EFFECTS OF HONEYSUCKLE (*LONICERA MAACKII*) MANAGEMENT ON AVIAN ABUNDANCE

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Abstract

Amur honeysuckle (*Lonicera maackii*) is an invasive shrub that is found in many parts of Ohio and grows well in Ohio's forest ecosystems. This study attempted to assess the effect of treating Amur honeysuckle on avian abundance within Germantown MetroPark in Germantown, Ohio. The honeysuckle was chemically treated with a foliar glyphosate spray and left to break down naturally. The birds were grouped into three different guilds: ground nesting species, shrub nesting species, and fruit eating species. In addition to the effects of treatment, the important vegetation characteristics, such as honeysuckle and native shrub densities, percent forb or grass cover on the plots, basal area, and percent canopy cover within in the plots were also measured and compared among treatment courses for each guild. Overall, there was very little effect on treatment on bird abundance within the species guilds, either positively or negatively. There were some differences between the different treatment courses but that was likely due to inherent differences in the plots making up those courses. Vegetation characteristics of plots were more important in determining avian abundance. There is a time gap between honeysuckle treatment and the desired results. How the treatment of invasive species effects native species of birds is important because it can help to preserve threatened species or assist managers in making habitat management decisions.

Introduction

The influx of invasive species is a management concern for the natural resources field and one species that is now prevalent in the Ohio landscape is Amur honeysuckle (*Lonicera maackii*). Invasive species in general tend to outcompete native vegetation and cost over one billion dollars annually for their management in the United States alone (Wilcox and Beck 2007; Gleditsch and Carlo 2011). Honeysuckle is officially considered invasive in 27 states and Ontario, and banned in 2 states (Gleditsch and Carlo

2011, Runkle et al. 2007). Some studies have assessed the impact of invasive species on avian abundance and diversity of species but few studies have been done that specifically examined how the presence of honeysuckle affects abundance of native bird species found in our Ohio forests.

Amur honeysuckle is native to Asia and occurs in multiple forest types in northeastern Asia (Hutchinson and Vankat 1997). Honeysuckle was introduced to the United States for use as an ornamental shrub and was first planted in Ohio in 1960 in Oxford (Hutchinson and Vankat 1997). This invasive shrub has since escaped urban areas and can be found in many forest ecosystems in Ohio. The success of honeysuckle can be attributed to the large amount of berries it produces that can then be spread over relatively large areas by birds. Native plant species have not evolved with honeysuckle so there are not natural checks on the plant to prevent it from taking over the understory in some areas (Hutchinson and Vankat 1997).

Honeysuckle is more prevalent in younger or earlier successional woods (Runkle et al. 2007) and areas where disturbance has occurred because of an increase in availability of resources such as sunlight and reduced competition (Hutchinson and Vankat 1997). Disturbances can be anthropogenic, such as urban development or hard forest edges due to agriculture, or natural, such as single tree mortality and openings caused by wind or tornadoes. This allows honeysuckle to become established and from there it can spread with the help of other species dispersing its seed. Younger successional forests and canopy disturbance, such as would result from thinning, also facilitate the invasion of honeysuckle (Hutchinson and Vankat 1997).

Another key for invasive species success is the ability to incorporate native fauna in mutualistic interactions. Many species have been found to incorporate the fruit or other food sources of invasive species into their diet (Bartuszevige and Gorchov 2005), and honeysuckle is no exception.

Honeysuckle is also one of the earliest plants to leaf out in the spring, and often keeps its leaves later into the fall than most of our native plant species (Hutchinson and Vankat 1997, Borgmann and Rodewald 2004, Rodewald et al. 2009). This may be one reason early nesting birds are attracted to honeysuckle when constructing nests despite the fact that nest predation is higher when nesting in

honeysuckle than native vegetation during the early part of the breeding season (Borgmann and Rodewald 2004).

Honeysuckle affects native vegetation though competition and by outcompeting native plant species and can indirectly affect avian species by removing native food sources, higher quality nesting sites, and opportunities for cover from predators. Hutchinson and Vankat (1997), found light was a key factor in the initial establishment of this invasive woody plant species. Once honeysuckle was established, the number of native tree seedlings and herbaceous species decreased (Hutinson and Vankat 1997, McCusker et al. 2010) which could persist years into the future as the current canopy trees die and are not replaced by native tree species.

Spring ephemerals and other herbaceous plants that have low relative shade tolerance ratings likely show reduced species richness in invaded areas because of the early leafing out of honeysuckle (Hutchinson and Vankat 1997). However, more research needs to be done on the effects of honeysuckle on individual species to understand the direct impacts of this invasive species (Hutchinson and Vankat 1997).

Runkle et al. (2007) examined the effects of honeysuckle removal on ground layer species and tree seedlings in a park in west-central Ohio. Honeysuckle re-sprouts prolifically from cut stumps and therefore stumps need to be treated with herbicide shortly after cutting. Eight years after the treatment, honeysuckle had re-established itself as seedlings and sprouts. But the removal still proved to be effective because the honeysuckle was still small and was present at much lower densities. Some native species, however, did not begin to appear until 2 or 3 growing seasons after the treatment was applied (Runkle et al. 2007). Both herbaceous plants and tree seedlings were found in greater abundance in both young and old forests by the end of the study where honeysuckle had been removed.

Woody plant species take longer to recover than herbaceous species when honeysuckle is removed (Vidra et al. 2007) possibly because many of those species are perennials and therefore do not produce seed after the first year they become established. It could also be because the invasive species has been there long enough that the native species seeds are no longer viable. It is common to see a canopy of

native tree species and very little to no regeneration of those species in areas where honeysuckle is abundant (Vidra et al. 2007).

Plant community is the primary factor determining avian species composition in an area (Smith et al. 2008). Multiple groups of bird species will be represented if there are multiple plant community types. The greater the vegetation heterogeneity, the greater the number of avian species that can be found in a woodland area (Smith et al. 2008). Land use in the surrounding areas can also play a role in the number of species found. If neighboring land does not contain foraging opportunities, such as a farm field that does not contain sufficient food resources after harvest, it can lower the number of species that are found there (Smith et al. 2008). The homogeneity in the forest understory due to high amount of honeysuckle could reduce the number of species that find the habitat suitable because vertical structure is important in attracting a variety of bird species.

At least 17 forest bird species consume berries produced by honeysuckle (Bartuszevige and Gorchov 2005). Interestingly though, only 5 of those 17 species actually dispersed the seed; including: American Robins (*Turdus migratorius*), Cedar Waxwings (*Bombycilla cedrorum*), Northern Mockingbirds (*Mimus polyglottos*), European Starlings (*Sturnus vulgaris*) (an invasive bird species) and Hermit Thrushes (*Catharus guttatus*). However, not all of the species actually dispersed viable seed. For example, seed that had passed through the digestive tracts of Cedar Waxwings did not germinate (Bartuszevige and Gorchov 2005). This may occur because of the way the individual species' digestive tracts affect the seed. These researchers believe American Robins and European Starlings are the two most important species for dispersing honeysuckle seed due to the sheer numbers of their populations. Based on the movements of American Robins, Bartuszevige and Gorchov (2005) found that robins dispersed seed more often in edge habitats and because honeysuckle is often found in edge habitats, they participate in a positive feedback loop. It is unknown if the Eastern Mockingbird contributes to the spread of honeysuckle seeds because it was not caught in any of the mist nets that were set up, though it was observed eating the berries (Bartuszevige and Gorchov 2005).

Bird species use honeysuckle in both winter and summer, though species composition of the bird community changed between seasons (McCusker et al. 2010). Some species, such as American Robins, Northern Cardinals (*Cardinalis cardinalis*), and Gray Catbirds (*Dumetella carolinensis*) which are all understory species were positively correlated with honeysuckle presence in summer. American Robins and Gray Catbirds are the two species recorded eating honeysuckle berries most often (Gleditsch and Carlo 2011). The increase in abundance of those species could mean that if a significant portion of the honeysuckle is removed, then there may not be enough native vegetation producing fruit in the fall to support the current populations of birds relying on fall fruit. Other species that depend on fruits for their diet were found in greater numbers where honeysuckle was growing. There was less of an effect on species during the winter (McCusker et al. 2010). Both American Robins and Northern Cardinals have expanded their range northward, especially in areas where honeysuckle is abundant, and appear to feed almost exclusively on honeysuckle berries during winter (McCusker et al. 2010). Because honeysuckle can grow in more northern areas, it could have allowed those two bird species to expand their range since they can use the berries as a food source.

Migratory species that become frugivores during fall migration can also depend heavily on honeysuckle fruits (Gleditsch and Carlo 2011). Removing honeysuckle could result in a decrease in habitat quality due to lack of food in stopover sites for these migratory species. Because of the dependence of some resident species along with migratory species on berries, the replacement of honeysuckle with native replacement species should be considered when making ecological restoration plans (Gleditsch and Carlo 2011).

However, canopy species such as the Eastern Wood-pewee (*Contopus virens*), Parid species (McCusker et al. 2010), and woodpeckers such as Red-bellied Woodpeckers (*Melanerpes carolinus*) and Downy Woodpeckers (*Picoides pubescens*) along with Dark-eyed Juncos (*Junco hyemalis*) (Gletitsch and Carlo 2011) were negatively impacted by honeysuckle. These forest birds need more open forest in which to forage. For example, the Eastern Wood-pewee forages on flying insects, and areas that have dense honeysuckle will make it more difficult to fly through the forest in search of food (McCusker et al. 2010).

