GUIDELINES TO SLOW THE GROWTH AND SPREAD OF EMERALD ASH BORER

DEPARTMENT OF AGRICULTURE

MISSION

A mission of the Minnesota Department of Agriculture (MDA) is to prevent the movement of invasive plant pests into areas of the state that are not yet infested. This document provides communities and other entities responsible for ash trees in landscaped areas with guidelines to slow the spread of emerald ash borer to areas of Minnesota that are not yet infested. While communities and others following these guidelines may derive additional benefits, such as a reduced rate of ash mortality, this document was written from the perspective of protecting for as long as possible the areas of the state where emerald ash borer does not yet exist. As such, other planning documents should also be consulted and used in developing a comprehensive community emerald ash borer management strategy.

DEPARTMENT OF AGRICULTURE

CONTENTS

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Minnesota Department of Agriculture

Minnesota Department of Natural Resources

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University of Minnesota

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BACKGROUND

EAB 101

Emerald ash borer (EAB), *Agrilus planipennis*, is an invasive wood-boring beetle first detected in the U.S. near Detroit, Michigan in 2002. Since that time, EAB has killed millions of ash trees. All ash trees native to Minnesota are considered highly susceptible to EAB. Minnesota has about one billion ash trees in our forests, and ash accounts for about 15 percent of trees in the average community (Minnesota Department of Natural Resources, 2010).

A single generation of EAB is completed in one to two years. Eggs are laid during the summer on trunks and branches of ash trees. Larvae hatch from the eggs and tunnel beneath the bark. Larvae make distinct "S"-shaped (serpentine) galleries and feed on the phloem of the tree. Larvae may spend the winter inside pupal chambers in the outer sapwood, bark, or in feeding galleries, and some larvae will feed for another summer before completing development. Adults emerge from ash trees through a distinct "D"-shaped exit hole from May through September. Upon emergence, adults will feed on ash leaves in the canopy before mating and laying eggs.

Trees are killed by continual larval feeding, and tree mortality accelerates as EAB populations increase in density. Although the beetle is capable of spreading to nearby areas through flight, the primary means of long distance EAB spread to new areas is through the transport of firewood or other woody material from ash trees.

EAB STATUS

The best strategies for slowing the growth and spread of EAB depend on the level of infestation. We define here three broad categories of infestation, each of which would warrant different types and levels of management. These categories should not be considered exclusive, but rather a spectrum.

- Not Known To Be Infested – these are areas where EAB has not yet been found. EAB will be present in an area for several years before being detected. However, until detection has been made, areas where EAB has not been found are best considered not infested. As of January 2018, most of Minnesota falls into this category.
- Generally Infested – EAB infested trees have been found, but trees are not yet being killed by the insect. As of January 2018, this includes a large area of southeastern Minnesota through the Twin Cities metro, a portion of Duluth, and a portion of Martin County.
- Heavily Infested – trees killed by EAB are present. In this stage, the EAB population is sufficiently large enough to kill trees faster than they can be removed. As of January 2018, this includes the core area of the Twin Cities (mainly Minneapolis and St Paul) and a larger area in southeast Minnesota.

TREE CANOPY MANAGEMENT VS EAB MANAGEMENT

It is important to understand the goals of any particular management work before it is implemented. A very general but important distinction is the difference between activities that only impact the tree canopy versus those that also impact EAB populations. The difference between the two is simple:

EAB management tactics directly reduce the population size of EAB, tree canopy management tactics do not.

For instance, the removal of ash trees not infested with EAB would be considered a tree canopy management tactic because it has no direct impact on the EAB population. The removal (and destruction) of EAB infested ash trees would be considered an EAB management tactic because it directly reduces the EAB population. In every forest there is a need for tree canopy management; where EAB is present, there is the additional opportunity for EAB management.

EAB IN NATURAL FORESTS VS LANDSCAPED AREAS

EAB in natural forests is difficult to manage because the trees are generally less accessible, more numerous, and of lower value on a per tree basis than trees in community or landscaped areas. As a result, the only practical EAB management tool for natural forests at this time is biological control (see **Biological Control Section**). Consequently, management in natural forests primarily needs to focus on tactics for managing the tree canopy and not EAB – even in areas where EAB is present. "Ash Management Guidelines for Private Forest Landowners" as well as other resources are available from the University of Minnesota (U of M):

www.myminnesotawoods.umn.edu/2011/07/emerald-ash-borer-and-your-minnesota-woodlands/

In landscaped areas such as communities and other residential areas, there are greater potential benefits from implementing EAB management tactics. These areas are also likely to be the first places where EAB appears and also the easiest places from which EAB spreads. Thus, the potential benefits from EAB management tactics in communities and other residential areas is much greater than in forested areas.

The remainder of this document focuses on tree canopy and EAB management in community forests and residential areas rather than natural forests.

MANAGEMENT TACTICS FOR EAB IN LANDSCAPED AREAS

As described earlier, what management tactics are implemented and how they are used will vary depending on the goals (manage the tree canopy or manage EAB) and EAB status (not infested, generally infested, heavily infested). The following table lists categories of management tactics and their suitability for these different stages of EAB status and management goals:

- Dark Gray – not appropriate tactic at this time
- Green – a good time to utilize this tactic
- Yellow – getting late to implement this tactic
- Red – last chance before opportunity is lost

Management Tactics for EAB

EAB Status >>>	Not Infested		Generally Infested		Heavily Infested	
Management Target >>>	Tree	EAB	Tree	EAB	Tree	EAB
Management Tactic						
Communications – critical to all tactics						
Planning						
Inventory						
Monitoring*						
Treatments						
Removals/Sanitation**						
Wood management Utilization						
Replanting						
Biological Control						

*When EAB arrives, monitoring should shift from general surveillance to an organized effort to inform EAB management efforts – see **Monitoring Section**.

Removals for tree canopy management should focus on low quality trees or some other criteria regardless of EAB status, removals for EAB management should focus exclusively on EAB infested trees – see **Removal/Sanitation Section.

These guidelines provide communities and other entities responsible for ash trees in landscaped areas the tactics available to manage EAB and to slow its spread. These tactics include: planning, inventory, monitoring, treatments, removals/sanitation, wood management/utilization, replanting, and biological control. For each management tactic, suggested activities are divided by EAB status (not infested, generally infested, and heavily infested). Thus, each tactic has three sections where activities appropriate for a given EAB status are described. Appendices are also included in this document that explain how to confirm and report EAB, the various detection methods that can be utilized by communities, and how winter weather in Minnesota affects EAB.

PLANNING

Photos to the left of Belvedre Drive in Toledo, Ohio before EAB (top) and after infestation five years later (bottom).

Photo Credit: Daniel A. Herms, The Ohio State University

An EAB Management Plan should address each of the tactics listed in the Management Tactics for EAB table, with citizen communication a primary consideration for each tactic. Citizens should play an important role in EAB management and can provide assistance with everything from inventorying trees, detecting new infestations, properly disposing of wood waste, replanting, etc. At the very least, an effort needs to be made to alert residents that they will need to make one of three choices (remove, treat, or tree death) for all of the ash trees on their property, and that once EAB is present on their property, options quickly become fewer and more expensive.

Just as every community is different, every EAB Management Plan will also be different. Similarly, each agency or entity in a position to help develop an EAB Management Plan may have a slightly different approach based on their priorities and responsibilities. Several resources are listed here, and we recommend looking at all of them and then using the information provided to create a plan that works for your community.

PLANNING GUIDELINES

- A Community Preparedness and Response Plan template is available from the U of M along with the EAB Community Preparedness Manual, assembled by U of M, Minnesota Department of Natural Resources (DNR), and MDA in 2009. While some of the information available about managing EAB in 2009 is now outdated, many of the resources identified in the Community Preparedness Manual are still relevant in 2018 and are referenced throughout this document.
  www.myminnesotawoods.umn.edu/eab/
- A Model Emerald Ash Borer Management Plan is available from the Minnesota Shade Tree Advisory Committee.
  www.mnstac.org/
- The Community Engagement and Preparedness (CEP) program began in 2009, as a response to the first EAB identification in the metropolitan St. Paul/ Minneapolis area. The program was originally developed by the U of M Extension and the DNR. The Urban Forestry Outreach Research and Extension program at the U of M's Department of Forest Resources has managed the program since 2009. The

goal of the program was to work with communities in Greater Minnesota as well as the metropolitan area, providing technical assistance and community volunteer training that would elevate the communities' awareness of EAB's consequences, their particular community's vulnerability to EAB, and the communities' capacity to successfully prepare for, manage and recover from the projected infestations. To that end, the CEP program has trained community volunteers to conduct tree inventories or surveys to establish levels of vulnerability to EAB infestations and prepare reforestation plans in more than 40 communities statewide. To learn more about the CEP program, please access its website at **www.mntreesource.com.**

MODELING TOOLS

- The EAB Cost Calculator, developed at Purdue University, allows you to use your tree inventory to model community canopy structure and costs under different EAB management regimes utilizing removal, treatment or no action.
  int.entm.purdue.edu/ext/treecomputer/
- The EAB Planning Simulator, developed at University of Wisconsin - Stevens Point, also provides an opportunity to model canopy structure and costs under different management scenarios. This model is run in an Excel spreadsheet rather than an online interface.
  www.michigan.gov/documents/dnr/EABPlanning_374200_7.xls

AREAS NOT KNOWN TO BE INFESTED

Preparing for EAB before it has been identified in your community or is in close proximity is a key component of EAB management and maintaining overall tree canopy. If communities are prepared, the inevitable impact from EAB may be spread over many years as opposed to a relatively short amount of time. This creates a more manageable financial situation and also allows for an orderly transition to a community forest with fewer ash trees while maintaining the benefits provided by the tree canopy.

