MONITORING ASSOCIATIONS BETWEEN AVIAN AND PLANT COMMUNITIES ON THE MARY GRAY BIRD SANCTUARY, FAYETTE COUNTY, INDIANA

A RESEARCH PROJECT

SUBMITTED TO THE GRADUATE SCHOOL

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MASTER OF ARTS

BY

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ABSTRACT

RESEARCH PAPER: Monitoring Associations Between Avian and Plant Communities on the Mary Gray Bird Sanctuary, Fayette County, Indiana

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A large body of research has documented declines in bird species diversity and population size of some bird species in eastern North America and linked these declines to large-scale land-use changes after European settlement of this region. However, the vegetation of landscapes in eastern North America continues to change in many parts of this region as previously farmed lands are left fallow and natural succession leads to reestablishment of forests. This study initiates long-term monitoring of the associations between vegetation characteristics and the diversity and composition of bird communities on the Mary Gray Bird Sanctuary. This area is currently undergoing both managed and natural restoration of vegetation after a history of extensive human disturbance. The Sanctuary is dedicated to providing a secure habitat for wildlife and is an excellent location for long-term monitoring of ecological changes over time. The study has established 60 permanent plots and set baseline data for vegetation composition and structure. Species composition and diversity of the bird community have been determined on these same permanent plots and associations between the vegetation and bird communities

have been evaluated. This system of permanent plots also provides a framework for future monitoring studies of other wildlife species, including small mammals and herpetofauna.

Overall, the bird/habitat associations were as expected or predicted from the established literature, within the bounds of normal biological variation of any ecosystem. The ten most abundant bird species (in descending order) were Northern cardinal (*Cardinalis cardinalis*), Acadian flycatcher (*Empidonax virescens*), Eastern wood-pewee (*Contopus virens*), wood thrush (*Hylocichla mustelina*), red-eyed vireo (*Vireo olivaceus*), tufted titmouse (*Baeolophus bicolor*), ovenbird (*Seiurus aurocapilla*), red-bellied woodpecker (*Melanerpes carolinus*), white-breasted nuthatch (*Sitta carolinensis*), and gray catbird (*Dumetella carolinensis*). The property has a number of different habitat stages present, although, as the list of common bird species would suggest, it is mostly edge and deciduous forest. Habitats noted include grassland/prairie, thorny scrub, young shrubby second growth forest, near-mature beech-maple forest, as well as small areas of fairly mature oak-hickory forest, a few select red pine plantations and some small ponds. It is worth note that, despite having areas of grassland, only few grassland bird species were detected, with no bobolinks (*Dolichonyx oryzivorus*) or eastern meadowlarks (*Sturnella magna*) at all. Research has suggested that this may be due to excessive fragmentation of the prairies such that each individual patch is too small for the more specialized grassland bird species (Fletcher, 2005).

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INTRODUCTION

Most of the landscape of central and northern Indiana has been altered from the pre-settlement vegetation dominated by hardwood forest, and many species of wildlife associated with these forests have exhibited population declines. In particular, habitat alteration has been blamed for population declines of many bird species in eastern North America and Indiana, especially Neotropical migrants whose breeding range is in this region (Robbins et al. 1989).

In response to concerns about losses of Indiana's natural heritage, the Indiana Audubon Society acquired and currently manages the Mary Gray Bird Sanctuary, with over 700 acres of forest, prairie, meadows, and ponds. The Sanctuary provides stable habitat for birds and other wildlife and is used for nature education programs provided to Society members and the public at large. Historically, this land was impacted by various human activities, including agriculture, logging, and grazing. The biological community on the Sanctuary is currently undergoing natural succession as the vegetation recovers from these past disturbances. Management of the recovery of vegetation has involved a variety of plantings, including both native and exotic species, and limited prescribed burning (Carl Wilms, Onsite Manager, Pers. Comm.). However, there has not been any systematic monitoring of vegetation recovery, and so, land managers have little information to guide them as they try to manage the land resource as a habitat for wildlife. While members of the Indiana Audubon Society have been observing birds in the Sanctuary for many years, this information has not been collected in a systematic framework that would provide valid data to guide management for the objective of sustaining and increasing diversity of the native avian community on the Sanctuary. Without such information, there is limited basis for making management decisions regarding how vegetation should be managed to provide

habitat for specific bird species and to enhance diversity of the native avifauna on the Sanctuary. At the request of the Indiana Audubon Society, this study establishes a framework for long-term studies of vegetation change and the associations between vegetation characteristics and the composition and diversity of the avifauna on the Sanctuary. This same framework can also provide structure for studying and monitoring other components of the wildlife community (e.g., mammals and herpetofauna) on the Sanctuary and a basis for long-term monitoring of changes in the biological community.

This study accomplishes four main goals. First, it will determine the density and distribution of each avian breeding species at the Sanctuary, using standardized sampling methods. Second, it will determine forest composition/structure and floral biodiversity, also using standardized sampling methods. Thirdly, it will evaluate the associations between habitat utilization by avifauna and vegetation characteristics. And, finally, it will establish a system of permanent study plots and provided baseline data for future monitoring of change in vegetation and wildlife populations as this site continues to undergo ecological succession and recovery. Results of these analyses will then be used to inform site-specific management activities intended to enhance breeding bird populations on the Sanctuary.

SITE DESCRIPTION

Mary Gray Bird Sanctuary (MGBS), in Fayette County, Indiana (Fig. 1), was founded in 1943 when Alice Green Gray donated 264 acres to the Indiana Audubon Society as a memorial to her deceased daughter Mary. In the subsequent years, additional tracts were donated to bring the total up to the current 700+ acres. The sanctuary is 1.7 miles long (east-west) and 0.8 miles wide

(north-south) at its longest and widest points.

The vast majority of the property is comprised of deciduous forest dominated by maple and beech, with some areas that are oak and hickory. There are also some red pine plantations, grassland, and second growth scrub. In addition, there are a number of exotic species such as dwarf periwinkle (*Vinca minor* L.) and Chinese yam (*Dioscorea oppositifolia* L.) in the eastern portion of the property that were established when it was still in the Gray's possession. There are four ponds, three of which are located near the park buildings. In the southwest corner of the property, there are four areas of hay field/grassland that are all between four and six acres and are divided by narrow tree lines.

At this time, there is minimal active property management for resource optimization. The grasslands are mowed twice a year to keep the weedy shrubs and brambles in check. There is no active management schedule for the old hay fields in the southwest corner of the property, and, consequently, the early stages of succession are beginning to occur, as evidenced by an influx of brambles and shrubby trees such as blackberries (*Rubus* L. spp.), multiflora rose (*Rosa multiflora* Murray), and black locust (*Robinia pseudoacacia* L.)**.** The only tree harvesting currently implemented is removal of some windfalls to supply firewood for the two residences of the on-site managers (C. Wilms, Pers. Comm., 2013). Despite continuing efforts to battle invasive herbs such as garlic mustard, there is still a notable presence of these plants in some portions of the property. There is a lightly used primitive campground near the property offices, used mainly by those attending Society meetings. There are also several miles of hiking trails that traverse the property through the different habitats. There are multiple ongoing research projects on MGBS, the most active of which is a turtle monitoring program. This program has been in place since 1985 and is the work of Professor Gary Breitenbach, Indiana University East.

The MGBS watershed drains into four creeks that lead off the property, all of which drain from north to south. Of the four, the north branch of Garrison Creek flows year round, whereas the eastern three are seasonal. MGBS is located in the Whitewater River watershed (USGS Cataloging Unit: 05080003) (EPA 2015).

The terrain itself is hilly, with a total elevation change of roughly 41 m between the east central portion of the southern border at the lowest and the west central portion of the northern border at the highest. There are two low points on the property which reach roughly 277.4 m elevation, both are in creek basins just before those creeks enter the adjacent properties to the south. The high point, approximately 318.5 m above sea level, is on the side of a hill in the northwest portion of the property. The hill's crest is just across the property line east-northeast of MGBS's high point (Fig. 2).

The soil on the more gradual slopes (2 to 25 percent grade) is primarily composed of slightly to mildly eroded Russell silt loam, which is characterized as well drained, and where the steeper slopes (25 to 50 percent grade) are mostly comprised of Hennepin loam, which is also characterized as well drained. The bottoms of the creek basins are composed almost entirely of Eel silt loam, which is characterized as moderately well drained (WSS 2015) (Fig. 3).

The climate for Fayette County, Indiana, has an average of 98.8 cm of precipitation per year, with 123 days per year of precipitation, and 180 sunny days per year. From 1896 to 1998 the maximum precipitation in any one year was 147.1 cm and the minimum annual precipitation was 62.5 cm. The overall high temperature for the above time block was 26.3^{o} C, with the low being -12.9^{o} C and the average temperature being 10.4^{o} C. The average first frost date for Rush county (the adjacent county to the west), as determined by first instance of 0^{o}C, is October 14, with the earliest on September 14, recorded in 1923. Rush County's data was used because

Fayette County did not have any published records for that particular data. The average last date of lows reaching 0^{o} C is April 22, with the last date recorded since 1901 being June 1, 1966. This means that the average growing season is from the third week of April to the second week of October (roughly twenty-three weeks). (Appendix 1)

