Greenwood Furnace State Park

Emerald Ash Borer Management Plan

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Photo Credits

Cover page: background - Greenwood Lake Dam (D. Coine), center left - ash seeds (H. Liu), center right - EAB adult (H. Liu).

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Executive Summary

Greenwood Furnace State Park recognizes the economic, ecological, and social benefits of trees to the long term health of the park and the quality of recreation and outdoor experience for park users. Ash is an integral part of our forests, with more than 200 trees in the day use and surrounding areas. Additional ash trees are also found in various woodlots along trails and campgrounds within the park. The introduction of the emerald ash borer (EAB) in 2011, however, threatens the health of these trees.

To protect our precious forest resources and to mitigate potential damages, we have adopted a Selective Management approach toward the management of this invasive pest in the next 10 years (2012-2021) within park limits. A total of 15 high-value ash trees in the picnic area will be protected through chemical treatment with emamectin benzoate. The remaining 85 trees in that area will be removed and replaced with non-host tree species gradually in the next five years to reduce safety risks and to prevent sudden loss of canopy cover in the community. Minimum tree removal is also planned in the woodlots when dead or dying trees along popular trails and property boundaries become hazardous. Working with Bureau of Forestry, Forest Pest Management (FPM) scientists, biological control with parasitoids such as *Oobius agrili, Spathius agrili,* and *Tetrastichus planipennisi* will also be attempted in one woodlot plot for the potential long term management of this pest.

The total cost for this program is estimated at $115,277 over 10 years, with an annual cost of $2,430 to $25,200. Total cost covers chemical treatment, tree, removal, biological control, replanting, and community outreach. This amount represents about 1/2 of the total compensatory value of all ash trees. Awards and grants from federal, state, and local agencies, organizations, and institutions will be actively sought by the park to offset a portion of the cost for this project.

Community outreach is an integral part of this project as information seminars and field trainings will be scheduled on yearly basis to promote community-based EAB management across the state. Adoption of such a plan by various communities could have a positive impact on the EAB management in Pennsylvania.

This project will be co-administrated by Greenwood Furnace State Park and FPM. Annual review of the project will be conducted by the professional staff from both units. Necessary adjustments will be recommended each year based on progress reports on the status of forest conditions and EAB infestations within the park. A Greenwood Furnace State Park with healthy high-value ash trees, diverse woodlots contains surviving ash trees, replaced urban canopy, and hazard-free day use areas will emerge from its embattlement against EAB when this project is completed.