GENERALLY INFESTED AREAS

Communities unable to make an EAB Management Plan prior to the arrival of EAB can still create an effective plan and manage EAB. However, impacts from EAB may be seen in a shorter time period and there may be larger budget constraints. EAB will eventually kill most untreated ash trees, and these trees will have to be removed or be left to fall apart. Removal costs will vary depending on the size and location of the tree in proximity to utilities and structures. Delaying removal of infested trees will increase costs as dead ash trees become brittle and hazardous. Without an effective plan in place to mitigate this process, ash in a community forest can change from apparently healthy to mostly dead in just a few years.

HEAVILY INFESTED AREAS

Very few management tactics are available at this stage and management plans will focus on Removal/Sanitation and Wood Management/Utilization. This is the last opportunity to preserve or protect any trees that remain in treatable condition. Replanting should also be included in the plan to ensure a healthy community forest in the future.

EXAMPLE COMMUNITY MANAGEMENT PLANS

Management Tactics			Elk River	Rochester	Apple Valley	Lake City	Rushford
Management Target			EAB	EAB	EAB	EAB	Tree
EAB Status			**Not Infested**	**Generally Infested**	**Generally Infested**	**Generally Infested**	**Generally Infested**
Tree Inventory			All public, no private	All public, no private	All public, no private	All public, no private	Public ash
Shade Tree Pest Ordinance			No	Yes	Yes	Yes	No
Yearly Monitoring			As needed basis	Yes, winter	Yes, winter	Yes, winter	Yes, winter
Disposal Site			City compost site	Private site within City	County compost sites	City compost site	City compost site
Ash Utilization			Mulch	Milled lumber for Park projects, mulch, energy plant	Mulch, energy plant	Energy plant, millerd lumber for Park projects	Sold to logging firm, firewood for residents
Replanting			Replace every public ash tree removed	Replace every public ash tree removed	No public boulevard, City runs tree sale	Replace every public ash tree removed	Where appropriate
Biological Control Site			Undetermined	Undetermined	No	Undetermined	No
Ash Tree Removals	Not infested	Public boulevard	No	Yes, poor quality or city project conflict	Yes	Yes	No
		Public park landscape	Yes, hazard trees prioritized	Yes	Yes	Yes	No
		Public natural forest	Yes, as time allows, prioritize hazards	Yes	Not yet	No	No
	EAB Infested	Public boulevard	N/A	Yes, unless treated	Yes	Yes	Yes
		Public park landscape	N/A	Yes, unless treated	Yes	Yes	Yes
		Public natural forest	N/A	Yes, chipped in place	Not yet	Yes	No
		Private	N/A	Within 100 feet of any developed parcel	Yes	Yes	No
Insecticide Treatments		Public boulevard	Residents can treat public trees	Yes, good condition. Residents can treat with city permit.	Yes	No	No
		Public park landscape	Yes, based on tree condition	Yes, based on tree condition	Yes	No	No
		Public Natural forest	No	No	No	No	No
		Private – not infested	Seeking grant funds for a program	City licensed contractor	Residents receive City contracted rate	Yes	Yes
		Private – lightly infested	N/A	Yes residents can treat in place of removal	Yes, if the tree appeared healthy the previous summer	Yes	Yes

EAB Management Plan information described in the table was provided December 2017. Management Plans may have changed since this document was produced.

INVENTORY

An essential component of an EAB Management Plan is having a tree inventory. Without inventory data, any predictions of costs and impacts will be merely guesswork. Every effort should be made to complete a tree inventory before EAB is identified in a community. This is an area where citizen volunteers have been important contributors in some communities. The U of M's Community Engagement and Preparedness Project has completed over 25 tree inventories or surveys using trained volunteers. More information is available from the U of M (see **Planning Section**).

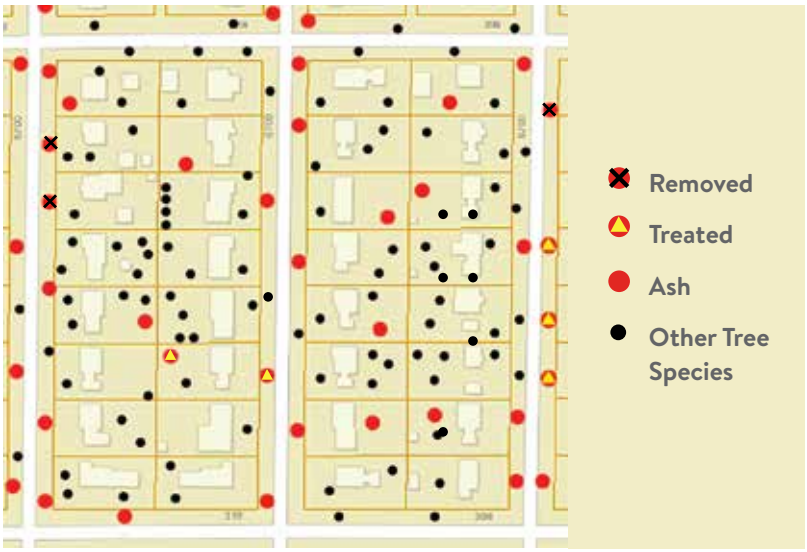
At minimum, an inventory should include species, location information, size class, and tree condition. If a complete tree inventory is not possible, an inventory of just ash trees is an option. With an inventory, the modeling tools described in the **Planning Section** can be used to predict how EAB will impact a community's ash canopy and budget over time based on the management strategy used. If possible, include ash trees on private property as part of an inventory. Impacts to private trees are part of the impact to the community, regardless of whether they will be managed under ordinance or not.

INVENTORY RESOURCES

- Community Engagement and Preparedness Project – Tree Inventory Manual **www.mntreesource.com/uploads/2/0/7/0/20706756/communitymanual-_2014.pdf**
- The EAB Preparedness Plan includes an entire section with information on conducting tree inventories: **www.myminnesotawoods.umn.edu/eab/eabmanual/**
- How to develop a good street tree master plan **www.myminnesotawoods.umn.edu/2008/12/road-to-a-thoughtful-street-tree-masterplan/**

AREAS NOT KNOWN TO BE INFESTED

This is the ideal time to do a complete tree inventory and create good street tree master plan for your community (see **Replanting Section**). An inventory will also determine trees that are candidates for treatments and trees to remove to reduce ash tree density (see **Treatments Section** and **Removal/ Sanitation Section**).



GENERALLY INFESTED AREAS

Ideally, a complete tree inventory would be conducted. However, due to time and budget constraints, an "ash only" inventory can be conducted. This can be used to remove trees showing signs of infestation (see **Appendix 2 - Detection Methods)**, trees in poor condition (see **Removal/Sanitation Section**), and determine trees to receive treatments (see **Treatments Section**). A complete tree inventory can be completed as time and budgets allow to create a good street tree master plan for a healthy community forest.

HEAVILY INFESTED AREAS

An inventory should focus on ash trees due to the hazards they pose when heavily infested. With an ash inventory, you can determine the removal priorities of hazard trees (see **Removal/Sanitation Section**) and if there are any trees left in a condition suitable for treatments (see **Treatments Section**). A complete tree inventory can be completed as time and budgets allow to create a good street tree master plan for a healthy community forest.

MONITORING

Monitoring is a critical aspect of EAB management. In order to effectively use EAB management tactics, you need to know where EAB is or at least where it is having impacts. Tree canopy management tactics, on the other hand, are not dependent on monitoring data unless some aspect is triggered by the discovery of EAB.

The status of EAB in and around your community has a direct impact on the usefulness of monitoring data and the best methods for obtaining it. The MDA has extensive experience conducting detection and monitoring surveys for EAB (see **Appendix 2 - Detection Methods**). Since before EAB was discovered in Minnesota, the MDA has worked with a variety of partners from local units of government to state and federal agencies and local industry to monitor for EAB. Based on these many years of experience, we recommend the following monitoring regimes based on the EAB status.

AREAS NOT KNOWN TO BE INFESTED

Monitoring for EAB in areas where it is not yet known to occur is important, but the costs of an intensive monitoring program may outweigh the benefits depending on the likelihood of EAB reaching your community in the near future.

A good strategy is to incorporate EAB surveillance into other activities, such as having all Public Works employees trained in recognizing signs of EAB and reminding them of the importance of watching for and reporting suspicious trees. In a situation like this, it is best to have one person on staff who is the contact for reports of possible finds of EAB and who can decide what should be sent in to the MDA. See **Appendix 1 - How to Confirm and Report EAB** for tips on identifying suspect EAB infestations and procedures for reporting them.

Another important strategy is to engage motivated citizens to participate in training opportunities for recognizing EAB. It is important for volunteers who help to conduct tree inventories or other activities in the community be knowledgeable about how to recognize and report signs of EAB.

Trees with woodpecker damage consistent with EAB (see **Appendix 2 - Detection Methods**) had 2.5 times as many EAB than trees without woodpecker damage.

If your community is near a known infestation, then there is greater value in more intensive monitoring such as is described for generally infested areas.

GENERALLY INFESTED AREAS

Monitoring for EAB is most important in areas where it is present but not yet at high levels. These areas provide the best opportunity for effective use of EAB management tactics such as sanitation and targeted insecticide treatments to limit EAB population growth. However, in order to have maximum impact on EAB populations, those tactics need to be targeted where EAB is most abundant.