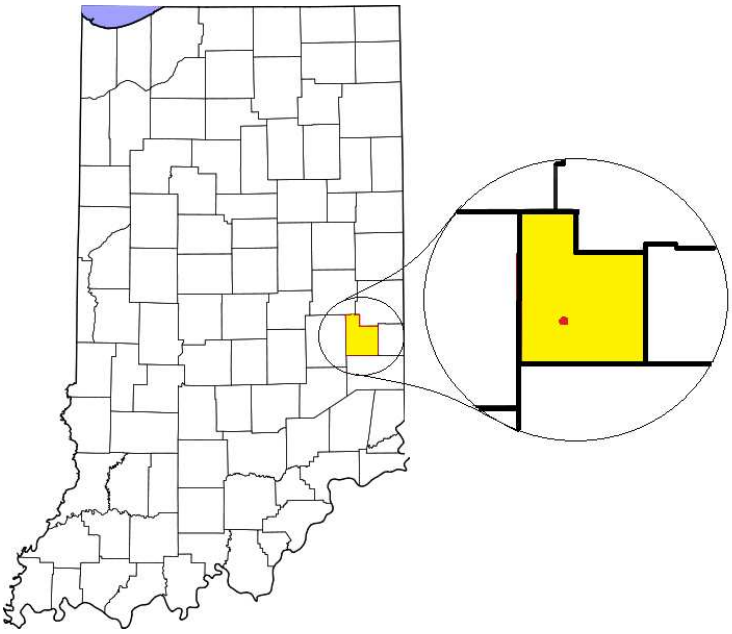

Figure 1: Location of Fayette Co. in Indiana

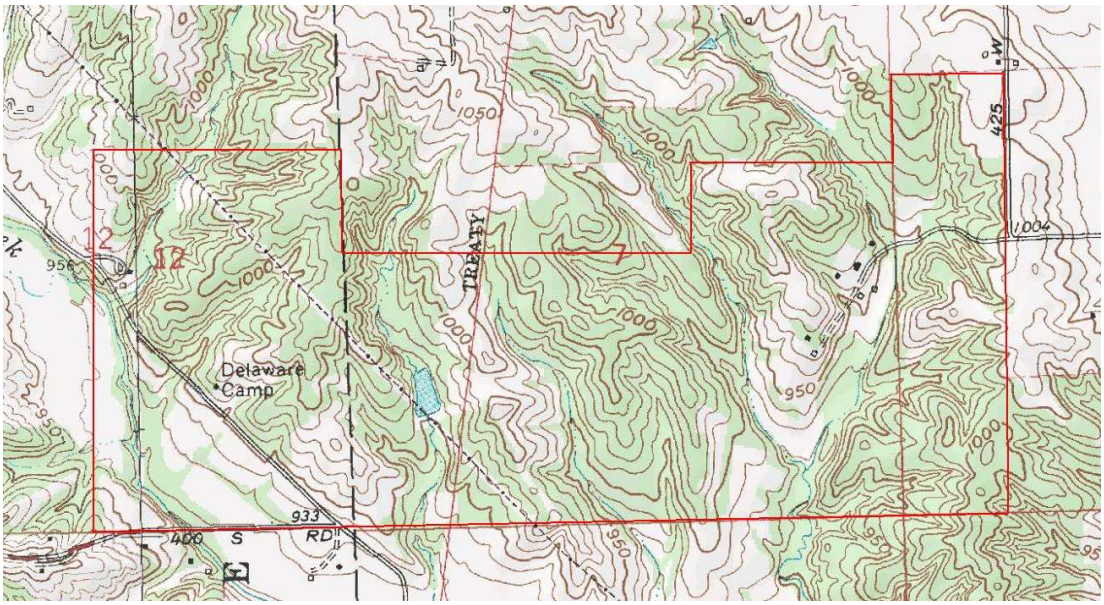

Figure 2: Topographical Map of MGBS

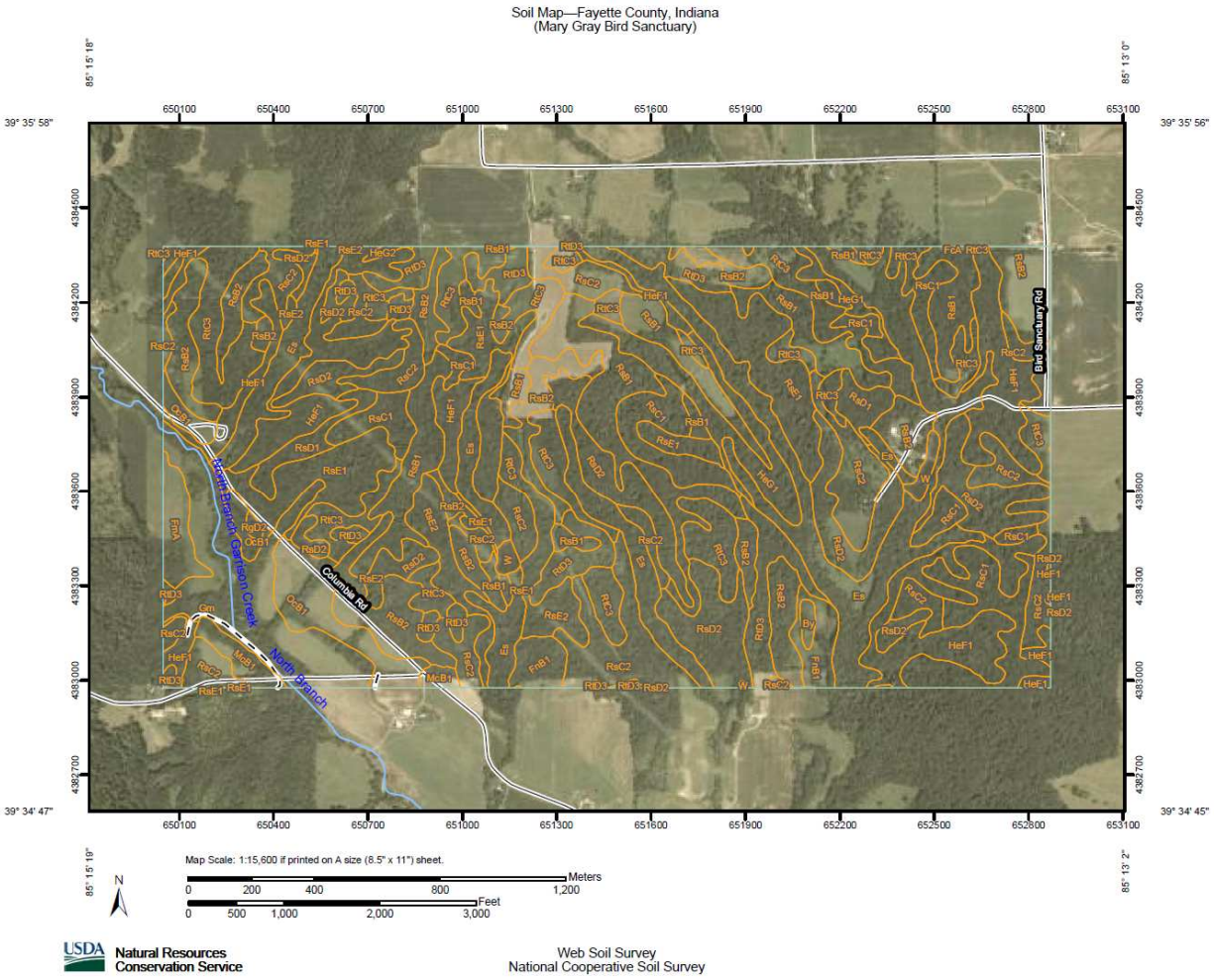

Figure 3: Soils of MGBS

LITERATURE REVIEW

Blake & Karr (1987) examined breeding bird communities and habitat characteristics in fifteen woodlots in east central Illinois. These woodlots were between 1.8 and 600 ha. Fifteen minute fixed radius point counts were used to establish the number of active nesting pairs. Points were located 150 m apart to minimize double-detections. They used an 11.28 m radius circle for measuring the habitat features, and took readings on shrub density, tree size and

species, and number of standing dead trees. Bray-Curtis analysis (BCA) and principal components analysis (PCA) were used to analyze the habitat data, and stepwise multiple regression was used for bird analyses. Significant correlations were found between woodlot area and individual bird species abundance, with various other habitat quality variables coming to the forefront in select cases.

The current study, though sharing several similarities with Blake & Karr's study, differs in significant ways, as well. The study questions are very similar; namely, both examined how breeding birds use habitat features. In addition, both studies were located in Midwestern temperate deciduous forests with mature canopies and well established understories. The Blake & Karr study, in comparison to the current study, examined locations with little habitat variety. Specifically, the current study included examination of young second growth and grassland habitats that were not addressed in the Blake & Karr study. Both studies did, however, use the same type of sampling procedure, including counting observed birds without calculating predicted values beforehand. The current study also differed in using larger radii points, longer counting periods, and a different form of multiple regression in analyzing the bird data.

Cherkaoui et al. (2009) addressed the issues of shape, size, and vegetative structure of habitat patches in relation to the number of wintering, breeding, and migrating birds that were using particular cork oak patches of fragmented forest in north-western Morocco. They used point counts for determining the bird populations and used five 10 m x 10 m plots in each patch to sample the habitat. For the point counts, they used ten minute intervals and unlimited radius points with the understanding that smaller patches would have points closer together and therefore possible double-entries for individual birds. They found that there was a strong

positive correlation between the tree and shrub density and diversity and bird species richness for all three of the above mentioned categories of birds.

Chesser (1998) analyzed the literature to establish a form of quantified distribution of a migrant passerine bird family (Tyrannidae, the tyrant flycatchers). He examined distributional data, as well as habitat references, to obtain concrete data. He then used the numbers he had obtained to run simple linear, quadratic regression, and stepwise regression analyses. He found that almost 100% of the tyrant flycatchers in the most extreme cold climates were migratory, and that those in the milder climates were as low as 20% migratory. In this case, it was the southernmost tip of South America, and parts of southern Brazil, respectively.

The significance of his study to the current one is to show that regression analysis is an effective method of analyzing avian research data when comparing the bird population to habitat and/or climate variables. In both studies, some form of regression analysis was/will be used to compare populations of specific Passerine birds to various environmental variables. It should be noted that Chesser used three simpler forms of regression analysis, whereas the current study will use a single, more complex form (namely ordinal logistic regression).

Chisholm & Leonard (2008) examined twenty-nine managed forest stands in New Brunswick, Canada, to determine the response of Bicknell's thrush (*Catharus bicknelli*) to commercial thinning of timber stands in their various stages of succession. They studied stands that had been clear cut and re-planted for commercial timber, with the stands ranging from too young for pre-commercial thinning to stands that had been thinned several years prior to their study. To detect the birds, they did a ten minute point count at each of five count locations

evenly spaced along the 1 km road that bisects each of the timber stands (~ 125 m radius count circles). They measured and recorded the trees, shrubs, and foliage density in plots located along a 100 m line transect that extended into the forest on either side of the road and was centered on the count point. When measuring the large-scale correlation between Bicknell's thrush and forest stage, they used single factor analysis of variance (ANOVA). For the finer scale correlations to individual habitat variables, they used stepwise multiple regression with thrush abundance as the dependent variable. They found a significant positive correlation between thrush abundance and increased stem density and minimum elevation of the stand.

There are a number of ways in which Chisholm & Leonard's study is similar to the current one. First, both used ten minute point counts for recording the bird populations, though their study used 125 m radius circles for plotting out the bird survey where the current study will use only 100 m radius circles. While the methods were not exactly the same, both studies also recorded both vertical and horizontal cover at different canopy levels. For comparing the bird results to the habitat results, both studies used/will use a type of multiple regression analysis, although Chisholm & Leonard used stepwise multiple regression and the current study will use ordinal logistic regression. Finally, a rather notable difference between the two studies was that Chisholm & Leonard's site was considerably further north than the current study.

Connolly et al. (2002) examined two mountains in southern Quebec to find the correlations between habitat features and usage by Bicknell's thrush. They used point counts in early morning and late evening to find what areas were being used by the thrushes, and then the habitat features were measured using a hybrid between line transect and quadrat sampling methods. They used detrended correspondence analysis (DCA) for the vegetation, principle

components analysis (PCA) for habitat structure, and discriminant function analysis (DFA) to look for differences between occupied and unoccupied sites. They found that Bicknell's thrushes seem to prefer areas with high tree density in conjunction with a high number of snags. The main relevance of this study to the current one is that they used the same size of fixed radius point counts (namely 100 m radius). Particularly notable is that Connolly et al. found similar results in bird/habitat relationships as Chisholm & Leonard, despite using different sized circles and almost all entirely different methods.

Dickson et al. (2009) conducted their study to determine what the effects of prescribed burning are on the local avifauna in the ponderosa pine (*Pinus ponderosa* Douglas ex C.Lawson) forests of northern Arizona and New Mexico. They examined four national forest sites and established a total of 134 treatment points and 144 control points, all of which were permanent sampling points. Permanent sampling locations were located roughly 250 m apart. The habitat features they measured were diameter at breast height (dbh), overall species composition, total tree density and snag density. The current study examined all of these features, with the exception of snag density. With patch scale habitat they added canopy cover to that list, although the current study looked at canopy cover in much more detail than their study did. They measured the birds by counting all birds seen or heard during a five minute period and estimating their distance into approximate predefined distance bins. The current study extended that time to a ten minute period and disregarded any specific distance estimates. They analyzed the habitat variables using PCA while only retaining habitat factors with eigenvalues >1.0. For avian species density they used multi-model inference within the statistical program DISTANCE v5.0. They used a spatial mixed model in SAS v9.1 for the examination of the interaction between

avian density, habitat, and fire response. In contrast, the current study used ordinal logistic regression in Minitab v15 Eng.

