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The Population and Behavioral Response of Woodpeckers to the Emerald Ash Borer Invasion

By
Maria G. Herman

Submitted to the Graduate Faculty as partial fulfillment of the requirements for

The Master of Science Degree in Biology (Ecology track)

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August 2010
The emerald ash borer (*Agrilus planipennis*) is an invasive wood-boring beetle native to Asia. Discovered in Michigan in 2002, it has decimated populations of ash trees in surrounding areas. Woodpeckers are a native predator of the beetle. This research focused on the impact emerald ash borer has had on the population and behavior of woodpeckers. Does emerald ash borer affect local woodpecker populations? Do woodpeckers demonstrate preferential feeding on ash trees over non-ash trees in infested areas? Are more woodpeckers observed in areas with a higher percentage of ash cover? This research found that woodpecker populations in infested areas are not positively affected by the beetle. However, woodpeckers in infested areas do demonstrate
preferential feeding on ash trees over non-ash trees, and more woodpeckers are observed in areas with a higher percentage of ash cover. This research underscores the impacts an invasive species has on native species populations.
Acknowledgments

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Chapter 1

Introduction

The emerald ash borer (*Agrilus planipennis* Farimair) is an invasive phloem-feeding beetle that is native to Asia. It attacks only ash trees of the genus *Fraxinus* (McCullough et al., 2004). Ash trees in the United States have evolved no defense against this insect. It kills any ash species it may infest: red/green (*F. pennsylvanica*), black (*F. nigra*), blue (*F. quadrangularis*), white (*F. americana*), or pumpkin ash (*F. profunda*) trees are all susceptible (Cappaert et al. 2005), although white and green ash are more susceptible than others (Anulewicz et al. 2008, Lindell et al. 2008). In 2002, the emerald ash borer was discovered in southeastern Michigan and Ontario, and in 2003, emerald ash borer was detected in Lucas County, Ohio in the town of Whitehouse. Woodpeckers are the one of the only native predators of this invasive insect (Gould et al. 2005, Bauer et al. 2003). This study focuses on the impact that emerald ash borer beetle has had on populations of woodpeckers.

Adult emerald ash borers lay their eggs and live as larvae under the bark of ash trees or in bark crevices (Cappaert et al. 2005), thus becoming an additional food resource for woodpeckers. Emerald ash borers only lay their eggs in trees that are 2 cm diameter at breast height (DBH, considered at 1.3 m high) or larger. (Cappaert et al. 2005)
The eggs are laid from mid-May to mid-August. The eggs hatch into larvae in about two weeks after being laid, feed under the bark from July to autumn, and develop into adults in one to two years (Poland & McCullough 2006). The adults emerge in May and June. From mid-summer to autumn, the larvae feed on phloem, creating S-shaped galleries under the bark. The larvae’s feeding prevents the tree from properly translocating water and nutrients, girdling the tree and eventually leading to its death (Poland & McCullough 2006).

Because approximately 10% of Ohio’s trees are ash, making up an estimated 254 million ash trees 2.54 cm diameter and greater in Ohio (Ohio Department of Natural Resources website 2008), the impacts of emerald ash borer beetle could be substantial and impact the entire ecosystem. An increase in the number of dead trees could influence plant succession in some systems by increasing light penetration into the forest, such has been seen in outbreaks of mountain pine beetles (Dendroctonus ponderosae; Romme 1986). The death of ash trees may also affect native insect populations and decomposition rates in forests, and cause alterations of food-webs, such as increasing food resources for insectivores, causing an increase in the populations of those insectivores. Though there have yet to be studies demonstrating increased light penetration due to emerald ash borer, there has been evidence of increased woodpecker activity in areas infested by emerald ash borer beetle (Smith 2006), and that
“woodpeckers spent significantly more time in foraging bouts on ash than on other tree species in emerald ash borer infested areas” (Lindell et al. 2008), supporting the idea that woodpeckers may change their foraging strategies to focus on emerald ash borer in infested areas.