For example, the U of M and the MDA studied the impact of tree removal on EAB populations in St. Paul and Minneapolis from 2009-2013[1]. The study found that the removal of approximately 63 percent of the available phloem in the infested area reduced the EAB population by approximately 54 percent from what would have occurred with no removals. However, the same EAB population reduction could have been achieved with approximately 34 percent of the phloem removed if only trees that had been woodpecked were removed. In this study, EAB larvae were 2.5 times more likely to be found in a woodpecked tree than a non-woodpecked tree.

There are multiple options available for conducting EAB monitoring, including visual survey, branch sampling and purple prism traps. The U of M and the MDA conducted a study funded by the State of Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources to determine the relative efficacy of each of these monitoring tactics[2]. The study found that all three methods had utility for detecting EAB infestation in an area prior to significant canopy decline. However, visual survey was by far the most time- and cost-effective method to implement. In this study (eight sites over three years), visual survey took 12-24 minutes of labor to find a positive tree compared to 3.5-3.6 hours of labor for branch sampling and 4.3-5.4 hours of labor for purple prism trap. With basic training, municipality staff can easily identify EAB infested trees using a pair of binoculars to look for woodpecker damage. (**See Appendix 2, Visual Survey**)

Ideally, all areas of a community where EAB is known to occur, as well as bordering areas, would be monitored on a yearly basis (late winter / early spring) to help inform the level of management needed in that area – i.e., how many trees need to be removed, how many should be treated, etc. Research findings[3] indicate that insecticide treatments can be implemented on infested trees, but need to occur when trees are relatively healthy (greater than 50 percent of canopy intact). Work in Ohio[4] found that the transition from a greater than 50 percent intact canopy to a less than 50 percent intact canopy occurred when EAB density was in the range of approximately 40-80 larvae/square meter. The MDA and U of M study found that the density of 40 EAB larvae/square meter of phloem was not reached until approximately 50-75 percent of trees in an area had woodpecking damage. This indicates that monitoring should be able to identify areas of infestation while trees in the area are still treatable and that treatment could be concentrated only in the areas that need it.

While the MDA and U of M study referenced above showed some promise for allowing estimates of EAB density in an area based on the frequency of infested trees identified by visual survey or the density of EAB in branch samples, more research should be conducted before basing management decisions solely on these kinds

of observations. Our recommendation at this time is to consider the discovery of EAB in an area to be the time to begin treatments.

Expanding monitoring to a broader area of the community should help to identify new areas of infestation before substantial damage occurs. Additionally, similar to areas not yet known to be infested, training staff and citizens who can watch for infestations in new areas of the community is also worthwhile for generally infested areas (see **Appendix 1 - How to Confirm and Report EAB**).

[1] 2017 Fahrner, et al. Strategic removal of host trees in isolated, satellite infestations of emerald ash borer can reduce population growth. Urban Forestry & Urban Greening. 24:184-194.

[2] 2016. Abrahamson, et al. "When do you pull the trigger? Using Monitoring Data to Optimize EAB Management." Presentation at Science & Management of Ash Forests after EAB, Duluth, MN

[3] 2015. Flower, et al. To treat or not to treat: Diminishing effectiveness of emamectin benzoate tree injections in ash trees heavily infested by emerald ash borer. Urban Forestry & Urban Greening. 14: 790-795.

[4] 2013. Flower, et al. The relationship between the emerald ash borer (Agrilus planipennis) and ash (Fraxinus spp.) tree decline: Using visual canopy condition assessments and leaf isotope measurements to assess pest damage. Forest Ecology and Management. 303: 143-147.

HEAVILY INFESTED AREAS

In heavily infested areas, there is little value in the kind of intensive monitoring warranted for generally infested areas. However, note that it is likely that some areas of a community could be considered heavily infested while other areas are only generally infested or not known to be infested and still warrant close monitoring.

In heavily infested areas, most trees are infested beyond treatment thresholds and the focus should be on tree removal and wood management. Survey work will be needed to mark trees for removal. Monitoring may be needed to prevent wood from being mishandled – such as a privately-owned tree being removed to a location outside of the infested area.

There is no need to report infested trees to the MDA in heavily infested areas.

TREATMENTS

Through research trials conducted by multiple universities, properly applied EAB insecticide treatments have demonstrated high efficacy for protecting ash trees from EAB. These results are laid out in a publication from the North Central IPM Center as well as many research papers published by the contributing authors and others. This North Central IPM Center publication is an excellent baseline reference for EAB insecticide treatments:

Insecticide Options for Protecting Ash Trees from Emerald Ash Borer
www.emeraldashborer.info/documents/Multistate_EAB_Insecticide_Fact_Sheet.pdf

While this document is an excellent reference, it may also be somewhat technical for many citizens. A good document for citizens who need to understand the basics of EAB insecticide treatments is available from the MDA:

Emerald Ash Borer: Homeowner Guide to Insecticide Selection, Use, and Environmental Protection

www.mda.state.mn.us/~/media/Files/plants/eab/eabtreatmentguide2.ashx

In addition to understanding how treatments are done, it is also important to consider the rationale behind treating any particular tree. To be protected, an individual tree needs to contain sufficient insecticide to prevent EAB damage when EAB populations are high enough to significantly damage that tree that year. There is no value derived by that particular tree in containing insecticide at any other time. Thus, understanding the current risk of EAB damage to the tree could potentially save unnecessary insecticide applications and costs.

Moreover, treatments do not have to occur before EAB reaches an area or even a tree. EAB insecticide treatments can be used therapeutically unless so much of the stem is damaged that the tree cannot translocate the insecticide through the vascular tissue and canopy. Generally, trees with greater than 50 percent canopy decline are not considered good candidates for treatment due to the amount of damage already done to the tree. Thus, if a tree is going to be protected from EAB, treatment needs to occur before infestation within the tree has reached this extent. Research has shown that some trees with greater than 50 percent canopy decline can survive even if treatedl; however, branches that have been killed as a result of infestation do not recover and, consequently, the remaining tree may not be worth the investment.

The cost of treatment is a common concern for both individual property owners and communities. Tools like the EAB Cost Calculator and the EAB Planning Simulator (see **Planning Section**) show clearly that treatment costs are generally lower than removal costs. This is true in actual expenditures in the short-term and also over the long-term through the benefits derived from mature trees retained through treatment.

AREAS NOT KNOWN TO BE INFESTED

It is not uncommon for EAB populations to be sufficiently high enough to cause some ash tree decline or death before the insect is discovered in a new area. However, the risk of this occurring to an individual tree is very small, particularly the farther the tree is from existing infestations. Typically, EAB infestations are discovered before more than a small percentage of trees are affected in a given area. For an individual considering the treatment of private trees, this is an important consideration. The risk of EAB damaging their trees is small, but it is not zero. Some trees may have sufficient value to the landowner that they are willing to accept the risk of paying for unnecessary treatments to avoid the risk of EAB killing their trees.

Assessing risk is a key message to pass on to property owners in a community. However, without having a framework for identifying the level of risk to the trees they own, it is difficult to make an informed decision. The following table is a qualitative assessment of risk based on the experience of MDA staff working in a wide variety of EAB-infested sites in which tree condition, EAB signs and EAB density have been quantitatively measured; and could be used by individuals to assess the risk EAB poses to trees on their property using the parameters listed. EAB status can be tracked to the community and often neighborhood level using the MDA's interactive EAB status map, **www.mda.state.mn.us/eabstatus**. Tracking beyond that level will generally need to be done by the community, neighborhood or property owner.

EAB Status	Tree Risk	Woodpecking/Bark Cracks due to EAB	Canopy Decline Due to EAB Present
EAB not yet found in County	Very Low		
EAB present in County	Low		
EAB present in Community	Moderate		
EAB present in Neighborhood	High	Present on some trees	Maybe
EAB present in your tree	May not be treatable	Present on your tree	Yes

Trees in a community are at greater risk than trees on a single property due to their greater abundance and distribution, and some communities begin insecticide treatments before EAB is detected in an area. Using insecticide treatments in this way should not be considered an effective EAB management tool since without the confirmed presence of EAB, there is no known impact on an EAB population. Rather, using insecticide treatments in this way could be considered a tree canopy management "insurance policy" to reduce the risk that EAB will kill trees in the community before it can be discovered.

Moreover, the MDA and the U of M documented (as described in the **Monitoring Section**) that visual observation, branch sampling and purple prism traps are all effective at identifying the presence of EAB before substantial tree decline has occurred. Thus, a community should be able to implement monitoring activities that allow them to delay treatment until EAB is discovered with low risk of losing trees. Depending on the situation, this could be a substantial cost savings and is worth evaluating before a decision is made to begin preemptive insecticide treatment.

GENERALLY INFESTED AREAS

Insecticide treatment is an important management tool for generally infested areas, where EAB is known to be present. Insecticide treatments can be used to not only preserve treated trees but also to potentially provide protection to untreated trees, and slow the population growth and spread of EAB to new areas.

Insecticide treatments are a potentially powerful management tool for EAB. Given enough resources, a community could in theory treat 100 percent of their ash trees in perpetuity, thereby rendering EAB a non-issue. While resources are always constraining, the good news is that there may not be a need to treat every tree to provide acceptable and even strong control of EAB. A model developed at Michigan State and published in 2011 predicts that treating a random selection of 20 percent of ash trees in a community every year may sufficiently depress EAB populations enough to protect most of the trees in the community:

> McCullough and Mercador, 2011
> **scholars.opb.msu.edu/en/publications/evaluation-of-potential-strategies-to-slow-ash-mortality-slam-cau-4**

This study is the basis for the Model EAB Management Plan developed by the Minnesota Shade Tree Advisory Committee (**www.mnstac.org/uploads/2/0/9/3/20933948/mnstac_model_eab_management_plan.pdf**). The idea that treated trees can protect untreated trees is currently being field-tested by the U of M. They are conducting a study to compare the impacts of EAB to un-treated trees across sites with progressively higher frequencies of treated trees. The answer should be the percentage of trees that need to be treated in an area to protect the untreated trees.