1. Introduction

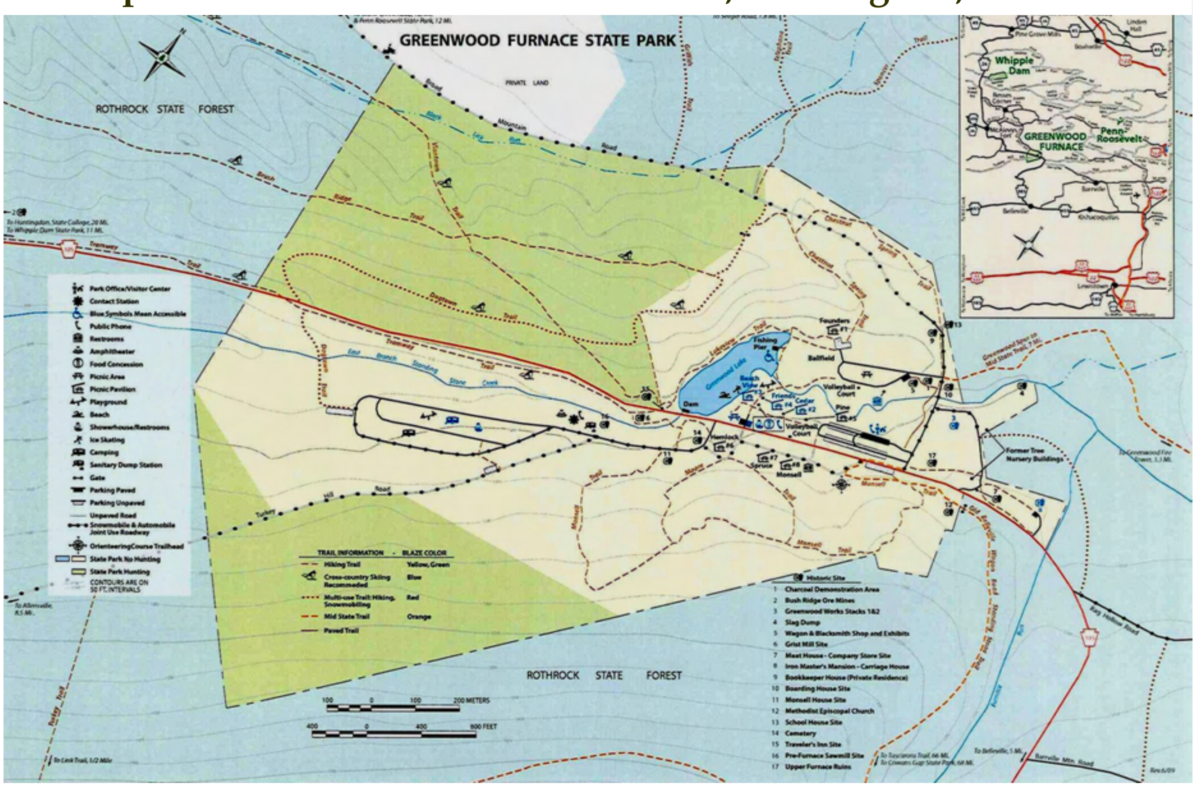
1.1. Greenwood Furnace State Park

Stone stack at Greenwood Iron Furnace http://en.wikipedia.org/wiki

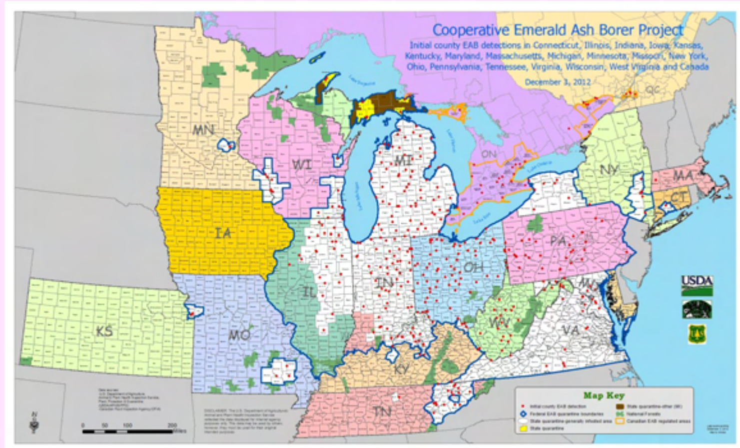
Greenwood Furnace State Park is located in Jackson Township, Huntingdon County in the Seven Mountains area in central Pennsylvania (map *below*). The park is near the historic iron-making center of Greenwood Furnace within the 80,000-acre block Rothrock State Forest. It encompasses 423 acres with a 6 acre Greenwood Lake. The park's rugged beauty, abundant wildlife, breathtaking vistas, and peaceful solitude attracts over 200,000 visitors annually with recreational opportunities such as camping, picnicking, fishing, swimming, hiking, bird watching, ice fishing, snowmobiling, and hunting. It is one of the "Twenty Must-See Pennsylvania State Parks" recommended by PA Department of Conservation and Natural Resources.

Greenwood Lake © D. Coine

Map of Greenwood Furnace State Park, Huntingdon, PA 16652



1.2. Emerald Ash Borer



EAB distribution map as of October 1, 2012 *USDA APHIS*

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), an exotic woodborer from northeast Asia, was first discovered attacking ash trees in Michigan in 2002. Since then, it has been found in 17 additional U. S. states (Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Minnesota, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, Wisconsin), and two Canadian provinces (Ontario, Quebec) across the Great Lakes region and beyond (map *above*).

1.2.1. Life history

EAB has a one- or two-year life cycle depends on geographical location and infestation stage. It overwinters as young larvae (two-year generation), mature larvae or prepupae (one-year generation) in the outer sapwood or outer bark. Adults begin to emerge in early May with the accumulation of 400-500 growing degree days (GDD) based on 50°F, and reach peak emergence in early to mid June at approximately 1,000 GDD. After emergence, adults fly to tree canopy where they feed on ash leaves throughout their lives. Adults start to mate one week after emergence, and females begin laying eggs in bark crevices or between bark layers 2-3 wk later. Each female can produce 70-80 eggs in her life. Newly hatched larvae bore directly into the bark until reaching the cambial region and phloem where they feed, often forming serpentine galleries under the bark. There are four instars in the larval stage. By mid-October to early November, most larvae reach last instar or become prepupae. Pupation occurs in early April next year. For those overwintering as young larvae (1st - 3rd instar). Pupation may not take place for another year.


Adult, 7-14 mm, metallic green © H Liu


Eggs, 1 mm, brown © H Liu


Pupa, 7-14 mm, creamy white © H Liu


Larva, 26-32 mm, creamy white © H Liu

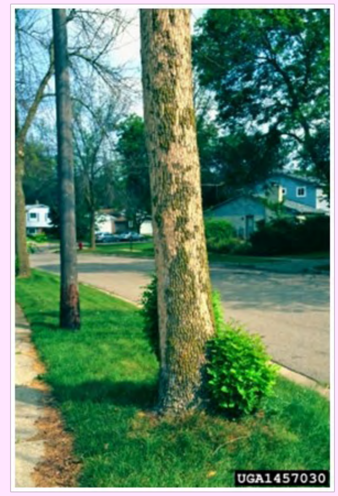
1.2.2. Damage, signs, and symptoms

EAB damage ash trees through feeding by its larvae under the bark. Larval feeding at the cambium region disrupts nutrient and water flow with in the vascular system, which eventually leads to host mortality within 4-5 years. Signs and symptoms of EAB infestation include crown dieback, epicormic shoots, woodpecker damage, bark split, dead tree, serpentine larval gallery, and D-shaped exit holes.

Crown dieback © H Liu

D-shaped exit hole © H Liu

Epicormic shoots on trunk © H Liu



Woodpecker damage on bark
© S. Katovich - Forestry Archive, Bugwood

Vertical bark splits on small trunk © H Liu

Dead ash tree © H Liu

Serpentine larval gallery © H Liu

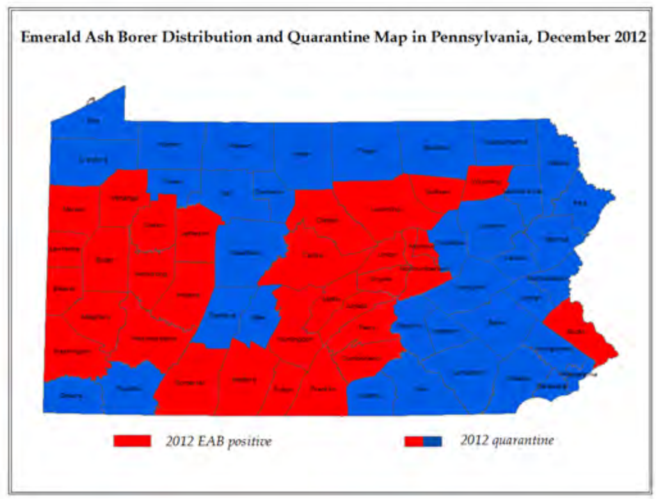
1.2.3. Host species

EAB attacks only ash trees (*Fraxinus* spp.)(Oleaceae). Host species in its native range include Chinese ash (*F. chinesis* Roxb.), Manchurian ash (*F. manshurica* Rupr.), and Korean ash (*F. rhychophylla* Hance). In North America, EAB has been recorded from green ash (*F. pennsylvanica* Marshall), white ash (*F. americana* L.), black ash (*F. nigra* Marshall), blue ash (*F. quadrangulata* Michx.), and pumpkin ash (*F. profunda* (Bush) Bush) so far. Potentially all 16 native ash species in North America are threatened by this pest when it spreads to all ash growing areas.

