant health and diversity that could attract wildlife to the area. Karaban *et* *al.* (2017) found that duff depth was only important to caterpillar survival if predators were present as it provided shelter from predation. Predators like birds and small mammals are probably drawn to areas of higher duff depth because insect resources have been found to be more diverse (Christensen & Crumpton, 2010). Larger herbivores like White-tailed Deer may not benefit as much from increases in duff depth since a study conducted by Zou *et al.* (2016) found that higher duff depth was associated with lower plant diversity. So large herbivores could have a less diverse plant selection and possibly move from these areas of low resource diversity (Mandle *et al.* 2015).

One correlation was surprising. In this study I found that increasing CWD correlated with a decrease in the abundance of mammalian observations. This is surprising because most studies find that CWD like downed logs and piles of sticks increase abundance as it gives smaller animals shelter from predation (Grodsky *et al.* 2016, Fritts *et al.* 2017). Thirteen lined ground squirrels are more abundant in areas with CWD like brush piles or CWD (Larsen *et al.* 2016). Southern red-backed vole (*Myodes gapperi*), deer mouse (*Peromyscus maniculatus*), southern bog lemming (*Synaptomys cooperi*) and masked shrew (*Sorex cinereus*) abundance saw an increase with more CWD present (Fauteux *et al.* 2012). It is possible that some wildlife view these logs and stones as barriers to their movement and this may deter them from entering areas of high CWD. Fox squirrels were never detected in unsalvaged plots and only found in plot where CWD was removed (Loeb 1999). Loeb also found mixed responses from other taxa in her study (Loeb 1999). McCay and Komoroski (2004) found mixed effects among various small mammalian species. CWD is an environmental factor that needs further study in various systems, since most results are dependent on decay time, and various spatial scales it is difficult to detect strong correlations between CWD and other variables.

Based on my results and analysis, I came up with a few ideas to improve my study for future efforts. Observations of reptiles and amphibians were less common in my study. I used cover boards in a rotational system with four boards per plot with two being made of wood and the others were carpet. MacNeil & Williams (2013) found that different coverboard materials were better at capturing salamander species. I could have used more boards, assorted colors, or different materials. In Hesed's (2012) review they found that there was a great variation in types of wood used for coverboards and a difference in diversity and detections among those coverboard materials. They also found that arrangement and size of boards is a key factor in predicting the microhabitat that would harbor one species of salamander and not another. My coverboards were large at 60 cm by 60 cm and could have cooled down the environment underneath to a point where ectothermic species would avoid those cool areas (Mathis, 1990). Another problem with my herpetofauna surveying was the lack of cover boards. I had to rotate my twelve coverboards between three sites every two weeks. The first week was for acclimation and the second week I would check these boards three times during that week. If I had enough coverboards for all my sites at one time that would be the best scenario as I could have set out the boards weeks in advance and let them acclimate. One study found that more weathering of the boards has a positive effect on your detection probability of herpetofaunal species (Carlson and Szuch 2007). More field assistants would be needed to be able to check boards over the summer or set drift fences. I would also advocate for more camera traps for the same reasons I stated for my lack of cover boards, to increase the probability of detecting cryptic fauna. In the future incorporating different sampling methods like setting up drift fences may be better. I would change just a few things about my study design as well. I would have more plots per preserve and more preserves. A couple more preserves are in the Oak Openings Region like Secor Metropark and/or Wildwood.

There were several correlations found in this study that are important for the ecological community as a whole and for the Oak Openings Region. The goal of this study was to find relationships between management variables, structural features and abundance of wildlife observations to aid managers in decision making. I found that mechanical management instances are related to structural features. Even outside of this small study area in Northwest Ohio these results are applicable to other systems with similar structural features as seen in the oak savanna study plots. Mechanical management instances were correlated with CWD and vegetation density. I also found correlations between structural features and total abundance of observations. Our mixed effects models showed us that CWD, vegetation density, and snag density were all important for various wildlife taxa. Based on these results, management that alters structure of early successional habitats can enhance the function of these habitats for wildlife.

