



Using the Emerald Ash Borer (EAB) Cost Calculator: A Case Study for Milford, Connecticut

Gabriela Doria & Chris Donnelly

Urban Forestry Program, Forestry Division
Department of Energy and Environmental Protection

State of Connecticut

79 Elm Street, Hartford, CT 06106-5127

Phone: (860) 424-3178

Email: Chris.Donnely@ct.gov

Website: www.ct.gov/deep/forestry



Plate I (opposite page). **Life cycle of emerald ash borer (EAB).** The biological characteristics of EAB define the effects of the infestation in ash trees and forests. This paper introduces the use of the EAB Cost Calculator, a web-based tool that considers aspects of the biology of EAB and its implications for management of urban forests. EAB adults (upper left) lay eggs on bark crevices. Larvae (upper right) hatch in about one week. Larva feed on the inner bark and phloem of the tree creating S-shaped serpentine galleries (center left). Larvae go through four feeding stages and then excavate a pupal chamber in the fall (center right showing overwintering larvae). Pupae (lower left) develop in late spring. Adults emerge through D-shaped exit holes (lower right) in May and Early June. Upper left image courtesy of Forestry Images. Photo credit Chris Donnelly and Gabriela Doria.

1. Introduction

Since the summer of 2012, the emerald ash borer (EAB) has been known to be in Connecticut. The goal of this paper is to provide guidance regarding the management of ash trees for tree wardens and others responsible for the public's trees. In developing plans for these trees, it is important to know the options available to a municipality. The Emerald Ash Borer Cost Calculator can be a helpful tool for this purpose.

The Emerald Ash Borer Cost Calculator was developed by Purdue University's Extension Entomology program. Through a series of charts, this tool allows a manager to rapidly consider his or her choices. The results of these choices are presented based on both cost figures and the volume of trees likely to remain in the urban forest following infestation by EAB. Both amounts will vary depending upon the management options chosen.

The cost calculator, <http://extension.entm.purdue.edu/treecomputer/>, is free and can be accessed online. In the example presented here, the tree data used was drawn from a 100% inventory of the City of Milford's street trees. This inventory was conducted by Milford Trees Inc. and completed in 2004. In conducting this inventory, volunteers collected data on some 15,871 street trees, of which 518, or roughly 3%, were either green or white ash.

Milford's inventory was used as being representative of a typical Connecticut urban forest. Having data on the ash trees in a community is important for being able to use the EAB Cost Calculator. This data can be collected either from a 100% street tree survey or from a representative sample. Options for communities that do not have either an inventory or survey will be discussed later in this paper.

2. The EAB Invasion Wave Concept

The EAB cost calculator uses an invasion wave model for its estimations. According to this model all untreated ash trees in an area will have become infested within eight years after an EAB infestation begins. Understanding how advanced the invasion wave is in your community is crucial to defining the most appropriate management plan for your specific case.

EAB invasions have three main stages: the cusp, crest, and post-crest (Figure 1). The cusp and the crest stages correspond to the aggressive phases with regards to management. The cusp stage occurs over the first few years as the EAB population builds slowly. During this stage EAB is difficult to detect. Trees with low densities of the beetle show no or little external symptoms. During this stage the beetles tend to be higher in the crowns of the trees. In the crest stage the EAB population reaches its peak density and causes high levels of ash tree mortality. The post-crest stage begins around 12 years after the initial infestation. By this time all untreated trees have died. As EAB deplete ash resources, the beetle population disperses and begins to colonize new areas. In terms of management, the post-crest stage is also the maintenance phase.

EAB Cost Calculator management plans are based on two premises. As the infestation begins and then when the EAB population is high (the cusp and crest stages), management needs to be aggressive. During the post-crest stage, the inspection and treatment of the remaining ash trees continues, but with the focus more on the maintaining of these remaining trees than on the aggressive prevention of EAB becoming established and doing damage.