Farnsworth et al. (2005) examined a number of statistical methods that can be used for analyzing point count data. Of particular interest to the current study is their discussion of two of the methods, i.e., the double-observer method and removal sampling. The former uses a primary observer who counts birds from the point, and a second observer records any birds that may have been missed by the primary observer. They then switch roles at the next point. Removal sampling is a modification of the early method of sampling wherein individuals were captured and/or killed, thereby removing them from the population. Farnsworth et al. recommended a more environmentally friendly method that counts the birds when they are detected, and ignores them after their initial detection (treating them as having been removed from the population). This method divides the count period into time intervals with birds from the first interval being disregarded in the second, and so on. A variant of this is what was used in the current study, although it was necessary to use a single observer and to combine records from the two years of measurement.

Fischer & Fischenich (2000) examined the state of literature regarding riparian buffer strips and riparian habitat corridors. They noted that while there is much confusion in the literature, the general understanding is that riparian buffer strips are primarily maintained for the purpose of reducing pollution, especially non-point-source pollutants (NPSPs), whereas riparian corridors are primarily managed for the benefit of wildlife habitat and movement. Another point that they raised was that corridors in particular are most useful when connecting two larger areas

of habitat, rather than being stand-alone habitat in and of themselves. They also listed a number of studies that discussed the benefits of various types and/or sizes of both forms of riparian habitat. Of particular note is a table wherein they showed that a riparian corridor managed for birds needs to be a minimum of 50 m wide and would ideally be ≥ 100 m. This information will be useful in making recommendations to the Audubon society on the management of the land along the major stream that flows through the southwest corner of the Mary Gray Bird Sanctuary. The current riparian corridor along the north branch of Garrison Creek (the non-seasonal creek in the southwest of the property) is between approximately 110 m and 130 m. The overall length of the corridor is only roughly 260 m before it continues into larger blocks of forest on either end. Considering all of these measurements, it is evident that the riparian corridor on MGBS is above and beyond the ideal size to function quite well for bird habitat, pollution and runoff preventative, as well as any other functions of riparian corridors.

Fletcher (2005) examined ten grassland sites in northern Iowa to determine their usage by breeding male bobolinks. Within each study site, he delineated at least two 150 x 150 m plots. Each site had one plot with edge habitat on only one side, and one with two edges. Five of the sites were large enough that he was able to add a third plot which did not contain any edge habitat at all. He used four fixed-width line transects across each plot and counted all bobolinks found within 25m of each transect, recording the location within the plot of each. He conducted his surveys during the first four hours after sunrise, as breeding birds are most active then. He used logistic regression to determine the correlation between breeding male bobolink numbers and proximity of an edge. He found that occurrence of breeding male bobolinks was greatest in edge-free plots and least in double-edge plots.

His findings will be of particular significance in establishing a management regime for the grasslands in the southwest corner of MGBS where there are three interconnected strips of edge habitat that subdivide an area of ~ 9.8 ha. As they stand currently, the tree lines leave only small grasslands of no more than 1.7 ha. These tree lines could be contributing to the lack of certain grassland birds such as bobolinks and eastern meadowlarks, and, if removed, may improve their populations. According to the Northern Prairie Wildlife Research Center's web database, bobolinks prefer tracts of grassland ≥ 10 ha and meadowlarks prefer ≥ 2 ha habitats. Additionally, Fletcher's study demonstrates that regression analysis (specifically logistic regression) is an effective form of statistics to use for bird/habitat studies.

Frelich, et al. (2003) thoroughly mapped all trees greater than 1.5 m tall in two stands in northeastern Minnesota. They then created sub-plots within which they measured the understory vegetation in detail. They also measured the canopy density and light penetration, as well as the soil composition in the sub-plots. Using a battery of statistical tests, including ordinal logistic regression, they compared species distribution to various environmental variables. They found nitrogen mineralization and light levels were higher in sub-plots dominated by shrubs, as opposed to those dominated by herbaceous plants. They also found that incidence of tree seedlings was independent of the shrub and herb communities.

Goslee (2006) compared four different habitat survey methods and how they behaved in patchy (i.e. non-uniform) landscapes. She examined systematically-located quadrats, randomly-located quadrats, non-nested multiscale schemes, and nested multiscale schemes. The multiscale schemes were a modified Whittaker plot and a North Carolina Vegetation Survey (NCVS) plot,

respectively. Each of the four methods were applied to ten simulated levels of patchiness varying from zero to one hundred, with zero being uniform across the area and 100 having large clearly defined patches. She found that all four methods provided good estimates of mean cover for the entire area, while there is significant disparity among them when looking at species cover estimates when patchiness increased. Systematically located quadrats were most affected by patchiness, while randomly located quadrats were much less sensitive. The differences between nested and non-nested multiscale plots were negligible, but both overestimate species richness where patchiness is low, and both underestimate it when patchiness is high. They are, however, more apt to detect rare species than the quadrat methods, as they encompass a larger percentage of the total area in the given study. She also noted that the shape of the sampling plot made little difference in the outcome of the sampling. The current study will use a form of systematically located plots, using circular areas around each bird count point. Overall, the patchiness of the bird sanctuary is fairly low, with large tracts of uniform habitat in clearly defined areas.

In an effort to determine the best means of accurately detecting forest bird species and density, Lee & Marsden (2008) used a distance sampling point transect method and adjusted the time spent at each point as well as the presence or absence of a ten-minute “settling down” period. They positioned points 200 m apart along fifteen transects, and randomly located the transects between 0.25 and 1.0 km apart, with the one caveat that they avoided roads and other edges that would disturb the continuity of the forest habitat along the transect. They divided each ten-minute count period into five two-minute intervals, and only recorded the birds in the interval in which they were first detected. They re-sampled a subset of eighty-four points on a different day with two consecutive count periods at each: the first to represent absence of a

settling down period, and the second to include the settling down period. They found that the number of new bird detections dropped off significantly over the ten-minute period, with over 95% of the bird species being detected by the eight-minute mark. Overall bird density estimates only changed slightly over the course of the ten minutes. They found that the numbers both of species and of individuals decreased significantly when a settling down period was implemented, implying that birds continue to move away from the observer rather than calming down and moving back in closer. The current study will use a full ten minutes at each point, and will not use a settling down period. It will also use 200 m spacing between observation points. The basic trends that Lee & Marsden described in their study were also noted in this study, although no focus is being put on that, as that is not the question being addressed.

Nixon et al. (2001) conducted modified point count surveys of six mountains in New Brunswick that had previously experienced some clear-cut logging. They positioned points 200 m apart along transects that ran vertically over the peak of each mountain and surveyed each point a total of six times. They visited each site three times in the first three hours after sunrise and three times just before dusk. They did not survey during high wind or during precipitation. They counted all Bicknell's thrushes that were detected within 75 m of the plot center. Count at each point lasted for roughly ten minutes. They laid out transects that started 15 paces from the point and were 50 m long and measured all trees along the transects and noted whether they were regenerated growth or original growth that had been missed or skipped during logging. They also measured canopy density using a convex densitometer. They analyzed their data using stepwise logistic regression.

Pimm & Askins (1995) created a statistical model to compare to observed data so see how deforestation may or may not affect bird population declines and extinction. They looked at historical data for forest coverage and bird populations, and established a mathematical model that should be able to predict trends. They applied this model to the list of known extinctions and the peak of deforestation, and they found that the model alone was insufficient to predict extinctions, as it predicted several times greater extinctions that actually occurred. There were, however clear trends noted of bird populations suffering drastically when deforestation occurred on a large scale.

Register & Islam (2008) studied ten sites in the large forested region of southern Indiana, that is comprised of the Hoosier National Forest, Morgan-Monroe State Forest, and Yellowwood State Forest, to see if different selective forestry practices affect the breeding use of those areas by Cerulean warblers (*Dendroica cerulea*). They used point counts with survey points 200 m apart in a 7 point x 7 point grid for seven of the ten study sites, and used the same spacing but a smaller grid on the remaining three sites (all in the two state forests) because of private property constraints. They spent seven minutes at each survey point, sub-divided into a three minute observation period, a one minute playback period of recorded males' songs, and a final three minute observation period. All surveys were conducted between 5:30 and 10:30 am and never during rain or on windy days, conditions that would not allow bird song to be detected. The silvicultural histories of each plot were recorded based on data from the Indiana Department of Natural Resources and the Hoosier National Forest, and all fell into one of three categories. They were either unharvested (control) sites (35-100+ years old), single tree selective cut sites, or combined single tree and group selective cut sites. Both selective cut types were between two

and thirty years since the last cut. Using the detection data and the tree harvest data, they overlaid them using Geographic Information System layers to see any correlations between bird detections and habitat structure. The current study will use 200 m spacing of the survey points, just as they did, as well as using a similar part of the early morning for counting birds.

Register & Islam used an analysis of variance (ANOVA) at a 0.05 alpha level to test for statistical differences between the three treatment types. The data were non-normal, so they had to use a Spearman's rank correlation to find correlations between bird detections and years since harvest. They did not find any significant differences between bird detections and either age treatments or harvest methods. This indicates that Cerulean warblers are able to use all types of re-grown forest, regardless of presence or absence of selective cutting. It was suggested that this is because Cerulean warblers use the edges of the canopy surrounding small gaps caused by windfalls in mature forest, a condition mimicked by selective cutting methods. The same concepts can be applied to MGBS, despite that Ceruleans were detected only once during the current study. There are, however, other more common canopy nesting birds that may fit similar trends as Cerulean warblers, such as red-eyed vireos and Eastern wood-pewees.

Robbins, et al. (1989) used several years' worth of the annual North American Breeding Bird Survey data to examine overall bird population trends for forest dwelling and scrub dwelling species. They also incorporated field data both from Mexico and from the United States to be able to compare the bird data to habitat trends. They found that the majority of the bird species that are year-round northern residents did not suffer notable declines during the time of their study. Most of the forest dwelling birds that migrated, however, experienced significant declines over the period examined. These declines coincided with trends of deforestation both in

the wintering grounds and the breeding grounds. The scrub-dwelling species did not experience any notable declines.

Ruch et al. (2012) performed an inventory study of Mississinewa Woods to determine the flora of the property and to assess its conservational quality. Mississinewa Woods is a property that is mostly a narrow riparian forest surrounded by crop fields. Of the things they measured, one was the mean Coefficient of Conservatism (mean C). Mean C is based on a number from one to ten that indicates how strongly a plant species is associated with an undisturbed habitat. All exotic species are given a value of zero. They found the mean C for Mississinewa Woods to be 3.0 with a total of 311 species total. While they state that floodplain forests typically have lower mean C values than some other habitats, they also state that human activity has both directly and indirectly contributed to the low mean C for this property. These human impacts include actively maintaining the loop road on the property, using one central area as a hay field, and the disruptions caused by increased fertilizer and pesticide run-off from nearby fields. They noted that the majority of "undesirable" species were found in association with the fields on the property, and, as a result, recommended to the managing agency to return those fields to forest. This would drastically reduce the run-off problems, as well, not to mention considerably widening the effective habitat found in the riparian corridor.

