Emerald Ash Borer:
Monitoring and Management Recommendations for the City of Iowa City, Iowa

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Introduction

The emerald ash borer (*Agrilus planipennis* Fairmaire) is an invasive species of Asian beetle first detected in the United States in 2002 in southeastern Michigan (Herms and McCullough 2013). It is believed to have been inadvertently introduced in the 1990s, likely via contaminated shipping materials made from infested ash (Cappaert et al. 2005). The beetle has spread rapidly since its introduction to North America, likely through the movement of unprocessed logs and firewood from infested areas (USDA Forest Service 2008). Infestations are currently confirmed in 25 states, resulting in the loss of tens of millions of ash (*Fraxinus* spp.) trees, costing state, county, and city governments and private property owners tens of millions of dollars in removal costs and lost revenue (USDA Forest Service and Michigan State University 2015).

Emerald ash borer (EAB) was first discovered in Allamakee County in northeast Iowa in the early part of 2010. Since that time, its presence has been officially confirmed in 19 additional counties according to the Iowa Department of Agriculture and Land Stewardship (2015). While EAB has not yet been confirmed in Johnson County, it is anticipated to arrive in the Iowa City area in the near future. Given this, a plan aimed at monitoring for the presence of this destructive tree pest, along with strategies for managing its imminent effects, is necessary. This report will assist the City of Iowa City with this process by 1) providing basic information on the ecology of EAB; 2) completing an inventory of ash trees at various sites throughout the Iowa City area, including a summary of this data; 3) suggesting methods for monitoring for EAB; 4) suggesting treatment options for ash trees, along with tree species suitable for replacing ash trees that must be removed.

Emerald Ash Borer: Identification

Emerald ash borer belongs to the genus *Agrilus*, one of the largest genera in the world with nearly 3,000 described species that can be found on every continent except Antarctica (Bellamy 1997). EAB is indigenous to China, Taiwan, Japan, Korea, Mongolia and eastern Russia (Yu 1992; Jendek 1994). In its native range, EAB preys on ash trees that are stressed, declining, or dying, but does little damage to healthy trees; in the U.S. and Canada ash species evolved in the absence of this particular member of the *Agrilus* genus and therefore lack the defenses necessary to repel infestations, even in healthy trees (Zhao et al. 2005).

Adult beetles are similar to North American *Agrilus* species but are generally larger and brighter green. They are slender, elongate, and 7.5 to 13.5 mm in length and are typically bronze, gold, or reddish green overall with darker, metallic emerald green wing covers (USDA Forest Service 2008). The dorsal surface of the abdomen is bright, metallic coppery-red and is most visible when the elytra (wings covers) and wings are raised. EAB is the only *Agrilus* beetle currently present in North America with this particular feature, making it an important diagnostic characteristic (Parsons 2008). While this beetle is easily distinguished from native *Agrilus* beetles by trained entomologists, many researchers and field workers may confuse other similarly shaped or colored insects with EAB. Therefore, it is recommended that specimens suspected of being EAB are submitted to entomologists for confirmation. In Iowa, contact State Entomologist Robin Pruisner with the Iowa Department of Agriculture and Land Stewardship for assistance.

Emerald ash borer larvae are typically 26 to 32 mm in length, white to cream in color, and flattened rather than cylindrical. The head is brown but mostly hidden within the prothorax; only the mouthparts are visible. The abdomen has ten segments, the last of which possesses a pair of brown, pincer-like appendages (USDA Forest Service 2008).

Emerald Ash Borer: Ecology and Impacts

Emerald ash borer typically completes its life cycle in a single year (USDA Forest Service 2008), but some research suggests that two-year development can occur occasionally in areas with moderate to heavy levels of infestation (Cappaert et al. 2005). Upon hatching from eggs deposited within crevices and beneath flaps on the bark of ash trees, larvae bore through the outer bark and begin feeding in serpentine tunnels known as galleries in the phloem and cambium (Cappaert et al. 2005). Larvae feed from mid-summer into the fall, completing four instars (developmental stages) before overwintering between the inner and outer bark of the tree. Pupation occurs the following spring (Herms and McCullough 2014).