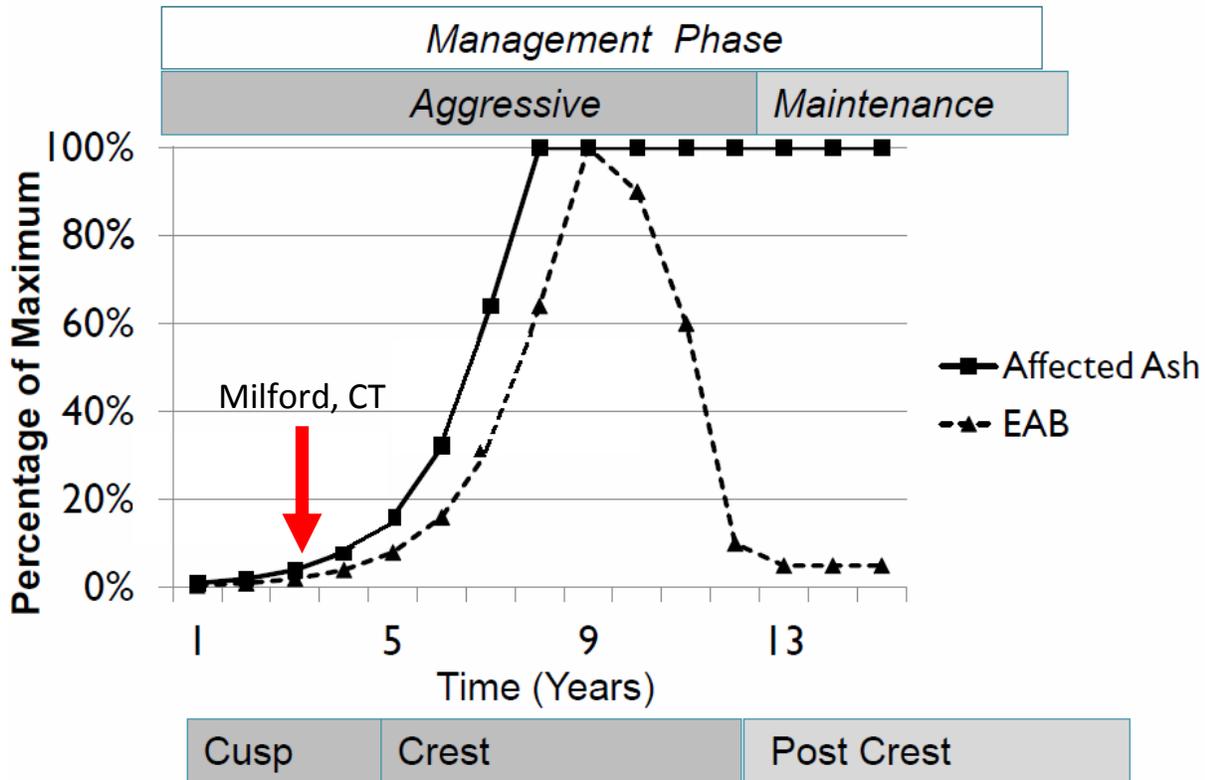


Figure 1. Emerald Ash Borer (EAB) Wave Infestation. Red arrow shows the approximate stage of infestation in Milford, CT. Adapted from EAB Cost Calculator website.

3. Using the EAB Cost Calculator

To use the EAB Cost Calculator it is best to have an inventory of the street tree population in your municipality. A complete inventory is preferred, but a sample based survey also works. The third alternative is to use an approach such as a ‘windshield survey’ of only ash trees. The Cost Calculator is based on numbers, so the user will have to enter some numeric input for the Calculator to work. The Cost Calculator does come with a set of demonstration numbers. These allow the user to explore how the Calculator works and can be modified if the user wishes to vary the scenarios. If you have inventory data, it can be easily input into the calculator in just a few minutes. Simulations can be run immediately, and interpretation of the results begun right away.

