Colorado Emerald Ash Borer
First Responder Manual

Emerald Ash Borer (*Agrilus planipennis*) Adult
Photo: David Cappaert, Michigan State University, Bugwood.org

Colorado State University Extension

Colorado State Forest Service

Colorado Department of Agriculture

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Section 1

Introduction

Purpose of this Manual

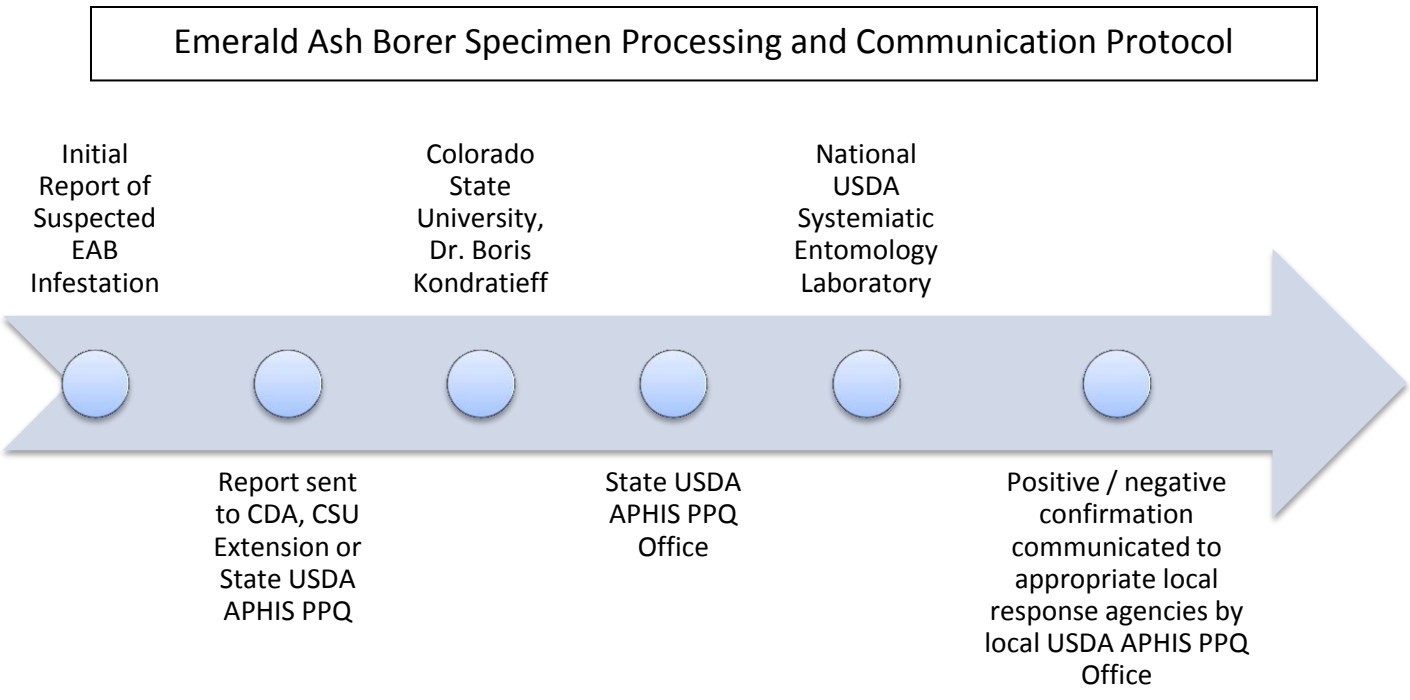
The purpose of this manual is to provide resources to those involved in Emerald Ash Borer education, outreach, detection and management efforts in Colorado. This manual is based largely on the North Dakota Forest Service *North Dakota Emerald Ash Borer First Detector Manual*, and fact sheets and other materials in this manual are used with the generous permission of several University Extension Services and other agencies.

What is a First Responder?

For the purposes of this manual, a First Responder may be anyone involved in the education, outreach, detection, and/or management of Emerald Ash Borer in Colorado, including personnel of state or local governmental agencies, Green Industry professionals, volunteers and educators.

Protocol for Obtaining a Positive Identification of Emerald Ash Borer

Submission of specimens should be made following the protocol outlined in the form titled ***Emerald Ash Borer: How to Submit Samples***. This form can be found in Appendix 2 of this manual. Positive identification of Emerald Ash Borer, *Agrilus planipennis* (Fairmaire), is ultimately determined by the USDA Systematic Entomology Laboratory following the protocol below, and cannot be made at the local level. ***Confidentiality should be maintained at all times pending the official release of findings!***



List of Commonly Used Acronyms

The following is a list of acronyms commonly used in this manual and their meaning:

APHIS: Animal and Plant Health Inspection Service
CDA: Colorado Department of Agriculture
CSU: Colorado State University
EAB: Emerald Ash Borer
NPDN: National Plant Diagnostic Network
PPQ: Plant Protection and Quarantine
USDA: United States Department of Agriculture
USDA-CSREES: United States Department of Agriculture-Cooperative State Research, Education, and Extension Service
USFS: United States Forest Service

Important Considerations for First Responders

- **Maintaining confidentiality is of primary importance.** EAB has only been found and confirmed in Boulder County. Premature and incorrect reports can occur and it is important that these situations be avoided. Experts will ID and confirm samples that have been tentatively identified as EAB as rapidly as possible.
- Being a First Responder does not give you the authority to enter private property without the property owner's permission. It is strongly recommended that the property owner accompany you whenever you enter private property.
- Being a First Responder is a voluntary activity. You will not be compensated or reimbursed for any cost associated with your voluntary visit. You may not charge for your services in the capacity as a First Responder.

Reporting Suspected Emerald Ash Borer Infestations

Contacts to Report Possible EAB Infestations			
AGENCY	**CONTACT**	**EMAIL**	**PHONE**
USDA APHIS PPQ	PPQ Officer		303-371-3355
Colorado Department of Agriculture	Cooperative Agricultural Pest Survey (CAPS) Program	CAPS.program@state.co.us	1-888-248-5535
CSU Extension	Local County Extension Office	Contact information for CSU Extension offices by county can be found at: http://www.ext.colostate.edu/cedirectory/countylist.cfm	

1. For each report that you receive, make sure to fill out an ***Emerald Ash Borer Survey Call Record/Site Visit*** form as thoroughly as possible. That form is located in the ***Materials for Reporting*** in Appendix 2 of this manual.

2. If possible, have the Reporter run through the ***Emerald Ash Borer Checklist*** found in Appendix 1 in this manual. Consider sending the Reporter a copy of fact sheet ***Does My Tree Have Emerald Ash Borer?***, which has photos of symptoms and signs of EAB. This fact sheet can be found in Section 4 of this manual.

3. Refer the caller to additional sources of information on EAB:

    - www.eabcolorado.com
    - www.emeraldashborer.info

4. Come to a conclusion about the possibility of EAB :

    a. If it is not likely EAB, make sure the Reporter has access to information and tell the individual to call again in the future if necessary.

    b. If you believe it is likely EAB refer the issue to one of the contacts listed at the beginning of this section.

    Professionals in the field must have the property owner's permission to conduct a site visit, and it is strongly recommended that the property owner accompany you whenever entering private property.*****

    Please fill out the ***Site Visit Log*** in the ***Materials for Reporting*** section of tis manual for each site visit. This can then be used to report suspected infestations to any of the agency contacts listed above.

5. **If EAB cannot be ruled out with absolute certainty**, report to one of the above-listed contacts closest to your area.

***CSU Extension Colorado Master Gardener volunteers may not, under any circumstances, make site visits. If you are a CSUE Colorado Master Gardener volunteer, report suspected EAB infestations to CSU Extension staff immediately.**

Submitting Samples

When submitting samples, follow the protocol outlined in the document ***Emerald Ash Borer: How to Submit Samples***, found in Appendix 2, ***Materials for Reporting***.

1. **Digital pictures:** If at any time sample submissions can be expedited by taking a picture (by you or the Reporter), please do so. Digital pictures should be submitted as an email attachment to one of the contacts above. If attaching pictures, please provide a good quality (not blurry) picture of:

- Insect(s), larvae, galleries or other signs of infestation;
- Specific areas of interest on the tree (wounds, exit holes, galleries, etc.);
- General tree pictures:
    - Root flare, trunk base, main stem, branches and crown, leaves;
- Also include a picture showing the overall site where the tree is growing.

2. **Insects:** If an insect is obtained that could be EAB, it should be secured in a sealable container, preferably a vial, jar or other solid container where the insect cannot be crushed. If at all possible, vials containing insect specimens should be filled with rubbing alcohol – over the counter hand sanitizer is a suitable alternative that is often readily available. **Specimen condition affects the accuracy and speed of identification.**

    - If possible, store the sample in a freezer or somewhere cool until it can be delivered to CSU.
    - Contact local CSU Extension Office to receive a **postage-paid mailer** with a small vial for submitting insect specimens.

3. **Wood or bark:** If a portion of wood or bark is obtained, the sample should be handled as if it contains live insects. If the presence of EAB cannot be ruled out, the sample should be secured so that an emerging adult cannot escape. Double-bagging with heavy plastic bags should be considered a minimum measure and, if possible, the sample should be kept in a sealed container somewhere cool until it can be delivered to or retrieved by CSU.

Caution:

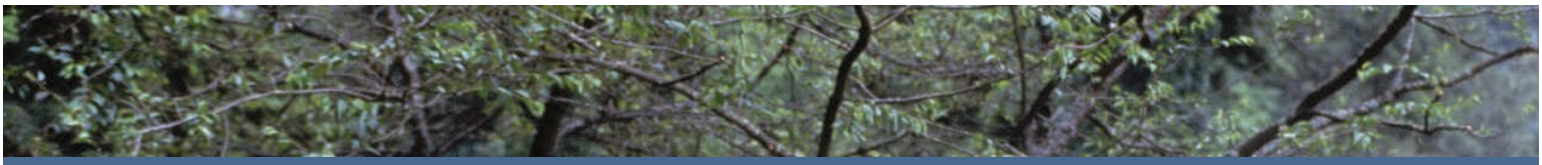
Official Confirmation of EAB requires identification of samples by USDA APHIS identifiers. Suspect samples will be rapidly sent to official identifiers for confirmation.

If EAB is confirmed the official announcement will be made by CDA and USDA APHIS. You or your agency will be informed as soon as possible.

Please do not make premature and unofficial announcements or start any rumor mills.

Section 2

Ash Tree Identification



Extension Bulletin E-2942 New, May 2005

Ash Tree Identification

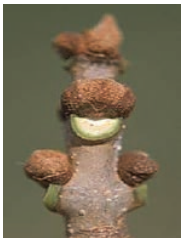
Ash species attacked by emerald ash borer include green (*Fraxinus pennsylvanica*), white (*F. americana*), black (*F. nigra*), and blue (*F. quadrangulata*), as well as horticultural cultivars of these species. Green and white ash are the most commonly found ash species in the Midwest with blue ash being rare.

While other woody plants, such as mountainash and pricklyash, have "ash" in their name, they are not true ash, or *Fraxinus* species. Only true ash are susceptible to attack by emerald ash borer.

To properly identify ash trees, use the following criteria:

Branch and Bud Arrangement

Branches and buds are directly across from each other and not staggered. When looking for opposite branching in trees, please consider that buds or limbs may die; hence not every single branch will have an opposite mate.



Diane Brown-Rytlewski

Leaves

Leaves are compound and composed of 5-11 leaflets. Leaflet margins may be smooth or toothed. The only other oppositely branched tree with compound leaves is boxelder (*Acer negundo*), which almost always has three to five leaflets. White ash (on left) and green ash (on right)

*Paul Wray, Iowa State University

Bark

On mature trees (left), the bark is tight with a distinct pattern of diamond-shaped ridges. On young trees (right), bark is relatively smooth.

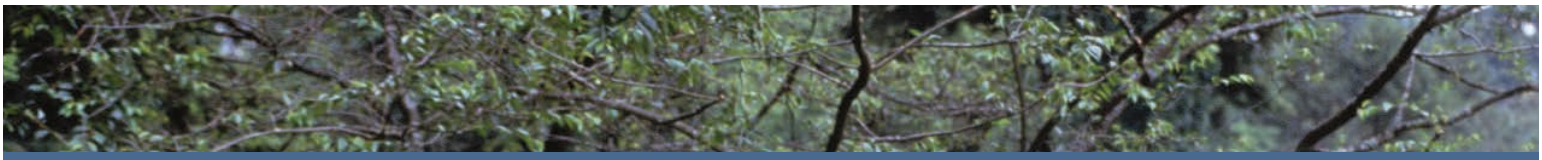
*Paul Wray, Iowa State University

Seeds

When present on trees, seeds are dry, oar-shaped samaras. They usually occur in clusters and typically hang on the tree until late fall, early winter.

MICHIGAN STATE UNIVERSITY EXTENSION

Emerald Ash Borer

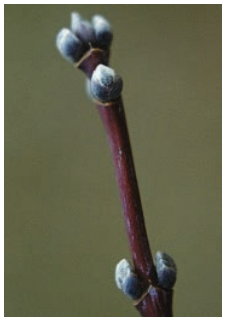


Tree Species Resembling Ash

Boxelder *(Acer negundo)*

Exhibits opposite branching and compound leaves. However, has 3 to 5 leaflets (instead of 5 to 11) and the samaras are always in pairs instead of single like the ash.

*Paul Wray, Iowa State University



*Bill Cook, Michigan State University

European Mountainash *(Sorbus aucuparia)*

Leaves are compound with alternate (staggered) branching. Tree bears clusters of creamy white flowers in May. Fruits are fleshy, red-orange berries.

Diane Brown-Rytlewski

*Boris Hrasovec, University of Zagreb

Shagbark Hickory *(Carya ovata)*

Leaves are compound with 5 to 7 leaflets, but the plant has an alternate branching habit. Fruit are hard-shelled nuts in a green husk.

*Paul Wray, Iowa State University

*Paul Wray, Iowa State University

Elm *(Ulmus species)*

Branching is alternate and the leaves are simple with an unequal leaf base.

*Paul Wray, Iowa State University

*Paul Wray, Iowa State University

*Paul Wray, Iowa State University

Black Walnut *(Juglans nigra)*

Leaves are compound with 9 to 15 leaflets, but the plant has an alternate branching habit. Fruit is a large dark brown nut inside a green husk.

*Paul Wray, Iowa State University

Authors: Kimberly Rebek and Mary Wilson

*www.forestryimages.org

New - 5:05 - 6,250 - KMF/LB

Does My Tree Have Emerald Ash Borer (EAB)?

I suspect I have seen EAB.

Emerald Ash Borer

Japanese Beetle

Bronze Birch Borer

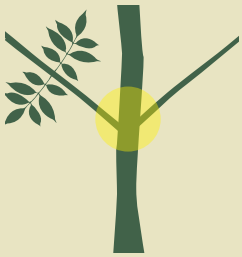
Two-lined Chestnut Borer

YES

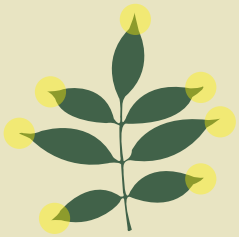
I think my ash tree may be infested with EAB.

YES

Is my tree an ash?


Opposite Branching


Compound Leaves


5 to Many Leaflets

YES NO

Does my tree have symptoms of EAB?

Woodpecker Holes

Bark Cracks

S-Shaped Galleries

YES NO

It could be EAB.

Call the Colorado Department of Agriculture at (888) 248-5535

It isn't EAB; so what is it?

Find out at:
www.ext.colostate.edu

COLORADO DEPARTMENT OF AGRICULTURE

Colorado Department of Agriculture - Division of Plant Industry
700 Kipling Street
Lakewood, Colorado 80215
(303) 239-4100

What's In That Wood Pile?

Identifying 3 groups of trees found in Minnesota wood piles

By Gary Johnson and Rebecca Koetter - University of Minnesota, Department of Forest Resources - 2007

Overview

Photo: Joseph O'Brien , USDA Forest Service

Figure 1: Oak tree infected with oak wilt

Firewood identification and quarantine has been one of the important tactics for managing oak wilt (OW) (Figure 1) and Dutch elm disease (DED) (Figure 2) in the Upper Midwest. Both of these fungal diseases can spread from standing dead and dying trees to healthy trees by insect vectors that are attracted to healthy trees, or fresh pruning wounds in the case of oak wilt. Firewood from these trees may harbor insect vectors (DED) and promote conditions for production of fungal disease spores, which then may attract insect vectors to the fungus (OW). Thus, proper disposal or treatment of firewood from such diseased trees is extremely important.

Photo: Dave Hanson, U of MN/Dept. of Forest Resources

Figure 2: Elm tree infected with Dutch Elm Disease

A relatively new devastating pest has been killing both urban and rural trees - the emerald ash borer (EAB) (Figure 3). All species of ash in the *Fraxinus* genus (green, black, white) are susceptible to this aggressive insect and once again, monitoring the movement and storage of firewood is critical to a complete management program. The main way the insect is spreading across the Upper Midwest is through transportation of ash firewood from trees that were killed by the insect and still harbor the borer. States currently affected by EAB include Michigan, Illinois, Indiana, Ohio, Maryland and Ontario, Canada.

Photo: Penn. Dept. of Conservation & Natural Resources

Figure 3: Epicormic sprouting that occurs ~2 years after EAB infestation.

Elm (*Ulmus* species), oak (*Quercus* species), and ash (*Fraxinus* species) have unique wood grain and bark characteristics. Often it is combination of these characteristics that distinguish the exact species, and sometimes even odors and colors help. Very often, firewood piles have wood from both mature tree trunks as well as smaller, younger branches. The bark from tree trunks and tree branches of the same species look very different, so firewood identification from bark samples alone can be difficult and confusing.