1.2.4. Potential impact

Ash is a valuable resource with multiple applications in the manufacture of tool handles, baseball bats, furniture, cabinetry, basketry, solid wood packing material, pulp, and paper. EAB has the potential to spread and kill ash trees throughout North America. An estimated 8 billion ash trees are found in U. S. timberland, with a compensatory value of $282 billion. Green, white, and black ash make up 7% hardwood stand in northeastern Unites States and eastern Canada. An estimated 20 to 55 million ash trees have been killed by this pest in the infested areas. The potential economic damage may exceed $10 billion in 25 states expected to be affected within in the next 10 years (Kovacs et al. 2010). In Pennsylvania, ash makes up 3.6% of the forest canopy, with more than 300 million trees. About the same number of ash trees are estimated existing in the urban areas. The potential impact of EAB on forest biodiversity, wildlife habitats, riparian areas and urban landscape could be significant.

1.2.5. Infestation in Pennsylvania



EAB was first discovered in Pennsylvania in Cranberry Township, Butler County in 2007. Subsequently, neighboring counties such as Allegheny, Beaver, and Lawrence were found infested. It has since spread to Mercer in 2008; Armstrong, Indiana, Juniata, Mifflin, Washington, and Westmoreland in 2009; Bedford, Centre, Clarion, Cumberland, Fulton, Somerset, and Union in 2010; Huntingdon, Lycoming, Sullivan, and Wyoming in 2011; and Bucks, Clinton, Franklin, Jefferson, Montour, Northumberland, Perry, Snyder, and Venango in 2012. A total of 31 counties in Pennsylvania are currently infested with EAB, with the quarantine extended to the entire state (map *above*).

1.3. EAB in Greenwood Furnace

EAB was first found at Greenwood Furnace State Park in winter 2011 when woodpecker damage along the trunk of a large ash tree at the entrance was noticed by park staff. Further investigation by Forest Pest Management (FPM) personnel confirmed its identity and additional infestations in the woods south of Greenwood Road, as well as the picnic area between Greenwood Lake and Broad Mountain Road. Dendrochronological evidences suggest that the initial infestation occurred at least 7 to 8 years ago.


Signs and symptoms © P. Weiss


Initial infested ash tree © T. Marasco

2. Objective

The objective of this plan is to protect key ash resources in Greenwood Furnace State Park from EAB damage through the following actions:

1). Conduct inventory on ash resources within the park;

2). Survey for EAB infestation on ash trees;

3). Identify priority areas for treatment;

4). Select appropriate management tools for priority areas;

5). Explore ash wood utilization and material disposal options;

6). Determine replanting and community outreach activities;

7). Perform cost/benefit analysis for selected management option;

8). Implement the management plan for a period of 10 years;

3. Ash Inventory

About 55% of the park is covered by forest. Dominate and co-dominate tree species found in the park include white oak (*Quercus alba*), black oak (*Q. velutina*), red oak (*Q. rubra*), white ash, chestnut oak (*Q. montana*), eastern white pine (*Pinus strobes*), eastern hemlock (*Tsuga canadensis*), and black locust (*Robinia pseudoacacia*). Common understory species include flowering dogwood (*Cornus florida*), rhododendron (*Rhododendron maximum*), mountain laurel (*Kalmia latifolia*), and witch hazel (*Hamamelis virginiana*) (DCNR BSP, 1996).

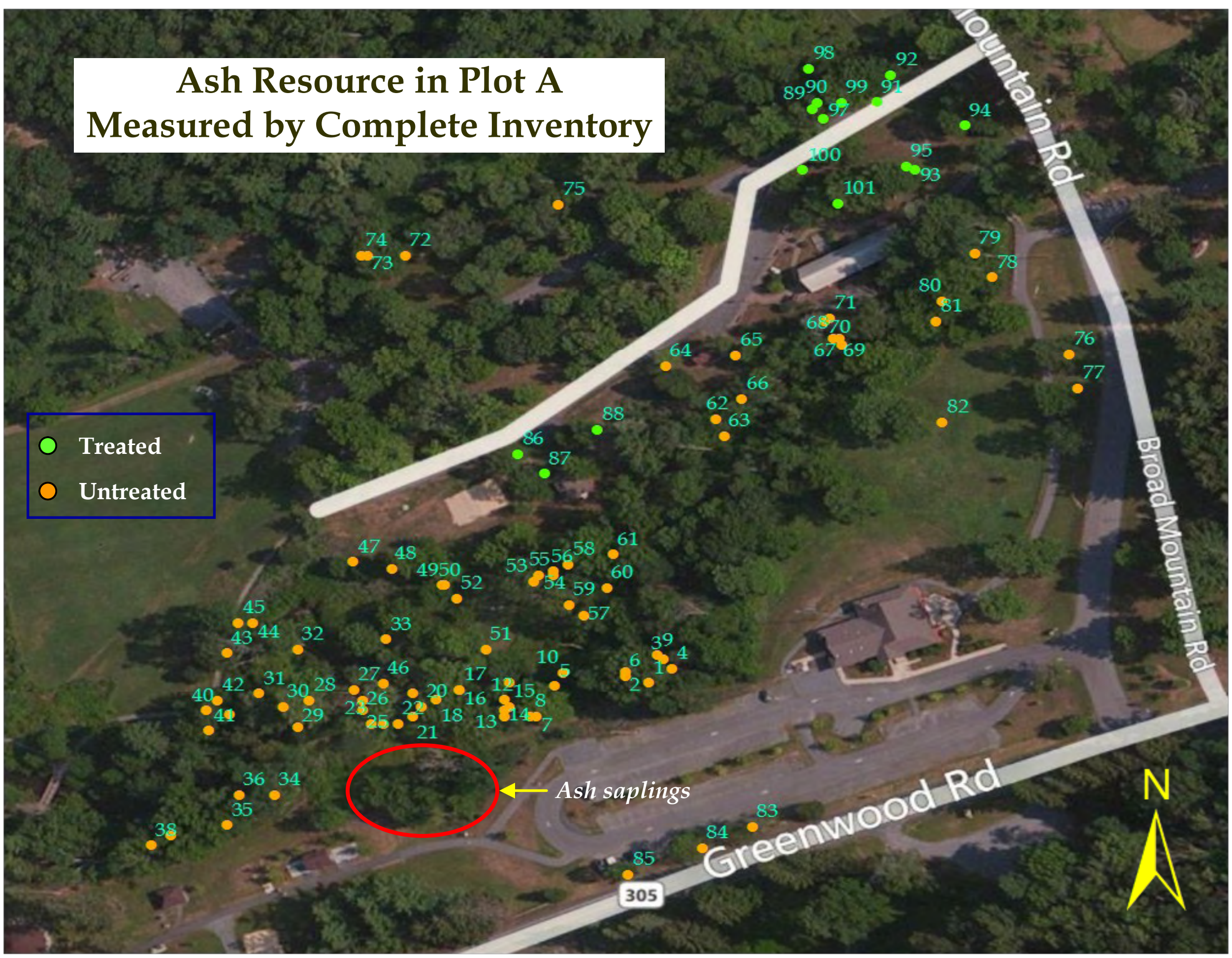
White ash is an important species in forest composition at Greenwood Furnace State Park. Concentrated white ash trees are found in two locations in the park: a 3-acre picnic area north of Greenwood Road (SR 305) between Greenwood Lake and Broad Mountain Road (Plot A); and a 4-acre woodlot south of Greenwood Road from the Old Church up to the ridge tops (Plot B) (map *left*). Ash trees in the picnic area are in pockets in open space, or along the creek that flows westward to Greenwood Lake; whereas trees in the woodlot area are scattered within mixed oak or eastern pine stands.