If using local data, the user starts by entering the data on a municipality's ash trees by size class, using diameter at breast height (dbh). Inputting the distribution of tree sizes is important because costs for treatment and removal vary by dbh. As size increases, insecticide dosage increases and labor and equipment costs also rise. The EAB Cost Calculator does not include maintenance costs beyond tree planting costs and EAB insecticide treatments specific to individual options (Sadof et al., 2011).

To estimate the costs, the EAB Cost Calculator makes use of a range of inputs. Default values can be used. However, inputting values reflective of your municipality will result in more accurate economic analyses. The following values can be entered to the Calculator:

- Number of years over which the replacement/removal work will be completed
- Cost per dbh for insecticide treatments
- Frequency of insecticide applications during aggressive and maintenance phases of management
- Cost of replacing a tree
- Cost of removing a tree
- Discount rate

The calculator includes three simple strategies of management: (1) remove all trees, (2) replace all trees and (3) treat all trees. It also includes eight options based on varying degrees of these three simple strategies. You may also design new plans that might better fit your municipality.

The EAB Cost Calculator represents the size of the urban forest size by calculating the sum of all tree diameters. In the dbh total, the Cost Calculator includes both remaining ash trees and any trees planted to replace ash trees, depending upon the option chosen. All trees are assumed to grow at a constant rate. Costs and total dbh are each presented as an annual total over a twenty-five year period, and also as a cumulative total over that same time period.

4. Milford's Case

We used Milford's tree inventory data to run simulations with the EAB Cost Calculator. The results are an interesting illustration of factors to consider when selecting a management plan.

Where the infestation is along the EAB invasion wave does influence the results. It also allows one to predict how many trees will die or become hazardous at each point of time.



Plate II. Symptoms of EAB infestation in ash trees include: branch dieback starting by the upper crown (A), s-shaped serpentine galleries in the bark (B), and epicormic branching on the tree trunk (C).

EAB was first detected in Connecticut in Prospect, New Haven County in 2012. Since then it has been found in four counties and fifteen towns in the state. Hamden, in New Haven County, 14 miles northeast of Milford, is the closest town with confirmed EAB. The first report in Hamden is from May 2013.

On its own, an EAB infestation spreads at a rate of half a mile to one mile per year. When carried by humans, such as in firewood, it can travel hundreds of miles in a very short period of time. Connecticut towns where EAB is present (e.g. Hamden) are probably 3-4 years into the infestation. All of these factors add up to a conclusion that EAB very likely is, or very soon will be, present in Milford.

Hence, we chose “Year 0” as the starting point for our first simulation.

For our simulation we defined 10 dbh categories. For the most of the other inputs, we used the default values suggested by the calculator. For replacement tree size we chose to use trees 2.0” dbh and we used 5% for a discount rate on expenditures. We selected the most inexpensive insecticide option (imidacloprid) and determined, when used, treatments will be applied annually during the aggressive management phase (the cusp and crest stages - the first 12 years) and every three years during the post-crest stage.

We chose to run four options in our first simulation. These four were picked primarily because the results differed enough that they provide a good contrast of what can be expected from the various options. The results are shown in the four charts depicted in Figure 2.

Our first scenario was “Remove All”. In this scenario, we chose to remove all ash trees over an eight year time frame (this time frame is also subject to choice). This strategy leads to the lowest annual and cumulative costs. However, under this option, all ash canopy is lost and is not replaced.

Our second scenario was “Replace Unsafe Ash”. Under this scenario, ash trees are removed as they die and become hazardous, and then are replaced with a substitute species. One clear outcome from this strategy is a huge peak in costs over the first eight years, largely due to the pressing need to remove trees. Ash trees tend to deteriorate quickly after they die, and so there is little opportunity to leave dead ash trees standing for long. However, due to the growth of the replacement trees, the urban forest will be more than 50% of its pre-EAB size after 25 years.

The cumulative, 25 year cost of the “Replace Unsafe Ash” Scenario is better than double the cost of the “Remove All” scenario. Much of this is due simply to the cost of replacing trees.