Management Recommendations

The purpose of this study was to examine the relationships between animal diversity and abundance of observations to structural features that are potentially influenced by management. My results examined how a management action that correlates with a habitat variable can in turn correlate with a measure of wildlife in that area. Avian and mammalian taxa benefited from structural diversity, which can provide a greater variety of resources. Several controllable habitat variables were found correlated with an increase in abundance of observations. Those habitat variables were also related to specific management actions. Based on my findings I would recommend executing management actions targeted to control duff depth, CWD and snag density. Mechanical management actions were the most influential action detected in my study. Understanding and implementing adaptive management plans are necessary to maintain biodiversity now and especially into the future.

REFERENCES

Adkins, Matthew. (2006). A burning issue: using fire to accelerate tree hollow formation in eucalyptus species. *Australian Forestry. 69(2).*

Artman, Vanessa., Sutherland, Elaine., Downhower, Jerry. (2008). Prescribed burning to restore mixed-oak communities in Southern Ohio: effects on breeding-bird populations. *Conservation Biology. 15(5),* 1423-1434.

Baonari, Gianmaria., Fajmon, Karel., Malenovsky, Igor., Zeleny, David., Holusa, Jaroslav., Jongepierova, Ivana., Kocarek, Petr., Konvicka, Ondrej., Uncar, Jan., Chytry, Milan. (2017). Management of semi-natural grasslands benefiting both plant and insect diversity: The importance of heterogeneity and tradition. *Agriculture, Ecosystems & Environment. 246,* 243-252.

Behangana, Mathias., Kasoma, Panta., Luiselli, Luca. (2009). Ecological correlates of species richness and population abundance patterns in amphibian communities from the Albertine Rift, East Africa. *Biodiversity and Conservation. 18*(11), 2855-2873.

Bock, Carl., Jones, Zach., Bock, Jane. (2006). Rodent communities in an ex-urbanizing southwestern landscape (U.S.A.). *Conservation Biology. 20*(4), 1242-1250.

Bolker, Benjamin., Brooks, Mollie., Clark, Connie., Geange, Shane., Poulsen, John., Stevens, Henry., White, Jada-Simone. (2009) Generalized linear mixed models: a practical guide for ecology and evolution. *Trends in Ecology and Evolution. 24(3),* 127-135.

Bruegel, P., Friis, I., Demissew, Sebsebe., Lillesa, Jens-Peter., Kindt, Roeland (2015). Current and future fire regimes and their influence on natural vegetation in Ethiopia. *Ecosystems. 19*(2), 369-386.

Brewer, Lawrence., Vankat, John. (2004). Description of the oak openings of northwestern Ohio at the time of Euro-American settlement. *Ohio Journal of Science. 104*(4), 76-85.

Brys, Rein., Jacquemyn, Hans., Endels, Patrick., De Blust, Geert., Hermy, Martin. (2004). The effects of grassland management on plant performance and demography in the perennial herb *Primula veris. Journal of Applied Ecology. 41,* 1080-1091.

Carlson, Adriane. & Gorchov, David. (2004). Effects of herbicide on the invasives biennial *Alliaria petiolata* (Garlic Mustard) and initial responses of native plants in a Southwestern Ohio forest. *Restoration Ecology. 12(4),* 559-567.

Carlson, T. A. & Szuch, E.J. (2007). Un-weathered (new) artificial cover objects effectively sample plethodontid salamanders in Michigan. *Herpetological Review. 38,* 412-415.

Christensen, Jay, Crumpton, William. (2010). Wetland invertebrate community responses to varying emergent litter in a prairie pothole emergent marsh. *Wetlands. 30(6),* 1031-1043.

Coppoletta, Michelle., Marriam, Kyle., Collins, Brandon. (2016). Post-fire vegetation and fuel development influences fire severity patterns in reburns. *Ecological Applications. 26*(3), 686-699.

Connor, Richard & Dickson, James. (1997). Relationship between bird communities and forest age, structure, species composition, and fragmentation in the West Gulf Coast Plain. *Texas Journal of Science. 49(3),* 123-138.

Crooks, Kevin. (2002). Relative sensitivities of mammalian carnivores to habitat fragmentation. *Conservation Biology. 16(2),* 488-502.

Davies, K.W., Bates, J.D., Nafus, A.M. (2012). Comparing burned and mowed treatments in mountain big sagebrush steppe. *Environmental Management. 50*(30), 451-461.

Defries, Ruth., Foley, Jonathan., Asner, Gregory. (2004). Land-use choices: balancing human needs and ecosystem function. *Frontiers in Ecology and Evolution. 2(5),* 249-257.