When bark is not enough to identify a piece of firewood, a close examination of the end grain is necessary. A sharp knife or a single-blade razor, a 10x hand lens, and a liquid that will enhance the end grain all help the process. Shellac or boiled linseed oil are very effective end grain enhancers. Simply spray or brush the liquid on and the wood features (pores, rays, rings) become much more obvious. Even water works for a short time.

~~~~~~~Please note that seemingly different trees are referred to as groups throughout this fact sheet. Trees within these groups often have similarities among bark, wood, and leaves.~~~~~~~

Identifying Firewood: Types of End Grain

There are three types of end grain used to identify firewood: ring porous, diffuse porous, and semi-ring porous. Of these three types only one type- **ring porous**- is characteristic of firewood that may house a harmful disease or insect in Minnesota. All species in the elm group, oak group and ash group have ring porous wood. Identification by end grain type may be difficult but with enough practice you will be able to distinguish ring porous wood from diffuse and semi-ring porous firewood.
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Identifying Firewood: Types of End Grain *continued*.

Ring Porous. Within an annual growth ring there will be two regions– *springwood* (distinctly larger pores) and *summerwood* (distinctly smaller pores).

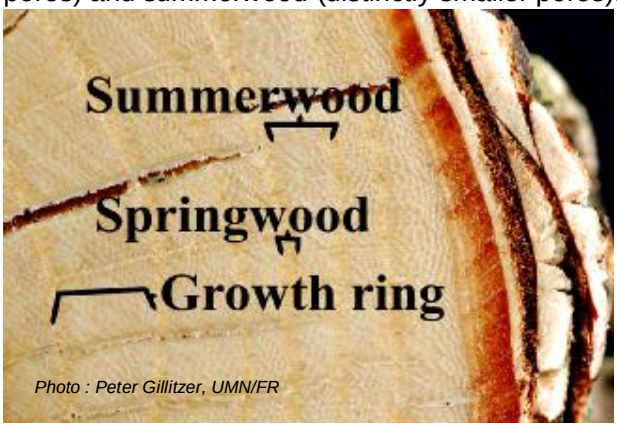

Figure 4: Group examples- oak, elm (including hackberry), and ash

Diffuse Porous. Within an annual growth ring, *springwood* and *summerwood* are not distinctly different. Wood within an annual ring looks uniform.

Figure 5: Group examples- maple (including boxelder), birch, some poplars, basswood (a.k.a. linden), ironwood, buckeye, and black cherry

Elm group (including hackberry)

Figure 6: Summerwood is wavy. Bark resembles bacon strips.

Figure 7: Leaves of elm group (including hackberry) have an oblique base.

Note: Split sections of American and rock elm can have stringy, long grain wood (Figure 8).

Photo: Gary Johnson, UMN/FR

Figure 8: Stringy firewood characteristic of some elm species.

End grain– ring porous: *Summerwood*: small pores arranged in a wavy "tire track" pattern (Figure 6). *Sapwood*: white to tan colored. *Heartwood*: brown to reddish brown.

Bark: Cross-sections of American elm (*Ulmus americana*) and rock elm (*Ulmus thomasii*) bark have alternating bands of dark and light colored tissue that gives the appearance of “bacon strips” (Figure 6). Slippery elm (*Ulmus rubra*) does not have “bacon strip” bark.

Exception: Hackberry, another member of the elm group, also has summerwood pores arranged in a wavy “tire track” pattern. However, it is not susceptible to DED. Also, its bark is characteristically corky and rough (Figure 9).

Photo: Dave Hanson, UMN/FR

Figure 9: Corky hackberry bark.

Oak group

Oak wilt affects all species of oak in Minnesota including the **red oak group** (Figure 10)- Northern red oak (*Quercus rubra*), Northern pin oak (*Q.* ellipsoidalis), Eastern pin oak (*Q. palustris*), and black oak (*Q. velutina*) and the **white oak group** (Figure 11)- white oak (*Quercus alba*), bur oak (*Q. macrocarpa*), and swamp white oak (*Q. bicolor*). Red oak group identification is most important because it is so susceptible to oak wilt and is the firewood most likely to have spore mats under the bark. Firewood from red oaks killed by oak wilt that have bark attached should be completely enclosed with black plastic for 12 months after tree death or until bark sloughs off.

Leaves: Red oak group

Photo: Dave Hanson, UMN/FR

Figure 10: Species of red oaks have pointed leaf margins.

Leaves: White oak group

Photo: Dave Hanson, UMN/FR

Figure 11: Species of white oaks have rounded leaf margins.

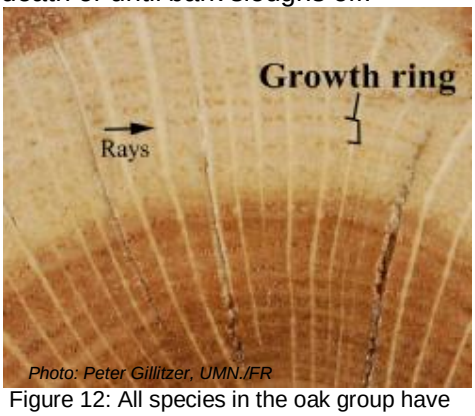

Photo: Peter Gillitzer, UMN./FR

Figure 12: All species in the oak group have rays visible to the unaided eye. The growth ring includes one season of springwood and one of summerwood.

Sodium Nitrite ($NaNO_2$) Test:

Applying a 10% solution of sodium nitrite to the heartwood makes the natural light brown color of the red oak group heartwood only slightly darker (Figure 13). However, it turns the white oak group heartwood yellow-orange, then red-brown, and then dark green or purple to black (Figure 14).

Photo: Rebecca Koetter, UMN/FR

Figure 13: Red oak sprayed with $NaNO_2$. Notice that wood color does not significantly change, not even with time lapse.

Photo: Rebecca Koetter, UMN/FR

Figure 14: White oak sprayed with $NaNO_2$. Left: color change within seconds of application. Right: color change within minutes of application.

End grain– ring porous:

Large wood rays are clearly visible to the naked eye. Within an annual growth ring, *springwood* has distinctly larger pores versus the smaller pores of *summerwood* (Figure 12).

Notes: Freshly cut or split red oak has a very distinct odor– sweet or rancid. *Heartwood* of red oak is light reddish brown versus the light to dark brown *heartwood* of white oak.

Photo: Dave Hanson, UMN./FR

Figure 15: Mature bark of red oak (*Q. rubra*)

Bark: Red oak group- The smaller diameter pieces of wood have flat, gray, and smooth bark. Larger diameter pieces have ridged and furrowed bark (Figure 15).

Bark: White oak group- Bark ranges from gray and platy (*Q. alba*) to deeply ridged and furrowed (*Q. macrocarpa*) (Figure 16).

Photo: Dave Hanson, UMN/FR

Figure 16: Mature bark of bur oak (*Q. macrocarpa)*

Ash group

End grain– ring porous: Within an annual growth ring, s*pring-wood* has large obvious pores with an abrupt transition to *summerwood* that has very small pores (Figure 17).

Photo: Dave Hanson, UMN/FR

Figure 18: Mature bark of green ash

Bark: deeply furrowed, narrow ridges that are diamond to canoe shaped; ash gray to ash brown (Figure 18).

Notes: Unlike the oak group, large visible rays are absent to the naked eye.

Photo: Peter Gillitzer, UMN/FR

Figure 17: Cross-section of green ash. Notice no obvious wood rays are present.

Glossary

Diffuse porous- all pores are of similar size and can be found evenly distributed throughout the growth rings.

Growth ring- contains two layers (springwood and summerwood) of cells resulting from one year of growth.

Heartwood- nonliving and commonly dark-colored wood in which no water transport occurs; it is surrounded by sapwood.

Ring porous- pore sizes found in springwood and summerwood are very different, forming conspicuous bands.

Sapwood- outer part of the wood of stem or trunk, usually distinguished from the heartwood by its lighter color. Water transport takes place in sapwood.

Springwood- large cells formed when the tree is rapidly growing and are usually visible without a hand lens.

Summerwood- small to tiny cells formed during slower growth period of summer; not usually visible without a hand lens.

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Technical Advisors: Harlan Petersen, Extension Specialist and Assistant Professor, University Of Minnesota. Jennifer Juzwik– Northern Research Station, USDA Forest Service. Minnesota Shade Tree Advisory Committee Information Transfer subcommittee.

For more information on oak wilt, Dutch elm disease, emerald ash borer and firewood identification visit: http://fr.cfans.umn.edu/extension. Search under Tree Health tab for Management Options and Urban Forestry tab for Firewood Identification.

Section 3

Emerald Ash Borer Information: Background, Symptoms and Signs

Pest Alert

United States
Department of Agriculture
Forest Service
Northeastern Area
State and Private Forestry
NA-PR-02-04
Revised September 2008

Emerald Ash Borer

A beetle from Asia, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), was identified in July 2002 as the cause of widespread ash (*Fraxinus* spp.) tree decline and mortality in southeastern Michigan and Windsor, Ontario, Canada. Larval feeding in the tissue between the bark and sapwood disrupts transport of nutrients and water in a tree, eventually causing branches and the entire tree to die. Tens of millions of ash trees in forest, rural, and urban areas have already been killed or are heavily infested by this pest.

A. planipennis has been found throughout Michigan, across much of Ohio, and in parts of Indiana, Illinois, Maryland, Missouri, Pennsylvania, Virginia, West Virginia and Wisconsin. Infestations have also been found in more areas of Ontario and in the province of Quebec. The insect is likely to be found in additional areas as detection surveys continue. Evidence suggests that *A. planipennis* is generally established in an area for several years before it is detected.

The broad distribution of this pest in the United States and Canada is primarily due to people inadvertently transporting infested ash nursery stock, unprocessed logs, firewood, and other ash commodities. Federal and state quarantines in infested states now regulate transport of these products.

Identification

Adult beetles are generally larger and brighter green (Fig. 1) than the native North American *Agrilus* species. Adults are slender, elongate, and 7.5 to 13.5 mm long. Males are smaller than females and have fine hairs, which the females lack, on the ventral side of the thorax. Adults are usually bronze, golden, or reddish green overall, with darker, metallic emerald green wing covers. The dorsal side of the abdomen is metallic purplish red and can be seen when the wings are spread (Fig. 2). The prothorax, the segment behind the head and to which the first pair of legs is attached, is slightly wider than the head and the same width as the base of the wing covers.

Figure 1. Adult emerald ash borer.

Larvae reach a length of 26 to 32 mm, are white to cream-colored, and dorso-ventrally flattened (Fig. 3). The brown head is mostly retracted into the prothorax, and only the mouthparts are visible. The abdomen has 10 segments, and the last segment has a pair of brown, pincer-like appendages.

Figure 2. Purplish red abdomen on adult beetle.

Biology

A. planipennis generally has a 1-year life cycle. In the upper Midwest, adult beetles begin emerging in May or early June. Beetle activity peaks between mid June and early July, and continues into August. Beetles probably live for about 3 weeks, although some have survived for more than 6 weeks in the laboratory. Beetles generally are most active during the day, particularly when it is warm and sunny. Most beetles appear to remain in protected locations in bark crevices or on foliage during rain or high winds.

Throughout their lives beetles feed on ash foliage, usually leaving small, irregularly shaped patches along the leaf margins. At least a few days of feeding are needed before beetles mate, and an additional 1 to 2 weeks of feeding may be needed before females begin laying eggs. Females can mate multiple times. Each female probably lays 30-60 eggs during an average lifespan, but a long-lived female may lay more than 200 eggs. Eggs are deposited individually in bark crevices or under bark flaps on the trunk or branches, and soon darken to a reddish brown. Eggs hatch in 7 to 10 days.

Figure 3. Second, third, and fourth stage larvae.

After hatching, first instar larvae chew through the bark and into the phloem and cambial region. Larvae feed on phloem for several weeks, creating serpentine (S-shaped) galleries packed with fine sawdust-like frass. As a larva grows, its gallery becomes progressively wider (Fig. 4). Beetle galleries often etch the outer sapwood. The length of the gallery generally ranges from 10 to 50 cm. Feeding is usually completed in autumn.

Prepupal larvae overwinter in shallow chambers, roughly 1 cm deep, excavated in the outer sapwood or in the bark on thick-barked trees. Pupation begins in

Figure 4. Gallery of an emerald ash borer larva.

Figure 5. D-shaped hole where an adult beetle emerged.

Figure 6. Jagged holes left by woodpeckers feeding on larvae.

Figure 7. Ash tree killed by emerald ash borer. Note the serpentine galleries.

Figure 8. Epicormic branching on a heavily infested ash tree.

late April or May. Newly eclosed adults often remain in the pupal chamber or bark for 1 to 2 weeks before emerging head-first through a D-shaped exit hole that is 3 to 4 mm in diameter (Fig. 5).

Studies in Michigan indicate 2 years may be required for *A. planipennis* to develop in newly infested ash trees that are relatively healthy. In these trees, many *A. planipennis* overwinter as early instars, feed a second summer, overwinter as prepupae, and emerge the following summer. In trees stressed by physical injury, high *A. planipennis* densities, or other problems, all or nearly all larvae develop in a single year. Whether a 2-year life cycle will occur in warmer southern states is not yet known.

Distribution and Hosts

A. planipennis is native to Asia and is found in China and Korea. It is also reported in Japan, Mongolia, the Russian Far East, and Taiwan. In China, high populations of *A. planipennis* occur primarily in *Fraxinus chinensis* and *F. rhynchophylla*, usually when those trees are stressed by drought or injury. Other Asian hosts (*F. mandshurica* var. *japonica*, *Ulmus davidiana* var. *japonica, Juglans mandshurica* var. *sieboldiana,* and *Pterocarya rhoifolia)* may be colonized by this or a related species.

In North America *A. planipennis* has attacked only ash trees. Host preference of *A. planipennis* or resistance among North American ash species may vary. Green ash (*F. pennsylvanica*) and black ash (*F. nigra*), for example, appear to be highly preferred, while white ash (*F. americana*) and blue ash (*F. quadrangulata*) are less preferred. At this time all species and varieties of native ash in North America appear to be at risk from this pest.

Signs and Symptoms

It is difficult to detect *A. planipennis* in newly infested trees because they exhibit few, if any, external symptoms. Jagged holes excavated by woodpeckers feeding on late instar or prepupal larvae may be the first sign that a tree is infested (Fig. 6). D-shaped exit holes left by emerging adult beetles may be seen on branches or the trunk, especially on trees with smooth bark (Fig 5). Bark may split vertically over larval feeding galleries. When the bark is removed from infested trees, the distinct, frass-filled larval galleries that etch the outer sapwood and phloem are readily visible (Fig. 4 and Fig. 7). An elliptical area of discolored sapwood, usually a result of secondary infection by fungal pathogens, sometimes surrounds galleries.

As *A. planipennis* densities build, foliage wilts, branches die, and the tree canopy becomes increasingly thin. Many trees appear to lose about 30 to 50 percent of the canopy after only a few years of infestation. Trees may die after 3 to 4 years of heavy infestation (Fig. 7). Epicormic shoots may arise on the trunk or branches of the tree (Fig. 8), often at the margin of live and dead tissue. Dense root sprouting sometimes occurs after trees die.

A. planipennis larvae have developed in branches and trunks ranging from 2.5 cm (1 inch) to 140 cm (55 inches) in diameter. Although stressed trees are initially more attractive to *A. planipennis* than healthy trees are, in many areas all or nearly all ash trees greater than 3 cm in diameter have been attacked.

Resources

For more information on the emerald ash borer and related topics...

- Visit the following Web sites:
  - Multi-agency Emerald Ash Borer Web Site: www.emeraldashborer.info
  - USDA Forest Service: www.na.fs.fed.us/fhp/eab/
  - USDA Animal and Plant Health Inspection Service: www.aphis.usda.gov/plant_health/
- Contact your state Department of Agriculture, State Forester, or Cooperative Extension Office.

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Questions and Answers about the Emerald Ash Borer in Colorado

What is the emerald ash borer? The emerald ash borer is a type of beetle that develops under the bark of ash trees. Its scientific name is *Agrilus planipennis*. It is a type of beetle in the family Buprestidae, which are known as metallic wood borers in their adult form and flatheaded borers in the immature stage.

Where did the emerald ash borer come from? The natural range of the emerald ash borer is eastern Russia, northern China, Japan, and Korea. Before June of 2002, it had never been found in North America.

How did it get here? We don't know for sure, but it most likely came in ash wood used for stabilizing cargo in ships or for packing or crating heavy consumer products (Solid Wood Packaging Materials).

What types of trees does the emerald ash borer attack? In North America, it has only been found in ash trees (*Fraxinus* species). Trees in woodlots as well as landscaped areas are affected. Larval galleries have been found in trees or branches measuring as little as 1/2-inch in diameter. All species of North American ash appear to be susceptible.

Ash commonly grown in Colorado include green ash (*Fraxinus pennsylvanicus*) and white ash (*F. americana*). Both are highly susceptible to emerald ash borer.

Is mountain-ash susceptible to emerald ash borer? No. Despite the name, mountain-ash (*Sorbus* species) are very different types of plants and are not attacked by emerald ash borer.

What do emerald ash borers look like? The adult beetle is dark metallic green in color, 1/2 inch-long and 1/8 inch wide. The larvae, which are found under the bark, are a type of flatheaded borer which is pale-colored, has an elongate body, and a slightly flattened area behind the head.

There are numerous sites where one can find excellent images of emerald ash borer. Several are accessed through the national emerald ash borer information web site: http://www.emeraldashborer.info (To find the publications on EAB identification go to the link "About EAB" and then view the site "How to Identify EAB".) A great many images of this insect, which can be downloaded and used for educational purposes, are available through IPMImages.org (aka BugWood.org): http://www.ipmimages.org/search/action.cfm?q=emerald%20ash%20borer Photos of EAB taken in Colorado can be viewed at the EAB Photo Gallery site established by the Colorado Department of Agriculture: http://www.colorado.gov/cs/Satellite/ag_Plants/CBON/1251646275463

Are there other insects that are similar in appearance to emerald ash borer? There are several beetles native to Colorado that one may mistake for emerald ash borer. Also, there are some other types of insects that tunnel in ash trees. One source to help identify these "EAB lookalikes" can be found at: http://bspm.agsci.colostate.edu/files/2013/03/Emerald-Ash-Borer.pdf

I have treated my ash trees in the past for borers. Wasn't this for the emerald ash borer? There are several insects that are native to North America, long present in Colorado, and that tunnel into trunks and limbs of ash. Most commonly encountered is the **lilac/ash borer** (*Podosesia syringae*) a type of wood boring caterpillar that usually tunnels into the lower trunk of the tree. Various **ash bark beetles** (*Hylesinus* species) are fairly common in branches, particularly those that are damaged or overshaded. Some other insects that may be found occasionally tunneling limbs of ash include the **flatheaded appletree borer** (*Chrysobothris femorata*) and **redheaded ash borer** (*Neoclytus acuminatus*).

These are all insects that are normal residents of ash trees. Most cause very little damage and may only be found in trees or limbs that are suffering from serious stress or injury. Of these native, wood boring insects of ash, the lilac/ash borer is potentially the most injurious. However, the damage potential of the emerald ash borer far exceeds any of these other insects.

Why should I try to control emerald ash borer? Emerald ash borer (EAB) is an extremely destructive insect of ash trees (*Fraxinus* species), including the kinds of ash (green ash, white ash) that are widely planted in Colorado. It is far more damaging to trees than any other insect that previously has been found in the state and, as populations of the insect increase in the infested areas, it very likely will kill any unprotected ash trees within a few years.

Emerald ash borer is a species native to parts of eastern Asia that was accidentally introduced into North America, probably sometime in the 1990s. It is not a very damaging insect in its native land, where the ash species that grow there have evolved resistance to it and natural controls limit its injury.

Unfortunately the species of ash that are native to North America have very little resistance to this new pest and emerald ash borer is devastating to the kinds of ash trees grown in the state. In the Midwest and eastern areas of North America where this insect has been present for several years, EAB has already killed many millions of ash trees. It is expected that emerald ash borer will ultimately kill almost every unprotected ash tree presently growing in North America.

Mountain pine beetle kills enormous numbers of trees in Colorado. How does this compare with emerald ash borer damage? Other than both can kill large numbers of their host trees, these involve different situations.

Mountain pine beetle is a native insect of the pine forests of western North America. Periodically it occurs in outbreaks that cause massive die-offs of their host plants (mostly lodgepole and ponderosa pine). Over the past decade much of the state has experienced a very damaging outbreak and 25-30 years before that there was also a serious outbreak. These are natural events, sometimes abetted a bit by human activities, but they always end at some point with surviving trees that will allow regeneration of the forest over time.

The emerald ash borer is not a native insect to North America. It is a new organism to the continent and its host trees (ash) are extremely susceptible to its damaging effects. Where it becomes established it not only can be expected to kill essentially all of its hosts but it will do it forever as long as susceptible species of ash are present.

The invasion of the emerald ash borer is an ecological disaster that is unprecedented. Never before has there been a newly introduced insect that will so permanently destroy and irreversibly alter an important component of the North American forests. Its potential effects on forest ecology are only rivalled by such previous ecological disasters as the introduction of the chestnut blight fungus (which functionally exterminated the American chestnut in the early 1900s) and the smaller European elm bark beetle and fungus that produces Dutch elm disease (which has largely eliminated American elm since its introduction in the 1930s).

How fast does emerald ash borer kill ash trees? Emerald ash borer damages trees by tunneling areas under the bark, producing girdling wounds that interfere with movement of water and nutrients. The damage is progressive, with more effects of infestation becoming visible as increasing numbers of insects develop within and damage the plant.

When emerald ash borer first arrives and becomes established in a neighborhood it is usually present in low numbers and is very difficult to detect. However, they survive and reproduce well so that populations build steadily and within a few years it may be possible to observe some external evidence of infestation. A thinning of the leaf canopy is the most consistent symptom associated with EAB injury.

Often, about the time symptoms first become noticeable the populations of EAB explode in numbers and damage accelerates greatly. During this period of peak outbreak even trees that previously appeared healthy may die within just a couple of years.

Where is emerald ash borer found in North America? Emerald ash borer was originally detected in southern Michigan in 2002, but is thought to have been present in the area a decade before this detection. It has since spread rapidly and, by the end of 2013, has been found to be established in 22 states and two provinces. Colorado is the most recent state where this insect has been detected, being found in Boulder in September 2013. It is also the first state in the western US where EAB has been detected. Maps of the present distribution of the insect within North America can be accessed through the national emerald ash borer web site at:
http://www.emeraldashborer.info/map.cfm#sthash.hWvMiNj5.dpbs

At present (winter 2014) Boulder is the only place within Colorado where EAB has been detected. However, the insect will spread in the upcoming years and it is reasonable to expect that essentially all of northeastern Colorado will be infested within a decade.

Also, with greater attention being given to this insect following the Boulder detection, it is now much more likely that any other infestations in the state, if any, may be identified. Any needed updates on the distribution of emerald ash borer in Colorado will be made available through several outlets, including the Colorado Department of Agriculture site at www.eabcolorado.com

Now that emerald ash borer has been found in a part of the state, can we eradicate it? Unfortunately, there is no chance that emerald ash borer can be eradicated once it has become established.

In the first few years after it had been detected in Michigan, several efforts were made to attempt eradication of emerald ash borer. Efforts were also made in other states (e.g., Maryland) when first detections were made and infestations were limited. These eradication efforts typically involved removal of all ash trees over a wide area (1/2-1 mile diameter) of known infestations and widescale use of insecticides on ash trees in areas within the vicinity. Very large sums of money were expended in these efforts. None were successful.

A fundamental problem hampering eradication is the inability to detect emerald ash borer when it is in low populations. Whereever EAB is known to occur, at least a small number of beetles can be expected to have dispersed beyond the area where they establish and continue the infestation.

How does emerald ash borer spread? The adult beetle can fly and that is how it spreads naturally. Normally they will fly only short distances, staying in the near vicinity of the tree from which they developed. However, some will fly longer distances and, with the aid of favorable winds, it is possible that a few may fly several miles if the right conditions come together. This natural spread will cause the present outbreak of EAB to expand beyond Boulder in the next few years to progressively encompass the areas of the state within the South Platte Drainage. This includes the greater Denver Metro area, Fort Collins, Greeley and all the communities further down river.

However, emerald ash borer can also be spread if it is carried by humans. Transport of firewood or other ash materials harboring live emerald ash borers is the way that this insect is carried over long distances. This is undoubtedly the means by which it carried across the eastern plains and was introduced into Boulder, an event which seems to have occurred at least four years prior to its detection.

Geographic barriers present in Colorado, notably mountains and large expanses of ash-free forest, can be expected to prevent natural spread of EAB to much of Colorado outside the South Platte drainage. However, the entire state will always be at risk of the insect being introduced on infested firewood or other material containing live EAB that originated from some area where this insect is present. National quarantines of infested counties (including Boulder County in Colorado) are in place to try and prevent this type of human-assisted spread of EAB.

Will altitude restrict where emerald ash borer can become established? Altitude should have no direct effect on whether emerald ash borer can survive. As long as there host trees (ash) emerald ash borer should be able to survive.

Indirectly, there may be some effects of higher elevations that may act to affect EAB. Often temperatures are cooler at higher elevations. Cooler temperature will slow development of the insect and slow development of the ash trees.

Will cold temperatures kill emerald ash borer in Colorado? On rare occasions it may be cold enough to kill some insects, but never will all be killed. Furthermore the types of winter temperatures required to kill any emerald ash borers is very low. During winter the larvae within trees may be killed if they can be exposed to temperatures of -13^0F or below. However, it would take a cold period sustained for days to

produce temperatures that would reach this point within the tree where the insect is developing. One study on this subject can be seen at:
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5191794.pdf

Extreme winter temperatures that occur in some areas of the state (e.g., San Luis Valley) may suppress the effects of EAB, if it ever reaches these areas. But extreme winter temperatures are unlikely to significantly affect EAB in most all of Colorado.

However, it is possible that EAB may be affected by cold temperatures occurring at other times of the year. Warm spells in late winter and spring, followed by abrupt freezing events, are not uncommon in the state. When this occurs the first flush of ash leaves can be frozen, which would eliminate the food needed by the newly emerged adults. It is also likely that the pupae and adults present in spring may be more susceptible to freezing. For example, there are some indications that the extreme cold temperatures that occurred in early May 2013 (ca 8^0-15^0F) may have killed many of the adults that were preparing to emerge from trees at that time.

What is the life history of the emerald ash borer? Emerald ash borer has a life cycle that normally takes one year to complete. During winter the life stage present is a full grown larva (a type of flatheaded borer) that lives within a chamber cut into the outer sapwood of the wood. In spring it will transform to the pupal stage, during which it transitions to the ultimate adult form.

The adult, a type of metallic wood borer, emerges from the tree by cutting through the bark, producing a D-shaped exit hole. Adults of the emerald ash borer likely will normally begin to emerge in early –to-mid May, with peak emergence in June. However, there is some range in the time of beetle emergence, which may extend into midsummer.

They then move to the crown of the tree where they feed on ash leaves, making small cuts along the edges of the leaves. After about a week of feeding, the now mature adults will begin to mate and a few days after mating females will begin to lay eggs. Eggs are laid on the surface of the bark, usually deposited singly into cracks and crevices. Females typically live for about a month and during this time will lay several dozen eggs.

Eggs hatch in about a week and the tiny, newly hatch larvae burrow through the bark. They enter and begin to feed on the tissues under the bark, the phloem, cambium and outer sapwood where they spend all of their larval life. During the course of feeding the larvae produce meandering galleries that progressively widen as the larvae grow. Ultimately the gallery produced by a single larva may range over an area ranging from 4 to 20” (10-50 cm) in length. Larvae feed until cooler fall temperatures arrive, when they prepare for overwintering by tunneling a bit deeper into the sapwood to produce the overwintering chamber.

Can plants recover from injury by emerald ash borer? Trees can recover from EAB injury – to a point. If one attempts to control EAB with insecticides it is most likely to be effective if the ash tree is still relatively healthy. If trees have already sustained EAB injuries that have caused the leaf canopy to thin more than 30-50%, it is probably too late to save the tree.

This is because most of the insecticides used for EAB control act systemically — the insecticide must be transported within the tree. When EAB larvae feed, their galleries injure the phloem and xylem, the vascular tissues that move water and nutrients. This also interferes with the ability of the tree to transport and distribute insecticides that move systemically in the vascular system. As a tree becomes more and more infested, the injury becomes more extensive. When damage has progressed too far, insecticides can no longer move within the tree in a manner to provide effective EAB control.

Often if the canopy of a tree is already declining when insecticide treatments are initiated, the condition of the tree may continue to deteriorate during the first year of treatment. When effective controls are applied, in many cases, the tree canopy will begin to improve in the second year of treatment. This lag in the reversal of canopy decline probably reflects the time needed for the tree to repair its vascular system after the EAB infestation has been reduced.

Can we control emerald ash borer? The answer to this question depends on how one defines "control".

There are treatments that can be applied to individual ash trees that can be used to limit the damage caused by emerald ash borer and usually can save trees threatened by emerald ash borer. These primarily involve the use of various insecticides that can move systemically within ash trees. Depending on the treatment these are applied either to soil (for root uptake), as a spray on the lower trunk, or injected into the base of the tree.