3.1. Complete Inventory in Plot A

Metal tag at the base of the tree © P. Weiss

A complete inventory was conducted on the 3-acre plot in the picnic area during spring 2012. All ash tree with a diameter-at-breast-height (DBH) greater than 3 inches were included in the inventory. Data collected from each tree include tree species, DBH, and GPS coordinates. A tree number was also assigned to each tree, with a metal tag attached to the base of each tree for future reference. Trees with multiple trunks below breast height were recorded as single trees, but the diameters were measured and recorded separately.

A total of 101 white ash trees ranging from 3.0 to 37.0 inches in diameter were recorded in this area (map *below*). The total diameter for those trees accumulated to 1346.9 inches, with an average of 12.2 inches, (*Appendix A*). In addition, a group of 100-120 small ash saplings (1-3 inches) were found at the northwestern corner of the parking lot in front of the park office.

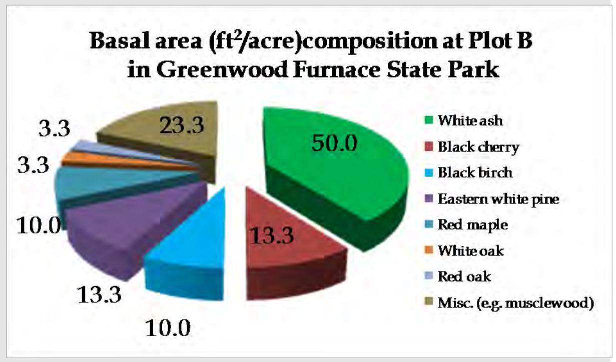


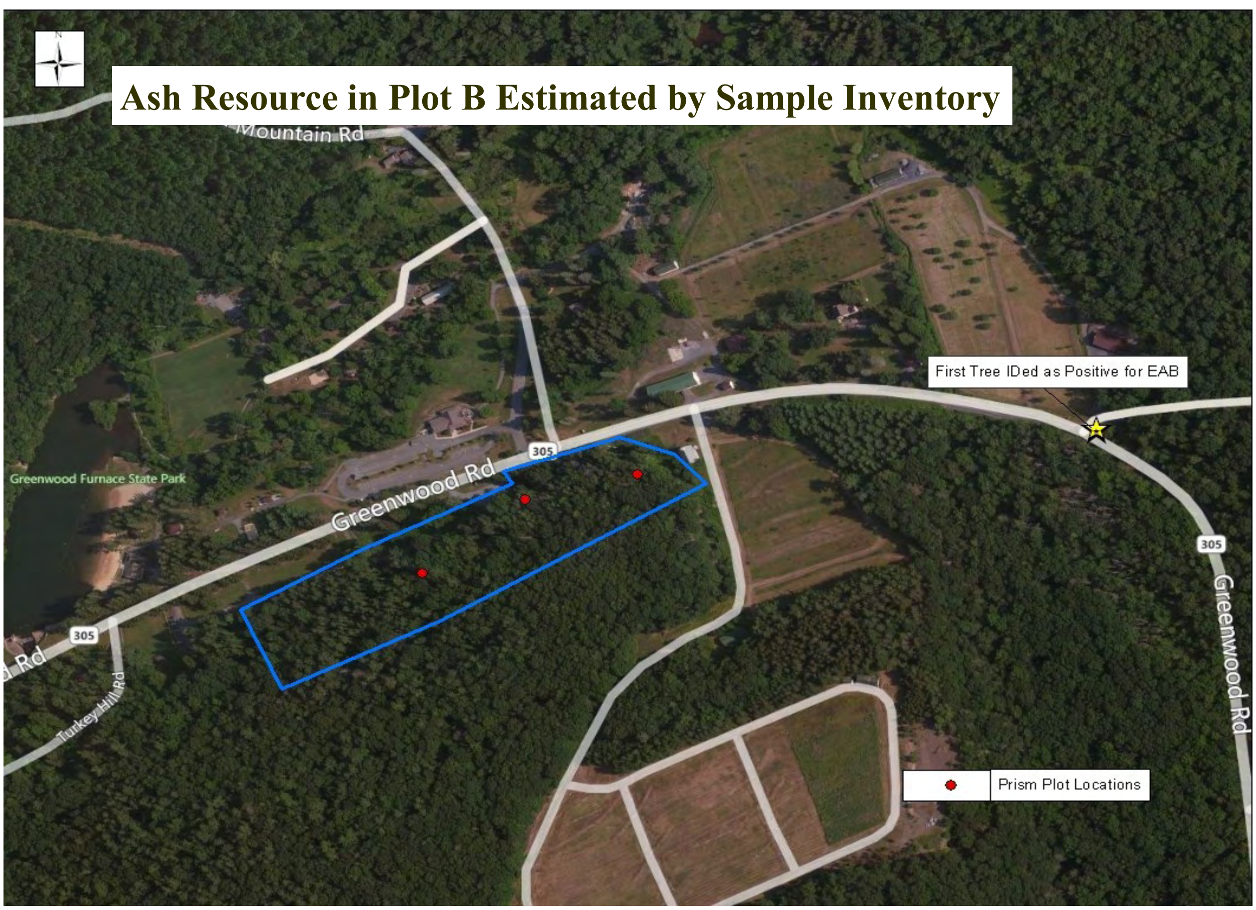
3.2. Sample Inventory in Plot B

A 10-factor (BAF 10) wedge prism was used to survey the 4-acre plot in the woodlot (*map below*). A total of 3 readings were taken from three random locations (1 reading/location) within the area to represent the plot during spring 2012.

Results showed that the average basal area for this plot was 126.7 ft^2/acre. White ash accounted for 39.5% (50 ft^2/acre) of the basal area in the woodlot. Other major species include black cherry, eastern white pine, black birch, red maple, white oak, and red oak. In addition, miscellaneous species such as musclewood contributed 18.6% (23.3 ft^2/acre) of the overall basal area.

White ash trees were scattered across the plot, with most located near Greenwood Rd. Large and declining trees were generally found at the northeastern corner, whereas those at the west edges were small but healthy. About 50% of the trees were dead during the observation, while the rest showed some sort of decline, with unacceptable growth (*Appendix B*).



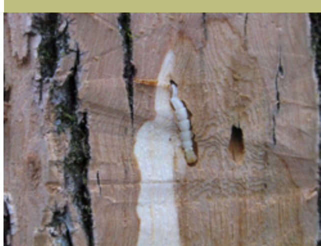


4. Pest Population


White ash trees in the picnic area © D. Coine

4.1. EAB Population in Plot A

EAB population in plot A at the picnic area was measured indirectly by a combination of crown dieback ratings and infestation signs and symptoms. Crown conditions for each tree was evaluated based on dieback ratio (0-100%) at an increment of 5% after full flush in July using a standard rating system. Other signs and symptoms such as woodpecker damage, bark splits, epicormic shoots, larval galleries, and adult exit holes were also used to help determining whether the host tree was infested, as well as the severity of the infestation. No adult trapping or log dissection for pest immature stages were included. The final crown dieback rating for each tree was the average of at least three different observers at the same time.


Exposed EAB larva on trunk © P. Weiss

Results showed that 60.4% (61/101) of the white ash tree in plot A were infested by EAB based on signs and symptoms from the tree. Crown dieback rate for these trees average 65.6%(10-100%). The heaviest infestation within this plot was found on trees along the creek east of picnic pavilion Pine #5, with multiple dead trees observed. No signs of EAB infestation was observed from the remaining 40 trees (39.6%), with an average dieback rate of 16.7% (0-80%). Overall, crown dieback rate ranged from 0 to 100% for the trees, with an average of 46.2% (*Appendix A*). All ash seedlings within this plot appears very healthy.