In northwest Ohio/southern Michigan, there are seven species of woodpeckers, which are seasonally insectivorous. The seven species are the downy woodpecker (Picoides pubescens), the hairy woodpecker (Picoides villosus), the red-bellied woodpecker (Melanerpes carolinus), the red-headed woodpecker (Melanerpes erythrocephalus), the northern flicker (Colaptes auratus), the yellow-bellied sapsucker (Sphyrapicus varius), and the pileated woodpecker (Dryocopus pileatus). These woodpeckers use their beaks to excavate holes in trees from which they extract insect larvae. They forage for insects in trees by listening for activity under the bark. For example, hairy woodpeckers find their prey using percussive techniques, i.e., they strike the tree with their beaks, and then listen for resonance when tapping above the tunnel of a wood-boring insect (Jackson et al. 2002). The species are also all primary cavity nesters (that is, they all excavate their own nests), and, with the exception of the yellow-bellied sapsucker, all are present year-round in this region. Different species have slightly different preferences, and food may be a limiting factor for the woodpeckers during certain times of the year. For example, Reller (1972) observed that red-bellied and red-headed woodpeckers have different nesting preferences: red-headed woodpeckers prefer
to nest in the trunks of dead trees, while red-bellied woodpeckers prefer to nest in the dead limbs of live trees. During the breeding season, which can begin as early as January and last until May, Reller showed that niche partitioning between red-bellied and red-headed woodpeckers was pronounced (1972). However, during the non-breeding season, food is a more important limitation than nesting, and competition is more obvious (Willson 1970, Reller 1972).

In winter and non-breeding season, when insect larvae are usually dormant, woodpeckers alter their diet, consuming fruit and nuts and other more easily obtainable food in addition to insects that they are able to find (Moskovits 1978, Willson 1970, Connor 1981, Jackson 1970, Jackson et al. 2002, Reller 1972). According to Willson (1970), territories remain established in the winter, and inter-species conflicts, in which birds defend these territories and thereby the resources within those territories, sometimes occur. Willson (1970) also observed that female and male red-bellied woodpeckers are quite specialized to feed on certain tree species in the winter (oaks and ash), whereas the red-headed woodpecker is the one of the most generalized woodpeckers in the winter.

Pileated woodpeckers also increase their feeding specialization in the winter, focusing on excavating deep into trees to take advantage of carpenter ants (Camponotus sp.) that become more concentrated deep in logs in the winter (Conner 1981). Conner observed that hairy and pileated woodpeckers increased the number of tree species that
they foraged on during the breeding and winter season compared to post breeding season (1981). Downy woodpeckers also partition niches within their own species, with males and females foraging slightly differently. The males tend to forage lower on smaller trees, using a different foraging technique than the females (Jackson 1970; Willson 1970). Jackson (1970) also demonstrated evidence of seasonal variation in the ways that downy woodpeckers forage overall, variation in the ways they forage on living vs. non-living trees, as well as seasonal changes in their foraging on live or dead trees. A change in the food resources in an area could lead to changes in woodpecker competition, which could lead to changes in the overall population of an area.

The principle of competitive release states that when a food resource is abundant, competition for resources, either between species and/or within a species, will be lessened. For example, a mast year of acorns could result in a change in niches and foraging techniques used by woodpeckers. Woodpeckers could specialize on the abundant resource, or they could supplement their normal diet to include this abundant item. It is observed that mast years of acorns play an important role in winter behavior of woodpeckers in Florida (Moskovits 1978). In the case of an outbreak of a type of insect, competitive release could be apparent and woodpeckers may change their foraging behaviors and diet preference accordingly. An abundance of food caused by an insect outbreak could support a larger population of woodpeckers, and/or more species of woodpeckers, in a given area. This has been the case in Colorado during outbreaks of
pine bark beetle (*Dendroctonus sp.*), causing an increase in the populations of three-toed woodpeckers (*Picoides tridactylus*), hairy woodpeckers and downy woodpeckers (Koplin 1969, Crockett and Hansley 1979).

In support of this theory, Tim Schetter of the Toledo Metroparks (personal communication) noted that pileated woodpeckers were not seen in the Oak Openings Metropark in Lucas County, Ohio until after the ash trees in the park were infested with emerald ash borer beetles (the park was officially considered infested in 2004). This observation is supported by the Audubon Society’s annual Christmas Bird Count Survey data, which reported no pileated woodpeckers in 2004/2005, one in each of the counts in the years 2005-2008, and three in the year 2008/2009 (National Audubon Society CBC online historical records, see Table 1). However, this could be caused by pileated woodpeckers increasing in numbers in second-growth forests, after initially declining in the mid-1900’s (Birds of North America Online 2010, Peterjohn, personal communication, 2010).

