MEASURING AVIAN BREEDING DIVERSITY AND NESTING ACTIVITY IN FRAGMENTED PINE PLANTATIONS

Kathryn R. Ware

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Committee:

Karen Root, Advisor

Kevin McCluney

Timothy Schetter

ABSTRACT

Karen Root, Advisor

In the 1930's 194.7 ha of non-native conifers were planted in the Oak Openings Region of Ohio as cash crops. They were not harvested or actively managed, and are now in declining condition. Metroparks Toledo have developed a management plan to clear-cut the pine stands to facilitate restoration to historical oak-dominated ecosystems. This research sought to evaluate the value of several white and red pine stands in supporting avian diversity and productivity. Bird diversity and abundance were estimated in nine sites of similar size (1.3-2.3 ha) with three white pine, three red pine, and three oak forest sites and in one larger intact oak forest site (29.3 ha) using point-count surveys and nest surveys. For each site I estimated structural characteristics, composition, and landscape context. The large oak site had the highest richness and average abundance, followed by small oak, white pine, then red pine. The majority of species found were resident/generalist species (58-65% of the species detected in each site type) and less than five percent of the species were pine-specialists. For nests, large oak had the most nests, followed by white pine, then small oak, and lastly red pine. No pine-specialist species were found nesting in any of my sites, including pine. Site type (red pine, white pine, small oak, or large oak) had significant effects on richness (ANOVA; ($F(3,6)=5.45$, $p=0.04$) ($\alpha=0.1$) and significant effects on abundance (ANOVA, ($F(3,6)=3.73$, $p=0.08$). Larger sites had significantly more species (linear regression; ANOVA; $F=10.58$, $p=0.01$) and greater abundance (linear regression; ANOVA; $F=14.53$, $p=0.01$). For compositional variables, the number of saplings and seedlings had significant negative effects on richness (linear regression; ANOVA; $F=7.70$, $p=0.02$). Lastly, for spatial variables, the amount of wet forest (linear regression; ANOVA; $F=4.07$, $p=0.08$), dry forest (linear regression; ANOVA; $F=5.25$, $p=0.05$), and non-forest area (linear regression;

ANOVA; F=2.46, p=0.16) surrounding a site had significant positive relationships with richness. Based on my results, the effects of the white and red pine plantations in the Oak Openings Region on bird communities are complex and influenced by many factors. This study, though, supports Metroparks Toledo's management plan to clear-cut the red pine stands and manage the white pine stands.

For my mom. I wish you were here and I hope you’re proud. XOXO

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INTRODUCTION

In a 2019 report in *Science* (Rosenberg et al), a staggering decline of North American bird populations was declared with a net loss approaching three billion birds, or 29% of 1970 abundance. "(This) signals an urgent need to address threats to avert future avifaunal collapse and associated loss of ecosystem integrity, function, and services" (p. 120). With about 70% of global terrestrial ecosystems currently altered by human activities (Ellis et al 2013), the influence of management or lack thereof on ecosystem functionality needs to be understood, especially in relation to the native bird communities, to help solve this problem.

Pine plantations are one example of a human-modified ecosystem that is poorly understood in their effects on bird populations. Researchers have found inconsistent results, with effects ranging from positive (Pawson et al., 2010; Archaux and Martin 2009), to negative (Zurita, et al. 2006). While they are generally more popular in the southeastern United States, there are also currently stands of these forest plantations in the Oak Openings Region of Northwest Ohio and Southern Michigan, which is the location of this study. With forest plantations currently covering approximately 200 million ha worldwide (Bremer, Farley 2010) and expectations for them to increase (Paquette and Messier 2010), this further heightens the demand to understand how bird communities are affected. Results from this study will help guide management actions for the pine plantations in Oak Openings Preserve Metropark (OOPMP), potentially increase the quality and quantity of bird habitat in the Oak Openings Region, and increase our understanding of the ecological function of planted non-native forest stands.

Beginning in the 1930s, 194.7 ha of mixed conifers were planted in the Oak Openings Region of Northwest Ohio to be used as future cash crops (Schetter and Gallaher 2019). Species planted included Eastern white pine (*Pinus strobus*), red pine (*Pinus resinosa*), Jack pine (*Pinus banksiana*), and others, which are all non-native to the region. These plantations were not harvested as intended or actively managed, and are now in declining condition. Gradually, these pine plantations are being removed by Metroparks Toledo with the intent to restore the habitat to the historical Oak Openings vegetation (Abella, Schetter, Walters, 2017). While the patches do consist of exotic tree species, there are some past records of nesting birds in these areas (Rodewald, et al. 2016). There have been brief bird surveys in the pine patches in prior years, but there is a need for more intensive breeding surveys to distinguish presence from use, which is the focus of this study. The question of interest is whether these non-native stands are functioning as productive habitat for birds.

OOPMP is part of the Oak Openings Region, which stretches through four counties of northwest Ohio and two counties in southwest Michigan (Green Ribbon Initiative n.d.). The Metropark is about 2,000 ha (5,000 acres) (Schetter and Gallaher 2019), the largest protected area in the region and the most diverse, which makes it ecological valuable. The goal of management is to restore the area to historical ecosystems that occurred before settlers arrived and colonized the region in the mid-1800s, which excludes the pines planted in the 1930s.

The original intent for the pine plantations was to harvest them as cash crops, but that has never happened, and now the sites are deteriorating from lack of active management. Before 2002, there was essentially no management of the pine plantations. But from 2002-2006, 63 ha were thinned or removed. In 2010, a tornado came through the area and removed 22 ha of the pines, leaving 160 ha (Schetter and Gallaher 2019). Currently, these remaining pines are collapsing and in declining condition. In addition to the conservation goals of Metroparks Toledo, the collapsing stands also pose safety concerns to park visitors. Moreover, without management, the stands could naturally succeed into dense maple forests (Schetter and Gallaher 2019), which are not considered part of the historical Oak Openings. Artigas and Boerner (1989) studied a similar forest matrix to the Oak Openings with introduced pine stands within a large hardwood forest. They pointed out that since the species, particularly Red Maple (*Acer rubrum*), that are most abundance during the early successional period are not significant components of the surrounding components of the matrix, they may delay subsequent establishment of other hardwoods by shading or site pre-emption. This may not be desirable bird habitat (Jacobs and Warburton, n.d.).

To build on Artigas' and Boerner's study, Abella, Schetter, and Walters (2017) monitored the transition of pine stands in OOPMP that were clear-cut and compared it to pine stands that were left untouched. The 14-year experiment showed that oak trees only became established on plots where pines were cut and understory native species richness was 34-50% higher in the cut pine stands than in uncut pine stands. Overall, they found that removing the pine plantations "increased plant diversity and cover, benefited conservation-priority native species, (and) stimulated landscape diversity…" (p. 272). This led to a long-term plan of gradually removing each conifer stand and restoring it to oak savanna or oak woodland.

While these results support the removal of the pine stands in Oak Openings, there is still evidence that there are some benefits to exotic tree plantations. Even though tree plantations are viewed by most conservation biologists as biologically impoverished (Perley, 1994, Potton, 1994) compared to the surrounding native forests, plantations can still contribute to diversity. In New Zealand, plantations represent about 20% of New Zealand's total forest area (Pawson et al., 2010). Pawson et. al (2010) found that a total of 118 threatened species have been recorded or observed within exotic forest stands. These threatened species spanned multiple taxa, including reptiles, amphibians, and mammals. Exotic tree plantations in Malaysia have also provided unexpectedly high moth and other invertebrate diversity, given the plantations' diverse understories and structures (Chey, Holloway, Speight, 1997). Plantations can also improve connectivity among forest patches and buffer edges between natural forests and non-forest lands (Hartley, 2002), also seen in the plantations in New Zealand (Norton, 1998).

While examining contributed diversity across multiple taxa is beyond the scope of this study, my focus on birds provides an efficient way to assess the effects on diversity, activity and abundance of a diverse taxa. In addition to the need to study the effects of human-modified landscapes on bird communities, avifauna are also excellent biological indicators of ecosystem functioning. As O'Connell, Jackson, and Brooks (2000) state, "Many birds occupy high trophic levels and may integrate functional disturbance at lower levels (Cody 1981; Sample et al. 1993; Pettersson et al. 1995; Rodewald and James 1996)." Bird community composition also reflects "interspecific dynamics and population trends (Cody 1981)" and many species' distributions are affected by habitat fragmentation or other large-scale habitat structure parameters. Therefore, the condition of bird communities across a given region can reflect the overall "structural, functional, and compositional condition of ecosystems" (O'Connell, Jackson, and Brooks, 2000). More specifically, the Oak Openings Region hosts globally rare ecosystems and provides breeding habitat for species of birds whose populations are in decline. It is one of only six locations in Ohio featuring breeding Blue-headed Vireos (*Vireo solitarius*) and has one of the easternmost breeding populations of Lark Sparrows (*Chondestes grammacus*) (Audubon Society n.d.). The size of the forest fragments also hosts breeding Wood Thrush (*Hylocichla mustelina*), which has suffered a 60-percent drop in population between 1970 and 2014 (American Bird Conservancy 2020).

Since the pines have become incorporated into the habitat matrix for almost 100 years, birds may have adapted to utilize them for critical ecological functions, such as breeding. The important ecological question is do these non-native stands serve a critical ecological function? For example, in a study in eastern Washington (2019), researchers found that removing half of the invasive, yet established, Russian olive (*Elaegnus angustifolia*), which comprised 90% of the woody riparian vegetation, negatively affected occupancy rates for 96% of the recorded breeding bird species and significantly reduced species richness. Stinson and Pejchar (2018) also conducted a systematic literature review to evaluate songbird breeding response to introduced vegetation and found that while 35% of reproductive responses were negative, 31% of responses were positive.

It was initially thought that since the pine plantations could be potential breeding habitat, it was important that they be conserved. Given the species of pines that were planted, the plantations could potentially serve as breeding habitat for boreal forest specialists, such as the White-throated Sparrow (*Zonotrichia albicollis*) and Alder Flycatcher (*Empidonax* alnorum): two birds that are common spring migrants in Northwest Ohio and whose breeding ranges are just out of reach of Oak Openings.

In the United States, pine plantations have been planted all over the country, with most of them being in the southeastern U.S., accounting for 20% of forest cover (Schultz 1997). There has been some research regarding how to best manage these pines for bird communities (Lantschner, Rush, Peyrou, 2008; Owens, Stouffer, Charmberlain, Miller, 2014; Singleton, Sladek, Burger, Munn, 2012), but the pine plantations in OOPMP are severely declining in condition and would require substantial management and restoration efforts to mitigate any potential hazards. Past research has also investigated the effects of invasive vegetation on breeding birds (Valente, et al., 2019), but the Oak Openings Preserve pine plantations are unique as they are simply introduced, rather than actively spreading and crowding out native vegetation.

In this study, I compared avian species richness, abundance and breeding activity across white pine, red pine, and oak forest patches to measure the level of ecosystem functionality of the pine plantations. I am emphasizing richness as "the benefits of biodiversity to ecosystem function are frequently quantified using species richness (Spehn et al. 2005)" (Brophy et al. 2017), but I also measured abundance as it has been hypothesized to be an important driver in experiments studying biodiversity-ecosystem functioning (Hulvey and Zavaleta 2011). Finally, I also included the analysis of breeding activity in order to parse out use of the habitat from presence.

Rather than simply lumping together white and red pine sites as just "pine", I kept this category stratified as the red and white pine sites have structural differences. These structural differences can be analyzed to evaluate if they play a role in the observed richness, abundance, and breeding activity results. Since oak woodland is target habitat for the pine restoration plan, I also compared the species, richness, and breeding activity between several pine plantations with several similar-sized oak forest sites. The purpose of this comparison was to understand if bird diversity in the white pine or red pine stands was less than, more than, or equal to the diversity in the oak forest sites. If there were different bird species using the oak forest sites compared to the pine sites, then it could be inferred that there may be a preference for coniferous over deciduous trees. A preference could also be inferred if there is no activity in the pine sites, but activity in the oak sites. Finally, if there was no difference, and the oak and pine sites were being used by the same species of birds, then it could be inferred that there is no preference.

A direct comparison can be made between similar-sized oak and pine sites, but it is a possible that these sites are too small to sustain increased richness, diversity, or breeding regardless of dominant tree species, due to territory sizes. The pine sites in my research were approximately 1-2 ha each. Using MacArthur and Wilson's (1967) biogeography theory, it is expected that the number of forest bird species should decrease with decreasing patch size and increasing isolation. Additionally, for forest-interior specialist species, a certain amount of core to edge habitat is required to sustain breeding territories. Some of these species, including the Acadian Flycatcher (*Empidonax virescens*), Wood Thrush, and Hooded Warbler (*Setophaga citrina*), are generally categorized as being area sensitive and require large (>150 ha) contiguous tracts of forest for breeding (Therres 1992). Further, Robbins et al. (1989) found the highest probability of breeding by area sensitive species in forests that were >3,000 ha in size, and that there were few species that could be supported in forests that were <10 ha. To accommodate for this possibility in my research, I surveyed breeding birds in a large, contiguous oak forest site (29.3 ha).