The reasons for incorporating treatment are important for determining how treatments are implemented.

- If the goal is reducing EAB population growth and spread into new areas, then treatments should be targeted at areas where it is present, which means that a systematic monitoring program should be included. Trees may be treated only as long as it is considered effective for the management of EAB rather than to preserve them indefinitely.
- If treatments are meant as an "insurance policy" so replacement plans can proceed on track, then trees may be treated at random or chosen using some variable other than presence of EAB. However, an EAB monitoring

program may help to determine whether management efforts are proceeding quickly enough relative to EAB population size. Under this scenario, trees are not treated indefinitely but rather only as long as needed for removal and replacement efforts to stay on track.

- If the goal is to preserve high-value trees indefinitely, then trees should be chosen based on factors such as location, structure, size, etc. and be treated as often as necessary to preserve them. In this case, a monitoring program will help to track EAB pressure and how often trees need to be retreated for protection.

Incorporating insecticide treatment into an EAB management plan can provide a community control over how a landscape is transitioned into one with fewer ash trees. An analysis conducted at Purdue University modeled the utility of insecticide treatments to delay the need for removals, preserve canopy and reduce costs of dealing with EAB.

Sadof, et al, 2017
www.emeraldashborer.info/documents/Sadof%20et%20al%202017%20Staging%20EAB%20Infestation.pdf

This study found that delaying management until damage was visible did not have a major impact on the ultimate success of the management strategy and supports the idea of using monitoring programs to determine when management actions should begin.

Private trees are an important component of managing EAB in generally infested areas. Some communities have been able to secure treatment rates with city contractors and then extend those rates to citizens. This can help to encourage treatment in areas where it is needed. At the very least, citizens in EAB infested areas need to understand that nearly all ash trees will be lost without treatment and that removal costs will likely be greater than treatment costs.

HEAVILY INFESTED AREAS

When EAB is abundant in a community it is, by definition, too late for many or most of the trees to be treated. This is the last opportunity to preserve or protect any trees that remain in treatable condition. At this point, management strategies should rely on removal and processing of ash trees. Any treatable trees that remain may have a major impact on the remaining EAB population since adult activity in the area will be concentrated on these trees. Creating treated sink trees for killing beetles could help reduce the number of insects that ultimately disperse out of the area.

It is important for citizens in heavily infested areas to understand that there is no opportunity to wait if trees are to be treated. Trees could appear healthy one year and be near death the next due to the delayed impact of damage and the numbers of beetles available to infest the remaining trees.

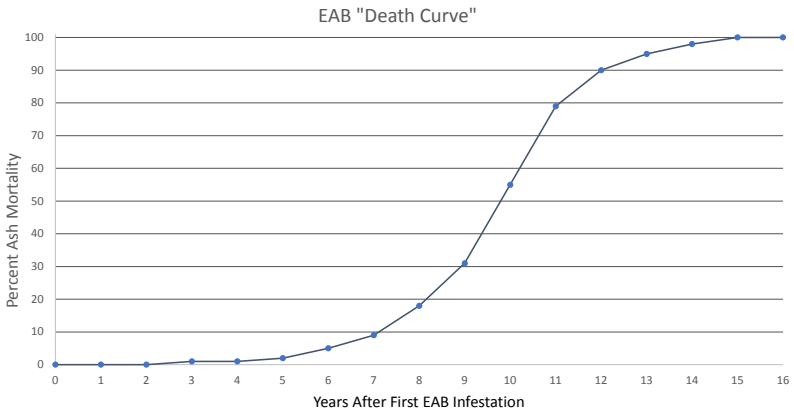
REMOVAL/ SANITATION

Much like insecticide treatments, the value of and reasons for removing trees may vary substantially depending on the status of EAB in an area.

AREAS NOT YET INFESTED

Removing trees that are not infested with EAB can be an important element of tree canopy management. In any community forest there are ash trees that are of low quality because of structural defects, obstructions such as overhead powerlines, declining health, etc. Removing and replacing these trees with non-ash genera before the arrival of EAB improves the resilience of a community forest to EAB. Moreover, once EAB arrives, the number of ash trees requiring attention will grow, leaving fewer resources to address low quality trees on the landscape.

In some communities, local opinion may be less favorable towards insecticides for management of EAB. In these instances, tree removal is the only other option for dealing with EAB infested trees. However, management of EAB through tree removal alone may be difficult. A systematic monitoring program can help to identify areas of infestation before significant damage has occurred. However, after an area has been identified, aggressive removal may be needed in order to stay ahead of the EAB "Death Curve". This tactic may work in smaller communities where there are not many trees to manage, but in larger communities this will be difficult to implement as EAB spreads. For many communities who have relied on removal as a management tactic, the rate of EAB population growth and tree mortality has outpaced the rate at which trees can be removed.



For communities where insecticides will not be used, removal and replacement activities should be initiated sooner rather than later. Removing a large number of mature trees from a

community at one time will have significant negative impacts on storm water runoff, air quality, property values, aesthetics, etc. This will also happen in communities not using insecticides that wait until EAB arrives to begin tree removal and replacement. Removing and replacing a small number of trees at a time over a long period reduces the negative impacts of tree removal, but to do this without using insecticides to manage the EAB population will require a community to start well in advance of EAB detection.

A Minnesota city boulevard with all ash trees removed.

Outreach is important for communities who elect to initiate tree removal and replacement before the arrival of EAB so that citizens understand the reasons for the work. This is also a great opportunity to bring attention to the issue of EAB and begin educating citizens about how it will affect them. Emerald ash borer doesn't discriminate between trees on public and private land. So even if a community is able to quickly remove all ash trees on public land after the arrival of EAB, residents with ash trees on their properties will still be dealing with the issue.

In addition to outreach, having a plan for quick replanting is a critical component for maintaining public support of ash tree removal prior to the arrival of EAB. More resources regarding this can be found in in the **Replanting Section**.

GENERALLY INFESTED AREAS

Like insecticides, sanitation is an important component of EAB management in generally infested areas. Sanitation is different than tree removal in advance of EAB as it specifically means removing and destroying EAB-infested trees in order to kill the beetles within them. Sanitation can have a significant effect on the population growth of EAB. As described under the **Monitoring Section**, a study by the U of M and the MDA found that EAB population growth was reduced by 54 percent through sanitation efforts in both St. Paul and Minneapolis. This reduction likely delayed the onset of tree mortality in neighboring areas but did not prevent it. This highlights the point of how difficult it can be to manage EAB through tree removal alone.

The study also demonstrated how important it is to concentrate removal efforts on the right trees to maximize the impact on the EAB population while minimizing the impact on the community forest. Trees with woodpecker damage consistent with EAB (see **Appendix 2 - Detection Methods)** had 2.5 times as many EAB than trees without woodpecker damage. Ideally, management plans will incorporate both insecticide treatments and tree removal into an integrated strategy that puts both tactics to best use. For example, a community could remove trees in a neighborhood that show obvious signs of EAB and treat trees that do not.

Communities commonly ask about grinding out stumps from infested trees. From an EAB management perspective, this is not an important step. EAB numbers left to emerge from a cut stump are not likely to be very high, even in a heavily infested tree. The time and dollars needed for stump grinding could be more effectively used dealing with other infested standing trees. However, from a tree canopy management perspective, stump grinding may be a mandatory step in order to free up the planting spot for a new tree.

Many communities have all they can handle in dealing with trees on public property. However, at some point, trees on private property will also need attention. In a worst case scenario, trees on private property in the vicinity of buildings or other activity areas are left to become infested and die. Ash trees quickly become brittle and hazardous once dead. Unfortunately for the property owners, these brittle, hazardous trees in many cases will be much more expensive to remove than they would have been to treat or remove while still living.

The more proactive a community is in addressing privately-owned trees, the more likely they are to be successful in addressing EAB. Some communities already have a diseased tree ordinance in place for managing Dutch elm disease and oak wilt that can be amended for EAB management. It will be up to managers to decide if there are enough resources to take action when private trees are identified as infested. Ideally, citizens will be well-educated about EAB and understand that they will end up treating or removing any ash trees that they do not want to pose a danger to property or human health.

Some communities have taken steps to identify EAB infested trees on private property through monitoring activities and require the owner to either treat or remove the trees. While this may seem onerous for both the city and the property owner, it is in everyone's best interest to proactively address infested trees. While trees in woodlots or other natural areas can often be left to become infested, die and fall apart, this is generally not acceptable in yards and other landscaped areas. Infested trees will produce many beetles over the course of their decline and death. It is in the best interest of all citizens to have as few EAB flying around as possible. Treating or removing infested trees in the early stages of infestation is an important part in limiting the size of the EAB population. For those communities who choose to address trees on private property, a model Shade Tree Pest Control Ordinance can be found on the League of Minnesota Cities website **www.lmc.org**.

HEAVILY INFESTED AREAS

In heavily infested areas, the primary management option available is tree removal. From an EAB management perspective, the most important trees to remove are those that are the largest but also infested and still alive as those likely contain the greatest numbers of beetles. In heavily infested areas however, a more important criteria to consider is the safety and property risk posed by dead and dying trees which would mean first addressing trees in the most potentially damaging locations. In any area where EAB is present, wood management and avoiding the movement of EAB is important. However, this is especially so in heavily infested areas due to the number of EAB present and the number of trees needing removal.