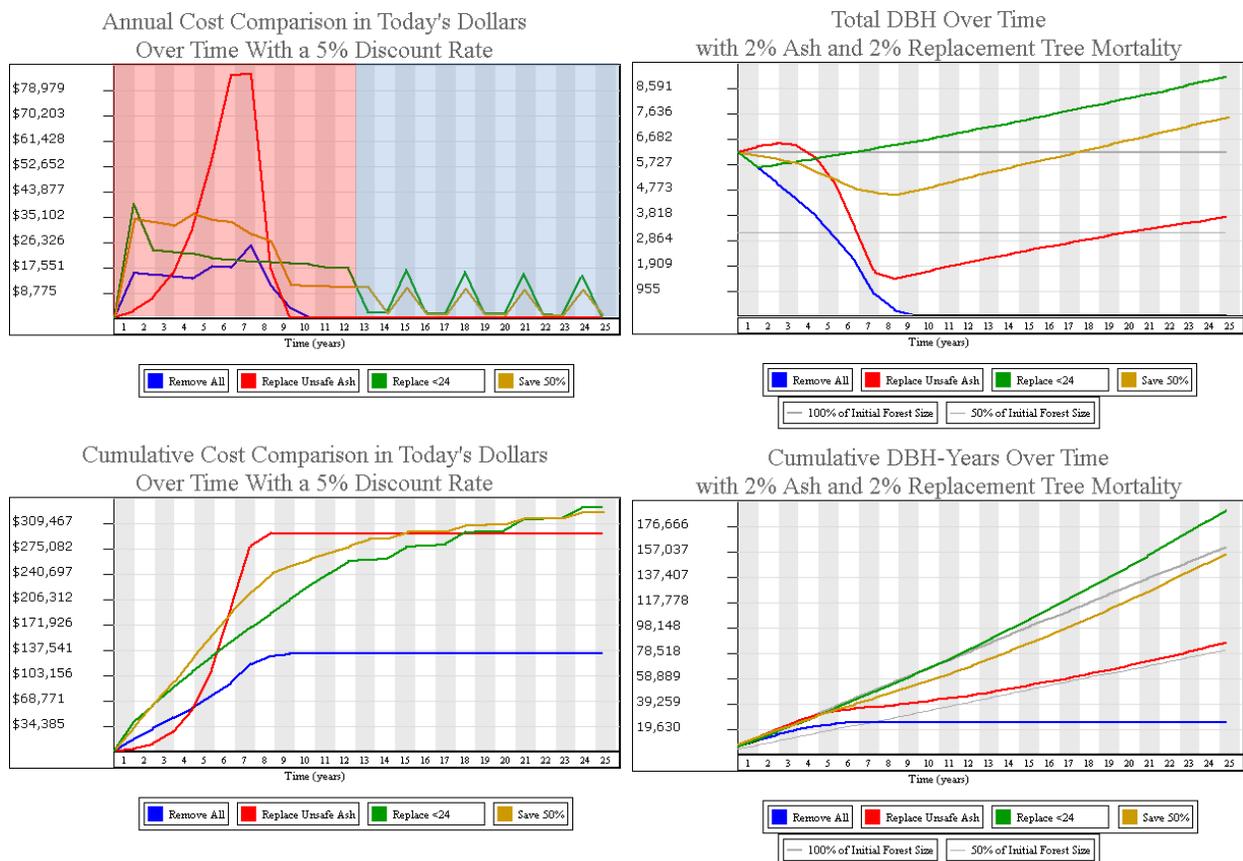


Figure 2. Comparison of management plans for Milford, CT, under first scenario: “Year 0” as the starting point of simulation. Red and blue shade areas correspond to aggressive and maintenance phases of management respectively. Compare to figure 3. Modified from EAB Cost Calculator comparisons output.