Emergence of adults begins between early May and mid-June, peaks from mid-June to early July, and concludes by early August (USDA Forest Service 2008). Beetles leave distinctive D-shaped exit holes approximately 2 to 3 mm in diameter in the bark of the trees from which they emerge (Herms and McCullough 2014). Adults live for three to six weeks, feeding on ash leaves but causing little damage to the foliage (USDA Forest Service 2008). After mating, females deposit eggs on nearby ash trees, which hatch in one to two weeks (Wang et al. 2010).

Ash trees that have been recently infested by EAB show few, if any, external symptoms. The canopy of large trees are typically colonized before lower portions of the tree, making early detection of new infestations difficult, particularly from ground level (Cappaert et al. 2005). EAB is a phloem-feeding beetle, and damage to this tissue disrupts the tree's ability to transport nutrients and water. As the number of EAB larvae feeding on the tree rises, signs of the infestation begin to become visible. Thinning of the canopy and branch die-back occur (Herms and McCullough 2013), large portions of the cambium are often exposed by woodpecker predation on EAB larvae (McCullough and Katovich 2004), and epicormic shoots may emerge from the trunk or branches at the margin of living and dead tissue (USDA Forest Service 2008). Heavily infested trees usually die within two to four years (Herms and McCullough 2013).

Survey Methods

Sites were selected randomly using ArcMap's "Create Spatially Balanced Points" tool with the parameters of equal probability (0.5) and 150 m raster. The site points were all placed within a 107 m buffer zone to account for the average block size in Iowa City and some were adjusted for accessibility reasons or moved slightly to encompass an ash-likely area. These selection methods were used for both the Iowa City street sample sites and the Iowa City park sample sites.

Field surveying at each site included GPS waypoint marking, ash tree measurements, and tree identification and counts. GPS locations were taken for each ash tree located within a study site boundary. Each tree was given a different marker name so that they could be matched up to the size measurements that were also taken. These location measurements were taken in UTMs and uploaded to ArcMap for later use.

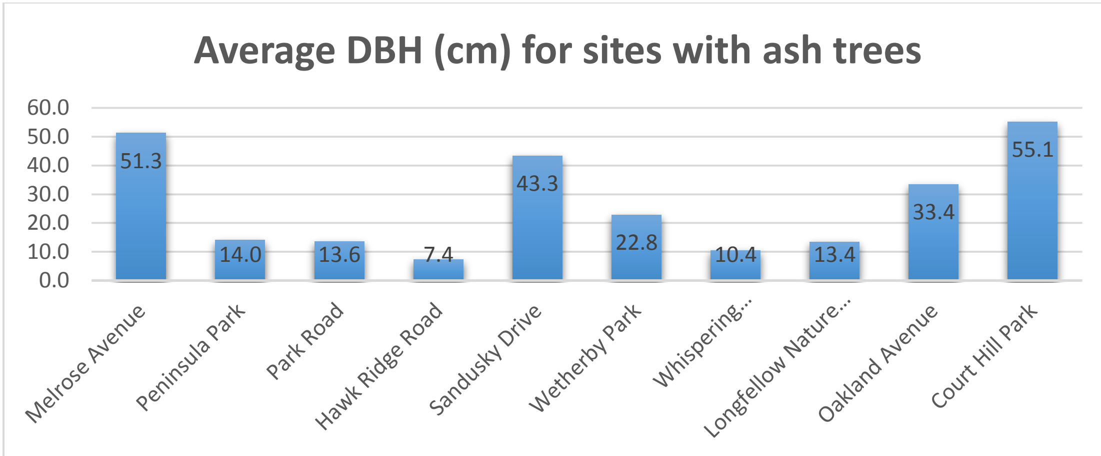
Ash trees were all individually measured to find diameter at breast height (DBH), tree height, and tree crown width. Tree diameter was taken using a flexible tape measure at a height 1.37 m above the ground, approximately perpendicular to the longitudinal axis of the tree. For ash trees whose trunks split at the base, diameter measurements were taken on each trunk section and then added together. Tree heights were measured using a Suunto clinometer and a WGI Innovations Ltd. XRT range finder. The clinometer was used to find the percent angle to the top of the tree. A range finder was used to find the distance from the observation location to the tree. These measurements were combined to find the total tree height using the equation $h = (c * d) + i$, where h is height, c is the percent angle, d is the distance from the tree, and i is the height to the observer's eye level. Crown width is the measure of all the foliage and branches growing out from the trunk. All crown widths were measured using the cross method which involved taking two measurements, one at the widest and one at the narrowest point in the tree crown. These measurements were then averaged together to find the crown width.