Woodpeckers have been observed taking advantage of the emerald ash borer beetles as a food source (Cappaert et al. 2005, Smith 2006). In fact, woodpeckers are the “most important source of mortality” of emerald ash borers in the United States (Cappaert et al. 2005) because they can get through the bark of the tree to where the larvae are feeding. Woodpeckers focus their attacks on emerald ash borer beetle in the pupae/pre-pupae stage when they are under the bark of trees and rarely attack adults
when they are emerging in May-June. However, because some emerald ash borer larvae take two years to develop, some larvae are under the bark in the spring and summer months as well. Lindell et al. (2008) reported that the amount of woodpecker attacks on a tree is positively associated with emerald ash borer density in the tree. Increased abundance of food may reduce the amount of competition among woodpeckers, which would allow woodpeckers to devote more energy to reproduction, and thereby increase their populations. Therefore, an abundance of emerald ash borer larvae has the potential to have a major impact on woodpeckers in northwest Ohio.

Although emerald ash borer larvae become inactive during the winter, woodpeckers still forage on the ash trees, and continue to find larvae even in the winter, when other food options are limited. It could be argued that woodpeckers feeding on emerald ash borer larvae will have no effect on the woodpecker population because the larvae are primarily available in the non-breeding season and are thus not generally fed to woodpecker offspring. However, I hypothesize that an extra food source in the winter may allow more first year woodpeckers to survive their first winter and cause populations of woodpeckers to increase in areas infested by emerald ash borer beetle. I believe it is likely that the availability of an abundant food source in the non-breeding season may, therefore, increase the overall woodpecker population in a given area.

The goal of my research is to address the effects that emerald ash borers are having on the population and foraging behaviors of woodpeckers in order to inform
conservation efforts aimed at understanding and managing this invasive species. This study focuses specifically on the impact of emerald ash borer beetle on the population numbers and foraging habits of woodpeckers across a gradient of emerald ash borer infestation levels.

To determine if emerald ash borers are having an impact on woodpeckers, I tested the following three hypotheses:

1) Hypothesis – the level of infestation of emerald ash borers will be positively correlated with the relative population abundances of woodpeckers.

2) Hypothesis – the number of woodpecker attacks will be significantly higher on ash trees when compared to non-ash deciduous hardwood trees in areas infested with emerald ash borers.

3) Hypothesis – the number of woodpeckers observed at a given count point will be positively correlated with the total percent of ash trees as well as the percent basal area of ash in that location.

In addition to testing the above hypotheses, Christmas Bird Count Data were assessed for changes in woodpecker communities’ composition in the region of my study since the introduction of emerald ash borer beetle. Over the course of this one-year study, additional data were also collected and quantified, including tree composition and DBH at the three sites, and various species of woodpeckers observed at the three sites. These data will also be presented and discussed.
Chapter 2

Methods

Three sites that had been infested at different times were chosen to represent a gradient of emerald ash borer infestation: low/none (pre-infestation), medium (currently infested) and high (currently infested/post-infestation). The sites had to be similar in habitat and accessible to research on foot. The sites were in the same region, to ensure similar flora, fauna, climate and bird species composition, but they were far enough apart to ensure independence of sampling, and near enough to be able to drive to each site twice monthly over the course of one year.

The three sites chosen were Kensington Metropark in Oakland and Livingston Counties near Milford, Michigan, at a high level of infestation, Goll Woods State Nature Preserve in Fulton County near Archbold, Ohio, with a low level of infestation, and Oak Openings Preserve in Lucas County near Swanton, Ohio, with a medium level of infestation (Figure 1). Working in conjunction with the managers at each of the various sites as well as accessing the state records, I ranked the ash tree condition at each of the sites using a 1-5 scale, with 1 representing a healthy tree and 5 representing a dead tree, levels two, three and four represent the progressive degrees of canopy thinning (Smith 2006). The average rating of trees on the whole at each site was considered when
choosing the sites. Kensington Metropark, an 1814 hectare location was listed by the park as having emerald ash borer beetle first, in 2003, but the beetle was likely there well before that year, so this site was considered late/post infestation, with most of the ash trees already dead/dying and the average tree classification was a level 5. Goll Woods, a 130 hectare state nature preserve, had not yet been listed by the state of Ohio as having emerald ash borer beetle in summer of 2007 when it was selected to be used in the study, although eastern portions of Fulton County had been quarantined by the USDA as early as 2004 for having emerald ash borer beetle. In December of 2007 I found signs of infestation when I visited the site, including D-shaped exit holes and woodpecker activity on two trees. However, the majority of the trees at this site were in excellent condition with no signs of infestation when the site was chosen. On average, the trees were classified as healthy (level 1). Oak Openings, a 1516 hectare site, was listed by the park as infested in 2004, but, like Kensington, emerald ash borer beetles were likely there before that year. This site was considered to be currently infested at a mid-level of infestation the time data was collected. The trees at this site were an average of 3-4 on Smith’s scale.