Ability to "control" emerald ash borer on an area-wide basis is much more problematic. There are some strategies that have been proposed to "slow the spread" of emerald ash borer. These usually involve a coordinated treatment plan over a wide area that involves extensive use of insecticides and timely removal of EAB-infested trees. It is possible that such strategies can be used to slow the rate at which EAB causes damage at a site, which can provide more time for implementing methods for mitigating EAB effects, such as planting alternative replacement trees. However, within Colorado EAB will eventually disperse from the present location (2014) where established (Boulder) throughout the northeastern part of the state within the South Platte drainage.

Of course, EAB can become established anywhere, immediately, if a human carries the insect to a new location via movement of EAB-infested wood or other means. The use of quarantines, which presently exist in every US county where EAB is known or expected to occur, is designed to inhibit this human assisted spread. However, we will always be at risk that uninformed or criminally negligent individuals ignore these quarantines and assist the spread and damage of this insect.

What treatments can be used to control emerald ash borer? There are several treatments that have been identified that can be used to manage emerald ash borer in an individual tree. All involve the use of insecticides which have to be applied on an annual or biannual basis to maintain control.

In general there are four control approaches considered for use in management of emerald ash borer:

1. ***Soil applications of systemic insecticides.*** Two insecticides can be applied to the root system of ash trees and will subsequently be taken up by the roots – imidacloprid and dinotefuran.

2. ***Non-invasive systemic trunk sprays.*** The insecticide dinotefuran can be applied as a coarse spray onto the trunk of ash trees and will be absorbed through the bark.

3. ***Trunk injections with systemic insecticides***. Some insecticides can be injected into the lower trunk of trees and then will move systemically in the tree. These include emamectin benzoate, azadirachtin, and imidacloprid.

4. ***Persistent surface-applied contact insecticides.*** A standard method of controlling many borers and bark beetles is to apply a persistent insecticide onto the trunk and branches to kill adults as they lay eggs and to kill newly hatched larvae before they enter the plant. Various pyrethroid insecticides are usually used for this purpose (e.g., bifenthrin, cyfluthrin, permethrin).

What stages of the emerald ash borer are controlled by these treatments? The systemic insecticide treatments (soil drench/injection, trunk bark spray, trunk injection) used for EAB generally target two of the life stages. Adults can be killed as they feed on ash leaves on trees treated with insecticides effective against EAB. These treatments are best timed to be present in trees during the peak period of adult activity, which likely will occur sometime between mid-May and late June.

Early stage larvae that tunnel under the bark can be killed with insecticides that move systemically in the tree to the tissues where they are feeding (phloem, outer sapwood). These treatments are optimally timed to be present when young larvae are present and before there has been extensive injury; prior injuries that disrupt movement of water and nutrients will similarly disrupt distribution of systemic insecticides. The peak period when early stage larvae are present will likely occur sometime between late May and early July.

The persistent surface-applied contact sprays are primarily applied to bark and can kill adults that walk on the bark and the larvae when they hatch from eggs and tunnel into trees. They cannot kill larvae within the tree. Sprays applied to the foliage can also kill adults that feed in the canopy leaves. However, to effectively catch all the susceptible stages with this control method at least two applications are needed per year, and it is rarely used for EAB control.

What are the effects of these insecticides on other insects, birds, mammals….? The best summary of the subject presently available is the sheet *Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used To Control Emerald Ash Borer* (http://www.emeraldashborer.info/files/Potential_Side_Effects_of_EAB_Insecticides_FAQ.pdf) This was prepared by University Extension and research scientists from the Midwest and is a good summary of the subject.

Are there biological controls useful for control of emerald ash borer? In the areas of Asia where emerald ash borer is native there are several important natural controls at work. Most important are defenses produced by the trees, which protect them from attacks of invading organisms common to the region, such as emerald ash borer. In addition, there are numerous natural enemies, notably various species of parasitic wasps. Together, the inherent resistance of Asian species of ash combined with the natural enemies very effectively limit emerald ash borer so that it rarely causes serious damage.

Host plant resistance is largely absent from the native North American species of ash that we grow, and always will be, greatly undermining the potential of natural controls. However, there is work being done by federal agencies to identify parasites of the emerald ash borer present in Asia. Some of these have been found suitable for introduction and release into North America. Already a few of these introduced natural enemies have been released in EAB outbreak areas of the Midwest and in some cases they seem to have proved capable of establishing and reproducing.

This work with natural enemies is ongoing. It is hoped that natural enemies may be useful in helping to suppress EAB populations in the post-outbreak phase. If effective, these may then allow some reduction in the need for treatments in the future and, possibly, allow some of the remaining native ash to survive without treatment. Only preliminary information is presently available but, in a few years, we can expect there to be a much better understanding of how much potential they may have in suppressing emerald ash borer in North America.

At some point in the future it may be decided that some of the more promising natural enemies may be suitable for introduction into Colorado. This is a decision that will be done by state and federal agencies, who will consider not only the possible benefits of such introductions but also possible risks.

Should I try to control emerald ash borer? The decision on what to do about managing this insect will have to be done individually by every owner for every ash tree in an area where this insect becomes established. This calculation will have to consider all the costs of treatment and balance these against the costs associated with not attempting to control EAB injury. Often the most critical factor in these decisions will be how much the tree is valued.

Unfortunately there will be costs associated with this insect regardless of what choice is made. Trees that are infested with emerald ash borer that are untreated or ineffectively treated will die prematurely, requiring their removal and, often, the purchase of replacement trees.

Some models exist to attempt to determine the economic value of trees, such as the National Tree Benefit Calculator: http://www.treebenefits.com/calculator/ These can come up with figures on values related to benefits the trees provide in terms of air quality, shade, property value, etc. What they cannot capture is personal value of the tree to the owner.

When should I begin to treat for emerald ash borer? There can be some benefit to the health of the tree if treatments are applied to trees that are already infested or can be expected to be infested with emerald ash borer during the present growing season. However, since EAB is extremely difficult to detect in trees in early stages of infestation this decision will often have to be an educated guess, based on the information available on where the insect is known to be present within Colorado.

As of January 2014 EAB had only been found within a relatively confined area of the City of Boulder and overall EAB populations still appear to be low at these areas. Trees within the area of known EAB infestation, and up to a 5 mile radius of this infestation, may benefit from EAB treatment beginning in 2014. However, over time emerald ash borer will expand its distribution and an increasingly large area will be determined to be infested with EAB. As new infestations are detected, information on the

distribution of the insect in Colorado will be updated. One source summarizing the distribution of this insect in the state that is useful to reference is the web site maintained by the Colorado Department of Agriculture: www.eabcolorado.com.

Since most EAB treatments provide control for one year or, at most, two years following application there is no benefit in treating a tree prior to when EAB is present.

When can I discontinue treatments for emerald ash borer? Once established at a location emerald ash borer can be expected to survive in the area as long as any ash trees remain. Therefore some management of emerald ash borer will be required for as long as one wishes to maintain the tree.

Controls will have to be particularly intensive during the period when the insect populations increase to high levels and many ash trees in the neighborhood decline rapidly and die. After this wave of ash tree mortality is past, and populations of remaining trees consist largely of those that were effectively treated, numbers of emerald ash borers can be expected to decline dramatically. In this post-outbreak period it may be possible to reduce treatment intensity, although some management will always be required. Several years from now, when the first areas of Colorado affected by EAB go into the post-outbreak phase, there should be considerably more information available as to how to manage this phase of the emerald ash borer infestation.

What do I do if I suspect that I have emerald ash borer in a part of the state where it is not known? It is very important to identify any new areas where this insect may be established so that management plans can be adjusted. Therefore if you suspect that you have an EAB-infested tree that is outside the areas where it is previously known please do follow-up so that it can be investigated to determine positively whether - or whether not - it is emerald ash borer. Updated information regarding EAB in Colorado and the present information on its distribution within the state is found at: http://www.eabcolorado.com

Often it is easiest to first contact local agencies to make the initial follow-up inspection. City forestry personnel, Colorado State Forest Service offices and county CSU Extension offices are examples of places where one might find help in determining whether it is likely to be emerald ash borer. (Remember there are some other insects that resemble emerald ash borer or also damage ash: http://bspm.agsci.colostate.edu/files/2013/03/Emerald-Ash-Borer.pdf)

If there is strong likelihood that a new infestation is detected then it is important to communicate this to the Colorado Department of Agriculture. The CDA can be contacted by phone (888-248-5535) or through the Emerald Ash Borer web site: http://www.eabcolorado.com

Federal agencies, specifically the regional branch of the USDA/APHIS/PPQ, also are involved in making final determination of whether new infestations are positively confirmed. Their phone contact is (303) 371-3355.

Prepared by: Whitney Cranshaw, Department of Bioagricultural Sciences and Pest Management, Colorado State University

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QUICK GUIDE SERIES UCF 2014-1

Emerald Ash Borer

Much of the information for this brochure was provided by the USDA Animal and Plant Health Inspection Service, the Colorado Department of Agriculture and Colorado State University Extension.

What is the Emerald Ash Borer?

The emerald ash borer (EAB), *Agrilus planipennis*, is an exotic insect responsible for the death or decline of tens of millions of ash trees in more than 20 states and Canada. Native to Asia, the beetle most likely arrived in the U.S. in the 1990s, hidden in wood-packing materials commonly used for shipping. The first detection occurred in southeastern Michigan in 2002. EAB already has cost communities billions of dollars to treat, remove and replace ash trees. Infestations are difficult to detect, as the larvae reside under the bark, the adults generally are only present from May through September, and ash trees may be infested for up to four years before there are visible signs of decline.

Figure 1. *Adult emerald ash borers are approximately ½-inch long. Photo: David Cappaert, Michigan State University**

Potential Impacts in Colorado

In Colorado, EAB was detected for the first time in September 2013 in the City of Boulder. As a non-native insect, EAB has no native predators to keep populations in check, and threatens all true ash species (*Fraxinus spp.*). As a result, the beetle poses a serious threat to Colorado's urban forests, where ash trees comprise an estimated 15 percent to 20 percent of all trees; the Denver Metro area alone has an estimated 1.45 million ash trees. Green and white ash, including 'Autumn Purple' ash and other varietals, have been widely planted in Colorado due to their fast growth, ability to tolerate urban growing conditions and high aesthetic value. Many of the state's ash trees are located on private property and in parks and other community areas.

Figure 2. *Ash trees comprise an estimated 15 percent to 20 percent of all trees in Colorado cities, neighborhoods, parks and backyards. Photo: Colorado State University Facilities*

This quick guide was produced by the Colorado State Forest Service to promote knowledge transfer.

April 2014
www.csfs.colostate.edu

Commonly mistaken for EAB:

Lilac/ash borer exit holes

Figure 3. *When lilac/ash borers exit an ash tree, they create irregular round holes. Photo: Whitney Cranshaw, Colorado State University*

Other metallic wood borers

Figure 4. *Several metallic green beetles are native to Colorado, including* Phaenops gentilis *(left) and* Buprestis langii *(right), both associated with declining or recently killed conifers. Photo: Whitney Cranshaw, Colorado State University*

Flatheaded appletree borer

Figure 5. *Dead and dying branches on ash trees may be infested with the flatheaded appletree borer. Photo: James Solomon, USDA Forest Service*

Life History

EAB adults are approximately ½-inch long, with a metallic, emerald-green head/back and a coppery reddish-purple abdomen. The adult beetles consume ash foliage, but cause little damage to affected trees, which allows them to remain unnoticed by homeowners.

Females lay eggs in bark crevices, where they develop into worm-like larvae in the fall. The larvae are cream colored and consist of bell-shaped segments. The EAB larvae feed on the inner bark of ash trees, girdling the tree and disrupting the transportation of water and nutrients, much like mountain pine beetle larvae affect pines.

The tunneling and feeding under the bark is what eventually kills impacted trees. Once the larvae mature into adults in the spring, they emerge from under the bark, leaving D-shaped exit holes. The adult beetles may fly up to a half-mile to infest new trees; however, under certain conditions, they are capable of flying up to several miles. Adults also may re-infest the same tree from which they emerged.

Figure 6. *S-shaped emerald ash borer galleries under the bark. Photo: David Cappaert, Michigan State University**

Figure 7. *Emerald ash borer larva. Photo: David Cappaert, Michigan State University**

Figure 8. *Adult beetles can fly approximately a half-mile to infest a new tree. Photo: Howard Russell, Michigan State University**

Figure 9. *EAB adults have an emerald-green head/back and a coppery reddish-purple abdomen. Photo: David Cappaert, Michigan State University**

Ash Tree Identification

Only ash trees are at risk from EAB – but all species of true ash (*Fraxinus spp.*) are at risk. To detect an EAB infestation, it is important to first identify the type of tree in question to ensure that it is an ash tree. In Colorado, ash trees can be found in most communities, although many private landowners may not realize they have them. Ash trees have the following characteristics:

- Leaves are compound, which means multiple leaflets occur on a common stalk, and typically have five to nine leaflets. The exception is single-leaf ash (*Fraxinus anomala*), which may have simple or compound leaves, with up to five leaflets.
- Leaflets are smooth or finely toothed along the edges.
- Seeds on female trees are paddle-shaped.
- Branches and buds grow in pairs, directly opposite from each other.
- Mature bark displays diamond-shaped ridges.

Figure 10. *Ash trees have been planted extensively in Colorado over the last 50 years because they grow quickly and can tolerate the growing conditions in urban areas. Photo: William M. Ciesla*

Figure 11. *Ash trees have five to nine leaflets on each stalk. Photo: Robert Vidéki, Doronicum Kft.**

Figure 12. *The bark on mature ash trees has diamond-shaped ridges. Photo: Richard Webb, horticulturist**

Figure 13. *Seeds on ash trees are paddle-shaped. Photo: Franklin Bonner, USDA Forest Service**

Figure 14. *Ash leaves can either have smooth or finely toothed edges. Photo: Robert Vidéki, Doronicum Kft**

Figure 15. *The buds on ash trees grow in pairs, directly opposite from each other. Photo: Paul Wray, Iowa State University**

Figure 16. *EAB is responsible for the death or decline of tens of millions of ash trees in more than 20 states. Photo: Jared Spokowsky, Indiana Department of Natural Resources**

Figure 17. *New sprouts grow on the lower trunk of an ash tree infested with EAB. Photo: James W. Smith, USDA APHIS PPQ**

Figure 18. *Woodpeckers are an important predator of EAB. Photo: David Cappaert, Michigan State University**

Signs and Symptoms of EAB Infestation

Signs of EAB infestation include:

- Sparse leaves or branches in the upper part of the tree
- D-shaped exit holes approximately ⅛-inch wide
- New sprouts on the lower trunk or lower branches
- Vertical splits in the bark
- Winding, S-shaped tunnels under the bark
- Increased woodpecker activity

If an ash tree is experiencing dieback or appears unhealthy, have it examined by a professional. Landowners that suspect the presence of EAB in their ash trees should visit the website www.eabcolorado.com, contact the Colorado Department of Agriculture (CDA) at (888) 248-5535 or send an email to CAPS.program@state.co.us.

Figure 19. *D-shaped exit holes can indicate the presence of EAB. Photo: Pennsylvania Department of Conservation and Natural Resources**

Figure 20. *Ash trees may be infested with EAB for up to four years before signs of decline are visible. Photo: David Cappaert, Michigan State University**

Figure 21. *Vertical splits in the bark are another sign that EAB has infested the tree. Photo: Joseph O'Brien, International Society of Arboriculture**

Figure 22. *S-shaped tunnels or galleries can be found under the bark of an infested ash tree. Photo: Ryan Lockwood, CSFS*

Responding to EAB

Quarantines

Like many other states, Colorado has established a quarantine and detection process to prevent the spread of EAB into new areas, and to reduce the impacts of EAB on ash trees in already impacted areas. The EAB quarantine prohibits the movement of all regulated material that has not met treatment requirements – which includes ash nursery stock, green lumber, ash wood products, all hardwood firewood and related products – out of EAB-regulated areas. To legally move regulated material out of a quarantined area, it must meet the treatment options defined by the federal quarantine. For updated information on the Colorado EAB quarantine and treatment requirements, visit www.eabcolorado.com.

Figure 23. *A CSFS forester and CSU Extension specialist assess the branch of an ash tree to determine the presence of EAB. Photo: Ryan Lockwood, CSFS*

Management & Prevention

The best EAB management option depends on the value of each ash tree to a landowner, and the costs associated with each option. Options for treating at-risk or infested trees include removal, replacement and chemical treatments. For more information about treatment options, visit www.eabcolorado.com.

Tree Removal

Trees killed by EAB will need to be removed at some point, but homeowners who are concerned about future infestation also may elect to remove dying or even healthy trees. Trees may become more expensive to remove as they decline and after they have died. Dead and dying trees also may represent a hazard to surrounding property and infrastructure. When choosing to remove an ash tree, it is best to hire a licensed and insured arborist or tree service company. A list is available at http://www.isa-arbor.com/publicOutreach/findATreeCareService/index.aspx.

Figure 24. *Planning for tree replacement is an effective management strategy for EAB. Photo: Vince Urbina, CSFS*

Tree Replacement

Planning for tree replacement can begin prior to the removal of an ash tree. To reduce the impacts of EAB and other insect and disease threats in Colorado's urban and community forests, the Colorado State Forest Service encourages diversity when planting new trees. A single type of tree should comprise no more than 10 percent of all trees in a planted landscape. Ash trees (*Fraxinus* spp.) have been widely planted in Colorado, but due to the risk of EAB, future plantings are not recommended. The Colorado Tree Coalition maintains a list of trees suitable for planting in Colorado communities, which is available at www.coloradotrees.org/PDFs/TreeRecommendationList.pdf.

Chemical Treatments

Homeowners may opt to periodically apply insecticide treatments to help protect high-value trees; however, the early presence of EAB in Colorado may not warrant immediate preventive treatment. When an EAB population is low and known to occur in only a few isolated areas, treatments are not recommended for ash trees located more than 5 miles from the known boundary of the infestation. However, recommendations regarding EAB treatments in specific areas of Colorado will change over time, as the extent of the infestation broadens and EAB populations rise. Current information on the extent of the EAB infestation within the state is available at www.eabcolorado.com.

Figure 25. *A syringe-like applicator is used to inject imidacloprid to control EAB. Photo: David Cappaert, Michigan State University**

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*Photos are from www.forestryimages.org

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Trees not treated with an insecticide are at higher risk of EAB damage than those managed with periodic treatments. Ash trees can be chemically treated if they are healthy or are showing only early signs of EAB. If a tree appears unhealthy, or is showing many outward signs of EAB, it most likely is too late to save the tree. Talk to a forestry professional first when considering the use of chemical treatments to protect high-value trees, and only hire licensed professionals certified by the Colorado Department of Agriculture to administer treatments.

Don't Move Firewood!

Removed ash trees can be used for firewood or mulch at the removal site. However, this wood should not be transported to other locations due to the high risk of spreading EAB to healthy trees. Remember, moving regulated wood materials outside of a quarantine area is illegal and punishable by significant fines.

Never transport firewood or other untreated products from ash trees, including logs or nursery stock, as this is the most likely method of accidental spread. Transporting firewood is a primary cause of many costly insect introductions, often due to the larvae's ability to survive under the bark. When wood is moved from one place to another, pests can hitchhike to new locations and spread further. More information is available at www.dontmovefirewood.org.

For More Information

- General EAB information: www.EmeraldAshBorer.info or http://stopthebeetle.info
- EAB in Colorado (survey progress, identification, reporting, quarantine boundaries and treatment options): www.eabcolorado.com
- Facts about insects and diseases that threaten Colorado's trees (Colorado State Forest Service): www.csfs.colostate.edu
- Information about the dangers of moving firewood: www.dontmovefirewood.org
- Common problems of ash trees (Iowa State University): www.extension.iastate.edu/Publications/SUL21.pdf
- Treatment options (Colorado State University): http://bspm.agsci.colostate.edu/files/2014/02/EAB-control-options-February-11.pdf
- General tree facts (Colorado Tree Coalition): www.coloradotrees.org/find.php
- Insect Information Website (Colorado State University): http://bspm.agsci.colostate.edu/outreach-button/insect-information/

COLORADO DEPARTMENT OF AGRICULTURE

Colorado State Forest Service

Colorado State University Extension

DONTMOVEFIREWOOD.org

COLORADO TREE COALITION

Extension Bulletin E-2938 Reprinted December 2005

Signs and Symptoms of the Emerald Ash Borer

Mary Wilson, MSU Extension. Eric Rebek, Michigan State University Dept. of Entomology

Adult

A

Michigan State University

B

Michigan State University

- Bright, metallic green (Figs. A, B).
- 1/2 inch long, flattened back (Figs. A, B).
- Purple abdominal segments beneath wing covers.

Larva

C

D. Cappaert, MSU

- Creamy white, legless (Fig. C).
- Flattened, bell-shaped body segments (Fig. C).
- Terminal segment bears a pair of small appendages.

Canopy Dieback

D

E. Rebek, MSU

E

E. Rebek, MSU

- Begins in top one-third of canopy (Fig. D).
- Progresses until tree is bare (Fig. E).

Epicormic Shoots

F

J. Smith, USDA APHIS PPQ

- Sprouts grow from roots and trunk (Figs. F, G).
- Leaves often larger than normal.

G

J. Smith, USDA APHIS PPQ

Emerald Ash Borer

MICHIGAN STATE UNIVERSITY EXTENSION

THE OHIO STATE UNIVERSITY EXTENSION — OARDC

Signs and Symptoms of Emerald Ash Borer

Bark Splitting

H

J. Smith, USDA APHIS PPQ

I

A. Storer, Mich. Tech. Univ.

- Vertical fissures on bark (Fig. H) due to callous tissue formation (Fig. I).
- Galleries exposed under bark split.

Serpentine Galleries and D-shaped Exit Holes

J

D. Cappaert, MSU

K

D. Cappaert, MSU

- Larval feeding galleries typically serpentine (Fig. J).
- Galleries weave back and forth across the woodgrain.
- Packed with frass (mix of sawdust and excrement).
- Adults form D-shaped holes upon emergence (Fig. K).

Increased Woodpecker Activity/Damage

L

D. Cappaert, MSU

M

Karen D'Angelo, MSUE

- Several woodpecker species (Fig. L) feed on EAB larvae/pupae.
- Peck outer bark while foraging (Fig. M).
- Create large holes when extracting insects (Fig. M).

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Section 4

Emerald Ash Borer Sampling and Management

Natural Resources Canada
Ressources naturelles Canada

Frontline

Forestry Research Applications

Canadian Forest Service - Sault Ste. Marie
Technical Note No. 111

Detection of emerald ash borer in urban environments using branch sampling

K. L. Ryall, J. G. Fidgen, J.J. Turgeon

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Fig. 1), a non-native insect pest of Asian origin, presently infests large numbers of ash (*Fraxinus* spp.) trees in Ontario and Québec and could soon spread to other provinces.

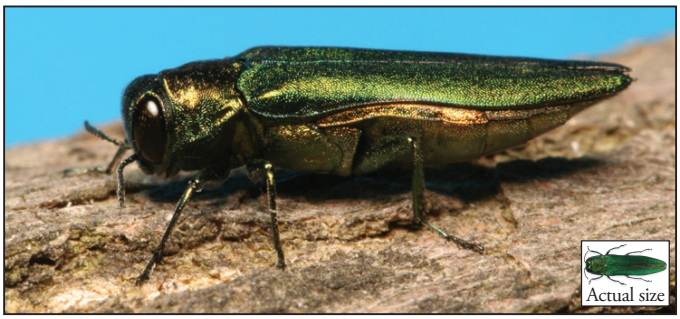

Fig. 1. Adult emerald ash borer.

One of the many requirements for effective management of EAB is early detection of infestations, when densities are still low and before signs and symptoms are obvious. *Visual surveys* rely on external signs and symptoms (e.g., exit holes, larval tunnels seen through cracks in the bark, feeding by woodpeckers or squirrels) that may not be noticeable for 2 to 3 or more years after the arrival of the population, particularly if the infestation begins in the upper part of the tree. *Sticky traps* baited with an attractant have the potential to detect EAB adults in an area before signs or symptoms become visible, but may not necessarily provide information on the infestation status of individual trees.

Ryall et al. (2010) sampled many ash trees with **no** obvious sign or symptom of EAB attack (Fig. 2) and showed that *branch sampling* was an effective method of detecting EAB-infested trees; indeed, 74% of the infested trees would have been discovered if the method described below had been used. The purpose of this note is to describe this basic sampling technique.

Fig. 2. Healthy-looking ash trees with no visible sign or symptom, but determined to be infested with EAB using branch sampling.

DESCRIPTION OF THE BRANCH SAMPLING METHOD

This method is suitable for sampling open-grown ash in any landscape, but it is of particular value in urban areas with high-value ash trees (Fig. 2). Branch sampling can be performed at any time between September and May; however, because larvae continue to feed and grow in size in early fall, their galleries are easiest to see if branches are sampled after October. This technique can be performed using the following steps:

1. Select an open grown black, red, green, European or white ash, 6-18 m tall and 15-50 cm DBH (diameter at breast height) with large open crown;

2. Identify **two** live branches in the mid-crown preferably 5-7 cm in diameter at the base (minimum 3 cm; maximum 10 cm) ideally from the south side of the tree. **NOTE**: Be sure to follow appropriate safety procedures and to cut branches using proper tree pruning methods.

Canada

3. Cut each branch at its base using a pole, chain or pruning saw (see Fig. 3a);

4. Measure off 75 cm from the base and cut the branch again at this point. Remove any lateral branches from this piece (Fig. 3b);

5. Secure the 75 cm piece in a vise (Fig. 3c);

6. Peel (whittle) the bark in thin strips (1-2 mm thickness) from the basal 50 cm of the branch using a good quality draw- or paring-knife (Fig. 3d);

7. Examine the branch carefully, looking for EAB galleries and/or larvae. Remember that gallery length varies from a few millimetres to (Fig. 4a) several centimetres (Fig. 4b).

If the objective is only to detect EAB, then sampling can stop when the first gallery is found. If the objective is to assess densities, then it is important to count all EAB galleries and living larvae on the sample. Counts take 2-3 times longer to carry out than presence/absence sampling.

The branch sampling technique can be done concurrently with other tree management activities, such as pruning. Samples from ash trees could be rerouted to a centre where whittling is performed. Because ash tree material can contain live EAB, **it must <u>not</u> be moved outside of regulated areas established by the Canadian Food Inspection Agency (CFIA). In non-regulated areas, discovery of EAB galleries or of a live specimen must be reported to the CFIA**. Procedures for **movement and disposal** of ash wood are available at: http://www.inspection.gc.ca/english/plaveg/pestrava/agrpla/regrestrice.shtml.

Fig. 3. Cutting (a), measuring and trimming (b) ash branches. Branches, cut to a length of 75 cm, are placed in a vise and bark is whittled off the basal 50 cm (c) (1.5 m piece shown here). Whittling removes bark in thin 1-2 mm strips (d).

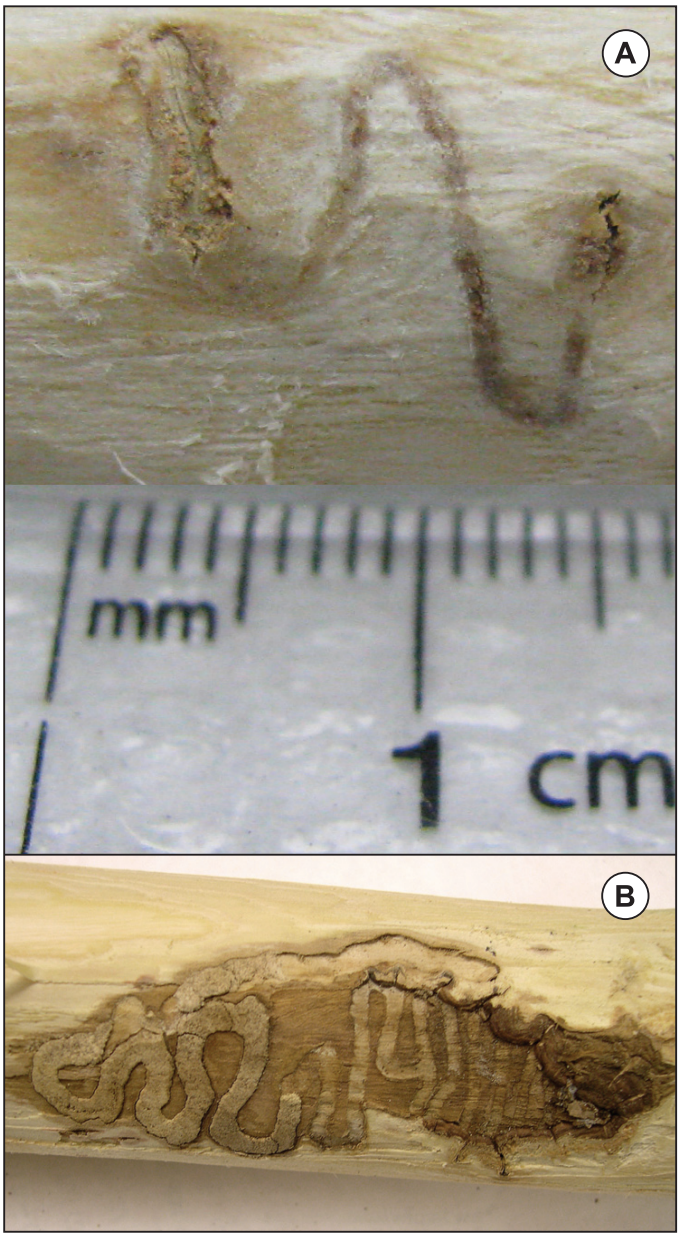

Fig. 4. Early (a) and late (b) stage serpentine galleries made by EAB larvae, found by branch sampling.

CAVEATS

This technique was developed using open-grown urban trees. Its efficacy for use in woodlots has not been tested. Similarly, sampling of much larger or smaller branches and trees than those recommended herein may result in lower detectability of EAB infestations.

CONCLUSIONS

Branch sampling is a highly effective tool for detection of incipient EAB populations, before outward signs or symptoms become apparent. Early detection of EAB populations can provide managers with additional time to identify and implement management options before unacceptable ash mortality occurs. This technique can be used for early detection of incipient EAB populations; to provide estimates of EAB density on infested trees and to delimit the extent of outbreaks. Ongoing research is developing area-wide detection and delimitation survey protocols, is relating EAB density to severity of visual signs and symptoms, and is calibrating effectiveness of baited traps as another early detection tool.

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ADDITIONAL READING

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USING GIRDLED TRAP TREES EFFECTIVELY

FOR EMERALD ASH BORER

DETECTION, DELIMITATION & SURVEY

Michigan State University
Michigan Technological University
USDA Forest Service, Forest Health Protection

in cooperation with

Michigan Dept. of Agriculture
Michigan Dept. of Natural Resources
Ohio Dept. of Agriculture
Indiana Dept. of Natural Resources

July 2007

Using Girdled Trap Trees Effectively for Emerald Ash Borer Detection, Delimitation and Survey

by
Dr. Deborah G. McCullough and Dr. Nathan W. Siegert
Dept. of Entomology and Dept. of Forestry
Michigan State University

Introduction

Emerald ash borer (EAB) (Buprestidae: *Agrilus planipennis* Fairmaire) is an exotic pest of ash (*Fraxinus* spp.). Feeding by the larval stage of this beetle occurs in tunnels called galleries that are excavated in the inner bark and phloem. The galleries created by feeding larvae affect the ability of trees to transport food and water. Low densities of EAB have little effect on the health of a tree. However, when EAB populations increase, the canopy declines, branches die and eventually the entire tree dies. Trees ranging from 1 inch to more than 60 inches in diameter have been killed by EAB.