One way of assessing species success is nest predation because it has an important role in determining the number of individuals that are added to the population. Wood Thrushes (*Hylocichla mustelina*), Gray Catbirds, American Robins and Northern Cardinals are all species that are known to nest in honeysuckle (McCusker et al. 2010).

Species that use honeysuckle for their nesting site have a greater risk of nest predation during the first few days of nesting (Schmidt and Whelan 1999, Borgmann and Rodewald 2004). This may be due to height of nest placement, easier movement of predators through the honeysuckle because of branching structure or lack of thorns (Schmidt and Whelan 1999) or lack of leaf emergence (Rodewald et al. 2009). The height of the nest above the ground is influenced by the type of vegetation used. Cardinal nest placement was studied and those that used honeysuckle and rose (*Rosa multiflora*) for nesting sites were two and a half times lower than the nests found in native vegetation (Borgmann and Rodewald 2004).

The daily nest survival rates change in both exotic and native species throughout the breeding season. Survival rates were especially low (14%) for nests in honeysuckle during the early part of the nesting season (Rodewald et al. 2009). However the survival rates did increase as the breeding season progressed. This led Rodewald (2009) to develop the idea of an ephemeral ecological trap because the negative outcomes for choosing honeysuckle are controlled by the time of year. This could be due to changes in vegetation as the spring season progresses, predator characteristics, or concealment of the nests (Rodewald et al. 2009). Because the increase in nest predation occurs at the beginning of the season, it affects resident and early migrant species that nest in honeysuckle, but not later migrant species. This is most likely a result of an increase in the amount and type of vegetation to choose from for nesting as well as a decrease in detectibility due to leaf emergence (Rodewald et al 2009).

There have not been many studies done on the actual impacts of honeysuckle on avian diversity, but some species use honeysuckle for various reasons. Wilcox and Beck (2007) conducted a study done in a forested landscape on another invasive, Chinese privet (*Ligustrum sinense*), the negative impacts of this invasive was on the native vegetation rather than songbird diversity. There were higher numbers of birds found in plots containing a high density of Chinese privet than in low density plots during winter but

overall the density of privet did not affect either the species richness or the abundance of those species (Wilcox and Beck 2007). The authors of this study determined that removal would not harm bird populations or affect species richness despite the fact that they foraged on the Chinese privet berries.

There appears to be a short term an increase in avian densities (McCusker et al. 2009, Gleditsch and Carlo 2011) but not necessarily in avian diversity. However, not as much is known about the long-term effects of honeysuckle on species density.

The removal of honeysuckle, especially where it is dense, could temporarily decrease avian diversity and density because there is often no regeneration beneath the honeysuckle. Therefore species that depend on understory vegetation for food, cover, and nesting sites may not be found in the area until native species have a chance to grow (McCusker et al. 2009). It is also very possible that the area will be recolonized by honeysuckle due to the seed bank that exists under the shrubs as well as the spread of its seed by some bird species. Therefore, managers will likely need to follow up the initial removal with subsequent treatments until native understory species can become established. It then would be better to focus on restoring areas that will be less likely to have a reintroduction of honeysuckle (Borgmann and Rodewald 2005).

Aslan and Rejmanek (2010) surveyed 173 ornithologists and compiled reports of avian interactions with non-native plant species with the intent to guide future research and management actions involving invasive plants. The reports cannot be verified and therefore need to be interpreted conservatively, though they are still informative. The interactions that were reported fell into one of two groups: 1) feeding on non-native seeds or fruits, and 2) using the plant itself for various functions such as perching or nesting. At least one feeding action was recorded in a vast majority of the reports, indicating the potential for seed dispersal and consequent spread of the invasive plant (Aslan and Rejmanek 2010). However, not all species that consume seed from invasives will defecate viable seed (Bartuszevige and Gorchov 2005). Specific species interactions and general trends between birds and non-native plants and a variety of spatial scales need to be studied to determine the best way for managing impacts of invasives or preventing invasion of new areas (Aslan and Rejmanek 2010).

Few experiments have assessed the affects of Amur honeysuckle on the abundance of avian species found in Ohio forests. The research that has been done on effects of honeysuckle indicates that bird abundance increases with more honeysuckle, though not necessarily species richness. Management actions will depend on whether the conservation focus is on avian abundance, native shrub species, or other factors such as ecosystem function. Some invasives are neutral in terms of affecting biodiversity and abundance and some invasive species may even be beneficial (Smith et al 2008). For example, some invasives may provide food or nesting sites for birds in areas where the native species they previously depended on was extirpated (Aslan and Rejmanek 2010). If this is the case, then the time and money spent on removing the species is not the best use of available resources. Because species interactions are multifaceted, there are many variables that can affect the success of the invasive, the continued survival or eradication of the native vegetation, and the way the invasive is used by the local fauna.

Objectives

A local breeding bird survey was conducted using the same points on two different trails in 2006 and 2009 to 2012 in Germantown MetroPark, Ohio. The employee in charge of the survey believes there has been an increase in both the number of species and the overall abundance of birds as a result of honeysuckle treatment that began in 2008. I attempted to determine if that was actually the case. My objectives were to determine if there was an overall increase in avian abundance across species as well as within three species guilds. I also considered vegetation characteristics within the plots to determine the effect on bird abundance the species richness detected during the point counts. Data from areas where the honeysuckle was treated and where it has not been treated was collected at points used in the local survey of breeding birds. That, along with past data taken at the same points could allow the managers to see how the treatment of honeysuckle influenced the local bird abundace. The results could then influence future management practices affecting how invasive honeysuckle is handled, not only in Germantown MetroPark, where the study will be conducted, but also in the other Five Rivers MetroParks as well as in similar forest ecosystems in the region.

Study Area

This study was conducted in Germantown MetroPark in Montgomery County, Ohio (Figure 1). The park is located in the southwest part of the county, near Dayton, Ohio (Figure 2). Germantown MetroPark is 1,655 acres and was established in 1967 (Five Rivers MetroParks n.d.). It is located at: Latitude: 39.641357 and Longitude: -84.431159, and has approximately 14 miles of trails (Five Rivers MetroParks n.d.).

Location of Germantown, Montgomery County, Ohio
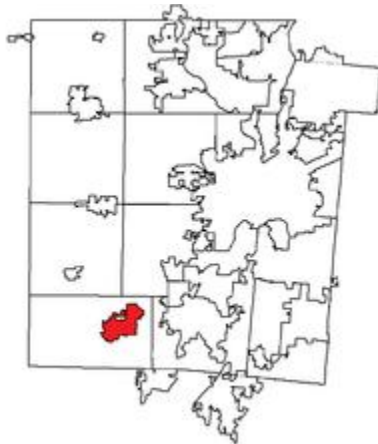
Location of Germantown MetroPark within Montgomery
County, Ohio

Figure 1. Montgomery County within the state of Ohio, and the location of the city of Germantown within Montgomery County.
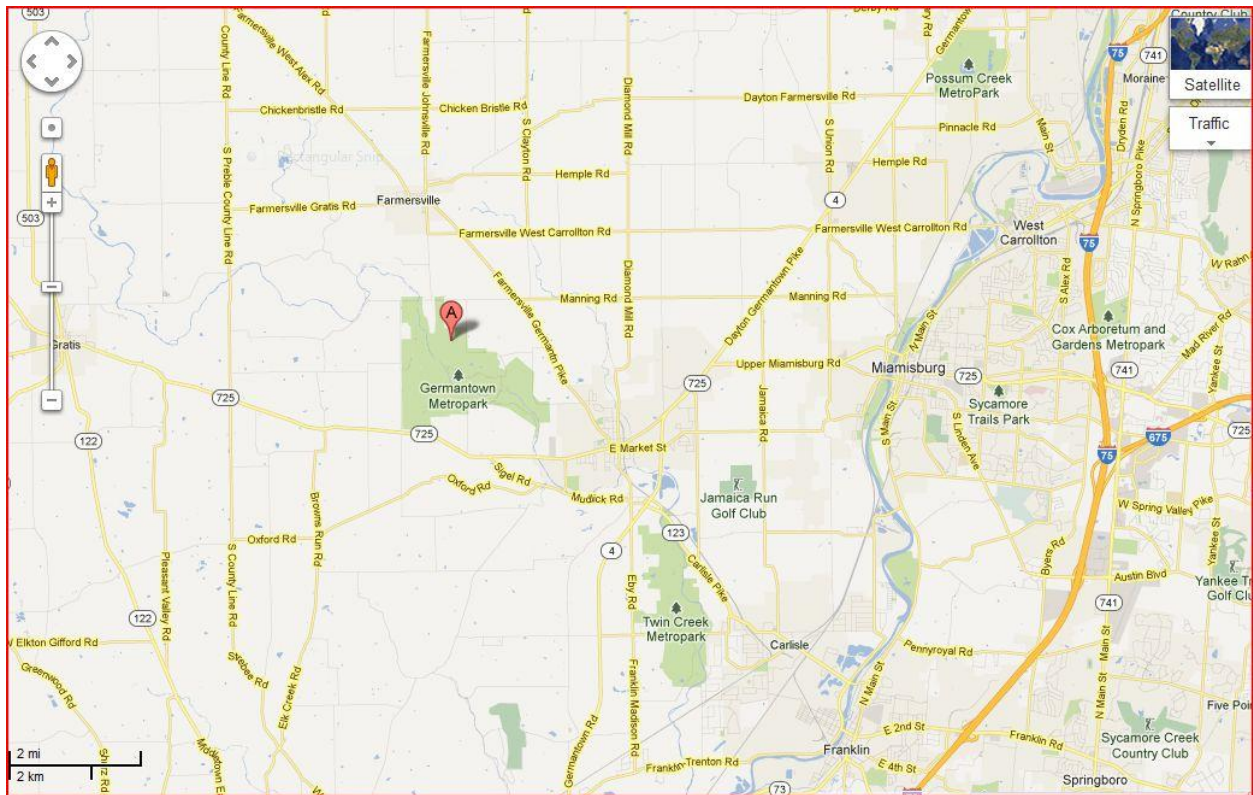
Figure 2. Germantown MetroPark, located northwest of the city of Germantown in Montgomery County, near Dayton, Ohio.