Although the Audubon Society’s Christmas bird counts had been conducted in areas including two of the three sites, no year-round studies specific to woodpeckers had been done at any of the sites. This study aims to substitute space for time to determine how woodpecker populations will change over the course of the emerald ash borer
invasion. To assess the differences in bird communities across this gradient, birds were surveyed within each site over the course of a 12-month period from January-December, 2008. Since there were no previous studies of woodpeckers specifically at these sites before emerald ash borers invaded them, I could not conduct a study of before and after effects. The sites differed in the age of the stands of trees, the average size of the trees, and the size of the sites. However, the research was conducted along the same length of transect within each site. Because both emerald ash borers and woodpeckers occur year round in all of these locations, with the exception of the migratory yellow-bellied sapsucker, a 12-month time period was decided upon for counting the birds in case there were major seasonal differences. Because of the known seasonal differences in woodpecker behavior and diet, to address the hypotheses listed above, woodpecker abundance at each site was surveyed over the course of an entire year, as well as the birds’ activity level on ash vs. non-ash hardwood tree species in each of the three sites.

To test Hypothesis 1, a fixed-radius method of point counts was used for counting birds to compare woodpecker abundance among the three sites (Hutto et al. 1986, Verner 1985, Bibby 1992). At each site, ten points were sampled along an established walking path. These ten points were located 100 meters apart from each other, in order to ensure sample independence (Hutto et al. 1986). At each of the ten points, woodpeckers seen and/or heard within and beyond an estimated 30-m radius during a 10-minute period were counted. If there was any uncertainty if a bird was a new individual or an already
observed bird, it was counted as new, as recommended by Dawson and Bull (1975).

Observations were made only by me, to prevent sampling error between observers. The observation period began between 15 minutes before and 15 minutes after sunrise. The point counts were conducted in a different order (1-10 or 10-1) at each outing. This sampling method allows for comparing relative results between sites that are applicable for many species and different areas (Sutherland et al. 2004). The habitats selected were similar, so that detectability of the woodpeckers would be nearly the same (Bibby et al. 1992). Narrative records of birds counted were made with a digital voice recorder to prevent visually missing a bird while recording the counting of a previous bird. Surveys were conducted two times per month at each of the three sites, beginning in January 2008 and concluding in December 2008 for a total of 72 survey days. Surveys were not conducted during heavy rains, although a light mist/snow was deemed acceptable, nor were surveys conducted when wind speeds were greater than 30 miles per hour (Bibby et al. 1992).

Totals and average number of birds per point and per site were calculated. Due to flooding in January and February, there were three occasions when one count point at Oak Openings could not be accessed. For statistical comparisons between and among sites, the three days of flooding were omitted. However, these observations were used for calculating species totals and in statistics involving only Oak Openings. An ANOVA was conducted to determine if there was a significant difference in the average number of
birds counted at the three sites. T-tests were also conducted to determine specific
differences between the average number of birds counted per site.

To determine if woodpeckers demonstrate a preference for foraging on ash trees
vs. non-ash trees in the areas where emerald ash borers are present (Hypothesis 2), the
number of woodpecker attacks was counted on 20 pairs of trees (ash vs. non-ash) at Oak
Openings, and on 21 pairs of trees at Goll Woods and Kensington. In December 2007,
these pairs of ash and non-ash deciduous trees of similar DBH in close proximity to each
other were randomly selected in each site. A woodpecker attack was defined as obvious
pecking with a definite hole where an emerald ash borer larva, or another type of
invertebrate, was likely extracted from the tree by the bird. Sometimes it was observed
that woodpecker attacks on the tree were larger at a later observation than at previous
ones and it was more difficult to determine if one large excavation had previously been
two small holes. The attacks were counted in a marked one-meter high section on each
tree pair. Since woodpeckers forage at several different heights, and no certified tree
climbers were available, two ranges were marked which were accessible by ladder: either
a height of 1-2 meters or 2-3 meters from the ground. Half of the pairs of trees were at
the lower height and half at the 2-3 m range. The DBH of each of the trees was recorded
as well as the initial number of woodpecker attacks found. The number of D-shaped exit
holes was also recorded on ash trees at the initial marking of the trees, indicating how
many emerald ash borer adult beetles emerged from the tree. Woodpecker attacks were
counted again in March, June, September and December. These numbers revealed if woodpeckers showed a preference for foraging on ash trees in infested areas, as well as at what time of year woodpeckers were excavating the larvae. The end of year average number of woodpecker attacks on ash vs. non ash trees was also compared using a paired t-test to determine if there was a preference demonstrated for ash trees in infested areas at each site. Seasonal changes in woodpecker attack numbers/occurrence were also compared.