Each site I chose for this study also had varying surrounding habitat. As stated by Estades and Temple (1999), "Avian communities in forested landscapes composed of high-quality forest fragments embedded in a lower-quality forest matrix are not well studied" (p. 574). This is the kind of fragmentation that characterizes the pine sites I have chosen, since each pine site is embedded in a larger forested habitat. McGarigal and McComb (1995) did not find any significant negative effects of this type of fragmentation on avian communities in the western United States, but Enoksson et al. (1995) did find that isolation of hardwood forest patches reduced the occurrence of some bird species with restricted dispersal capabilities. In Estades' and Temple's fragmentation study (1999) in Chile, they found that the type of vegetation adjacent to forest fragments had a significant effect on the composition of the bird community inhabiting them. I incorporated an analysis of the landscape context of each site to explore this issue.

Overall, I expected there to be lower species richness, abundance, and breeding activity in the pine sites, a moderate richness, abundance, and breeding activity in the small oak sites, and higher richness, abundance, and breeding activity in the large oak site. I also expected that as the amount of continuous forest increased around each patch, the richness, abundance, and activity would also increase.

The Oak Openings Region provides unique habitat for birds, which is becoming increasingly important as millions of acres of bird habitat are lost or degraded every year due to conversion to farmland, urban development, or forestry practices (U.S. Fish and Wildlife Service, 2021). The goal of this study is to add to the understanding of optimizing ecosystem function and therefore adding quality habitat for birds.

MATERIALS AND METHODS

Study Sites

All of my data collection took place in a total of ten survey sites in OOPMP. The three white pine sites averaged 1.34 ha and the three red pine sites averaged 1.37 ha in size. The three small oak sites averaged 1.72 ha, and my large contiguous oak forest site was 29.31 ha in size. These sites and their individual sizes can be viewed in Table 1. A map of my sites in OOPMP is shown in Figure 1.

For my point-count surveys, each of the small sites, including pine and oak forest, were assigned one point in the center of the sites, allowing for a 40-m radius circle around each point, while still remaining within the boundaries of the site. For the large oak forest site, there were 29 individual points, each allowing for a 40-m radius circle to surround that point, without intersecting with any other points. These survey points are shown in Figure 2.

Point-Count Surveys

I surveyed birds at each survey point with an audio and visual point-count survey. Point-counts follow the survey protocol established by the Black Swamp Bird Observatory (Shieldcastle 2018). At each point, I stood for five minutes, and recorded any bird heard or seen. I recorded the species and the number of individuals of that species observed. Each individual was recorded as either within the 40-m radius circle surrounding the point, and thus within the small sites, or outside of it. Flyovers were also recorded.

Each individual was also charted in a diagram of the study site to indicate its general location. This allowed me to make comparisons among each point-count to determine any possible territories. If the same species of bird was continuously singing, calling, or was spotted at similar locations each week, then this area possibly consisted of its mating territory. This information was indicative of breeding behavior and was later used to help find nests. Finally, I marked down any behaviors that were possibly indicative of breeding. Such behaviors included a bird carrying nesting material or fecal sacs in its bill, as these are also indicative of nesting. In addition to bird identity, behavior, and location, I also recorded the identity of the surveyor, the start and stop times of the survey, and basic weather data for each survey period, including cloud cover, temperature, wind speed, and humidity. The form used for my point-count surveys is shown in Figure 3.

I started the point-count surveys on May 20, 2021, and concluded the surveys on July 18, 2021. The surveys began later in May so as to limit the number of individuals counted that are simply migrating through the area in the spring. My goal was to time my surveys to include birds that breed in the summer in the region, as well as year-round residents, to better describe ecosystem functionality. Migratory stopover habitat is comprised of different habitat characteristics not the focus of this study. The timing of the conclusion of my surveys results from similar reasoning as the spring. Each point was surveyed about once a week. This amount of time allowed for any changes of species and individuals in the habitat, including the initiation of breeding behavior or nest-building, while not being too repetitive or intrusive.

I started my point-count surveys thirty minutes after sunrise for sufficient visibility, but still early enough for peak activity and for detection of calls and songs. I ended my surveys no later than 10:30am, as activity significantly decreases past this time. I did not conduct surveys if it was raining heavily as this would also impact the amount of activity. Because of the time required for the point-count surveys, Karen Menard, the Monitoring and Research Supervisor with Metroparks Toledo, kindly assisted me by performing the surveys at several of my points in the large contiguous oak site. I also constructed rarefaction curves to see if sampling was sufficient.

To better understand the bird community species composition in each site, I categorized each species in to one of four categories: resident/generalist species, resident/ woodland-specialist species, probable migrant species, and pine-specialist species. Each species detected was classified by these identities based on life history. “Resident/Generalist Species” refers to birds that either reside in the area year round or migrate to the area in the spring, breed, and then migrate out of the area in the fall, and are generalists. “Resident/Woodland-Specialist Species” is similar to resident/generalists, but are woodland-specialists. “Probable Migrant Species” are birds that are likely just using the area as a stopover point during their migration as this area is not included in their documented breeding range. Finally, “Pine-Specialist Species” refers to species that have a documented breeding range in this area, but are pine-specialists. It should also be noted that Blue-headed Vireo is not exclusively a pine-specialist species, as it also breeds in deciduous forests (Holmes and Robinson, 1981). However, for the purpose of this study, I considered it a pine-specialist.

Nest Surveys

While the point-count surveys characterized presence at each site, nest surveys characterized use of the site. These surveys distinguished if a bird was simply passing through a site, or if it was using it to nest. I located the nests through opportunistic sampling. If I saw a bird carrying nesting material, food items, or a fecal sac, I followed the bird back to the nest. When possible, I viewed the nest with binoculars in order to cause the least amount of disturbance. For the majority of nests, I was able to record its general existence and location. I followed through with each nest that I found in order to observe if it was used, but due to time constraints and in the interest in collecting data on more individuals, I was not able to collect more specific data for every nest, such as success rates. Time constraints prevented me from revisiting some individuals that displayed breeding behavior, so these instances were noted, and these individuals were marked as "probable" breeders in a given site, rather than confirmed. Only nests with identifiable species were included. Any failed nests were also noted; these were nests that I saw that were started, but were abandoned during or after construction.

Structural Characteristics

To evaluate the structural differences between the pine, small oak, and large oak sites, I measured clutter, qualitative clutter, and canopy cover. For each site, I measured vertical clutter using a clutter board that is 6.5 m by 0.5 m. The clutter board is a long strip of cloth that is divided into squares. Those squares are counted to determine the "percentage of clutter," and was ultimately used to facilitate the estimation of obstruction of vegetation at various heights. The clutter board was placed vertically 20 m away from the central point (also used for the point-count) at north, east, south, and west directions. The percentage of clutter calculated at each cardinal direction was then averaged for the entire site. A picture of how a clutter board was placed is shown in Figure 4. For each of the small sites, this was done once, using the central point that was used for the point-count surveys. For the large oak site, this was done five times, spread evenly throughout the site.

I also rated the amount of clutter for the understory (0-6 m), middlestory (6-12 m), and upperstory (12 m and above) on a scale of 1 to 10, 1 representing the least cluttered and 10 representing the most cluttered. This qualitative clutter measurement, though limited, provided an additional way to relate the structure of all my sites, as well as above the 6.5-m clutter board limit. Examples from my sites of my qualitative clutter scale can be viewed in Figure 5.

Canopy cover was also measured at each point where the clutter board was used. For each canopy cover measurement point, I took a picture up towards the canopy from 1 m above the ground using my cell phone oriented parallel to the ground. Using the program ImageJ, I converted the images to black (branches, leaves, etc.) and white (sky), and used the program to calculate the percentage of black pixels, which indicated canopy cover. All of these measurements were also done once in the small sites and five times for the large oak site.

Compositional Characteristics

I conducted vegetation surveys and examined a number of environmental characteristics to compare the composition among my sites. In the small sites, I picked one point at random that appeared to be an adequate representation of the whole site based on a brief visual survey. These points were closer to the center of the site than the edge, so as not to sample edge habitat. In the large site, similarly to the structural characteristics measurements, this was done in 5 different spots. This environmental sampling point was different from the survey point used for the point-count surveys. I measured a circle with 5-m radius around the environmental sampling point. In that circle, I recorded each piece of vegetation, and the species when possible. For trees, I identified the species as specifically as I could and I measured the diameter at breast height (DBH) in cm.

The tree was considered a sapling if the plant was a tree species and had a DBH of 2.54-12.7 cm and a seedling if it had a DBH of 2.54 cm or less. It was considered a tree if it had a DBH of over 12.7 cm. It was considered an herbaceous plant if it was not a tree species. For trees, saplings, and seedlings, the number of each identifiable species were counted, and the DBH taken for each. Given the limited number of saplings found, the total number of saplings and seedlings were combined for the results. The numbers of the herbaceous plants were also counted and the species identified when possible. For the O613 site, the method used for the results was the same as the method used for the site structure results: 5 total points were measured to better evaluate this much large site, and then averaged.

Spatial Characteristics

One variable that I took into consideration while choosing sites was the surrounding habitat of each type. As each of the pine sites are situated in a larger forest matrix, I wanted to understand if there were any influences from the surrounding habitat types. I quantified the surrounding habitats using ArcMap and a land cover map (Martin and Root 2020). A 200-m buffer was drawn around the outside edges of the polygon (site). The width of the buffer remained the same, but varied in circumference based on the shape and size of the site, in order to account for site size. Land cover richness was calculated as the number of habitat types found in the buffer surrounding each site. The number of patches of each habitat type was also counted and the relative percentages of each type were calculated. Land cover types were classified as forest or non-forest, and the forest types were further classified as either wet forest, like floodplain or swamp forest, or dry forest, like upland deciduous forest or upland coniferous forest.

Statistical Analysis

My goal was to assess if different structural, compositional, or spatial traits influenced bird communities. For the majority of my results, I tested for two main dependent variables: these were species richness (total number of species detected) and average abundance (average number of individuals found on a single point-count survey). I did not include breeding activity (total number of nests and probable breeders found) as a dependent variable in my statistical analyses due to small sample sizes. As the large contiguous oak site was the largest out of the ten sites, weighted averages for abundances were used for the purpose of comparison. Each small site had one single point for point-count surveys, situated in the middle of the site, with a 40-m radius circle surrounding it. In O613 (the large oak site), 29 of these points were able to fit inside the entire site with no overlap. The average abundance result for each of the other nine sites was 1/29 of its value for the purpose of a weighted average of abundance. All average abundance results are in this weighted form.

Since there was some potential overlap among my structural variables, I ran Spearman Correlation tests to determine if any of the variables could be eliminated for the purpose of analysis. Since understory clutter, middlestory clutter, and upperstory clutter were the least correlated variables, these were used for analysis going forward. This selection procedure eliminated the use of canopy cover percentage and clutter percentages. A Spearman Correlation test was also used for the variables used in the spatial analysis. Based on the results, dry forest area and non-forest area were eliminated as they were closely correlated to dry forest percentage and non-forest percentage, respectively. Land cover richness and number of patches were also closely correlated, eliminating number of patches. This made land cover richness, number of forest and non-forest patches, wet forest area and wet forest percentage, dry forest and non-forest areas the variables that were used for analysis.

The two main statistical tests I used for my data was one-way Analysis of Variance (ANOVA) and simple linear regression. For any of my count data to fit the assumptions of these tests, I transformed all count data with either a log, log(x+1), or reciprocal transformation. Transforming count data, especially with a log transformation, in order to use parametric testing is often used in ecological research (O'Hara and Kotze, 2010; Gebeyehu and Samways, 2002; Magura, Tóthmérész, and Elek, 2005; Cuesta, et al., 2008). I used one-way ANOVA tests to identify any significant relationships between average abundance and richness and my categorical variables (site type, under, middle, and upperstory clutter). I transformed my richness data with a log transformation and my abundance data with a reciprocal transformation to achieve normality. To test if the assumption of equal variances was met, I used Bartlett's test. For the tests involving site type, O613 was treated as a whole, and four types of sites were run in the ANOVAs: red pine, white pine, small oak, and large oak as a whole. For the remaining ANOVAs, O613 was broken down into five previously mentioned sections, rather than averaged. This accounted for the varying microhabitat types as well as increased the sample size. The richness and abundance values were totaled and averaged each of the five sections. For example, for the section designated as O613-7, six of the bird survey points that were situated in that section were included, with the total richness added together and the abundance averaged for those six points. As I was limited to small sample sizes in my study, $\alpha=0.1$ is being used to measure significance (Mudge, Baker, Edge, Houlahan, 2012). If a significant result was calculated from the ANOVA, a Tukey-Kramer HSD test was used for multiple comparisons.