4.1. EAB Population in Plot B


Infested white ash tree © H. Liu

Indirect method was also used to estimate EAB population in plot B in the woodlot. Three routes were randomly selected from the woodlot to cover the entire plot. Every white ash tree encountered through the walk through was examined for symptoms of EAB infestation. Suspicious trees were further evaluated by destructive sampling along the main trunk for EAB larval gallery, various larval stages, pupae, adults, and exit holes. However, crown conditions were not rated for any trees as they were in plot A.

The initial EAB infestation in Greenwood Furnace was found in plot B along Greenwood Road close to the Old Church. As a result, about 90% white ash trees in the nearby woodlot were infested, extending from the point of introduction to the west and south end. Un-infested ash trees were only found at the western and southern edge of the plot.

5. Management Approaches

Managing EAB in North America has proven to be difficult because of the size of initial infestation, the lack of effective early detection tools, the limitations in control options, the speed of infestation spread, as well as scarcity in available resources. Consequently, many communities across the states follow the same path chronologically to certain degree in their battle against this invasive pest: exclusion through regulatory efforts and public outreach, preparedness by drafting an action plan, response by implementing control and management measures, and recovery through replanting and restoration activities. Results varied due to difference in ash resources, management goals, approaches, resources availability, and general commitment.

Currently there are three control options for EAB management:

Tree Removal. Cut and remove infested ash trees and grind them to chips < 1 inch (2.54 cm) in two dimensions. It's 100% effective against EAB larvae, prepupae, pupae, and adults before emergence. The high cost associated with this option may limit its use to small and early outlier infestations.

Tree removal © H. Liu

Chemical Control. Treat infested or susceptible ash trees with chemical insecticides. Insecticides such as imidacloprid (Merit®, Xytect™), emamectin benzoate (Tree-äge®), and dinotefuran (Safari®) can be applied directly into the tree through trunk injection or bark spray; or indirectly by treating the soil around the tree (imidacloprid only) (Herms et al. 2009). Treatment efficacy ranges from 60% to 99% depends on insecticide selected and lasts from 1 to 3 years. This option is mostly useful for the protection of high-value urban ash trees.

Trunk injection with Tree-äge © H. Liu

Biological Control. Release of parasitoids for classical biological control. One egg parasitoid - *Oobius agrili* Zhang and Huang (Hymenoptera: Encytidae), and two larval parasitoids - *Spathius agrili* Yang (Hymenoptera: Braconidae) and *Tetrastichus planipennisi* Yang (Hymenoptera: Eulophidae) are currently available to state cooperators from USDA APHIS Rearing Facilities in Brighton, MI (Gould et al. 2010). This option is intended for long term EAB population control in wooded areas where tree removal or chemical control is not feasible. However, its efficacy is still being evaluated.