Ash trees with relatively high densities of EAB larvae are likely to have visible signs of infestation. These external symptoms include thin crowns, vertical bark splits above galleries, dead and dying branches and epicormic sprouts on the trunk or large branches. D-shaped exit holes left by emerging EAB adult beetles can sometimes be found. Woodpecker holes on the trunk or large branches of an ash tree are often the first indication of an EAB infestation.

In contrast, it can be incredibly challenging to find new EAB infestations or to identify trees with low densities of EAB. Newly infested trees often appear healthy and have no external symptoms of EAB infestation. A few D-shaped exit holes may be present, and on small trees (< 4-8 inches DBH) they may be on the trunk and fairly easy to find. On larger trees, however, galleries are usually in the upper canopy for the first couple of years. Often this means that you must climb up into the canopy to see those exit holes.

Using Trap Trees

Several studies conducted by MSU and USDA Forest Service scientists since 2003 have shown that EAB beetles are attracted to stressed ash trees and tend to lay more eggs on stressed trees than on healthy trees. Girdled trees, called trap trees, are currently used for EAB detection and survey in many states.

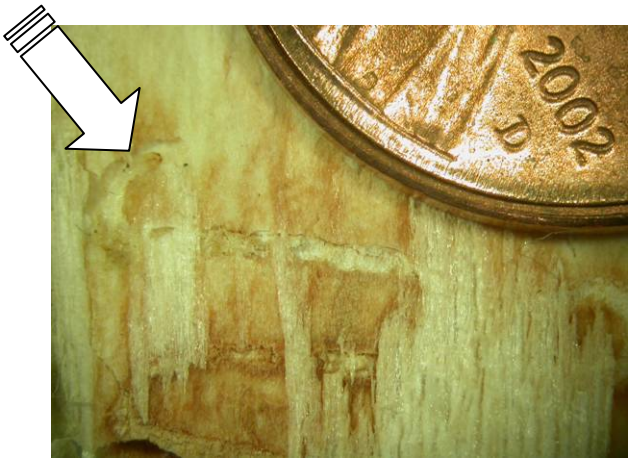
Girdling, or removing a band of bark and phloem around the trunk of a tree, interrupts the ability of the tree to transport carbohydrates – the food needed by the tree. Girdled trees become

increasingly stressed over the summer. As stress increases, the chemicals emitted from the foliage, bark or wood of the tree change. The wavelengths of light reflected by the leaves (hyperspectral reflectance) also differ between healthy and girdled trees. Beetles can apparently detect these changes and are often more attracted to the stressed trees than to surrounding or nearby ash trees.

Recent studies by MTU and MSU scientists have shown that many ash trees can survive for at least two years after girdling. These trees are, of course, highly stressed and may be even more attractive to EAB beetles than trees girdled for only one year.

Debarking Trap Trees – Helpful Hints

WHY DISSECT TRAP TREES IN AUTUMN? Trap tree dissections usually don't begin until September. This is because EAB eggs hatch in July and early August so most larvae don't start feeding until late July or August. As they feed and grow, the galleries lengthen and become more apparent. By late September, most larvae will be 4th instars – the largest stage. Large galleries are obviously easier to find than small galleries.



GALLERIES MAY BE SMALL! Keep in mind, however, that some larvae require two summers of feeding to complete their development. This two-year life cycle seems to be most common in healthy ash trees that have relatively few EAB larvae. Two-year larvae usually spend the first winter as first or second instars, instead of prepupae. These are tiny larvae with very small galleries that are often less than two inches in size. These are the galleries that you want to find when you're surveying for new infestations!

DEBARK SUSPICIOUS AREAS OF THE TREE. When you approach a trap tree, look it over carefully. Look for dying branches, bark cracks, evidence of epicormic shoots or other signs that could be associated with an EAB infestation. When you have a relatively small tree with mostly smooth bark (e.g. most white ash trees), pay extra attention to where the bark is rough, cracked or "rippled". Those areas are often near branch crotches and they may be a good place to find EAB larvae.

PLAN AHEAD WHEN DROPPING TREES. When you fell a trap tree, make it easy on yourself. Try to leave a knee-high "hinge" or set the top of the tree on a sawhorse so that you can debark it while standing up. If the tree is laying flat on the ground, it's hard on your knees and it's difficult to peel bark from the sides of the tree.

BE PATIENT! When you use your drawknife, try to peel the phloem in thin sections, to avoid missing small larvae. Be patient - small larval galleries may be shallow and only present in the upper layer of the phloem. If you peel too deeply, you may not even see them. On the other hand, some small larvae seem to chew nearly straight down to the sapwood before they start to make S-shaped galleries. Be sure to peel the phloem all the way down to the wood. Try to peel areas around branch crotches or anyplace that has relatively rough or fissured bark. It's more difficult to remove bark from those areas but female beetles seem to like rough texture or cracks and crevices for egg-laying.

OTHER INSECTS GET INTO ASH PHLOEM TOO. Other insects will occasionally be found under the bark in ash trees. Larvae of bark beetles (family Scolytidae), round-headed borers (family Cerambycidae), caterpillars (moth larvae) and little maggots (fly larvae) will also feed on ash phloem or wood. Sometimes it can be difficult to distinguish between these insects and EAB. If you are not sure, try to collect the insect and show the gallery to a supervisor or someone with plenty of experience.

Factors to Consider When Selecting Trap Trees

We don't fully understand how beetles select their host trees and how females select areas on a tree for egg-laying. The beetles probably respond to several tree characteristics, including stress. There are, however, some general traits we have observed in our studies that may help you select trap trees or locate galleries when you debark trap trees.

STRESS: Stressed trees that have been girdled, or are otherwise injured or diseased, are consistently more attractive to EAB than healthy trees. Volatile chemicals (compounds that are released into the air) emitted by ash leaves or the wood and bark are different on stressed and healthy trees; hyperspectral reflectance changes and defensive chemicals in the leaves or phloem may be affected by stress.

TREE SPECIES: Beetles seem to demonstrate a preference for some ash species over others. For example, when green ash (*F. pennsylvanica*) and white ash (*F. americana*) trees are growing together, the green ash trees usually have higher EAB densities and decline faster than white ash trees. Green ash and black ash (*F. nigra*) appear to be highly preferred by EAB. White ash is less preferred and blue ash (*F. quadrangulata*) is least preferred. This may be related to differences in leaf, wood or bark chemicals, physical traits like bark texture, or the quality of foliage or phloem. When multiple ash species are available to use as trap trees, it's best to select the tree species most likely to be attacked by EAB.

We recommend selecting ash trees for use as trap trees in this order:

1) Green ash (most preferred);

2) Black ash;
3) White ash;
4) Blue ash (least preferred).

GROWING CONDITIONS: Whenever possible, try to select trees that are growing in the **open** and are fully exposed to the sun. We know that beetles are attracted to light and are more active in sunny, warm locations. Beetles may also be better at detecting the volatile chemicals released into the air by ash leaves, bark or wood when the trees are out in the open. Plus, open-grown trees may simply be more apparent when beetles are looking for hosts. Trees that are shaded or partially shaded, overtopped or in dense forest stands or woodlots are less likely to be attacked by EAB than open-grown or exposed trees.

We recommend selecting trap trees in the following locations:

1) Open-grown trees (e.g. along a roadside or in a field) (most preferred);
2) Hedgerow trees (e.g. at least 2-3 sides mostly open);
3) Edge trees (e.g. trees along the edge of a woodlot, crown exposed on 1-2 sides);
4) Closed canopy trees (least preferred).

BARK TEXTURE: Female beetles seem to prefer laying eggs in bark cracks or crevices and are less likely to lay eggs on smooth sections of bark. When we debark lightly infested trees, we often find most larval galleries are located near branch crotches or other areas that have cracks or "ripples" in the bark.

TREE SIZE: Tree size does not seem to strongly affect EAB host selection, so we generally select trap trees based on practical considerations. Choose trees that are at least 4 inches DBH, so they won't break in the wind after girdling. Avoid using trees that are more than 10-12 inches DBH – bigger trees are more difficult to fell, debark and remove. Avoid trees that are overtopped by larger trees whenever possible.

SAFETY & HAZARD TREES: Avoid trees that could cause damage or injury if they break. Trap trees should be at least two times their height away from campsites, picnic tables, frequently used trails, or other features that could be damaged by a falling tree.

Girdling Trap Trees

HOW TO GIRDLE TRAP TREES: Use a drawknife, pruning saw, chainsaw or other tool and make two parallel cuts, about 4-8 inches apart. Each cut should completely encircle the trunk. Cut through the phloem and down to the wood on each cut. Then use your drawknife, saw or chisel to remove the bark and phloem in the space between the two cuts. Try to get all the way down to the sapwood. Young, vigorous ash trees will sometimes begin to callus over the girdle during the summer. This reduces the level of stress and presumably makes the tree less attractive to EAB.

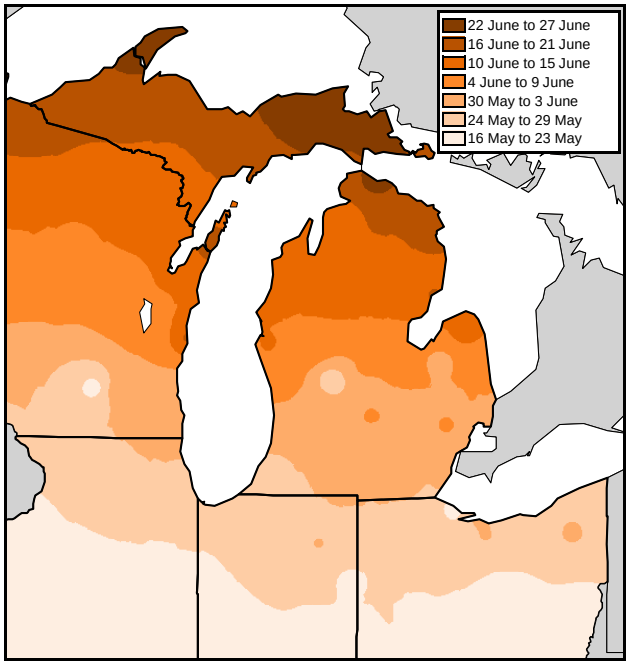
If you cut into the sapwood, you will disrupt xylem cells that transport water. This will increase the stress on the tree and can cause the trap tree to die by the end of the summer. If the tree will be used as a trap tree for two years, it's best to avoid cutting into the sapwood all the way around.

Note: Wounding the tree by removing bark on one side or half of the tree, etc. does not seem to attract beetles as well as a complete girdle.

TIMING: Trees can be girdled in the fall, winter or spring. Don't wait until too late in the spring to girdle trees, however. You want the tree to be sufficiently stressed by the time EAB adults are active and laying eggs. If you plan to girdle trees in spring, try to have the girdling completed by early June, so that trees are stressed by the peak activity period for EAB. Fall girdling can be more difficult than spring girdling because the bark does not separate easily from the wood. You may want to carry a chisel or similar cutting tool to help remove the bark and phloem between the two cuts.

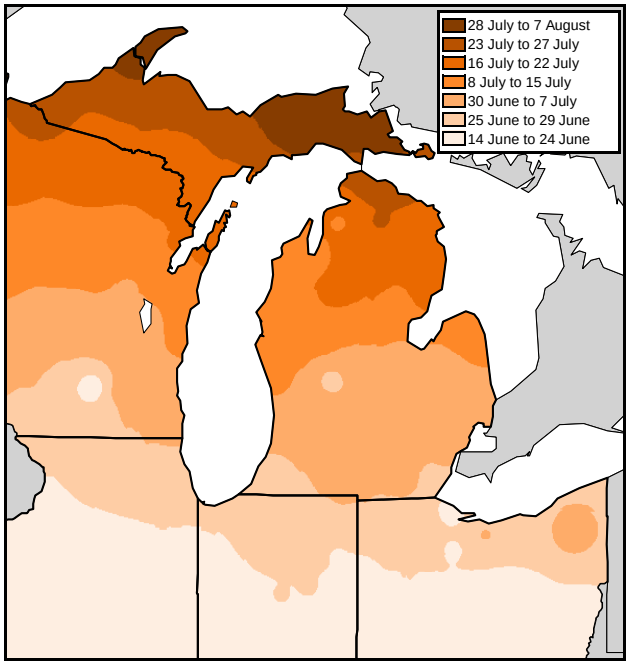
In southern Michigan, EAB adults begin to emerge between mid to late May and early June. Adult EAB are most common and active in late June and early July. If you have access to degree day measurements, EAB emergence usually begins around 450 to 500 degree days, base 50°F. Peak activity, when beetles are most abundant, occurs around 1000 degree days, base 50°F. Up-to-date degree day accumulations for many locations in Michigan and surrounding areas can be accessed through the MSU IPM web site at: http://www.enviroweather.msu.edu/home.asp

EAB Emergence Begins around 450 Degree Days



Calendar dates by which 450 growing degree day thermal units (base 50°F) are reached in the Lake States. Estimates are based on an interpolation of average seasonal daily accumulations (calculated by the Baskerville-Emin method) at 92 locations throughout the region, 1971 to 2000.

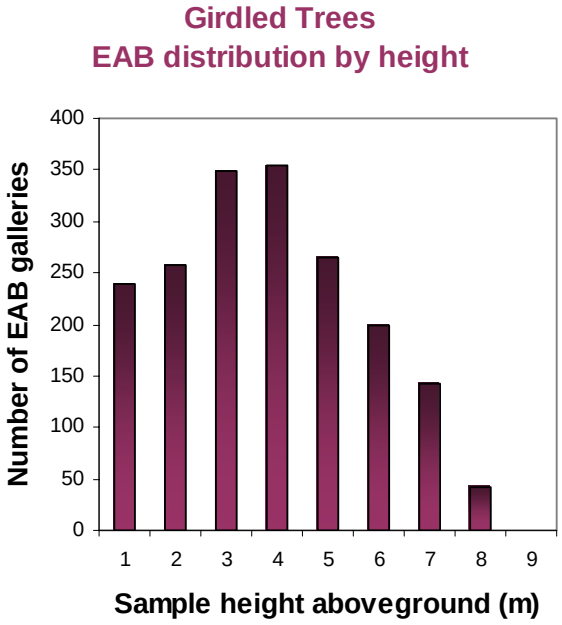
EAB Activity Peaks around 1000 Degree Days

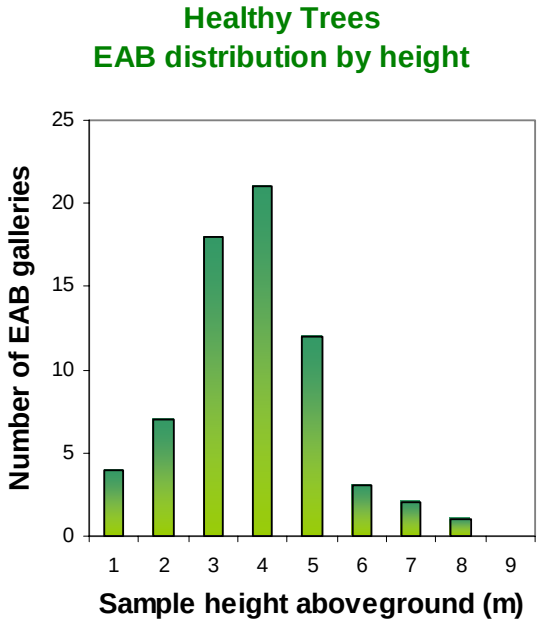


Calendar dates by which 1000 growing degree day thermal units (base 50°F) are reached in the Lake States. Estimates are based on an interpolation of average seasonal daily accumulations (calculated by the Baskerville-Emin method) at 92 locations throughout the region, 1971 to 2000.

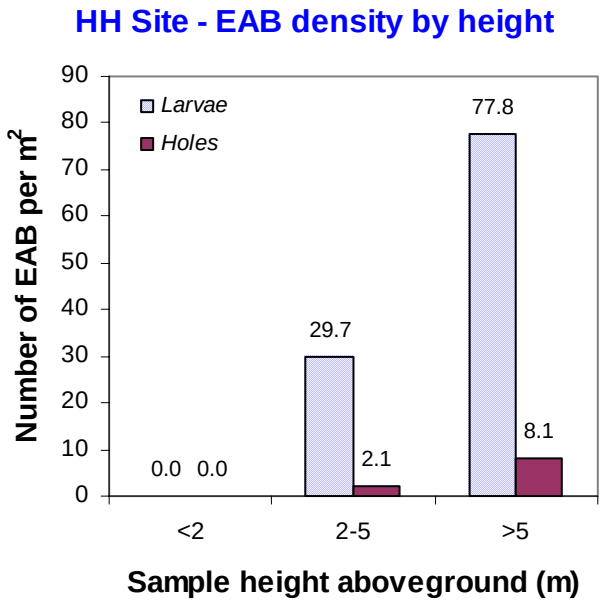
Finding EAB on Newly Infested Trees

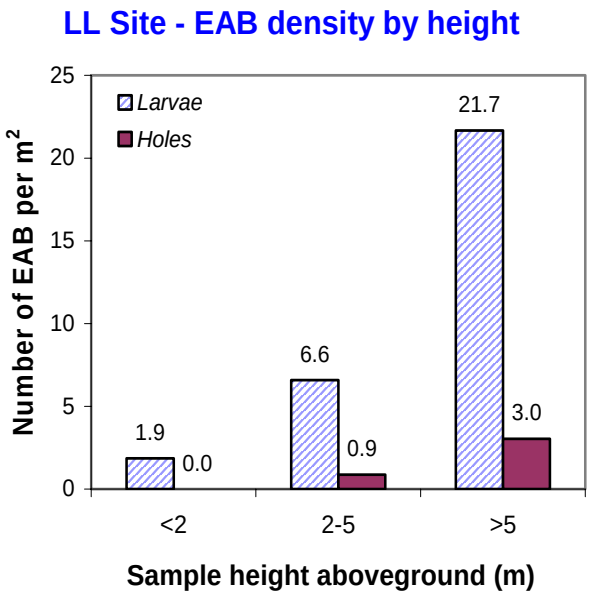
On relatively small ash trees (e.g. ≤ 4-8 inches in DBH), most exit holes and larval galleries will be found on the trunk. For example, in 2006-2007, we felled 30 girdled and 30 healthy ash trees in a plantation with a relatively recent EAB infestation. The trees were 3.5 to 8 inches in DBH. We cut each tree into 1 meter long sections (1 m = 39 inches) and counted the number of galleries on each section. Overall, the girdled trees had 25 times as many galleries as the healthy trees. On the healthy trees, with a low EAB density, 75% of the galleries were 2 to 4 meters aboveground. On the girdled trees, EAB density was high and beetles had to compete for space. Even so, nearly 40% of the galleries were 2 to 4 meters aboveground (6 to 12 ft).





On large trees, however, EAB exit holes and galleries are usually present in the canopy before the trunk becomes infested.





These figures show the density of EAB larvae and D-shaped exit holes for large ash trees sampled at two different sites in late autumn in 2004. "Holes" refers to D-shaped exit holes left when adult beetles emerged in 2003 or in the summer of 2004. "Larvae" refers to the number of larvae feeding in autumn 2004.

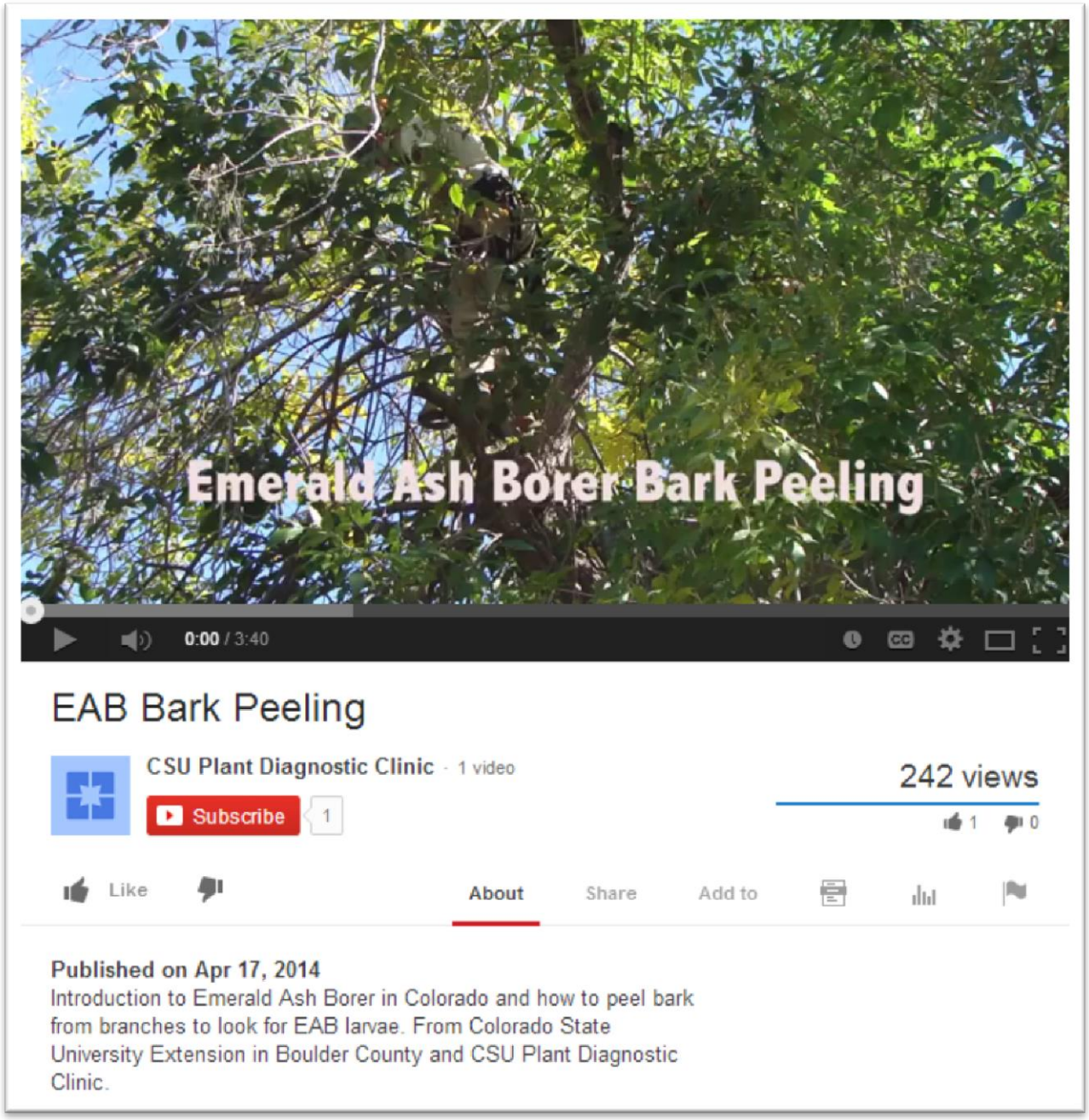
You can see that most of the D-shaped exit holes that were present in 2004 were high in the canopy – above 15 ft. We did not find any exit holes on the trunk from the ground to 6 ft aboveground. Even in 2005, most of the EAB exit holes would have been at least 15 ft aboveground on these large trees.

In Conclusion

When EAB was discovered in North America in 2002, very little was known about its general biology. Since then, university and government scientists have learned much about the life cycle, host preference and population dynamics of EAB. Results from many studies were used to develop the recommendations provided here. Research is still progressing, however, and every year we learn more about this invasive pest. We expect to continue to incorporate new information into recommendations to ensure that girdled trap trees are used as effectively as possible for the detection, delimitation and survey of EAB populations.

Emerald Ash Borer Bark Peeling Video

CSU Plant Diagnostic Clinic: http://youtu.be/caOw3Be0w_8



Managing Emerald Ash Borer: Decision Guide

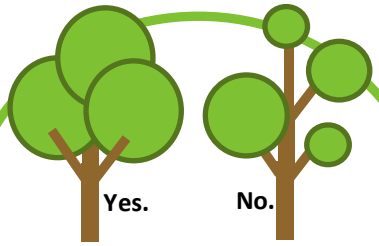
Begin with an inventory of your ash trees
- How many?
- Where are they?

Do you want to save your ash trees from EAB?

No.

Ash trees may be killed and will need to be cut down.

Yes.



Are some worth saving?
- Valuable to landscape or owner?
- Healthy and few signs of EAB?
- Located in the right site?

No.

Yes.

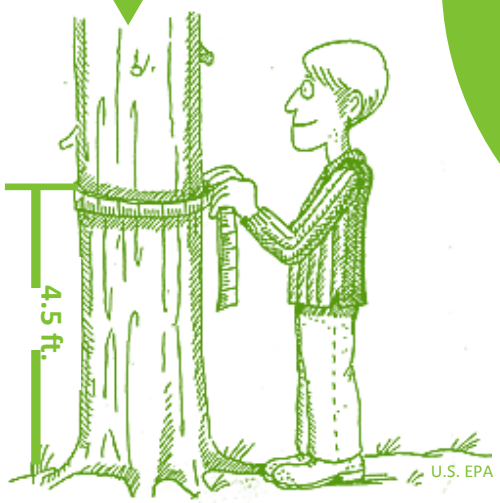
I don't know.
A professional can help.

Hire a Tree Care Professional
- Get at least two estimates
- Hire a certified licensed professional
- Ask for references and insurance

To find one in your area visit:
www.treesaregood.com

Team up with your neighbors and seek discounts for managing all your trees at once!

Save money. Have unwanted ash removed before they die.



Determine how big your trees are. Get DBH.

Measure the distance around the trunk (at 4.5 ft. above the ground) and divide it by three to get Diameter at Breast Height.

Are they greater than

?

Yes. You will need professional insecticide treatment.

Ensure that drenches are applied to bare soil within 1 ft. of the trunk.

No.

Homeowners can treat trees themselves.

Consider using a soil drench containing imidacloprid. Treat trees between May 1st and June 15th. Always follow all insecticide label directions.

Protect your urban forest. Act Now. Save Trees. Save $!

Managing Emerald Ash Borer: Decision Guide

Which trees can be saved?

Trees CAN be saved if they are:

- **Healthy** and vigorously growing, with more than half their leaves.
- Enhancing the landscape.
- Valuable to the owner.
- Showing only few outward signs of EAB infestation.

These ash trees are healthy, have all of their leaves, and provide benefits to the landscape. They would be good treatment candidates.

Trees should NOT be saved if they are:

- **Unhealthy**, with dead branches and more than half of their leaves missing.
- Planted in poor sites or are not important to the landscape.
- Showing many outward signs of EAB or other insect infestation, such as woodpecker damage, bark splits, and water sprouts at the tree base.

John Obermeyer, Extension Entomology, Purdue University

These ash trees are too unhealthy to be effectively treated.

This ash tree is not planted on the right site. It will require maintenance to keep it clear of power lines.

Contact your city forester about local ordinances before performing any tree work!

What are the treatment options?

Homeowners can protect healthy ash trees:

- With a trunk **less than 15 in.** Diameter at Breast Height (see reverse for DBH measurement).
- With over the counter soil drench products. One option are products containing 1.47% imidacloprid. These products are most effective when applied between May 1st and June 15th.

Disclaimer: Over the counter formulations are not as strong as professional formulations and are not advised to be used on trees with a DBH of greater than 15 inches.

Professionals can protect ash trees:

- With a trunk **greater than 15 in.** DBH.
- Later in the year, using specialized equipment to apply insecticides that contain imidacloprid, dinotefuran, azadirachtin or emamectin benzoate.

For more information on treatments and your ash tree managment zone Go to: www.eabcolorado.com

Which new trees should be planted?

The tree species you choose should match the conditions of the site. Remember that some trees can become very large. Contact your city forester, Colorado State University Extension Office or your local garden center or nursery for advice on choosing a good replacement.

For a list of replacement trees, visit:
www.coloradotrees.org
or the
Front Range Tree Recommendation List©
www.greenco.org/images/FR%20tree%20rec%20list%202014.pdf

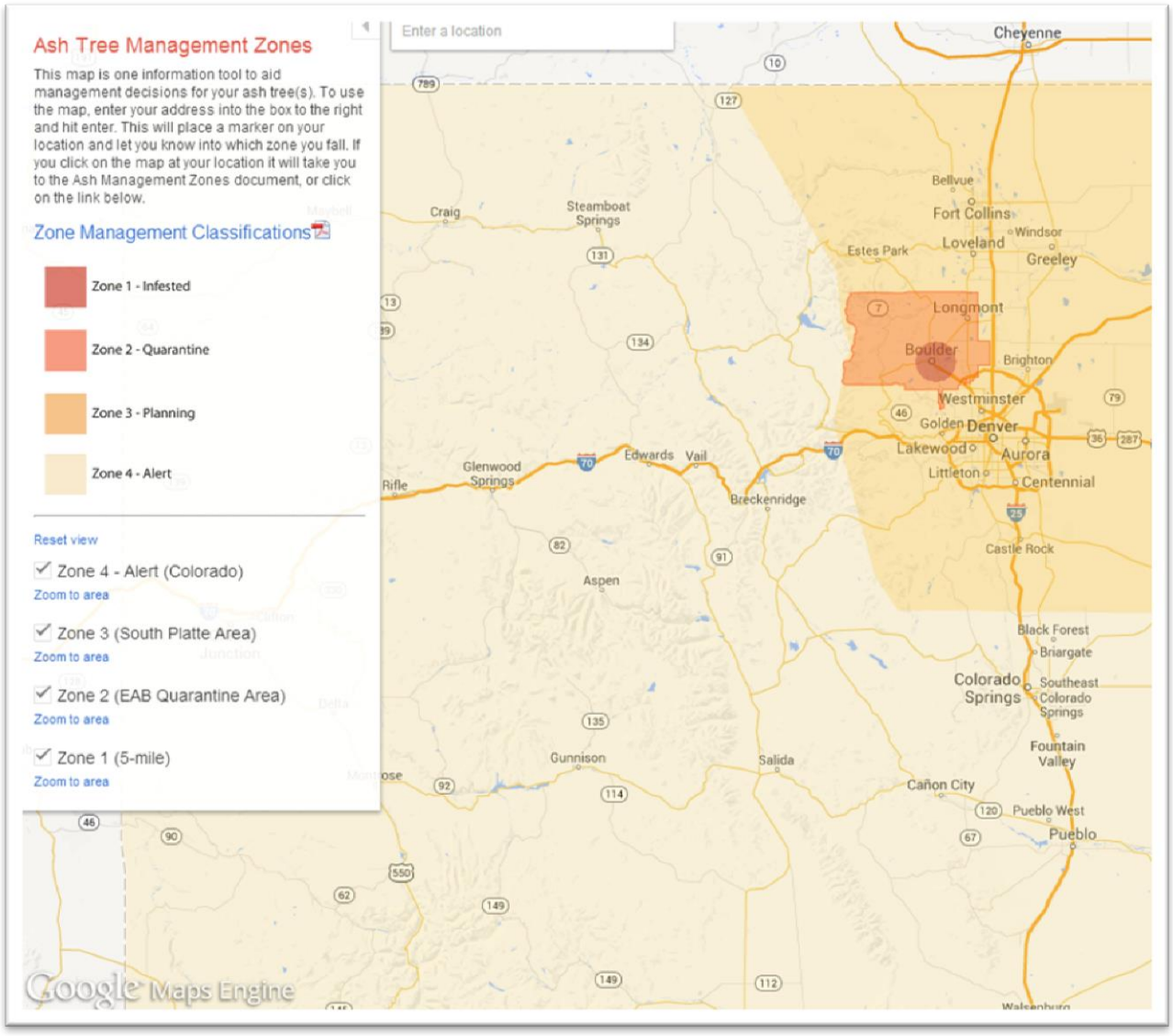
This document was developed by Annemarie M. Nagle and Cliff Sadof from Purdue University along with the Indiana Department of Natual Resources.

EAB Ash Management Zones

Interactive Map

Colorado Department of Agriculture

https://mapsengine.google.com/06606903391052419324-13464369061086462890-4/mapview/?authuser=0



Control Options for Emerald Ash Borer in Colorado

Colorado State University Extension

Introduction – Some Common Questions Related to the Control of Emerald Ash Borer

www.eabcolorado.com

Introduction

Some Common Questions Related to the Control of Emerald Ash Borer (EAB)

Adult of the emerald ash borer. Photograph courtesy of Howard Russell/Michigan State University and BugWood.org.

Why should I try to control emerald ash borer? Emerald ash borer (EAB), *Agrilus planipennis*, is an extremely destructive insect of ash trees (*Fraxinus* species), including the kinds of ash (green ash, white ash) that are widely planted in Colorado. It is far more damaging to trees than any other insect that previously has been found in the state and, as populations of the insect increase in the infested areas, it very likely ultimately will kill any unprotected ash trees.

Emerald ash borer is a species native to parts of eastern Asia that was accidentally introduced into North America, probably sometime in the 1990s. It is not a very damaging insect in its native land, where the ash species that grow there have evolved resistance to it and natural controls limit its injury.

Ash trees showing advanced thinning due to effects of emerald ash borer feeding injuries. This photograph was taken in Michigan in 2002, the first year emerald ash borer was detected in North America. Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

Unfortunately the species of ash that are native to North America have very little resistance to this new pest and emerald ash borer is devastating to the kinds of ash trees grown in the state. In the Midwest and eastern areas of North America where this insect has been present for several years, EAB has already killed many millions of ash trees. It is expected that emerald ash borer will ultimately kill almost every unprotected ash tree presently growing in North America.

I have treated my ash trees in the past for borers. Wasn't this for the emerald ash borer?

Lilac/ash borer larvae and associated damaged under the bark of ash. This insect has long been present in Colorado and has often been known as the 'ash borer'. It is far less damaging to ash trees than is the emerald ash borer. Photograph by David Leatherman/Colorado State Forest Service, retired.

There are several insects that are native to North America, long present in Colorado, and that tunnel into trunks and limbs of ash. Most commonly encountered is the **lilac/ash borer** (*Podosesia syringae*) a type of wood boring caterpillar that usually tunnels into the lower trunk of the tree. Various **ash bark beetles** (*Hylesinus* species) are fairly common in branches, particularly those that are damaged or overshaded. Some other insects that may be found occasionally tunneling limbs of ash include the **flatheaded appletree borer** (*Chrysobothris femorata*) and **redheaded ash borer** (*Neoclytus acuminatus*).

These are all insects that are normal residents of ash trees. Most cause very little damage and may only be found in trees or limbs that are suffering from serious stress or injury. Of these native, wood boring insects of ash, the lilac/ash borer is potentially the most injurious. However, the damage potential of the emerald ash borer far exceeds any of these other insects.

Larva of the emerald ash borer. Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

How fast does emerald ash borer kill ash trees?

Emerald ash borer damages trees by tunneling areas under the bark, producing girdling wounds that interfere with movement of water and nutrients. The damage is progressive, with more effects of infestation becoming visible as increasing numbers of insects develop within and damage the plant.

Extensive larval tunneling in an ash tree killed by emerald ash borer. Photograph courtesy of Eric Day/VPI & SU and BugWood.org.

When emerald ash borer first arrives and becomes established in a neighborhood it is usually present in low numbers and is very difficult to detect. However, they survive and reproduce well so that populations build steadily and within a few years it may be possible to observe some external evidence of infestation. A thinning of the leaf canopy is the most consistent symptom associated with EAB injury.

Often, about the time symptoms first become noticeable the populations of EAB explode in numbers and damage accelerates greatly. During this period of peak outbreak even trees that previously appeared healthy may die within just a couple of years.

Where is emerald ash borer found in North America?

'EAB tree #1', the first tree in Colorado where emerald ash borer was detected, in Boulder, in September 2013. Photograph by Whitney Cranshaw/Colorado State University.

Emerald ash borer was originally detected in southern Michigan in 2002. It has since spread rapidly and, by the end of 2013, has been detected in 22 states and two provinces. Colorado is the most recent state where this insect has been detected, being found in Boulder in September 2013. It is also the first state in the western US where EAB has been detected.

At present (winter 2014) Boulder is the only place within Colorado where EAB has been detected. However, the insect will spread in the upcoming years and it is reasonable to expect that essentially all of northeastern Colorado will be infested within a decade.

An ash tree across the street from 'EAB tree #1'. This tree has been infested for several years and is showing EAB-related canopy thinning. Photograph by Whitney Cranshaw/Colorado State

Also, with greater attention being given to this insect following the Boulder detection, it is now much more likely that any other infestations in the state, if any, may be identified. Any needed updates on the distribution of emerald ash borer in Colorado will be made available through several outlets, including the Colorado Department of Agriculture site at www.eabcolorado.com

How does emerald ash borer spread? The adult beetle can fly and that is how it spreads naturally. Normally they will fly only short distances, staying in the near vicinity of the tree from which they developed.However, some will fly longer distances and, with the aid of favorable winds, it is possible that a few may fly several miles if the right conditions come together. This natural spread will cause the present outbreak of EAB to expand beyond Boulder in the next few years to progressively encompass the areas of the state within the South Platte Drainage. This includes the greater Denver Metro area, Fort Collins, Greeley and all the communities further downriver.

Adult of the emerald ash borer with wings spread showing the purple abdomen. Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

However, emerald ash borer can also be spread if it is carried by humans. Transport of firewood or other ash materials harboring live emerald ash borers is the way that this insect is carried over long distances. This is undoubtedly the means by which it carried across the eastern plains and was introduced into Boulder, an event which seems to have occurred at least four years prior to its detection.

Geographic barriers present in Colorado, notably mountains and large expanses of ash-free forest, can be expected to prevent natural spread of EAB to much of Colorado outside the South Platte drainage. As a result these areas of the state (outside the South Platte drainage) remain no more-nor less-at risk of emerald ash borer infestation than they were before the Boulder detection. However, the entire state will always be at risk of the insect being introduced on infested firewood or other material containing live EAB that originated from some area where this insect is present. National quarantines of infested counties (including Boulder County in Colorado) are in place to try and prevent this type of human-assisted spread of EAB.

Can plants recover from injury by emerald ash borer? Trees can recover from EAB injury–to a point. If one attempts to control EAB with insecticides it is most likely to be effective if the ash tree is still relatively healthy. If trees have already sustained EAB injuries that have caused the leaf canopy to thin 30-50%, it is probably too late to save the tree.

This is because most of the insecticides used for EAB control act systemically—the insecticide must be transported within the tree. In other words, a tree must be healthy enough to carry a systemic insecticide up the trunk and into the branches and canopy. When EAB larvae feed, their galleries injure the phloem and xylem that make up the plant's circulatory system. This interferes with the ability of the tree to transport nutrients and water, as well as insecticides. As a tree becomes more and more infested, the injury becomes more extensive. When damage has progressed too far, insecticides can no longer move within the tree in a manner to provide effective EAB control.

An ash tree that is showing epicormic branching on the trunk. Epicormic branching occurs when normal movement of nutrients and water is disrupted, such as occurs with the wounding produced by emerald ash borer. Photograph courtesy of Edward Czerwinski/Ontario Ministry of Natural Resources and BugWood.org.

Often if the canopy of a tree is already declining when insecticide treatments are initiated, the condition of the tree may continue to deteriorate during the first year of treatment. When effective controls are applied, in many cases, the tree canopy will begin to improve in the second year of treatment. This lag in the reversal of canopy decline probably reflects the time needed for the tree to repair its vascular system after the EAB infestation has been reduced.

Are there treatments to control emerald ash borer? There are several treatments that have been identified that can be used to manage emerald ash borer. All involve the use of insecticides which have to be applied on an annual or biannual basis to maintain control. These treatments are the subject of this publication and are discussed below.

What are the effects of these insecticides on other insects, birds, mammals, etc.? The best summary of the subject presently available is the sheet *Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used To Control Emerald Ash Borer* (www.emeraldashborer.info/files/Potential_Side_Effects_of_EAB_Insecticides_FAQ.pdf) This was prepared by University Extension and research scientists from the Midwest and it attempts to answer the most commonly asked questions on this subject based on the information that is known.

Are there biological controls useful for control of emerald ash borer? In the areas of Asia where emerald ash borer is native there are several important natural controls at work. Most important are defenses produced by the trees, which protect them from attacks of invading organisms common to the region, such as emerald ash borer. In addition, there are numerous natural enemies, notably various species of parasitic wasps. Together, the inherent resistance of Asian species of ash combined with the natural enemies very effectively limit emerald ash borer so that it rarely causes serious damage.

Host plant resistance is largely absent from the native North American species of ash that we grow, and always will be, greatly undermining the potential of natural controls. However, there is work being done by federal agencies to identify parasites of the emerald ash borer present in

Asia. Some of these have been found suitable for introduction and release into North America. Already a few of these introduced natural enemies have been released in EAB outbreak areas of the Midwest and in some cases they seem to have proved capable of establishing and reproducing.

This work with natural enemies is ongoing. It is hoped that natural enemies may be useful in helping to suppress EAB populations in the post-outbreak phase. If effective, these may then allow some reduction in the need for treatments in the future and, possibly, allow some of the remaining native ash to survive without treatment. Only preliminary information is presently available but, in a few years, we can expect there to be a much better understanding of how much potential they may have in suppressing emerald ash borer in North America.

At some point in the future it may be decided that some of the more promising natural enemies may be suitable for introduction into Colorado. This is a decision that will be done by state and federal agencies, who will consider not only the possible benefits of such introductions but also possible risks.

Should I try to control emerald ash borer? The decision on what to do about managing this insect will have to be done individually by every owner for every ash tree in an area where this insect becomes established. This calculation will have to consider all the costs of treatment and balance these against the costs associated with not attempting to control EAB injury. Often the most critical factor in these decisions will be how much the tree is valued.

Unfortunately there will be costs associated with this insect regardless of what choice is made. Trees that are infested with emerald ash borer that are untreated or ineffectively treated will die prematurely, requiring their removal and, often, the purchase of replacement trees.

Some models exist to attempt to determine the economic value of trees, such as the National Tree Benefit Calculator: www.treebenefits.com/calculator/ These can come up with figures on values related to benefits the trees provide in terms of air quality, shade, property value, etc. What they cannot capture is personal value of the tree to the owner.

When should I begin to treat for emerald ash borer? There can be some benefit to the health of the tree if treatments are applied to trees that are already infested or can be expected to be infested with emerald ash borer during the present growing season. However, since EAB is extremely difficult to detect in trees in early stages of infestation this decision will often have to be an educated guess, based on the information available on where the insect is known to be present within Colorado.

As of January 2014 EAB had only been found within a relatively confined area of the City of Boulder and overall EAB populations still appear to be low at these areas. Trees within the area of known EAB infestation, and up to a 5 mile radius of this infestation, may benefit from EAB treatment beginning in 2014. However, over time emerald ash borer will expand its distribution and an increasingly larger area will be determined to be infested with EAB. **As new infestations are detected, information on the distribution of the insect in Colorado will be updated. One source summarizing the distribution of this insect in the state that is useful**

to reference is the web site maintained by the Colorado Department of Agriculture: www.eabcolorado.com.

Since most EAB treatments provide control for one year or, at most, two years following application there is no benefit in treating a tree prior to when EAB is present.

When can I discontinue treatments for emerald ash borer? Once established at a location emerald ash borer can be expected to survive in the area as long as any ash trees remain. Therefore some management of emerald ash borer will be required for as long as one wishes to maintain the tree.