DeGraaf, Richard., Healy, William., Brooks, Robert. (1991). Effects of thinning and deer browsing on breeding bird in New England oak woodlands. *Forest Ecology and Management. 41(3-4),* 179-191.

Druille, M., Garcia-Parisi, P.A., Golluscio, R.A., Cavagnaro, F.P., Omacini, M. (2016). Repeated annual glyphosate applications may impair beneficial soil microorganisms in temperate grassland. *Agriculture, Ecosystems & Environment.* 230, 184-190.

Edworthy, Amanda., Martin, Kathy. (2014). Long-term dynamics of the characteristics of tree cavities used for nesting by vertebrates. *Forest Ecology and Management. 334,* 122-128.

Fonatine, Joseph., Kennedy, Patricia. (2012). Meta-analysis of avian and small-mammal response to fire severity and fire surrogate treatments in U.S. fire-prone forests. *Ecological Applications. 22*(5), 1547-1561.

Fritts, Sarah., Moorman, Christopher., Grodosky, Steven., Hazel, Dennis., Homyack, Jessica, Farrell, Christopher., Castleberry, Steven., Evans, Emily., Greene, Daniel. (2017). Rodent response to harvesting woody biomass for bioenergy production. *Journal of Wildlife Management. 81(7),* 1170-1178.

Garcia-Ruiz, Esteban., Loureiro, Inigo., Farinos, Gema., Gomez, Pablo., Gutierrez, Elena., Sanchez, Francisco., Escorial, Maria., Ortego, Felix., Chueca, Maria., Castanera, Pedro. (2018). Weeds and ground-dwelling predators' response to two different weed management systems in plyphosate-tolerant cotton: A farm scale study. *PLOS One. 13(1),* e0191408.

Goffnet, Amanda., Sprague, Christy., Mendoza, Fernando., Cichy, Karen. (2016). Preharvest Herbicide Treatments Affect Black Bean Desiccation, Yield, and Canned Bean Color. *Crop Science.* 56(4), 1962-1969.

Green, Rachel., Iglay, Raymond., Evans, Kristine., Miller, Darren., Wigley, T., Riffell, Sam. (2016) A meta-analysis of biodiversity responses to management of southeastern pine forests-opportunities for open pine conservation. *forest ecology and Management. 360,* 30-39.

Greenberg, Cathryn., Otis, David., Waldrop, Thomas. (2006). Response of White-footed Mice (*Peromyscus leucopus*) to fire and fire surrogate fuel reduction treatments in a southern Appalachian hardwood forest. *Forest Ecology and Management. 234*(1-3), 355-362.

Greenberg, Cathryn., Tomcho, Aimee., Lanham, J., Waldrop, Thomas., Tomcho, Joseph., Phillips, Ross., Simon., Dean. (2007). Short-term effects of fire and other fuel reduction treatments on breeding birds in a southern Appalachian upland hardwood forest. *Journal of Wildlife Management. 71*(6), 1906-1916.

Greenberg, Cathryn., Miller, Stanlee., Waldrop, Thomas. (2007). Short-term response of shrews to prescribed fire and mechanical fuel reduction in a southern Appalachian upland hardwood forest. *Forest Ecology and Management. 243*(2-3), 231-236.

Grodsky, Steven., Moorman, Christopher., Fritts, Sarah., Hazel., Homyack, Jessica., Castleberry, Steven., Wigley, T. (2016). Winter bird use of harvest residues in clear cuts and the implications of forest bioenergy harvest in the southeastern United States. *Forest Ecology and Management. 379,* 91-101.

Gusewell, Sabine., Buttler, Alexandre., Klotzli, Frank. (2009). Short-term and long-term effects of mowing on the vegetation of two calcareous fens. *Journal of Vegetation Science. 9(6),* 861-872.

Hagenah, Nicole., Prins, Herbert., Olff, Han. (2009). Effects of large herbivores on murid rodents in a South African savanna. *Journal of Tropical Ecology. 25*, 483-492.

Hiers, Kevin., O'Brien, Joseph., Will, Rodney., Mitchell, Robert. (2007). Forest floor depth mediates under story vigor in xeric *Pinus palustris* ecosystems. *Ecological Applications. 17*(3), 806-814.