Parasitoid release © H. Liu

O. agrili ♀ 1 mm © H. Liu

S. agrili ♀ 3-5 mm © J. Gould

T. planipennisi ♀ 3-4 mm © H. Liu

By utilizing one or more of the control options above, communities approach EAB infestations in their areas in one of the following ways:

Dead ash tree on park lawn © H. Liu

A. No Action. EAB is allowed to run its course in the community without any human intervention. No effort will be taken to prevent, detect, and monitor the spread of EAB, or to mitigate its damage. No tree replacement plan for affected areas either. As a result, all ash trees will likely be killed by the end. It cost nothing up front. However, the community is still responsible for the removal of hazard trees along roadways and woodland trails. Significant changes in neighborhoods and local landscapes can also be expected.

B. Selective Management. High-value ash trees in selected areas (streets, landmarks, historic sites, popular parks, important ecological sites, etc.) will be managed actively, whereas those in other areas (e.g. woodlots) will be left alone except limited biological control activities. Ash health and EAB population will be monitored. Chemical control and tree removal will be applied wherever appropriate in a cost-effective manner. Tree replacement will be prioritized towards community needs. As a result, most ash trees in the natural areas may be killed by the end, whereas high-value ash trees are protected. In addition, dead or dying ash trees in streets and parks will be replaced with non-host species to prevent major canopy gaps in neighborhoods. Annual cost for this option is moderate to the community, with minimal disturbance to the urban forests. Habitat change in untreated areas is expected.

C. Preemptive Management. Ash trees in urban areas (streets, parks, golf courses etc.) will be removed preemptively and replaced with non-host species, whereas those in natural areas (e.g. woodlands) will be left alone. No EAB survey activity will be conducted. As a result, treatment areas will contain no ash trees, with no concerns over EAB in the future either. The initial cost of this option could be very high due to expenses associated with tree removal and replacement. Neighborhoods also need to deal with major canopy gaps temporarily at the beginning before replacement trees become well established. However, no annual cost will be incurred after the completion of the project. Habitat change in untreated areas is still expected.

D. Aggressive Management. All ash trees in the community will be managed actively with available control tools. EAB population will be monitored on both roadways and woodlands. Chemical control will be actively pursued to protect the maximum portion of ash trees and their canopy. Only dead or dying ash trees will be replaced with non-host species. Biological control is actively considered for ash resources in the natural areas. As a result, most high value ash trees in the streets and parks will be protected from EAB damage, whereas dead ash trees will be replaced with non-host species. In addition, ash resources in natural areas may have a chance to survive in the long term when effects of introduced natural enemies are realized. The community suffers the least socially and environmentally from the infestation, with less risk of losing urban canopy cover. However, annual cost is the highest among all options.

Greenwood Furnace State Park has chosen the Selective Management option for its ash resources.

5.1. Tree Removal

EAB infested ash trees will be removed from the park to reduce potential safety hazard and EAB population. Untreated trees close to pavilions, buildings, picnic tables, roads and trails in Plot A will be removed (*Appendix A*). No concerted tree removal will be scheduled at Plot B.

5.1.1. Prioritization

Tree removal © H. Liu

Tree removal will be prioritized based on risk factors, tree health, and location. Trees that are dead or dying will be removed first, followed by those with the highest dieback rate until all untreated white ash trees are removed by 2016. The main trunk of each removed tree will be considered for wood utilization whereas all branches will be chipped onsite and disposed according to quarantine guidelines. Tree removal will be scheduled annually during the winter or early spring to prevent next generation EAB adults from emerging. Special arrangements are being developed with utility companies to remove trees when necessary to protect the integrity of their equipment and lines in the area.

Chipping ash branches © H. Liu

5.1.2. Schedule

All untreated white ash trees in Plot A are slated to be removed in the next 5 years (2012-2016). A total of 27 trees with a crown dieback rate >90% based on inventory data are to be removed (including five trees already removed by the electric company) in 2012, followed by 13 (60-90%) in 2013, 16 (30-60%) in 2014, 4 (20-30%) in 2015, and 25 (0-20%) in 2016 (*Table 1*).

Table 1. Proposed tree removal schedule for Plot A in Greenwood Furnace State Park

Year	*2012 dieback rate (%)*	*Tree Number*	*DBH (inches)*	
			Total	*Average*
2012	90 - 100	27	379.9	14.1
2013	60 - 90	13	233.4	18.0
2014	30 - 60	16	167.2	10.5
2015	20 - 30	4	69.4	17.4
2016	0 - 20	25	302.2	12.1
Total		85	1,152.1	13.6

5.2. Chemical Treatment

High-value ash trees will be protected by chemical treatment. Emamectin benzoate is selected for this project because it is highly effective for 2 - 3 year when injected directly through the trunk. Treatment is usually scheduled in later spring or early summer after full flush of ash leaves to destroy the current generation EAB larval population.

5.2.1. Treatment

Chemical treatment © P. Weiss

Tree I.V. system © P. Weiss

A total of 15 ash trees (179 inches of total DBH) from Plot A were chosen to receive chemical treatment in summer 2012, with an additional tree received rinse from injection equipment (*Appendix C*). Trees with a DBH <10 inches were treated with at the rate of 5 ml /inch DBH, whereas those > 10 inches received 10 ml/inch DBH. Selecting criteria included tree location, size, growth condition, EAB infestation, and potential as seed banks in the future. Reasonably health (<50% crown dieback rate) trees near picnic table, parking lot, building, and along major roads were used (*Appendix A*). Treatment was carried on June 19, 2012 by trunk injection using Arborjet Tree I. V. Micro Infusion® systems. Treatment on these trees will continue in 2014, 2017, 2019, and 2021 for long term protection (*Table 2*).