Controls will have to be particularly intensive during the period when the insect populations increase to high levels and many ash trees in the neighborhood decline rapidly and die. After this wave of ash tree mortality is past, and populations of remaining trees consist largely of those that were effectively treated, numbers of emerald ash borers can be expected to decline dramatically. In this post-outbreak period it may be possible to reduce treatment intensity, although some management will always be required. Several years from now, when the first areas of Colorado affected by EAB go into the post-outbreak phase, there should be considerably more information available as to how to manage this phase of the emerald ash borer infestation.

Generalized Life History of the Emerald Ash Borer

Emerald ash borer in Colorado has a life cycle that normally takes one year to complete. During winter the life stage present is a full grown larva (a type of flatheaded borer) that lives within a chamber cut into the outer sapwood of the wood.

Full grown larvae of emerald ash borer in the typical curled position they take during winter and prior to pupation. Photograph courtesy of Houping Liu/Michigan State University and BugWood.org.

Pupa of the emerald ash borer. Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

In spring it will transform to the pupal stage, during which it transitions to the ultimate adult form.

The adult, a type of metallic wood borer, emerges from the tree by cutting through the bark, producing a D-shaped exit hole. Adults of the emerald ash borer likely will normally begin to emerge in early–to-mid May, with peak emergence in June. However, there is some range in the time of beetle emergence, which may extend into midsummer.

(left) Emerald ash borer adults in process of emerging from trunk. Photograph courtesy of Debbie Miller/USDA Forest Service and BugWood.org.

(right) Mating pair of emerald ash borers. Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

They then move to the crown of the tree where they feed on ash leaves, making small cuts along the edges of the leaves. After about a week of feeding, the now mature adults will begin to mate and a few days after mating females will begin to lay eggs. Eggs are laid on the surface of the bark, usually deposited singly into cracks and crevices. Females typically live for about a month and during this time will lay several dozen eggs.

Emerald ash borer eggs. Eggs are laid on bark and originally are white, darkening within a couple of days. Photograph courtesy of Debbie Miller/USDA Forest Service and BugWood.org.

Eggs hatch in about a week and the tiny, newly hatched larvae burrow through the bark. They enter and begin to feed on the tissues under the bark, the phloem, cambium and outer sapwood where they spend all of their larval life. During the course of feeding the larvae produce meandering galleries that progressively widen as the larvae grow. Ultimately the gallery produced by a single larva may range over an area ranging from 4 to 20" (10-50 cm) in length. Larvae feed until cooler fall temperatures arrive, when they prepare for overwintering by tunneling a bit deeper into the sapwood to produce the overwintering chamber.

Emerald ash borer larvae. The larvae are minute after egg hatch but grow steadily through the summer. Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

Larval tunnels produced by emerald ash borer. Such wounds interfere with the movement of water, nutrients – and systemic insecticides. Photograph by Art

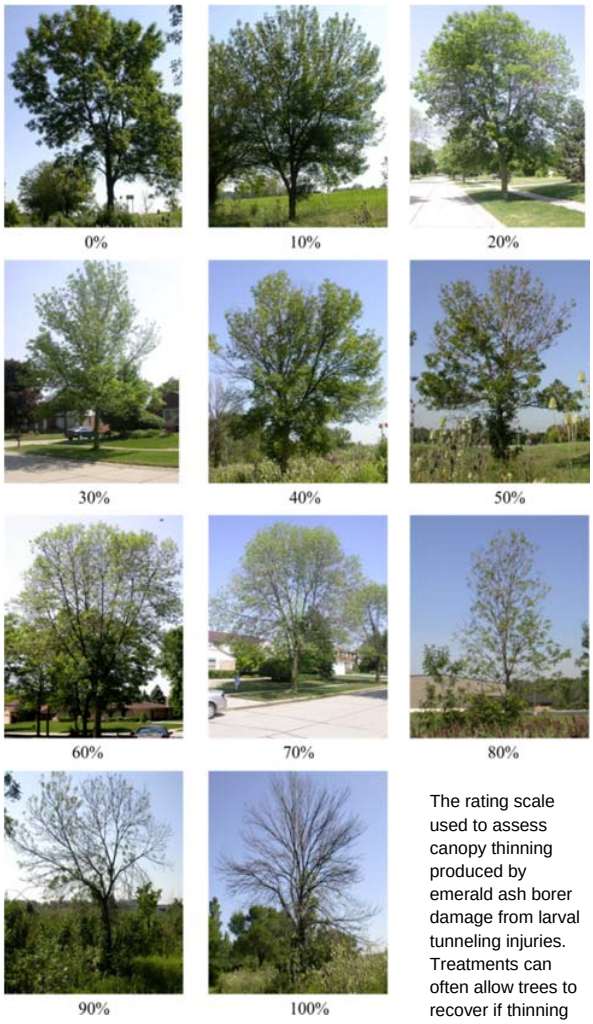
Nature of the Damage Produced by Emerald Ash Borer

Damage by the emerald ash borer is produced by the developing larvae, a type of flatheaded borer. They feed under the bark, chewing through the tissues of the phloem and outer sapwood of the tree, producing meandering tunnels that widen as the larvae grow.

These injuries interrupt the flow of water and nutrients through the tree. Continued infestation and damage cause progressive negative effects on the overall health of

the tree. As effects of injuries from EAB accumulate, external symptoms begin to appear, notably a thinning of the leaf canopy. Left untreated, infestations of EAB will progress to ultimately kill the tree.

Trees have some ability to repair injuries produced by EAB larval tunneling, forming callous tissues that overgrow damaged areas. The ability of trees to recover is related to tree health, with vigorously growing trees best able to produce some recovery. Trees in poor health from stress such as poor siting, drought and previous injuries may have very little ability to tolerate and repair EAB damage. However, during peak periods of outbreaks, when large numbers of EAB are present laying eggs on trees, even the most vigorously growing ash trees will be quickly overwhelmed by EAB attacks and will decline rapidly.



The rating scale used to assess canopy thinning produced by emerald ash borer damage from larval tunneling injuries. Treatments can often allow trees to recover if thinning has not exceeded 30-50%. This series of photographs was provided courtesy of David Smitley/Michigan State University.

The timely use of effective treatments for control of EAB can prevent much of the injury. And, to a point, treatments can stabilize the effects of past EAB injury. Where previous EAB injuries have not been too extensive and effective treatments are used, trees may recover. As a guideline, ash trees that are showing less than between 30-50% crown thinning as a result of EAB injuries may recover if effective treatments are employed; trees showing greater evidence of injury likely cannot be salvaged by any treatments.

Many factors will affect the speed that EAB will damage a tree. Initial tree health is one factor but most important is the size of the local EAB population. When EAB originally colonizes a neighborhood they are present in low numbers and trees may sustain little damage during this initial period of establishment. However, EAB populations build rapidly and often within 5 years of the initial infestation in a neighborhood very large numbers of EAB may be present. During this period, when EAB outbreaks peak, large number of eggs are laid and large amounts of injury may be done in a very short time. Trees may be so extensively damaged that they may die within a year or two during the outbreak phase.

The emerald ash borer is now a permanent resident in parts of northeastern Colorado, and, in areas where it is present, some control will have to be maintained for the life of any ash tree that the owner wishes to keep. However, after the peak outbreak passes and most ash trees have

been killed, EAB populations will drop dramatically. It is thought that at this time, after the peak outbreak, it may be possible to reduce treatment intensity and still maintain adequate control of new injuries.

Target EAB Stages for Control and Control Options

Controls used for EAB generally target two of the life stages. Adults can be killed as they feed on ash leaves on trees treated with insecticides effective against EAB. These treatments are best timed to be present in trees during the peak period of adult activity, which likely will occur sometime between mid-May and late June.

Emerald ash borer adult and associated chewing injury. Adults feed on leaves before they lay eggs and systemic insecticides can kill them during this period. Photograph courtesy of Debbie Miller/USDA Forest Service and BugWood.org.

Early stage larvae that tunnel under the bark can be killed with insecticides that move systemically in the tree to the tissues where they are feeding (phloem, outer sapwood). These treatments are optimally timed to be present when young larvae are present and before there has been extensive injury; prior injuries that disrupt movement of water and nutrients will similarly disrupt distribution of systemic insecticides. The peak period when early stage larvae are present will likely occur sometime between late May and early July.

Emerald ash borer egg just prior to hatch. After hatch the larva will begin to tunnel into the tree, ultimately settling below the bark where it spends most of its life. Photograph courtesy of Houping Liu/Michigan State University and BugWood.org.

In general there are four control approaches considered for use in management of emerald ash borer:

1. ***Soil applications of systemic insecticides.*** Two insecticides can be applied to the root system of ash trees and will subsequently be taken up by the roots–imidacloprid and dinotefuran.
2. ***Non-invasive systemic trunk sprays.*** The insecticide dinotefuran can be applied as a coarse spray onto the trunk of ash trees and will be absorbed through the bark.
3. ***Trunk injections with systemic insecticides***. Some insecticides can be injected into the lower trunk of trees and then will move systemically in the tree. These include emamectin benzoate, azadirachtin, and imidacloprid.
4. ***Persistent surface-applied contact insecticides.*** A standard method of controlling many borers and bark beetles is to apply a persistent insecticide onto the trunk and branches to kill adults as they lay eggs and to kill newly hatched larvae before they enter the plant. Various pyrethroid insecticides are usually used for this purpose (e.g., bifenthrin, cyfluthrin, permethrin).

Table 1. A Summary of Control Options Used for Emerald Ash Borer Control

Method of Application	Active Ingredient	Trade Names	Optimum Timing*	Notes
Soil drench, soil injection	imidacloprid	Merit®, Criterion®, Xytect®, Zenith®, Bandit®, several retail formulations	Around bud break	Relatively slow to move into tree so allow 4-6 weeks to reach highest levels in leaves. Soil must remain moist following application. Do not apply to any areas of soil where flowering plants that are visited by bees could pick up residues of the insecticide. Annual treatments required.
Soil drench, soil injection	dinotefuran	Safari®, Zylam®Transtect®	A few weeks after bud break, often mid-late May	Moves into plants faster than imidacloprid (2-3 weeks) so applications are later. Highly water soluble and should not be used if there is risk of leaching into water bodies or groundwater. Do not apply to any areas of soil where flowering plants that are visited by bees could pick up residues of the insecticide. Annual treatments required.
Systemic bark spray	dinotefuran	Safari®, Zylam®, Transtect®	A few weeks after bud break, often mid-late May	Moves into plants at effective levels within 2-3 weeks. Some, but not all, formulations suggest use of adjuvant. Do not allow drift onto any flowering plants that are visited by bees that could pick up residues. Annual treatments required.
Trunk injection	emamectin benzoate	TREE-Age®	Typically when adults are starting to emerge and lay eggs. However, long residual activity allows considerable latitude in application timing.	*Restricted Use Pesticide* due to acute toxicity. Biannual application. Has repeatedly demonstrated high level of control that can persist at least two years. Requires drilling holes into lower trunk.
Trunk injection	azadirachtin	TreeAzin®	Typically when adults are starting to emerge and lay eggs (May).	Natural product derived from neem tree seeds. Annual treatments likely to be required but there is some evidence of ability to control larvae in second year of application. Requires drilling holes into lower trunk.
Trunk injection	imidacloprid	Ima-Jet®, Imicide®, Pointer®, Xytect® Infusible	Typically when adults are starting to emerge and lay eggs (May).	Requires drilling holes into lower trunk (Ima-Jet, Imicide, Xytect) or injecting insecticide directly under bark (Pointer). Annual treatments required.
Residual bark, foliage spray	bifenthrin, permethrin, cyfluthrin	Onyx®, Astro®, Tempo®, many other formulations	Applied to bark when adults lay eggs and egg hatch. Applications to foliage can kill adults when they feed after emergence.	Requires whole tree sprays that cover bark to kill adults on bark and larvae as they hatch from eggs before they enter trees. Spraying foliage to kill adults can improve control. Two applications normally will be needed annually. High potential for drift. Non-systemic in plants and will not kill larvae under bark.

* The target life stages of the emerald ash borer with systemic insecticides (soil injections, soil drenches, systemic bark sprays with dinotefuran, trunk injections) are adults that feed on leaves after emergence and young larvae under the bark. The target life stages of the residual bark surface sprays with pyrethroid insecticides (bifenthrin, permethrin, cyfluthrin) are primarily adults when they are on bark and the larvae as they hatch from eggs before they enter trees. Application to the foliage can kill adults feeding on foliage before eggs are laid.

Soil Applications of Systemic Insecticides

Two insecticides that can move systemically in plants can be applied to the soil and will subsequently move in the plant to help manage emerald ash borer. Imidacloprid is most widely available, including formulations available through retail outlets. Dinotefuran is marketed solely to commercial applicators. A summary of the available products for soil treatment use is in Table 1 (above).

Table 2. Systemic insecticides used for control of emerald ash borer that are applied to the soil. Percent active ingredient is in parentheses ( ). Rates of use are specified on the label directions and all insecticides must be used only in a manner that is consistent with specified label uses. Links to the labels of commercially marketed formulations are provided (links tested January 10, 2014).

Imidacloprid-containing insecticides sold for use by commercial applicators

Criterion® 2F (21.4%) www.backedbybayer.com/lawn-and-landscape-management/insecticides/merit-2-f/label_and_sizes
Criterion® 75WSP (75%) www.backedbybayer.com/lawn-and-landscape-management/insecticides/merit-75-wsp/label_and_sizes
Lesco Bandit® 2F (21.4%) www.backedbybayer.com/lawn-and-landscape-management/insecticides/merit-2-f/label_and_sizes
Lesco Bandit® 75WSP (75%) www.backedbybayer.com/lawn-and-landscape-management/insecticides/merit-75-wsp/label_and_sizes
Merit® 2F (21.4%) www.backedbybayer.com/system/product/product_label_pdf/52/Merit-2F-432-1312-1-gal-110519AV1-SRL.pdf
Merit® 75WSP (75%) www.backedbybayer.com/lawn-and-landscape-management/insecticides/merit-75-wsp/label_and_sizes
Merit® 75WP (75%) www.backedbybayer.com/system/product/product_label_pdf/32/Merit-75-WP.pdf
Prokoz Zenith® 2F (21.4%) www.backedbybayer.com/lawn-and-landscape-management/insecticides/merit-2-f/label_and_sizes
Prokoz Zenith® 75WSP (75%) www.backedbybayer.com/lawn-and-landscape-management/insecticides/merit-75-wsp/label_and_sizes
Xytect® 2F (21.4%) www.treecarescience.com/pdf/Insecticides/Xytect-2F_Specimen_Label.pdf
Xytect® 75WSP (75%) www.treecarescience.com/pdf/Insecticides/Xytect-75-WSP_Specimen_Label.pdf

Imidacloprid-containing insecticides sold through retail outlets

Bayer® Advanced 12 Month Tree & Shrub Insect Control Concentrate (2.94%)
www.bayeradvanced.com/tree-shrub-care/products/12-month-tree-shrub-insect-control-landscape-formula/sizes
Bayer® Advanced 12 Month Tree & Shrub Protect & Feed (1.47%)
www.bayeradvanced.com/tree-shrub-care/products/12-month-tree-shrub-protect-feed/sizes
Bayer® Advanced 12 Month Tree & Shrub Protect & Feed Concentrate II (0.74% + 0.37% chlothianidin)
Bonide® Annual Tree and Shrub Control (with Systemaxx) (1.47%) www.bonide.com/lbonide/backlabels/l609.pdf
Ferti-lome® Tree and Shrub Systemic Insect Drench (1.47%)
www.fertilome.com/ProductFiles/10206%20Tree%20Shrub%20Systemic%20Insect%20Drench%20Approved%2003-26-12.pdf
Ortho Bug B gon Year-Long Tree & Shrub Insect Control (1.47%) www.scotts.com/smg/goprod/ortho-bug-b-gon-year-long-tree-and-shrub-insect-control/prod10700018/ (Note: This link is not the label, which is apparently unavailable on-line)

Dinotefuran-containing insecticides sold for use by commercial applicators

Safari® 20SG (20%) www.valent.com/Data/Labels/2012-SAF-0001%20Safai%2020%20SG%20-%20form%201510-D.pdf
Zylam® Liquid (10%) www.gordonsprofessional.com/pdfs/ZylamLiquid-SL.pdf
Transtect® 75WSP (75%) www.treecarescience.com/pdf/Insecticides/Transtect_Specimen_Label.pdf

Rates of use vary depending on the size of the tree. The diameter of the tree at breast height (DBH) is normally used as the measure of tree size and all formulations marketed for commercial application have label uses directions for amount to apply that is based on DBH. (DBH measurements are generally measured at 4.5 feet above the ground.) Most commercial formulations of imidacloprid (2F, 75WSP formulations) allow higher rates of use on larger trees (greater than 15 inches diameter). These higher rates are usually required to get consistent EAB control on large trees, which have a proportionately greater canopy and trunk volume than do small diameter trees.

Formulations of imidacloprid sold through retail outlets specify application rates that vary by *tree circumference* (about 3X tree diameter).

Both can be applied either as a soil drench or injected into the soil using special equipment for this latter type of application. With soil drench applications the amount of insecticide needed for the tree is premeasured and mixed with several gallons of water. It is then poured onto the soil at the base of the tree, within 2-3 feet of the trunk. If present, mulches and weed fabric barriers must be removed from the site where the insecticide is applied. Soil drench treatments cannot be applied to areas of soil where flowering plants are present that are visited by bees. If flowering plants are present at the base of the tree where treatments are applied (e.g., dandelion weeds, flowers planted at the base of the tree) alternative controls must be used.

Alternately these insecticides can be injected into the soil. This involves the use of specialized equipment that allows the injection of small amounts of diluted insecticide in

Altering Rates of Imidacloprid by Tree Size

Imidacloprid is the most widely accessible of the insecticides used for emerald ash borer and is primarily applied as a soil drench or injection early in the season around the time of bud break. It is then picked up by the roots of the tree and moves systemically to the leaves (where adults feed) and the phloem/sapwood area under the bark (where larvae feed).

All soil-applied imidacloprid products indicate that the amount of insecticide to be used varies by the size of the tree. This is normally determined by the trunk **d**iameter at **b**reast **h**eight (DBH). Retail formulations of imidacloprid sold through nurseries and hardware stores indicated rates of use based on trunk circumference.

Furthermore, all commercial formulations (2F, 75WSP) indicate a range of rates. For example, the 2F formulations normally allow uses of 0.1-0.2 fl. oz. of the product for each inch of trunk diameter. In this example the higher rate (0.2 fl. oz.) corresponds to what is often referred to in research trials as the "1X rate", which is equivalent to 1.4 grams of imidacloprid active ingredient per inch diameter.

Lower rates (1/2X-1X) are usually adequate for smaller ash trees, particularly when there are not large populations of EAB present. However, in larger trees, which have proportionately much greater volume, higher rates usually are needed to provide control of emerald ash borer. These higher rates—the "2X rate"—are allowed in trees exceeding 15 inches diameter and are recommended for control.

The amounts of various imidacloprid formulations that would provide a 1/2X, 1X, or 2X rate are summarized as follows:

1X Rate of Imidacloprid for Soil Application to Control Emerald Ash Borer

For the 75% Water Soluble Packet (75WSP) formulations: 1.6 oz (1 packet) for trees of 24 inches of cumulative trunk diameter (DBH)

For the Flowable (2F) formulations: 0.2 fl oz per inch of tree diameter (DBH)

For the Merit 75WP formulation: 1.4 teaspoons/inch trunk diameter (DBH)

2X Rate (Allowed only on trees exceeding 15 inches diameter)

For the 75% Water Soluble Packet (75WSP) formulations: 1.6 oz (1 packet) for trees of 12 inches of cumulative trunk diameter (DBH)

For the Flowable (2F) formulations: 0.4 fl oz per inch of tree diameter (DBH)

½X Rate (Generally used on smaller trees and when local infestations are low)

For the 75% Water Soluble Packet (75WSP) formulations: 1.6 oz (1 packet) for trees of 48 inches of cumulative trunk diameter (DBH)

For the Flowable (2F) formulations: 0.1 fl oz per inch of tree diameter (DBH)

For the Merit 75WP formulation: 0.7 teaspoons/inch trunk diameter (DBH)

For the 1.47% formulations sold at retail outlets: 1 fl. oz/inch of tree circumference*

Note: Rates of most formulations used for control of emerald ash borer as soil treatments are based on trunk diameter (DBH – diameter breast height) at 4.5 feet. * However, retail formulations (typically 1.47% active ingredient) have use directions based on *trunk circumference*.

multiple spots within the drip line of the tree. The use of soil injections avoids the presence of surface residues of the insecticide and allows the insecticide to bypass surface barriers (e.g., mulch, fabric barriers, thick layers of turfgrass thatch) that may prevent the insecticide from sufficiently reaching the root system of the tree.

An application of a systemic insecticide being applied as a soil drench to the base of a tree. Photograph courtesy of University of California Statewide IPM Program.

The optimum timing of treatment depends on the product being used. Imidacloprid is relatively less water soluble and mobile in plants than is dinotefuran, but persists considerably longer. It is often best applied around the time of bud break or within a couple weeks after bud break–levels of insecticide needed to control EAB can be expected to be present in ash foliage about 3-6 weeks after application. Dinotefuran will be absorbed and mobilized in the plant much quicker, typically being present in foliage at sufficient levels for EAB control within 2-3 weeks after application. Soil applications of dinotefuran are therefore best applied a few weeks later than imidacloprid, typically in mid-May through early June. (Note: Trees will not begin to absorb and translocate any insecticides until leaves are present and water is moving through the plant for transpiration.)

Regardless of method of application, following treatment *the area where the insecticide was applied must be irrigated sufficiently to remain moist enough so that roots of the trees can absorb the insecticide*; soil applied insecticides will not be adequately taken up by plants from dry soil. The treated site should remain moist for at least two weeks following application. Excessive irrigation that saturates soils for long periods and/or allows run-off should be avoided as it will decrease uptake, and may cause insecticide to leach into groundwater or run-off the site. (Dinotefuran, being much more water soluble, carries far greater risks of run-off and leaching into groundwater than does imidacloprid.)

There is a restriction on the amount of imidacloprid that can be used on an area basis. Total use per year is limited to 0.4 lbs of imidacloprid (active ingredient)/acre.


A systemic insecticide (dinotefuran) being applied as a non-invasive trunk spray. Photograph courtesy of Utah State University IPM Program.

Non-invasive Systemic Trunk Sprays

The systemic insecticide dinotefuran (Safari®, Zylam®, Transtect®) can be applied as a coarse spray onto the trunk. It is a highly water soluble insecticide and is quite mobile in plants, which allows it to be absorbed through the bark where it can then be moved through the tree to provide control. Under favorable

conditions it can be expected within 2-3 weeks after application to move into leaves in sufficient concentration to kill emerald ash borer adults feeding on leaves. It also will distribute to areas under the bark where larval stages of the emerald ash borer feed.

Rates of use are based on tree size (DBH) and a range of rates are listed on labels. Although not specified on labels, the higher rates are likely more appropriate on the larger diameter trees with thicker bark, whereas lower rates can be effectively used on smaller trees with thinner bark.

The use of a surfactant is included in the label directions of some formulations (e.g., Zylam) but not others. Surfactants may be useful in improving coverage and allowing the applied insecticide to move into the bark fissures where it is more readily absorbed by the tree.

Optimum timing of the dinotefuran trunk sprays for EAB control would be in the period beginning a couple weeks after bud break. Although it is readily absorbed by the tree, dinotefuran is less persistent than are the other systemic insecticide used for EAB control, and treatments made too early in the season may diminish in concentration during periods when emerald ash borer is active later in the season.

There is a restriction on the amount of dinotefuran that can be used on an area basis. Total use per year is limited to 0.54 lbs of dinotefuran (active ingredient)/acre.

Limits on the Maximum Use of Imidacloprid and Dinotefuran for Emerald Ash Borer Control

The use of injected systemic insecticides to trees always involves relatively high amounts of insecticide be applied/plant. Furthermore, most of the insecticides used in this manner–whether soil applied, trunk banded or trunk injected–do specify maximum amounts of the active ingredient that can be used on an area (acre) basis.

To date this has rarely, if ever, been a problem in Colorado since the maximum amounts of use have not been met by the suite of insect problems for which these insecticides have been applied in the past. However, with the establishment of emerald ash borer, and the treatments that will be used for its management, there will very likely be conflicts in this area. These will involve two of the systemic insecticides that are used for control, imidacloprid (Merit, Zenith, Xytect, etc.) and dinotefuran (Safari, Zylam, Transtect).

Imidacloprid. This is likely to be the most commonly used insecticide for emerald ash borer due to cost, effectiveness, and ease of use. It will be applied primarily as a soil drench/soil injection treatment; trunk injections may be a minor use. Application rates will typically be at the "1X" rate of 1.4 grams ai/inch of trunk diameter. On larger trees above 15 inches diameter the 2X rate is recommended. Homeowner/retail products of imidacloprid appear to allow a rate of use of about 1/2X.

The maximum rate of imidacloprid allowed per acre per year is 0.4 lbs, from all uses in a year. If imidacloprid is applied at the 1X rate the maximum amount of imidacloprid allowed per year is the amount that would be used to treat ash trees of a cumulative diameter (DBH) of 126 inches. At the 2X rate, required for larger trees, the maximum amount is met at when trees of a cumulative diameter of 63 inches are treated (e.g., 2 or 3 trees).

Dinotefuran. Dinotefuran will likely be used primarily as a trunk band spray, applied as a drenching spray to the lower trunk for uptake through the bark. It is also labeled for use as a soil injection but its higher cost (relative to imidacloprid) – and high potential for leaching– will likely mean it is little used in this manner.

The maximum amount of dinotefuran that can be used is 0.54 lbs/acre/year. (This is equivalent to 2.7 lbs of the formulated Safari 20SG product or 79 fl oz of Zylam Liquid). A range of rates are labelled for trunk spray applications of dinotefuran products that would allow trees of cumulative diameter between 64-120 inches be treated with this product per acre in a single growing season.

Trunk Injections with Systemic Insecticides

Systemic insecticides can be applied to trees by injecting them into the trunk. Two insecticides used for control of emerald ash borer–TREE-Age® (emamectin benzoate) and TreeAzin®

(azadirachtin) can only be used for EAB control when injected. Imidacloprid, most commonly used as a soil treatment for EAB control, can also be trunk injected (IMA-jet, Imicide, Pointer®, Zytect Infusible).

A systemic insecticide being injected into the soil near the base of a tree. Photograph courtesy of Utah State University IPM Program.

Trunk injected insecticides are most often applied by drilling holes into the base of the tree, typically at intervals of about 6 inches. The insecticides flow into the trees either from a series of individual capsules or a reservoir of insecticide used to treat the entire tree. Most applications are designed to allow the insecticide to flow fairly passively into the tree with minimal pressurization, although one system (Arbor-jet) uses a system of sustained pressurization. The Wedgle® system, involving Pointer®, injects small amounts directly under the bark without drilling.

Injecting trees correctly requires considerable skill so that the insecticide may flow readily into the tree and to avoid excessive tree wounding. Trunk injections should only be done by licensed professional arborists with experience in the practice of injecting trees.Use of TREE-age® is further restricted being registered as a *Restricted Use Product*, which can only be used by a certified pesticide applicator or person under immediate supervision of a certified applicator.

Trunk injections require holes be drilled into the base of the tree. The insecticide is then injected into these openings. Photograph courtesy of Bob Hammon/Tri-River Extension, Colorado.

The tree wounding required by trunk injections is of some concern. Evidence from the Midwest indicates that trunk injection wounds usually close over rapidly as callous tissues overgrow the wounded area. The ability to close over wounds will be related to the overall health of the tree, with more vigorous trees most capable of producing rapid wound closure. Slow growing trees with little stored energy reserves, such as ash trees grown on sites where drought and heat stress are common, can be expected to have poorer capacity to close over trunk injection wounds.

Trunk injection using the Arbor-jet system. For emerald ash borer control this is usually used to apply the insecticide TREE-Age® (emamectin benzoate). Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

Trunk injected insecticides often can move rapidly into and through plants. Thus they are often best applied at some point after EAB adults have begun to emerge, are feeding on leaves, and are beginning to lay eggs. However, since all the insecticides used

as trunk injections can persist for months and can kill young larvae as well as adults, optimal treatment timing may occur over a several week period.

Another consideration of when to apply trunk injected insecticides is whether conditions exist for rapid uptake of the treatments during application and their subsequent movement through the plant. This occurs most rapidly when plants are actively transpiring (moving water through the plant and evaporating it through leaves and stems.) Conditions that favor transpiration include soil that is sufficiently moist, soil temperatures are above 45°F, and ambient air temperatures are between 40° to 90°F. Uptake of the insecticide and movement within the tree will be slow if soils are too dry (or persistently saturated), temperatures are too cold or too hot, and significant transpiration does not occur in the dormant season when leaves are not present.

Trunk injection using the EcoJet system, which applies the emerald ash borer treatment TreeAzin® (azadirachtin). Photograph courtesy of Paul Bolan/BioForest Technologies, Inc.

The length of time these trunk injected insecticides can provide control varies by product. Imidacloprid trunk injections can provide control for a single season, as do the more commonly used soil applications of this product. At the other extreme, TREE-age® (emamectin benzoate) has been shown to consistently provide a very high level of EAB control for two years following application. TreeAzin® (azadirachtin), a product more recently marketed and used in the U.S., seems to provide intermediate persistence, showing some ability to control EAB larvae the year following application.

Persistent Surface-Applied Contact Insecticides

Insecticides can be sprayed on the trunk, branches and (depending on the label) foliage to kill adult EAB beetles as they feed on ash leaves, and newly hatched larvae as they chew through the bark. Thorough coverage is essential for best results. Products that have been evaluated as cover sprays for control of EAB include some specific formulations of permethrin, bifenthrin, cyfluthrin, and carbaryl. Protective cover sprays are designed to prevent EAB from entering the tree and, unlike the control options with systemic activity, will have no effect on larvae feeding under the bark.

Trunk injection using the Mauget system. For emerald ash borer control this is usually used to apply the insecticide Imicide (imidacloprid). Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

Cover sprays should be timed to occur when most adult beetles are feeding and beginning to lay eggs. Adult activity can be difficult to monitor because there are no effective pheromone traps for EAB. However, first emergence of EAB adults generally occurs between 450-550 degree days (starting date of January 1, base temperature of 50˚F), which in the Midwest

corresponds well with full bloom of black locust (*Robinia pseudoacacia*). Generally two applications have to be applied during late spring/early summer to maintain adequate coverage throughout the period when emerald ash borer is present on trees, laying eggs and eggs are hatching.