To identify any relationships between my continuous variables and richness and abundance, I used simple linear regression, with ANOVAs used to test for significance. The independent variables used for these linear regressions were site size in ha, total number of trees, samplings and seedlings, and herbaceous plants, and the spatial analysis variables. For site size and the spatial analysis, the large oak site, O613's richness and abundance values were averaged for the site as a whole. Since O613's richness and abundance values were outliers, linear regressions were run with and without these values. For the compositional variables, O613 was treated as the previously mentioned five individual sections. Total number of trees was treated with a log transformation and number of saplings and seedlings and number of herbaceous plants with a log(x+1) transformation. Similarly for several of the spatial variables, log transformations were done land cover richness and number of forest and non-forest patches. O613 had a larger buffer relative to the site size, so several of the linear regression tests for the spatial analysis were also run with and without O613. For all of the simple linear regressions, except for one set, the assumption of homogeneity was met by visually inspecting the residual by predicted plots. The exception was the tests of log(forest patches) versus log(richness) and reciprocal(abundance). This was due to the number of forest patches being the same for all sites except for one. These tests were not included in the results.

RESULTS

As the large contiguous oak forest site was the largest of all of my sites, it was expected that it would have the highest total species richness, average abundance, and total nests found. I expected the small oak sites to have the next highest results, followed by the white pine sites, and with the red pine sites having the lowest results. The majority of these expectations held true. The only difference was in the numbers of nests found: white pine sites had more nests than the small oak sites. These results can be viewed in Table 2, with each of the sites grouped into their respective types. The large oak site had the highest richness (59 species) and average abundance (5.1 species/survey). Small oak had the next highest richness (15.3) and abundance (0.28), followed by white pine (12.7 and 0.19, respectively), then red pine (8.3 and 0.18, respectively). For nests and probable breeders, large oak had the most (21), followed by white pine (5), then small oak (3), and lastly red pine (1). In Table 3, the results are listed for each individual site, rather than grouped by site type. The five sections that were used to split up O613 are also listed in this table, with their respective richness and abundance results. The number of nests and probable breeders were not counted for these sections, but as O613 as a whole, and thus are not included.

Species Results

For the point-count surveys, rarefaction curves were constructed for each site, including O613 as a whole, to gauge sufficiency of sampling. These curves are pictured in Figure 6. Each rarefaction curve approaches an asymptote, but additional sampling would better represent the full diversity of each site. Additional surveys throughout this study also identified other species that were not represented in the point-count surveys. I believe, however, that the trends identified are strong and still likely to hold even with additional sampling.

My results show the largest number of species was generally found in the oak sites, followed by the white pine and red pine sites (Table 3). As previously mentioned, each species of bird detected in the point-count surveys was categorized in one of four identities. Table 4 lists gives the breakdown of these different identities. Table 5 lists which species were found in each site and the scientific names for each species can be found in Table 6.

The type of species that were detected varied within and across the sites. The majority of the species found in all of the sites were resident/generalist species (58-65% of the species detected in each site type). Less than five percent of the species were pine-specialists and the greatest proportion of pine specialists were found in the red pine sites (10.5% of the species detected), followed by the white pine sites (4.2% of species detected) with none found in the oak sites, see Figure 7 and its corresponding table, Table 7. Figure 7 shows the breakdown of the total species richness into these identity categories and illustrates the differences among the sites. It is notable that the pine sites are dominated by generalist species, not pine specialist species. A proportion of the species found in the pine sites were forest specialist species (33% and 21% for white and red pine, respectively). This is important as each of my pine sites were embedded in a larger forest matrix (see the section on Spatial Results), and forest specialists may be present because they are inhabiting the forests surrounding the pine plantations.

Nest/Breeding Results

The total number of nests and probable breeders found in each site are displayed in Table 8 and ranged from 0 to 3 in the smaller sites, and 21 in the large oak site. This table also includes any nests that failed, which were both in pine sites. The large oak site had the most breeding activity, followed by white pine, then small oak, and finally red pine. No pine specialist species were found nesting in any of my sites, including pine.

Structural Results

Table 9 lists the structural results of each site, with O613 split up into five sections. It also includes the measurements that were excluded due to high correlation coefficients. The measurements listed in the table are average percentage of canopy cover, average percentage of clutter 0-3m, average percentage of clutter 3-6.5m, understory clutter, middlestory clutter, and upperstory clutter. The highest amount of canopy cover was found in the oak sites, followed by white pine and red pine. The white pine sites had noticeably higher clutter values at both the 0-3 m and 3-6.5 m heights, followed by the oak sites. The red pine sites had noticeably less clutter than white pine and oak. While the middlestory clutter was similar across the sites, the white pine sites had the highest understory and upperstory clutter. The oak sites had the second and third highest understory clutter but the second and fourth highest upperstory clutter; the red pine sites had higher upperstory clutter than the oak sites.

For the one-way ANOVA tests, all of the tests satisfied the assumption of equal variance based on Bartlett's test results. Two relationships were statistically significant ($\alpha=0.1$). For the test of site type versus log(richness), there was a statistically significant difference between groups ($F(3,6)=5.45$, $p=0.04$). A Tukey post-hoc test found that the mean value of log(richness) was significantly different between large oak and red pine ($p=0.03$, 90% CI=0.28, 3.95) and large oak and white pine ($p=0.09$, 90% CI=-0.27, 3.39. For the test of site type versus reciprocal(abundance), there was also a statistically significant difference between groups ($F(3,6)=3.73$, $p=0.08$). From the Tukey HSD test, the mean value of reciprocal(abundance) was significantly different between large oak and red pine ($p=0.07$, 90% CI=-0.19, 4.32) and large oak and white pine ($p=0.08$, 90% CI=-0.25, 4.26). No other relationships were statistically significant. A complete table of these results can be seen in Table 10. Graphs of the significant results (site type versus richness and abundance) are included in Figure 8.

Site size was the only structural variable that required simple linear regression tests. This showed a significant positive relationship between site size and log(richness) when O613 was included (ANOVA; F=10.58, p=0.01). The slope coefficient was 0.06, so the log(richness) of a site increases by 0.06 for each additional ha added to the site size. The R^2 value was 0.57, so 57% of the variation in richness can be explained by the model containing only site size. Site size and reciprocal(abundance) also had a significant relationship when O613 was included (ANOVA; F=14.53, p=0.01), with a slope coefficient of 0.07 and an R^2 value of 0.64. Tables of these results can be seen in Table 11 and a graph including the regression line is in Figure 9.

Compositional Results

Table 12 lists the compositional results for each site, with O613 again split up into its five sections. The compositional traits included in the table are the total number of trees, total number of saplings and seedlings combined, and the total number of herbaceous plants. All four types of sites had similar numbers of trees, but varied in the numbers of saplings and seedlings and herbaceous plants. The white pine and red pine sites had the highest numbers of saplings and seedlings, followed by small oak, and lastly the large oak sites, which had trace numbers. The small oak sites had the most numbers of herbaceous plants, then red pine, white pine, and large oak.

For the compositional simple linear regressions, a statistically significant relationship was found between the log(number of saplings and seedlings) and log(richness) (ANOVA; F=7.70, p=0.02). The slope was -0.23 and the R^2 value was 0.39, meaning that the log(richness) decreases by 0.23 for every increase in the log(number of saplings and seedlings), and the model containing only the number of saplings and seedlings explains 39% of the variation in richness. No other relationships were significant. These results are included in Table 13 and the graph of log(richness) versus log(number of saplings and seedlings) is in Figure 10.

Spatial Results

Table 14 lists the results of the spatial analysis of my study sites. For each site, the type of site is listed, as well as the area in ha included in the buffer, the number of different habitat patches calculated within the buffer, and the land cover richness. This table also includes the number of forest and non-forest patches, wet forest and dry forest area and their percentages, and non-forest area and its percentages. As the large oak site had the largest relative buffer size (99.1 ha), it also had the highest number of patches within the buffer (160). The red pine sites had the next highest number of patches, followed by the small oak sites, and the white pine sites. The large oak site had the highest land cover richness (10), then the small oak sites, then the red and white pine sites. All of the sites had similar, if not the same, numbers of forest patches, and similar numbers of non-forest patches. Again, since the large oak site had the highest buffer area, it also had the highest area of wet forest, dry forest, and non-forest. For wet forest area and wet forest percentage, the small oak sites had the highest amounts, then white pine, then red pine. The large oak site had the smallest percentage of wet forest, but had the highest percentage of dry forest. Red pine had the second highest area and percentage of dry forest, then white pine, then small oak. Finally for non-forest area, red pine had the second highest, but the highest non-forest percentages, the small oak sites had the third highest non-forest area, and the third highest non-forest percentage, and the white pine sites had the least amount of non-forest area, and the lowest non-forest percentage. The large oak site had the second highest percentage of non-forest area.

For the spatial simple linear regressions, three significant relationships were found. These were log(richness) and wet forest area (ANOVA; F=4.07, p=0.08; slope=0.08, R^2=0.34), log(richness) and dry forest area with O613 included (ANOVA; F=5.25, p=0.05; slope=0.04, R^2=0.40), and log(richness) and non-forest area with O613 included (ANOVA; F=2.46, p=0.16; slope=0.05, R^2=0.44). In separate models, as wet forest area, dry forest area, and non-forest area increases, the log(richness) also increases. No other significant relationships were found. These results are found in Table 15 and correspond with the graph in Figure 11.

DISCUSSION

The purpose of this study was to understand the functionality of the pine plantations in Oak Openings Metropark through the lens of bird communities, specifically through abundance, richness, and breeding activity. I compared all of my structural, compositional, and spatial characteristics to abundance, richness, and breeding activity for several reasons. Species richness, or the number of species present, is a measure of biodiversity, which is a high-priority goal for conservation. However, species richness itself does not speak to the viability of these species, which is the purpose of including abundance measures. The abundance data I collected reinforces our understanding of the richness data and helps us to better interpret the results beyond sheer presence of a particular species. Species richness indicates presence while abundance can reveal how individuals are using the habitat, but these two measures alone do not answer my question of ecosystem functionality. This is why I also measured breeding and nesting activity, which provides additional information of how species are using the study sites. My results showed that neither the red nor white pine stands were functional for pine-specialist birds, and support Metroparks Toledo's management plan of clear-cutting the stands to incorporate them into a broader forest matrix.

This question was first raised because the pine plantations have been an historical feature of Oak Openings Metropark, and through Metroparks Toledo's effort to educate the public on the pines' removal, word of this removal spread. One species of interest that bird-watchers raced to defend was the Pine Warbler (*Setophaga pinus*). In the first Ohio Breeding Bird Atlas survey (1987), the few reports of breeding populations of Pine Warblers were in the Oak Openings-Maumee State Forest area and few records in northeast Ohio as well (p. 290). Most of the records were from glaciated Ohio along the Allegheny Plateau in southern Ohio. This small one or two breeding populations of Pine Warblers could in and of itself speak to a possible sink dynamic, where the population is not large enough to sustain itself. Nonetheless, they are consistently listed as a highlight of the Oak Openings by multiple birding organizations. It is also important to note that even today, not much is known about the Pine Warbler's life history, given its nesting biology. This species nests high in pine trees making nests difficult to find and observe, and as a result, it is "one of the more understudied North American wood-warblers" (Rodewald, Withgott, and Smith 2020). My results suggest that pine specialists are rare in these forests even within the pine sites themselves (less than 10% of species detected) and no nesting activity was detected for these species. In fact, the majority of the species that were detected in any of the sites were residential/generalist species followed by resident forest specialists.

At the time of the first Ohio Breeding Bird Atlas survey in the 1980s, these pine plantations may have been viable habitat for pine-specialists and other species of birds. In other parts of the world, tree plantations are important resources. For example, between 1990 and 2015, there was a 6% decline in the global area of natural forest, but the implementation of forest plantations were able to offset that total forest loss by half (Keenen et al., 2015). However, the pine stands planted in the Oak Openings were not meant to be sustained, as they were planted to be harvested to generate park revenue, and thus have not been managed. For most red pine forests, spacing is typically different and more open than what is seen in the Oak Openings, fires naturally open the canopy allowing for the natural seedbed to be exposed, and variable density thinning is regularly done to increase the habitat value (USDA Forest Service, n.d.). For white pine forests, pure stands of natural white pine are rare, as they are commonly found in mixtures with other species, allowing for a suite of vegetative species to grow. White pine is also more intermediate in shade tolerance, and more white pine trees can grow and "clutter" the space under the main canopy. Additionally, White pine are capable of outgrowing hardwood competition where the soil has a high proportion of sand (Martin and Lorimer, 1997), which is one trait for which the Oak Openings Region is famous. These differences in life history between red pine and white pine are seen in the structure results of my sites: white pine generally had lower qualitative clutter than the red pine sites. White pine also had more herbaceous plants and more saplings and seedlings than red pine, adding to that clutter (Table 9).