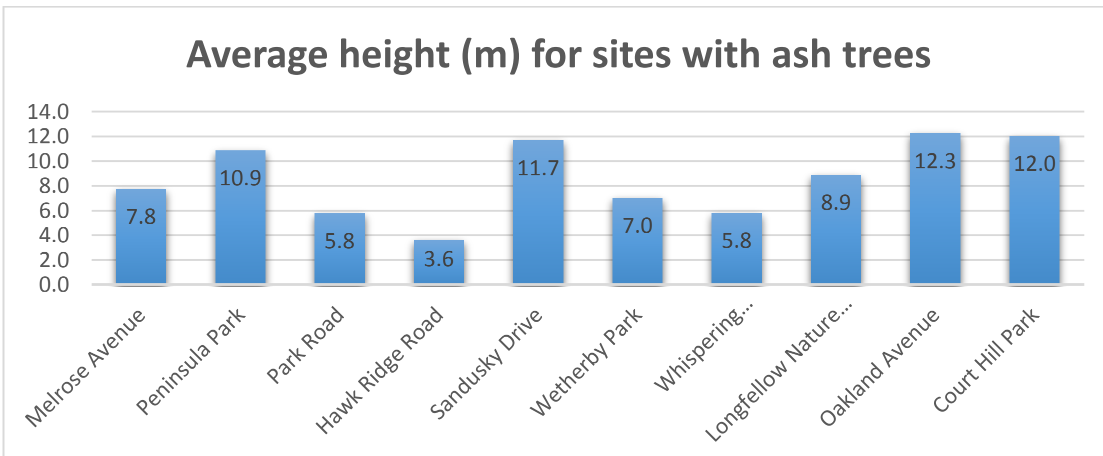
Tree counts were conducted at each survey site. Ash trees were identified and counted, then added to a count of all non-ash trees to arrive at a total count for all trees at the site. Saplings and mature trees were also counted separately for a better overall inventory of the trees contained within the site boundary.

Survey Results

Based on tree measurements including DBH, tree height, and crown width, the largest trees were located at the Court Hill Park, Melrose Avenue, Oakland Avenue, and Sandusky Drive survey sites (see Figure 1). The park sites with the highest number of ash trees were Whispering Meadows Wetland (26) and Longfellow Nature Trail (19). The Whispering Meadows Wetland site also contained a high percentage of ash (22 percent), while ash made up 12 percent of the trees at Wetherby Park (see Figure 2). Street sites with the highest ash tree count were Park Road (24) and Hawks Ridge Road (14), although Hawks Ridge Road had a higher percentage (22 percent) of ash than Park Road (11 percent). Melrose Avenue had the highest percentage of ash of all street sites at 25 percent (see Figure 3).

When averaged, the sampled park sites had 6.3 percent ash, the sampled streets sites consisted of 9.4 percent ash, and a combination of all trees at sample sites were 7.3 percent ash. Based on these findings, and assuming the sites sampled are representative of the composition of the urban forest throughout the city, it is possible that residential areas of Iowa City could lose up to one-tenth of their total street tree population.