To determine if there was a relationship between the number of birds counted and the number of ash trees at a given count point (Hypothesis 3), all the trees greater than 3 cm DBH within 7.62 meters of each of the 10 point locations at all of the sites (ash trees and non-ash trees) were tallied by species and the DBH of each tree was measured. A total of 300 trees were counted at Kensington Metropark, 292 at Goll Woods, and 235 at Oak Openings. The average DBH overall was calculated, as well as the average DBH of non-ash and ash trees.

To determine if there was a relationship between the number of woodpeckers counted and the number of ash trees occurring in an area, a correlation analysis was conducted between the percent ash occurrence and the number of woodpeckers observed at each of the 10 count points at each of the 3 sites. The percent basal area of ash trees was also calculated for each of the sites and correlated with the average number of birds observed per count point.
Chapter 3

Results

Based on CBC data, for the area including Oak Openings no pileated woodpeckers were observed before the year 2005, while from 2005-2008, one pileated woodpecker was included in each count, and in the 2008/2009 count, three pileated woodpeckers were included (National Audubon Society CBC online historical records, Table 1). The number of red-headed woodpeckers, red-bellied woodpeckers and downy woodpeckers also experienced an overall increase during that same period of time (2004-2009), after Oak Openings was officially considered infested with emerald ash borer beetle in 2003 (Table 2).

A total of 788 woodpecker sightings were made at Goll Woods State Nature preserve, more than at the other two sites (365 at Kensington, 507 at Oak Openings; Table 3). The most woodpeckers in one month (113) were counted at Goll Woods in April of 2008 (Figure 2). The fewest woodpeckers in one day (4) were counted at Kensington Metropark on 15 Sept. and 21 Dec. 2008. More woodpeckers were counted at each site between the months of Jan.-Apr., corresponding with breeding season and pre-breeding season behaviors (Figure 2). The detectability of the birds also increases at this time of year due to the leaves being off the trees.
The mean number of woodpeckers counted per outing was different across sites (Figure 3). The mean was 32.83 at Goll Woods, 15.21 at Kensington and 19.95 at Oak Openings. A single-factor ANOVA revealed a significant difference among the three sites, $F(2, 66)=7.47$, $p=0.001$. A significant difference was found between Goll Woods ($M=32.83$, $SD=22.00$) and Kensington ($M=15.21$, $SD=10.79$); $t(46)=3.52$, $p=0.0009$, and between Goll Woods ($M=32.83$, $SD=22.00$) and Oak Openings ($M=19.95$, $SD=13.65$); $t(43)=2.23$, $p=0.03$. No significant difference was found between Kensington ($M=15.21$, $SD=10.79$) and Oak Openings ($M=19.95$, $SD=13.65$); $t(43)=0.238$, $p=0.20$. Although a significant difference among the average numbers of woodpeckers observed at each of the three sites is demonstrated, the first hypothesis is rejected, because the highest number of woodpeckers was not observed at Kensington, the site with the highest level of infestation.

At the two infested sites, woodpeckers demonstrated a preference for attacking ash trees (Hypothesis 2), as evidenced by the significant difference shown in paired t-tests for the pairs of trees at each site. At Kensington Metropark, the average number of attacks on ash trees was 26.52 ($SD=22.502$), which was higher than on non-ash trees, where the mean was 0.095 ($SD=0.436$); $t(20)=5.38$, $p<0.001$. The average number of woodpecker attacks on ash trees at Oak Openings was 44.8 ($SD=49.54$) and was different from those on non-ash trees, where the average was 0 ($SD=0$); $t(19)=4.044$, $p=0.0007$. The statistical analyses reveal a significant difference between the number of woodpecker
attacks on ash vs. non-ash trees at the two infested sites, Kensington and Oak Openings, and support the hypothesis that woodpeckers demonstrate a preference for foraging on ash trees in areas infested by emerald ash borer beetle.

The mean number of woodpecker attacks on ash trees was 3.29 (SD=10.26), which was not significantly different from attacks on non-ash trees, where the average was 0 (SD=0); t(20)=1.468, p=0.15. The results indicate no significant difference, supporting the hypothesis about preferential feeding on ash trees in infested areas. Goll Woods was not an infested area, so woodpeckers had no reason to preferentially feed on ash trees.