Hinsley, S., Hill, R., Fuller, R. Bellamy, P., Rothery, P. (2009). Brid species distributions across woodland canopy structure gradients. *Community Ecology. 10(1).*

Holoubek, Nathan., Jensen, William. (2015). Avian occupancy with habitat structure in oak savanna of the south-central United States. *The Journal of Wildlife Management.* 79(3), 458-468.

Homyack, Jessica., Haas, Carola., Hopkins, William. (2011). Energetics of surface-active terrestrial salamanders in experimentally harvested forest. *Journal of Wildlife Management. 75*(6), 1267-1278.

Horvath, Gyozo., Herczeg, Robert. (2013). Site occupancy response to natural and anthropogenic disturbances of root vole: Conservation problem of a vulnerable relict subspecies. *Journal of Nature Conservation. 21*(5), 350-358.

Hossack, Blake., Eby, Lisa., Guscio, Gregory., Corn, Paul (2009). Thermal characteristics of amphibian microhabitats in a fire-disturbed landscape. *Forest Ecology and Management. 258*(7), 1414-1421.

Jones, Devin., Hammond, John., Relyea, Rick. (2010). Roundup (R) and amphibians: the importance of concentration, application time, and stratification. *Environmental Toxicology and Chemistry. 29*(9), 2016-2015.

Jones, Clark., Stodala, Kirk., Coombs, Jason., Ward, Michael., Cooper, Robert. (2017). Responses of Bachman's sparrows and prairie warblers to fragmentation. *Journal of Wildlife Management. 81(2),* 347-355.

Karaban, Richard., Grof-Tisza, Patrick., Holyack, Marcel. (2017) Wet years have more caterpillars: interacting roles of plant litter and predation by ants. *Ecology. 98(9),* 2370-2378.

Kettenring, K. M. & C. R. Adams. (2011). Lessons learned from invasive plant control experiments: a systematic review and meta-analysis. *Journal of Applied Ecology 48(4),* 970–979.

Kumar, Raman., Shahabuddin, Ghazala., Kumar, Ajith. (2014). Habitat determinants of woodpecker abundance and species richness in sub-Himalayan dipterocarp forests of north-west India. *Acta Ornithologica. 49*(2), 243-256.

Leach, Mark & Givnish, Thomas. (1999). Gradients in the composition, structure, and diversity of remnant oak savanna in Southern Wisconsin. *Ecological Monographs. 69(3),* 353-374.

Loeb, Susan. (1999). Responses of small mammals to coarse woody debris in a Southeastern pine forest. *Journal of Mammalogy. 80(2),* 460-471.

Luvuno, L. B., Kotze, D.C., Kirkman, K.P. (2016). Long-term landscape changes in vegetation structure: fire management in the wetlands of KwaMbonambi, South Africa. *Africa Journal of Aquatic Science. 41*(3), 279-288.

MacNeil, Jami & Williams, Rod. (2013). Effectiveness of two artificial cover objects in sampling terrestrial salamanders. *Herpetological Conservation and Biology. 8(3),* 552-560.

Mandle, Lisa., Ticktin. Tamara., Zuidema, Pieter. (2015). Resilience of palm populations to disturbance is determined by interactive effects of fire, herbivory, and harvest. *Journal of Ecology. 103,* 1032-1043.

Mathis, A. (1990). Territoriality in a terrestrial salamander: the influence of resource quality and body size. *Behaviour. 112:* 162-175.

McCoy, Timothy., Kurzejeski, Eric., Burger, Loren., Ryan, Mark. (2001). Effects of conservation practice, mowing, and temporal changes on vegetation structure on CRP fields in Northern Missouri. *Wildlife Society Bulletin. 29(3),* 979-987.

Noss, Reed., LaRoe, Edward, Scott, Michael (1995). Endangered Ecosystems of the United States: A status report on America's vanishing habitat and wildlife. Defenders of Wildlife, Washington, DC.

Nuzzo, V. (1986). Extent and status of Midwest oak savanna: pre-settlement and 1985. *Natural Areas Journal. 6,* 6-36.

Pastro, Louise., Dickman, Christopher, Letnic, Mike. (2014). Fire type and hemisphere determine the effects of fire on the alpha and beta diversity of vertebrates: a global meta-analysis. *Global Ecology and Biogeography. 23(10),* 1146-1156.