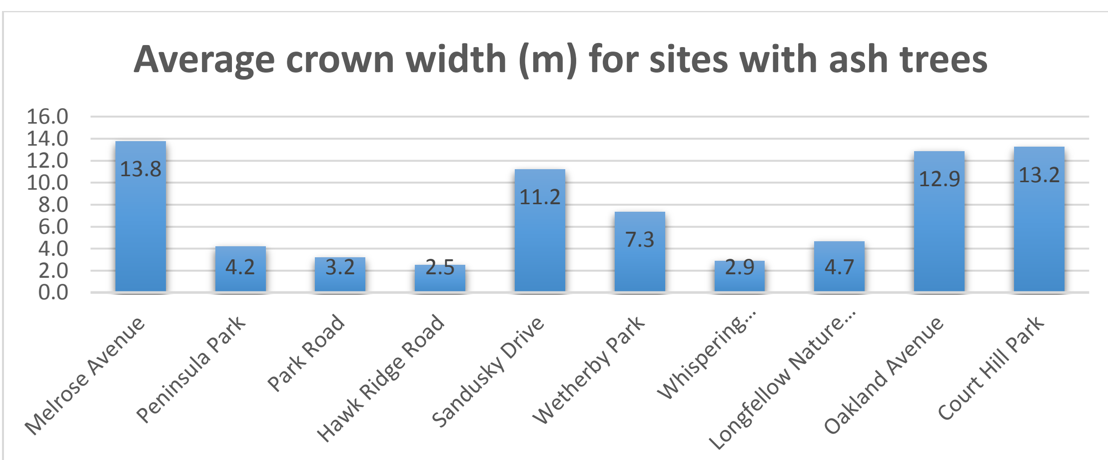


Figure 1. Average DBH, height, and crown width for sites possessing ash trees.

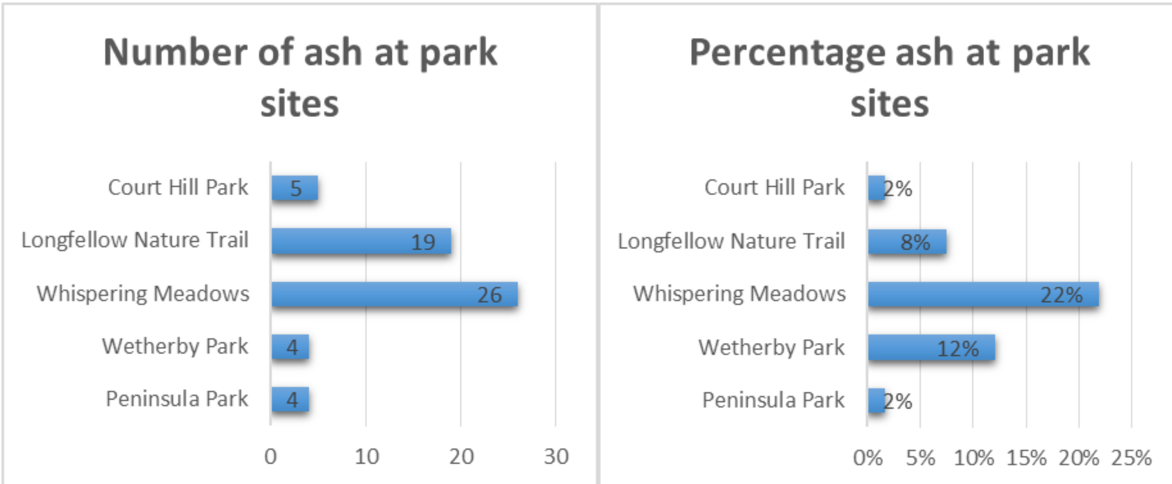


Figure 2. Comparison of number of ash trees by site versus percentage of ash at all park sites.