WOOD MANAGEMENT/ UTILIZATION

On its own, EAB can fly a few miles a year and over time populations will naturally spread. However, the primary reason that new areas of infestation develop is the movement of wood containing the immature life stages of EAB. Consequently, preventing the movement of EAB in wood is one of the most important things an infested community can do for un-infested areas. This is true not only for wood movement out of a community but also for movement within thus delaying spread into new neighborhoods.

Like other elements of EAB management, actions related to wood management and utilization are best begun before EAB arrives. Once EAB arrives in a community, the supply of wood will increase. If EAB is not successfully managed, the wood supply will increase exponentially along with the EAB population and number of dead trees.

Many innovative solutions have been devised by communities with EAB infestations to utilize the wood generated. However, often times these communities had to identify these opportunities after standing dead trees were already present along their streets. A better model is for a community to identify these options before EAB arrives. Creating uses for this wood that do not spread EAB may provide incentives for citizens to avoid spreading EAB to new areas. For instance, some citizens have milled lumber from a tree or trees on their property by a portable sawmill operator. This is a great option for managing EAB as the milling process separates the outer layers of the tree which contain the insects from the inner sapwood and heartwood which are not infested by EAB. The outer layers should be destroyed but the inner layers can be sawn into lumber. This same approach could be taken at the community level in order to acquire lumber needed for a variety of building purposes, or a local business may be able to utilize the wood, or perhaps with the right incentive a new local business could be developed to help utilize the wood.

Utilization of urban wood has been well-studied and a number of excellent resources are available.

> Urban and Community Forestry Resource Directory, directory developed by the University of Minnesota for companies for various tree and wood related services **www.mntreesource.com/resource-directory.html**
>
> Wood Utilization Options for Urban Trees Infested by Invasive Species, 2012, National Resources Research Institute **www.fs.usda.gov/naspf/sites/default/files/naspf/pdf/werc-2009-dg-087_2.pdf**

Using Industrial Clusters to Build an Urban Wood Utilization Program: A Twin Cities Case Study, 2010, Dovetail Partners
www.dovetailinc.org/report_pdfs/2010/werc63010finalreportsm.pdf

The Use of Wood from Urban and Municipal Trees, 2014, Connecticut Department of Energy and Environmental Protection
www.ct.gov/deep/lib/deep/forestry/urban_forestry/biomass_final-6-29-14.pdf \

Urban Wood and Traditional Wood – a Comparison of Properties and Uses, 2014, Purdue Extension
extension.purdue.edu/extmedia/FNR/FNR-490-W.pdf

AREAS NOT YET INFESTED

This is the time to prepare for EAB's eventual arrival and to plan for managing and utilizing wood. One of the most important things is identifying easy ways for citizens to dispose of wood. Does your community have a site where citizens can dispose of wood? If not, it is worth investigating the potential for establishing one. Many people will be inclined to make firewood out of ash trees that are removed after EAB arrives. It will take significant outreach to convince citizens that this is not a good idea and that it is a better idea to have the wood processed so that beetles cannot emerge. However, all of the outreach in the world will not accomplish this if there is not some kind of processing or transfer site where wood can be brought. The time to do this kind of planning is before EAB arrives.

GENERALLY INFESTED AREAS

Once EAB is present in a community, it is very important to take steps to keep it from being moved to new parts of the community or out of it altogether. One way to accomplish this is to follow the best management practice of not pruning or removing ash trees when EAB are actively flying (May-September) to avoid the risk of EAB emerging from this material in transit or at a processing location. EAB only emerge from wood during these months so the rest of the year (October – April) should be a safe time for removing and processing this material to kill any beetles infesting it.

See the MDA website for more information on these BMP's
www.mda.state.mn.us/plants/pestmanagement/eab/bmpsinfested.aspx

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In addition, state regulations are likely to already exist or to be put in place that prohibit the movement of materials out of the area that could harbor EAB. Regulated areas are typically defined at the county level. Residents will need to be aware of these legal restrictions on wood movement and where infested material can be brought for processing.

This is a critical time for outreach to citizens so that they understand the risks posed by infested wood. Without repeated reminders, it is easy for people to forget this and unwittingly move EAB to a new area via infested

firewood. Ideally, at this point there is a plan for utilizing material and a way for privately owned trees to enter that stream as well as publicly owned trees. If so, intensive outreach is justified to educate people about the plan and how to participate.

In particular, during this period it is important to remind citizens not to hold infested wood for firewood. It is self-defeating to allow EAB to emerge from cut wood while the EAB population is still small and management efforts are underway to keep it that way. During this period of general infestation, all infested trees that are not being treated should be removed and processed to prevent beetle emergence.

HEAVILY INFESTED AREAS

In heavily infested areas, the focus should be on preventing infested wood from leaving the area. In these situations there may be little opportunity to have any more influence on EAB populations through management. If that is the case, there is little harm in citizens retaining infested wood for firewood, provided that it does not leave the area of infestation. Again, this is a time when significant outreach is needed to educate and remind citizens of this important point. The need for sites where wood can be brought and processed will grow during this period until most of the untreated ash trees have been killed and removed. It is important to keep in mind that the supply of wood may increase very rapidly. Once EAB populations begin growing exponentially, it may only take a few years for most of the untreated ash trees to die. It is also important to remember that the supply of wood will decrease almost as quickly unless removal and processing efforts fall behind.

REPLANTING

We have learned from Dutch elm disease and now EAB that replanting requires species diversity. There are many insects and diseases on the horizon that could make it to Minnesota in the future and affect many of our remaining tree species. Replacing the ash trees with a variety of species and creating more species diversity within neighborhoods is essential in preventing future widespread tree deaths.

How to develop a good street tree master plan
www.myminnesotawoods.umn.edu/2008/12/road-to-a-thoughtful-street-tree-masterplan/

A guide to recommended trees for Minnesota by region
www.myminnesotawoods.umn.edu/2008/11/recommended-trees-for-minnesota-by-region/

Gravel beds are a good way to increase the survival of bare root trees
www.mntreesource.com/uploads/2/0/7/0/20706756/all_you_need_to_know_about_community_gravel_beds_2013_edition.pdf

Proper tree planting techniques
www.dnr.state.mn.us/arbormonth/planting.html

Landscape alternatives to invasive plants
bugwoodcloud.org/mura/mipn/assets/File/MIPN%20Landscape%20Alternatives%202013.pdf

Trees and shrubs for pollinators
www.extension.umn.edu/environment/agroforestry/pollinator-trees-shrubs.pdf

Climate change effects on forests
www.forestadaptation.org/urban

Community Preparedness Manual
www.myminnesotawoods.umn.edu/eab/

Tree sales are a way to reforest and diversify the urban tree canopy through private residents purchasing wholesale priced trees and shrubs. Tree sales are run by counties, cities, non-profits, gardening groups, soil and water conservation districts or other entities. The sales typically take place in the spring and can be comprised of bare root, container or air pot trees and shrubs. Trees purchased through the sales are typically planted on private property; however, some cities allow plantings in the public boulevards. Depending on the entity holding the sale, residents may also purchase trees and donate them to a municipal park.

A Nursery Stock Dealer Certificate is required for tree sales when trees are planted on private property. Contact the MDA Nursery Inspection Unit directly at 651-201-6388 or visit **www.mda.state.mn.us/licensing/licensetypes/nurseryprogram.aspx** for more information.

AREAS NOT YET INFESTED

This is the time to take a good look at your urban canopy and start increasing the variety of species within your community. Begin planting trees in areas not yet infested to replace the ash trees that will be removed after EAB arrives. Communicating to residents the importance of species diversity in their yards and neighborhoods is needed at this time.

GENERALLY INFESTED AREAS

There is still time in generally infested areas to start increasing the species diversity within the community. However, as infested trees are removed, homeowners will notice the drastic changes to their ash-lined boulevards and the small replacement trees will not provide the same services as did the ash trees. Replanting efforts will most likely vary year to year in generally infested areas depending on the number of infested removals needed. An effort should be made to replant if funding is available or have a replanting plan in place that can be communicated with the community.

HEAVILY INFESTED AREAS

In heavily infested areas the focus will be on tree removals and replanting efforts when funding is available. If possible, replanting should be done along with removals. Having a replanting plan that begins after all ash tree removals are completed should be communicated with the community.

BIOLOGICAL CONTROL

Biological control means managing the population of one organism (pest) by introducing another organism that will prey upon it (predator). Biological control does not completely remove the pest from the environment, but in a successful program, the predator population will suppress the pest population to a tolerable level.

Biological control of EAB was initiated in Minnesota in 2010 after three species of parasitic wasps *(Tetrastichus planipennisi, Oobius agrili and Spathius agrili)* were approved for release by the United States Department of Agriculture (USDA). An important aspect of any biological control program is the specificity of the predator for the pest, in this case the wasp specifically predating a life stage of EAB. The release of biological control organisms in the United States is closely monitored by the USDA. The approved parasitoid species were discovered in the native range of EAB by the USDA and tested extensively to insure that they will not harm other species in North America. The USDA rears these biological control agents at a specialized facility in Brighton, Michigan and provides them to states with EAB infestations for release. In 2013, releases of *Spathius agrili* were discontinued in locations north of the 40th parallel due to synchronicity issues with the EAB life cycle. In 2016, releases of *Spathius galinae* began in Minnesota and should be in-sync with the EAB life cycle as well as cold-hardy. The *Spathius* spp., along with *Tetrastichus planipennisi*, attack the larval stages of EAB below the bark surface. *Oobius agrili*, on the other hand, attacks the egg stage of EAB on the bark surface.