Structure

Site size had significant positive relationship to species richness and abundance. This was not a surprising result, as different species of birds have varying territory sizes. While I did find a Pine Warbler in four of my pine sites, I only came across these individuals once, and they were all identified as males. As noted before about the lack of information on the Pine Warbler's life history, not much is known about their territory size, but 1.0 ha seems typical (Howe 1979). Conversely, in the first Ohio Breeding Bird Atlas (1987), in Ohio, most of the breeding pairs were found in sizeable wooded tracts exceeding 40 ha, and a good portion found in 10 ha or more. These conflicting territory sizes could be due to habitat quality; 1.0 ha might be a sustainable territory size if the pine resources are high quality and plentiful (like in Northern Minnesota where the previously cited study was done), but as the pine plantations in Oak Openings are not as high quality, then it could take a larger area to sustain a breeding pair.

My results regarding site size and its effect on richness and abundance is what is likely to be the primary reason as to why the large contiguous oak forest site (O613) had much more breeding activity, with 21 total nests and probable breeders found. In the literature, site size is consistently a driving factor of bird community composition (Dale, 2019; Lehnen and Rodewald, 2009). Specifically in Durban, South Africa, in a study of a similar forest matrix (2020) to my study area, Maseko et al. (2020) found that an increase in patch size did significantly increase species richness, and emphasized “the importance of large forest fragments/patches for the conservation of forest birds and for maintaining ecosystem functioning” (p. 533).

O613’s larger size also allowed for a wide variety of micro-habitat types, with more diversity in vegetation and structure. On a broader scale, O613 could be considered a mixed-stage forest, which has been shown to be the most desirable for terrestrial birds. Mixed-staged forests are important for post-fledgling birds, or the period between hatching and migration. During this period, birds are developing mobility and foraging skills and are susceptible to starvation and predation (King et al, 2006), and seek out the structure that early-stage successional forests provide, after hatching in a mature-stage forest structure (Chandler, King, and Chandler, 2012).In my large contiguous oak forest site, I made several notable breeding bird discoveries: including Red-shouldered Hawk (*Buteo lineatus*), and Northern Waterthrush (*Parkesia noveboracensis*). During my study season, I found one Red-shouldered Hawk nest with two chicks. This was of interest because it is one of the few nests that have been documented past a certain boundary in OOPMP (unpublished data).

The Northern Waterthrush is a large terrestrial wood warbler has a documented breeding range in southern Ohio, along the Allegheny Plateau, and had not before been documented in northern Ohio. This particular oak forest “hosts transitions from typical closed canopy standard deciduous forest dominated by oak trees to an open woodland or savanna dominated by ferns and other shrubs, with fewer trees” (Ware, 2020). It also contains a small stream that runs throughout Oak Openings Metropark that had significant fern cover along portions of the stream. Combined with the resources the stream provides, this was perfect habitat for a Northern Waterthrush, and I was able to discover the first nesting record in this part of the state. The mixture of habitat features required for this particular species is unique, and not found in other parts of the metropark.

Composition

For my compositional variables, only one result has a significant relationship: the number of saplings and seedlings negatively affected richness. Saplings and seedlings contribute to clutter in habitat, which can crowd out different guilds of birds. This is an interesting result considering none of my results regarding qualitative clutter were significant, however, the number of saplings and seedlings only explain 39% of the variation in richness. Other significant results, or higher R^2 values, may not be detectable due to the small sample size. There are also other compositional factors that could be driving bird communities that were not included in this study. One such factor could be potential food resources. Pine Warblers feed on conifer seeds in addition to insects. An analysis on seed availability in the pine plantations would be useful here; since the pine trees have not been selectively thinned, the majority of the branches are not living, thus it can be inferred that fewer seeds are being produced, limiting potential food resources. Other important plants providing berries or other seeds in all of my sites could also be useful for other bird species.

The importance of composition in this particular study could also be reflected in the species present. Since generalist species were the majority of species found in my sites, the effect of composition might be lower. In a study in Mediterranean forests (Gil-Tena, Saura, and Brotons, 2007), researchers found that structure plays a more important role in generalist species richness than composition.

Space/Surrounding Habitat

Several significant relationships between my spatial variables and richness and abundance were found, including the amount of wet forest area (ANOVA; F=4.07, p=0.08) and dry forest area (ANOVA; F=4.07, p=0.08), positively affecting richness. This supports my hypothesis that the surrounding habitat types influences the species composition of my sites. All of my sites, except for two red pine sites had a type of forest dominating the surrounding habitats. While RP7 and RP16A were the exceptions, types of forest were still surrounding the sites to an extent (just not the majority). Since forest-specialist species and generalist species made up the majority of the species found in my sites, it is possible that these birds are leaking in from the surrounding forests, especially since my study site sizes were so small.

The amount of non-forest area also positively affected richness, but by a small amount. The non-forest area result can be intuitively conflicting, but it is important to remember that in the Oak Openings Region, non-forested area includes more than just buildings, roads, or parking lots, but many other potential bird habitats, like prairies and wetlands. The significant relationship between an increase in non-forest area and richness just demonstrates the importance of heterogeneity; simply having a type of forest in a region will not maximize bird species richness. This further emphasizes the importance of viewing the Oak Openings Region as a fragmented landscape of many different native ecosystems in a human-dominated matrix (Martin and Root 2020).

Conclusion

The results of my study show that the question of ecosystem functionality of the pine plantations is complex, given that site type had a significant relationship with richness (F(3,6)=5.45, p=0.04) and abundance (F(3,6)=3.73, p=0.08). Even though I measured the white pine and red pine sites separately, as I was beginning to interpret my results, I was considering the question of whether or not pine plantations as whole were functional for bird communities. The differences in structure, and species richness and abundance between the red and white pine stands shows this is more complex, and this must be taken into account when developing management plans. The increased clutter amounts for the white pine stands means that there is a chance they can still be managed for birds, since more vegetation is able to grow other than white pine trees. My red pine sites had very limited vegetation and activity, so it could be in the birds' best interests to clear-cut them. In addition, the surrounding habitat influenced the species richness of these sites and should also be considered when evaluating management options.

My results had mixed levels of significance and did not always meet my hypotheses. For example, I expected that the amount of qualitative clutter would significantly impact richness and abundance but my results did not support this. This leaves some interesting questions unanswered and points to some future research directions. In addition to potential food resources as previously mentioned, some other variables could prove useful in further exploring ecosystem functionality, such variables could include limiting my study to a single guild of species (e.g., cavity-nesters, insectivores, etc.) or more intensively surveying for nesting pine-specialist birds. It would also be beneficial to explore if the white pine plantations would be able to serve as habitat for pine-specialists if they were managed and better quality, or if they are simply too small to sustain breeding pairs. For now, the results of my study support Metroparks Toledo's management plan to remove the red pine plantations and incorporate them into a larger forested matrix, and selectively manage the white pine plantations as a better choice to foster avian diversity and productivity.

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APPENDIX A: FIGURES

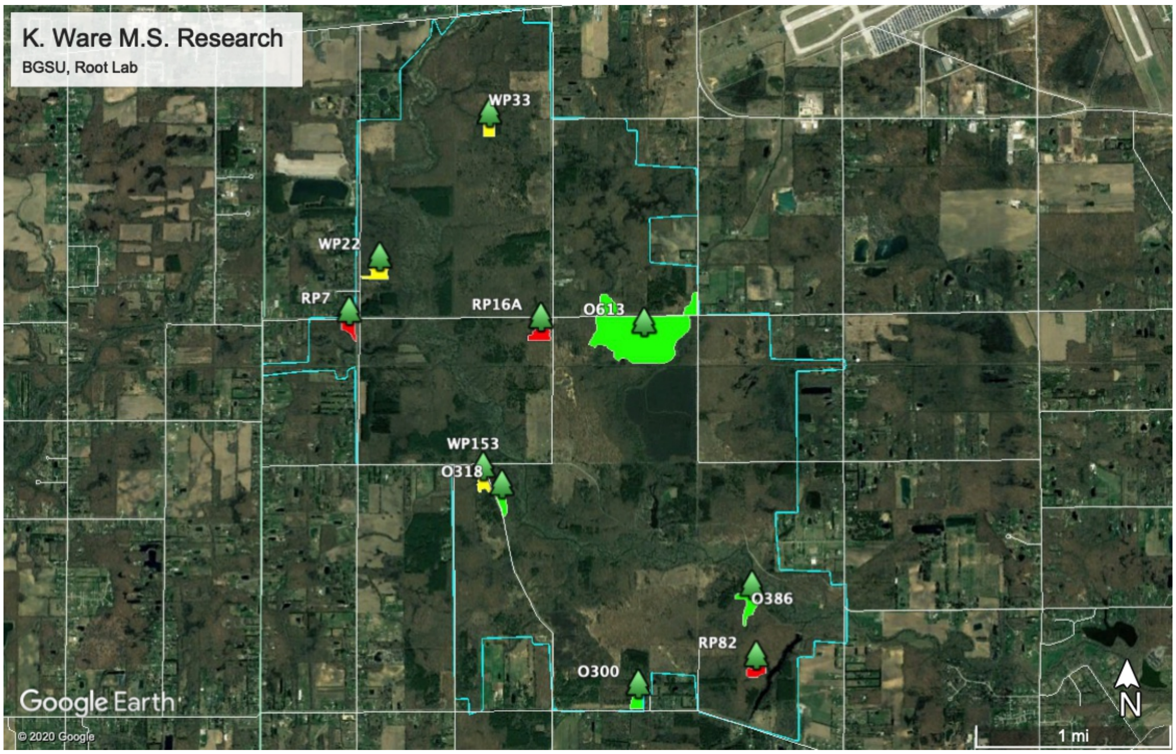


Figure 1: A map of all of my research sites in Oak Openings Preserve Metropark. There are three white pine sites (WP), three red pine sites (RP), three small oak forest sites (O), and one large contiguous oak forest site (O613). These sites correspond with those described in Table 1.

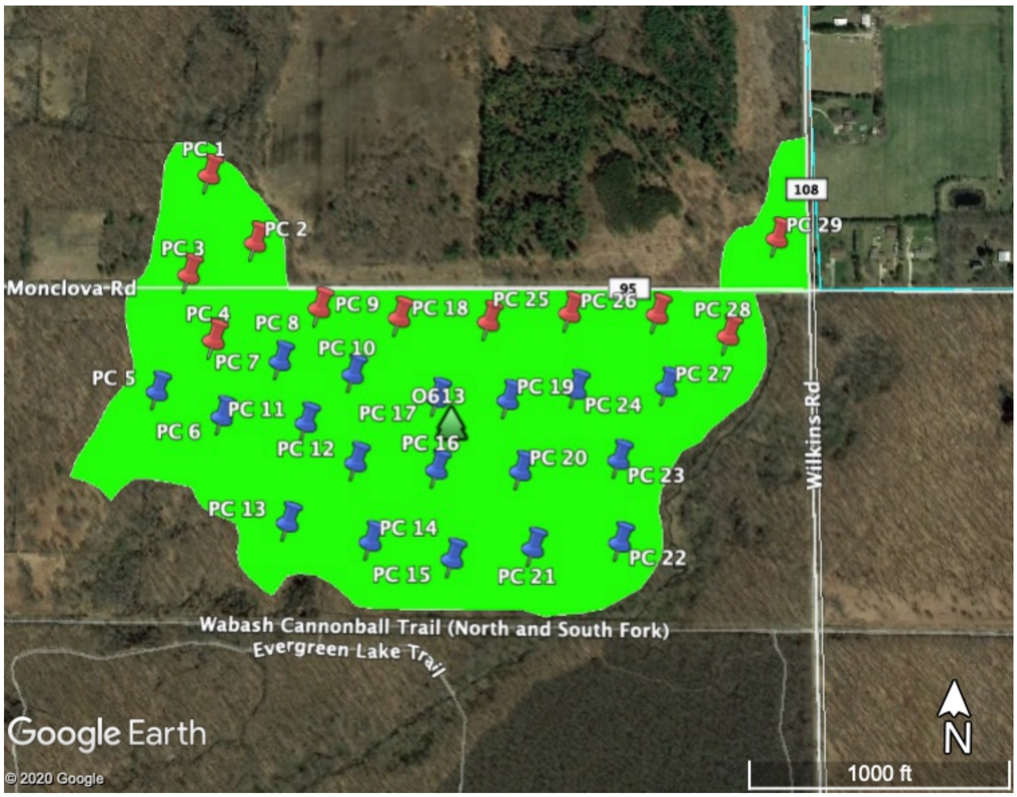
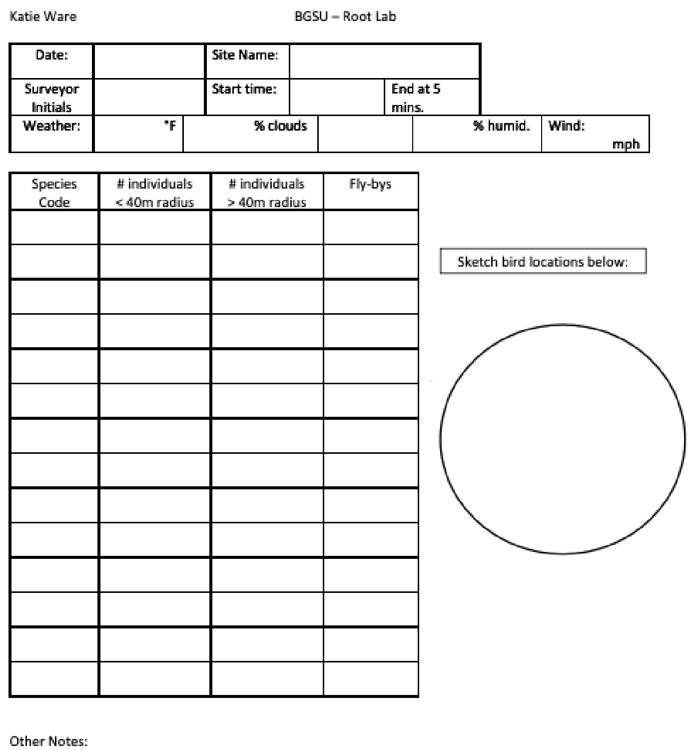


Figure 2: A map of the 29.3 ha contiguous oak forest site is shown here. Point-counts were done at each point, for a total of 29 points. Each point allowed for a 40-meter radius circle to surround it, without intersecting any other point.