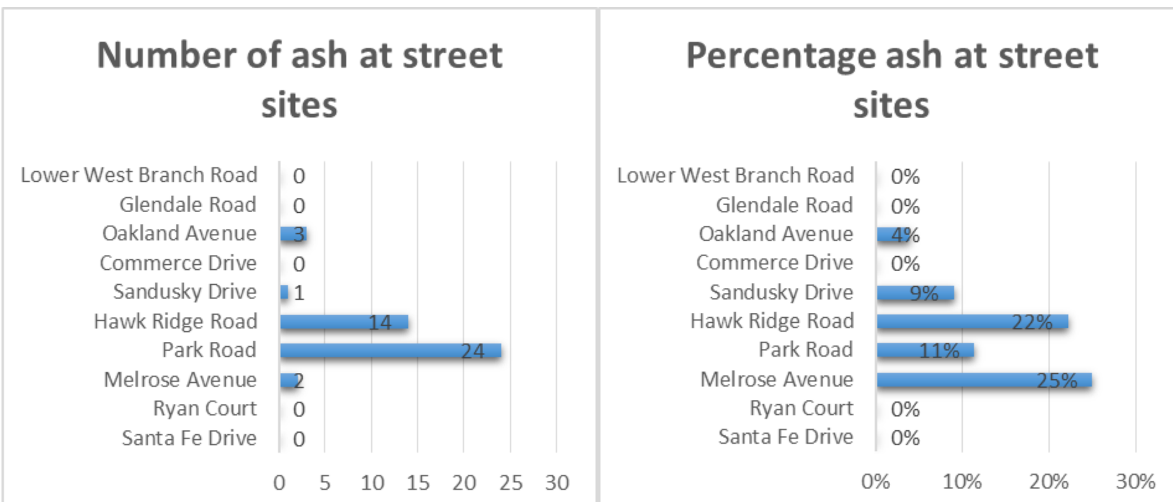


Figure 3. Comparison of number of ash trees by site versus percentage of ash at all street sites.

Monitoring for Emerald Ash Borer

Signs of EAB infestation in ash become visible only after beetle densities have reached high levels. By this time, several generations of adult beetles may have already dispersed from the point of initial infestation (Mercader et al. 2012). Instead of relying on visual surveys to observe impacts of EAB on ash trees, it is much more effective to monitor for the presence or arrival of the beetle itself. Several strategies for monitoring EAB have been developed since the arrival of this invasive species in North America.

In order to attract ovipositing (egg-laying) EAB females, ash trees can be girdled, which involves removing a band of bark and phloem from the trunk of the tree. This disrupts nutrient transport within the tree, leading to increasing levels of stress as time goes on. Research has shown that EAB beetles are attracted to ash trees that are stressed, and lay more eggs on stressed trees than on healthy trees. These trees are then debarked in the fall or winter to look for EAB larvae or the serpentine galleries created by feeding (McCullough and Siegert 2007). The use of sticky traps wrapped around the bark above the girdled area of the tree can be incorporated to capture adult beetles as well (Cappaert et al. 2005). While girdling is probably the most effective method for detecting the presence of EAB, this process can be labor intensive and may not be suitable in urban areas where damage to street trees is undesirable (Herms and McCullough 2014).

Since 2008, detection surveys in the United States have relied heavily on sticky prism traps made primarily from purple coroplast and placed in the canopy of ash trees (Crook and Mastro 2010). These traps are usually purple because EAB beetles are responsive to visual cues, and tests have shown that adult beetles are sensitive to light in the red, green, and in particular the violet part of the visible spectrum (Crook et al. 2012). Various volatile compounds that mimic chemicals produced by stressed ash trees are used as lures to attract adult beetles (McCullough and Herms 2014) that then become stuck by the trap. Another type of canopy trap, Lindgren green multi-funnel traps, exhibit higher catch rates than purple prism traps but must be monitored more frequently (USDA Animal and Plant Health Inspection Service 2015).

A variation on the canopy trap, the double-decker prism trap is composed of two prism traps attached one above the other on a 3 m by 10 cm PVC pipe supported by a T-post. Using the same type of lures as the canopy trap, the double-decker trap is designed to be placed near the edge of forest areas in direct sunlight. This creates an obvious source of volatiles and exploits the preference of EAB beetles for sites with sunny conditions. Double-decker traps are considered most effective at detecting the presence of EAB where beetle densities are low, making them an attractive monitoring tool in areas where widespread infestations have yet to occur (Herms and McCullough 2014).

Biological Control of Emerald Ash Borer

The prospective use of biological controls are becoming more and more prevalent when it comes to the management of invasive species. A biological control is essentially the introduction of a native or non-native predator to control the population of a pest species. The United States

Department of Agriculture Forest Service has recently been looking in to biological controls and has been able to find a few promising candidates for future use in the management of EAB (Bauer et al. 2014).

The *Atanycolus hicoriae* is a small wasp species indigenous to China that usually attacks the two-lined chestnut borer and the bronze birch borer. A study in Michigan was conducted to find out the possible effects that this wasp could have on the EAB. The study concluded that their effect was dependent on whether the EAB was on a one- or two-year life cycle, finding that they were most effective against those on the two-year cycle. This study found much higher parasitism rates than previous studies (Bauer et al 2014).

The *Oobius agrilli* is another parasitoid wasp native to China. This wasp species preferentially attacks EAB so impact to other *Agrilus* species is minimized. Its sole host is the EAB, and has been found to have a 53-61 percent parasitism rate in July and August where the wasp and EAB life cycles match up best (Houping et al. 2007).