For a community, biological control is a good tactic to incorporate into management of natural areas such as large parks, river valleys, or other areas where sanitation and insecticide treatment are not feasible. However, biological control on its own is not going to preserve boulevard trees or even necessarily large trees in natural areas. In fact, at this time, the best chance of biological control to substantially contribute to managing EAB appears to be for the preservation of smaller trees that may make up the next cohort of large ash trees in the forest canopy.

Incorporating biological control is relatively easy at the local level as all that needs to be done at this time is contact the MDA. Thanks to support from the Environment and Natural Resources Trust Fund as recommended by the Legislative Citizen Commission on Minnesota Resources, the MDA is available to work with communities to implement EAB biocontrol. In general, these are the steps that the MDA will take in cooperation with a community to implement a biocontrol program.

1) **Assessment of EAB Infestation:** The best sites for biocontrol should be expected to have substantial EAB populations for

several years – i.e., generally infested areas. Areas where EAB is not known to be present are not eligible for biocontrol releases because the wasps are too valuable to release in areas where it is not certain that a food source is available for them. Likewise, heavily infested areas may also not be great candidates for biological control. The determining factor is how much longer the site will remain heavily infested. Emerald Ash Borer populations will decline rapidly in areas once most of the available ash trees have been killed. Sites that are close to having an EAB population crash are not good candidates for biological control as there may not be sufficient time for the biocontrol agents to become established.

For sites where EAB has been identified, the MDA will also follow these steps to determine if conditions are suitable for releases:

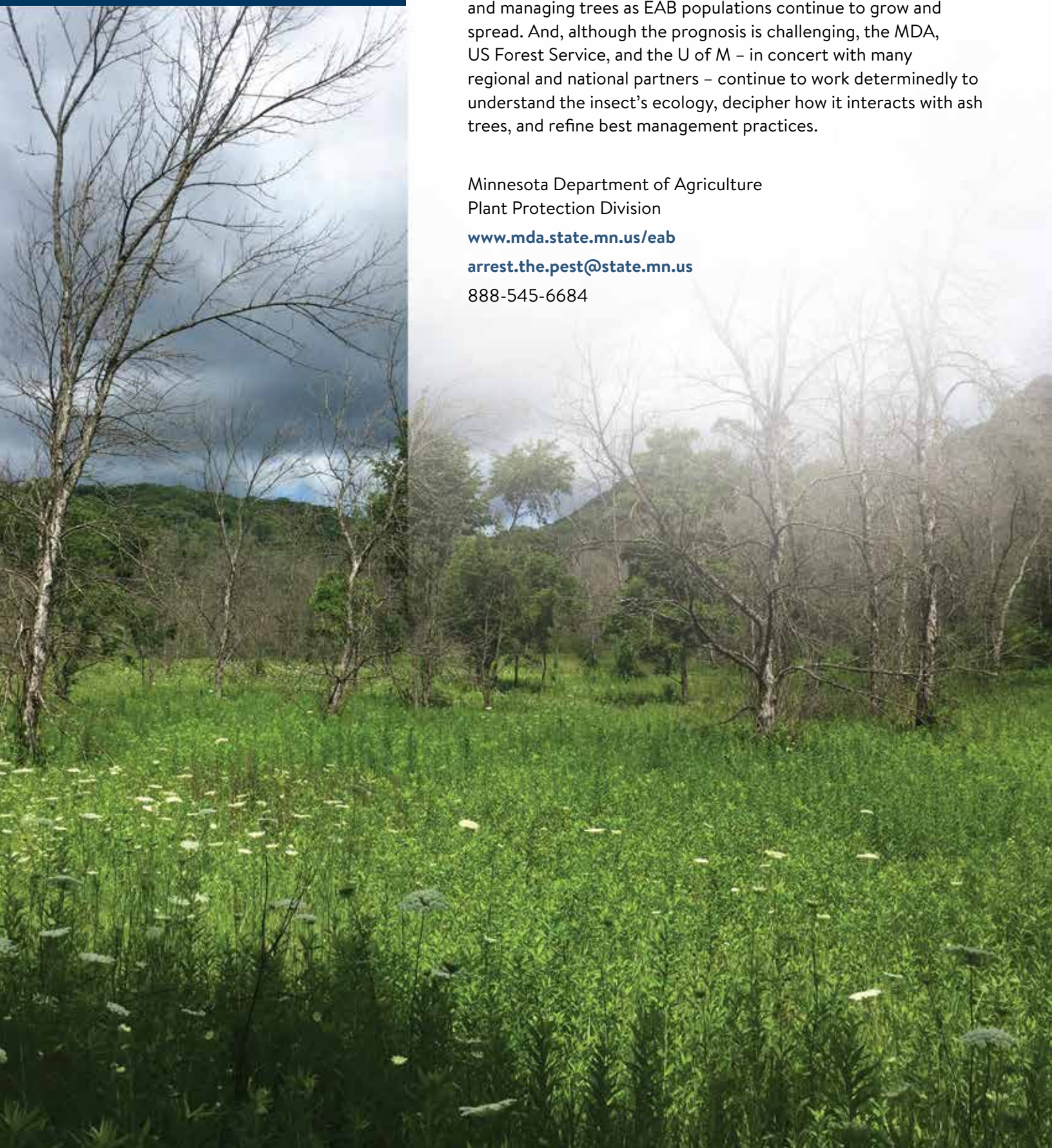
- Perform a delimit survey of the infestation to identify the perimeter where signs are visible.
- Gauge the intensity of the pest pressure in the area based on severity of EAB signs throughout the identified visibly infested area. Low to moderate EAB densities are recommended for potential sites. It is important that there are enough EAB for the parasitoids to feed on and there are enough living ash trees to sustain the populations over time.
- Identify forested areas on public or private land within the visibly infested area where removal and/or treatment of infested ash trees will not be feasible. Size and composition of the forest should be at least 40 acres and at a minimum include 20 percent ash of varying size class. Ideally, the site would be greater than 25 percent ash and connected to other woodlots.

2) **Coordination:** After a viable biological control site is identified, coordination by the MDA with local natural resource managers, property owners and the USDA EAB Parasitoid Rearing Facility are necessary. At each site, the MDA has to obtain permission, guarantee access, and ensure other management objectives won't interfere with implementation. Special permits may be necessary depending on the ownership and designation of land. Long-term site access is important for follow-up monitoring of ash health and documenting parasitoid establishment.

3) **Parasitoid Recovery:** After parasitoids have been released, it is important to recover some to confirm that populations are overwintering and reproducing. There are multiple ways the MDA recovers parasitoids from release sites including traps for the adult parasitoids, removing branches to search for parasitized EAB larvae, and scraping bark off of trunks to search for parasitized EAB eggs. After determining that parasitoid establishment has occurred at a site, a more complex question to address is the impact they are having on the EAB population. The MDA is working with the U of M using the same sampling methods over time to monitor rates of parasitism and EAB density at sites with parasitoids present to answer that question.

For more information on biological control of EAB in Minnesota, including parasitoids, release sites and recovery locations, visit MDA's biological control webpage:
www.mda.state.mn.us/plants/pestmanagement/eab/eabbiocontrol.aspx

CLOSING



North America has seen very few challenges like emerald ash borer. The insect will change the appearance of Minnesota's cities and woodlands over the next decades as ash trees begin to die. This guide provides some guidance on preparing for, detecting, and managing trees as EAB populations continue to grow and spread. And, although the prognosis is challenging, the MDA, US Forest Service, and the U of M – in concert with many regional and national partners – continue to work determinedly to understand the insect's ecology, decipher how it interacts with ash trees, and refine best management practices.

Minnesota Department of Agriculture
Plant Protection Division

www.mda.state.mn.us/eab

arrest.the.pest@state.mn.us

888-545-6684

APPENDIX 1
HOW TO CONFIRM AND REPORT EAB

To confirm that an ash tree is infested with EAB, you must have at least one of the following:

An "S"-shaped gallery visible underneath the bark of the suspect ash tree. There are many native insects that will make galleries under the bark of ash but none will be "S" shaped.

A larva pulled out from a suspect ash tree and identified as EAB. Emerald ash borer larvae look much like our other native flatheaded borers but they have characteristic urogomphi (circled below), which look like small spine-like projection at the tail end of the insect.

An adult EAB identified by the MDA (see how to report EAB). This will be a very rare occurrence. Adult insects are not commonly seen except in areas of high insect pressure.

A "D"- shaped exit hole; however, if you think you have this, you should peel back the bark of the tree and make sure you can find the "S"-shaped gallery. "D"- shaped exit holes are easily misidentified. Only peel back bark when and if the tree is on your property or you have the permission to do so.

If EAB is suspected in a new county, the MDA must have larvae or adult insects collected and submitted so that the MDA can submit the specimen to a trained USDA identifier.

If EAB is suspected in a new area (town or city) of an already quarantined county, gallery photos and/or samples of larvae, adult insects and/or photos may be submitted to the MDA for identification. This allows us to keep our online map updated and allows public access to this information.

EAB does not need to be reported to or identified by the MDA in areas that are considered heavily infested.

Visit the MDA's interactive EAB status map to view the current EAB distribution in Minnesota. **www.mda.state.mn.us/eabstatus**

REPORT

There are three main ways to report EAB to the MDA: Arrest the Pest, EDDMapsS Midwest, and the Great Lakes Early Detection Network Application (GLEDN App).

GLEDN App:

The GLEDN App is the easiest way to report EAB and other invasive species and is free for iOS and android smart phones and tablets. It is designed so that all the necessary information can be taken from the field and sent to a verifier; the MDA in the case of EAB. The app allows you to take a GPS point of the location and take a picture of the insect or insect damage to send to the MDA. Your contact information is also sent so the MDA can follow up or make a confirmation quickly.