During the years of 1991 through 1994, Victoria Saab (1998) examined the cottonwood (*Populus* spp.) riparian forests that border the South Fork of the Snake River in southeastern Idaho to determine what land use factors affected the habitat in those areas and, in turn, populations of breeding birds. She recorded data for bird distribution and abundance and

vegetation characteristics, and determined what vegetation and land use factors affected the bird data. She used both ANOVA and MANOVA for analyzing the individual bird data sets and then used Poisson regressions for comparing the means from the bird analysis to the large scale habitat data to search for overarching trends. She found that both bird species richness and relative abundance were most reduced in areas that were recreational campgrounds. The ground nesting neotropical migrants specifically were harmed most by livestock grazing, as well as being most affected by habitat fragmentation. There were also some species that were unaffected by patch size in undisturbed areas but were affected by patch size in areas that were managed as either camp grounds or as grazing land. She also found that the landscape level features had the greatest impact on bird species richness and distribution, with finer level habitats bearing less significance. Overall, she found that the habitat features that led to the greatest bird species richness were natural and heterogeneous landscapes, large patch size, close proximity of other patches, and microhabitats with fairly open canopy layers. Her main recommendation for management consideration of riparian habitat, at least for her study area, was to focus on landscape level features when managing and when selecting reserve areas.

Seavy et al. (2005) conducted a study in southwestern Oregon to demonstrate what statistical tests are good for use with point count bird survey data. They did point counts in sagebrush habitats both with and without encroachment from western juniper and then narrowed down their analysis to the five most abundant bird species that occurred in both habitat types. They state that, because of various problems with point count data collection techniques, the best statistical methods to use are those that fall under the umbrella of generalized linear models or GLMs. Among these are several types of regression, including logistic and binomial regression,

although they used a combination of techniques known as “Poisson regression”. Although other factors come into play, they found that all species examined showed an increase in statistical power with an increase in number of sampling stations, though the increase was not consistently linear.

Stonehouse et al. (2003) conducted a floristic inventory and analyzed the structure of the plant communities of Botany Glen in Grant County, Indiana. They established permanent plots throughout the property and sampled all woody stems > 5 cm diameter at breast height (dbh) and within 15 m of the plot centers. Each tree was identified by species, dbh measured, and its distance from the plot center determined. The understory was also recorded for both woody shrub density and herbaceous cover. A modified Daubenmire cover class scale was used for expressing herbaceous cover. While their specific methods are not exactly the same as those used in the current study, the basic techniques are very similar. Their tree plots were 15 m in diameter, where those in this study were 12.6 m. Their study also included those trees between 5 – 10 cm, where the current one only includes those that are ≥ 10 cm. The modified Daubenmire cover classes were used in both studies for initial recording of understory densities, although the current study will use them for shrubby horizontal cover and all levels of vertical cover rather than just herbaceous cover.

Vos et al. (2000) constructed a detailed description of what should be considered when designing a monitoring program. As the current study is intended to be a baseline study for a future monitoring program, the concepts they discuss are quite pertinent. They indicate that a monitoring program must have a clearly defined purpose beyond merely collecting information.

It must state what the intended goal is from a biological, economical, or sociological standpoint. They list seven main components that need to be included and defined for an effective monitoring program. These are monitoring objectives, objects and variables, sampling strategy, data collection, data handling, maintenance of aspects of the program, and overall organization of all aspects. There are, however, constraints that must be addressed for any or all of the components of a monitoring program. The constraints that they mention are ecological, technical, methodological, statistical, and physical. In addition, they warn against solely basing one's study objectives on statistical power, rather than balancing them with actual diagnostic power as well. They state that the main priority of a monitoring study should be measurement of variables that describe the intended management actions and that examine their efficacy.

Wilcove (1985) set up eleven study sites in eastern North America to determine the levels of nest predation as well as what factors may affect those levels. He set up artificial nests of an open-cup design both near the ground and elevated one or more meters off the ground and placed three fresh Japanese quail (*Coturnix japonica*) eggs in each. At the end of seven days, he checked back to see the percentage of nests raided. He used this as an indicator of predation rate for that particular forest patch size and nest height. He also built twenty-two artificial cavity nests roughly patterned after the cavities excavated by downy woodpeckers, nailed them to trees, placed three quail eggs, and checked the nests for predation as he had done with the open nests. He found that a basic trend could be found showing that the larger the patch of forest, the lower the nest predation. He also found that ground nests are preyed upon more than elevated nests and that open cup nests suffer much worse predation than cavity nests.

METHODS AND MATERIALS

Permanent Plot Grid: —A grid of permanent plot markers was established so that current base line conditions could be determined and future changes could be documented in a scientifically rigorous manner. Plot centers occurred at 200 m intervals on lines running East – West. Plots were numbered from 1-60 from east to west (Fig.4). The 200 m interval was chosen, as this is a standard distance for fixed-radius point count methods used to assess bird species abundance (Elzinga et al. 2001; Lee & Marsden 2008). Based on the shape and size of the property, four lines with thirteen plots each, a fifth line with seven plots, and a single plot in a sixth row were established, for a total of sixty plot centers. Each plot center was marked by a six-foot metal fence post for ease of locating at a later time. The exact coordinates of each plot center can be found in the table in Appendix 2. The approximate locations of each plot center can be seen in the map of Mary Gray Bird Sanctuary (Fig. 5), as indicated by the green dots. The property boundary itself is marked with the red line. It will be noticed that the fifth plot from the left (west) in the second row from the bottom is shifted several meters to the left. This is because it would have been in the middle of the pond had it been placed on its correct position on the grid. To solve this problem, it was placed roughly 2 m from the shoreline to allow for vegetative analysis on all sides of the plot center.

Forest Composition / Structure Analysis: — At each permanent plot center, woody species composition was documented in 12.6 m radius circular plots centered on the fence post marker. Within each plot, all living woody stems with a diameter at breast height (dbh) $\geq$ 20 cm were sampled. For each stem, the dbh, the species identification, the distance from the center, and the azimuth (exact, using compass) from the plot center were recorded in a clockwise fashion starting with due north. Live tree data was used to calculate basal area/ha, frequency/ha,

density/ha, and relative importance value of each tree species encountered in the sampling (Elzinga et al. 2001; Stonehouse et al. 2003). All standing, dead woody stems with a dbh ≥ 10 cm were measured, and distance and azimuth recorded, and they were visually evaluated for characteristics relevant to wildlife habitat, including bark condition (intact, partial, absent) and presence of cavities, though no precise matrices were used to evaluate these features. The tree stem densities were then labeled as extremely low for those plots with greater than zero but less than 100 stems per hectare, low for those with greater than 100 but less than 150 stems per hectare, medium low for those plots with greater than 150 but less than 180 stems per hectare, medium density for plots with 180 to 200 stems per hectare, medium high for plots with 200 through 220 stems per hectare, high for plots with 240 through 280 stems per hectare, and extremely high for those plots with 300 stems per hectare or more.

Percent overstory vertical cover was determined by a single digital photo taken vertically at the center of each plot. In each plot, a Velbon S-4000 tripod was set up, leveled using the built-in level, and extended to maximum height (approximately 145 cm) to minimize the effect of understory vegetation. Two photos were taken, one of the post's marker tag, then one of the canopy. The photos were all taken when the sky was a fairly bright overcast to illuminate the background of the photos without washing them out. They were then converted to 800 x 600 pixels grayscale using IrfanView, and the gamma correction set to 0.8 and contrast set to -50 to maximize clarity in distinguishing between leafy cover and sky. Each photo was then saved as a bitmap (not the original jpeg). The edited photos were analyzed using HxD, a program that reads the hexadecimal code for each pixel in the photo and produces a bar graph with relative proportions, percent of the total photo, and number of pixels for each shade in the photo. In this case, it looked at the 256 shades from black to white. It was noticed in preliminary analysis that

photos that contained both foliage and sky produced a bar graph that was clearly bimodal. As a result, the total percents of the photos for each shade approaching and including white, starting with the minimum between the two peaks, were summed to produce a total percentage of sky for each photograph. This was, in turn, converted to percent cover by simple subtraction from 100%.

Percent shrub vertical cover was determined via visual estimates of the area within a circle that extended 12.6 m from the center of the plot, the border of which was marked with survey flags in each of the cardinal compass directions. The percent of shrubby vegetation was then visually estimated using the modified Daubenmire cover class scale: CC0 = 0, CC1 = 1-7%, CC2 = 8-25%, CC3 = 26-50%, CC4 = 51-75%, CC5 = 76-93%, CC6 = 94-100%. A similar procedure was used for the herbaceous groundcover and for separating out the sub-canopy cover from the canopy cover. The total canopy (i.e., sub-canopy plus top-tier canopy) was assessed photographically as stated above. Horizontal cover by both woody and herbaceous plants was recorded for 50 cm thick strata from ground level to 250 cm above ground. These were taken at each cardinal compass bearing, proceeding (as with the tree data) in a clockwise fashion starting with north. Percent horizontal cover was averaged for each stratum such that each plot has a total of only five cover readings, one for each layer. In each plot, a board that was painted in alternating bands of light and dark 50 cm wide was tied to the t-post that marks the plot center and the researcher stood approximately 15 m from the plot center and looked back at the board to visually estimate the percent of each band that was visible, using the modified Daubenmire cover class scale. When describing shrub vertical cover in the results below, cover classes one and two were labeled as low density, three was labeled as medium low density, four was labeled as medium density, five was labeled medium high density, and six was labeled as high density.

Avian Analysis: — Breeding bird species data was recorded using fixed-radius point count methods (Elzinga et al. 2001). Count points were located at each of the plot centers, such that each circular plot was 200 m in diameter with the edge of one just touching the edge of the next (Fig. 6). Plot centers were at least 100 m from the nearest property boundary. Sampling was accomplished by standing at the plot center for five minutes and recording all bird species that were seen or heard (Elzinga, et al. 2001). Sampling occurred during the first three hours immediately after dawn each day until all plots had been sampled. This sampling period was chosen since most avian species are most vocal during this time (Register & Islam, 2008). The majority of birds present were identified via sound recognition. A small microphone/amplification unit was used to enhance the calls of those birds which were detected from the plot center but were too quiet to identify accurately. Those birds which were detected with the microphone but not detected at all with the naked ear were not included, as they were likely outside the 100 m radius of the individual plot. A portable recording device was used in some cases to collect sound data for identification of those calls that could not be immediately identified. As per Blake & Karr (1987) the large highly mobile bird species, such as crows and larger raptors, were not counted unless a nest was found, as they are not highly dependent on the habitat structure below the treetops.

Point-count bird data was analyzed using ordinal logistic regression, a statistical method similar to those described by Saab (1998) and Chisholm & Leonard (2008). The goal of these tests was to determine bird species abundance and to evaluate the associations between the plant community composition/structure and presence of bird species. The variables of interest were frequency of occurrence of the ten most abundant bird species; percent cover, both vertical and horizontal; basal area of woody stems over 10 cm; and statistical correlation between the bird

variables and each of the vegetation/habitat variables. The results of the statistical tests were used to determine which birds showed statistically significant correlation(s) between abundance and habitat variables and, for those that were significant, which habitat variables showed the association.