Tetrastichus planipennisi is a parasitic wasp species native to northern Asia that has been shown to attack only actively feeding EAB larvae with a parasitism rate up to 50 percent. This species is unique in that it can survive winters inside the EAB so it is very good at establishing continuous populations year to year (Houping et al. 2007).

The *Spathius agrili* is also a wasp species native to northern Asia. This particular species is very unique in that not only is the EAB its only host species, it also has a very small host tree range, meaning that it will not attack unless the EAB is on a particular tree species. *Spathius agrili* is very effective in the control EAB populations, with a parasitism rate of up to 90 percent (Houping et al. 2007). Continued research on biological controls and their effects on local and regional ecology is still needed to understand the full effects of their usage, but this method of control has the potential to be a sustainable solution to the emerald ash borer problem.

Treatment, Removal, and Replacement of Ash Trees

The city of Cedar Rapids can be used as a good example for an EAB management plan. The City estimates that around 30 percent of city trees are ash trees, and that there are approximately 15,000 street ash trees. They plan to use a slow-the-spread approach by combining tree removal and insecticide treatment. This slow-the-spread approach will disperse the impact of EAB over a greater timeframe to alleviate some of the strain on funding and resources. This will help give tree removal crews more time to remove ash trees, and will also buffer the rate at which the ash tree canopy is lost to allow new trees to grow larger and form a new canopy. The City plans to treat as many as 6,000 ash trees while removing the other 9,000 ash trees. They also plan on gradually reducing the number of trees that are treated over time to allow replacement trees of different species ample time to grow to a sufficient size (Todd Fagan, Cedar Rapids City Arborist, personal communication).

To treat ash trees, the City plans on using TREE-age injection (emamectin benzoate) which costs around 5 dollars per inch of tree diameter (e.g. 100 dollars for a 20 inch diameter tree). The trees need to be retreated every two to three years, but the treatment is only 90 percent effective. It was originally claimed that a single treatment only lasted two years but recent trials have found that one TREE-age injection may protect an ash tree for as long as three years. The City does not plan to treat ash trees located in parks because they only account for five to ten percent of the City's total ash trees. Also, not every ash will be a good candidate for treatment so they plan to treat only quality ash trees between 18 and 20 inches DBH with good form or outstanding centennial ash trees. The smaller trees may be removed because it is less expensive to do so. Very large ash can become a public safety hazard once they are infested with EAB so they too may be candidates for removal. On city blocks where street trees consist mostly or entirely of ash, the City plans to treat approximately half of the trees to help keep the canopy intact. A treatment buffer will also be created around infected sites to slow the spread of EAB (Todd Fagan, Cedar Rapids City Arborist, personal communication).

Tree removal is another large portion of the management plan. In anticipation of the arrival of EAB in the Cedar Rapids area, the City has proactively removed over 1000 ash trees (150-300 per year) since 2009. Trees that possess poor form, are poorly located (e.g. sited under power lines), are in decline, or pose a possible public safety hazard are designated for early removal. Once the infestation occurs, the City plans to ramp up removal rates to 500-1000 trees per year. The management plan will also remove all ash trees within a two block radius of an infected tree to help slow the spread of EAB (Todd Fagan, Cedar Rapids City Arborist, personal communication).

The EAB infestation will come at a high cost, but this management plan is also a middle-of-the-road approach compared to the costs of other options. If the City were to treat all 15,000 trees, it would cost taxpayers 3.15 million dollars for an initial treatment and 20.4-26.7 million dollars for treatment over a 16 year period (depending on two or three year treatment plans). This also does not factor in the removal of infected trees that have been treated with TREE-age injections but still succumbed to the EAB infestation. It would cost 15.22 million dollars to remove and replace all 15,000 ash trees within a ten year period. The management plan to save some trees and remove others would cost 16.1-17.6 million dollars over 18 years depending on the treatment cycle. The City also plans to complete an ash tree survey of all the trees within city limits and to identify possible trees to save at a cost of approximately 400,000 dollars (Todd Fagan, Cedar Rapids City Arborist, personal communication).