Methods

Data were collected in June 2012 on 2 of the existing hiking trails where fixed-radius point counts have been done in previous years (Figure 3). That data was compiled with data taken in June of 2006, 2009, 2010 and 2011. A 10-meter radius was used for the point count and any birds within that area were counted. The first trail, designated 'Trail B' contained 15 forested points and the second trail, referred to as 'Trail Y' contained 15 forested points. Data were collected once a week on each trail for 3 - 4 weeks in a row. In years 2009 and 2010, when data could only be collected for 3 weeks, the numbers were increased by 25% and rounded to the nearest whole number to match the sampling effort of the years with a longer data collection period. The point counts lasted for 5 minutes, and 2 observers recorded data. The birds seen and heard were counted; however, if a bird was both seen and heard, it was only counted once. A Bad Boy Buggy was used to drive the trails to the point count locations and once there, a microphone and recorder were used to record the date, location and time as well as record for the 5 minutes while the

point count was done. This way there was a record of birds that were singing during the count so if an unusual or rare species is heard, it could be validated by the recording.

Much of honeysuckle in the area where the trails occur was treated in fall of 2008 using a glyphosate foliar spray once the native species had gone dormant, but the honeysuckle was still green (Figure 4). The dead shrubs were left standing and allowed to degrade naturally. Six areas containing point count locations were treated that fall, one area with 5 point count locations was treated in 2009 and another area with 3 point count locations was treated in 2010. The forested points on Trail B and Trail Y that do not occur in treated areas served as controls.

The vegetation on the plots was also measured. A 10 factor angle gauge was used to determine the basal area of living and dead trees within each point count location. The point-centered quarter method was used to determine the density of native shrubs and honeysuckle cover at each point count with a maximum radius of 11 meters. If no shrubs were located within any quarter of the plot, that quadrat not used to calculate shrub density. The distance used for the radius was chosen for ease of data collection and because that created a very similar area as what was used at those points to detect the birds during the point counts. In addition to measuring honeysuckle density using the point-centered quarter method, the overall rating of honeysuckle was estimated on a scale from A to D: A = 0-9% cover, B = 10-39%, C = 40-69% and D = 70+ % honeysuckle cover. A Daubenmire frame was placed in the center of each of the four quadrats and the percentage of ground litter, forbs, and grasses/sedges, and "other" were estimated. Percent canopy cover was determined using a densiometer 11 meters from the plot center in the four cardinal directions and averaging those four values. The species were separated into three species guilds for ease of comparison using the Birder's Handbook (Ehrlich et al, 1988): ground nesting species, shrub nesting species, and fruit eating species (Appendix 1). The overall count data for those species in 2012 were compared in relation to vegetation found within the plots and then between years, taking into account the treatment of the honeysuckle that occurred on some of the plots.

The statistical program R (R Core Team, 2012) was used to analyze the data collected. General linear models were used to analyze the effects of the 2012 vegetation data and generalilzed linear mixed

effects models utilizing the Poisson method to account for non-normal count data were used to determine statistical significance of the honeysuckle treatment. In these analyses the plot was the random effect. Orthogonal contrasts were done to compare control plots with those that were treated at some point during the study (Table 1). Course 1 included all plots that were only controls and compared them to those that were eventually treated at some point during the study. Course 2 compared the plots that had been treated for two years with those that were treated for 3 or 4 years and Course 3 compared plots that had been treated for 3 years with those that had been treated for 4 years. Poisson regression models were used to determine which vegetation variables were associated with numbers of birds for each guild. The test was run to determine which parameters regarding forbs, grass/sedges, and litter were most important for each guild, then again to determine the same for native shrub density and honeysuckle cover and a third time for percent canopy cover and basal area. Then for each guild, the most important vegetation parameters from the initial tests were compared, and the best fitting model was chosen. A Canonical Correspondence Anaylsis (CCA) test including all species was run to visualize what vegetation factors were most important and how the factors influenced where species were found.

Table 1. Orthogonal contrast table for treatment.

	C1	C2	C3
0T5C	3	0	0
2T3C	-1	2	0
3T2C	-1	-1	1
4T1C	-1	-1	-1
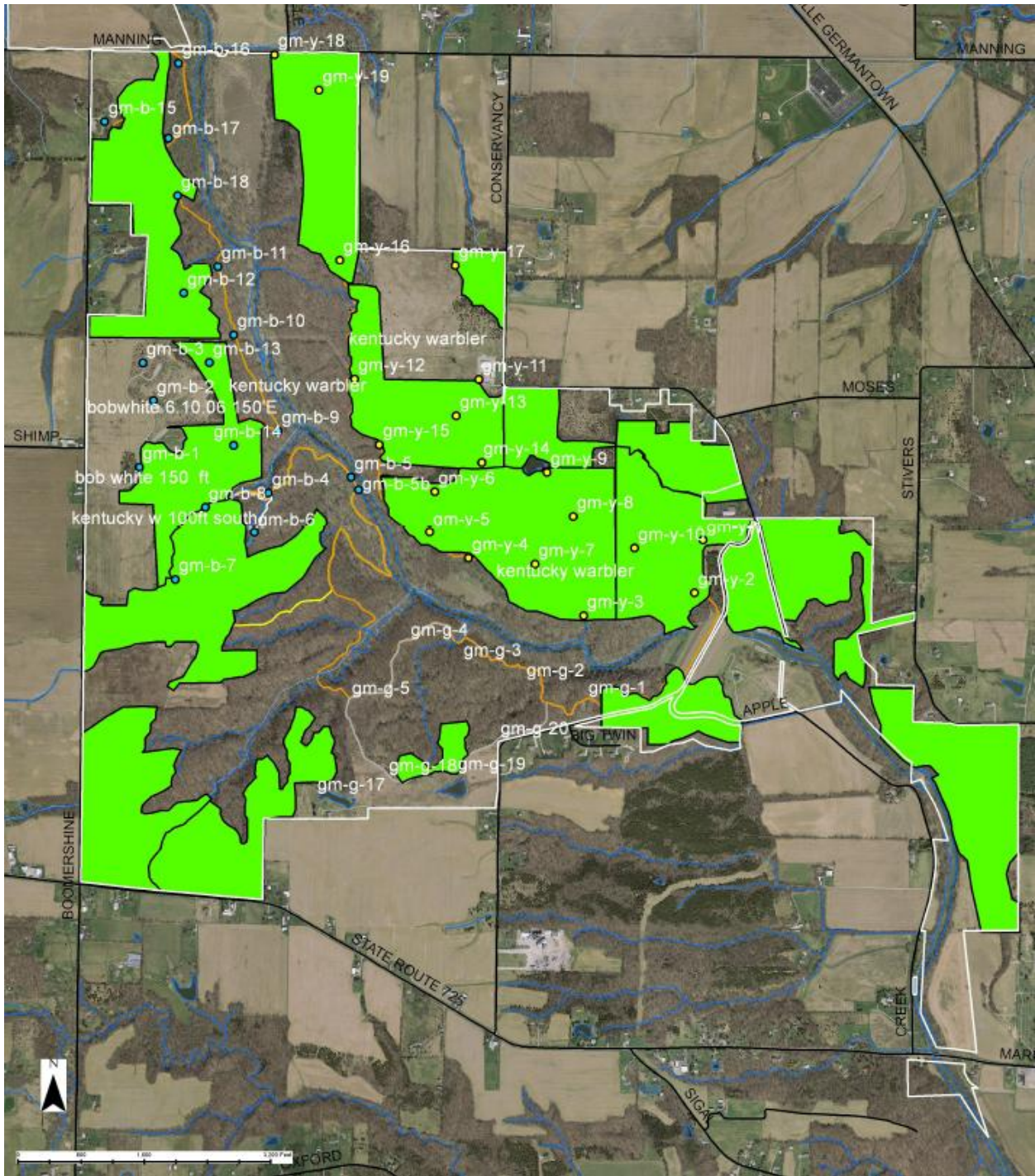
Figure 3. Breeding bird survey point count locations (dots) and areas where honeysuckle was treated (green areas). The labels refer to the trail and the point count number for each point to allow for repeated surveys year after year. Those points that fall outside the green shaded areas were control plots for the entire study. Germantown MetroPark, Montgomery County, Ohio.

Figure 4. Green shading showing areas treated for honeysuckle, with respective years, in Germantown MetroPark, Montgomery County, Ohio.