A t-test was used to ensure there was no significant difference in the DBH of the ash and non-ash trees in each of the pairs at the all three sites (Figure 4). The average DBH of the ash trees in the pairs at Kensington Metropark was 22.21 cm (SD=9.45) and the average DBH of the non-ash trees in the pairs was 22.58 cm (SD=12.94); t(20)=0.21, p=0.84. The average DBH for ash trees at Oak Openings was 18.23 cm (SD=8.50), and for non-ash trees, the average DBH was 18.97 cm (SD=6.71); t(19)=0.43, p=0.67, revealing no significant difference between the two. The average DBH of ash trees at Goll Woods was 22.31 cm (SD=17.68), and the average DBH of non-ash trees at Goll Woods was 20.53 cm (SD=14.47); t(20)=0.97, p=0.34.

The site that had the most overall percent ash stems was Oak Openings (Table 4), which also had the highest correlation between percent ash stems and the number of
woodpeckers counted; approximately 24.68% of the total trees were ash. A correlation analysis yielded an $R^2$ value of 0.8588 and a p-value of <0.001 (Figure 5). The two count points with the highest percentage of ash tree stems (100% and 93.75%) were also the points with the highest number of woodpeckers observed at Oak Openings. The other two sites showed no significant positive correlation between the number of woodpeckers counted and the percent ash stems at each count point. The $R^2$ value for Goll Woods was 0.0447 with a p-value of 0.95 (Figure 6). For Kensington, the $R^2$ value was 0.1703 with a p-value of 0.32 (Figure 7).

When analyzed by percent basal coverage using average basal area of ash vs. average basal area of non-ash at each count point, correlations were slightly different. Goll Woods had an $R^2$ value of 0.046 and a p-value of 0.5511 (Figure 8), Kensington had an $R^2$ value of 0.005 with a p-value of 0.838 (Figure 10), and Oak Openings had an $R^2$ value of 0.04 with a p-value of 0.583 (See Figure 9).

An ANOVA of the average DBH of the trees counted at the ten count points revealed a significant difference between the average DBH of all the trees among the three sites $F(2, 824) = 3.30, p = 0.04$, as well as among the non-ash trees at each of the sites $F(2, 703) = 3.40, p = 0.34$. However, an ANOVA revealed no significant difference between the average DBH of the ash trees among the three sites $F(2, 118) = 1.83, p = 0.16$. The largest overall average DBH of both ash and non-ash trees was found at Oak Openings. The average ash DBH was 13.03 cm (SD=7.08) and the average non-ash
DBH was 15.67 cm (SD=15.10) at Oak Openings. At Kensington Metropark, the average ash DBH was 9.97 cm (SD=5.122) and the average non-ash DBH was 13.21 cm (SD=12.022). The average ash DBH at Goll Woods was 11.73 cm (SD=12.58), and the average non-ash DBH was 12.18 cm (SD=14.82).
Chapter 4

Discussion

Increased woodpecker activity has been a noted indicator of the presence of emerald ash borer beetle; however, my results do not show a higher abundance of woodpeckers in locations that have been infested with emerald ash borer beetle for several years. In fact, this research revealed the highest number of woodpeckers observed at the site with the lowest level of emerald ash borer infestation. Similarly, Kensington Metropark and Oak Openings, the two sites with higher levels of emerald ash borer beetles, were the only two sites that had no significant difference between the numbers of woodpeckers counted at those sites. Perhaps the level of infestation was not significantly different between these two sites because these sites were declared infested within one year of each other. This result could also be caused by the timing of tree death. Because of these two potential similarities between those two sites (potential similar level of emerald ash borer infestation and the amount and timing of tree death at these sites), the amount of food available for woodpeckers at Kensington and Oak Openings may have been comparable, thereby supporting a similar number of woodpeckers. Yet another reason for this similarity could be the number and concentration of ash trees at Oak Openings. It could be that the woodpecker population
at Kensington is in fact higher than at Oak Openings, but the woodpeckers were not as easily observed because my count points at Kensington Metropark did not contain an area of concentrated ash trees as Oak Openings did. That is, the concentration of ash trees could have had a greater overall affect on the number of woodpeckers seen than the time/level of infestation between the two sites. Or, it could be that emerald ash borer beetles do not increase the abundance of woodpeckers in that short of a time period, and the relative abundances I found are the same as what would have been found prior to emerald ash borer infestation.