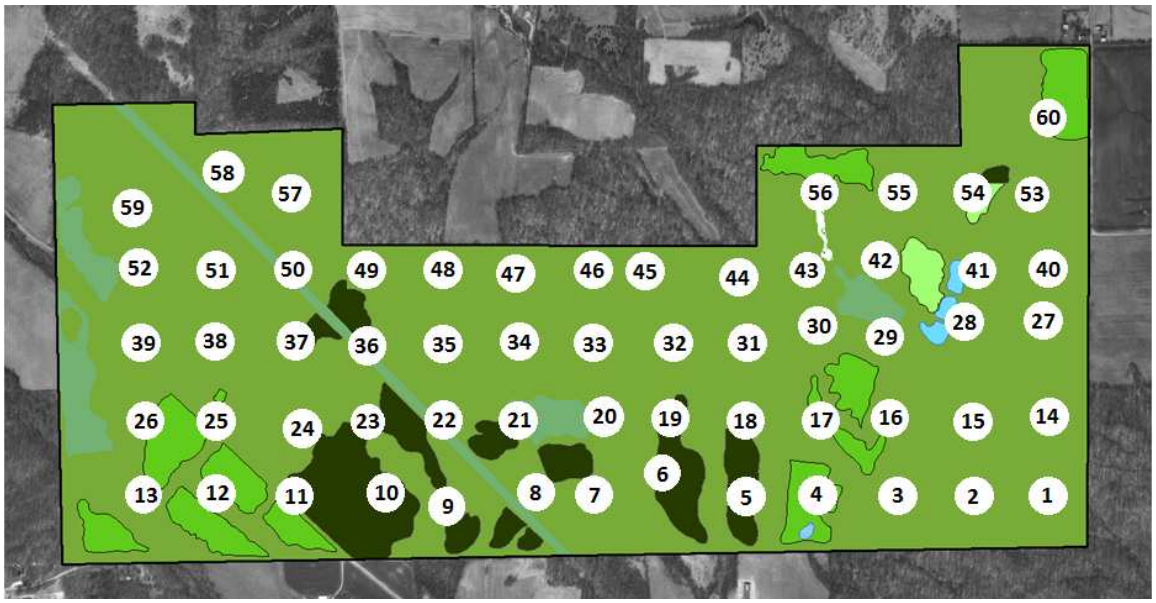

Figure 4: Map of MGBS with Plot Numbers

Figure 5: Map of MGBS Post Locations

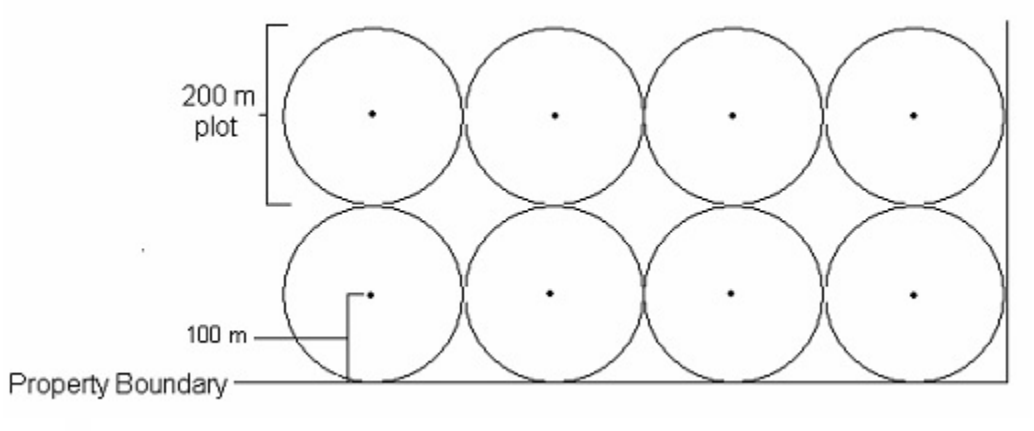

Figure 6: Plot Layout Design

RESULTS AND DISCUSSION

Forest structure analysis: — While the majority of Mary Gray Bird Sanctuary (MGBS) is woodland, there are a number of different types of forest present with a range of maturity levels, as well as, different distinct types of species composition. At first glance, the percent basal area (BA) seems to be extremely unpredictable from looking at the map (Fig.7), but becomes more understandable when one looks at the finer differences present (see Appendix 3). It should be noted that areas having similar percent basal areas may have completely different species composition. A perfect example of this disparity is that plots 1-3 have similar basal areas. Plots 1 & 2 obtain their BA from a low number of large hickory trees with few other species found, while Plot 3 gets its BA from a somewhat larger number of smaller woody stems, especially beech and maple**.** These trends become even more apparent when one reviews the following plot-by-plot analysis.

Plot 1 had a stem density of 160 trees per ha, which when compared to the rest of the property, this was determined to be a medium-low density. The basal area of this plot was 25.88 m^2/ha. The tree composition at this plot was primarily oak and hickory. These matrices, along

with visually observations, suggest that this area was in a later stage of succession. The canopy was open enough that there was medium-high shrub vertical cover. The most common bird species at this location were Eastern wood-pewee, wood thrush, ovenbird, and red-bellied woodpecker, each with three individuals detected during the count period.

Plot two had a stem density of 80 trees per ha and a basal area of 11.59 m^2/ha. Although both of these matrices were fairly low in relation to the property as a whole, like Plot 1, this was a mature forest of primarily beech and hickory. It is probably that the beech trees will likely decrease in number as oaks and hickories continue to increase. Due to low density, there was ample light reaching the ground, allowing for a medium-high shrub vertical cover. The most abundant bird species were Northern cardinal, Eastern wood-pewee, and wood thrush, each with three individuals detected during the count period.

Plot 3 had a density of 160 trees per hectare and a basal area of 23.96 m^2/ha. This was determined to be a plot with medium-low tree density. This section of the woodland was a mixed deciduous forest with a large percent of sugar maple (*Acer saccharum* Marshall), as well as some red oak (*Quercus rubra* L.), tulip (*Liriodendron tulipifera* L.), and black locust (*Robinia pseudoacacia*). Despite this being forest interior and having a high number of sugar maples, the canopy still was open enough that there was medium-high shrub vertical cover. The most common bird species were all forest interior species, namely: Eastern wood-pewee, wood thrush, and red-bellied woodpecker, at three individuals each.

Plot 4 was centered in an open area and was on the edge of a seasonal wetland. There were no trees within the 12.6 m radius plot, and the amount of shrub cover was dependent on how recently the area had been mowed. If it has been more than a year since mowing, then there was a healthy willow scrub on the edge of the wetland. If it has been mowed recently, then the

cover is only that of the tall herbaceous plants growing for less than one season. There was also considerable edge habitat surrounding the clearing containing the wetland that was inside the bird count circle of 100 m. The dominant bird species at this location was gray catbird. This is not surprising due to their affinity for both edge and wet scrub. When the willows have had a chance to grow, there are also warbler species such as American redstart that forage in this location.

Plot 5 had a high stem density at 380 trees per hectare. The basal area was 32.76 m^2/ha, which is lower than might expect based on the stem density. This plot was a red pine plantation with a large number of small diameter trees. There were also several other young deciduous trees of various species present. With the high density at this plot, and therefore low light penetration to the ground, the shrub vertical cover was medium-low. This plot was populated by a large number of both Acadian flycatchers and Northern cardinals, with five and four being detected respectively. Despite the high numbers of both of these species, the overall species richness was remarkably low. This is a phenomenon that has been reported previously in plantations of non-native trees like this one.

Plot 6 had a density of 480 trees per hectare, which is extremely high compared to the rest of the property. The basal area was 37.74 m^2/ha and, like plot 5, was due to a red pine plantation. There was also one medium size black cherry tree and one medium aspen tree. Like plot 5, the high density leads to medium-low shrub vertical cover. Unlike plot five, however, there were considerably more bird species present, namely, Northern cardinal, Acadian flycatcher, red-eyed vireo, and ovenbird, all having three individuals detected.

Plot 7 had medium stem density at 180 trees per hectare and a low basal area of 9.77m^2/ha. The species composition was mixed and included oak, walnut, cherry, elm, and

basswood. This indicates that this area is medium aged, in that cherry trees often exhibit heart rot before reaching old age, elm trees in this part of the country typically die from Dutch elm disease (pers. observation), and basswood trees are fast growing and have a maximum age of 140 years (compared to 400 years for red oak and 250 years for black walnut)(Virginia Tech Department of Forest Resources and Environmental Conservation 2012). Shrub vertical cover was moderate, as would be expected for an area of forest with this wide of variety of trees, a state often observed to coincide with slightly more light penetration of the canopy. The top bird species for this plot were Eastern wood-pewee and tufted titmouse, both with three individuals.

Plot 8 had a density of 240 stems per hectare and a basal area of 28.19 m^2/ha indicating a medium-high density. This was a medium-young mixed deciduous forest with several holes in the canopy allowing light for three shorter, but good-sized, red cedars and fairly high shrub vertical cover. The habitat measurement circle was fully forest interior; however, it was fairly near a high-tensile power line easement and just off the fire break that bisects the property. This means that their associated edge and scrub will affect the bird species present to some extent. The top bird at this location was Northern cardinal with four individuals detected.

Plot 9 was medium density with 180 stems per hectare and a comparatively high basal area of 29.19m^2/ha. This increased basal area is most likely because of its proximity to a small stream. The overall species composition was mixed deciduous, including two medium-large sycamore trees. It had moderate shrub vertical cover and a small amount of edge. The top bird species were Northern cardinal and Eastern wood-pewee, both having two individuals.

Plot 10 had very high density of 480 trees per hectare and a basal area of 41.63m^2/ha. The high density is due to the fact that this plot was in the heart of an established white pine grove; there were some black locust trees as well. As is often preferred by white pines, it was in

an area of well-drained soil near the top of a hill. Because of the high tree density, shrub vertical cover was medium-low. The dominant bird species at this plot was Northern cardinal, with four individuals found.

Plot 11 was also on the side of a hill with the terrain sloping southward toward the road and ultimately the north branch of Garrison Creek. The density was high with 380 trees per hectare and a basal area of 35.87m^2/ha. The canopy was fairly dense, leading to low light at ground level and, therefore, low shrub vertical cover. Like plot 10, the tree species composition was primarily white pine with some black locust mixed in. The dominant bird species was Northern cardinal, with two individuals detected.

Plot 12 was on the edge of a substantial tree line in the southwest corner of the property. To the northeast of the plot center was a short grass prairie/hay field with the tree line to the southwest side of the plot. The number of stems were medium-low density with a density per hectare of 140 and a basal area per hectare of 11.96 m^2/ha. The composition of the tree line was mixed deciduous with a predominance of hackberry. The shrub vertical cover was low. The top birds detected were both low numbers, namely, one each of Northern cardinal and red-bellied wood pecker.

Plot 13 was in the riparian corridor of the north branch of Garrison Creek. The canopy layer was fairly dense in part of the plot and quite open over the creek itself due to meanders and tree-fall. The stems were medium-high density with 260 per hectare, and the basal area per hectare was 26.90 m^2. There was virtually no shrub cover. There was a hay field/grassland within the bird detection area. Despite the presence of both water and grassland, the top bird was still Northern cardinal with only two individuals detected.

Plot 14 had medium-high density forest at a density of 240 trees per hectare and a basal

area of 49.46 m^2/ha. The composition was a mix of moderately mature deciduous trees. There was medium-high shrub vertical cover. This area was deciduous forest interior with no edge or open area anywhere within the bird detection zone. As a result, the dominant birds were forest interior species, namely, Acadian flycatcher and ovenbird with six and five individuals, respectively.

Plot 15 was medium-high density with 220 stems per hectare and a basal area of 25.53 m^2/ha. Like Plot 14, this plot was entirely deciduous forest interior; however, this plot contained only beech/maple forest with no notable presence of oak or hickory. As is common with areas that have a high population of sugar maple, the canopy was fairly dense and blocked enough sun to the forest floor that there was no shrubby ground cover. The predominant bird species were wood thrush and tufted titmouse, both species having four individuals detected.

Plot 16 had medium-low density at 160 trees and 14.55 m^2/ha basal area. This plot was fairly young mixed deciduous forest with somewhat open canopy. Thus, there was enough light for moderate shrub cover at ground level. It was located right by the bank of a seasonal stream and in the flood plain for that stream. It was close enough to both edge and grassland that it had birds more typical of edge. The primary species detected was Northern cardinal with three individuals.