Katie Ware BGSU – Root Lab

Date:		Site Name:			
Surveyor Initials		Start time:		End at 5 mins.	
Weather:	°F	% clouds		% humid.	Wind: mph

Species Code	# individuals < 40m radius	# individuals > 40m radius	Fly-bys

Sketch bird locations below:

Other Notes:

Figure 3: The standardized form I used for all of my point-count surveys. It includes the date, site name, surveyor initials, and start time. Basic weather information was also recorded, including the temperature, cloud cover, humidity, and wind speed. For the bird survey, the species code was listed and the number of individuals within the 40-m radius circle and outside of the circle were written. Fly-overs were also recorded. A circle to plot the individuals' locations was added to chart potential territories.

Figure 4: A picture of the clutter board is shown here. The 6.5-m tall strip of cloth was placed 20 m from the survey point, and the number of squares covered by vegetation were counted. The percentage of clutter was then calculated to describe the structure of the site. (Credit: Kelly Russo)

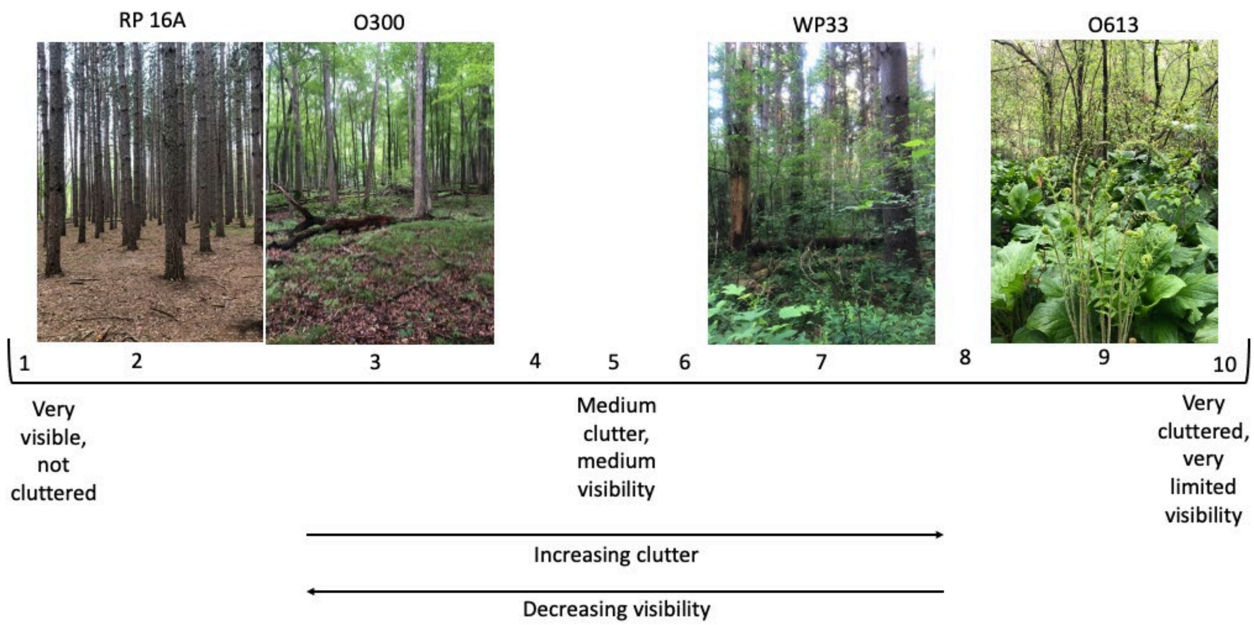
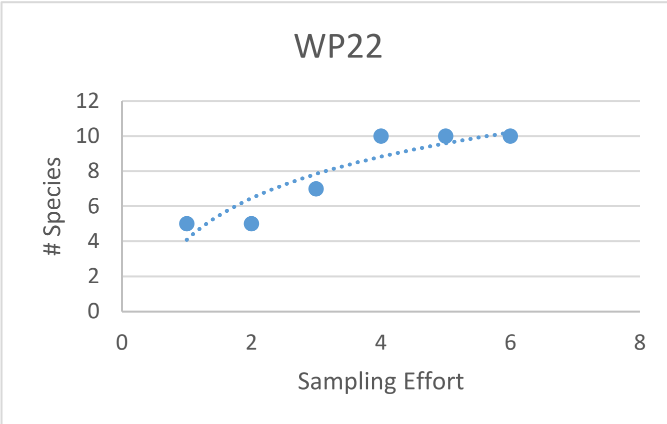
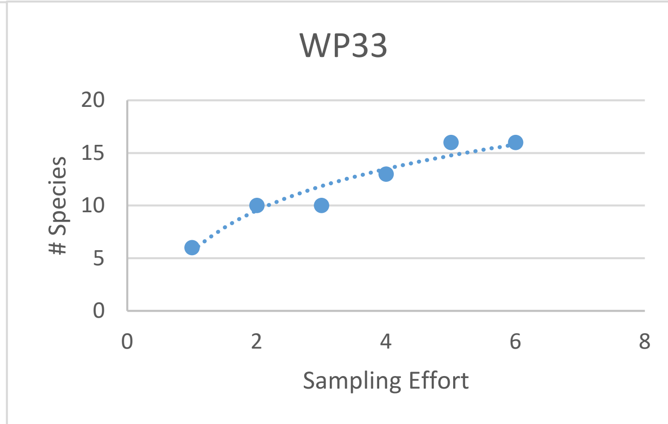
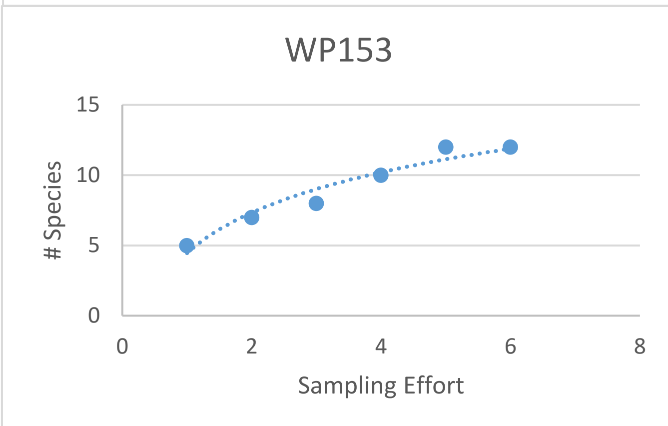
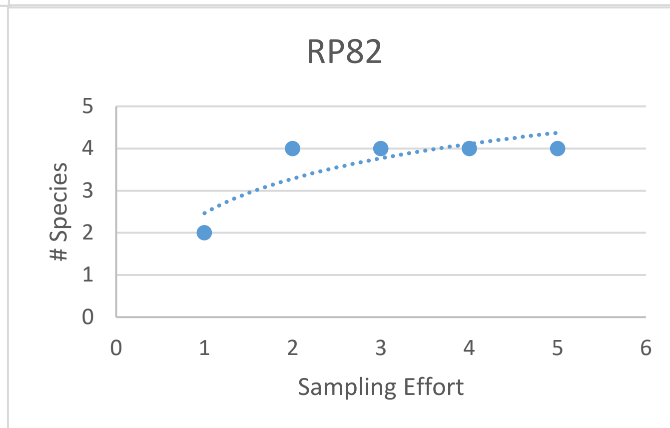


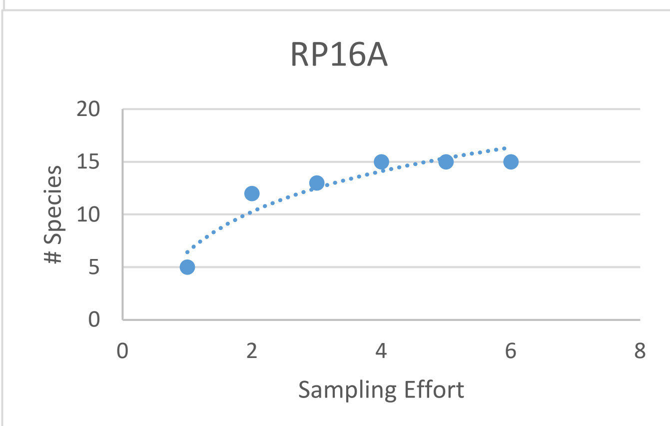
Figure 5: A chart is shown above depicting the qualitative clutter scale that I used to further describe the structure of my study sites. The scale is from 1-10, with 1 indicating a low level of vegetative obstruction, and 10 indicating a high level of vegetative obstruction. Pictures from several of my sites are included with the site name above them, and the number assigned to the site below them.