In conjunction with my first hypothesis, I anticipated that I would count the most woodpeckers at Kensington Metropark, the site that had been infested by emerald ash borer beetles first. From the increase in the number of woodpecker attacks on the ash trees at Kensington, it was evident that although many of the trees at Kensington were dead/dying, the woodpeckers were still feeding on emerald ash borers. However, the largest number of woodpeckers was observed at Goll Woods, the least infested of the three sites. Goll Woods is the last remaining stand of old growth trees in northwest Ohio, which could indicate that Goll Woods is better habitat in general for woodpeckers compared to the other two sites, although it did not have the same abundance of food in the form of emerald ash borer beetle. In fact, Goll Woods was the only one of the three sites where breeding woodpeckers were observed; specifically, red-headed woodpeckers
were observed nesting, and juvenile red-headed woodpeckers were also counted, indicating woodpecker recruitment.

The most woodpeckers were observed between January and April at each of the sites (Figure 2). This observation could potentially be the result of two factors. First, woodpeckers tend to vocalize more during breeding season (around Jan-April) as they establish territories and seek out mates, which could make them more conspicuous to an observer. Second, the absence of leaf cover could affect the birds’ detectability at this time of year. However, if this was the main cause, more birds would have also been observed in late fall and in December.

Though my results do not show an abundance of woodpeckers in areas with emerald ash borer beetle, the CBC data show increases in woodpeckers since the introduction of emerald ash borers in certain areas. The suggestion that emerald ash borer beetles may support a larger variety and/or greater abundance of woodpeckers in the Oak Openings (Tim Schetter, personal communication) is supported by the Audubon Society’s Christmas Bird Count data (Table 1). However, records may also be reflecting a historical decline in overall bird numbers with historical deforestation as well as an increase in overall bird numbers corresponding to expansions in forested areas throughout the region surrounding Oak Openings (Peterjohn, personal communication, 2010). Although Oak Openings has not experienced the same re-forestation as other
areas in the region, pileated woodpecker populations on the whole in the region have increased, potentially leading these birds to expand their range.

Woodpeckers prefer to attack ash trees infested with emerald ash borers over non-ash trees, as shown when testing my second hypothesis. My finding no difference between the number of attacks on ash trees vs. non-ash trees in Goll Woods also supports my second hypothesis. Because the level of infestation at Goll Woods was not yet high enough to create an abundant food source in the ash trees, woodpeckers were not demonstrating a preference for foraging on them.

My results also suggest that in infested areas, more woodpeckers are found associated with a higher occurrence of ash trees. At the site with the highest percent of ash trees (Oak Openings), a very high positive correlation was seen between the percentage of ash coverage and the number of woodpeckers observed in those locations. However, the other two sites showed no significant correlation between number of ash trees and woodpeckers. This could be because neither Goll Woods nor Kensington had areas that approached 100% ash cover, like Oak Openings did. Kensington and Goll Woods only approached 30% ash coverage at the maximum points. However, this could also be caused by the density of emerald ash borer being lower at these sites, Goll Woods not being infested, and Kensington not having as many living ash trees left for emerald ash borers to infest.
Not only does this research answer some questions about the relationship between emerald ash borers and woodpeckers, it also raises some questions that future research could answer. Oak Openings and Kensington Metropark were listed as having emerald ash borer beetles within one year of each other, meaning that the sites were likely infested near the same time, up to five years before they were officially listed as being infested. However, these sites showed no significant difference in the relative populations of woodpeckers there, possibly indicating that the point at which emerald ash borer beetles are discovered may not be the only significant factor in understanding and potentially controlling the effects of this invasive species. That is, finding emerald ash borer beetles 1-2 years earlier and implementing some type of regulation immediately or waiting a year or two may or may not make a large difference in the overall effect the pest has on an ecosystem. Emerald ash borer beetles having no positive effect on woodpecker populations leads to the question: Do emerald ash borer beetles have a negative impact or no impact on the populations of woodpeckers over time? Conducting studies in non-infested areas before emerald ash borer beetles have a chance to invade and continuing these studies during and after the course of the infestation would help to answer this question. It could be that emerald ash borer beetles so drastically alter an entire ecosystem by killing all the ash trees, affecting the primary productivity of the area and negatively affecting the populations of woodpeckers in that ecosystem. Woodpecker populations have been shown to respond numerically to an abundance of insect prey.
(Koplin 1969), thus the overall impacts that emerald ash borer beetles have on woodpecker populations may be imminent, but delayed longer than the course of my one-year study. One may think that once emerald ash borer beetles have killed all the ash trees and other wood-eating insects move into the space that woodpeckers would still have an abundant food resource. However, could it be that once the emerald ash borer beetles are gone, the habitat is negatively impacted enough to actually cause a decline in the number of woodpeckers in an area? My results showed that the abundance of woodpeckers was not higher in emerald ash borer infested areas; it was higher in non-infested, more pristine habitats.
References