Plot 17 had low tree density; namely, one cedar tree within the habitat measurement circle. That tree put the density per hectare at 20 stems with a basal area of 0.80 m^2/ha. The remainder of the measurement plot was primarily grasses and forbs with some scrub meadow with low shrub vertical cover. Just outside the habitat measurement area but inside the bird detection circle was deciduous forest. Due to the presence of the small meadow and abundant edge at this bird survey plot, the primary bird species detected was Northern cardinal with three

individuals detected.

Plot 18 had a density of 300 stems per hectare and a basal area of 23.88 m^2/ha, classifying it as high density. Part of the plot was red pine plantation and part of it was fairly young mixed deciduous forest with the post location roughly between the two. Shrub cover was medium-high. This particular combination appears to be remarkably conducive to small songbirds, as the top two bird species found here were tufted titmouse and Acadian flycatcher, with five and four individuals, respectively.

Plot 19 was medium density with a density of 180 trees per hectare and a basal area of 16.66 m^2/ha. The forest composition within the measurement circle was fairly young mixed deciduous forest, although it was just outside a red pine plantation that falls well within the bird detection area. The shrub cover was medium-high. The top bird species was Northern cardinal, with five individuals detected.

Plot 20 had medium-high density with 200 stems per hectare and a basal area of 28.26 m^2/ha. It was medium-age mixed deciduous forest, though the majority of the trees were nut trees, such as bitternut hickory (*Carya cordiformis* (Wang.) K. Koch) and black walnut (*Juglans nigra* L.). Shrub vertical cover was medium-high. The plot center was right next to the hiking trail/service road, allowing for very easy access. The top bird species found at this location were tufted titmouse and Northern cardinal with five and four individuals, respectively.

Plot 21 was medium-high density with a density per hectare of 240 trees and a basal area of 15.23 m^2/ha. The forest composition was mixed deciduous with some light entering from the side at an area of scrubby second growth that allowed for medium-high shrub vertical cover. It was also close to the hiking trail/service road. The fire break was very close to the boundary between plots twenty-one and twenty-two. The top bird species detected at this location was

Northern cardinal, with three individuals found. Early in the summer of 2009, there was a mixed feeding flock of a dozen or more small warblers that was seen between plots twenty and twenty-one; however, they were seen outside the count period and were therefore not included in the count.

Plot 22 had a low density of 40 trees per hectare and a basal area of 3.85 m^2/ha. The two trees within the measurement circle were both medium size ash trees. The plot center location itself was shifted west by a few meters to avoid being in the water of Pond 4. There was medium-low shrub vertical cover, although right along the bank of the water was a near-continuous line of shrubs. There was a pine grove within the bird detection area, though it was outside the habitat measurement circle. The top bird detected was catbird, with five individuals detected. Also of note was the one Bell's vireo that was seen singing from the tip of a twig at this location during the summer of 2009.

Plot 23 was medium-low density forest with a stem density per hectare of 160 and a basal area of 41.53 m^2/ha. This plot was primarily mature mixed deciduous forest but with a few pines. The shrub vertical cover was medium-low. There were not any large numbers of any one bird species, although there were a variety of species found. The top species, each having only two individuals, were Acadian flycatcher, Eastern wood-pewee, red-eyed vireo, and white-breasted nuthatch.

Plot 24 was low density deciduous forest interior with a density of 120 trees per hectare and a basal area of 9.72 m^2/ha. The forest at this location was mixed deciduous of moderate maturity. The shrub vertical cover was medium-low. The bird numbers there were below average with the top bird species being red-eyed vireo with only two individuals detected.

Plot 25 had no trees within the habitat measurement circle, although there were scattered

mature trees throughout the bird detection area. As a result, the basal area per hectare and the stem density were both zero for this measurement location. Shrub vertical cover was very low. This plot was located in what was at one time a Girl Scout camp, and, therefore, was formerly mowed lawn. Large portions of it are still mowed with a brush hog occasionally. The overall habitat type would be considered an open deciduous forest due to the significant number of trees. There was also well developed edge along the perimeter of the camp. The top bird species found at this location were white-breasted nuthatch and Eastern wood-pewee, with three and two individuals, respectively.

Plot 26 was medium density mixed deciduous forest with a density per hectare of 180 trees and a basal area of 17.41 m^2/ha. There was moderate shrub vertical cover. This area was in a healthy riparian corridor along Garrison Creek, but not right by the bank of the creek. In addition to the trees in the habitat measurement circle, the bird detection area also included grassland/hay field, edge habitat, and a relatively major second to third order stream. The top bird species detected at this location was red-bellied woodpecker with two individuals detected.

Plot 27 had a density of 220 trees per hectare and a basal area of 17.51 m^2/ha. This indicates that the trees in this location were fairly young, since the forest was medium-high density but the total basal area was still relatively low. This was a mixed deciduous forest interior on slightly elevated ground. The top bird species detected at this location were Acadian flycatcher and red-eyed vireo, with three individuals each.

Plot 28 had a high tree density of 280 stems per hectare and a total basal area of 38.74 m^2/ha. The composition of the forest at this location was mixed deciduous, with a portion of the high stem density being due to an aspen grove. The shrub vertical cover was medium-high. The plot center was on well drained high ground overlooking the three ponds on the east of the

property. As a result, the bird detections occasionally picked up species associated with the ponds such as red-wing blackbirds. The top bird species detected at this location was Northern cardinal, with six individuals found.

Plot 29 had a low tree density of 80 stems per hectare and a total basal area of 6.86 m^2/ha. The few trees that were present were medium-sized deciduous trees, primarily associated with the tree line that the ends right near the plot center. The shrub cover was moderate at this location. The remainder of the plot area was grassland/prairie with the service road running a few meters from the marker post at the center of the plot. The overall bird richness was fairly low with the top bird species being Northern cardinal at only three individuals.

Plot 30 was medium-high density forest interior with a density of 200 trees per hectare and a total basal area of 16.65 m^2/ha. As suggested by the low basal area, the forest is fairly young mixed deciduous forest with a high number of small trees. The shrub vertical cover was medium-high, as well. The top bird species were Northern cardinal, at four individuals, and Acadian flycatcher and ovenbird, both at three individuals detected.

Plot 31 was medium-high density deciduous forest interior with a density of 200 trees per hectare and a basal area of 20.40 m^2/ha. As the slightly higher total basal area would suggest, this forest is slightly more mature than that of the previous plot. Plot 31 included a stand of medium age hickory trees. The shrub vertical cover was also medium-high. The top bird species at this location were Acadian flycatcher and Eastern wood-pewee, both with three individuals detected.

Plot 32 had a high density of 360 trees per hectare with a total basal area of 56.18 m^2/ha. It was mixed deciduous forest interior near the top of a large hill in the north-central part of the MGBS property. The shrub vertical cover was medium-high. The two top bird species at this

location were tufted titmouse and ovenbird, both with four individuals detected.

Plot 33 was also near the top of the same large hill as Plot 32; however, it had a medium-low tree density of 160 trees per hectare and a total basal area of 21.14 m^2/ha. The forest at this location was also mixed deciduous, but it was dominated by hickory. Shrub vertical cover was medium-high. The top bird species was Northern cardinal with five individuals found. The second and third most common species were the Acadian flycatcher and tufted titmouse, both with three individuals.

Plot 34 was a low density woodland, having only 120 trees per hectare and a total basal area of 7.00 m^2/ha. It was mixed deciduous forest with high shrub vertical cover. The plot was mostly deciduous forest interior, but there was edge within the bird detection area. The plot center was located just east of the fire break that bisects the property. The top bird species detected at this location were Northern cardinal, red-eyed vireo, and tufted titmouse, all with only two individuals.

Plot 35 was a medium-high density woodland having a density of 240 trees per hectare and a total basal area of 22.03 m^2/ha. The forest was mixed deciduous, although it was dominated by tulip trees (*Liriodendron tulipifera*). This plot was located in low moist ground near the stream that feeds pond number four and just upstream of the pond. The shrub cover was medium-high. The predominant bird species was Northern cardinal with five individuals found.

Plot 36, located on high ground near the power line easement, had a medium-low density of 140 trees per hectare with a total basal area of 18.08 m^2/ha. The shrub vertical cover was medium-low. This plot contained a deciduous forest interior with the forest itself being mixed deciduous. Because the power line easement was extremely close by, the edge and scrub associated with it could have impacted the birds that were detected from the plot center. The top

bird species found at this location were red-eyed vireo and catbird, both with two individuals found.

Plot 37 was medium-low density mixed deciduous forest with a density of 160 trees per hectare and a basal area of 26.92 m^2/ha. The shrub vertical cover in contrast was medium-high. This plot was located on high ground in deciduous forest interior; however, there were pines well within the bird detection area. The leading bird species to be found at this location were Northern cardinal, Acadian flycatcher, and white-breasted nuthatch, all of which had only two individuals detected.

Plot 38 was medium-high density woodland with 200 trees per hectare. However, despite the high number of tree stems, the total basal area was only 16.85 m^2/ha. This disparity between density and basal area was due to the young age of most of the trees within the sampling area. This was mixed deciduous forest with medium-high shrub vertical cover. The plot center was in the ravine of a seasonal stream. There was a more even spread of individuals per bird species here, as the top birds were a five-way split between Acadian flycatcher, Eastern wood-pewee, tufted titmouse, ovenbird, and white-breasted nuthatch. All five species had only two individuals detected.

Plot 39 was medium-high density with a density of 200 trees per hectare; however, this was fairly mature mixed deciduous forest. As a result, the basal area was much higher than Plot 38 at 44.55 m^2/ha. Like the previous plot, it had an abnormally low shrub vertical cover, most likely due to the dense canopy layer and the fact that the sampling area was on the well-drained side of a hill. It was fairly close to the paved road that cuts through the southwest corner of the property, and, therefore, has edge and grassland within the bird detection area in addition to the deciduous forest interior at the plot center. The top bird species found at this location was tufted

titmouse with four individuals.

Plot 40 had medium-low tree density with 160 trees per hectare and a basal area of 29.64 m^2/ha. The plot center was located on the top of a ridge just south of the driveway that services the property. The forest was primarily mature sugar maples, whose dense shade resulted in low shrub vertical cover. Except for the slight opening caused by the property entrance road, this plot was fairly solid forest interior. The bird numbers at this location were comparatively high, with the top species, Northern cardinal and Acadian flycatcher, having five individuals each.

Plot 41 had 180 trees per hectare and a total basal area of 14.66 m^2/ha. This plot had medium density but a reduced total basal area due to a higher number of younger trees. This plot was also mixed deciduous forest, as opposed to the plot to the east of it (Plot 40) being primarily maple. Due to younger trees with a higher species diversity, more light penetrated to the ground resulting in a moderate shrub vertical cover. This plot was located on the side of the hill that is right next to the north end of pond number one. The top bird species detected at this locale were Acadian flycatcher and red-eyed vireo, both species having three individuals.

Plot 42 was a medium density woodland with 180 trees per hectare, but the basal area was higher at 27.34 m^2/ha. Like the previous plot, this plot was mixed deciduous forest interior; however, this one also had some edge nearby and had several larger trees. This plot center was located just to the north of the houses and mowed lawn area. The shrub vertical cover was low at this location. Despite the proximity of the open mowed area, there were no uniquely open terrain birds detected at this plot. The top species detected were both fairly ubiquitous, namely, Northern cardinal and Eastern wood-pewee, with three individuals each.