Table 2. Proposed chemical treatment schedule for Plot A in Greenwood Furnace

Year	*No. Trees*	*Total DBH (inches)* [b]	*Treatment rate (ml/inch)*	*Total volume (ml)*
2012	15	179	5-10	1,630
2014	15	183	5-10	1,652
2017	15	189	5-10	1,713
2019	15	193	5-10	1,747
2021	15	197	5-10	1,783
Total [a]	75	941		8,525

[a] *accumulative;* [b] *assuming 1% annual increase in diameter for those trees*

5.2.2. Efficacy evaluation

Efficacy of emamectin benzoate against EAB infestation will be evaluated by comparing crown dieback rate of treated trees before and after treatment. Comparison will also be made on crown dieback progression between treated and untreated control trees for the first five years (2012-2016). Efficacy data will be examined yearly to make necessary adjustments.

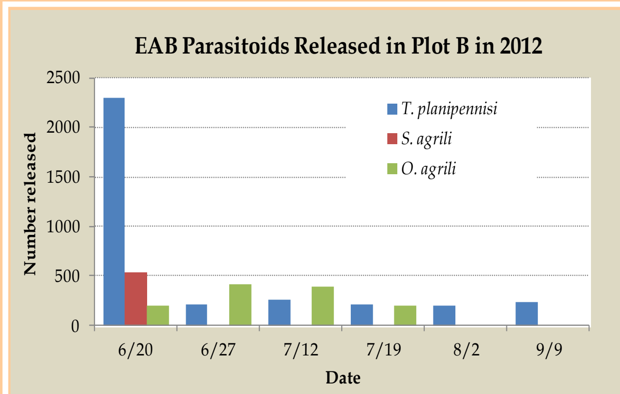
5.3. Biological Control


Release apparatus for O. agrili © H. Liu

Biological control with parasitoids has the potential for long term EAB management. All three species of parasitoids (*O. agrili*, *S. agrili*, and *T. planipennisi*) from USDA APHIS Rearing Facility will be introduced to Plot B in the park. A total of 12 live trees were selected from Plot B to receive parasitoids (map *below*). Successful establishment and spread by one or all released parasitoid species could bring EAB population in the plot under control in the future.

5.3.1. Parasitoids release

Parasitoids were released on the same day upon receiving and evenly distributed among all release trees. Weather conditions and time of release were recorded. Dead individuals were excluded from the final count. A total of 5,153 parasitoids were released in Plot B between June and August 2012, including 3,414 T. *planipennisi* (6 releases), 535 *S. agrili* (1 release), and 1,204 *O. agrili* (4 releases).



5.3.2. Parasitoids recovery

Recovery of released parasitoids will be attempted the following years after the introduction by dissecting release trees for EAB eggs (*O. agrili*) and larvae (*T. planipennisi* and *S. agrili*).

6. Replanting

All removed ash trees will be replaced by non-host native species in the next year to prevent major canopy gap in the park (*Table 3*). Right species will be selected for each site based on site conditions. Broad species diversity is recommended across the park under the widely accepted 10/20/30 rule, which suggests no more than 10% of any one species, or 20% of any one genera, or 30% of any one family. Bare root stock is also recommended.

Table 3. Proposed Replanting Schedule for Plot A in Greenwood Furnace State Park

Species	2013	2014	2015	2016	2017	Total
Black cherry	3	2	2	0	3	10
Black walnut	3	1	1	0	2	7
Eastern white pine	3	1	2	0	3	9
Red maple	3	1	2	1	2	9
Sugar maple	2	1	1	0	2	6
White oak	2	1	2	0	3	8
Red oak	3	2	1	1	2	9
Yellow poplar	2	1	1	1	2	7
Hickory	2	1	1	0	2	6
American Linden	2	1	2	1	2	8
Black gum	2	1	1	0	2	6
Total	**27**	**13**	**16**	**4**	**25**	**85**

7. Wood Utilization

EAB damage to ash trees through larval feeding under the bark is limited only to the outer 1-2 inches of sapwood. Ash wood from EAB infested trees may have more value than firewood, mulch, and compost. It is therefore sensible to make better use of the removed trees. Large trees (> 10 inches) with straight boles may have residual value. Efforts will be made by the park to seek local vendors for wood utilization of the logs from EAB infested ash trees. Potential usages include but not limited to wood boards, poles, and crafting materials. Care will be taken through compliance agreements with PA Department of Agriculture and USDA APHIS to ensure no infested ash materials (barks, outer sapwood, branches, etc.) will cross quarantine boundaries without being treated by approved methods (heat treatment, fumigation, etc.).

Milling ash log © D. Eggen

Coring ash logs for baseball bats
© PA DCNR - Forestry Archive, Bugwood.org

8. Material Disposal

Materials from removed ash trees need to be disposed properly to avoid inadvertent transport of EAB out of the generally infested areas. Chipping and burning are effective ways to destroy live EAB stages within the trees. A small marshalling yard may need to be created to handle the volume of disposing ash materials. All materials generated from this project will be disposed in this marshalling yard. Chips can then be mulched and used in landscape projects. Dead trees in the woodlot may be left alone for self decomposition.

Ash logs in marshalling yard © D. Cappaert - Forestry Archive, Bugwood.org

Ash chip pile in marshalling yard © D. Cappaert - Forestry Archive, Bugwood.org

9. Community Outreach

When completed, the EAB Management Plan for Greenwood Furnace State Park can be used as a model for other state, county, and community parks across the state. Annual seminars and field trainings are expected in the park to promoted integrated management of EAB in all Pennsylvania communities. Public education will be the focal point of all community outreach activities.

Field training © H. Liu

A permanent EAB Information Display will be assembled and placed in the visitor center in the park to educate the public on EAB and its impact on communities.

Information seminar © H. Liu

A permanent EAB Management Interpretive Panel is proposed at the entrance of the project site to help visitors better understand the management plan.

Getting information from interpretive panel © PA DCNR

10. Cost/Benefit Analysis

Ash is a valuable natural resource in Pennsylvania state parks, with compensatory values on shade, air quality, storm water discharge, heating/cooling costs, and aesthetic or property value. The introduction of EAB changed the species status of ash for individual trees and those in various landscapes. Dead trees in high use areas present real threats to public safety. Removing ash from the local ecosystem will permanently alter the natural habitats for related species. Sudden changes in park appearance may result in negative impacts to park visitors. It is therefore important to conduct a cost/benefit analysis for any management plan before it can be fully implemented. Positive benefit will validate the suggested approaches, whereas negative benefit may scratch the plan.