The third option involves replacing all ash trees less than 24" dbh with substitute plantings, and treating all ash trees 24" and greater with imidacloprid. Of the 518 ash trees in Milford, 44 have dbh larger than 24". One characteristic feature of this line on the chart is the sawtooth pattern during the maintenance years, starting at Year 12. This is due to the application of the insecticide to the remaining large ash trees, every third year for the remainder of the scenario.

The other striking feature of this scenario is the "total dbh" at the end of 25 years. The sum of tree dbh at this point is approximately 40% greater than was the original sum of ash dbh prior to the infestation occurring. Of course, this comes at a cost. The cumulative cost for this scenario at the end of 25 years is slightly greater than that of the "Replace Unsafe Ash Scenario".

These charts, of course, just outline two of the factors that would go into making a decision. They highlight good reasons for considering a plan based on removing and replacing smaller ash trees (<24 inches) and treating the larger trees (Kovacs, et al., 2010). From an economics perspective, larger trees are of greater value. This value can be sustained with treatment. The value of these trees is much greater than the treatment costs. Conversely, removing and replacing small ash trees effectively exchanges the near-term benefits that would come from the smaller ash trees for those that will come from the longer-living replacement trees, without the need for EAB treatment. It is true that the cumulative cost of "Remove <24" strategy is the highest in our comparison. However, the annual cost is relatively evenly distributed during the 25 years of forest management, leading to easier budget projections.

The fourth alternative we considered was "Save 50%". In this strategy half of the trees in each size class would be treated and the other half would be replaced. Similar to "Remove <24"", the "Save 50%" strategy illustrates the relative advantage of saving some of the community ash trees. The outcome of this strategy is comparable, in terms of costs and retained dbh total, to that of saving only the largest ash trees. However, the number of ash trees from the original population preserved is much higher, at 259 trees compared to 44 in the "Replace <24" strategy". This is important as trees of various sizes could be deliberately allowed to remain in certain specified areas (e.g. neighborhoods). Depending on the case, considering which strategy would replace ash trees more equitably among the municipality's neighborhoods could be crucial to its acceptance.