Results

     Table 2 shows the 95% confidence intervals for the vegetation characteristics within the study plots. The average number of birds seen over the various treatments were too close to one another to be considered different (Table 3).
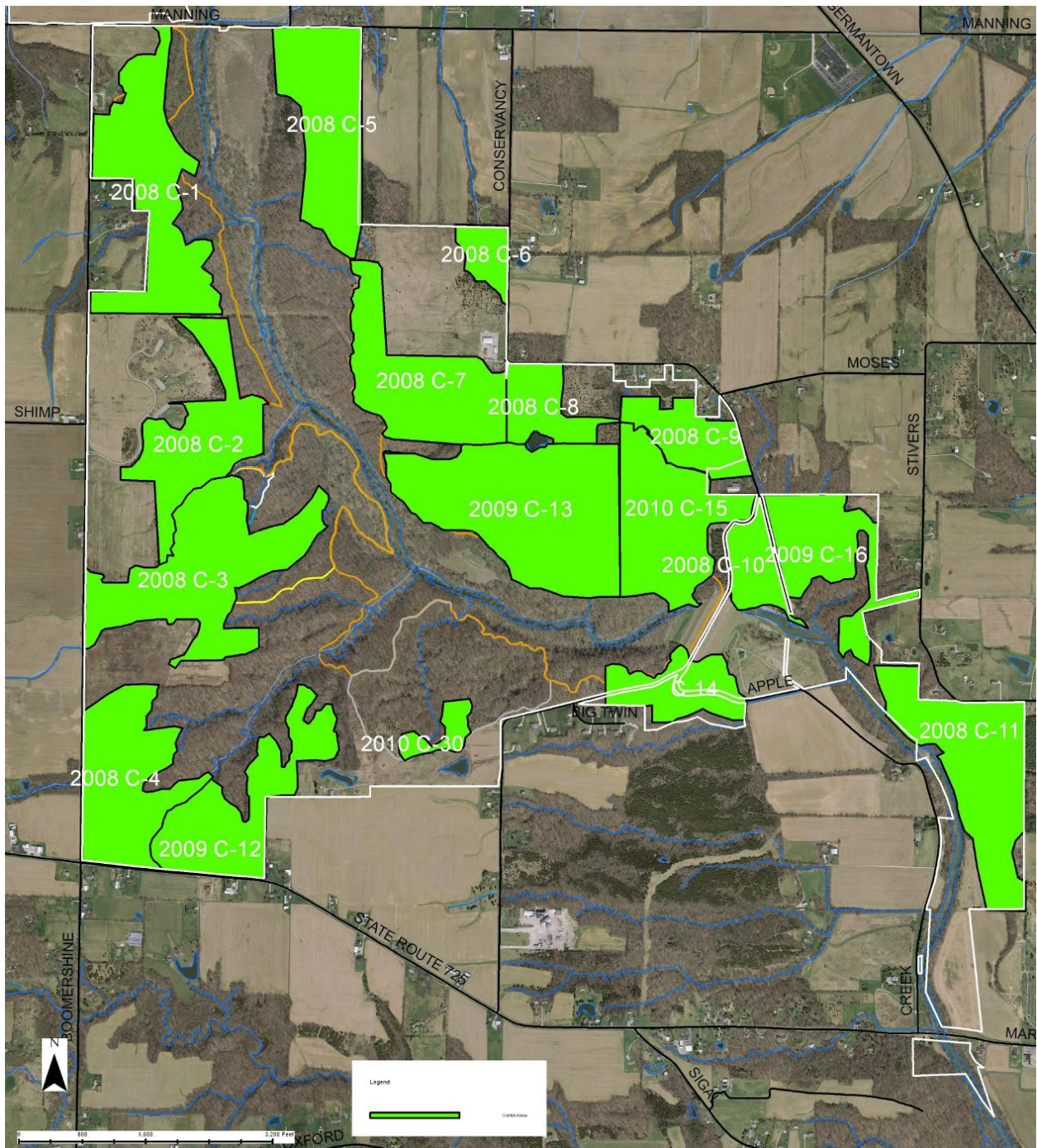
     The results from the CCA test show the constrained and unconstrained results for the avian abundance when including vegetation characteristics (Table 4). The relationship of the vegetation characteristics to the main axes of the CCA figure (Table 5) and the Eigenvalues (Table 6) are also listed. Figure 5 shows percent forb cover and honeysuckle density as important vegetation characteristics along the Y axis. Percent litter and native shrub density are associated along the x axis, though not strongly shown through how short the arrows are and the fact they are not located very close to the axis. There was some separation between the two most extreme courses: the control and those plots that had been treated for the longest period of time (4T1C). However there was still some overlap of the ellipses representing these two courses.

Table 2. 95% Confidence intervals for vegetation characteristics measured on all point count plots, separated into the four treatment groups based on when the honeysuckle was treated. The first number denotes how many years the plot was a treatment plot and the second denotes how many years it was a control plot. For example, 2T3C means those plots were control plots for 3 years before honeysuckle treatment and the plot had been treated for 2 years by the end of the study. Germantown MetroPark.

	0T5C	2T3C	3T2C	4T1C
Percent Canopy Cover	82.9±23.2	91.3±0.6	90.4±3.4	67.2±6.0
Basal Area of Trees	95.0±18.1	116.7±21.2	104.0±39.8	92.0±42.2
Native Shrub Density	25.6±42.5	17.6±25.9	242.1±612.2	15.5±13.3
Honeysuckle Density	45.5±66.5	8.2±6.1	9.3±10.8	16.9±13.2
Percent Forb Cover	22.0±27.4	12.5±5.6	30.0±27.4	16.6±12.2
Percent Grass Cover	4.9±8.8	3.3±2.4	6.0±12.6	6.0±5.5
Percent Litter Cover	48.9±38.7	63.3±26.8	33.0±19.0	49.3±15.9

Table 3. Mean number of birds seen per plot in each of the four treatment areas and the standard deviation for those averages. Germantown MetroPark, Germantown, Ohio.

Treatment	0T5C	2T3C	3T2C	4T1C
Average bird count	35.71667	36.6	38.94	33.66
Standard Deviation	11.03015	10.41839	9.050863	14.56668

Table 4. Inertia, proportion, and rank for constrained and unconstrained variables in the CCA analysis of all species. Germantown MetroPark, Ohio.

	Inertia	Proportion	Rank
Total	2.8163	1.0000	--
Constrained	1.0713	0.3804	9
Unconstrained	1.7450	0.6196	20

Table 5. Vectors of vegetation characteristics and their relationship to the two main axes in the CCA analysis. Germantown MetroPark.

	CCA1	CCA2	r2	Pr(>r)
TRT	-0.83007	0.55766	0.1192	0.325
Course	-0.95678	0.29080	0.1971	0.099
FORBS	-0.28421	-0.95876	0.1119	0.310
GRASS	-0.52826	0.84908	0.3494	0.032
LITTER	0.91003	0.41453	0.1855	0.141
CANOPY	0.54348	0.83942	0.5362	0.040
PCQ.HS	-0.26421	0.96447	0.2313	0.084
PCQ.N	0.94300	0.33279	0.1732	0.124

Table 6. Eigenvalues for constrained axes in CCA model for all bird species. Germantown MetroPark.

Axis	CCA 1	CCA 2	CCA 3	CCA 4
Eigenvalue	0.360	0.213	0.132	0.106
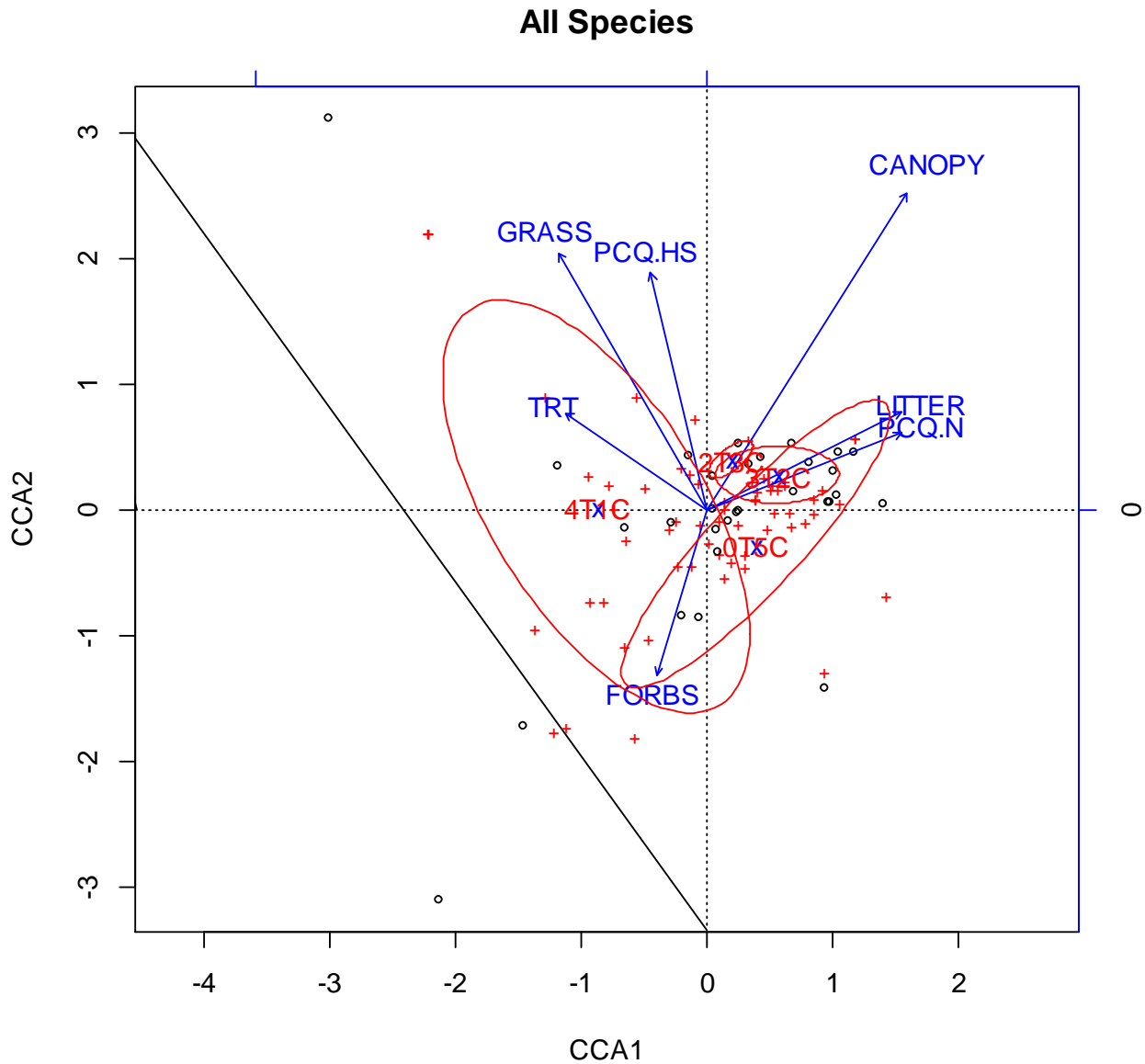
Figure 5. The graph of the vegetation characteristics in relation to bird species (represented by the x's). The circles are the study plots from Germantown MetroPark and the ellipses represent the 4 treatment courses.