Using a diverse selection of the best suited replacement trees can also save a community money in the long run. Cities today try not to plant more than ten to fifteen percent of one tree species in case there is another major reduction in the population of a single species due to an outbreak of pathogens such as Dutch elm disease and chestnut blight, or insect pests such as EAB. This will help ensure that large portions of the city tree canopy are not lost within a relatively short period of time. Along with good tree diversity, select tree species should be utilized in city environments that are resilient to such conditions. The most successful urban trees are able to cope with the additional stresses associated with soil compaction, road salt, reduced groundwater filtration, excessive heat radiation, and pollution. The survival rate of newly planted street trees is significant because a typical street tree needs to have a DBH of at least 1.5 inches, and trees of this size usually cost 175-225 dollars per tree (Todd Fagan, Cedar Rapids City Arborist, personal communication).

The City of Cedar Rapids conducted a tree survey for all 3087 street trees planted between 2009 and 2012. They found an average of 82 percent survivability and an 18 percent mortality rate among the trees. Tree species found to have the best rate of survivability were: the Amur corktree, black locust (Chicago Blues cultivar), hackberry, crabapple, Japanese zelkova, Kentucky coffeetree, and Miyabe maple. All had over a 90 percent survivability rate. Other trees with similar survivability rates but with a much smaller sample size (31 trees or less) were: Manchurian alder, Tartarian maple, Amur maple, Shumard oak, and horse chestnut. Other fairly resilient trees with survivability ratings over 85 percent but less than 90 percent were: hybrid elm, swamp white oak, honey locust, London planetree, and shingle oak. Some trees had a survivability rating below 70 percent and would not be recommended for street planting due to investment costs: serviceberry, blue beech, Japanese pagoda tree, tulip tree, black alder, Norway maple, and white oak (Todd Fagan, Cedar Rapids City Arborist, personal communication).

Recommendations

Following analysis of tree survey data, we recommend implementing monitoring strategies at survey sites located at Glendale Road, Hawks Ridge Road, Melrose Avenue, and Park Road. We elected to include the Glendale road site because although it contained no public ash trees a large proportion of private properties possessed ash trees with several lots containing multiple ash trees. While certain park and natural sites had ash trees constituting a high percentage of the tree canopy we prioritized street sites over these sites, as trees that succumb to EAB infestation will not create as many safety hazards or liability issues as trees situated along streets and sidewalks.

While girdling of ash trees is the most effective method of monitoring for EAB, we feel this technique is not suitable for application in an urban setting. Instead, we suggest the use of double-decker purple prism traps because they are relatively inexpensive to construct and bait and are most effective at detecting EAB in areas with low beetle densities. As an EAB infestation has yet to be documented in Johnson County or Iowa City, this monitoring tool is the most appropriate for this area.

Public outreach should be incorporated into EAB surveillance strategies as well. Given the limited number of monitoring sites and a shortage of staff to maintain and monitor prism traps, public knowledge relating to recognition of the beetle and signs of EAB infestation are integral to early detection. Campaigns aimed at disseminating information (e.g. fact sheets, newspaper articles) to the public on EAB identification, impacts, monitoring, and treatment could aid in tracking and slowing the spread of this invasive pest.

Following an inventory of all street trees within city limits, triage should be performed concerning which trees to treat versus those that should be removed. Centennial and other large mature ash trees should be treated over other ash trees that may be sited poorly (e.g. below power lines), possess poor form (e.g. trees with co-dominant leaders as opposed to those with a single dominant leader), pose a safety hazard, or have damage or are in decline. Treatment zones should be created around sites with infested ash, otherwise nearby ash should be removed to slow the spread of EAB.

In an ideal situation, trees will be replaced as they are removed in order to retain the valuable ecosystem services that urban forests provide. Replacement species will be chosen for their resilience to conditions found in urban environments, such as soil compaction and exposure to road salt. Possible species include but are not limited to Amur corktree, black locust, hackberry, crabapple, Japanese zelkova, Kentucky coffeetree, Miyabe maple, hybrid elm, swamp white oak, honey locust, and London planetree.

Acknowledgements

The authors would like to thank Cody Hodson, IGERT trainee at The University of Iowa, for his assistance with the survey site selection process. This research was made possible through funding by The University of Iowa's Iowa Initiative for Sustainable Communities.