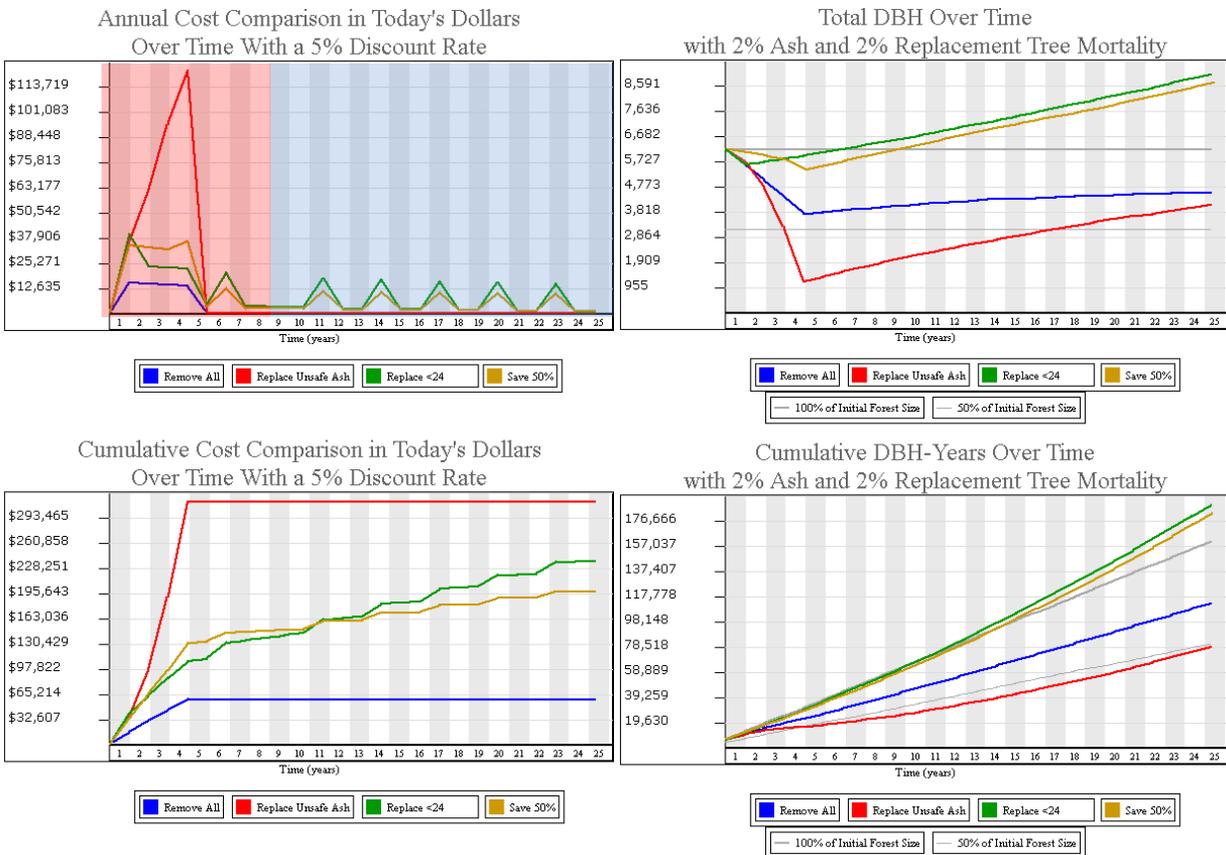


Figure 3. Comparison of management plans for Milford CT under second scenario: “Year 4” as the starting point of simulation. Red and blue shade areas correspond to aggressive and maintenance phases of management respectively. Compare to figure 2. Modified from EAB Cost Calculator comparisons output.

We also explored the implications of a pro-active attitude versus a late response to the infestation (Figure 3). We compared an infestation scenario where EAB has not yet been detected (Year 0 of infestation – Figure 2) with a scenario in which response began after a significant number of trees had become infested (Year 4 – Figure 3). We ran a second set of simulations using the same Ash treatment option but assuming implementation did not begin until the fourth year of the infestation. This corresponds to the beginning of the crest phase when about 8% of the ash trees are affected by EAB, and reduces the number of years of aggressive removal from 12 to 8. We found that delaying the start of the response leads to higher short term costs during the first years of management. This is because the cost of dealing with massive die-back during the crest stage has to be compressed into four years instead of being spread out over eight years. Interestingly, the long run cost of delaying the start of management plan is lower. This is due to the fact that the time during which aggressive insecticide treatment occurs is reduced by two years (Figure 3).

5. Integrating Tree Benefits

In comparing EAB management plans, it is important to consider the economic benefits of the ash trees. Keeping mature ash trees and treating them with systemic insecticides can produce gains in benefits that significantly exceed the cost of treatment.

Several tools are available to urban forest managers to quantify monetarily the ecosystem services provided by urban trees. To estimate the monetary value of the benefits provided by the current ash population in Milford we used i-Tree Streets (formerly known as STRATUM, or the Street Tree Resource Analysis Tool for Urban forest Managers, available at www.itreetools.org). This tool uses tree inventory data to quantify the dollar value of annual environmental and aesthetic benefits provided by these trees. The benefits include energy conservation, air quality improvement, carbon dioxide reduction, stormwater interception, and increases in property value.

An ash population such as in the 2004 inventory of the City of Milford will produce \$64,418 in benefits per year. On average, that is \$124.74 in benefits for each individual ash tree. This model does not show the increase in benefits that would occur as these ash trees increase in size over the course of twenty-five years, but the Emerald Ash Borer Calculator does show that the cost for treating all ash trees in Milford in one year would be around \$27,000, or an average of \$52 per tree.