It must be noted that spraying large trees is likely to result in a considerable amount of insecticide drift, even when conditions are ideal. Drift and potential effects of insecticides on non-target organisms should be considered when selecting options for EAB control and the use of whole tree spraying increases many of these risks to non-target organisms, in comparison with other EAB control options.

Acknowledgements. *The primary document used to prepare this publication was the excellent North Central IPM Center Bulletin Insecticide options for protecting ash trees from emerald ash borer. Many sections were borrowed, in whole or with modifications, from this publication which can be viewed in its entirety at:*
www.emeraldashborer.info/files/multistate_eab_insecticide_fact_sheet.pdf

Prepared by Whitney Cranshaw, Colorado State University. February, 2014. Please forward comments, suggestions for improvements to Whitney.Cranshaw@ColoState.EDU

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Handling of Regulated Ash Material from an Emerald Ash Borer Quarantined Area

Frequently asked questions about Emerald Ash Borer Compliance Agreements and the Handling of EAB regulated materials:

Q. What is a Compliance Agreement?

A. A Compliance Agreement is a document that describes how a company will properly treat regulated articles to mitigate the spread of EAB and adhere to the quarantine law. A USDA APHIS or CDA representative is available to discuss Compliance Agreements in more detail at the request of any business or other entity involved in moving regulated articles. USDA APHIS or CDA can provide training on EAB and also help determine how any business can lower the risk of spreading EAB with the least amount of disruption to business practices.

Q. Do I need a Compliance Agreement?

A. If you are moving regulated articles (e.g., ash material or hardwood firewood) out of a quarantine area you will need a Compliance Agreement. Ash material that originates from a non-quarantine county and transits the quarantine may require a Compliance Agreement, and it is recommended you contact CDA for further information.

Q. How do I get a Compliance Agreement?

A. You can contact CDA at 303-239-4152, or e-mail Cheryl Vestal at Cheryl.vestal@state.co.us. CDA official will work with you to determine which Compliance Agreements, if any, are needed, explain the requirements, and work with you to implement any needed quarantine restrictions.

Q. Why is all hardwood firewood regulated instead of only ash firewood?

A. Once a log has been cut and split, it is extremely difficult to identify ash wood from other hardwood species. While this is especially true for the casual firewood user and homeowners, the experience of other EAB regulatory agencies across the nation have shown that the same has often applied to firewood businesses, too. Therefore, due to the potential risk associated with moving EAB-infested firewood, all hardwood firewood is regulated. There are no EAB quarantine restrictions on coniferous species of firewood, such as pine, spruce and fir.

Q. Does the quarantine affect movement of hardwood (non-ash) nursery stock or hardwood (non-ash) wood products?

A. In regards to EAB there are no restrictions on the intrastate movement of non-ash hardwood products such as nursery stock, logs, branches, green lumber or chips in Colorado. However, the movement of all hardwood firewood out of the quarantined county is regulated.

Q. Does the quarantine affect the movement of material within the quarantine areas?

A. There are no legal restrictions for the movement of regulated materials within the quarantine.

Q. What can I do with my ash material from a quarantined county?

A. There are multiple options available: see 'Handling of Regulated Ash Materials' handout

Ash material can be brought to a disposal site within the quarantine. Material can be utilized within the quarantine for any legal purpose.

If removing ash material or other regulate articles from the quarantine, the following options on 'Handling of Regulated Ash Materials' Compliance Agreements tables may be used but require a Compliance Agreement with CDA and / or USDA. We advise that this Compliance Agreement be in place before beginning processing operations.

Q. If I sign a Compliance Agreement, will I be required to keep records?

A. Yes. If your company ships regulated articles under a compliance agreement or with USDA APHIS or CDA certification, you will need to maintain those shipping and/or certification records for 36 months, unless otherwise specified.

Q. Do I have to keep records of shipments or treatments that do not involve regulated articles?

A. CDA does not require records for treatment or shipment of non- regulated articles.

Q. Can I bring firewood from a non-quarantined area into a quarantined area?

A. There are no legal restrictions on firewood that originates from a non-quarantined county. At this time only Boulder County is quarantined. Firewood is allowed to come into Boulder County from a non-quarantined county. Once the firewood enters into a quarantined area, it becomes a regulated article.

Q. If I have further questions about EAB or compliance agreements, or if I think I have found EAB, who do I contact?

A. For more EAB info: colorado.gov/ag/dpi or CAPS program manager John Kaltenbach-1-888-248-5535; caps.program@state.co.us

Compliance agreements- Cheryl Vestal-303-239-4152; cheryl.vestal@state.co.us

Compliance agreements are NOT required when:

- Ash wood products (logs, lumber, chips, and hardwood firewood) are moved within the Colorado Emerald Ash Borer Quarantine Area.

- The handling of ash wood products is completed outside the quarantine area (i.e. cutting, hauling, milling, etc.).

- Ash materials are moved from a non-quarantined area outside of the quarantined area to inside of the quarantine area.

The following procedures and schedules must be followed in order to meet USDA APHIS and the Colorado Department of Agriculture requirements. Treatment methods become important when applying for certificates or when receiving ash materials from an EAB quarantined area. These treatment schedules, if required, will be written into your compliance agreement.

Compliance Agreements will be needed for the following Handling and Treatment of Regulated Ash Materials:

Regulated Article	Mitigation and Treatment Measures
Firewood of all hardwood species	• Remove bark and an additional ½ inch of Wood1: wane-free(no edges corners with bark) • Kiln sterilization treatment (T404-b-4) • Heat treatment (T314-a) in a heat treatment facility approved by APHIS • Fumigate according to treatment schedule T404-b-1-1 (Methyl bromide fumigation at NAP-tarpaulin or chamber) • Apply an APHIS approved method[2]
Chips and Mulch of all hardwood species	• Chip or mulch to < 1" in at least two dimensions- may move w/ compliance agreement Chip or mulch to > 1" cannot be moved w/o treatment • Follow an APHIS approved mulching or composting protocol • Apply an APHIS approved method[2].
Nursery Stock of Fraxinus spp. itself	No treatment available. Nursery stock cannot be moved from a quarantined area.

Green lumber of Fraxinus spp. itself	• Remove bark and an additional ½ inch of Wood1: wane-free(no edges corners with bark) • Kiln sterilization treatment (T404-b-4) • Fumigate according to treatment schedule (404-b-1-1 (Methyl bromide fumigation at NAP-tarpaulin or chamber) • Apply an APHIS approved method[2]
Logs and lumber of Fraxinus spp. itself	• Remove bark and an additional ½ inch of Wood1: wane-free(no edges corners with bark) • Kiln drying treatment (T404-b-4) • Heat treatment (T314-a) in a heat treatmentfacility approved by APHIS • Fumigate according to treatment schedule T404-b-1-1 (Methyl bromide fumigation at NAP-tarpaulin or chamber) • Apply an APHIS approved method[2]
Other material including wood waste, living, dead, cut or falling including stumps, roots, branches of Fraxinus spp.	• Chip or mulch to less than one inch in at least two dimensions • Apply an APHIS approved method[2] .
WPM containing regulated green lumber, including but not limited to, dunnage, crating, pallets, packing blocks, drums, cases, and skids.	• ISPM accredited treatments • Treatment/mitigations for green lumber of Fraxinus spp. itself as listed above • Apply an APHIS approved method[2]
[1] The bark and wood removed will be regulated separately. If intended for interstate movement the removed bark and wood must be treated as described in Table 1 for chips and mulch. If produced at a mill located outside the quarantine area but approved to handle green ash logs or lumber from within the quarantine area, wood waste must be treated or destroyed prior to adult flight season. [2] Consult a local USDA APHIS Official at 303-371-3355 or Cheryl Vestal-303-2239-4152; cheryl.vestal@state.co.us	
Detailed specifications for treatments can be found in the current edition of the PPQ Treatment Manual online at: http://www.aphis.usda.gov/import_export/plants/manuals/ports/treatment.shtml	

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Approved Treatments for Handling Regulated Ash Materials

Composting Requirements for Ash Material from an Emerald Ash Borer Quarantined Area

This protocol is used to treat hardwood and bark chips, nuggets, and mulch material that are larger than 1.00 inch (2.54 cm) in any dimension.

Compost using the following procedure:

1) Compost piles must be a minimum of 200 cubic yards.
2) Internal temperature at a depth of 18 inches must reach 140 degrees F (60 degrees C) for four consecutive days.
3) Using a front end loader or a bulldozer, remover the outer layer of the compost pile to a depth of three feet.
4) Start a second compost pile using the recently removed cover material as a core.
5) Move the core material from the first compost pile and place on the second compost pipe as a cover at least three feet deep.
6) Allow the second compost pile to remain undisturbed until the temperature reaches 140 degrees F (60 degrees C for at least four continuous days.)
7) Remove the second compost pile and use as fully composted material.

This procedure will allow continuous operation. After the first compost pile is “turned” to become the second compost pile, a new “first” compost pile can be started.

Material that meets these criteria may be moved outside of a quarantined area with a compliance agreement.

Mulch Sampling Protocol

Size Requirements and Screening Procedure for Hardwood Mulch and Chips in the Emerald Ash Borer Quarantine Area

The following procedure should be followed to determine if hardwood and bark chips, nuggets, and mulch materials can be considered safe for movement from the emerald ash borer quarantine area:

Step 1. Using a 12 inch diameter 3.25 inch deep sieve with 1.25 inch steel mesh openings (Fisher Scientific #04-884-1J) take 10 samples from random locations in the chip or mulch pile - - do not take all samples from the same location. If any chips are found that are greater than 2.5 inches in two dimensions the pile is rejected. If there are no chips found greater than 2.5 inches in two dimensions then proceed to Step 2.

Step 2. If four or more chips from the 10 samples do not pass through the sieve proceed to Step 3. If three or fewer chips from the 10 samples do not pass through the sieve, then the pile passes and can be moved.

Step 3. Resample. Take 10 additional samples from random locations in the chip pile. If any chips are found that are greater than 2.5 inches in two dimensions the pile is rejected. If there are no chips found greater than 2.5 inches then proceed to Step 4.

Step 4. If four or more chips from the 10 samples do not pass through/put through the sieve the pile is rejected. If three or fewer chips fail to pass through the sieve then the pile passes and can be moved.

Note: Mulch chips that do not meet the specified requirements as outlined above may be reground to meet this specification of 1 inch in two dimensions or alternatively composted.

Kiln Sterilization Treatment Schedule
(Used primarily for treating green lumber)

Treatment: T404-b-4 Kiln Sterilization

Note: When using this treatment method for interstate movement (i.e. moving ash wood products from the Colorado quarantine area to another state) the process will need to be certified by UDDA APHIS PPQ personnel. This should be done before the first treatment; otherwise the process will have to be repeated after being certified.

Dry Bulb Temperatures	Wet Bulb Temperatures	Relative Humidity	Moisture Content	Thickness of Lumber	Exposure Time
140° F	7° F	82%	13.8%	1 inch	3 hours
				2 inches	5 hours
				3 inches	7 hours
130° F	16° F	60%	9.4%	1 inch	10 hours
				2inches	12 hours
				3 inches	14 hours

1) After kiln drying, the wood will be checked with a moisture meter to verify the wood is at or below the appropriate moisture content listed above. Two readings will be taken per stack of wood: one near the top of the stack and one near the bottom of the stack. These reading will be recorded in a computer database along with the date and time. This database information will be supplied to USDA, APHIS, PPQ on a monthly basis.

2) If the wood does not meet moisture content guidelines, it will NOT be in compliance unless it undergoes additional kiln drying and can then demonstrate that the moisture requirement has been met.

Fumigation Treatment Schedule
(Used primarily for treating veneer logs)

Treatment: T404-b-1-1 MB at NAP-tarpaulin or chamber

Temperature	Dosage Rate (lb.1,000 $ft^{3)}$	Minimum Concentration Readings (ounces) At:			
		0.5 hour	2 hours	4 hours	16 hours
70° F or above	3 pounds	36	30	27	25
40-69° F	5 pounds	60	51	46	42

Heat Treatment Schedule
(Used for treating firewood for EAB)

Treatment: T314-a Heat treatment

Note: When using this treatment method for intrastate or interstate movement the process will need to be certified by USDA APHIS or Colorado Department of Agriculture personnel. This should be done before the first treatment; otherwise the process will have to be repeated after being certified.

1) Heat treatment procedures may employ steam, hot water, kilns, or any other method that raises the temperature of the center of the wood to at least 140°F (60°C) and maintains the center temperature for at least 60 minutes.

2) Facilities, temperature monitors and temperature sensors will be approved by CPHST (Center for Plant Health and Science Technology) prior to a compliance agreement being initiated.

3) Compliance agreements must contain a diagram of the treatment facility to include at a minimum: dimensions, capacity, circulation fans, heat input location, and door locations.

4) The temperature monitoring equipment (thermocouples, temperature data loggers etc.) must be accurate to within +/- 0.5 °C (0.9 °F) at the treatment temperature, capable of collecting temperature data at least once every five (5) minutes and recording or storing data for 30 days. The temperature monitoring equipment must also be calibrated (by a source that can provide accreditation such as NIST) prior to facility certification tests and a minimum of once an annually thereafter. In addition, if a permanent temperature recording system is used, the system must be recalibrated when any part or portion of the system is repaired or replaced.

5) Temperature monitoring equipment must be able to provide a record of the treatment that identifies each sensor and indicates time and temperature.

6) Internal wood temperatures shall be obtained and verified by sensors located in the larger pieces of firewood at representative locations within the stack. The number of temperature sensing elements required per load will vary with the size of the load. The minimum requirement is four (4) sensors – one (1) for measuring air temperature and three (3) for

measuring internal wood temperature. For loads greater than 5,000 ft3 (142 m3) of wood, a minimum of one additional sensor for measuring internal wood temperature must be provided for each additional 2,000 ft3. For example, a load of 9,000 ft3 would require a total of six (6) sensors (one ambient air temperature sensor and five [3 + 2 additional sensors]). At least one sensor shall be placed in a large firewood piece in a portion of the load furthest away from initial heat circulation. Sensors will be placed in the wood in pre-drilled holes to measure core wood temperature. Probes are to be sealed into each hole with putty (electricians putty is recommended) to prevent reading ambient air temperature. Other recording arrangements may be considered if approved by CPHST.

7) Begin treatment when all the temperature sensors reach the threshold temperature of 140°F (60° C). Treatment will be complete when all temperature probe readings are at or above the threshold temperature for the entire 60 minutes.

8) Temperature equipment will be certified by USDA APHIS personnel at regular intervals (suggested monthly) except in those cases where a facility is inactive in excess of 2 months. Certification will occur before production activities resume.

www.emeraldashborer.info

Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used To Control Emerald Ash Borer

Jeffrey Hahn, Assistant Extension Entomologist, Department of Entomology, University of Minnesota
Daniel A. Herms, Professor, Department of Entomology, Ohio Agricultural Research and Development Center, The Ohio State University
Deborah G. McCullough, Professor, Department of Entomology and Department of Forestry, Michigan State University

What systemic insecticides are commonly used to protect ash trees from emerald ash borer (EAB)?

Systemic insecticides containing the active ingredients imidacloprid, dinotefuran or emamectin benzoate are commonly used to protect ash trees from EAB. All three are registered for agricultural use and have been designated by the Environmental Protection Agency as Reduced-Risk insecticides for certain uses on food crops. The most widely used insecticide in the world, imidacloprid has been utilized for many years to control pests of agricultural crops, turfgrass, and landscape plants. Because of its low toxicity to mammals, it is also used to control fleas and ticks on pets. Dinotefuran is a relatively new product that has properties similar to those of imidacloprid, but it has not been researched as thoroughly. Emamectin benzoate, derived from a naturally occurring soil bacterium, has been registered for more than 10 years as a foliar spray to control pests in vegetable and cotton fields and parasitic sea lice in salmon aquaculture. Similar products are used in veterinary medicine as wormers for dogs, horses, and other animals.

The invasive emerald ash borer has killed millions of ash trees in North America.

To control EAB, some products containing imidacloprid or dinotefuran are applied as a drench directly to the surface of the soil or injected a few inches under the soil surface. Dinotefuran can also be applied by spraying the bark on the lower five feet of the trunk. Emamectin benzoate and specific formulations of imidacloprid are injected directly into the base of the tree trunk. Systemic insecticides are transported within the vascular system of the tree from the roots and trunk to the branches and leaves. This reduces hazards such as drift of pesticide to non-target sites and applicator exposure that can be associated with spraying trees with broad-spectrum insecticides, and has less impact on beneficial insects and other non-target organisms. Many products registered for control of EAB can be applied only by licensed applicators. In all cases, the law requires that anybody applying pesticides comply with instructions and restrictions on the label.

Ash trees lining a street before (left) and after (right) they were decimated by EAB.

Precautions should be taken to prevent pesticides from reaching surface or groundwater.

Will systemic insecticides applied to the soil impact ground or surface water quality?

Several surveys have been conducted in the United States and Canada to monitor imidacloprid in surface and groundwater. Results indicate that imidacloprid is rarely detected in surface water in agricultural or urban areas. Similar monitoring studies have not been conducted with dinotefuran, which is more soluble in water. In the presence of sunlight, imidacloprid and dinotefuran are very unstable in water and degrade rapidly, which reduces their environmental risk to surface water.

When not exposed to light, imidacloprid and dinotefuran break down slowly in water, and thus have the potential to persist in groundwater for extended periods. In surveys of groundwater, imidacloprid was usually not detected. When detected, it was present at very low levels, mostly at concentrations less than 1 part per billion (ppb) with a maximum of 7 ppb, which are below levels of concern for human health. The detections have generally occurred in areas with porous rocky or sandy soils with little organic matter, where the risk of leaching is high — and/or where the water table was close to the surface.

Every precaution should be taken to protect surface and groundwater from pesticide contamination. Trunk-injected insecticides pose little risk to ground and surface water when used as directed because the material is placed inside the tree.

To protect groundwater, soil applications of systemic insecticides should be made immediately adjacent to the trunk of the tree, which increases uptake (and efficacy) because the high density of absorptive roots in this area filters the chemical from the soil. Systemic insecticides bind to varying degrees to organic matter, silt, and clay, which restricts their movement in soil. They should not be applied to porous sandy soils lacking organic matter, especially where the water table is shallow, or when heavy rain is predicted within the next 24 hours.

To protect surface water, systemic insecticides should not be applied to soil near ponds, lakes, or streams. Soil drenches should not be applied to sloped surfaces from which runoff can occur, nor should pesticides be misapplied carelessly to impervious surfaces such as sidewalks or streets, or otherwise allowed to reach conduits to surface water such as drains, ditches, or gutters.

The imidacloprid profile presented in the Extension Toxicology Network Pesticide Information concluded there is generally not a high risk of groundwater contamination when products are used as directed and appropriate precautions are taken. Similarly, the Canadian Water Quality Guidelines for the Protection of Aquatic Life noted that when imidacloprid is used correctly, it does not characteristically leach into deeper soil layers.

Will these insecticides impact aquatic organisms?

The toxicity of imidacloprid to aquatic life varies. Studies indicate it has low toxicity to fish, amphibians, and some aquatic invertebrates such as Daphnia (small aquatic crustaceans), but high toxicity to other invertebrates such as mysid shrimp (a salt water species) and larvae of some aquatic insects such as midges, black flies, and mosquitoes. Dinotefuran is not as thoroughly researched, but existing data reflect a pattern of toxicity similar to that of imidacloprid. Toxicity to fish and Daphnia is low, while mysid shrimp are sensitive. As previously noted, imidacloprid and dinotefuran are broken down rapidly in water when exposed to light. In the rare occasions when imidacloprid has been detected in surface water, the levels were too low (less than 1 ppb) to impact even sensitive aquatic organisms.

Imidacloprid soil injections have been widely used in ravines of Smoky Mountain National Park and other forested areas to control hemlock woolly adelgid, an invasive insect that is devastating hemlock trees in the Appalachian Mountains. A risk assessment prepared for the USDA Forest Service ("Imidacloprid — Human Health and Ecological Risk Assessment") concluded that these treatments pose negligible risk to aquatic organisms when applied as directed to clay or loam soils, and that even a worst-case scenario of a major spill of imidacloprid into a small pond would have negligible effects on fish, amphibians, or tolerant aquatic invertebrates. When used as directed, imidacloprid soil treatments for EAB control are unlikely to impact aquatic organisms.

What about insecticide residues in senesced leaves that fall from trees in autumn?

This question has not been thoroughly researched. One study conducted in experimental microcosms found that imidacloprid residues in senesced (dead) leaves from treated trees had no effect on microbial respiration or decomposition, or survival of leaf-shredding insects that decompose dead vegetation. Insect feeding rates were decreased by imidacloprid concentrations of 1.3 parts per million (ppm), while lower concentrations (0.8 ppm) had no effect. When leaf-shredding insects or earthworms were given senesced maple leaves with higher concentrations of imidacloprid (3-11 ppm), their feeding rates were reduced but their survival was not affected. In another microcosm study, imidacloprid inhibited breakdown of leaf litter, but foliar concentrations in this study (18-30 ppm fresh weight) were more than an order of magnitude higher than those reported in leaves from trees treated for EAB control. In all of these experiments, organisms were exposed only to leaves from treated trees. In many situations, leaves from treated ash trees would be mixed with senesced leaves of other species growing nearby.

Similar studies have not been conducted with emamectin benzoate, which is broken down rapidly by microbial activity and sunlight. Because of its short residual activity on the surface of leaves, it is considered a biorational insecticide compatible with integrated pest management programs, including biological control. These characteristics suggest that environmental impacts will be negligible as emamectin benzoate is released from decomposing leaves. Regulatory agencies concluded that foliar applications of emamectin benzoate to vegetable crops will have no adverse effects on ground or surface water, birds, mammals, fish, or aquatic invertebrates when used as directed.

Will these insecticides harm honey bees?

Ash trees are wind-pollinated and are not a nectar source for bees. Furthermore, ash flowers are produced early in the growing season and are present for only a limited number of days. It is highly unlikely that bees would be exposed to systemic insecticides applied to ash.

Flowering plants that are pollinated by bees or other insects should not be planted immediately adjacent to ash or other trees that will be treated with systemic insecticides applied to the soil, as they may also absorb insecticide. Honey bees and other insects can be affected when systemic insecticides

Honey bees and other pollinators can be harmed by insecticides applied to flowering plants.

are translocated to nectar and pollen. Imidacloprid is fatal to honey bees when it reaches high enough concentrations, and can have harmful sublethal effects at lower concentrations.

There has been much concern recently about the potential role of imidacloprid and related neonicotinoid insecticides in colony collapse disorder (CCD). Research is ongoing to investigate the relative effects of pesticides, bee pathogens and parasites, and nutrition on honey bee health. To date there are no conclusive answers, but researchers have not been able to establish a link between imidacloprid and CCD. Stronger evidence implicates a combination of pathogens as well as other pesticides used in hives to control pests that afflict bees.

Will these insecticides harm other insects?

All of the systemic insecticides used to control EAB will impact other species of insects that feed on treated ash trees. However, ash trees that are not treated will be killed by EAB, which will also impact these insects. Some products can affect many kinds of insects, while others affect only certain groups of insects. For example, emamectin benzoate has been shown to affect a broad range of plant-feeding insects. Products with imidacloprid generally have little effect on caterpillars, mites, and armored scales, but will impact most sawflies, leaf-feeding beetles, and sap-feeding insects such as aphids and soft scales. Studies have shown that beneficial insect predators and parasitoids — such as lady beetles, lacewings, and parasitic wasps — can be killed by indirect exposure to imidacloprid through their prey, or directly by feeding on nectar from treated plants. However, systemic insecticides are generally considered to have less impact on natural enemies than broad-spectrum insecticides applied as foliar or cover sprays.

Woodpeckers are important predators of overwintering EAB larvae.

Will these insecticides harm woodpeckers?

This is unlikely. Woodpeckers feed on live, mature EAB larvae, mostly in late fall, winter and early spring. Many of these mature larvae overwinter in the nonliving, outer bark where they will not be exposed to systemic insecticides. Imidacloprid, dinotefuran, and emamectin benzoate are much more toxic to insects than to birds that have been tested, and insecticide concentrations that have been measured in treated trees are far below the levels known to be toxic to birds. An EAB larva that has been killed by insecticide will desiccate quickly and decompose. There is little evidence that woodpeckers will feed on larval cadavers. Furthermore, living larvae that are suitable prey for woodpeckers will not have been exposed to a lethal dose of insecticide, and these products do not bio-accumulate in animals in the way that fat-soluble insecticides such as DDT do. In Michigan and Ohio, where EAB has been established for several years, many ash trees have been treated with systemic insecticides. There have been no reported cases of woodpecker poisoning caused by insecticides applied for control of EAB.

Does injecting insecticides into trunks injure the trees?

Drilling through the outer bark creates a wound in the tree. The response of the tree to these wounds is affected by factors such as the size and depth of the hole and the vigor of the tree. In recent studies, the injury associated with drilling holes and injecting two insecticide products (Imicide® applied with Mauget® capsules and TREE¨age™ applied with the Arborjet Tree IV™ and Quickjet™) into trunks of ash trees was examined. In nearly all cases, ash trees that were relatively healthy and properly injected showed little evidence of damage. New, healthy wood was produced over the injection sites and there was no evidence of pathogen infection, decay, or other signs of serious injury. Other devices used to inject ash trees generate wounds that differ from those caused by drilling discrete holes in the tree. However, their impact has not been thoroughly evaluated in research projects. We do know that untreated ash trees in areas with EAB infestations will eventually be killed.

Will treating ash trees result in development of resistance of EAB to insecticides?

This is highly unlikely. Pests typically evolve resistance to pesticides only in situations where a high proportion of the insect population was subjected to strong selection pressure. For example, pesticide resistance has evolved in insect and weed populations in agricultural fields, greenhouses, and grain storage bins where nearly all of the pest population was exposed to the pesticide. Ash trees are very common in many natural environments. Landscape trees represent a small fraction of all the ash that will be colonized by EAB in a given area, and only a small proportion of high-value trees will ever be treated to control EAB. Thus, most of the EAB population will never be exposed to insecticides. Because the selection pressure is so low, and there will be plenty of cross breeding with individuals that have never been exposed to insecticides, the risk of a resistant EAB population evolving is minimal.

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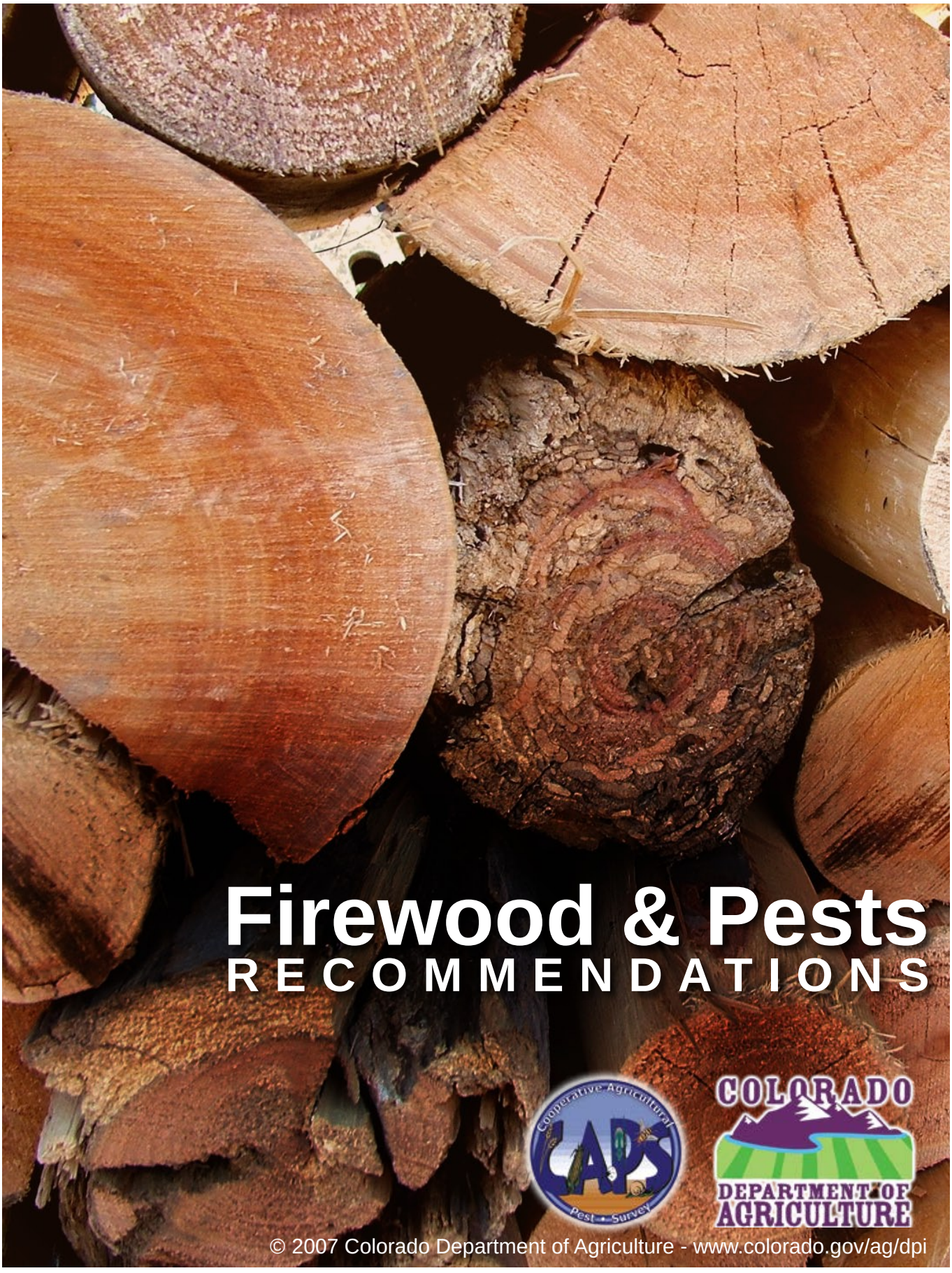


Firewood & Pests
RECOMMENDATIONS

Firewood & Pests Recommendations

from the Colorado Department of Agriculture's Cooperative Agricultural Pest Survey (CAPS)

To protect Colorado's trees from invasive and harmful tree pests, the CAPS program is recommending that people use firewood from Colorado whenever possible, and to always ensure that their firewood is properly seasoned (see below). In addition, when camping, people should try to buy firewood near their destination campground, to help prevent transporting pests elsewhere.

- **Colorado firewood**
  Exotic pests such as the emerald ash borer, gypsy moth, Asian longhorned beetle, Sirex woodwasp, and the water mold causing sudden oak death can be transported on or in firewood. To help keep these pests out of Colorado, we're encouraging people to use local firewood, rather than firewood from out of state. In the cases where local firewood does not meet the needs of the homeowner, we encourage people to ensure that their firewood has been properly seasoned at the point of origin (see below).

- **Cut, debark, and dry**
  Allowing adequate drying time of at least 1 year both improves the quality of the firewood, helps kill insects and pathogens in the firewood, and discourages re-infestation. Cutting (and properly stacking) the wood before drying significantly quickens the drying process. Debarking the firewood will help kill insects, remove egg masses, pupae, or fungal spores attached to the bark, and quicken the drying process. Debarking the firewood may be difficult for individuals to accomplish, but should be done whenever possible.