Plot 43 was low density with 120 trees per hectare and a basal area of 23.77 m^2/ha. The tree species composition was mixed deciduous with five hickories and one large sugar maple

being dominant features in this sampling area. Shrub cover was medium-high. The plot center was in deciduous forest interior just off the hiking trail near the south end of the small orchard that is a remnant of when the property was a farm. The top bird species detected were ovenbird and wood thrush, with five and three individuals, respectively.

Plot 44 was medium low density with only 160 trees per hectare, but a disproportionately high total basal area of 52.69 m^2/ha. This was due to a number of mature tulip trees, several which were quite large. There was moderate shrub cover with a number of dead snags present as well. The bird numbers were rather high, with the top species detected being five wood thrushes, four Northern cardinals, and three red-bellied woodpeckers.

Plot 45 had medium-low density and low basal area with 140 trees per hectare and 14.59 m^2/ha, respectively. Forest composition was mixed deciduous, and it had moderate shrub vertical cover. The habitat type was deciduous forest interior. The top bird species was Eastern wood-pewee with four individuals detected, followed by Northern cardinal, Acadian flycatcher, wood thrush and red-eyed vireo, each with three individuals.

Plot 46 was medium high density mixed deciduous forest with a density of 200 trees per hectare and a total basal area of 26.28 m^2/ha. There was low shrub cover, despite having some dead snags that allowed more light through to the understory. This plot was centered fairly close to the top of a hill and was in an area characterized by tall mature trees with only the occasional windfall to break the high canopy layer. There was a healthy forest interior bird population with four red-bellied woodpeckers, and three each of Acadian flycatcher, wood thrush, and red-eyed vireo.

Plot 47 had very similar habitat to Plot 46, with a medium-high tree density of 240 stems per hectare and a basal area of 27.22 m^2/ha. It was also mature mixed deciduous forest, although

there was slightly more understory growth with moderate shrub vertical cover. While many aspects of this plot were similar to Plot 46 to its east, there were not nearly as many birds. The top bird species was wood thrush, with only three individuals detected.

Plot 48 was at the top of a hill just west of the fire break. It had a medium-high density of 200 trees per hectare and a basal area of 36.67 m^2/ha. The forest composition was predominantly maple, although enough light penetration to allow for a moderate shrub cover. Most of the bird count area was deciduous forest interior, although the proximity of the fire break led to a little bit of edge habitat as well. The top bird species detected here was Northern cardinal with four individuals.

Plot 49 was medium-high density mixed deciduous forest interior with a density of 260 trees per hectare and a total basal area of 26.85 m^2/ha. The forest composition was predominantly ash and had moderate shrub cover. There were no notable standing dead trees, suggesting there was little to no predation by emerald ash borers to date. The predominant bird species found was Acadian flycatcher with three individuals.

Plot 50 was high density mixed deciduous forest with a density of 320 trees per hectare and a basal area of 28.77 m^2/ha. Most likely due to the tree density forming a closed canopy, there was no shrub cover. This plot was very near the power line easement, although that was only in the bird sampling area, not in the habitat sampling area. The remainder of the plot was deciduous forest interior. The peak bird detection was wood thrushes with four individuals being recorded.

Plot 51 was high density mixed deciduous forest interior with a density of 280 trees per hectare and a basal area of 45.65 m^2/ha. As can be seen by the slightly higher basal area per hectare, the trees in this area were more mature than in some of the other high density plots.

There was medium-low shrub vertical cover. Despite the plot being mature forest interior, the top bird found was Northern cardinal with three individuals rather than being a typically forest-interior-dependent bird species.

Plot 52 was medium-low density forest with 160 trees per hectare and a basal area of 30.69 m^2/ha. Most of the trees in this plot were young, although there were a couple of large trees that skewed the value for total basal area somewhat. There was medium-high shrub cover, probably a result of the plot lying in a creek bed. There was scrub nearby in an area that appeared to be a small flood basin. The top bird species detected at this location was Acadian flycatcher with three individuals.

Plot 53 was a high density mixed deciduous forest with a density of 280 trees per hectare and a basal area of 46.64 m^2/ha. There were several large tulip trees (*Liriodendron tulipifera*). A small stream traversed the plot. There was moderate shrub vertical cover. This plot was located somewhat close to the hiking trail that heads northeast out of the primitive camping area by the entrance of the bird sanctuary. There were more birds at this plot than at most, with the top bird species being Northern cardinal, Acadian flycatcher, and red-eyed vireo, all of which had four individuals detected.

Plot 54 was medium-high density with a density of 200 trees per hectare and the high basal area of 56.28 m^2/ha. The species composition of the plot was mixed deciduous with several large hickories. The plot center was just on the west edge of the primitive camping area with half of the habitat plot being mowed grassy area and half being deciduous forest interior and the edge habitat between. The wooded portion also had moderate shrub cover. The top bird species detected were Northern cardinal and Eastern wood-pewee with three individuals each.

Plot 55 had low stem density with 120 standing trees per hectare and a low basal area of

16.50 m^2/ha. Most of the trees were black walnut (*Juglans nigra*) and there was moderate shrub cover. There was also significant windfall debris, possibly from either storms or poor tree health. This contributed to the low density and basal area in this plot. It was on slightly higher ground heading uphill away from the houses and other structures on the east end of the property. The predominant bird species were Eastern wood-pewee, red-eyed vireo, and white-breasted nuthatch, all with three individuals.

Plot 56 had a high tree density of 280 trees per hectare despite part of the sampling area being open meadow. The basal area was also fairly high at 45.50 m^2/ha, mostly due to a number of large tulip trees. The shrub cover was medium-low. A good portion of the bird sampling area was mature deciduous forest, although there were also significant amounts of edge and meadow. Surprisingly, the meadow did not contribute a large number of birds to the count, as the top bird was wood thrush, with only three individuals.

Plot 57 was medium-high density mixed deciduous forest with a density of 220 trees per hectare and a fairly low total basal area of 15.50 m^2/ha. The shrub cover was medium-high. It should be noted that there were several black locust trees in the forest sampling area for this plot. The top bird species detected was Northern cardinal, with three individuals found.

Plot 58 was medium density mixed deciduous forest with a density of 180 trees per hectare and a basal area of 22.13 m^2/ha. A moderate shrub vertical cover was present. The primary habitat type at this location was deciduous forest interior. This plot was fairly close to the power line easement; however, the easement was outside the habitat sampling area. The top bird species at this location was wood thrush, with three individuals found.

Plot 59 was low density beech/maple forest with a density of 120 trees per hectare and total basal area of 15.03 m^2/ha. Despite being predominantly maple, enough light penetrated the

canopy to support moderate shrub cover. The main habitat type present was deciduous forest interior, but there was some scrub within the sampling area as well. The most abundant bird species at this location was wood thrush, with three individuals found.

Plot 60 was the last plot in the extreme northeast corner of the bird sanctuary. It had low forest density and low basal area, with 40 trees per hectare and basal area of 2.65 m^2/ha. The only two measurable trees in this plot were one black walnut and one tulip tree. It was measured as having medium-low shrub cover because half of the sampling area was mowed hay field and it averaged out the dense edge habitat that took up the better part of the forested portion of the habitat circle. The bird sampling area was likewise split half and half between mowed field and fairly young maple forest with a stripe of dense edge between the two. The top bird species detected at this location was Northern cardinal with three individuals, although there were several other bird species that made appearances while passing through and foraging such as Eastern towhee and black-capped chickadee.

Avian analysis:—Throughout the analysis of Mary Gray Bird Sanctuary (MGBS), there were certain bird species that stood out as being particularly prevalent. For the sake of this study, the ten most abundant species were examined in some detail. In most cases, there were definite correlations to be found between the habitat features analyzed above and the locations of those ten bird species.

The most abundant avian species found at MGBS during this study was the Northern cardinal (*Cardinalis cardinalis*) with a total of 147 individuals detected. The highest concentrations were found at plots 19, 28, 33, 35, and 40 (See distribution map, Appendix 4),

which were all areas of forest interior, rather than areas of extreme dense scrub or edge habitat, as would have been expected based on their nesting preferences (Cornell Lab of Ornithology, Northern Cardinal 2015). There was, however, at least one cardinal found at every plot throughout the property except for plots 4, 23, and 25. This was somewhat expected since cardinals are abundant throughout the region, being found in a wide variety of habitats in both rural and urban areas (Minnesota Department of Natural Resources 2015).

The second most abundant species was the Acadian Flycatcher (*Empidonax virescens*) with 111 individuals detected. They were found in greatest quantity at plots 14 and 40, both in or near a ravine in the contiguous forest. There were also a number of individuals scattered throughout the rest of the property. As the US Geological Survey (USGS 2000) page notes, they prefer nesting in areas with moist ground and/or near flowing water. This would explain why they were not found in plots that lacked any sort of seasonal streams or other water sources. It would also explain why they were detected at plot thirteen, which is riparian corridor and not true forest. They also will not use areas lacking a dense canopy layer.

The third most prominent bird species found at MGBS was the Eastern Wood-pewee (*Contopus virens*). In total, there were 68 individuals detected. They can typically be found in most, if not all, types of eastern forest. However, there is some evidence that in certain parts of North America, they tend to avoid streams (Cornell Lab of Ornithology, Eastern Wood-Pewee 2015). In the current study, it seemed as if they had no notable trends where they were found on the property. The most likely explanation for their apparent failure to follow distinguishable trends is that they were travelling away from their nest locations to find good foraging areas. Since they are flycatchers, this means that they would be found anywhere that there were

concentrations of flying insects on that given day (including edge habitat and other habitat types they would typically avoid).

Wood thrushes (*Hylocichla mustelina*) were tied with red-eyed vireos (*Vireo olivaceus*) for fourth and fifth most abundant bird species detected. Both species had 38 individuals spotted. Wood thrushes prefer fairly mature deciduous forest that also has shrubby ground level cover (US Fish and Wildlife Service 2001). This basic preference can be seen in their placement throughout the property (Appendix 4). As observed, the majority of the individuals found were in the southeast corner of the property among the mature nut trees, along the north edge among the mature mixed hardwood forest, and in the northwest corner where there is also fairly mature deciduous forest.

This is in comparison to red-eyed vireos, which were found throughout the property, except in the southwest corner of the property where the larger grasslands are found and in some wooded plots near them. There did not appear to be a strong correlation between type of forest and the number of vireos in any given location, with the majority of the plots having either two or three individuals. Prior researchers suggest, as is supported by the findings on MGBS, that there is some preference for mature faster growing deciduous trees such as beeches, maples, aspens, and cottonwoods (Northwest Power and Conservation Council 2004), as opposed to the slower growing and longer lived trees like oaks, hickories, and walnuts (Virginia Tech Dept. of Forest Resources and Environmental Conservation 2012).

The sixth most abundant bird species was the tufted titmouse (*Baeolophus bicolor*). There were 75 individuals detected. Literature indicates that this bird prefers mature forests with a wide variety of tree species and preferably at least some that produce “mast” or forageable

seeds and nuts (Wisconsin Bird Conservation Initiative 2013). On MGBS, they were found in small numbers throughout the property. There were, however, a few plots with larger numbers, particularly plots 15, 18, 20, 32, and 39. In several cases, these plots were ones that contained a wider mix of tree species, generally including some oaks and/or hickories along with beech, maple, or conifer close by. There were also some found near edge habitat, most likely due to foraging on berries and small seeds that grow in abundance in those type habitats.