The GLEDN App also allows you to see locations of past reports of EAB while in the field. This is a helpful tool to track EAB infestations reported within your community, as well as monitor management activities such as chemical treatments and removals.

* Note on taking pictures

Pictures should focus on definitive signs of EAB.

A picture of a standing ash tree will not give enough detail to identify EAB. Try to get a picture of an EAB insect gallery, EAB larva, adult beetle, or woodpecker damage (if taking pictures of woodpecker damage, try to get clear close-up pictures if possible)

*Reminder – If you think the signs of the tree you are reporting were caused by EAB and definitive signs are not present, please make sure to look at other ash trees in the immediate area. If EAB is present many times nearby ash trees will show signs as well.

If a clear, focused photo of signs is not possible, then detailed notes on the location and type of damage are very important.

Arrest the Pest:

You can go to the website **www.mda.state.mn.us/arrestthepest** for instructions. You can email at Arrest.the.Pest@state.mn.us or call and leave a detailed message at 888-545-6684 and a specialist will get back to you. You can also submit a sample by mail. Request a prepaid envelope and collection kit from the MDA to ensure the sample gets delivered intact and has the necessary information.

Information to submit to Arrest the Pest:

- Pictures of suspect trees: Pictures should be as detailed as possible and show individual signs rather than the whole tree. If possible, take pictures of individual woodpecks or a gallery.
- Location of suspect trees: Address or GPS coordinates. Either is acceptable. Also include details of location within property, including any landmarks or other features to help easily identify suspect pest location.
- Your contact information: The MDA will contact you if further clarification is needed.

APPENDIX 2
DETECTION METHODS

VISUAL SURVEY

When trees are lightly infested with EAB, it's unlikely there will be any visible signs of infestation on the exterior of the tree. In contrast, trees that are heavily infested with EAB are likely to display many signs of infestation including canopy thinning, damage caused by woodpecker foraging, and loose, splitting bark.

Impacts to the canopy of a tree from EAB will not be apparent until the density of larvae within the tree is relatively high with many tunnels in the stem of the tree. At this point, it may be too late to save the tree with insecticide treatments. However, other visual signs such as woodpecker foraging and loose, splitting bark can often be found well before EAB levels are high enough to impact the canopy.

EAB infestations tend to begin in branches, and as more larvae infest branches they are more likely to be discovered as a food source by foraging woodpeckers. This provides an opportunity to spot the damage left when EAB levels in a tree are still relatively light and generally limited to branches and upper stems. Likewise, loose bark splits may also form during this time, providing another sign that a tree may be infested with EAB.

While these signs are not diagnostic for EAB, there are characteristics particular to each that may increase suspicion that the damage is related to EAB.

The MDA has a "How To" video on visual survey techniques available at: **youtu.be/Bq9mZKy-3Ao**

What to look for when conducting a visual survey:
**While signs of EAB are present year round, it is best to conduct visual surveys in the late winter or early spring when leaves are absent from the trees. Woodpecker activity also increases in the early spring so there is likely to be more visual signs at this time of year.*

Woodpecker Damage

When woodpeckers forage on ash trees they generally knock some of the outer bark off of the area they are pecking, thereby exposing the lighter colored inner bark. These areas of lighter bark are noticeable from the ground and indicate areas where closer inspection is needed. However, it is good to note that black and white ash trees tend to display less contrast for the lighter colored inner bark compared to green ash trees due to the differing bark texture. This can lead to woodpecker damage being less noticeable at earlier stages in black and white ash trees.

Woodpecker damaged areas on an EAB-infested ash tree are circled in the photo below.

Woodpecks left by woodpeckers feeding on EAB larvae on ash trees.

When woodpeckers forage on EAB, they peck a dime to quarter-sized hole through the bark and to the surface of the sapwood. If these holes are not present, it is unlikely that woodpeckers are foraging on EAB or other insects beneath the bark of the tree. Sometimes trees have areas of outer bark that appear to have been knocked away by woodpeckers but there are no holes through the bark. There are a number of possible reasons why this could happen, including woodpeckers exploring trees for insects, squirrel activity, smooth bark pathogen, weather, or other unknown causes. The important point for EAB monitoring is that woodpecker foraging on EAB should leave behind light colored holes that go through the bark and to the surface of the wood.

Once it has been determined that woodpecker foraging with holes created through the bark is present, the only certain way to identify whether it is EAB is to view the tunneling left by the insect. This can be done by finding an area where enough bark has been removed already or removing some bark to enlarge the hole left by a woodpecker (see **Appendix 1 - How to Confirm and Report EAB**).

EAB larval gallery shown within a woodpeck.

*Note on Binoculars

While the light colored patches of inner bark are generally noticeable to the naked eye, determining whether or not woodpecker-created holes are present may require binoculars. Binoculars with greater magnifying power work better, but keep in mind that as viewing power increases the sensitivity of the view to movement also increases (it's hard to hold the binoculars steady enough). The MDA has had good success with binoculars offering 16 power (images magnified 16 times). The light gathering ability of binoculars is important as well, and generally the more light the better. Binoculars are generally labeled with both values, for instance, 10 x 20. This means that the binoculars will magnify images 10x and the diameter of the objective lens is 20 mm (wider lens = more light). The trade-off is that binoculars with greater power and light gathering ability will generally be bigger and heavier and more difficult to use.

Some characteristics make it apparent that the woodpeckers were foraging on native insects and not EAB. Native insects typically infest trees that are in obvious decline, or they may infest discrete areas of trees in decline such as dead branches, areas around wounds or near large pruning cuts. The occurrence of one of these factors is an indicator that the insects being predated are native insects and not EAB. Another indicator is the appearance of the holes left behind by woodpeckers. Wood in areas where native insects have been active is often stained dark in color, either from the decline of the tree or from organisms introduced by the insects. As a result, the woodpecker holes over these galleries will also appear dark. In contrast, EAB can generally be found tunneling in healthy trees and in wood that is not stained dark. As a result, woodpecker holes over EAB galleries will often appear light in color with the white wood visible through the woodpecker hole. EAB does not tunnel deeply into the wood of a tree like some native insects do, so large, deep holes in the wood can be excluded as indicators of EAB

Bark Cracks

Another early EAB visual sign in the canopy of ash trees are bark cracks. As the tree is initially attacked, the tree tries to heal around the larval gallery area and keep growing. As the branch continues to grow it forms callus tissue around the gallery and the bark will begin to crack open. When the crack becomes large enough you may be able to see the gallery with a pair of binoculars.

Ash bark cracks. The ash tree on the right also reveals an EAB larval gallery.

*Note on removing bark

Removing bark from a healthy area of a tree destroys food and possibly water conducting cells (if the outer wood is also damaged) in that area of the tree and also provides an entry point for pathogens. Areas in trees where insects have tunneled and woodpeckers have created holes through the bark have already sustained this injury and removing an additional small amount of bark will probably not add significant injury. However, bark missing from trees will attract the attention of other people who may not appreciate this argument and so you should never remove bark from a tree that you do not have authority or permission to sample in this way.

If an EAB gallery is present, bark should come off the tree relatively easy when pried up. This is due to how EAB feeds under the bark. If you are having to struggle to remove the bark, the damage is likely not caused by EAB.

The photo above shows the removal of ask bark at a woodpeck to determine if it is an EAB woodpeck.

Other Signs

There are characteristics associated with EAB in addition to woodpecker feeding damage and bark cracks, which can be seen while conducting a visual survey. While these things may in fact be present, they are not valuable indicators of EAB as they may be caused by many different things or are extremely difficult to see.

Canopy Thinning

Canopy thinning is typically a sign that occurs after woodpecker damage and bark cracks can be seen, usually around the fourth year a tree is infested. The top canopy will have a general thinning to it, not a leafless branch.

Epicormic Sprouting

Epicormic sprouting is often seen on ash trees that are stressed in general. However, sprouting within the lower canopy of the tree is often seen with EAB infestations. This is the least reliable visual sign of EAB.

"D"-shaped Exit Holes

Unless you are working in the canopy of the trees, you will not see "D"-shaped holes until much later in the infestation. There are also many native insects attacking ash trees that make oval shaped holes of similar size. Looking for "D"-shaped exit holes is not a good use of your time when conducting visual survey.

How visual survey can be beneficial to managing urban environments

Visual survey is an efficient way to detect EAB before impact to the canopy occurs. This is also the most economical method to find EAB. The MDA has observed that visual survey takes about 20 percent of the time it takes to branch sample a given area. The MDA has noted that the difference of EAB detection between branch sampling and visual survey is rather small. Branch sampling can detect EAB at a lower density when no outward signs are present; however, in most cases trees infested with EAB will have some visual signs. It is also important to note that trees in an infested area will have varying degrees of EAB density, meaning that some trees are likely be at the level where woodpeckers have begun to forage and feed on EAB. Depending on the management goals, the value of knowing where EAB is may outweigh knowing exactly how many trees are infested in that area.

Visual survey can be used as a surveillance strategy in areas where EAB is not known to be infested. Having staff trained in recognizing the signs of EAB and incorporating visual survey into other activities can result in early detections before a tree is reported due to canopy decline.

Knowing where EAB is located is essential to targeted treatments and removals of infested ash trees. The MDA has found that visual survey is the least labor intensive and most cost effective way to monitor EAB within your city. More details can be found in the **Monitoring Section**.

BRANCH SAMPLING

Branch sampling is a technique that can be used to identify EAB infestations in trees that are free from external signs - making it a more sensitive method for EAB detection. This detection method involves removing two healthy limbs from ash trees and removing the bark to look for the presence of EAB larvae or feeding galleries. While branch sampling is sensitive and capable of early detection, it is very labor intensive and the results may not justify the added labor over other methods. Branch sampling can also be used to aid in estimating the density of an EAB infestation; however, this information may not be pertinent to managing the infestation.