Pitt, Amber., Tavano, Joseph., Baldwin, Robert., Waldrop, Thomas. (2013). Effects of fuel reduction treatments on movement and habitat use of American toads in a southern Appalachian hardwood forest. *Forest Ecology and Management. 310,* 289-299.

Relyea, Rick. (2009). A cocktail of contaminants: how mixtures of pesticides at low concentrations affect aquatic communities. *Oecologia. 159*(2), 363-376.

Root, Karen. & Martin, Amanda. September 2017. Oak Openings biodiversity model progress report 1 (phase II). Report to the Nature Conservancy for grant #10009843.

Rose, Eli., Simons, Theodore., McKerrow, Alexa. (2016). Normalized burn ratios link fire severity with patterns of avian occurrence. *Landscape Ecology. 31(7),* 1537-1550.

Sallabanks, Rex., Haufler, Jonathan., Mehl, Carolyn. (2006). Influence of forest vegetation structure on avian community composition in West-central Idaho. *Wildlife Society Bulletin. 34*(4), 1079-1093.

Santos, Xavier., Poquet, Jose Manuel. (2010) Ecological succession and habitat attributes affect the postfire response of a Mediterranean reptile community. *European Journal of Wildlife Research. 56*(6), 895-905.

Schetter, Tim., Root, Karen. (2011). Assessing an imperiled oak savanna landscape in northwestern Ohio using Landsat data. *Natural Areas Journal. 31,* 118-130.

Sullivan, Thomas. (1990). Influence of forest herbicide on Deer Mouse and Oregon Vole population dynamics. *Journal of Wildlife Management. 54*(4), 566-576.

Suzuki, N., Hayes, JP. (2003) Effects of thinning on small mammals in Oregon coastal forests. *Journal of Wildlife Management. 67*(2), 352-371.

Tester, John. (1989). Effects of fire frequency on oak savanna in east central Minnesota. *Bulletin of the Torrey Botanical Club. 116(2),* 134-144.

Thompson, Sarah., Arnold, Todd., Fieberg, John., Gransfors, Diane., Vacek, Sara., Palaia, Nick. (2016). Grassland birds demonstrate delayed response to large-scale tree removal in central North America. *Journal of Applied Ecology. 53*(1), 284-294.

Turner, Monica. (1990). Spatial and temporal analysis of landscape patterns. *Landscape Ecology. 4(1),* 21-30.

Twedta, Daniel., Wilsona, R., Henne-Kerrb, Jackie., Hamiltonc, Robert. (1999). Impact of forest type and management strategy avian densities in the Mississippi Alluvial Valley, USA. *Forest Ecology and Management. 123(2-3),* 261-274.

Wegner, Martin., Balgheim, N., Mumme, H., Stibbe, C. Holtschulte, B. (2016). CONVISO ® SMART – an innovative approach to weed control in sugar beet. Sugar industry-zuckerindustrie 141(8), 51-524.

Yarnell, R.W., Scott, D.M., Chimimba, C.T., Metcalfe, D.J. (2007). Untangling the roles of fire, grazing and rainfall on small mammal communities in grassland ecosystems. *Oecologia. 154*(2), 387-402.

Zarnoch, Stanley., Blake, John., Parresol, Benard. (2014). Are prescribed fire and thinning dominant processes affecting snag occurrence at a landscape scale? *Forest Ecology and Management. 331,* 144-152.

APPENDIX A. INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE APPROVAL

DATE: May 9, 2017

TO: Karen Root

FROM: Bowling Green State University Institutional Animal Care and Use Committee

PROJECT TITLE: [1010659-2] Management practices and their effects on vertebrate taxa in an oak savanna ecosystem.

SUBMISSION TYPE: Revision

ACTION: APPROVED

APPROVAL DATE: May 9, 2017

EXPIRATION DATE: May 8, 2020

REVIEW TYPE: Designated Member Review

Thank you for your submission of Revision materials for the above referenced research project. The Bowling Green State University Institutional Animal Care and Use Committee has APPROVED your submission. All research must be conducted in accordance with this approved submission. Please make sure that all members of your research team read the approved version of the protocol.

Report all NON-COMPLIANCE issues regarding this project to this committee.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the Addendum Request form for this procedure.

This project requires Continuing Review by this office on an [review frequency] basis. Please use the Annual Renewal form for this procedure.

If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or orc@bgsu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Institutional Animal Care and Use Committee's records.