References

Bauer, L.S. J.J. Duan, and J.R. Gould. 2014. Emerald ash borer (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae). In: Van Driesche, R.; Reardon, R., eds. *The use of classical biological control to preserve forests in North America*. FHTET-2013-02. Morgantown, WV: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team: 189-209. Chapter XVII.

Bellamy, Charles L. 1997. "Buprestoidea." The Tree of Life Web Project. Retrieved 11 May 2015 <http://tolweb.org/Buprestoidea>

Cappaert, D., D.G. McCullough, T.M. Poland, N.W. Siegert. 2005. "Emerald ash borer in North America: a research and regulatory challenge." *American Entomologist*. 51:152–63

Crook, D.J., A. Khrimian, A. Cosse, I. Fraser, and V.C. Mastro. 2012. "Influence of trap color and host volatiles on capture of the emerald ash borer (Coleoptera: Buprestidae)." *Journal of Economic Entomology*. 105:429–37

Crook, D.J. and V.C. Mastro. 2010. "Chemical ecology of the emerald ash borer, *Agrilus planipennis*." *Journal of Chemical Ecology*. 36:101–12

Herms, D.A and D.G. McCullough. 2013. "Emerald ash borer: ecology and management." *Encyclopedia of Pest Management*. doi: 10.1081/E-EPM-120041656

Herms, D.A. and D.G. McCullough. 2014. "Emerald Ash Borer Invasion of North America: History, Biology, Ecology, Impacts, and Management." *Annual Review of Entomology* 59:13-30

Houping, L., L. Bauer, D. Miller, T. Zhao, R. Gao, L. Song, Q. Luan, R. Jin, and C. Gao. 2007. "Seasonal Abundance of *Agrilus Planipennis* (Coleoptera: Buprestidae) and Its Natural Enemies *Oobius Agrili* (Hymenoptera: Encyrtidae) and *Tetrastichus Planipennisi* (Hymenoptera: Eulophidae) in China." *Biological Control* 42:61-71

Iowa Department of Agriculture and Land Stewardship. 2015. "Iowa Tree Pests: Emerald Ash Borer." Retrieved 22 February 2015. <http://www.iowatreepests.com/eab_home.html>

Jendek, E. 1994. "Studies in the East Palearctic species of the genus *Agrilus* Dahl, 1823 (Coleoptera: Buprestidae). Part 1. *Entomological Problems* 25:9–25

Mercader R.J, N.W. Siegert, and D.G. McCullough. 2012. "Estimating the influence of population density and dispersal behavior on the ability to detect and monitor *Agrilus* *planipennis* (Coleoptera: Buprestidae) populations.” *Journal of Economic Entomology*. 105:272–81

McCullough, D.G. and A.S. Katovich. 2004. “Emerald Ash Borer. Pest Alert.” Newtown Square, PA: USDA Forest Service NA-PR-02-04.

McCullough, D.G. and N.W. Siegert. 2007. “Using Girdled Trap Trees Effectively for Emerald Ash Borer Detection, Delimitation, and Survey.” Michigan State University. Retrieved 6 May 2015. <http://www.na.fs.fed.us/fhp/eab/survey/eab_handout.pdf>

USDA Animal and Plant Health Inspection Service. 2015. “2015 Emerald Ash Borer Survey Guidelines.” Retrieved 12 May 2015. <http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/survey_guidelines.pdf>

USDA Forest Service. 2008. *Pest Alert: Emerald Ash Borer* [Fact Sheet]. Retrieved 20 February 2015. <http://www.emeraldashborer.info/files/eab.pdf>

USDA Forest Service and Michigan State University. 2015. “Emerald Ash Borer.” Retrieved 20 February 2015. <http://www.emeraldashborer.info/>

Yu, C. 1992. *Agrilus marcopoli* Obenberger. In G. Xiao (ed.), *Forest Insects of China*, 2nd ed. China Forestry Publishing, Beijing, China.

Zhao, T.H., R.T. Gao, H.P. Liu, L.S. Bauer and L.Q. Sun. 2005. “Host range of emerald ash borer, *Agrilus planipennis* Fairmaire, its damage and the countermeasures.” *Acta Entomologica Sinica* 48(4): 594–599.