How branch sampling can be beneficial to urban environments

Branch sampling can be a valuable tool if finding EAB early will direct how the infestation is managed. For example, a management plan may

Branch sampling a public ash tree pictured below.

involve insecticide treatments of healthy ash in an area once EAB is discovered. Branch sampling has the potential to detect EAB before outward signs are present and before the canopy is impacted resulting in a greater number of trees where treatments are viable. It is important to note that this method works best at unknown or low levels of EAB infestations and the labor costs are not justified once EAB is moderately or highly infested in a given area.

** It is important to note that while branch sampling is the most sensitive tool available for detecting EAB, it is only 75 percent accurate. There is still a 25 percent chance that the sampling results will produce a false negative if the branches sampled happen to not contain EAB galleries even though the tree is infested.*

Branch sampling a public ash tree pictured above.

How to process a branch sample

Bark needs to be removed carefully down to the sapwood where EAB feeds. This is achieved by peeling the bark off in thin layers from the outer bark through the inner bark. The most common mistake when removing the bark from a branch sample with a draw knife is to not go deep enough to uncover the larval galleries. If the sample was recently cut, this can be distinguished by a thin layer of moisture that is present when you reach the correct depth, as well as a change in texture.

A tree can be identified as positive when an EAB gallery or larva is uncovered. Depending on one's management goals, determining the density of EAB in a sample could be important. This is done by calculating the surface area of each sample and the amount of EAB galleries present. If the goal is to simply determine if a tree is infested, peeling can stop once one gallery is found. This can save time. It is important to note that other insects can leave feeding galleries, but the serpentine "s" gallery is unique to EAB in ash trees.

Processing a branch sample. Correct depth is shown in the bottom photo.

Things to consider before implementing

- Will results lead to targeted management?
- Are the results going to be used to influence the way a specific location is managed?

If you answered no to the questions above, then branch sampling may not be worth the time and resources as it won't impact tree canopy management objectives.

Is there enough staff time available for such work? Is there storage space available for the samples? Are there potential student worker/intern resources available?

Keep in mind that sampling 50 trees will create 100 branches that will need to be peeled and documented for presence of EAB.

Estimate of labor hours needed to sample 50 trees and peel 100 branches = 50 hours

An EAB larval gallery on a branch sample.

What is the intensity level of EAB Infestation in area (not infested, generally infested, highly infested)?

If known, is it worthwhile in terms of potential management outcomes? If infestation levels are already moderate to high in the surrounding area, then the potential to positively impact management may be too late or the resources may be better used on future management rather than detection. Trees in generally infested areas will likely show outward signs of EAB and could be spotted during a visual survey using far less resources.

Define area to be sampled

To begin preparing your branch sampling plan, decide the following:

Define the geographic area being targeted for sampling:

- Entire city – EAB is not known to be in area or adjacent communities.
- High risk neighborhood(s) based on – proximity to nearby infestations, ash density, or types of businesses (areas with wood products, land clearing and firewood industry).
- High value areas – areas where ash is highly valuable to canopy coverage.
- County level – parks, campgrounds, main travel corridors, high ash density, proximity to nearby infestations, etc.

Define the intensity of sampling:

Example: Grid based approach – create a grid using ArcGIS based on the intensity of sampling to be completed. (ex: place ½ mile x ½ mile grid over entire city and choose an ash tree within each grid) Modify it until desired level of sampling is reached based on available staff resources.

Example: Block by block- sample a designated number of ash trees per city block with boulevard ash

Other Options

Spot sample ash trees while performing other work such as trimming or removals. Have employees take a closer look while doing other work in the canopy of ash trees. This can be accomplished by peeling away bark if woodpecker damage or bark splits are noticed while pruning or removing a tree. Take a picture or collect a representative sample of the damage.

Recommended characteristics when selecting trees to sample

- Open grown, semi-mature trees
- 8-20 inch DBH
- Two branches per tree from mid-crown (cut branch at the base)
- Branches are minimum of 2-3 inches diameter (4-5 inch diameter preferred)
- Branches have rough bark opposed to smooth bark
- Branches are taken from the south/southwest facing side of tree if possible (part of tree that receives the most sunlight)
- Branches are a minimum of 20 inches in length (30-40 inch lengths are best size for handling when peeling)

*Remember that the goal of branch sampling is to detect EAB, not to prune the ash tree. Take the best branches possible based on the criteria listed above not what is best for the aesthetics of the tree.

Timing of branch sampling

October 1 through April 1

*not recommended to fell, trim or sample ash trees during the summer due to risk of spreading EAB through movement of infested materials.

Tools/Equipment needed for this method

- Bucket truck/pole saw/rope saw
- Chainsaw/ hand saw
- Drawknife
- Pocket knife
- Table vice/other with ability to hold branch in place

A purple prism trap hanging in an ash tree.

PURPLE TRAPS

Trapping for EAB involves placing prism traps in the canopies of ash trees during the EAB flight season. Traps are colored and contain a lure to attract EAB. Adult EAB flying around the canopy get stuck in a sticky substance on the outer surface of the trap. The USDA's Animal and Plant Health Inspection Service (APHIS) coordinates the placement of traps in counties that are not known to be infested with EAB. These traps are useful on a state or county level but are not designed to detect EAB in a way that will help manage the insect and tree canopy.

BIOSURVEILLANCE

Smoky winged beetle bandit wasp, *Cerceris fumipennis*, is a native, stingless wasp that preys on EAB and other similar beetles. The wasp is highly effective at finding wood-boring beetles from the family Buprestidae (to which EAB belongs), and typically bring EAB to their nest once surrounding trees are generally infested. The U of M's Wasp Watchers Program is working to use this wasp to detect EAB by monitoring wasp colonies and collecting beetle prey from the wasps. Beetles are intercepted from the wasps or found near nests by volunteers during the summer months. The Wasp Watchers Program is a great tool for engaging citizen scientists in EAB awareness and monitoring the state for undetected threats similar to EAB.

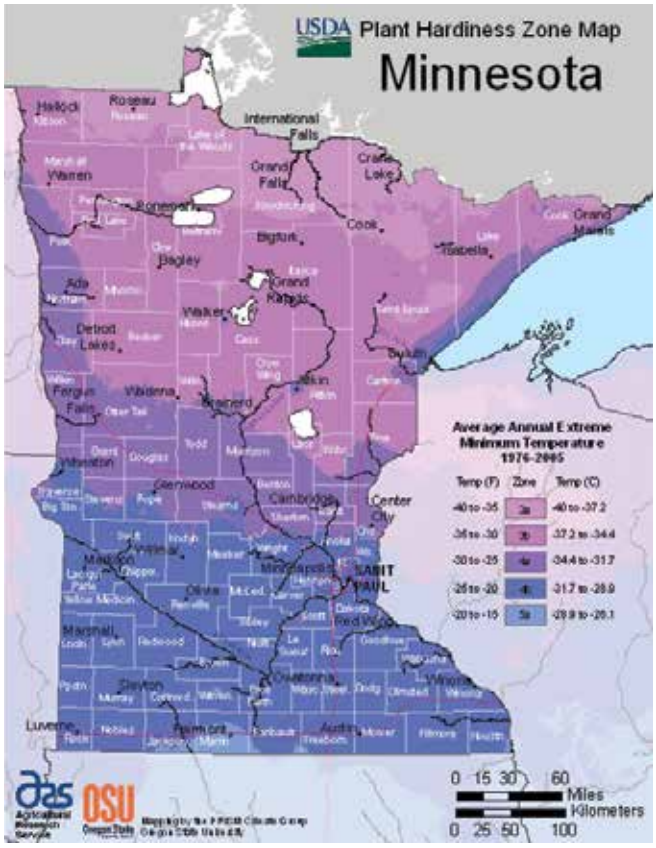
For more information on this program visit: **www.myminnesotawoods.umn.edu/eab/waspwatchers/**

Smoky winged beetle bandit wasp.

APPENDIX 3
WINTER AND EAB

The MDA, the US Forest Service, and the U of M partnered to study the winter hardiness of EAB larvae. Minnesota had a very cold "polar vortex" winter during the study period and an article was written regarding the effects on EAB titled "Cold snap is no snow day for emerald ash borer management" on January 31, 2014.

Emerald ash borer causes problems when it becomes very abundant in an area. Populations grow slowly until they reach a "tipping point" after which they can grow very rapidly – killing many trees in a short time (1-3 years). Some EAB larvae begin to freeze and die when temperatures within trees reach -20°F and that survival is very unlikely when temperatures reach below –30°F. In areas where the coldest winter temperature is generally warmer than -20°F, cold mortality is unlikely to have much or any impact on the population increase of EAB. In areas where the coldest winter temperature is generally between -20°F and -30°F, cold mortality may slow the growth of EAB numbers, but EAB should still be expected to reach tree-killing levels. In areas where the coldest winter temperature is generally colder than -30°F, cold mortality may have a major impact on population increase of EAB – perhaps to the point of constraining populations below tree-killing levels. This cannot be comfirmed right now, but research is being conducted to answer this question.



In most areas where EAB currently occurs in Minnesota, winter mortality should slow EAB population growth; but it is probably not enough to justify changing management plans. In these areas, EAB populations will likely recover and should still be expected to grow to tree-killing levels. EAB has not yet arrived (to our knowledge) in the coldest parts of the state.

The entire article can be viewed at: **www.nrs.fs.fed.us/disturbance/invasive_species/eab/control_management/cold_hardiness/bp-EAB-and-extreme-cold.pdf**