Next most common species was the ovenbird (*Seiurus aurocapilla*), with 67 individuals found. Research suggests that ovenbirds need large blocks of contiguous forest, both for breeding and foraging. It also indicates that mature/old-growth stands are preferred (North Carolina State University 2001). This is supported by the findings of the current study; namely, they were found in small numbers throughout most portions of the property that lacked edge nearby. They were found in larger concentrations in areas with more mature trees and in smaller numbers in the areas of slightly younger second growth forest such as plots 14, 32, and 43. They also seem to prefer areas of mature trees that are coupled with medium to high shrub cover. This would be supported by the fact that they nest on the ground and tend to stay within two meters of the ground while moving around foraging.

The eighth most common bird species found on MGBS was the red-bellied woodpecker (*Melanerpes carolinus*). Of the 57 individuals found, the majority were scattered throughout the property, with only a few slight concentrations in the more mature open forests of the southeast corner and the north central areas. This is supported by the established literature that indicates that they prefer open mature woodlands overall, but will readily go to other areas containing some full sized trees as well (National Audubon Society Guide to North American Birds 2013).

Their dispersal from the more established forest appears to be motivated by availability of good foraging locations, although they also frequently nest closer to the edge of the forests rather than deep interior.

The ninth most abundant bird species found was the white-breasted nuthatch (*Sitta carolinensis*), with 50 individuals detected. They typically prefer fairly mature mixed deciduous forests, up to and including those mixed with pines, though they do not prefer young scrubby forests or dense pine groves (Maryland Dept. of Natural Resources). These trends can be seen on Mary Gray, with low concentrations of these birds found throughout the mature mixed deciduous forests, only one individual in the younger forests of the northwest corner, one in the riparian corridor in the southwest corner, and near complete avoidance of the dense pine plantations.

The tenth most prevalent bird species detected was the gray catbird (*Dumatella carolinensis*), with 37 individuals. They were found in small numbers in most of the areas of edge habitat on the eastern half of the study site, and a few in the younger scrubby woods of the western half. The location with the greatest number of catbirds was the sampling location right by the edge of the fourth pond, with another secondary concentration spot at the seasonal wetland at plot number four in the southeast corner. The Maryland DNR indicates that this bird does, in fact, prefer moist scrub best, while the USDA Forest Service (2013) does not specify their preference for wet scrub but does state that they rely on dense thickets of some sort for both forage and nesting (Maryland Dept. of Natural Resources).

Statistical analysis:—In addition to observational analysis, the habitat features and bird abundance data were examined statistically to determine quantifiable trends that can be applied to other locations where those birds could be or should be found. Because of the complexity of the data being analyzed, ordinal logistic regression was determined to be the most appropriate statistical method. The habitat variables used were total basal area, shrub horizontal cover, herbaceous vertical cover, shrub vertical cover, sub-canopy vertical cover, and canopy vertical cover. For each of the top ten bird species these vegetation variables were used as predictor variables for the abundance of each species. Results of these logistic regression analyses are presented below.

Northern cardinal showed significant inverse correlation with both sub-canopy and canopy level vertical cover. The total P-value for the multivariate logistic regression with habitat features was 0.096, which indicates that the regression model for cardinal numbers only suggested an association. The individual P-value for sub-canopy vertical cover was 0.041 and the coefficient was -0.396, indicating that the number of cardinals decreases as the sub-canopy density increases. The individual P-value for canopy level vertical cover was 0.019 and the coefficient was -0.496. This indicates that there is a strong negative correlation between cardinal population and canopy density, more so than with the sub-canopy layer.

Acadian flycatcher showed significant correlation with shrub horizontal cover density. This refers to the density of the understory within the first 2.5m of the ground. The total P-value for correlation to habitat features in general was 0.004, indicating strong evidence for an association between bird numbers and vegetation structure. The individual P-value for shrub horizontal cover was 0.015 and the coefficient was 0.720. This indicates a strong positive

correlation between flycatcher population and shrubby understory density. Despite the fact that it is generally known that this bird is forest-dependent, there were no significant correlations in this study between population numbers and any habitat variables besides shrub horizontal cover.

Eastern wood-pewee did not show any significant associations with any habitat variables measured ($p = 0.188$).

Wood thrush showed very strong correlation between population and habitat features ($p < 0.001$). Individual variables that were significantly correlated with bird numbers included total basal area, shrub horizontal cover, and herb vertical cover. Like Acadian flycatcher, despite the fact that it is known that wood thrushes are forest dependent, there were no statistically significant correlations to any canopy density variables. The only exception to this is the correlation that was found to total basal area. The individual P-value for total basal area was 0.085 and the coefficient was 3.119. This suggests positive correlation between bird population and total basal area, but a larger body of data is required to establish a stronger correlation. The individual P-value for shrub horizontal cover was 0.006 and the coefficient was 0.917. This indicates a very strong positive correlation between bird population and shrub horizontal cover. The individual P-value for herb vertical cover was 0.003 and the coefficient was 0.543. This indicates a very strong positive correlation between bird population and the density of the herbaceous growth.

Red-eyed vireo abundance was correlated with habitat features ($p = 0.034$). The correlations that were found are somewhat unexpected, however. The individual P-value for shrub horizontal cover was 0.002 and the coefficient was 0.941. This positive correlation indicates that bird population increases as shrub horizontal cover increases. The other specific

habitat feature that showed a significant correlation was shrub vertical cover. The individual P-value for shrub vertical cover was 0.028 and the coefficient was -0.437. This indicates a negative correlation between bird population and shrub vertical cover. This seems to contradict the fact that there is a strong positive correlation between bird population and shrub horizontal cover. Further research will be required to seek out an explanation for this apparent discrepancy.

Tufted titmouse did not show any statistically significant correlations between bird population and any habitat variables ($p = 0.37$). The only conclusion that can be drawn from numbers such as this is that tufted titmice are near ubiquitous in the Midwest and are not influenced by habitat variations.

Ovenbird showed very strong correlation between population and habitat features ($p < 0.001$). The P-value for shrub horizontal cover was 0.011 and the coefficient was 0.866. This indicates that as the density of the shrubby understory increases, the population of ovenbirds also increases. The P-value for sub-canopy vertical cover was 0.012 and the coefficient was -0.673. The P-value for canopy level vertical cover was 0.034 and the coefficient was -0.629. This indicates that as both levels of canopy decrease in density, the population of ovenbirds increases. This might seem to contradict the established body of knowledge that ovenbirds are forest dependent, but, on closer inspection, it actually adds clarity to the situation. This is because one can see trends of increasing understory density when the canopy is less dense. Since ovenbirds nest on the forest floor and forage primarily within the first two to three meters of the forest floor, there is an increase in quality of used habitat when the canopy decreases in density, provided that the area is still forest of some sort.

Red-bellied woodpecker did not show any statistically significant correlations between

bird population and any habitat variables ($p = 0.6$). This indicates that the number of red-bellied woodpeckers is not affected by the type of habitat, as long as there are trees within reach for foraging. This is supported by the established knowledge that this bird is near ubiquitous in the American Midwest.

There was some indication that abundance of White-breasted nuthatch was associated with habitat features ($p = 0.098$). Additional data collection would be needed to make any more certain conclusions. The specific variables that showed correlations were shrub horizontal cover and canopy level vertical cover. The P-value for shrub horizontal cover was 0.093 and the coefficient was 0.502. This suggested a positive correlation between bird numbers and the horizontal density of the shrubby understory. The P-value for the canopy vertical cover was 0.017 and the coefficient was 0.528. This indicates there is a strong positive correlation between bird population and canopy density. This is most likely because their primary forage is insects that feed on the tree, and there are more insects up in the small branches of the canopy.

Catbird showed no correlations to any habitat variables measured ($p = 0.828$). This leads to one of only two conclusions, namely, catbird populations are not affected by habitat at all, or catbird populations are affected by a different variable than any that were measured in this study. Since some intuitive trends were noticed when looking at the bird distributions, such as the numbers appearing to increase near water, it is more likely that the populations are influenced by a variable that was not examined here (Fig.8).

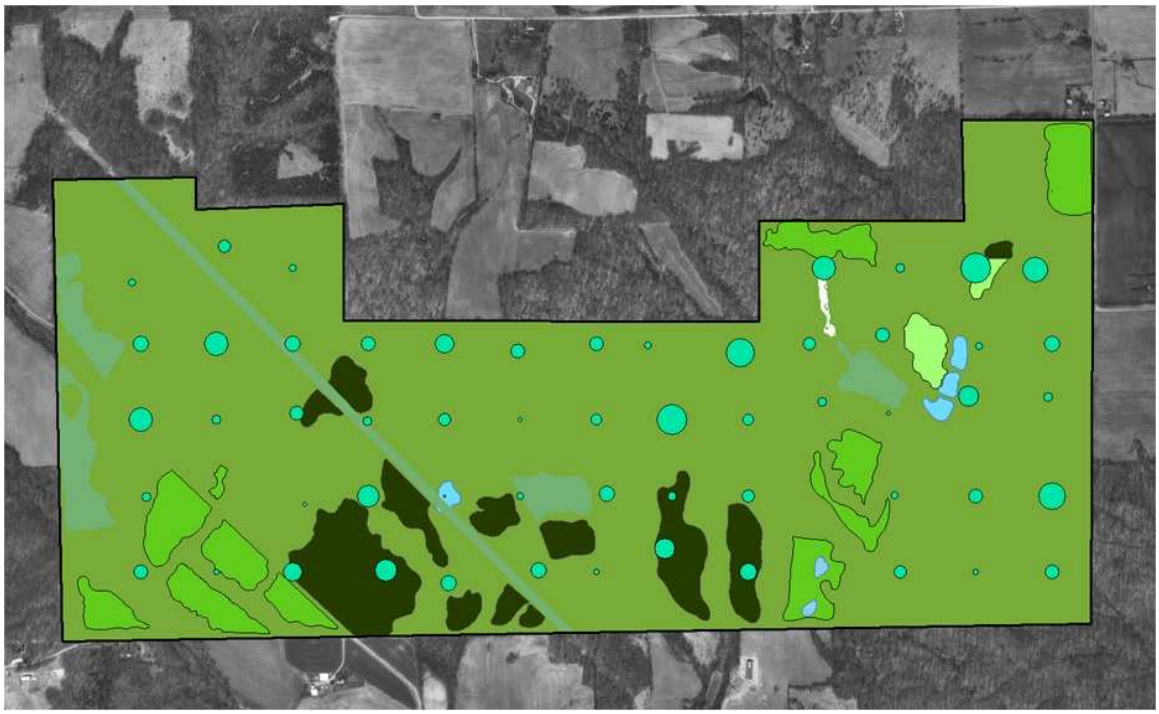

Figure 7: Basal Area by Plot

Figure 8: Gray Catbird Distribution

CONCLUSION

Mary Gray Bird Sanctuary is a fairly well established woodland-dominated property that has several habitat types and shows good potential as a valuable bird preservation asset for the Indiana Audubon Society. It contains several different forest types, including mature oak/hickory forest, mature beech/maple forest, both red and white pine plantations, and young mixed deciduous successional forest. As a result, the majority of the birds found on the property were woodland loving and woodland dependent species. There is, however, a considerable amount of edge habitat scattered throughout the property that leads to high population numbers of those bird species like Northern cardinal that prefer mixed habitat. The majority of the statistical data matches clearly with the established data on each of the birds that were examined in detail (the ten most abundant). The results of this study show that, overall, the property is an excellent site for bird abundance. The only improvements to that, given the land available, are to manage for better grassland coverage in the areas conducive to that (Fig. 9). It is the hope of those involved in this study that it will serve as a solid baseline for any others who may choose to study the bird sanctuary in future years to document bird population change, forest successional sequences, and their effects on one another.

Figure 9: Grasslands from Southwest Corner of MGBS

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