Ground Nesting Species

      Of the ground nesting species, Eastern Towhees (*Pilipo erythrophthalmus*) were observed in the point counts most often (Table 7). The average count of ground nesting species increased in treatment plots that had been treated for four years ($P = 0.002$) (Table 8 and Figure 6). However, Figure 6 also

shows that in 2006, for the 4T1C plots, there was a greater number of ground nesting birds before any treatment occurred so plots that were eventually treated may have had inherently more birds from this guild. The important vegetation parameters for ground nesting species were: treatment, percent grass cover, and native shrub density (Table 9). As the percent grass cover on the plots increased, so did the number of ground nesting birds detected within the plot, and as native shrub density increased, the presence of ground nesting birds decreased (Table 10).

Shrub Nesting Species

The three top species detected within the shrub nesting species guild during the point counts were American Goldfinches (*Carduelis tristis*), Indigo Buntings (*Passerina cyanea*) and Northern Cardinals (*Cardinalis cardinalis*) (Table 11). The average count of ground nesting species was higher in plots that had been treated for 2 years when considering plots from 2009 to 2012 and only looking at those in 2012 (*P*= 0.044 and 0.010 respectively) (Table 12, Figure 7). Figure 7 also shows that the counts were higher for those two treatments in 2006, prior to any treatment occurring, though not by as large of an amount. This could be one reason for the counts being higher in later years within those 2 treatment courses. The important vegetation parameters for shrub nesting species were: treatment and percent canopy cover (Table 13). The average number of shrub nesting birds detected increased with treatment and decreased as the canopy became more closed (Table 14).

Fruit Eating Species

The Northern Cardinal (*Cardinalis cardinalis*) was the highest detected species, within the fruit eating species guild (Table 15). Over 250 more Northernal Cardinal individuals were detected than the next most abundant species. The average number of fruit eating species detected during the point counts was lower in areas that had been treated after two years than in the control areas for the year groupings 2009-2012, 2010-2012 and nearly significant in 2011-2012 (*P*= 0.017, 0.023, 0.059 respectively) (Table 16, Figure 8). Figure 8 shows that 2T3C has an inherently larger count of fruit eating species before any

treatment begins, but as treatment occurred, those plots that remained as controls through the entire experiment had slightly higher counts for this guild. The important vegetation parameters for fruit eating species were: treatment, basal area, and native shrub density (Table 17) and the average number of birds detected decreased with increasing basal area and increased with increasing native shrub density (Table 18).

Ground Nesting Species

Table 7. Count of individual birds detected in the ground nesting guild for all 4 years.

Guild: Ground Nesters Species Common Name	Scientific Name	Number Detected 2006	2009	2010	2011	2012	Total Detected All Years
American Woodcock	*Scolopax minor*	0	0	0	1	0	1
Blue-winged Warbler	*Vermivora pinus*	0	3	1	0	1	5
Eastern Meadowlark	*Sturnella magna*	2	1	5	0	3	11
Eastern Towhee	*Pilipo erythrophthalmus*	24	55	63	57	67	266
Field Sparrow	*Spizella pusilla*	20	19	24	13	13	89
Kentucky Warbler	*Oporornis formosus*	7	11	11	25	19	73
Killdeer	*Charadrius vociferous*	2	4	4	4	2	16
Louisiana Waterthrush	*Seiurus motacilla*	3	5	2	2	1	13
Ovenbird	*Seiurus aurocapillus*	5	18	14	8	6	51
Song Sparrow	*Melospiza melodia*	5	6	5	3	7	26
Wild Turkey	*Meleagrus gallopavo*	0	0	0	3	0	3

Table 8. Estimates and significance tests for honeysuckle treatment effects on ground nesting species counts in all year groupings.

| 2006	Estimate	St. Error	z-value	*P*-value
(Intercept)	0.648	0.161	4.013	<0.001
COURSE1	-0.141	0.0812	-1.742	0.082
COURSE2	-0.139	0.162	-0.856	0.392
COURSE3	-0.458	0.194	-2.366	0.018
2009-2012				
(Intercept)	1.289	0.131	9.815	<0.001
COURSE1	-0.295	0.131	-2.247	0.025
2010-2012				
(Intercept)	1.247	0.117	10.662	<0.001
COURSE1	-0.135	0.076	-1.777	0.076
COURSE2	-0.298	0.154	-1.939	0.053
2011-2012				
(Intercept)	1.235	0.118	10.476	<0.001
COURSE1	-0.054	0.055	-0.974	0.330
COURSE2	-0.025	0.118	-0.211	0.834
COURSE3	-0.274	0.153	-1.795	0.0727
2012	**Estimate**	**St. Error**	**z-value**	***P*-value**
(Intercept)	1.223	0.123	9.954	<0.001
COURSE1	0.010	0.055	0.184	0.854
COURSE2	-0.004	0.120	-0.036	0.972
COURSE3	-0.524	0.171	-3.055	0.002
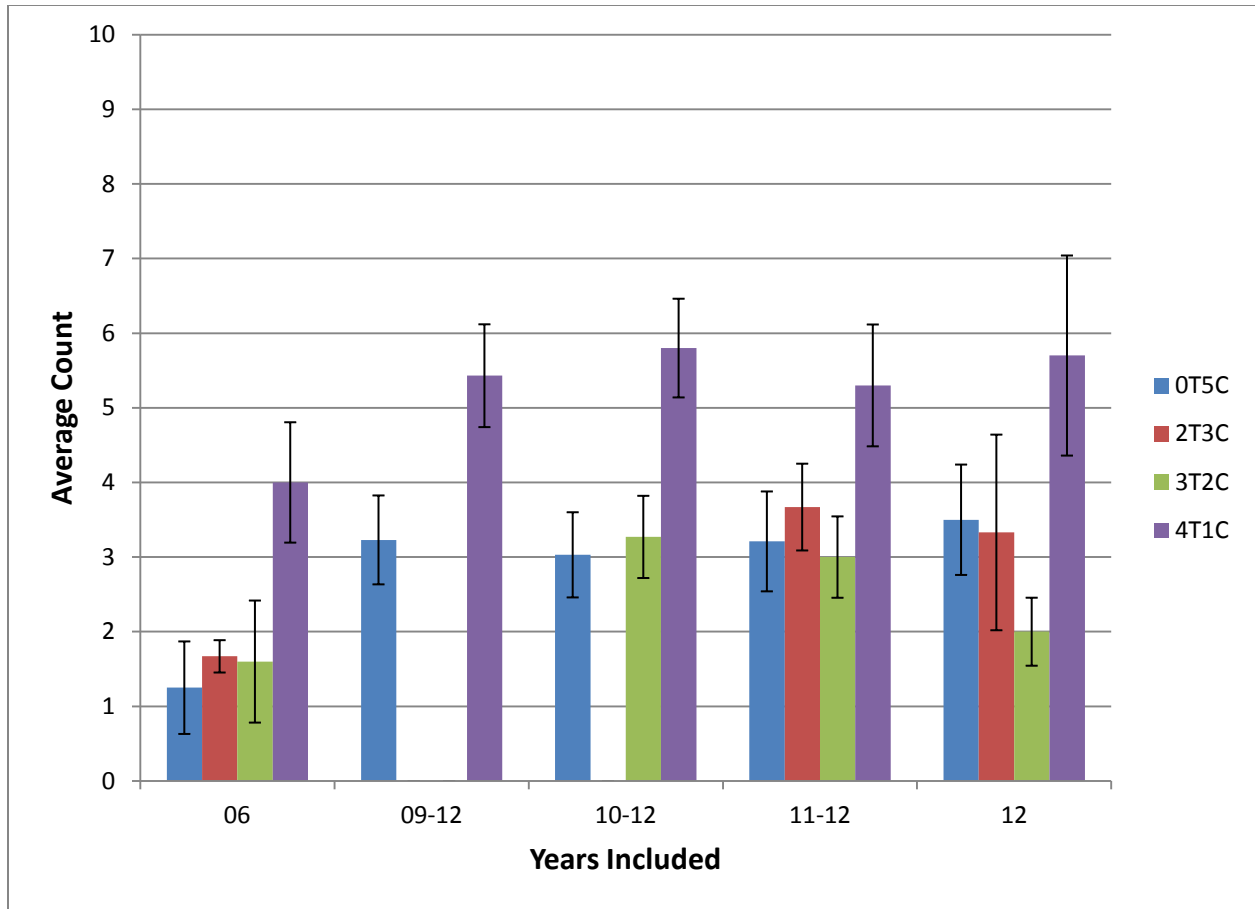
Figure 6. Comparison (with 95% confidence intervals) of the average number of ground nesting birds detected in the point counts conducted in Germantown MetroPark in years 2006 and 2009 through 2012. 2006 was a pretreatment year, so differences seen here are due to inherent differences between the plots.