The benefits produced by any one tree are in large part a function of the canopy volume of that tree. As such, the benefits from a large tree are much greater than those from a tree that is smaller in diameter and has a much smaller crown. This is another advantage of the option modeled by the EAB cost calculator, in which all ash trees over 24" dbh are retained. As the following table shows, keeping only these trees still allows the city to retain the majority of the benefits from its ash tree population while giving time for the replacement trees to grow. The 44 ash trees over 24" dbh in Milford represent 8.5% of the total ash tree population. This sole fraction provides benefits worth \$12,407 per year. This is almost 20% of the total benefits that would provide the entire ash tree population (\$64,418).

Table 1. Summary of the benefits provided by Milford’s ash trees population (all tree size classes included)

Annual Benefits of Milford's Ash Trees (\$/tree)						
Species	Energy	CO₂	Air Quality	Stormwater	Aesthetic/Other	Total
<i>Fraxinus americana</i>	\$52.28	\$1.07	\$9.45	\$11.63	\$46.33	\$120.76
<i>Fraxinus pennsylvanica</i>	\$57.02	\$1.16	\$10.25	\$12.65	\$47.64	\$128.72
Average <i>Fraxinus</i> spp.	\$54.65	\$1.12	\$9.85	\$12.14	\$46.99	\$124.74
Net Annual Benefits of Milford's Ash Trees- All ash trees						
Species	Energy	CO₂	Air Quality	Stormwater	Aesthetic/Other	Total
<i>Fraxinus americana</i>	\$16,521	\$339	\$2,986	\$3,674	\$14,639	\$38,160
<i>Fraxinus pennsylvanica</i>	\$11,632	\$236	\$2,091	\$2,580	\$9,718	\$26,258
Total <i>Fraxinus</i> spp.	\$28,154	\$575	\$5,077	\$6,254	\$24,358	\$64,418

Table 2. Summary of the benefits provided by Milford’s ash tree population after removing smaller ash trees (less than 24” dbh).

Annual Benefits of Milford's Ash Trees- After removing trees under 24” dbh (\$/tree)						
Species	Energy	CO₂	Air Quality	Stormwater	Aesthetic/Other	Total
<i>Fraxinus americana</i>	\$133.54	\$3.71	\$29.09	\$42.29	\$78.20	\$286.84
<i>Fraxinus pennsylvanica</i>	\$129.25	\$3.52	\$27.77	\$39.80	\$75.84	\$276.17
Average <i>Fraxinus</i> spp.	\$131.40	\$3.62	\$28.43	\$41.05	\$77.02	\$281.51
Net Annual Benefits of Milford's Ash Trees-After removing trees under 24” dbh						
Species	Energy	CO₂	Air Quality	Stormwater	Aesthetic/Other	Total
<i>Fraxinus americana</i>	\$3,204	\$89	\$698	\$1,014	\$1,876	\$6,884
<i>Fraxinus pennsylvanica</i>	\$2,584	\$70	\$555	\$795	\$1,516	\$5,523
Total <i>Fraxinus</i> spp.	\$5,789	\$159	\$1,253	\$1,810	\$3,393	\$12,407

6. Final Remarks

One clear lesson from the use of the EAB Cost Calculator is that it is not a good option to simply wait to react to the insect after its arrival. Once ash trees die, they tend to fall apart quickly and so need to be removed promptly to avoid their becoming a hazard. Waiting until the emerald ash borer is known to be in a community means that the death of trees is apt to drive the response. As the invasion wave concept chart shows, the rate of tree death accelerates quickly. Although the wave occurs over about eight years, the presence of EAB is typically not noted until the fourth or fifth year after the initial infestation. This means that the period of intensive removal becomes concentrated into the about 4 or 5 years after the infestation is noticed. Suddenly, resources need to be devoted to reactive tree removals while other priorities are put on hold.