- **Buy where you camp**
  Colorado too has tree pests that are unwanted elsewhere, including mountain pine beetle and banded elm bark beetle, among others. To protect tree resources everywhere, we encourage people to buy firewood near their destination campground. If this is not an option, they should ensure that the firewood they take with them is well-seasoned and completely burned during their visit. Protect your favorite vacation spot, as well as your home.

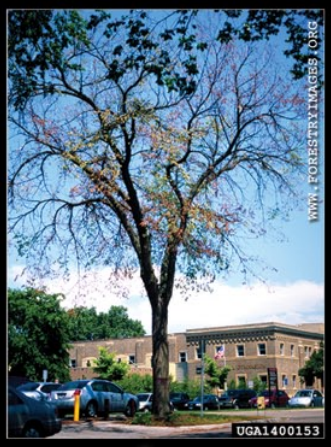
For additional information on firewood and the potential for spreading harmful exotic and native pests, we recommend the following websites:

CSU Extension:	http://www.ext.colostate.edu/pubs/insect/05563.html
Ohio State Univ. Extension:	http://ohioline.osu.edu/hyg-fact/2000/2065.html
USDA Forest Service:	http://www.na.fs.fed.us/fhp/eab/firewood/index.shtm
Firewood Buying Guidelines:	http://www.colorado.gov/ag/ics

For a listing of firewood dealers providing at least 50% of their wood product from Colorado forests, please go to the CDA Markets Division website at: http://www.colorado.gov/ag/markets

Buy It Where You Burn It!

DON'T TRANSPORT FIREWOOD



100 million elm killed by Dutch elm disease

Millions of hardwoods killed by gypsy moth

Over 50 million ash killed by emerald ash borer

Millions of pines threatened by European wood wasp

Transporting firewood can spread insects and diseases that KILL TREES.

It is unlawful to transport pests*

Please...buy firewood where you camp.

If you have firewood from out of state, please BURN IT IMMEDIATELY. Our forests thank you!

For more information contact:
Colorado Department of Agriculture at 303-239-4140,
Colorado State Forest Service at 970-491-6303, or
USDA APHIS PPQ at 303-371-3355.
*Colorado Revised Statute 35-4-108.

Coalition for Urban Ash Tree Conservation
- Emerald Ash Borer Management Statement -

www.emeraldashborer.info/files/conserve_ash.pdf

signed 06 Jan 2011

We the undersigned strongly endorse ash tree conservation as a fundamental component of integrated programs to manage emerald ash borer (EAB) in residential and municipal landscapes. Cost-effective, environmentally sound EAB treatment protocols are now available that can preserve ash trees through peak EAB outbreaks with healthy canopy intact. Used in association with tree inventories and strategic removal / replacement of unhealthy ash, tree conservation will help retain maximum integrity and value of urban forests. This integrated approach to urban EAB management is supported by university scientists with expertise in EAB management, commercial arborists, municipal foresters, public works officials, and non-governmental organizations (NGOs).

Emerald ash borer has killed millions of ash trees since its discovery in 2002 and the number of dead ash is increasing rapidly. Ash species are abundant in planted *and* natural areas of urban forests, representing 10 - 40% of the canopy cover in many communities.

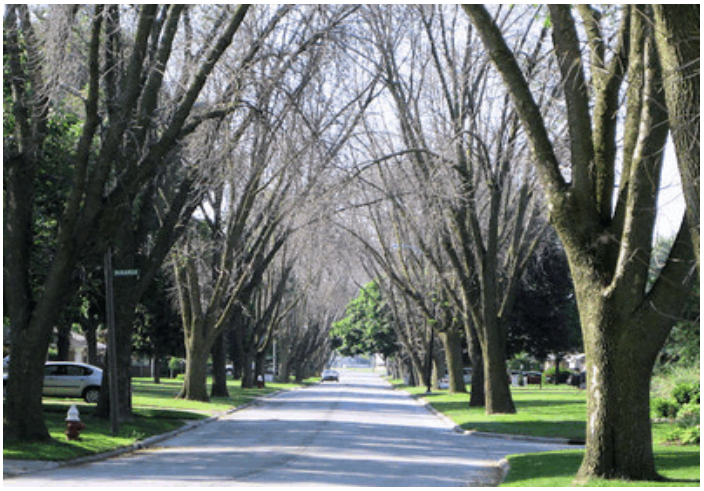
Ash trees provide substantial economic and ecosystem benefits to taxpayers, ranging from increased property value, to storm water mitigation, to decreased energy demands (http://www.coloradotrees.org/benefits.htm).

Consequently, widespread ash mortality in urban forests and residential landscapes is having devastating economic and environmental impacts. Indeed, EAB is predicted to cause an unprecedented $10-20 *billion* in losses to urban forests over the next 10 years. (http://ncrs.fs.fed.us/pubs/jrnl/2010/nrs_2010_kovacs_001.pdf)

After its initial discovery, regulatory agencies attempted to eradicate EAB through removal and destruction of all ash trees in infested areas. Unfortunately, this proved unsuccessful and was soon abandoned.

Since then, university scientists have developed and refined treatment protocols that can protect healthy ash trees from EAB and help conserve the urban forest.

Ash trees before EAB devastation -- Belvedere Dr., Toledo, OH, June 2006.



Untreated ash trees after EAB peak, Belvedere Dr., Toledo, OH, June 2009.

However, despite availability of cost-effective treatments, many municipalities, property managers, and homeowners continue to rationalize tree removal as the only viable management strategy for EAB. This is based on erroneous beliefs that tree removal slows the spread of EAB, or that treatment is not effective, economical, or environmentally sound. *Current science supports conservation via treatment as a sensible and effective tool for managing healthy ash trees in urban settings. In many cases, tree conservation is economically and environmentally superior to tree removal.*

Based on research conducted by university scientists, and careful review of the potential impacts on human health and the environment, the Environmental Protection Agency (EPA) has registered three systemic insecticides for control of EAB – dinotefuran is registered for basal trunk bark or soil application, emamectin benzoate for trunk injection only, and imidacloprid for soil application or trunk injection.

When applied *using formulations, products, and protocols documented as effective by university research,* these treatments can provide environmentally sound control of EAB, sufficient to maintain a functional and aesthetically pleasing ash canopy.

Treatment is most appropriate *after* EAB infestation has been detected within 15 miles, and is most effective when applied before trees are infested. However, treatment can also save ash trees with a low level of EAB infestation. Spring is the ideal time for treatment, but soil application in fall can be effective in some situations.

Different treatment regimens will be optimal under different situations *-- no one treatment plan or application method is best under all circumstances.*

A program of sustained treatment will be needed to conserve trees through peak EAB infestation. However, as the local EAB population declines due to death of untreated ash, it is possible that treatment frequency may be reduced. Research on this question and other aspects of EAB management is ongoing, *requiring practitioners to stay current.*

Up-to-date information about EAB insecticides, application protocols, and effectiveness can be found at:

http://www.emeraldashborer.info/files/multistate_EAB_Insecticide_Fact_Sheet.pdf

❧ ❧ ❧

In summary, urban ash conservation can be less costly than removal, especially when the significant environmental and economic benefits of established trees are considered (www.treebenefits.com, http://extension.entm.purdue.edu/treecomputer/). Furthermore, ash conservation can circumvent the substantial environmental impacts caused by wholesale deforestation of the urban landscape, as well as the documented public safety risks associated with standing dead ash trees and their removal.

-- Signed - 06 Jan 2011 --

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Standing dead ash, Belvedere Dr., Toledo, OH.

Curbside ash removed due to EAB, Belvedere Dr.

Ash trees under treatment, Lake Forest, IL, 2010.

Section 5

Comparisons of Emerald Ash Borer and Other Wood Boring Insects of Ash Trees

COLORADO EXOTIC INSECT DETECTION AND IDENTIFICATION FACT SHEET SERIES

Emerald Ash Borer in Colorado - Identification of Insects and Damage of Similar Appearance

Whitney Cranshaw and Matt Camper

Figure 1. Emerald ash borer larvae. *Photo courtesy of David Cappaert*

Figure 2. Emerald ash borer adult. *Photo courtesy of David Cappaert*

The emerald ash borer (*Agrilus plannipennis*) is a wood boring beetle of Asian origin that has become established in parts of the upper Midwest. It is extremely damaging to all North America species of ash (*Fraxinus*), including green ash and white ash that are very commonly grown in Colorado landscape settings.

Damage by this insect will continue to spread in the areas where it has become established - which currently (2008) includes much of Michigan and parts of Illinois, Ohio, Indiana and West Virginia. Ultimately it will likely extend into much of the eastern half of North America where ash is native and grows in continuous stands.

Potential establishment in Colorado through natural spread is unlikely. The largely ash tree-free Great Plains that cover the eastern areas of the state provide a serious ecological barrier to movement of this insect. Potentially it may some day move along river ways, although this will not likely occur soon, should be slow and will be so limited in distribution that it may be effectively contained.

However, introduction of emerald ash borer into Colorado is very possible through the careless movement into the state of ash firewood or nursery stock that contains developing stages of the insect. If this occurs, it will be important to identify infestations at an early stage. In Colorado, early identification may likely allow successful efforts to eradicate introductions that do occur or allow their containment.

Methods to Monitor Emerald Ash Borer in Colorado

Despite major effort that continues, to date there are no highly effective traps or lures for this insect. Its detection is largely dependent on interested individuals being able to identify adult insects and/or the pattern of injury larvae do to ash trees. Suspect insects or suspicious infestations should then be immediately brought to the attention of the Colorado State University extension, through a local county office.

Identification of the Emerald Ash Borer

Figure 3. Emerald ash borer adult. *Photo courtesy of PA-DCNR*

Emerald ash borer (Figure 2 and 3) has a general bullet-form body, typical of most beetles in the metallic wood borer/flatheaded borer family - Buprestidae. Emerald ash borer is about 9-13 mm in length, very large for members of the genus *Agrilus*, but mid-sized for members of this insect family. Perhaps the most conspicuous feature is that the emerald ash borer has uniformly green bright, metallic wing covers. The thorax may be more metallic brown and underneath the wing covers the abdomen is purple.

Several other metallic wood borers, as well as some leaf beetles, occur in Colorado that have some metallic green coloration. However, these either are not uniformly green and/or are distinctly smaller or larger than the emerald ash borer. These are discussed below.

Diagnosis of Emerald Ash Borer Injury


Figure 4. Emerald ash borer larval tunnels. *Photo courtesy of Art Wagner USDA-APHIS*

Emerald ash borer only develops in ash (*Fraxinus* species). Larvae (Figure 1) are a type of flatheaded borer that feed by chewing the cambium layer under the bark producing meandering tunnels (Figure 4) packed with fine sawdust-like excrement.

When full grown, the larvae chew into the heartwood of the trunk and there make a small chamber in which they pupate. After transformation to the adult beetle, they chew through the bark and emerge, *making a D-shaped exit hole* (Figure 5).

Presently in Colorado, there are no other flatheaded borers found in ash that create meandering tunnels just under the bark. Their excrement is tightly packed in their tunnels and fine grained. Emerald ash borer *does not expel sawdust* from the tree.


Figure 5. Emerald ash borer characteristic "D shape" exit hole. *Photo courtesy of David Cappaert*

Similarly, the D-shaped exit hole made upon exiting the tree is unique to metallic wood borers and may be the best indication of possible infestation of ash by this insect. Existing wood borers in Colorado that develop in ash make oval or circular exit holes.

(NOTE: In the Midwest the flatheaded appletree borer (*Chrysobothris femorata*) rarely will be found in highly stressed ash and similarly makes a D-shaped exit hole. However, this species makes larger and more deeply gouging wounds that often show evidence on the bark as a weeping site from oozing sap. (These are not produced by emerald ash borer injury.)

Regional Insects Similar in Appearance to Emerald Ash Borer

The emerald ash borer is a colorful beetle of moderate size that produces distinctive injuries that can be used to identify infestations. However, a few insect species found in the Colorado do have appearance or habits that may cause them to be mistaken for emerald ash borer. The following metallic green wood borers are native to Colorado and are most associated with forested areas.

Figure 6. *Cypriacus aurulenta. Photo courtesy of the Ken Gray Collection*

Figure 7. *Cypriacus intricata.*

Figure 8. *Cypriacus langii. Photo courtesy of the Ken Gray Collection*

***Cypriacis* spp.** Three species of large metallic green wood borers in the genus *Cypriacis* occur in Colorado, *Cypriacus aurulenta*, *C. intricata* and *C. langii* (Figures 6, 7, and 8 respectively). The wing covers are metallic green, but there is some purplish striping on the body with *C. aurulenta* and *C. intricata* and a few yellow spots may be present on the wing of *C. langii*. These beetles may range considerably in size, from 9-25 mm, but most all will be substantially larger than the emerald ash borer and the wings have furrows running their length. The *Cypriacis* spp. beetles develop in recently killed conifers including pines, spruce, and Douglas-fir.

Buprestis confluenta. This is a large (12-20 mm) metallic wood borer with green wing covers (occasionally a coppery-brown or purpley-blue) marked with yellow spots (Figure 9). These yellow spots are not found on any other species and make it easily distinguishable from other metallic green wood borers including the emerald ash borer. *Buprestis confluenta* develops in aspen and cottonwood (*Populus* spp.)

Figure 9. *Buprestis confluenta*

Figure 10. *Phaenops gentilis*

Phaenops gentilis. Known as the green flatheaded pine borer, *P. gentilis* (Figure 10) is likely to be the beetle most commonly encountered in Colorado that can be mistaken for emerald ash borer. It is approximately the same size as the emerald ash borer (9-13 mm) but has a broader body form and the wings are covered with minute punctures. The adults are bright bluish green and have no yellow spots. *Phaenops gentilis* develops in several species of pine.

Chrysophana placida. This is a moderately sized (6-10 mm) metallic wood borer found in the trunk and branches of dead and injured pines, true firs, Douglas-fir, and hemlock. *C. placida* (Figure 11) ranges in color from green to red and usually has a reddish-bronze stripe on each wing cover. This species is common in many areas of the west, but is not considered an economically important pest species of native trees.

Figure 11. *Chrysophana placida*

Native *Agrilus* species. Several woods borers well established in parts of Colorado are in the genus *Agrilus*, the genus to which the emerald ash borer also belongs. At least three may have metallic green hues of their wing covers, although all are smaller in size and less intensively colored than is the emerald ash borer. Most common is *Agrilus cyanescens* (Figure 12), a blue-green beetle about 6-mm in length that develops as a borer in honeysuckle. *Agrilus pulchellus* (Figure 13) has wings with a green center band, but the wings are bordered by reddish purple. It is known from Weld County and ranges in size from 7-11 mm. In southeastern Colorado *Agrilus pulchrellus* is present. It is usually bronze, but greenish forms exist.

Figure 12. *Agrilus cyanescens*

Figure 13. *Agrilus pulchrellus*

Figure 14. *Agrilus lacustris*

In addition there are other kinds of beetles that have metallic coloration and may be mistaken for emerald ash borer. This includes some tiger beetles, which are active insects that sometimes rest on tree trunks. Several species of leaf beetles, usually found on leaves, also have metallic green coloration.

Regional Insects that Produce Injuries Similar to Emerald Ash Borer Injury

There are several species of wood boring insects that have long been established in Colorado.

Figure 15. Lilac/ash borer damage to trunk.

Lilac/ash borer. By far the most common wood borer in ash, larvae of the lilac ash/borer (*Podosesia syringae*) makes gouging wounds under the bark and may tunnel into the sapwood (Figure 15). In addition, they often expel coarse sawdust from the tree during later stages of feeding. (In contrast the tunnels of emerald ash borer are meandering trails confined to the cambium and no external sawdust is present.) The larvae are caterpillars that have very short prolegs on the abdomen that are tipped with a series of hooks (crochets). They pupate just underneath the bark and when they emerge the old pupal skin is left behind, partially protruding from the trunk. The exit hole is irregularly rounded (Figure 16).

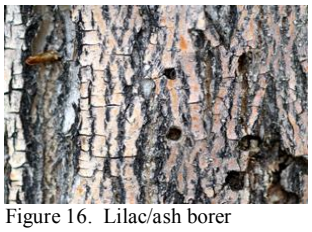


Figure 16. Lilac/ash borer rounded exit holes.

Adults (Figure 17) are a clearwing borer moth that superficially resembles a paper wasp. The lilac ash borer moths usually emerge from ash in early May through mid-June. A related species that may be present in Colorado is the banded ash clearwing, *Podosesia aureocincta*. The banded ash clearwing emerges in summer, rather than late spring.

Figure 17. A mating pair of the Lilac/ash borer.

Redheaded ash borer/Banded ash borer. The larvae of these two *Neoclytus* species are roundheaded borers that tunnel deeply into the trunk. They can be separated from the lilac/ash borer by the absence of prolegs. Larvae lack the flattened area behind the head of the emerald ash borer and do not cause the cambium mining. Exit holes are round or oval. Adults of these two species (Figure 18 and 19) are a type of longhorned beetle, although their antennae are not particularly long compared to other members of this insect family.

Figure 18. Redheaded ash borer. *Photo courtesy of Howard Ensign Evans*

Figure 19. Banded ash borer. *Photo courtesy of James Solomon*

Ash bark beetles. The ash bark beetles are much smaller than the above borers in ash. Adults (Figure 20) are tiny beetles, ca 3-mm and the larvae are legless grubs, that somewhat resemble a grain of rice with a dark head. They make tunnels typical of other bark beetles with a central egg gallery and perpendicular larval galleries. Exit holes adults make when emerging through the bark are round and a bit thicker than a pencil lead (Figure 21). Multiple exit holes are usually present in branches that were earlier infested with ash bark beetles.

Figure 20. Ash bark beetle. *Photo courtesy of David Leatherman*

Figure 21. Ash bark beetle exit holes. *Photo courtesy of James Solomon*

Wood Boring Insects of Ash Trees

Ash is one of the most widely planted trees in Colorado, with most plantings either involving green ash (*Fraxinus pennsylvanica)* or white ash (*F. americana*). Several insects are associated with these plants, including leafcurling aphids, various caterpillars and sawflies that chew the leaves, and wood borers and bark beetles that develop within the trunk and limbs of the tree.

The wood borers and bark beetles can be particularly difficult to identify since there is minimal evidence of their activity on the surface of the plant and there is some overlap in the injuries that different species produce. Furthermore, there is increased interest in these insects since the discovery of a new wood borer, the emerald ash borer, in central Boulder in September 2013. With the addition of this species there are six types of wood boring insects that may be found in ash trees growing in Colorado: lilac/ash borer, flatheaded appletree borer, emerald ash borer, redheaded ash borer, pigeon tremex and the ash bark beetles.

Major Wood Borers of Ash

Lilac/ash borer. The lilac/ash borer (*Podosesia syringae*) is a native insect to North America and is the most commonly encountered wood borer in ash throughout Colorado. It is a type of moth in the "clearwing borer" family Sesiidae.

Adults of this insect emerge from trees during warm days in mid spring. In warmer areas and during warm seasons emergence may begin to occur in April, although the adults are more commonly encountered in May and early June. After mating, the females will lay eggs in cracks on the bark of ash trees. Most egg laying is concentrated in the lower trunk, sometimes extending into the lower scaffold limbs and a bit above. Lilac/ash borer adults do not possess chewing mouthparts so they do not feed on leaves.

Upon egg hatch the newly emerged larvae tunnel into the trunks or limbs producing irregular gouging wounds just under the bark. Later stage larvae may extend the tunnels deeply into the trunk and lilac/ash borer will produce more generalized riddling of the trunk and limbs than do the other borers associated with ash. Larvae of lilac/ash borer are cream colored with a dark head and can be distinguished from the other wood borers by a series of short, paired prolegs on the underside of abdomen, each tipped with a series of small hook (crochets).

Larva of the lilac/ash borer. Photograph courtesy of David Cappaert/Michgan State University and BugWood.org.

Exit holes produced when the adult lilac/ash borer emerges in spring.

External symptoms of lilac/ash borer injury often include some areas of swelling on the trunk and some epicormic branching. Also, when adults emerge from the tree the pupal skin is often pulled out and will remain for some time partially extruded from the trunk. The hole through which the adults emerge is generally round and somewhat irregular. Late stage larvae may also expel sawdust from the hole in the trunk, and lilac/ash borer is the only wood boring insect on ash that produces sawdust visible on the outside of the trunk.

Larva of the lilac/ash borer showing prolegs tipped with hooked crochets on the abdomen. Photograph courtesy of Stanton Gill/University of Maryland.


Pupal skin of the lilac/ash borer extruding from exit hole in trunk.

Emerald ash borer. The emerald ash borer (*Agrilus plannipennis*) is an introduced insect to North America and is native to Asia. It is a type of beetle in the "flatheaded borer" (larval name) or "metallic wood borer" (adult name) family Buprestidae.


Larva of the emerald ash borer. Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

Adults of this insect emerge from trees during May and June, cutting their way through the bark. They then move to the crown of ash trees and for a period of weeks will feed on the foliage. After mating and maturation of the eggs, the females will lay eggs on the surface of the bark of ash trees. Originally, most egg laying is concentrated in the upper crown of the tree and areas near branch crotches appear to be a favored site of egg laying. Later, as the infestation

D-shaped exit hole produced by emerald ash borer (and flatheaded appletree borer). Photograph courtesy of David Cappaert/Michigan State University and BugWood.org.

elongate and somewhat flattened body.

As emerald ash borer infestations progress a thinning of the crown is one of the more easily observed external symptoms. Epicormic branching may also occur. Also present are D-shaped exit holes in branches and, in advanced stages, the trunk that are cut by the emerging adults. No external sawdust is expelled by emerald ash borer.

progesses, the tree is more extensively colonized and egg laying will occur on the all areas of the trunk and larger limbs.

Upon egg hatch the newly emerged larvae tunnel into the trunks or limbs. Feeding occurs shallowly, in the cambium, although they may be found as deeply as about ½-inch below the bark. Tunnels have a meandering form, gradually increasing in diameter as the insects grow, and are packed with fine sawdust-like excrement (frass). Just prior to pupation the larvae bore a bit more deeply into the trunk and form a cell within which they will pupate, head end facing outward. Larvae of emerald ash borer are cream colored, have a small head with pronounced dark jaws, feature a slightly flattened area behind the head, and have a very

Meandering tracks produced during larval feeding of the emerald ash borer. Photograph courtesy of Eric Day/VPI & SU and BugWood.org.

Minor Wood Borers of Ash

Flatheaded appletree borer. The flatheaded appletree borer (*Chrysobothris femorata*) is a native insect to North America and is associated with several hardwood trees in Colorado including oak, maple, ash, and apple. It is a type of beetle in the "flatheaded borer" (larval name) or "metallic wood borer" (adult name) family Buprestidae – as is the emerald ash borer.

Larva of a flatheaded appletree borer. Photograph courtesy of James Solomon/USDA-FS and BugWood.org.

Adults of this insect emerge from trees during May and June, cutting their way through the bark. They then move to the crown of ash trees and for a period of weeks will feed on the foliage. After mating and maturation of the eggs, the females will lay eggs on the surface of the bark of host trees, with egg laying concentrated on limbs that are showing decline or injury.

Upon egg hatch the newly emerged larvae tunnel into the trunks or limbs. Feeding occurs shallowly, in the cambium. Tunnels have a meandering form, gradually increasing in diameter as the insects grow, and are packed with fine, somewhat granular, sawdust-like excrement (frass). Just prior to pupation the larvae bore a bit more deeply into the trunk and form a cell within which they will pupate. Larvae of the flatheaded appletree borer are cream colored, have a small head with pronounced dark jaws, feature a broadly flattened area in the behind the head, and have a very elongate and somewhat flattened body. The broad area behind the head, wider in the flatheaded appletree borer, can generally be used to distinguish this insect from emerald ash borer. However, when the question of proper identification of flatheaded borers in ash is necessary, larvae should be sent for expert identification.

Exit holes produced by flatheaded appletree borer.

Tunneling in a dying ash limb produced by larva of the flatheaded appletree borer.

Redheaded ash borer. The redheaded ash borer (*Neoclytus acuminatus*) is a native insect to North America. It is a type of beetle in the "roundheaded borer" (larval name) or "longhorned beetle" (adult name) family Cerambycidae. The redheaded ash borer develops in a wide range of hardwood and, despite its common name, is infrequently found in ash; fruit trees are more common hosts of this insect in Colorado.

Adults of this insect emerge from trees from June through August, cutting their way through the bark. They feed for a brief period on foliage of host plants and, after mating and maturation of the eggs, the females will lay eggs in small pits that they chew into the bark of host trees.

Upon egg hatch the newly emerged larvae tunnel into the trunks or limbs. Feeding occurs deeply into the wood, producing riddling that may extend into the center of the plant and these tunnels are semicircular in cross section. Larvae of the redheaded ash borer are cream colored with a small head marked with pronounced dark jaws. The general body for is somewhat cylindrical. They can be distinguished from larvae of the lilac/ash borer in that they lack the small prolegs on the underside of the abdomen.

In ash trees flathheaded appletree borer is almost entirely restricted to limbs that are previously injured or in decline and it is not a primary pest of ash. Adults also produce D-shaped exit holes in branches which resemble those made by emerald ash borer.

The redheaded ash borer is an insect found in many kinds of hardwoods in decline or that have been recently killed. Larval picture (above) by Dan Herms/The Ohio State University; Adult photograph (lower) by David Leatherman.

Redheaded ash borer is almost entirely restricted to ash trees that are seriously injured or in advanced decline and it is not a primary pest of ash. Adults produce generally round, slightly semicircular, holes when exiting through the bark.

Pigeon tremex. The pigeon tremex (*Tremex columba*) is a native insect to North America. It is a type of wood boring wasp in the horntail family Siricidae. The pigeon tremex develops in a wide range of hardwood trees that are in advance stages of decline, including elm, maple, and ash.


Larvae of the pigeon tremex, a type of horntail wasp.

Adults of this insect emerge from trees in midsummer. The females, which are large, brown cylindrical bodied wasps, can sometime be observed as they search the bark of host plants. Periodically females will drill into trees with a long ovipositor and, when the plant is suitable, will lay eggs into the wood. Pigeon tremex also introduces white rot fungi when laying eggs, which will produce decay in the area where the young wasps develop.

Feeding occurs deeply into the wood, producing riddling that may extend into the center of the plant and these tunnels are round in cross section. Larvae of the pigeon tremex are cream colored with a cylindrical body. The head is large, compared to the other wood borers, but, except for the jaws, it is not darkened.

Pigeon tremex is restricted to ash trees that are in advanced decline and it is not a primary pest of ash. Adults produce round, smoothly cut holes when exiting through the bark.


Perfectly round exit holes are produced when the adult of the pigeon tremex horntail emerges from the trunk.

Bark Beetles

Ash bark beetles. Three species of ash bark beetles (*Hylesinus* species) are associated with ash in Colorado. Bark beetles are members (subfamily Scolytinae) of the "snout beetle" or "weevil" family Curculionidae. At least three species occur in Colorado, *Hylesinus californicus* appears to predominate in the western areas and *H. aculeatus* in the east. In addition, *H criddlei* has been found in several eastern Colorado locations.

Exit holes produced by ash bark beetles.

Adult bark beetles cut egg galleries under the bark and larvae tunnel perpendicular to the gallery. These injuries can girdle and sometimes kill branches. On rare occasions entire trees are killed by these insects. Injured limbs and heavily shaded branches in the interior of the tree are most commonly attacked. Transplanted trees can be at special risk. Ash bark beetles may infest almost the entire tree, from finger-diameter branches to the main trunk.


Larval galleries produced by ash bark beetles.

Egg galleries run across the grain and often have two "arms" with a central chamber in the middle. Also characteristic of these insects are that small "ventilation holes" perforate the bark above the egg galleries. The tunnels are almost invariably colonized by fungi that stain the wood a rich brown color around the feeding sites. The larvae are pale, legless grubs that develop by feeding under the bark. Sap may ooze from wounds in twigs, staining the bark.

Overwintering can occur as either late-instar larvae under the bark or as adults that winter within niches cut into green bark of the outer trunk. Adults begin to become active in early to mid-spring and females construct girdling tunnels under the bark that may encircle twigs and small branches. During this tunneling small ventilation holes are also constructed through the bark surface that are visible; sap may ooze from the wounds. These tunnels are the main egg galleries characterized by running at right angles to branch length. Brown wood-staining fungi are commonly associated with the galleries.

Whitney Cranshaw April 3, 2014 draft

A REFERENCE FOR

Recognizing Insect Galleries in Ash Trees in Minnesota

MINNESOTA DEPARTMENT
OF AGRICULTURE
PLANT PROTECTION

OVERVIEW:

The purpose of this document is to provide images of different types of damage from pests that may be found boring in ash trees in Minnesota and to contrast the appearance of these damage types with that caused by emerald ash borer (EAB). All images in this document are of insect damage found in ash trees in Minnesota unless otherwise noted. For information on external symptoms of EAB on standing trees or comparisons of larval and adult EAB with other insects, see the links below.

FOR MORE INFORMATION:

Identification of Emerald Ash Borer and Other Ash Insects:

http://www.emeraldashborer.info/identifyeab.cfm

http://na.fs.fed.us/fhp/eab/pubs/fieldguide/eabfg.pdf

http://www.forestpests.org/ash/

Emerald Ash Borer Information:

http://www.emeraldashborer.info

http://www.mda.state.mn.us/invasives/eab

Contents:

SCOLYTIDAE:

Unlike other insects, adult ash bark beetles feed under the bark just as the larvae do. Bark beetles galleries may take the shape of reproductive galleries like figures 3 and 4 or adult feeding galleries like figures 2 and 5.

During 2007-2008 EAB detection tree surveys, ash bark beetles (*Hylesinus* spp.) were found in ~70% of 1800+ ash trees sampled by Minnesota Department of Agriculture (MDA) across the state.

Figure 1. Bark beetle emergence holes.

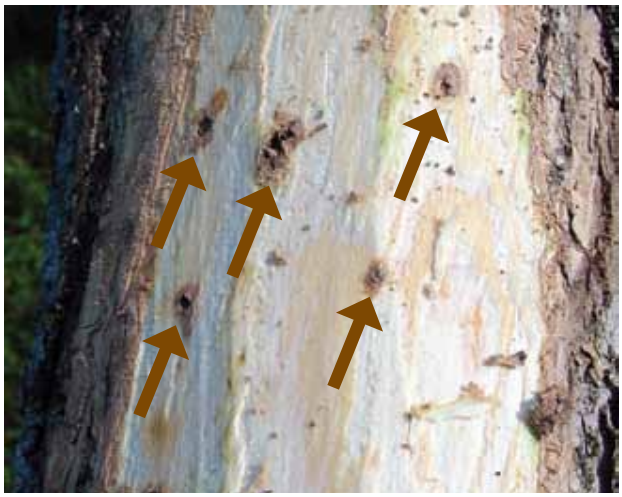


Figure 2. Feeding galleries of adult ash bark beetles beginning to show as phloem is removed.

Figure 3. Bark beetle egg-laying galleries cross the grain of the wood.

Figure 4. Larval galleries lie at right angles to egg-laying galleries and are often very closely spaced.

Figure 5. Adult ash bark beetle at knife tip next to gallery.

AGROMYZIDAE:

Ash cambium miner (*Phytobia* sp.) is a fly (Diptera) present under the bark of ash as a larva. Larva begin in branches where eggs are laid and tunnel all the way to the roots and out into the soil to pupate. Galleries tend to be at the surface of the sapwood, thin (width of pencil tip) and either straight or a broad zig-zag.

During 2007-2008 EAB detection tree surveys, evidence of ash cambium miner was found in ~30% of 1800+ sampled trees.