Table 9. Ranking of Poisson regression models to determine important vegetation characteristics for ground nesting species in Germantown MetroPark, Ohio in 2006 and from 2009 to 2012.

		k	AICC	d.AICC	w.AICC
1	TRT + GRASS + PCQ.N	4	145.895	0.000	0.398
2	TRT + GRASS + PCQ.N + BA	5	147.376	1.481	0.190
3	TRT + BA + PCQ.N	4	147.863	1.968	0.149
4	TRT + PCQ.N	3	148.912	3.017	0.088
5	TRT + BA	3	149.058	3.163	0.082
6	TRT + GRASS + BA	4	149.421	3.525	0.068
7	Null	1	152.371	6.475	0.016
8	TRT	2	153.547	7.651	0.009

TRT= treatment of honeysuckle, GRASS= percent grass cover, PCQ.N= native shrub density, BA=basal area of trees.

Table 10. Parameter estimates, standard error and test of significance from the highest ranking conditional logistic regression model to determine important vegetation factors for ground nesting species. Germantown, Ohio, years 2006 and 2009-2012.

	Estimate	Std. Error	z-value	*P*-value
(Intercept)	1.312	0.180	7.314	<0.001
TRTT	0.201	0.193	1.041	0.298
GRASS	0.027	0.011	2.481	0.013
PCQ.N	-0.023	0.009	-2.589	0.010

Shrub nesting species

Table 11. Count of individual birds detected within the shrub nesting species guild for each year.

Guild: Shrub Nesters		Number Detected					Total Detected All
Species Common Name	Scientific Name	2006	2009	2010	2011	2012	Years
American Goldfinch	*Carduelis tristis*	23	44	31	55	63	216
American Redstart	*Setophaga ruticilla*	0	0	0	0	0	0
Brown Thrasher	*Toxostoma rufum*	0	0	0	3	0	3
Common Yellowthroat	*Geothlypis trichas*	14	16	21	24	23	98
Eastern Kingbird	*Tyrannus tyrannus*	0	0	0	0	0	0
Gray Catbird	*Dumetella carolinensis*	4	22	12	10	9	57
Hooded Warbler	*Wilsonia citrina*	1	1	0	1	1	4
Indigo Bunting	*Passerina cyanea*	61	65	55	62	63	306
Northern Cardinal	*Cardinalis cardinalis*	77	121	123	131	87	539
Prairie Warbler	*Dendroica discolor*	29	16	27	32	28	132
Red-eyed Vireo	*Vireo olivaceus*	32	25	33	28	35	153
Swainson's Thrush	*Catharus ustulatus*	1	0	0	0	0	1
White-eyed Vireo	*Vireo griseus*	10	6	5	7	6	34
Willow Flycatcher	*Empidonax travillii*	1	2	1	2	2	8
Northern Mockingbird	*Mimus polyglottos*	0	0	1	0	0	1
Yellow-breasted Chat	*Icteria virens*	9	3	5	6	6	29
Yellow Warbler	*Dendroica petechia*	5	6	2	10	3	26

Table 12. Estimates and significance tests for honeysuckle treatment effects on shrub nesting species counts in all year groupings.

2006	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.207	0.069	31.844	<0.001
COURSE1	-0.057	0.034	-1.678	0.093
COURSE2	0.020	0.068	0.289	0.777
COURSE3	-0.069	0.090	-0.763	0.446

2009-2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.364	0.081	29.224	<0.001
COURSE1	-0.163	0.081	-2.016	0.044

2010-2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.297	0.088	26.086	<0.001
COURSE1	-0.060	0.057	-1.057	0.291
COURSE2	-0.170	0.117	-1.456	0.145

2011-2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.390	0.092	25.900	<0.001
COURSE1	-0.060	0.043	-1.395	0.163
COURSE2	0.067	0.092	0.726	0.468
COURSE3	-0.169	0.121	-1.400	0.162

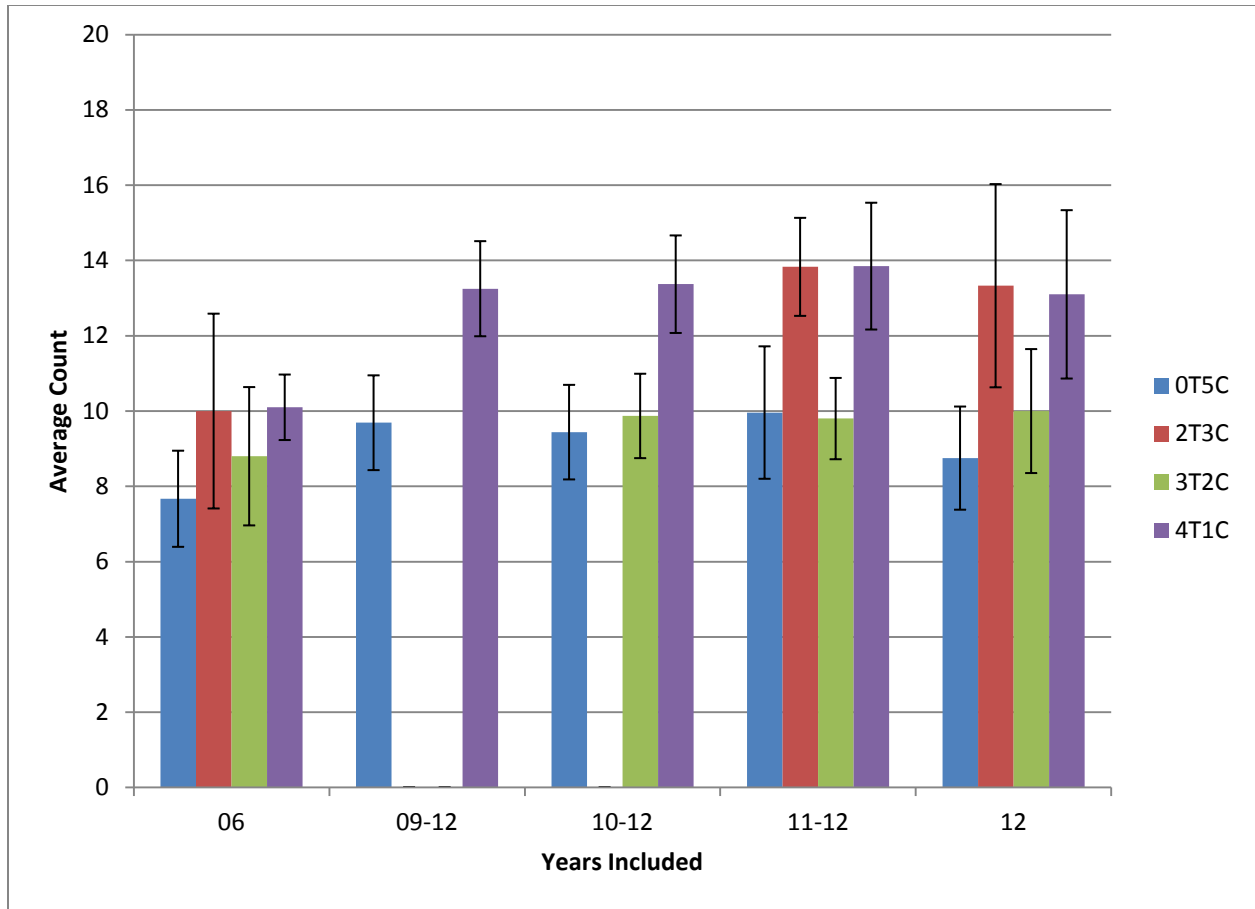| 2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.409	0.062	38.644	<0.001
COURSE1	-0.080	0.031	-2.576	0.010
COURSE2	0.051	0.060	0.855	0.393
COURSE3	-0.135	0.083	-1.624	0.104

Figure 7. Comparison (with 95% confidence intervals) of the average number of shrub nesting birds detected in the point counts conducted in Germantown MetroPark in years 2006 and 2009 through 2012. 2006 was a pretreatment year, so differences seen here are due to inherent differences between the plots.

Table 13. Ranking of Poisson regression models to determine important vegetation characteristics for shrub nesting species in Germantown MetroPark, Ohio in 2006 and from 2009 to 2012.

		k	AICC	d.AICC	w.AICC
1	TRT + CANOPY	3	176.596	0.000	0.417
2	TRT + FORBS + LITTER + CANOPY	5	177.250	0.654	0.301
3	TRT + CANOPY + PCQ.N	4	178.413	1.817	0.168
4	TRT + FORBS + LITTER + PCQ.N + CANOPY	6	179.335	2.739	0.106
5	TRT + FORBS + LITTER + PCQ.N	5	185.279	8.683	0.005
6	TRT	2	188.862	12.266	0.001
7	TRT + PCQ.N	3	189.462	12.866	0.001
8	1	1	195.040	18.443	0.000

TRT= treatment of honeysuckle, FORBS= percent forbs cover, LITTER= percent litter cover, PCQ.N= native shrub density, CANOPY= percent canopy closure.