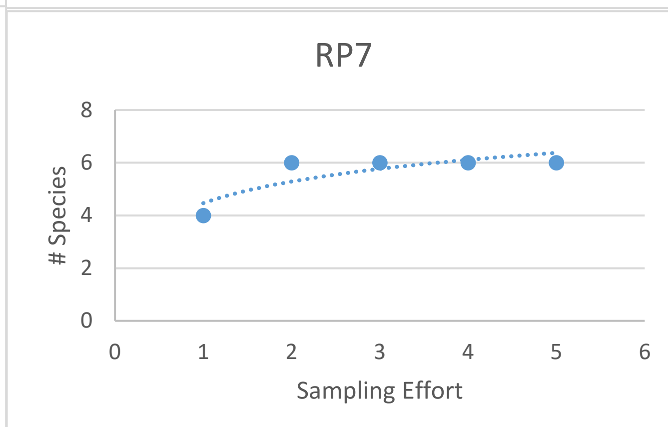

WP22
Species
12
10
8
6
4
2
0
0
2
4
6
8
Sampling Effort

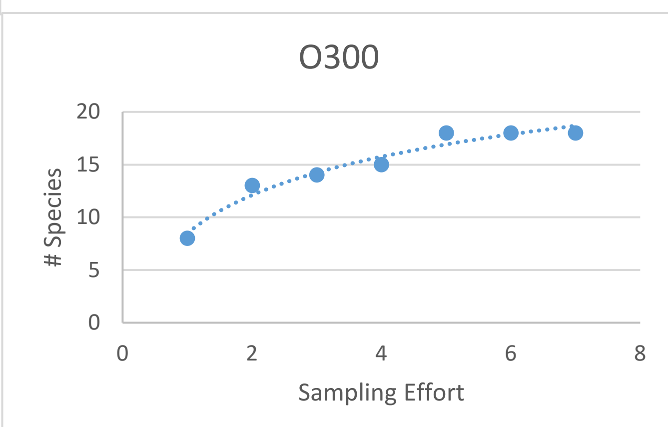

WP33
Species
20
15
10
5
0
0
2
4
6
8
Sampling Effort

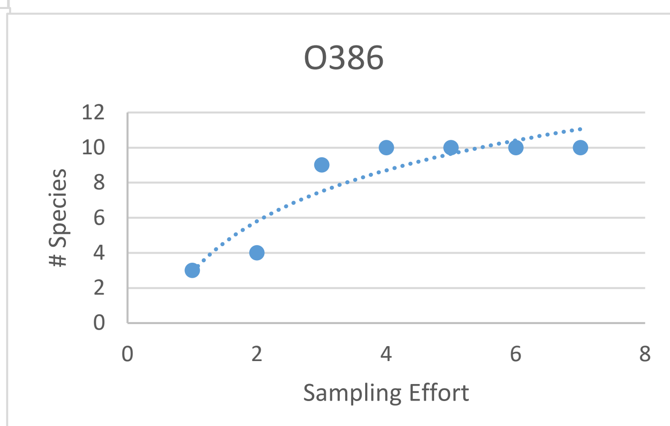

WP153
Species
15
10
5
0
0
2
4
6
8
Sampling Effort

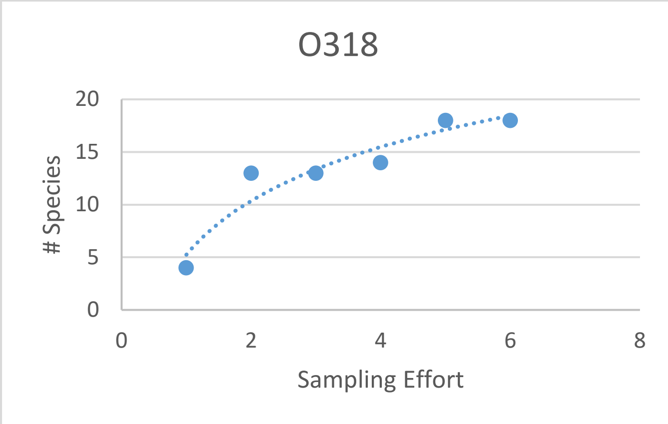

RP82
Species
5
4
3
2
1
0
0
1
2
3
4
5
6
Sampling Effort


RP16A
Species
20
15
10
5
0
0
2
4
6
8
Sampling Effort


RP7
Species
8
6
4
2
0
0
1
2
3
4
5
6
Sampling Effort


O300
Species
20
15
10
5
0
0
2
4
6
8
Sampling Effort


O386
Species
12
10
8
6
4
2
0
0
2
4
6
8
Sampling Effort



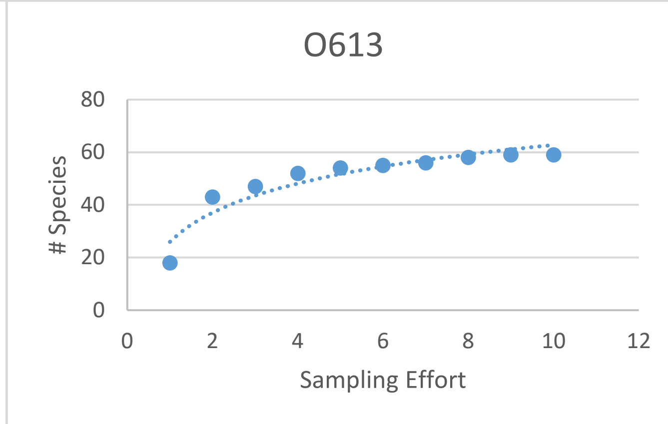


Figure 6: A collection of graphs showing the rarefaction curves for each of my study sites. The number of new species detected was plotted against each day sampling at that site. Each rarefaction curve begins to approach an asymptote, but additional sampling is necessary to better represent the full diversity at each site.

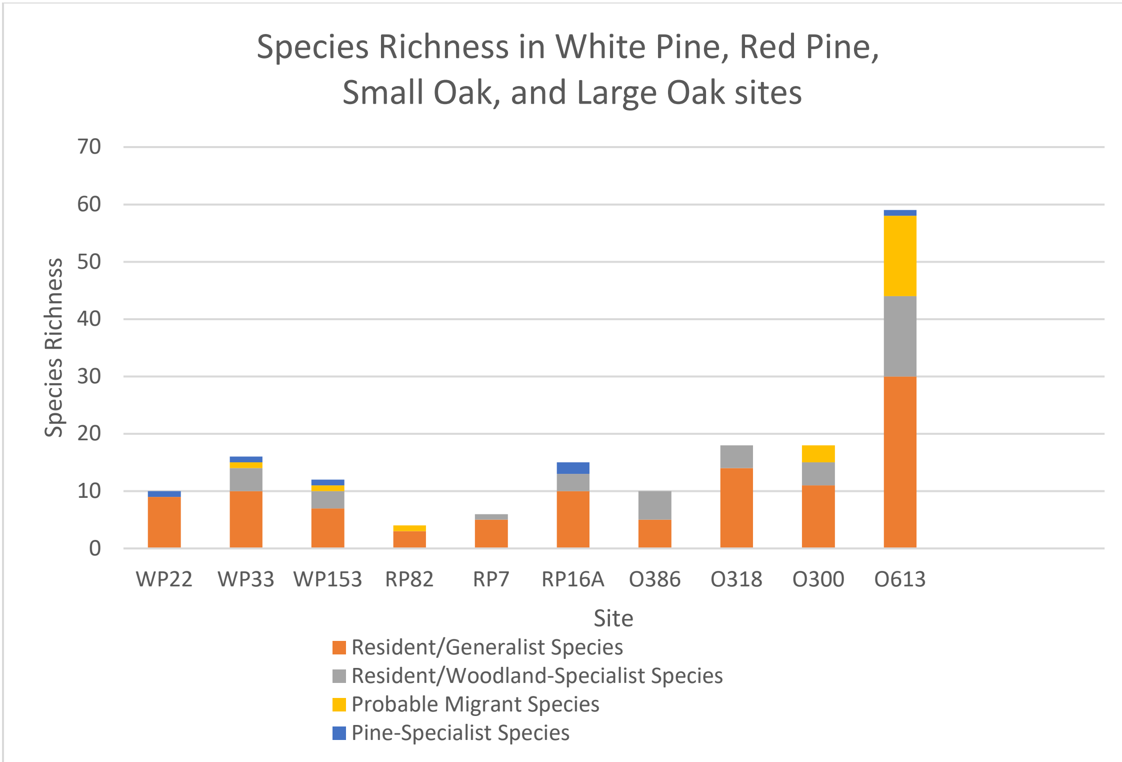
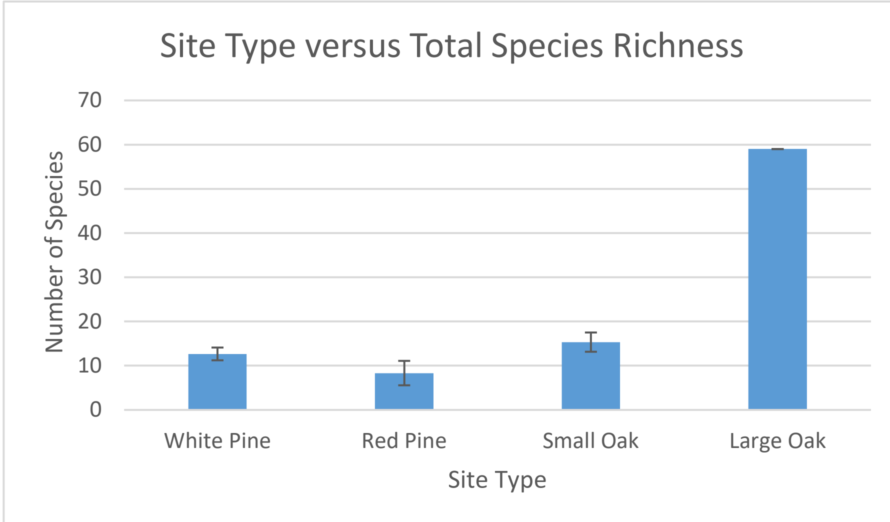


Figure 7: The species richness in each site. Each species detected was categorized as a resident/generalist species, resident/woodland-specialist species, probable migrant species, and pine-specialist species.



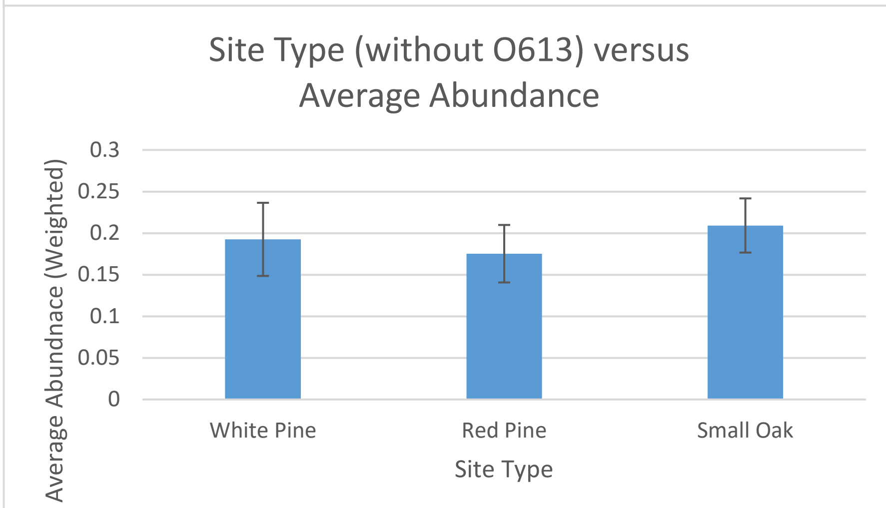
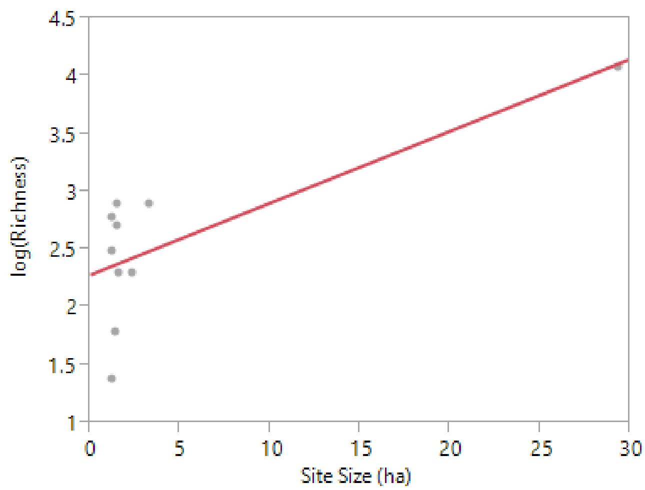


Figure 8: Graphs displaying site type (White Pine, Red Pine, Small Oak, or Large Oak) versus average species richness and site size in ha versus species richness. The relationship between site type and log(richness) was significant (F(3,6)=5.45, p=0.04), as well as the relationship between site size and reciprocal(abundance) (F(3,6)=3.73, p=0.08), with α=0.1. O613 is not included in the graph of site type versus abundance due to it being an outlier. O613's average abundance was 5.09.

Site Size (ha) versus Species Richness (with O613)



Site Size (ha) versus Average Abundance (with O613)

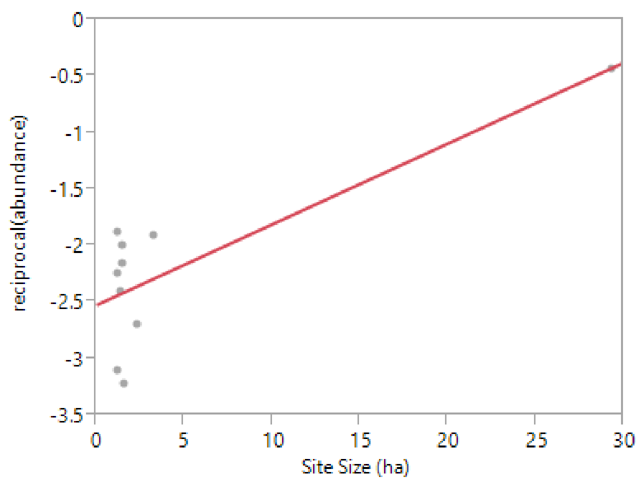


Figure 9: Graphs of site size (ha) versus richness and site size (ha) versus average abundance, with the least-squares regression line. These significant results correspond with Table 11. The equation of the regression line for the first graph is log(richness)= 2.28 + 0.06*site size, and the equation for the regression line for the second graph is reciprocal(abundance)= -2.52 + 0.07*site size.

Total Number of Saplings and Seedlings versus Species Richness

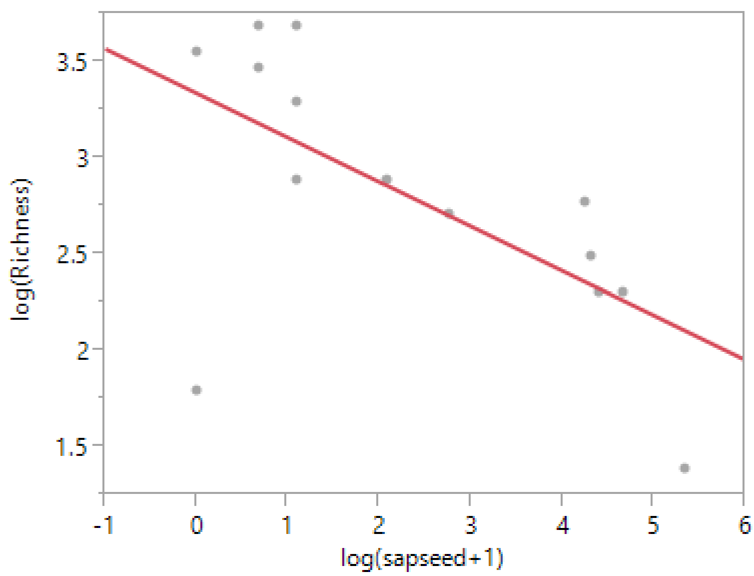


Figure 10: Graphs of log(number of saplings and seedlings + 1) versus log(species richness), with the least-squares regression line. These significant results correspond with Table 13. The equation of the regression line is log(richness)= 3.34 - 0.23(log(number of saplings and seedlings)+1).