The EAB Cost Calculator also underscores the importance of having an inventory. For planning purposes, it is important to know exactly how many ash trees a town is responsible for. Inventories that include the location of individual trees facilitate monitoring for the presence of EAB. Individual ash trees can be tracked and contractors, such as tree care companies working for utilities, can be advised as to the location of ash trees and asked to assist with the monitoring process.

If your municipality does not already have a 100% street tree inventory, there are other options. For instance, an inventory of all trees in certain sections of town or along critical streets and roadways could be used to focus attention on high priority areas. Specific concerns can be noted and plans made for a scenic roadway or significant park in advance of EAB's arrival. Similarly, a sample survey, based on a selected number of street sections, can be used to characterize the street tree population of the town as a whole. The researchers behind i-Tree suggest that a 5% sample of the streets in a town should be sufficient to draw some general conclusions, such as the total number of trees. One has to be careful when using sample data to describe a sub-set of the larger population, but the results of a sample survey can provide guidance as to the extent, condition and size distribution of the ash tree population.

Another option, less formal than a full inventory or a sample survey, is to do what is commonly called a 'windshield survey'. Windshield surveys are usually performed using two people, a driver and an observer. As the driver works his or her way through the streets of a community, the observer takes notes on the size, condition and location of individual ash trees throughout the community. As an alternative, a municipality could use information from inventories from nearby municipalities. For example, towns near Milford could assume that ash trees represent 3% of their street tree population.

Finally, EAB provides a great opportunity for public involvement. Individuals or groups

can be encouraged to ‘adopt’ individual ash trees, monitor them for indications that EAB is present and then report their observations to some central location. This information can be recorded formally, if desired. One of the more advanced technological tools being developed for this sort of purpose can be used.

Each of these methods provides a means to make use of the EAB Cost Calculator based on information on the extent of the ash population and, potentially, early recognition that EAB is beginning to infest an area. Meanwhile, Connecticut’s Department of Energy and Environmental Protection, the Connecticut Agricultural Experiment Station, the University of Connecticut and the USDA Animal and Plant Health Inspection Service (APHIS) each continue to support each other and local communities, as they seek to find where EAB is located in the state and the extent of infestation. Communities are encouraged to keep up with the findings of these state and federal agencies through regular visits to their websites and through otherwise being aware of the information that is being shared.



Plate III. Public involvement in emerald ash borer infestation control in Connecticut.

7. Acknowledgements

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8. References

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- Sadof, C. S., Purcell, L., Bishop, F. J., Quesada, C., & Zhang, Z. (2011). Evaluating Restoration Capacity and Costs of Managing the Emerald Ash Borer with a Web-based Cost Calculator in Urban Forests. *Arboriculture and Urban Forestry* 37(2), 74–83.

9. On-line Resources

- Department of Energy and Environmental Protection, State of Connecticut, EAB Educational Page, <http://www.ct.gov/deep/eab>
- Connecticut Agriculture Experimental Station EAB Page, <http://www.ct.gov/caes/eab>
- United States Department of Agriculture (USDA), - Animal and Plant Health Inspection Service (APHIS), <http://www.aphis.usda.gov/wps/portal/aphis/ourfocus/planthealth>
- Emerald Ash Borer Information Summary Web Site, <http://www.emeraldashborer.info>
- Neighbors Against Bad Bugs, <http://extension.entm.purdue.edu/eab>
- Dr. Richard Cowles, Connecticut Agriculture Experimental Station, Guidelines for preserving trees in the presence of emerald ash borer, <http://www.ct.gov/caes/eab>
- Coalition for Urban Ash Tree Conservation- EAB Management Statement , http://emeraldashborer.info/files/conserv_eab.pdf
- Dr. Jeff Ward's, Connecticut Agriculture Experimental Station, Summary of CT's Roadside Tree Population, <http://www.cturbanforestcouncil.org/CUFCJeff.pdf>
- i-Tree Tools for Assessing and Managing Community Forests, <http://www.itreetools.org>
- Firewood Movement and Regulations (DEEP page), <http://www.ct.gov/deep/forestry>