Table 14. Parameter estimates, standard error and test of significance from the highest ranking conditional logistic regression model to determine important vegetation factors for shrub nesting species. Germantown, Ohio, years 2006 and 2009-2012.

	Estimate	St. Error	z-value	*P*-value
(Intercept)	3.447	0.316	10.915	< 0.001
TRT	0.449	0.125	3.599	<0.001
CANOPY	-0.016	0.004	-4.070	<0.001

Fruit Eating Species

Table 15. Count of individual birds detected within the fruit eating species guild for each year.

Guild: Fruit Eating Species		Number Detected					Total Detected All Years
Species Common Name	Scientific Name	2006	2009	2010	2011	2012	Years
Acadian Flycatcher	*Empidonax virescens*	34	69	49	63	49	264
American Crow	*Corvus brachyrhynchos*	13	38	36	50	50	187
Blue Jay	*Cyanocitta cristata*	12	30	42	30	20	134
Brown Thrasher	*Toxostoma rufum*	0	0	0	3	0	3
Cedar Waxwing	*Bombycilla cedrorum*	11	7	12	14	4	48
Common Grackle	*Quiscalus quiscula*	6	10	3	6	3	28
Eastern Towhee	*Pilipo erythrophthalmus*	24	55	63	57	67	266
European Starling	*Sturnus vulgaris*	0	0	0	0	0	0
Great Crested Flycatcher	*Myiarchus crinitus*	9	7	8	18	10	52
Gray Catbird	*Dumetella carolinensis*	4	22	12	10	9	57
House Finch	*Carpodacus mexicanus*	0	1	0	0	0	1
Northern Cardinal	*Cardinalis cardinalis*	77	121	123	131	87	539
Red-bellied Woodpecker	*Melanerpes carolinus*	18	41	49	28	30	166
Red-eyed Vireo	*Vireo olivaceus*	32	25	33	28	35	153
Scarlet Tanager	*Piranga olivacea*	15	4	5	8	10	42
Summer Tanager	*Piranga rubra*	0	2	0	1	4	7
Swainson's Thrush	*Catharus ustulatus*	1	0	0	0	0	1
Tree Swallow	*Tachycineta alpestris*	5	9	1	3	3	21
Tufted Titmouse	*Parus bicolor*	31	47	80	50	45	253
Warbling Vireo	*Vireo gilvus*	0	1	1	2	1	5
Willow Flycatcher	*Empidonax travillii*	1	2	1	2	2	8
Northern Mockingbird	*Mimus polyglottos*	0	0	1	0	0	1
Wood Thrush	*Hylocichla mustelina*	16	39	32	21	18	126
Yellow-breasted Chat	*Icteria virens*	9	3	5	6	6	29

Table 16. Estimates and significance tests for honeysuckle treatment effects on fruit eating species counts in all year groupings.

2006	Estimate	St. Error	z-value	*P*-value
(Intercept)	0.024	0.062	38.341	<0.001
COURSE1	-0.017	0.030	-0.576	0.565
COURSE2	0.0893	0.060	1.489	0.136
COURSE3	<0.001	0.086	0.000	1.000

2009-2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.820	0.035	80.450	<0.001
COURSE1	0.084	0.035	2.39	0.017

2010-2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.825	0.033	84.53	<0.001
COURSE1	0.048	0.021	2.28	0.023
COURSE2	0.072	0.045	1.610	0.106

2011-2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.789	0.04215	66.170	<0.001
COURSE1	0.0361	0.0192	1.890	0.059
COURSE2	0.0431	0.0421	1.02	0.306
COURSE3	0.0650	0.056	1.160	0.246

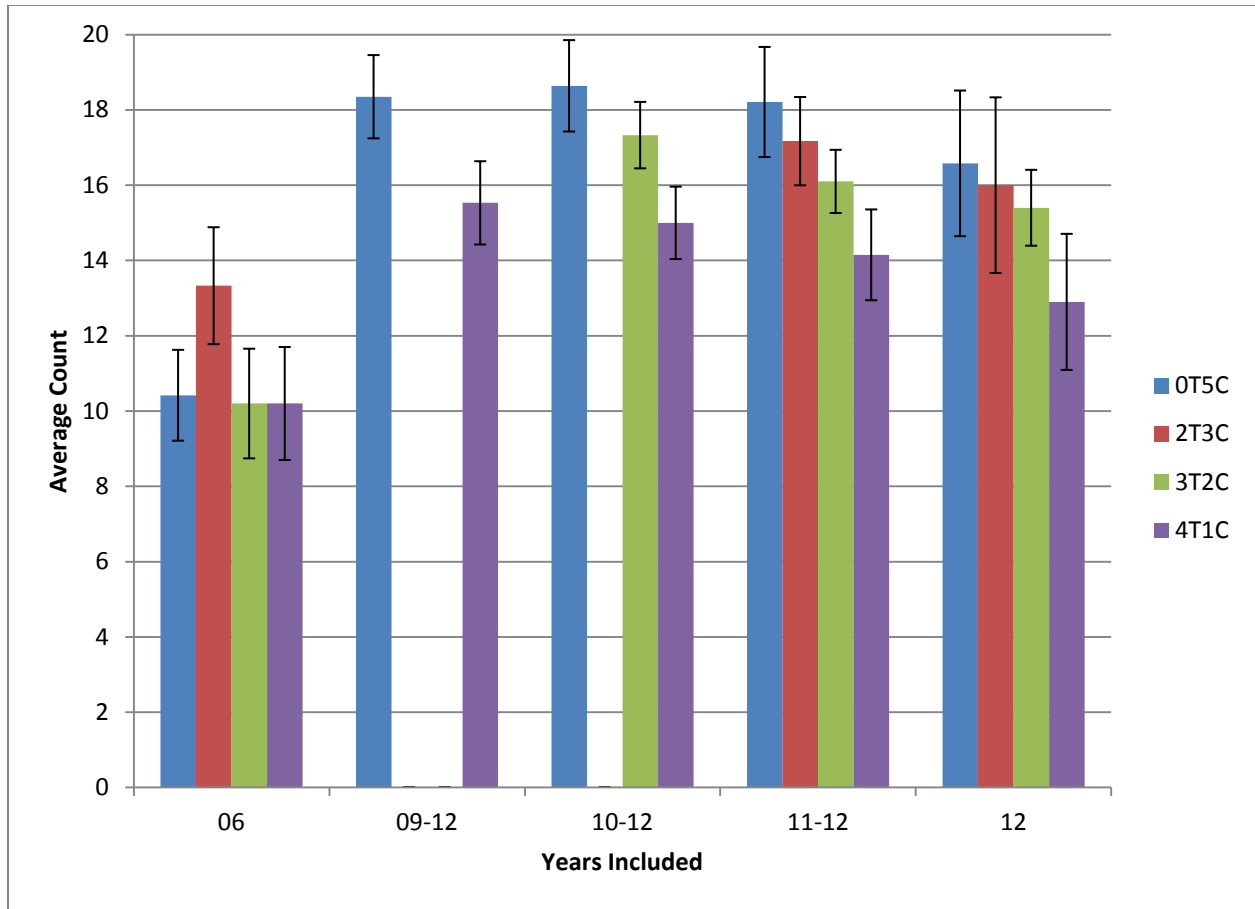| 2012	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.718	0.054	50.368	<0.001
COURSE1	0.030	0.025	1.225	0.220
COURSE2	0.042	0.054	0.786	0.432
COURSE3	0.0886	0.072	1.230	0.219

Figure 8. Comparison (with 95% confidence intervals) of the average number of fruit eating birds detected in the point counts conducted in Germantown MetroPark in years 2006 and 2009 through 2012. 2006 was a pretreatment year, so differences seen here are due to inherent differences between the plots.

Table 17. Ranking of Poisson regression models to determine the best fit for important vegetation characteristics for fruit eating bird species in Germantown MetroPark, Ohio in 2006 and from 2009 to 2012.

		k	AICC	d.AICC	w.AICC
1	TRT+ BA + PCQ.N	4	182.992	0.000	0.302
2	TRT + PCQ.N	3	184.484	1.492	0.143
3	TRT	2	184.558	1.566	0.138
4	TRT + BA	3	184.743	1.751	0.126
5	1	1	185.153	2.161	0.103
6	TRT + FORBS + PCQ.N + BA	5	185.561	2.569	0.084
7	TRT + FORBS + BA	4	186.233	3.241	0.060
8	TRT + FORBS + PCQ.N	4	186.846	3.854	0.044

TRT=honeysuckle treatment, BA=basal area of trees, FORBS=percent forbs cover, PCQ.N=native shrub density.

Table 18. Parameter estimates, standard error and test of significance from the highest ranking conditional logistic regression model to determine important vegetation factors for fruit eating species. Germantown, Ohio, years 2006 and 2009-2012.