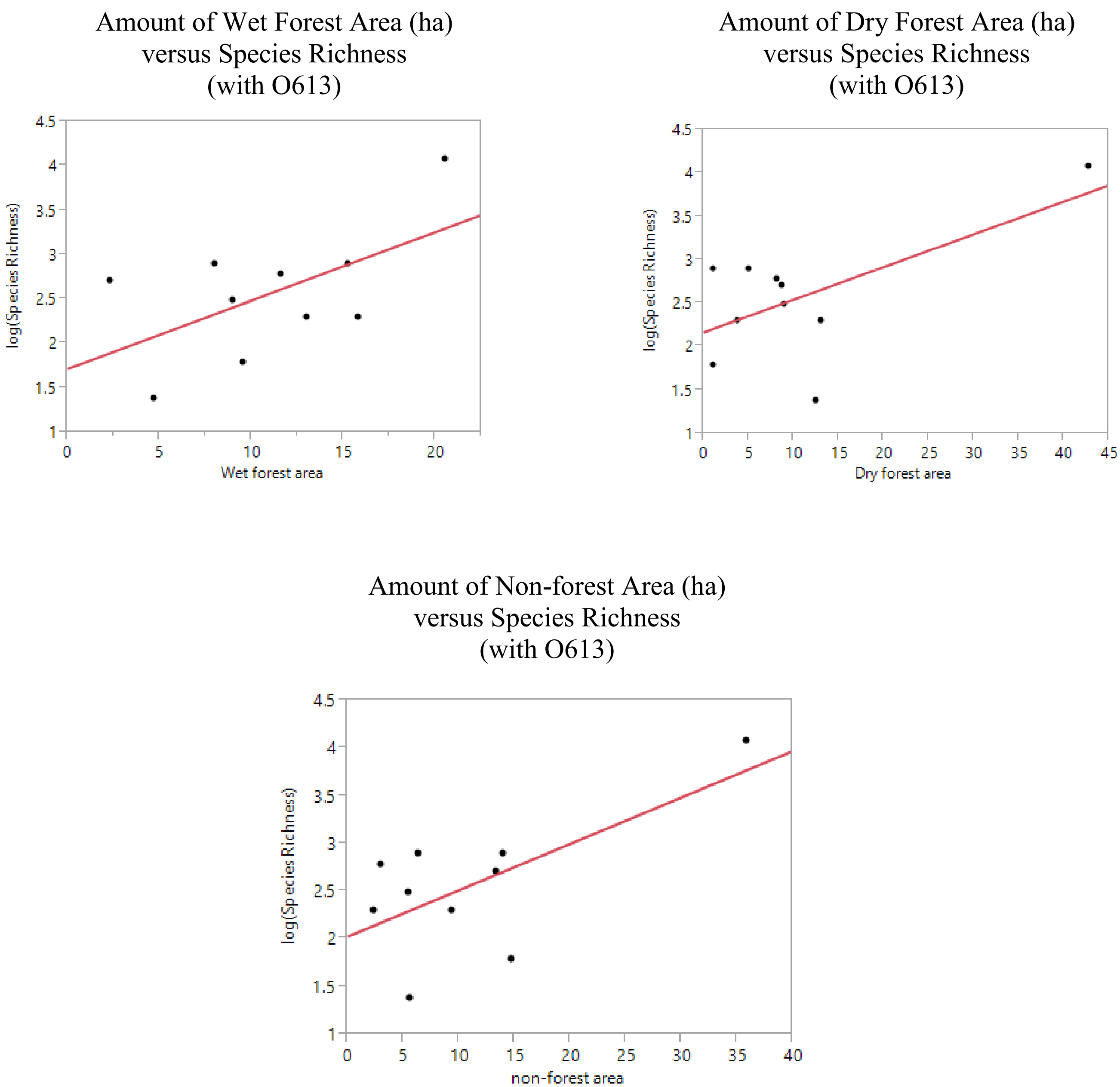


Figure 11: Graphs of wet forest area, dry forest, and non-forest area versus log(species richness), with the least-squares regression lines. These significant results correspond with Table 15. The equation of the regression line for the first graph is log(richness)= 1.71 + 0.08*wet forest area, for the second graph is log(richness)= 2.16 + 0.04*dry forest area, and for the third graph is log(richness)= 2.02 +0.05*non-forest area. Depending on whether or not O613 served as an outlier, it is listed if it was included in the graph.

APPENDIX B: TABLES

Table 1: The name, type of dominant vegetation in each site indicating site type, and the total area (in hectares) of each site.

Name	**Type**	**Hectares**
RP82	Red Pine	1.120
RP7	Red Pine	1.41
RP16A	Red Pine	1.51
WP13	White Pine	1.24
WP22	White Pine	1.57
WP33	White Pine	1.23
O300	Upland Deciduous/Oak Forest	1.32
O318	UD/Oak Forest	1.54
O386	UD/Oak Forest	2.30
O613	UD/Oak Forest	29.31

Table 2: The overall results of my study, categorized by site type. The species richness values were averaged among all of the sites of each type, including the standard error. The average abundance values are the average number of individuals counted in a single point-count survey and are weighted by site size.

Site Type	Average Richness	Standard Error (Richness)	Average Abundance	Standard Error (Abundance)	Total Nests and Probable Breeders
White Pine	12.67	7.31	0.19	0.04	5
Red Pine	8.33	4.81	0.18	0.03	1
Small Oak	15.33	8.85	0.21	0.03	3
Large Oak	59.00	0	5.09	0	21

Table 3: Overall results of my study listed by individual sites. This table shows the same results as Table 2, but in the individual sites rather than grouped by site type. The five sections used to split up O613 are also included here.

Site	Site Type	Richness	Average Abundance	Standard Error (Abundance)	Total Nests and Probable Breeders
WP22	White Pine	10	0.10	0.04	0
WP153	White Pine	12	0.20	0.05	3
WP33	White Pine	16	0.28	0.06	2
RP82	Red Pine	4	0.10	0.04	1
RP7	Red Pine	6	0.17	0.08	0
RP16A	Red Pine	15	0.25	0.06	0
O300	Small Oak	18	0.28	0.03	2
O318	Small Oak	18	0.22	0.05	0
O386	Small Oak	10	0.16	0.04	1
O613 (total)	Large Oak	59	5.09	0.02	21
O613-27	Large Oak	35	0.16	0.01	-
O613-22	Large Oak	32	0.14	0.01	-
O613-7	Large Oak	40	0.16	0.01	-
O613-16	Large Oak	40	0.19	0.01	-
O613-13	Large Oak	27	0.19	0.01	-

Table 4: Each species of bird that was detected, including its banding code, and how it was categorized according to its life history.

Resident/Generalist Species	Pine-Specialist Species	Probable Migrant Species	Resident/Woodland-Specialist Species
American Crow (AMCR)	Pine Warbler (PIWA)	Swainson's Thrush (SWTH)	Blue-gray Gnatcatcher (BGGN)
American Goldfinch (AMGO)	Blue-headed Vireo (BHVI)	Black-throated Green Warbler (BTNW)	Eastern Towhee (EATO)
American Robin (AMRO)		Tennessee Warbler (TEWA)	Eastern Wood-pewee (EAWP)
Baltimore Oriole (BAOR)		Nashville Warbler (NAWA)	Ovenbird (OVEN)
Black-capped Chickadee (BCCH)		Black-and-white Warbler (BAWW)	Pileated Woodpecker (PIWO)
Brown-headed Cowbird (BHCO)		Bay-breasted Warbler (BBWA)	Red-eyed Vireo (REVI)
Blue Jay (BLJA)		Magnolia Warbler (MAWA)	Red-headed Woodpecker (RHWO)
Chipping Sparrow (CHSP)		American Redstart (AMRE)	Scarlet Tanager (SCTA)
Common Yellowthroat (COYE)		Yellow-rumped Warbler (Myrtle) (MYWA)	Summer Tanager (SUTA)
Downy Woodpecker (DOWO)		Chestnut-sided Warbler (CSWA)	Wood Thrush (WOTH)
Eastern Bluebird (EABL)		Northern Parula (NOPA)	Hooded Warbler (HOWA)
Eastern Phoebe (EAPH)		Black-throated Blue Warbler (BTBW)	Blue-winged Warbler (BWWA)
Empidonax sp.		Veery (VEER)	Acadian Flycatcher (ACFL)
Field Sparrow (FISP)		Least Flycatcher (LEFL)	Red-shouldered Hawk (RSHA)
Great-crested Flycatcher (GCFL)			
Gray Catbird (GRCA)			
Hairy Woodpecker (HAWO)			
House Wren (HOWR)			
Indigo Bunting (INBU)			
Mourning Dove (MODO)			
Northern Cardinal (NOCA)			
Red-bellied Woodpecker (RBWO)			
Tufted Titmouse (TUTI)			
White-breasted Nuthatch (WBNU)			
Wood Duck (WODU)			
Yellow-billed Cuckoo (YBCU)			
Common Grackle (COGR)			
Song Sparrow (SOSP)			
Rose-breasted Grosbeak (RBGR)			
Carolina Wren (CARW)			
Northern Flicker (Yellow-shafted) (YSFL)			
Cedar Waxwing (CEDW)			
Ruby-throated Hummingbird (RTHU)			

Table 5: Each species that was detected throughout the survey period at each site throughout the study season, listed using the standardized banding code. This table corresponds with Figure 6.

Site	WP22	WP153	WP33	RP82	RP7	RP16A	O300	O318	O386	O613
Total Number of Species Present	10	12	16	4	6	15	18	18	10	59
Species	BCCH	CHSP	BCCH	AMRO	EATO	BHCO	EAPH	INBU	HOWA	BGGN
	WBNU	PIWA	NOCA	BLJA	NOCA	AMRO	AMRO	BGGN	REVI	AMRO
	BLJA	AMGO	CHSP	BHCO	AMRO	BLJA	BLJA	BCCH	WOTH	OVEN
	BHCO	OVEN	HAWO	SWTH	BCCH	DOWO	BAOR	DOWO	BLJA	RBWO
	AMCR	WBNU	TUTI		CEDW	CHSP	BCCH	SCTA	EAWP	BLJA
	AMGO	BCCH	WODU		BHCO	BCCH	AMCR	YBCU	HAWO	REVI
	empid sp.	GCFL	BHCO			PIWA	MODO	BHCO	GCFL	NOCA
	NOCA	EATO	SCTA			PIWO	EATO	COYE	AMRO	AMCR
	PIWA	BLJA	EABL			RHWO	INBU	BLJA	GRCA	TUTI
	TUTI	BTGN	PIWA			REVI	BTGN	FISP	BGGN	EAWP
		REVI	EAWP			INBU	NOCA	EATO		WBNU
		DOWO	GCFL			AMGO	PIWO	TUTI		SUTA
			SWTH			GRCA	REVI	MODO		DOWO
			BGGN			BHVI	TEWA	REVI		COYE
			AMGO			GCFL	NAWA	AMRO		BHCO
			SUTA				GRCA	GCFL		PIWO
							TUTI	RBWO		SWTH
							BGGN	HOWR		GCFL
										WODU
										BCCH
										RHWO
										AMGO
										EATO
										NOPA
										NAWA
										BTGN
										BBWA
										TEWA

Site	WP22	WP153	WP33	RP82	RP7	RP16A	O300	O318	O386	O613
										AMRE
										RSHA
										INBU
										WOTH
										RTHU
										MAWA
										SCTA
										YSFL
										CARW
										HOWR
										BLWW
										MYWA
										GRCA
										VEER
										CEDW
										Empid sp.
										YBCU
										SOSP
										BAOR
										LEFL
										BHVI
										ACFL
										EABL
										HAWO
										HOWA
										RBGR
										BAWW
										COGR
										CSWA
										BTBW
										EAPH

Table 6: The scientific names of all the birds found during my point-count surveys, listed in alphabetical order.

Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Acadian Flycatcher	*Empidonax virescens*	Hooded Warbler (HOWA)	*Setophaga citrina*
American Crow	*Corvus brachyrhynchos*	House Wren (HOWR)	*Troglodytes aedon*
American Goldfinch	*Spinus tristis*	Indigo Bunting (INBU)	*Passerina cyanea*
American Redstart (AMRE)	*Setophaga ruticilla*	Least Flycatcher (LEFL)	*Empidonax minimus*
American Robin	*Turdus migratorius*	Magnolia Warbler (MAWA)	*Setophaga magnolia*
Baltimore Oriole	*Icterus galbula*	Mourning Dove (MODO)	*Aenaida macroura*
Bay-breasted Warbler (BBWA)	*Setophaga castanea*	Nashville Warbler (NAWA)	*Leiothlypis ruficapilla*
Black-and-white Warbler (BAWW)	*Mniotilta varia*	Northern Cardinal (NOCA)	*Cardinalis cardinalis*
Black-capped Chickadee	*Poecile atricapillus*	Northern Flicker (Yellow-shafted) (YSFL)	*Colaptes auratus*
Black-throated Blue Warbler (BTBW)	*Setophaga caerulescens*	Northern Parula (NOPA)	*Setophaga americana*
Black-throated Green Warbler (BTNW)	*Setophaga virens*	Ovenbird (OVEN)	*Seiurus aurocapilla*
Blue Jay	*Cyanocitta cristata*	Pileated Woodpecker (PIWO)	*Dryocopus pileatus*
Blue-gray Gnatcatcher (BGGN)	*Polioptila caerulea*	Pine Warbler (PIWA)	*Setophaga pinus*
Blue-headed Vireo (BHVI)	*Vireo solitarius*	Red-bellied Woodpecker (RBWO)	*Melanerpes carolinus*
Blue-winged Warbler (BWWA)	*Vermivora cyanoptera*	Red-eyed Vireo (REVI)	*Vireo olivaceus*
Brown-Headed Cowbird	*Molothrus ater*	Red-headed Woodpecker (RHWO)	*Melanerpes erythrocephalus*
Carolina Wren (CARW)	*Thryothorus ludovicianus*	Red-shouldered Hawk (RSHA)	*Buteo lineatus*
Cedar Waxwing (CEDW)	*Bombycilla cedrorum*	Rose-breasted Grosbeak (RBGR)	*Pheucticus ludovicianus*
Chestnut-sided Warbler (CSWA)	*Setophaga pensylvanica*	Ruby-throated Hummingbird (RTHU)	*Archilochus colubris*
Chipping Sparrow	*Spizella passerina*	Scarlet Tanager (SCTA)	*Piranga olivacea*
Common Grackle (COGR)	*Qiscalus quiscula*	Song Sparrow (SOSP)	*Melospiza melodia*
Common Yellowthroat	*Geothlypis trichas*	Summer Tanager (SUTA)	*Piranga rubra*
Downy Woodpecker	*Picoides pubescens*	Swainson's Thrush (SWTH)	*Catharus ustulatus*
Eastern Bluebird	*Sialia sialis*	Tennessee Warbler (TEWA)	*Leiothlypis peregrina*
Eastern Phoebe (EAPH)	*Sayornis phoebe*	Tufted Titmouse (TUTI)	*Baeolophus bicolor*
Eastern Towhee (EATO)	*Pipilo erythrophthalmus*	Veery (VEER)	*Catharus fuscescens*
Eastern Wood-pewee (EAWP)	*Contopus virens*	White-breasted Nuthatch (WBNU)	*Sitta canadensis*
Empidonax sp.	-	Wood Duck (WODU)	*Aix sponsa*
Field Sparrow (FISP)	*Spizella pusilla*	Wood Thrush (WOTH)	*Hylocichla mustelina*
Gray Catbird (GRCA)	*Dumetella carolinensis*	Yellow-billed Cuckoo (YBCU)	*Coccyzus americanus*
Great-crested Flycatcher (GCFL)	*Myiarchus crinitus*	Yellow-rumped Warbler (Myrtle) (MYWA)	*Dendroica coronata coronata*
Hairy Woodpecker (HAWO)	*Leuconotopicus villosus*		

Table 7: Species richness composition in each of my sites. The number of each category of species detected in my point-count surveys is listed here. This corresponds with Figure 7.

Site	Resident Generalist Species	Resident Forest-Specialist Species	Non-Resident Migratory Species	Pine-Specialist Species
WP22	9	0	0	1
WP33	10	4	1	1
WP153	7	3	1	1
RP82	3	0	1	0
RP7	5	1	0	0
RP16A	10	3	0	2
O386	5	5	0	0
O318	14	4	0	0
O300	11	4	3	0
O613	30	14	14	1

Table 8: The nesting and breeding results of my survey. Each site is listed with its respective total number of nests detected throughout the season and the species that occupied those nests. The number of probable breeders is also included, with the species that were probably breeding in that site. Any failed nests that were found and their species are also included.

Site	Total Number of Nests	Species	Number of Probable Breeders	Species	Failed Nests	Species
WP22	0	-	0	-	0	-
WP153	2	DOWO, WOTH	1	CHSP	1	BCCH
WP33	2	TUTI, BCCH	0	-	0	-
RP82	1	AMRO	0	-	0	-
RP7	0	-	0	-	0	-
RP16A	0	-	0	-	1	AMRO
O300	2	EAPH, BLJA	0	-	0	-
O318	0	-	0	-	0	-
O386	0	-	1	HOWA	0	-
O613	17	BLJA (3), NOCA, RSHA, NOWA, HOWA, EATO, EAPH (3), OVEN, AMRO, DOWO, BCCH, HOWR	4	SUTA, SCTA, ACFL, YBCU	0	-

Table 9: This table shows the structural results of my vegetation surveys, including the average percentage of canopy cover, average percentage of clutter 0-3m and 3-6.5m, understory, middlestory, and upperstory clutter. For the largest site, O613, these measurements were taken at five different points throughout the site and the results for each individual section are listed.

Site	Average Percentage Canopy Cover	Average Percentage Clutter 0-3m	Average Percentage Clutter 3-6.5m	Understory Clutter	Middlestory Clutter	Upperstory Clutter
WP22	71.40	33.33	57.78	6	6	8
WP153	71.40	74.76	65.48	4	4	7
WP33	64.70	63.57	60.00	6	6	7
RP82	64.45	13.10	0.00	4	4	4
RP7	77.62	78.83	84.76	9	9	4
RP16A	51.50	2.14	0.00	2	2	8
O300	75.20	50.00	57.14	5	5	6
O318	66.71	35.95	39.29	7	7	3.5
O386	70.64	24.29	3.81	3	3	5
O613-27	78.50	32.62	66.91	5	5	7
O613-22	75.22	58.38	62.86	5	5	5
O613-7	67.25	61.91	61.91	5	5	7
O613-16	74.29	47.52	75.48	5	5	5
O613-13	75.41	3.57	19.25	6	6	5

Table 10: One-way ANOVA results of my structural variables. For p-values that were significant (α=0.1), a Tukey HSD test was done and is listed. Any significant values are marked with an asterisk.

One-Way ANOVA				**Tukey HSD**				
X	**Y**	**F-ratio**	**p-value**	**Level**	**Level**	**Lower CL**	**Upper CL**	**p-value**
Site Type	log(richness)	5.45	0.04*	Large Oak	Red Pine	0.28	3.95	0.03*
				Large Oak	White Pine	-0.27	3.39	0.09*
				Large Oak	Small Oak	-0.45	3.21	0.14
				Small Oak	Red Pine	-0.56	2.03	0.30
				White Pine	Red Pine	-0.74	1.85	0.50
				Small Oak	White Pine	-1.12	1.47	0.96
Site Type	reciprocal(abundance)	3.73	0.08*	**Level**	**Level**	**Lower CL**	**Upper CL**	**p-Value**
				Large Oak	Red Pine	-0.19	4.32	0.07*
				Large Oak	White Pine	-0.25	4.26	0.08*
				Large Oak	Small Oak	-0.44	4.06	0.11
				Small Oak	Red Pine	-1.34	1.85	0.94
				Small Oak	White Pine	-1.40	1.79	0.97
Understory Clutter	log(richness)	1.05	0.53					
Understory Clutter	reciprocal(abundance)	3.34	0.17					
Middlestory Clutter	log(richness)	5.19	0.33					
Middlestory Clutter	reciprocal(abundance)	0.64	0.75					
Upperstory Clutter	log(richness)	1.04	0.53					
Upperstory Clutter	reciprocal(abundance)	0.83	0.62					

Table 11: Simple linear regression results of site size versus richness and abundance. As O613 is an outlier, regressions were done with and without O613. Significant results are marked with an asterisk (α=0.1). The equation for the least-squares regression line is included where results are significant. These correspond with Figure 9.

X	**Y**	**B**	**R^2**	**ANOVA F-ratio**	**ANOVA p-value**	**Linear Regression Equation**
site size (without O613)	log(richness)	0.29	0.14	1.17	0.31	-
	reciprocal(abundance)	0.17	0.05	0.41	0.54	-
site size (with O613)	log(richness)	0.06	0.57	10.58	0.01*	log(richness)=2.28+0.06*site size
	reciprocal(abundance)	0.07	0.64	14.53	0.01*	reciprocal(abundance)= -2.52+0.07*site size

Table 12: The compositional results of my vegetation surveys for each site. The total number of trees, total number of saplings and seedlings combined, and the total number of herbaceous plants counted in each survey area. For O613, the results are listed individually for the five sections.

Site	Total Number of Trees	Total Number of Saplings and Seedlings	Total Number of Herbaceous Plants
WP33	3	69	93
WP22	3	81	0
WP153	4	74	7
RP16A	3	15	3
RP7	10	0	14
RP82	3	207	27
O318	7	7	60
O386	3	105	79
O300	3	2	20
O613-27	4	0	13
O613-22	5	1	22
O613-7	6	1	38
O613-16	5	2	12
O613-13	1	2	4

Table 13: Simple linear regression results for my compositional variables. O613 is divided into its five separate sections. Significant results are marked with an asterisk (α=0.1). A linear regression equation is included where the results are significant. These correspond with Figure 10.

X	Y	B	R^2	ANOVA F-ratio	ANOVA p-value	Linear Regression Equation
log(trees)	log(richness)	0.04	0.0009	0.01	0.92	-
	reciprocal(abundance)	0.001	$3.79e^{-6}$	0	0.99	-
log(sapseed + 1)	log(richness)	-0.23	0.39	7.7	0.02*	log(richness)=3.34-0.23(log(number of saplings and seedlings)+1)
	reciprocal(abundance)	-0.07	0.1	1.32	0.27	-
log(plants +1)	log(richness)	0.02	0.002	0.02	0.89	-
	reciprocal(abundance)	0.09	0.08	0.98	0.34	-

Table 14: Spatial analysis of my sites. A 200-m radius buffer was made around the edge of each site in ArcMap GIS. The total number of patches was counted, and the totals of each habitat type included in the buffer were counted as "land cover richness." Habitats were counted as either forest (wet or dry forest) or non-forest.

Site	Type	Total Buffer Area (ha)	Number of Patches	Land Cover Richness	Forest Patches	Non-forest Patches	Wet Forest Area (ha)	Wet Forest %	Dry Forest Area (ha)	Dry Forest %	Non-forest Area (ha)	Non-forest %
RP7	Red Pine	25.47	46	7	3	4	9.58	37.61	1.10	4.33	14.79	58.07
RP16A	Red Pine	24.44	76	10	4	6	2.31	9.46	8.72	35.66	13.41	54.88
RP82	Red Pine	22.89	47	9	4	5	4.74	20.70	12.47	54.49	5.68	24.81
WP22	White Pine	26.29	35	8	4	4	13.04	49.60	3.81	14.51	9.43	35.89
WP33	White Pine	22.77	38	7	4	3	11.59	50.91	8.20	36.00	2.98	13.09
WP153	White Pine	23.44	48	9	4	5	9.01	38.45	8.98	38.32	5.45	23.23
O300	Sm Oak	23.19	55	10	4	6	8.01	34.53	1.17	5.06	14.01	60.41
O318	Sm Oak	26.74	52	9	4	5	15.26	57.06	5.06	18.92	6.42	24.03
O386	Sm Oak	31.24	44	8	4	4	15.83	50.67	13.07	41.84	2.34	7.49
O613	Lg Oak	99.12	160	10	4	6	20.52	20.70	42.77	43.15	35.83	36.15

Table 15: Simple linear regression results for my spatial variables. Significant results are marked with an asterisk (α=0.1). A linear regression equation is included where the results are significant. These correspond with Figure 11. As O613 is an outlier, regressions were run with and without it.

X	Y	B	R^2	ANOVA F-ratio	ANOVA p-value	Linear Regression Equation
log(land cover richness)	log(richness)	2.42	0.21	2.15	0.18	
	reciprocal (abundance)	-3.67	0.09	83.00	0.39	
log(forest patches)	log(richness)	2.97	0.14	1.3	0.29	
	reciprocal (abundance)					
log(non-forest patches)	log(richness)	1.15	0.13	1.23	0.30	
	reciprocal (abundance)	-0.30	0.001	0.01	0.91	
wet forest area	log(richness)	0.08	0.34	4.07	0.08*	log(richness)=1.71+0.08*wet forest area
	reciprocal (abundance)	0.03	0.01	0.11	0.75	
wet forest %	log(richness)	-0.004	0.006	0.05	0.83	
	reciprocal (abundance)	-0.01	0.02	0.15	0.71	
dry forest area (without O613)	log(richness)	-0.03	0.07	0.54	0.49	
	reciprocal (abundance)	-0.03	0.005	0.03	0.86	
dry forest area (with O613)	log(richness)	0.04	0.40	5.25	0.05*	log(richness)=2.16+0.04*dry forest area
	reciprocal (abundance)	0.01	0.005	0.04	0.84	
non-forest area (without O613)	log(richness)	0.002	0.0004	0.003	0.96	
	reciprocal (abundance)	0.19	0.30	2.97	0.13	
non-forest area (with O613)	log(richness)	0.05	0.44	6.22	0.04*	log(richness)=2.02+0.05*non-forest area
	reciprocal (abundance)	0.08	0.23	2.46	0.16	