### Table 1:
National Audubon Society’s Christmas Bird Count Observation Data for Pileated Woodpeckers in Grand Rapids-Waterville, Ohio (Area including Oak Openings Metropark)

<table>
<thead>
<tr>
<th>Count Year</th>
<th>Number of Pileated Woodpeckers</th>
<th>Number/Party Hour</th>
<th>Number of Counts Reporting Pileated Woodpeckers</th>
<th>Number of Observers on Reporting Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004-2005</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2005-2006</td>
<td>1</td>
<td>0.017</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>2006-2007</td>
<td>1</td>
<td>0.011</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>2007-2008</td>
<td>1</td>
<td>0.0099</td>
<td>1</td>
<td>39</td>
</tr>
<tr>
<td>2008-2009</td>
<td>3</td>
<td>0.027</td>
<td>1</td>
<td>39</td>
</tr>
</tbody>
</table>
Table 2:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Red-headed</td>
<td>2</td>
<td>15</td>
<td></td>
<td>11</td>
<td>29</td>
</tr>
<tr>
<td>Red-bellied</td>
<td>59</td>
<td>70</td>
<td>92</td>
<td>112</td>
<td>179</td>
</tr>
<tr>
<td>Downy</td>
<td>143</td>
<td>105</td>
<td>189</td>
<td>163</td>
<td>253</td>
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</tbody>
</table>
Table 3: Total number of each species of woodpecker observed at each of the three research sites. Tapping denotes a woodpecker was heard tapping but was not seen.

<table>
<thead>
<tr>
<th>Species</th>
<th>Goll Woods</th>
<th>Oak Openings</th>
<th>Kensington</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downy</td>
<td>177</td>
<td>133</td>
<td>247</td>
</tr>
<tr>
<td>Red-bellied</td>
<td>159</td>
<td>61</td>
<td>80</td>
</tr>
<tr>
<td>Red-headed</td>
<td>70</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pileated</td>
<td>44</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Northern flicker</td>
<td>43</td>
<td>21</td>
<td>13</td>
</tr>
<tr>
<td>Hairy</td>
<td>7</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Yellow-bellied sapsucker</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Tapping</td>
<td>275</td>
<td>119</td>
<td>115</td>
</tr>
<tr>
<td>Not identified</td>
<td>9</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>788</strong></td>
<td><strong>365</strong></td>
<td><strong>507</strong></td>
</tr>
</tbody>
</table>
**Table 4:** Percent ash stems at Goll Woods, Kensington and Oak Openings

<table>
<thead>
<tr>
<th></th>
<th>Goll Woods</th>
<th>Kensington</th>
<th>Oak Openings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Trees</td>
<td>292</td>
<td>300</td>
<td>235</td>
</tr>
<tr>
<td>Percent Ash</td>
<td>7.53%</td>
<td>13.67%</td>
<td>24.68%</td>
</tr>
</tbody>
</table>
Figure 1: Map of research sites:
Figure 2: Total number of woodpeckers observed each month at each site.
Figure 3: Average number of woodpeckers observed per visit at each site. Based on ANOVA results, Kensington and Oak Openings averages are not significantly different from each other, but both are significantly different from Goll Woods.
Figure 4: Average DBH of tree types at each site
Figure 5: Linear relationship between the average number of woodpeckers observed and the percent ash stem coverage at the 10 count points at Oak Openings.

\[ y = 0.0271x + 1.4659 \]

\[ R^2 = 0.8588 \]
Figure 6: Linear relationship between the average number of woodpeckers observed and the percent ash stem coverage at the 10 count points at Goll Woods.
Figure 7: Linear relationship between the average number of woodpeckers observed and the percent ash stem coverage at the 10 count points at Kensington Metropark.

\[ y = -0.0151x + 1.7494 \]

\[ R^2 = 0.1703 \]
Figure 8: Linear relationship between the average number of woodpeckers observed and the percent ash basal area at the 10 count points at Goll Woods.
Figure 9: Linear relationship between the average number of woodpeckers observed and the percent ash basal area at the 10 count points at Oak Openings.
Figure 10: Linear relationship between the average number of woodpeckers observed and the percent ash basal area at the 10 count points at Kensington Metropark.

\[ y = -0.003x + 1.5461 \]

\[ R^2 = 0.0055 \]