	Estimate	St. Error	z-value	*P*-value
(Intercept)	2.965	0.139	21.337	<0.001
TRTT	-0.153	0.095	-1.618	0.106
BA	-0.003	0.001	-2.008	0.045
PCQ.N	0.007	0.003	2.153	0.031

Discussion

There was some response to treatment in reference to certain species guilds that would be affected by the change in vegetation structure due to the shrub layer changing, however, this evidence is weak. There was a difference in species found between the different groups of plots such as 0T5C and 4T1C in 2006, which was before any treatment occurred. This suggests that there were inherent differences between the plots themselves that could lead to the results found, regardless of treatment. It also takes a few years for the treated honeysuckle to decay and be replaced by native shrubs or tree seedlings. Because of this, there is a delay in the actual effects of the honeysuckle removal, and if bird abundance continued to be monitored into the future, it may be possible to see clearer trends in the populations.

Many of the variables were related, making it difficult to tease apart the effects of one specific variable, and the natural fluctuations in species' populations could also affect the count data that was taken. For the statistical analysis on the effects of treatment over time, some of the plots were double counted, which could skew results. This was accounted for as much as possible using the linear mixed effects test in R. The conditional Poisson models that were used to find the model with the best fit had AIC values that were very similar to one another within each guild. While the model with the lowest AIC value was chosen, they were similar to other models within the guild, and in some cases, very similar to the null, meaning that none of the models were great fits for the data set. The CCA results also showed that there was not any one or 2 vegetation characteristics that were greatly influential on the distribution of species detected in the point counts. The overlap of the ellipses on the treatment courses implemented

show that the bird species were not highly affected by the honeysuckle removal. There was some separation though, and this is likely due to the differing habitat characteristics needed by different species in addition to any changes caused by the treatment.

Ground nesting species increased slightly as a result of the honeysuckle treatment, and this could be due to an increase in grasses and shrubs once the honeysuckle is dead, especially considering the time since treatment showed an increase in the ground nesting birds detected. Figure 3 shows that overall, detections of these species were higher from 2009 to 2012 than in 2006, but the number of individuals was very similar in control plots and plots that had been treated for two and three years. The increase took place after four years and was not always within the significance value of 0.05, though was close to that cutoff. But because the increase was not consistent across time, it cannot definitely be said that the honeysuckle treatment caused this. Also, the plots that were treated for 4 years (4T1C) also had an inherently higher number of ground nesting species on those plots even prior to any treatments taking place.

The ground nesting species were most affected by the amount of grass and/or sedges found on the plot and the native shrub density. The higher the percentage of grass or sedges the more ground nesting birds were detected on the site because they often nest in grass (Ehrlich et al, 1988). The presence of the grass provides an essential part of the vegetation structure for them to complete their lifecycle (Ehrlich et al, 1988). As the density of native shrubs increased, the number of ground nesters decreased, and this is probably linked to the amount to grass and sedges found the on the sites. Less light reaches the forest floor on plots with a large percentage of shrubs, so these two factors are linked.

The fact that the shrub nesting species increased over time, even though only significantly when considering 2009-2012, is surprising because the honeysuckle was killed during treatment and therefore would not provide good protective cover for nesting species after it was treated. The shrubs would still be standing since they were not cut after treatment, but they would not leaf out in the spring and the native shrub species would not necessarily have had time to grow to maturity.

For shrub nesting species, the most important vegetation factors affecting that species guild was treatment of honeysuckle and amount of closed canopy, and for both factors, the birds increased, which does not make intuitive sense. However, the increased in birds after the honeysuckle was treated is consistent with the results found when looking specifically at the effects of treatment of honeysuckle over time. The fact that the shrub nesting species increased as the amount of closed canopy also increased is not what was expected because as canopy closure increases, less sunlight hits the forest floor and therefore there would be less native, or even invasive, shrubs found there (Barnes et al, 1998). But it also true that these results were not consistent across all the treatments and the decline could be due to an overall decline in abundance of the species that fall into that guild.

The fruit eating guild showed a slight decrease over time as a result of treatment as expected because honeysuckle berries are a food source for those species though it was only significant when looking at the year grouping 2009-2912. When the honeysuckle was treated, that food source was gone, but there were not yet any native shrubs to replace the honeysuckle that was of fruit-bearing age. It was not surprising that the species that have fruit or berries as a large part of their diet decreased in abundance because of the decrease in food availability. Since treatments started in the fall of 2008, and the treatment did not include cutting the honeysuckle stems, it takes a few years (Runkle et al, 2007) for the honeysuckle debris to break down and native shrubs or other honeysuckle seedlings from the seed bank, to replace the large dead shrubs. Therefore there is going to be a time gap between treatment and the desired positive effects. Once native shrubs are able to grow large enough to produce berries, the fruit eating species should increase once again. It is also interesting that in 2006, all observations were lower than from 2009 to 2012 regardless of whether the plot was a control or the number of years since treatment, which indicated that there may have been an increase in the fruit eating species overall in those years, but that the removal of a food source (honeysuckle) had a negative effect on the species.

However fruit eating species where affected most by basal area of the plot and the density of native shrubs, which is not a surprising result. The native shrubs produce fruit, which makes up a large portion of their diet for at least part of the year. The fact that fruit eating species decrease with increasing

basal area may be linked to the fact that the more trees on the plot, the less light is likely to hit the ground, and therefore there a likely to be fewer shrub species on those plots. Those two factors may be somewhat dependent upon one another.

Overall, there may be a slight trend beginning to show positive effects of honeysuckle treatment for some species guilds due to the removal of the invasive species, however there are many habitat factors that influence the effectiveness of the treatment. This evidence supporting the positive effect was also inconsistent, and therefore I would argue that treating honeysuckle with the foliar spray method that MetroParks currently employs is not effective in increasing avian abundance. There may be an increase in some individual species, however when assessing the effects on species sharing certain life characteristics there was not a definite increase. There is also a time lag in seeing the results of the treatment, and it is possible that the results desired could take longer than the time span of this study. The other vegetation in addition to the removal of invasive species is important for the maintenance of species richness and abundance. In agreement with Gleditsch and Carlo (2007)'s findings, the replacement of honeysuckle with native species may be needed to produce the positive desired effect on avian abundance. This is important for managers because it can help them decide if treating honeysuckle in this way is going to be a good monetary investment in the habitat and shows that the effects of this type of management is not going to be immediate. There are also multiple reasons for treating invasive species, and this study indicates that there this method does not have a negative effect` on the birds found within Germantown MetroPark. Other methods of honeysuckle removal, such as cut and treat, or the physical removal of the entire shrub itself may have a larger positive influence on avian abundance. Overall vegetation structure management is important, particularly if specialist species that have certain habitat requirements are the focus of management or conservation. Therefore, treating and removing invasive species, such as honeysuckle, alone may not produce the desired effect on species richness or conservation.

Acknowledgements

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Appendices

Appendix 1: Species in the three species guild used in the statistical analysis.

Ground nesting species: American Woodcock (*Scolopax minor*), Blue-winged Warbler (*Vermivora pinus)*, Eastern Meadowlark (*Sturnella magna*), Eastern Towhee (*Pipilo erythrophthalmus*), Field Sparrow (*Spizella pusilla*), Grasshopper Sparrow (*Ammodramus savannarum*), Henslow's Sparrow (*Ammodramus henslowii*), Kentucky Warbler (*Oporornis formosus*), Killdeer (*Charadrius vociferous*), Louisiana Waterthrush (*Seiurus motacilla*), Ovenbird (*Seiurus aurocapillus*), Song Sparrow (*Melospiza melodia*), Wild Turkey (*Meleagrus gallopavo*).

Shrub nesting species: American Goldfinch (*Carduelis tristis*), American Redstart (*Setophaga ruticilla*), Brown Thrasher (*Toxostoma rufum*), Common Yellowthroat (*Geothlypis trichas*), Eastern Kingbird (*Tyrannus tyrannus*), Gray Catbird (*Dumetella carolinensis*), Hooded Warbler (*Wilsonia citrina*), Indigo Bunting (*Passerina cyanea*), Northern Cardinal (*Cardinalis cardinalis*), Prairie Warbler (*Dendroica discolor*), Red-eyed Vireo (*Vireo olivaceus*), Swainson's Thrush (*Catharus ustulatus*), White-eyed Vireo (*Vireo griseus*), Willow Flycatcher (*Empidonax travillii*), Northern Mockingbird (*Mimus polyglottos*), Yellow-breasted Chat (*Icteria virens*), Yellow Warbler (*Dendroica petechia*).

Fruit eating species: Acadian Flycatcher (*Empidonax virescens*), American Crow (*Corvus brachyrhynchos*), Blue Jay (*Cyanocitta cristata*), Brown Thrasher (*Toxostoma rufum*), Cedar Waxwing (*Bombycilla cedrorum*), Common Grackle (*Quiscalus quiscula*), Eastern Towhee (*Pipilo erythrophthalmus*), European Starling (*Sturnus vulgaris*), Great Crested Flycatcher (*Myiarchus crinitus*), Gray Catbird (*Dumetella carolinensis*), House Finch (*Carpodacus mexicanus*), Northern Cardinal (*Cardinalis cardinalis*), Red-bellied Woodpecker (*Melanerpes carolinus*), Red-eyed Vireo (*Vireo olivaceus*), Scarlet Tanager (*Piranga olivacea*), Summer Tanager (*Piranga rubra*), Swainson's Thrush (*Catharus ustulatus*), Tree Swallow (*Tachycineta alpestris*), Tufted Titmouse (*Parus bicolor*), Warbling Vireo (*Vireo gilvus*), Willow Flycatcher (*Empidonax travillii*), Northern Mockingbird (*Mimus polyglottos*), Wood Thrush (*Hylocichla mustelina*), Yellow-breasted Chat (*Icteria virens*).