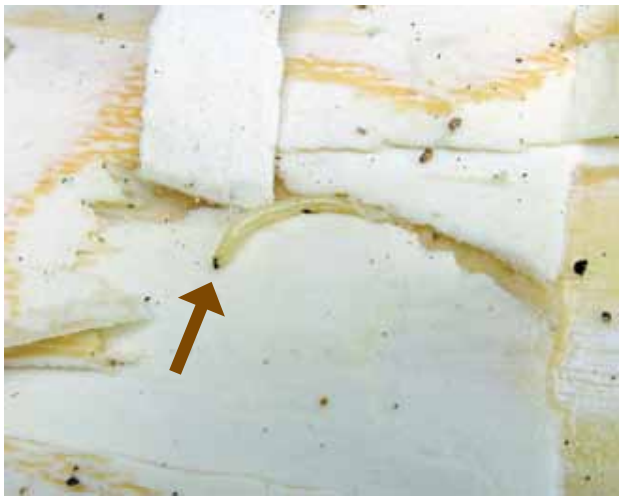


Figure 6. Larva of ash cambium miner.

Figure 7. Galleries of ash cambium miner.

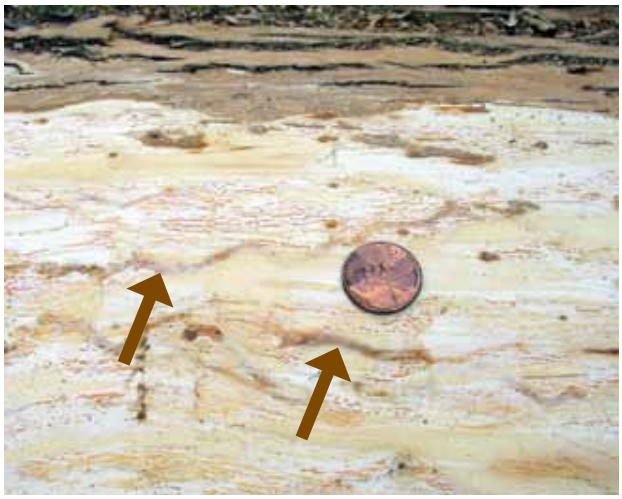


Figure 8. Galleries of ash cambium miner with a penny for reference.

Figure 9. Gallery of ash cambium miner just beginning to show as phloem is scraped away.

Figure 10. Gallery of ash cambium miner already present when tree girdled.

CERAMBYCIDAE:

A few species of this beetle family may be found under the bark of ash including: banded ash borer (*Neoclytus caprea* Say), redheaded ash borer (*Neoclytus acuminatus* Fabricius), and ash and privet borer (*Tylonotus bimaculatus* Haldeman). Galleries are generally meandering and may be nearly as wide as a pencil. Galleries eventually dive deep into the sapwood.

Galleries and/or larvae of cerambycid species were found in ~10% of 1800+ sampled trees during MDA detection tree surveys in 2007-2008.

Figure 11. *Cerambycid* larva.

Figure 12. High-density infestation of *Cerambycid* larvae – there is some similarity in appearance to a older EAB infestation.

Figure 13. Close up of figure 12 showing holes tunneled into wood.

Figure 14. Pupal chamber of a *Cerambycid* larva deep in wood.

Figure 15. Emergence hole of redheaded ash borer.

SESSIIDAE:

Galleries and/or larvae of clearwing borers, Podesia spp. (Lepidoptera: Sessiidae) were found in ~10% of sampled trees during MDA detection tree surveys in 2007-2008. The galleries in Figures 21, 23 and 24 are approximately the width of a felt-tip marker and deeply etched into the sapwood. Clearwing borers tunnel deeply into the wood as larvae and leave large round holes when they emerge as adults. Clearwing borer larvae have legs, distinguishing them from roundheaded and flatheaded borers.

Figure 20. Clearwing moth emergence hole (about size of pencil eraser, picture from Michigan).

Figure 21. Clearwing moth gallery starting at girdle.

Figure 22. Clearwing moth larvae.

Figure 23. Clearwing moth gallery at branch crotch.

Figure 24. Clearwing moth gallery.

BUPRESTIDAE [NOT EMERALD ASH BORER]:

Three genera of buprestids can be found boring in ash trees in Minnesota - *Agrilus* (EAB), *Chrysobothris* and *Dicerca*. Damage from *Chrysobothris* and *Dicerca* is similar and can be easily distinguished from that of *Agrilus*. During 2007-2008 EAB detection tree surveys, damage and larvae from *Chrysobothris* and *Dicerca* were found in ~10% of 1800+ sampled trees. The vast majority of larvae recovered from trees were *Chrysobothris* spp., though *Dicerca* was also represented. Two *Chrysobothris* adults were recovered from one tree and identified as C. *sexignata*. *Chyrsobothris* and *Dicerca* galleries are not tightly "S"-shaped though they are sometimes sinuous in shape.

Figure 16. *Chrysobothris* larva on black ash.

Figure 17. *Chrysobothris* larva and gallery in black ash.

Figure 18. Chrysobothris emergence hole.

Figure 19. Early *Chrysobothris* gallery.

Comparison of characteristics among common, native wood-boring insects of ash and emerald ash borer

Species	Larvae	Galleries	Exit Hole	Adults
Ash bark beetle Native Fam. Scolytidae	Cream-colored, grub-like appearance. Up to 1/4 in length. Small brownish-red head capsule.	Beneath the bark. Horizontal egg gallery. ~ 1/16 inch in width, ~ 2 to 3 inches in length. Larval mines extend from egg gallery.	Round. ~1/8 inch diam. and smaller.	Small. ~ 1/8 inch long. Black or brownish.
Red-headed ash borer Native Fam. Cerambycidae	Cream-colored. First 2 segments are slightly larger and rounder, giving slightly tapered appearance. ~ 1/2 inch in length.	Larvae feed beneath bark initially then bore into the sapwood.	Round. ~1/4 to 3/8 inch diameter.	Red head with long antennae. Long legs. Black wings with yellow horizontal stripes.
Ash/lilac borer Native Fam. Sesiidae	Yellow to light brown. Caterpillar-like appearance. ~ 1/2 inch in length.	Larvae bore ~ 2 inches into the sapwood.	Round. ~1/4 to 3/8 inch diameter.	Wasp-like appearance. Clear wings. Light brown body. Yellow legs.
Flathead appletree borer Native Fam. Buprestidae	Cream-colored. Slightly flattened. 1/2 to 3/4 inch in length. 2nd segment is much larger and wider than other segments.	Frass-filled galleries beneath the bark.	**D-shaped.** Size unknown.	Olive to purplish metallic appearance.
Carpenterworm Native Fam. Cossidae	Greenish-white. Reddish-brown head. 2 to 3 inch length.	Galleries extend into the sapwood and heartwood.	Round. ~5/8 inch diameter.	Mottled gray moth. ~2.5 inch wingspan.
Emerald ash borer **Exotic/Non-native!** Fam. Buprestidae	Cream-colored. Slightly flattened. 1 to 1-1/4 inches in length. Consists of 10 bell-shaped segments.	Found beneath the bark. Meandering, S-shaped galleries packed with frass. ~ 12 inches total length, ~ 1/4 inch in width.	**D-Shaped.** ~1/8 to 3/16 inch in length. Slightly shorter in height.	Bright metallic green beetle. ~ 5/16 to 1/2 inch in length.

Chart courtesy of North Dakota Forest Service

Ash Wood-Borer Comparison: Adult

EMERALD ASH BORER (NOT native)

Buprestidae, *Agrilus planipennis*

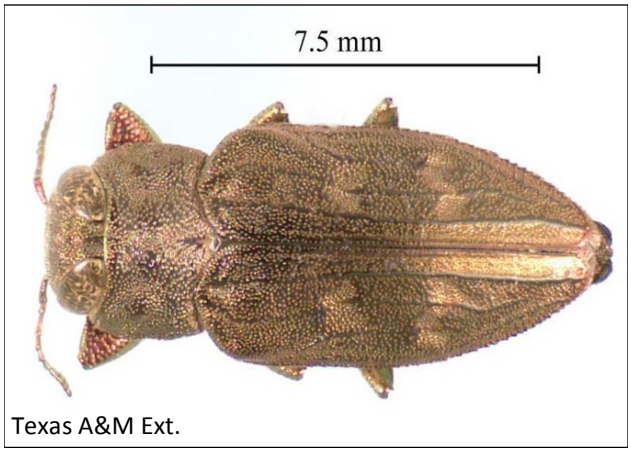
- **Bright, metallic-green**
- **~ 5/16 to 1/2 inch in length**
- **Slender body**
- **Flat , rough, emerald green wing covers**

ASH BARK BEETLES

Scolytidae, *Hylesinus* spp.

♦ **Black or brownish color**

♦ **Small, ≈ 1/8 inch in length**



FLATHEADED APPLETREE BORER

Buprestidae, *Chrysobothris femorata*

♦ **Emerge throughout the summer**

♦ **Olive to purplish-brown, metallic appearance**

♦ **Broad flat area behind head (thorax)**

Ash Wood-Borer Comparison: Adults

CARPENTER WORM

Cossidae, *Prionoxystus robiniae*

- **Mottled gray moths**
- **Wingspan of approx. 2.5 inches**
- **Males (only) have orange underwings**

ASH LILAC BORER

Sesiidae, *Podosesia syringae*

- **Clearwing moth that resembles a paper wasp**
- **Wings are narrow, dark brown and transparent**
- **Bodies are dark brown/black with a yellow bands on the abdomen.**

REDHEADED ASH BORER

Cerambycidae, *Neoclytus acuminatus*

- **Adults range from 1/4 to 2/3 inch long**
- **Reddish-brown in color**
- **Three transverse yellow bands on elytra**

Ash Wood-Borer Comparison: Larvae

EMERALD ASH BORER (NOT native)

Buprestidae, *Agrilus planipennis*

- **Larvae are flat and elongate**
- **Cream-colored body (head shaded brown)**
- **Reaching a length 1 to 1 1/4 inches**
- **The abdomen has 10 segments**

ASH BARK BEETLES

Scolytidae, *Hylesinus* spp.

♦ **Cream-colored, grub-like appearance**

♦ **Small brownish-red head**

♦ **Length ~ 1/4 inch and smaller**

***This photo shows the basic larval characteristics of a typical bark beetle larva. While this is not a picture of *Hylesinus spp.*, this larva**

FLATHEADED APPLETREE BORER

Buprestidae, *Chrysobothris femmorata*

♦ **Cream-colored**

♦ **Slightly flattened**

♦ **1/2 to 3/4 inch in length**

♦ **2nd segment is much larger and wider than other segments**

Ash Wood-Borer Comparison: Larvae

CARPENTER WORM

Cossidae, *Prionoxystus robiniae*

- **Full-grown larvae are 2 to 3 inches long, fleshy, and greenish-white or pinkish**
- **Considered the largest wood-boring caterpillar**
- **Dark brown heads**
- **Have leg-like appendages (prolegs), each with**

ASH LILAC BORER

Sesiidae, *Podosesia syringae*

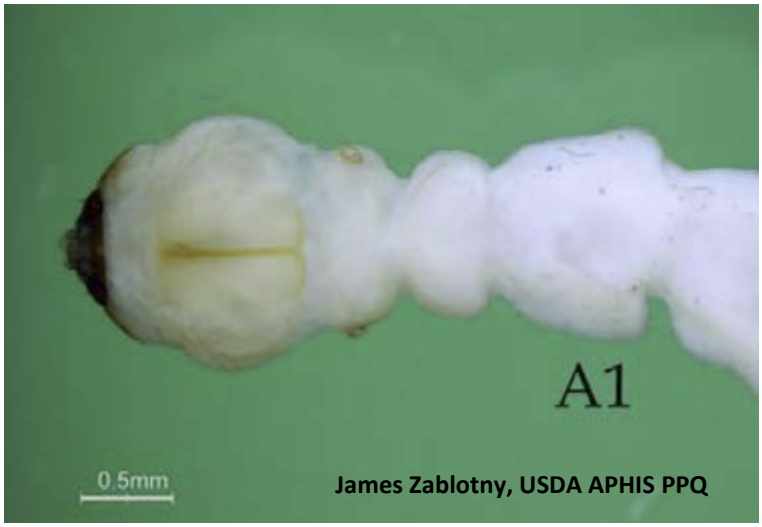
- **Yellow to light brown color**
- **Caterpillar-like appearance**
- **~1/2 inch in length**

REDHEADED ASH BORER

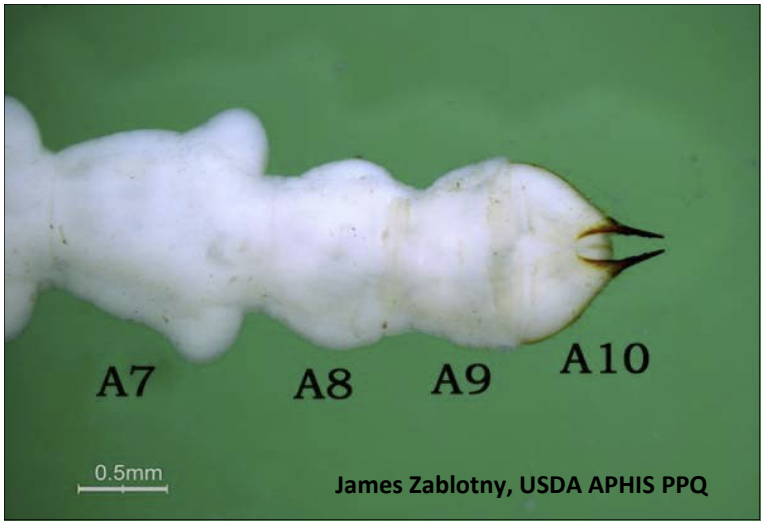
Cerambycidae, *Neoclytus acuminatus*

- **Cream-colored**
- **First 2 segments are slightly larger and rounder, giving it a slightly tapered appearance**
- **~1/2 inch in length**

Emerald Ash Borer Larva Close-up



There are ten abdominal segments. The first abdominal segment shape varies considerably but can be distinctly rectangular to trapezoidal shaped.



Segments A2 through A6 are somewhat trapezoidal with protruding flattened A7 is strongly bell shaped and A8 is somewhat trapezoidal in shape. The last abdominal segment (A10) contains a pair of urogomphi.

Ash Wood-Borer Comparison: Galleries

EMERALD ASH BORER (NOT native)

Buprestidae, *Agrilus planipennis*

- **Random s-shaped, serpentine galleries**
- **Found just under bark**
- **Packed with frass (wood dust and excrement)**

ASH BARK BEETLES

Scolytidae, *Hylesinus* spp.

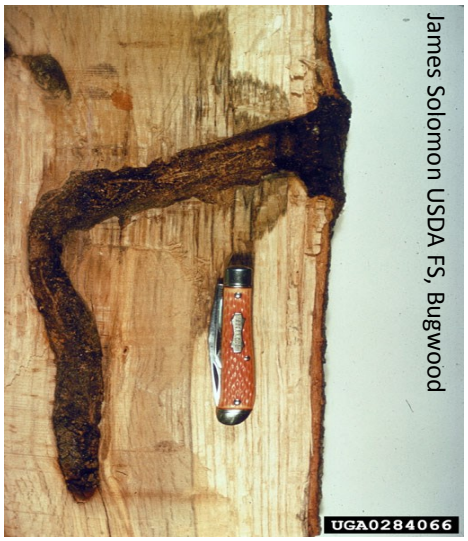
- **Main egg laying chamber with galleries extending from it**
- **Often filled with frass**

FLATHEADED APPLETREE BORER

Buprestidae, *Chrysobothris femorata*

- **Random**
- **Winding tunnels**
- **Packed with frass**

Ash Wood-Borer Comparison: Galleries



CARPENTER WORM

Cossidae, *Prionoxystus robiniae*

- **Extend from sapwood to heartwood, then turn downward**
- **Large**


U. of Illinois Ext

ASH LILAC BORER

Sesiidae, *Podosesia syringae*

- **1st year: Larvae feed under bark**
- **2nd year: Larvae feed within wood**
- **3rd year: Larvae return to just under bark**


Renee Pinski, Wisconsin DNR

REDHEADED ASH BORER

Cerambycidae, *Neoclytus acuminatus*

- **Resembles EAB gallery**
- **Not necessarily s-shaped**
- **Random pattern, packed with frass**
- **First larvae feed just under bark, then later into sapwood**

Ash Wood-Borer Comparison: Exit Holes

Mike Kangas, North Dakota Forest Service

EMERALD ASH BORER (NOT native)

Buprestidae, *Agrilus planipennis*

- **D-shaped**
- **≈1/8 inch long**
- **Often difficult to distinguish**
- **Found on trunk and main branches**

Mike Kangas, North Dakota Forest Service

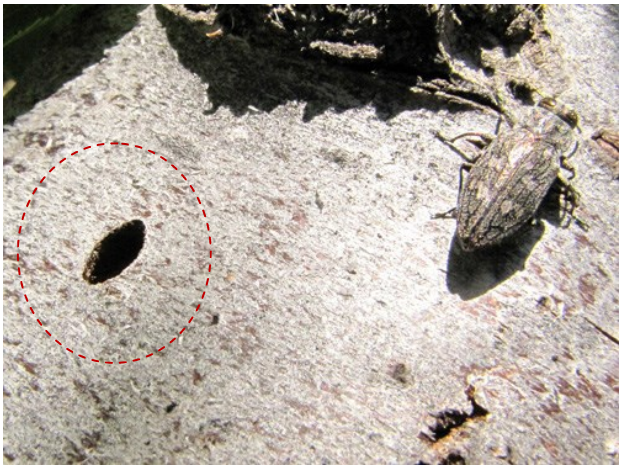
ASH BARK BEETLES

Scolytidae, *Hylesinus* spp.

♦ **Tiny, round holes**

♦ **Often found in higher densities**

- **Found on trunk and main branches**



*Pacific flatheaded borer exit hole, Utah State

FLATHEADED APPLETREE BORER

Buprestidae, *Chrysobothris femorata*

♦ **Same family as EAB**

♦ **D-shaped exit hole, size similar to EAB**

- **Found on trunk and main branches**

Ash Wood-Borer Comparison: Exit Holes


E. Beers

CARPENTER WORM

Cossidae, *Prionoxystus robiniae*

- **Large, round exit hole**
- **5/8 inch in diameter**
- **Found on trunk and main branches**

***No unobstructed exit <u>hole</u> photos available/Larval cases are fragile and may not be present.**


Iowa State Ext.

ASH LILAC BORER

Sesiidae, *Podosesia syringae*

♦ **Round**

♦ **1/4th — 3/8th-inch diameter**

♦ **Usually found singly**

- **Found on trunk and main branches**

REDHEADED ASH BORER

Cerambycidae, *Neoclytus acuminatus*

♦ **Round**

♦ **1/4th — 3/8th-inch diameter**

♦ **Usually found singly**

- **Found on trunk and main branches**

Bark Beetle

Family Scolytidae

Hylesinus spp.

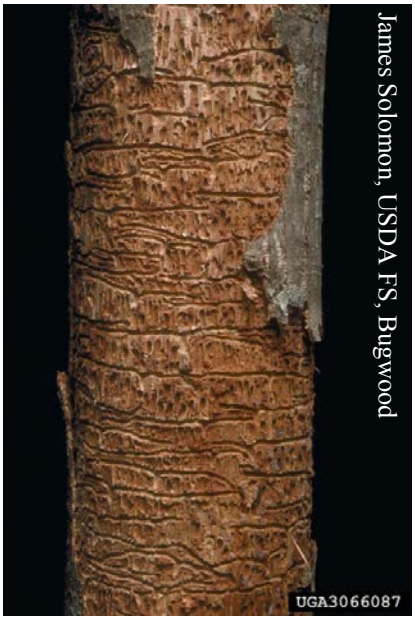
Characteristics:

Adults: Small (1/8 inch), cylindrical, brown beetles. Overwinter as adults under the bark. Females lay eggs in a tunnel straight across the wood grain (horizontal).

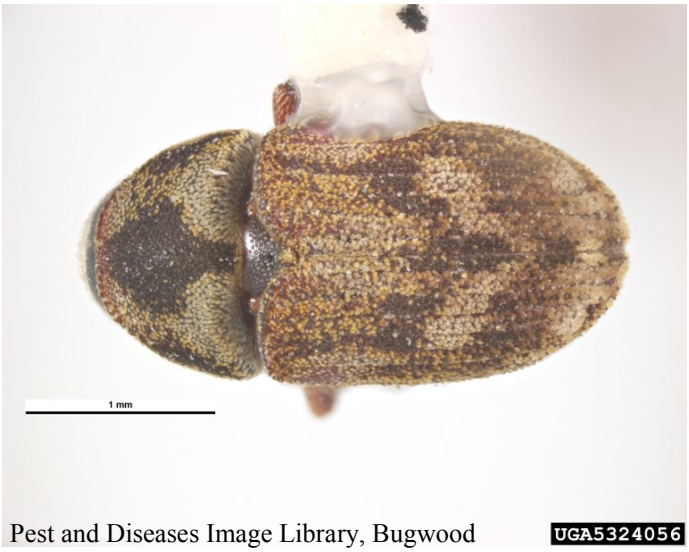
Larvae/Galleries: White, grub-like larvae hatch and feed, creating tunnels parallel to the wood grain (vertical).

Exit Holes: Small, (1/8 inch or smaller) circular exit holes, often numerous.

*No ash bark beetle larva picture available.



Bark Beetle Galleries



Bark Beetle Adult

Ash bark beetles are typically found on damaged branches and trunks of ash trees.

The western ash bark beetle, *H. californicus* can attack healthy ash trees.

Flatheaded Appletree Borer

Family Buprestidae

(*Chrysobothris* spp)

Characteristics:

Adults: Green to purplish black, metallic appearance.

Larvae: Cream-colored, slightly flattened. 1/2 to 3/4 inch in length, 2nd segment is much larger and wider than other segments.

Galleries: Frass-filled galleries beneath the bark.

Exit Holes: D-shaped, variable size.

Flatheaded Appletree Borer

Flatheaded Appletree Borer

emerald ash borer belongs to
of a D-shaped exit hole on an
indicate the presence of EAB.
hole should ALWAYS warrant
collection, and sample

Note: All beetles in this family (Buprestidae) produce D-shaped Exit Holes. The this family. The presence ash does not necessarily However, a D-shaped exit further inspection, sample submission.

Carpenterworm/Wood Worm

Family Cossidae

Prionoxystus robiniae

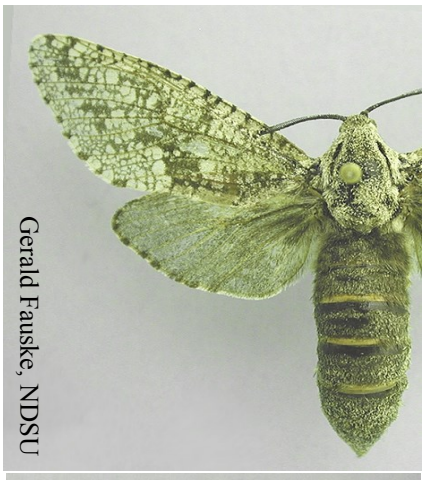
Characteristics:

Adults: Mottled gray moths with a wingspan of approximately 2.5 inches.

Larvae: Fully grown larvae are greenish white, 2 to 3 inches in length, reddish-brown head.

Carpenterworm:

adult female (top)



Carpenterworm/Wood Worm

Larva (note: larvae can vary in color)

Galleries: Larval galleries extend into the sapwood and heartwood.

Exit Holes: Large, round holes, approx. 5/8 inch in diameter found deep in the heartwood.

Notes: Found on trunk, main branches.

Ash/lilac borer

Family Sesiidae

Podosesia syringae

Characteristics:

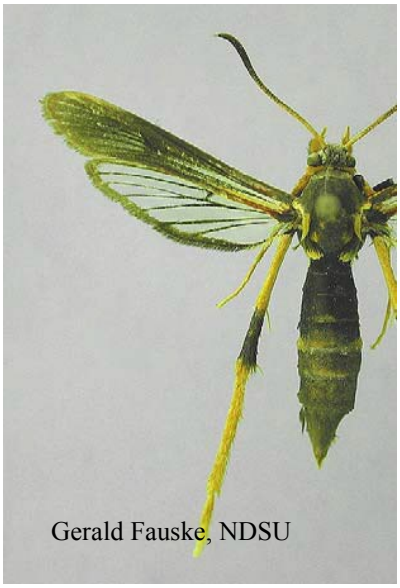
Adults: The ash/lilac borer adult is a clearwing moth that resembles a paper wasp. The wings are narrow, dark brown and transparent and the bodies are dark brown/black with a yellow band on the abdomen.

Larvae: Fully grown larvae are 1 inch long with creamy-white bodies and brown heads.

Galleries: During the first summer, larvae feed within the bark. Larvae then feed into the wood during the second year, and bore toward the surface just under a thin layer of bark during the third year.

Exit Holes: Usually found singly. Round, ~1/4 to 3/8 inch in diameter.

Notes: Found on trunk, main branches, and medium sized branches. Also attacks terminal leaders.



Ash Lilac Borer Adult

Ash Lilac Borer: larva making a gallery as it feeds.

***Pupal casings of ash and lilac borer can often be seen at exit holes**

Redheaded Ash Borer

Family Cerambycidae

Neoclytus acuminatus

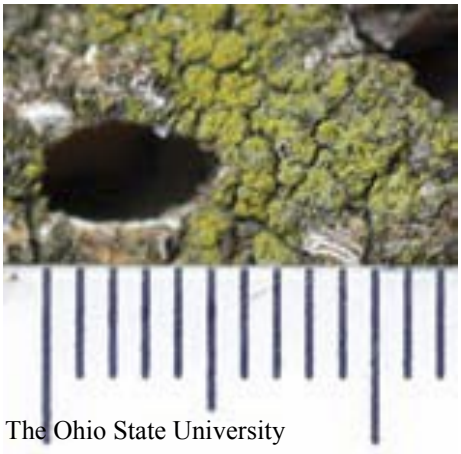
Characteristics:

Adults: Adults are about 1/4 to 2/3 inch long and reddish-brown in color with three yellow transverse bands on the hind wings (*elytra*).

Larvae: Found beneath the bark. Cream-colored, first two segments are slightly larger and rounder, giving it a slightly tapered appearance, ~1/2 inch in length.

Galleries: Larvae feed beneath the bark initially then bore into the sapwood.

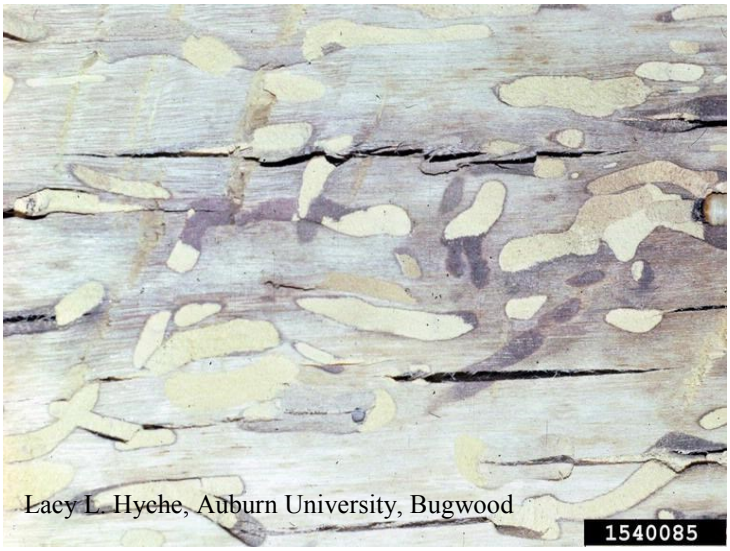
Redheaded Ash Borer Larva (above) and Galleries (lower



Redheaded Ash Borer Adult

Exit Holes: Usually found singly. Round, ~1/4 to 3/8 inch in diameter.

Notes: Found on trunk, main branches, and medium-sized branches.



Section 6

Emerald Ash Borer Look-alikes

Metallic-green insects in Montana that could be confused with the emerald ash borer and Japanese beetle

Ian Foley, Montana Department of Agriculture

Emerald Ash Borer

The emerald ash borer (EAB, image above), *Agrilus planipennis* Fairmaire, is an extremely devastating exotic pest of ash trees. First found in North America in Southeastern Michigan in 2002, EAB has spread to many Eastern states and provinces. As of 2008, EAB has been found in Michigan, Wisconsin, Missouri, Illinois, Indiana, Ohio, West Virginia, Virginia, Maryland, Pennsylvania, Ontario and Quebec. Where found, it has caused millions of dollars of damage to landscape and forest resources. Emerald ash borer attacks and kills healthy and stressed ash (*Fraxinus* sp.) trees. Montana has a very high number of urban landscape ash trees that are at risk from this invasive insect. If you suspect EAB in your neighborhood, please contact your local extension agent, the USDA, the Montana Department of Natural Resources, or the Montana Department of Agriculture.

Japanese Beetle

The Japanese beetle (JB image above), *Popillia japonica* Newman, is a highly destructive exotic pest of turf grasses and other ornamental plants. While larvae feed exclusively in the soil on turf grasses, adults are highly polyphagous, feeding on more that 300 different species of plants. Since it's discovery in North America in 1916, the Japanese beetle has infested nearly every state east of the Mississippi river. The Japanese beetle was first discovered in Montana in 2002 in the area around Billings Logan international airport in Yellowstone County. Subsequent monitoring and eradication efforts in the Billings area by the Department of Agriculture and USDA have not documented the spread of JB outside the general area of the airport. Japanese beetle could be a highly destructive pest in fruit and turf grass growing areas of Montana. The movement of this pest into and throughout the state is highly regulated to prevent it's spread. If you suspect JB somewhere in the state, please contact your local extension agent, the USDA, or the Montana Department of Agriculture.

Acknowledgements:
Crystal Meier and Ross Winton of the Ivie Insect Systematics lab at Montana State University provided access to the Montana State University Entomology Collection and helped identify specimens.

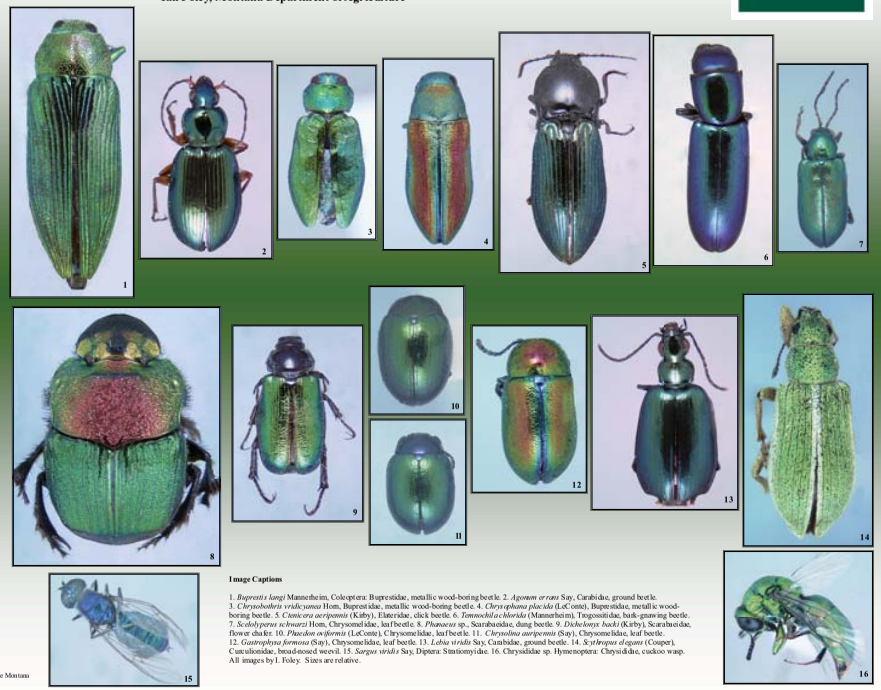


Image Captions

1. *Buprestis langi* Mannerheim, Coleoptera: Buprestidae, metallic wood-boring beetle. 2. *Agonum errans* Say, Carabidae, ground beetle. 3. *Chrysobothris viridicyanea* Horn, Buprestidae, metallic wood-boring beetle. 4. *Chrysophana placida* (LeConte), Buprestidae, metallic wood-boring beetle. 5. *Ctenicera aeripennis* (Kirby), Elateridae, click beetle. 6. *Temnochila chlorida* (Mannerheim), Trogossitidae, bark-gnawing beetle. 7. *Scelodyporus sculptus* Horn, Chrysomelidae, leaf beetle. 8. *Phanaeus* sp., Scarabaeidae, dung beetle. 9. *Dicheloyx haldi* (Kirby), Scarabaeidae, flower chafer. 10. *Pluedon uniformis* (LeConte), Chrysomelidae, leaf beetle. 11. *Chrysolina auripennis* (Say), Chrysomelidae, leaf beetle. 12. *Gastrophysa formosa* (Say), Chrysomelidae, leaf beetle. 13. *Lebia viridis* Say, Carabidae, ground beetle. 14. *Scythropus elegans* (Couper), Curculionidae, broad-nosed weevil. 15. *Sargus viridis* Say, Diptera: Stratiomyidae. 16. Chrysididae sp. Hymenoptera: Chrysididae, cuckoo wasp. All images by I. Foley. Sizes are relative.

The *Agrilus* species of Montana (Coleoptera: Buprestidae)

Ian Foley, Montana Department of Agriculture

With the recent North American introduction and spread of the exotic Emerald Ash Borer (EAB, *Agrilus planipennis* Fairmaire Fig. 1), 2008 saw the commencement of a statewide cooperative agriculture pest survey (CAPS). Purple prism traps (far right) were placed throughout Montana by the United States Department of Agriculture (USDA)-Animal Plant Health Inspection Service (APHIS)-Plant Protection and Quarantine (PPQ), the Montana Department of Natural Resources and Conservation (DNRC), and the Montana Department of Agriculture (MDA) in support of the nationwide USDA Emerald Ash Borer Survey. In order to accurately screen traps for EAB it is essential to have knowledge about other related species that may appear in MT EAB traps.

Twelve species of the buprestid genus *Agrilus* are recorded from Montana (Fisher 1928, Russell 1968, Westcott 1990, Nelson et al. 2008) and in the Montana Entomology Collection (MTEC) at Montana State University. Two species, *A. hyperici* a bio-control agent and *A. cuprescens* (=*A. aurichalceus* Redtenbacher) a pest of roses, are not-native to North America.

Species Recorded from MT	Hosts	Recorded by
Agrilus arcuatus (Say)	*Quercus* sp., *Fagus* sp., *Castanea* sp.	Fisher 1928
Agrilus cuprescens Ménétries	*Rubus* sp., *Rosa* sp.	Westcott 1990, Nelson et al. 2008
Agrilus anxius Gory	*Betula* sp., *Populus* sp.	Fisher 1928
Agrilus gibbicollis Fall	*Quercus* sp.	Westcott 1990
Agrilus granulatus (Say)	*Populus* sp., *Betula* sp.	Fisher 1928
Agrilus hyperici (Creutzer)	*Hypericum perforatum* L.	Nelson et al. 2008
Agrilus malvastri Fisher	*Malvastrum* sp., *Sphaeralcea* sp.	Fisher 1928
Agrilus masculinus Horn	*Acer* sp., *Gleditsia* sp.	MTEC
Agrilus politus Say	*Salix* sp., *Acer* sp.	Fisher 1928
Agrilus pubifrons Fisher	Unknown	MTEC
Agrilus quadriguttatus Gory	*Alnus* sp., *Salix* sp.	Westcott 1990
Agrilus vittaticollis (Randall)	*Prunus* sp.	Russell 1968, Nelson et al. 2008

EAB trap hanging in an Ash tree. Photo by I. Foley

Figure 1. EAB, *Agrilus planipennis* Fairmaire. Image courtesy of www.padil.gov.au.

Figures 2-7, left to right. Representative Montana *Agrilus* sp., Fig. 2-*A. politus*, Fig. 3-*A. cuprescens*, Fig. 4-*A. anxius*, Fig. 5-*A. gibbicollis*, Fig. 6-*A. masculinus*, Fig. 7-*A. quagriguttatus*. All images by I. Foley courtesy of Montana Entomology Collection (MTEC) at Montana State University, Bozeman, Montana.

REFERENCES:

Fisher, W. S. 1928. A revision of the North American species of buprestid beetles belonging to the genus *Agrilus*. U. S. National Museum Bulletin, 145: 1-347.

Nelson, G. H., G. C. Walters, Jr., R. D. Haines & C. L. Bellamy. 2008. A catalog and bibliography of the Buprestoidea of America North of Mexico. The Coleopterists Society, Special Publication No. 4, pp. iv + 1-274.

Russell, K.L. 1968. The Faunal Relationships of the Coleoptera of Montana, West of the Continental Divide, with a List of the Species Known to Occur There. Master's Thesis, Univ. of Washington, 208 pp.

Westcott, R. L. 1990. Distributional, biological, and taxonomic notes on North American Buprestidae. In secta Mundi, 4:73-89.

ACKNOWLEDGEMENTS:

Dr. Michael Ivie and Crystal Meier of the Insect Systematics lab at Montana State University provided access to the MTEC and help with the literature and nomenclature of the group.

Insects in Minnesota That May Be Confused With Emerald Ash Borer

Jeff Hahn, University of Minnesota Extension
Val Cervenka, Minnesota Department of Natural Resources

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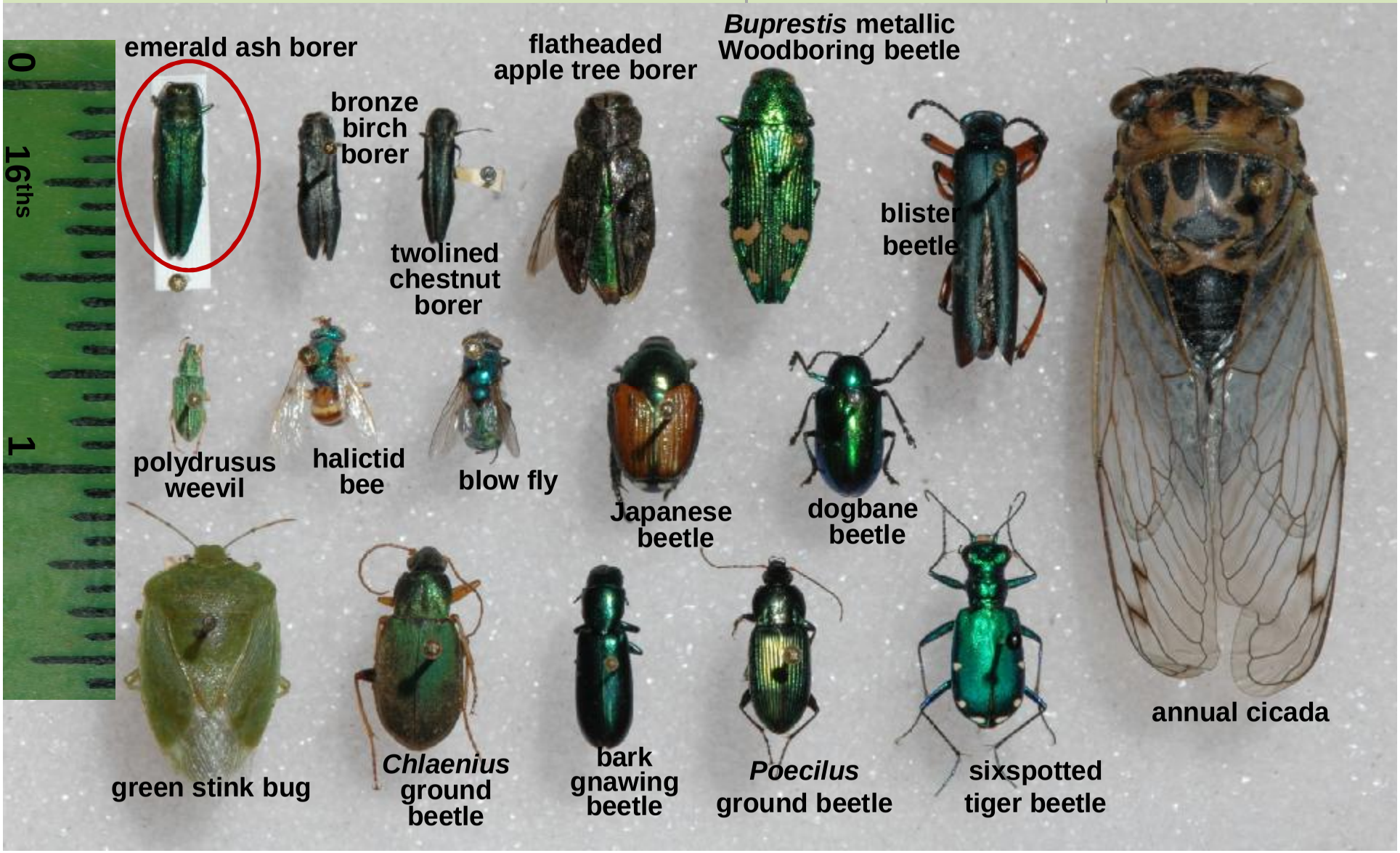
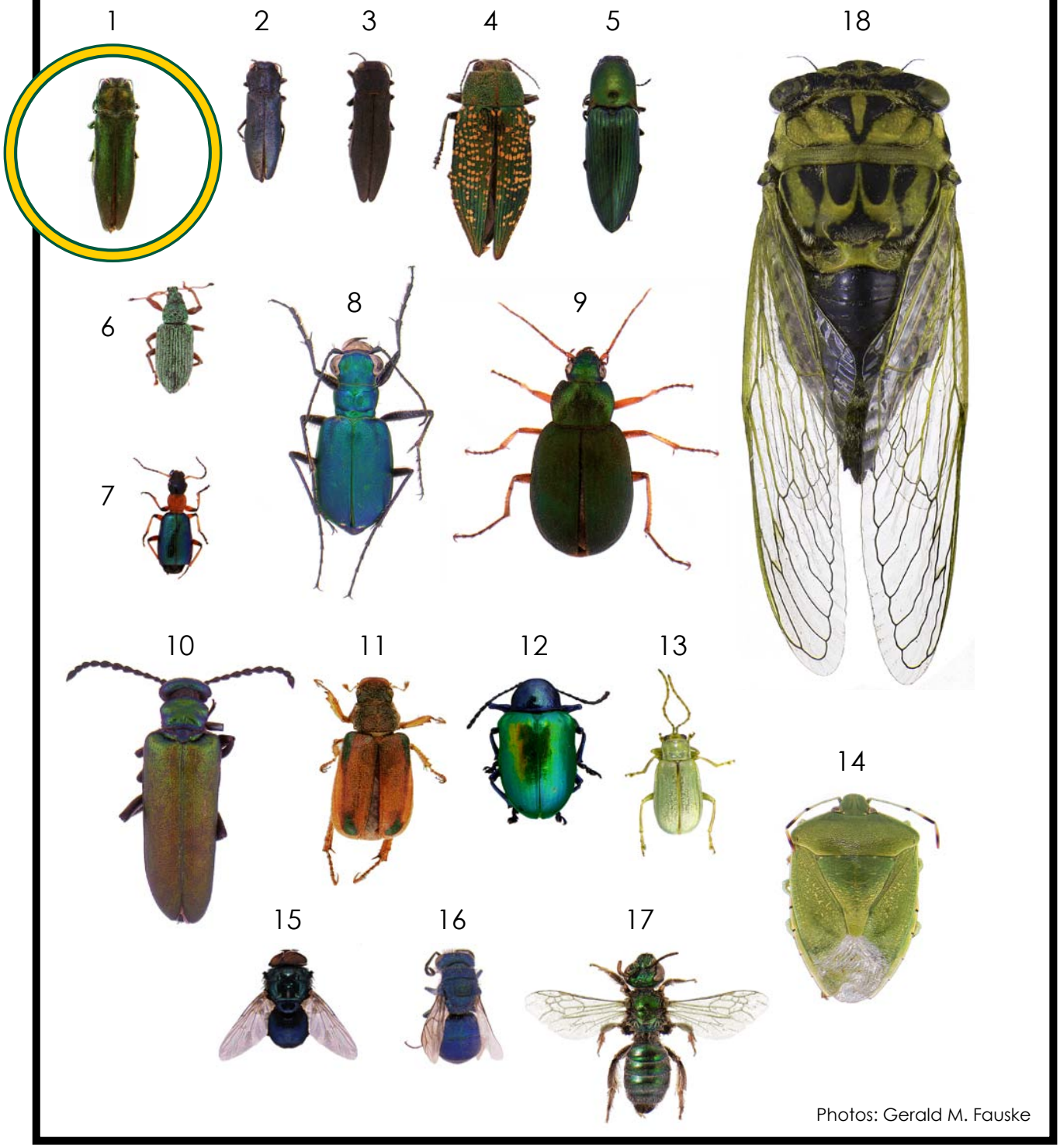


E-1604
February
2012

Insects Frequently Confused with Emerald Ash Borer in North Dakota



Photos: Gerald M. Fauske

NDSU EXTENSION SERVICE

Gerald M. Fauske, Collection Manager, Systematic Entomology Laboratory
Janet J. Knodel, Extension Entomologist, Department of Entomology

Emerald Ash Borer

NDSU EXTENSION SERVICE Entomology

The Emerald ash borer is a beetle (Order Coleoptera). Beetles are recognized by having shell-like front wings called elytra. When the wings are folded, they meet forming a median line down the back. Currently, Emerald ash borer has not been found in North Dakota.

Metallic wood-boring beetles
(Family Buprestidae)

Compact beetles with short legs and "saw-toothed" antennae

1. **Emerald ash borer**
   ***Agrilus planipennis* Fairmaire**
2. Honeysuckle borer
   Agrilus cyanescens Ratzeburg
3. Bronze birch borer
   Agrilus anxius Gory
4. Green metallic woodborer
   Buprestis confluenta Say

Click beetles (Family Elateridae)

Beetles with a flexible joint between thorax and abdomen

5. Green click beetle
   Ctenicera species

Weevils (Family Curculionidae)

Beetles with a "snout" and elbowed antennae

6. Green Polydrusus weevil
   Polydrusus species

Ground beetles (Family Carabidae)

Long-legged, agile beetles with long antennae

7. Calleida beetle
   Calleida species
8. Six-spotted tiger beetle
   Cicindela sexguttata Fabricius
9. Green pubescent ground beetle
   Chlaenius sericeus Forster

Blister beetles (Family Meloidae)

Soft-winged beetles with head narrowed behind eyes

10. Nuttall blister beetle
    Lytta nuttalli Say

Scarab beetles (Family Scarabaeidae)

Beetles with lopsided antennal club and flattened front legs

11. Green-marked chafer
    Dolichonyx subvittatus Capiomont

Leaf beetles (Family Chrysomelidae)

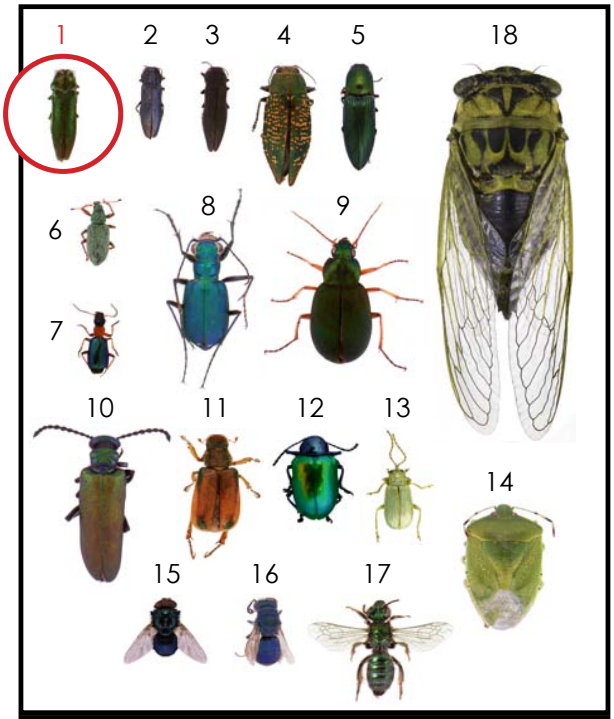
Oval beetles with long antennae

12. Dogbane beetle
    Chrysochus auratus (Fabricius)
13. Northern corn rootworm beetle
    Diabrotica barberi Smith & Lawrence

Other Insects

Front wings at least partially membranous

14. Green stink bug (Hemiptera: Pentatomidae)
15. Blow fly (Diptera: Calliphoridae)
16. Cuckoo wasp (Hymenoptera: Chrysididae)
17. Sweat bee (Hymenoptera: Halictidae)
18. Annual cicada (Hemiptera: Cicadidae)



Life Sized Images

For more information on this and other topics, see www.ag.ndsu.edu

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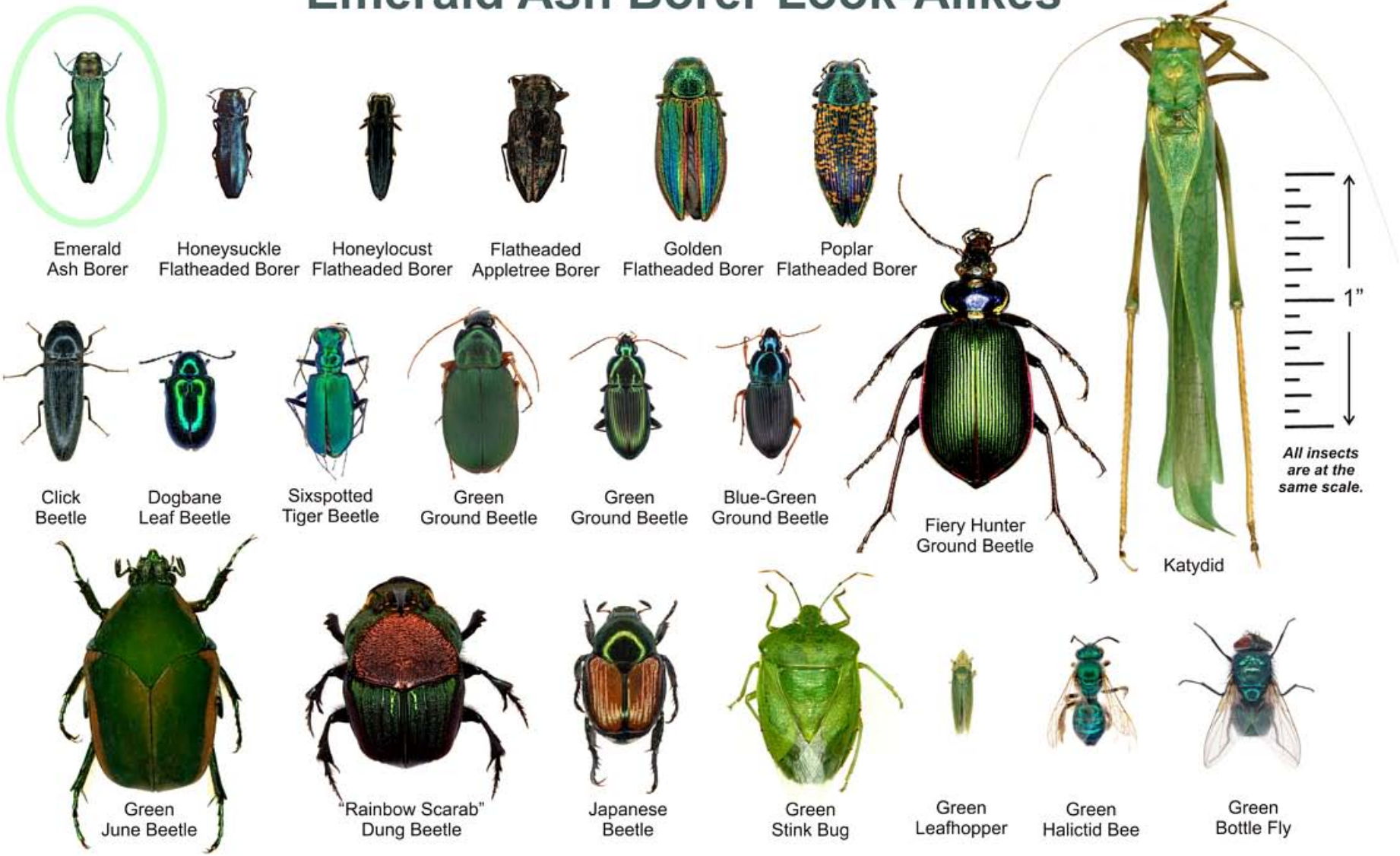
Emerald Ash Borer Look-Alikes



There are many bright metallic-green insects in Nebraska, but the emerald ash borer beetle is only a half-inch long and strictly associated with ash trees.

Produced as a cooperative effort by University of Nebraska-Lincoln Extension, Nebraska Department of Agriculture, Nebraska Forest Service, and USDA-APHIS.

Appendix 1

Emerald Ash Borer Checklist

Emerald Ash Borer Checklist

Is it Really Emerald Ash Borer?

1) I think a tree may be infested with EAB. **Go to #3.**
   It may be helpful to review Section 3 of this manual.

2) I suspect I have seen an Emerald Ash Borer adult. **Go to #5.**

3) Is the tree an ash? Review *"Ash Tree Identification"* in Section 2 of this manual and online at: www.mda.state.mn.us/news/publications/ext/ashtreeid.pdf.

   If yes, go to #4.

   If no, **it is not EAB**. Contact a local extension agent for help or visit the CSU Extension website at www.ext.colostate.edu to obtain fact sheets about yard and garden related topics.

4) Does the ash tree have symptoms of Emerald Ash Borer? Review *"Signs and Symptoms of the Emerald Ash Borer"*, which can be found in Section 3 of this manual and online at: http://www.emeraldashborer.info/files/e-2938.pdf.

   If yes, proceed to #6.

   If no, it is not likely EAB. Contact a local extension agent for help.

5) Review the guide cited in #4 and the guides found in Section 6 of this manual titled 'EAB Look-alikes and Native Wood Boring Insects of Ash'.

6) If you have reason to suspect EAB, contact your local county CSU Extension Office **before moving any wood**. Contact information for CSU Extension Offices by county can be found at: http://www.ext.colostate.edu/cedirectory/countylist.cfm.

   You can also visit www.eabcolorado.com and fill out the Emerald Ash Borer Report Form.

Appendix 2

Materials for Reporting

INSPECTING FOR INFESTED TREES

Useful Equipments and Supplies

- EAB Detector Information
- Digital Camera
- GPS Unit
- Vials for collection
- Pole saw
- Draw knife or chisel
- Pocket knife
- Binoculars

1. **Verify that the tree is an ash tree** (See Ash ID tab). Emerald ash borer only attacks ash trees.

2. **Look for symptoms of Emerald Ash Borer**.
    a. **Canopy dieback.** There are many biotic and abiotic causes of canopy dieback.
    b. **Epicormic shoots.** There are other causes including environmental stress and ash yellows phytoplasma.
    c. **Increased Woodpecker activity.** Increased woodpecker activity is generally associated with EAB infestation but there are other insects that could stimulate woodpecker activity and other causes of bark flecking.
    d. **Bark Splits.** Bark splits are a symptom associated with many wood boring insects. When tissue is killed beneath the bark, the bark frequently splits. Examine the area beneath the split carefully for S shaped galleries characteristic of EAB. A chisel is handy.
    e. **D shaped exit holes.** Any D shaped exit hole of the proper size (1/8") should be investigated further.
    f. **S shaped galleries.** Refer to the section on wood borers to see examples of the galleries produced by the various borers affecting ash.

Emerald Ash Borer
How to Submit Samples

If you suspect you have larvae or adults of *Agrilus planipennis* (emerald ash borer) submit them using the instructions below to the nearest Colorado State University-Extension office. A directory of offices can be found here http://www.ext.colostate.edu/cedirectory/countylist.cfm

Digital Pictures

Digital pictures can be used to document the condition of an ash tree and help determine if further investigation or a site visit is warranted. Good quality photos (non-blurry) can be emailed to the Colorado Department of Agriculture at CAPS.Program@state.co.us

Provide good quality photos of one or more of the following:
-The whole tree or trees showing symptoms (canopy dieback, epicormic shoots, bark splits)
-Adult insects resembling EAB
-Larvae found underneath the bark of an ash tree
-Serpentine galleries and or D-shaped exit holes

For pictures of larvae, adult insects, or exit-holes, use a ruler or coin to demonstrate the size of the subject.

Submitting Samples

Do not ship live specimens. Adults and or Larvae should be placed in a vial or some other leak proof container and placed in alcohol (rubbing alcohol or hand sanitizer). Specimen condition affects the accuracy and speed of identification. Specimens cannot be identified if they arrive crushed, broken or moldy. Use bubble wrap or some other material for cushioning. Submitted specimens will not be returned.

Label samples with the following information

Your Name_____
Your Phone_____
Your Email_____

Address of Collection Site
_____
_____
City_____Zip_____
County_____

To be identified (number by)
__Larvae
__Pupae
__Adults

Type of Property (check)
__Residential
__Agricultural
__Park
__Commercial
__Other_____

Signs and Symptoms Observed (check)
__Canopy Dieback
__D-shaped exit holes
__Serpentine Galleries
__Bark Splits
__Epicormic Sprouting
__Woodpecker activity

For Official Use Only

Identification	Date	By

Instructions for Extension agents:

If you suspect that the larvae or adult is an emerald ash borer, *Agrilus planipennis*, and you are in a non-infested county (all counties other than Boulder County), submit the specimen to the Plant Diagnostic Clinic (for Dr. Boris Kondratieff). If you submit an EAB suspect, please notify the Colorado Department of Agriculture (CDA) OR the United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (USDA APHIS PPQ).

Contact Information:

Plant Diagnostic Clinic
E215 Plant Sciences Bldg. 1177 Campus Delivery
Colorado State University Fort Collins, CO 80523-1177
Ph. 970-491-6950
Fax 970-491-3862
Email: plantlab@lamar.colostate.edu

Colorado Department of Agriculture
John Kaltenbach, john.kaltenbach@state.co.us
Ph. 888-248-5535
700 Kipling St. Suite 4000
Lakewood, CO 80215

USDA APHIS PPQ
Lisa Peraino, lisa.j.peraino@aphis.usda.gov
Ph. 303-371-3355
3950 N. Lewiston St. Suite 104
Aurora, CO 8001

Emerald Ash Borer Detection Survey-Call Record/Site Visit	
Detector Name:	Detector Contact phone/email:
Date of Phone call:	Date of site visit:
Reporter/Caller:	Reporter contact phone/email:
Location. Be specific enough that the exact site can be located if necessary	
GPS Coordinates	Legal Description
Trees verified to be ash:	
Symptom checklist (Describe the symptoms or signs observed)	
Woodpecker activity	
Dieback	
Epicormic Sprouts	
Bark Splitting (Examine the area beneath the bark in the vicinity of bark splits looking for s-shaped galleries)	
Exit Holes (Are any of the exit holes approximately 1/8" and D-shaped? Any trees with 1/8" D shaped holes should be reported. Digital pictures are useful (with scale). Further investigation warranted, including bark peeling.)	
Galleries Under Bark (If S-shaped, they could be EAB. See section of wood borers. S shaped galleries should be further investigated (bark peeling, looking for larvae recommended.) Digital photos are useful if you think galleries resemble those of EAB.)	
Larvae Collected (see section on wood borers to see if they resemble EAB (bell shaped abdominal segments). Collect any specimens thought to be EAB and submit per instructions. Label the sample and note which tree the sample was recovered from.)	
Pictures Taken (indicate if you took pictures and provide description)	
Bark or Branch Sample Taken (Samples with D shaped exit holes or S shaped galleries are useful. Label the sample and note which tree the sample was recovered from.)	
Additional Comments: (Write down anything here mentioned in the call that may assist in verifying suspect calls.)	

Appendix 3

Additional Resources

Colorado Emerald Ash Borer First Responder Manual
Additional Resources

Emerald Ash Borer Comparison to Similar Species

Emerald Ash Borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae): A guide to identification and comparison to similar species. Gary L. Parsons, Department of Entomology, Michigan State University (2008): http://www.emeraldashborer.info/files/eab_id_guide.pdf

Tree Recommendations to Replace Ash Trees in Colorado

Front Range Tree Recommendation List, ASLA Colorado, Colorado Nursery & Greenhouse Association, Colorado Tree Coalition, and Colorado State University Extension: http://www.ext.colostate.edu/pubs/garden/treereclist.pdf

Colorado State Forest Service Tree Publications: http://csfs.colostate.edu/pages/pub-trees.html

Colorado Tree Coalition: http://www.coloradotrees.org/

Colorado State University Extension Publications

Native Trees for Colorado Landscapes, CSU Extension Fact Sheet 7.421: http://www.ext.colostate.edu/pubs/garden/07421.html

Small Deciduous Trees, CSU Extension Fact Sheet 7.418: http://www.ext.colostate.edu/pubs/Garden/07418.html

Trees and Shrubs for Mountain Areas, CSU Extension Fact Sheet 7.423: http://www.ext.colostate.edu/pubs/Garden/07423.html

Evergreen Trees, CSU Extension Fact Sheet 7.403: http://www.ext.colostate.edu/pubs/garden/07403.pdf

Xeriscaping: Trees and Shrubs, CSU Extension Fact Sheet 7.229: http://www.ext.colostate.edu/pubs/Garden/07229.html

Appendix 4

Acknowledgements

Acknowledgments

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Colorado Department of Agriculture

Colorado State Forest Service

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Michigan State University Extension

Minnesota Department of Agriculture

Montana Department of Agriculture

Natural Resources Canada

North Dakota State University, Entomology Department

University of Minnesota, Department of Forest Resources

University of Minnesota Extension

University of Nebraska, Lincoln

USDA Animal and Plant Health Inspection Service

USDA Forest Service