10.1. Tree Appraisal

Both public and private trees can be appraised for a monetary value individually. The most accepted procedure is developed by the Council of Tree and Landscape Appraisers (CTLA 2000) based on base value, tree species, condition, and location using the following formula:

Tree Value = Base Value × Cross Section Area × Species Class
× Condition Class × Location Class

Where

Base Value = unit price of the replacement cost (dollars)
Cross Section Area = Tree size in unit area (in^2 or cm^2)
(at 1 ft above ground for trees < 12 inches in diameter)
(at 4.5 ft above ground for trees > 12 inches in diameter)
Species Class = an assigned value based on landscape merits (1 - 100%)
Condition Class = tree health, vigor, life expectancy, form quality (1 - 100%)
Location Class = functional and aesthetic contribution to the site (1 - 100%)

Assuming the replacement cost for a 2 in diameter tree is about $350 ($200 for the stock, $150 for installment) for most rural communities in Pennsylvania, with a base value of $112.9/in². According to the above formula, the Tree Value for a 10 inch (78.5 in² cross section area) excellent condition (100% condition class) white ash (50% species class) at a park (60% location class) is $2,659. Healthy trees with large diameter are worth more than small, unhealthy trees.

10.2. Tree Value at Greenwood Furnace

There are 101 (54% average condition class) white ash trees in Plot A with an average diameter of 12.2 inches (*Appendix A*). The total monetary value for those trees based on appraisal is calculated at $215,736, with an average of $2,136 per tree.

Woodlot trees have less monetary value than those around the house or in the park. There are about 90 white ash trees in Plot B based on inventory (*Appendix B*). However, most timber size ash trees are dead or dying, with a total estimated value of $2,000 for firewood.

10.3. Cost of Management Plan

The estimated total cost of this management plan is $115,277 over 10 years as described in Table 4. Total costs include $48,117 for tree removal, $9,410 for chemical treatment, $21,000 for biological control, $29,750 for replanting, and $7,000 for community outreach.

Table 4. Cost of EAB Management Plan in Greenwood Furnace State Park

Year	Tree Removal		Chemical control		Biological Control	Replanting		Community outreach	**Total**
	Trees	Cost	Trees	Cost		Trees	Cost		
2012	27	15,863	15	1,790	6,000	0	0	0	**23,653**
2013	13	9,750	0	0	3,000	27	9,450	3,000	**25,200**
2014	16	7,000	15	1,830	3,000	13	4,550	500	**16,880**
2015	4	2,900	0	0	0	16	5,600	500	**9,000**
2016	25	12,604	0	0	3,000	4	1,400	500	**17,504**
2017	0	0	15	1,890	0	25	8,750	500	**11,140**
2018	0	0	0	0	3,000	0	0	500	**3,500**
2019	0	0	15	1,930	0	0	0	500	**2,430**
2020	0	0	0	0	3,000	0	0	500	**3,500**
2021	0	0	15	1,970	0	0	0	500	**2,470**
Total	**85**	**$48,117**	**75**	**$9,410**	**$21,000**	**85**	**$29,750**	**$7,000**	**$115,277**

10.3.1. Tree removal

Tree removal is targeted for the 85 trees in Plot A (*Appendix A*). All untreated white ash trees will be removed in the first five years (2012-2016), ranging from 4 to 27 tree per year (*Table 1*). It can be handled in house by park staff, or through outside contractors. It may take 15-20 days to remove all 85 trees in Plot A at the rate of 5-6 tree/day with a three-man crew. The total cost of tree removal is projected at $48,117 based on the unit price of $500/tree for a 12 inch diameter tree (*Table 4*). It may cost the same or more to do it in house when cost of wage and benefits for staff ($600/day for a crew of three), equipments (e.g. a brush chipper costs $300-500/day for rental, and $35,000-40,000 for a new unit), and other factors are considered. No tree removal cost is anticipated in Plot B.

10.3.2. Chemical control

Chemical control is applied to 15 selected trees in Plot A (*Appendix A,C*). Trees will be treated every 2-3 years for 10 years (*Table 2*). The total cost of chemical treatment is projected at $9,410 for five treatments during the project period, ranging from $1,790 to $1,970 per treatment. The actual application of chemical insecticide can be contracted out at an approximate rate of $10/inch DBH, or handled in house by FPM or park staff at a similar cost when chemicals, equipment, and staff wage and benefits are considered. No chemical control cost is anticipated in Plot B.

10.3.3. Biological control

Biological control is applied in Plot B only. All EAB parasitoids are provided free of charge by USDA APHIS Rearing Facility at Brighton, MI according to interagency cooperative agreements. Cost of biological control ($21,000) comes mainly from FPM staff wage and benefits ($200/day per person) while conducting field operations, including site selection, parasitoid field release, monitoring, and recovery throughout the project. EAB parasitoids will be released in 2012 and possibly 2013, and monitored in 2013, 2014, 2016, 2018, and 2020.

10.3.4. Replanting

Replanting will take place in Plot A one year after the trees are scheduled to be removed. A total of 85 non-host native trees will be planted between 2013-2017 to replace the removed white ash trees (*Table 3*). It costs an estimated $350 to purchase ($200) and install ($150) a 2-inch tree in the park. The total cost of replanting is estimated at $29,750 for five years, ranging from $1,400 to 9,450 per year.

10.3.5. Community outreach

Community outreach is proposed on yearly basis throughout the entire project. Information seminars and field trainings will be scheduled to disseminate information on EAB and its management among interested communities. The total cost of community outreach is estimated at $7,000, including expense for annual seminars and trainings, and the manufacture of an EAB information display and EAB management plan interpretive panel (2013).

10.4. Analysis

The total cost of this project is $115,277. It represents 53% of the total compensatory value ($217,736) of all white ash trees in both plots. The return rate for the investment is 1.9.

This Selective Management approach will result in the protection of some high-value ash trees in the picnic area through chemical control, neutralization of safety risk in day use areas through planned tree removal, a new and diverse replacement urban forest through replanting, and potential survival of some woodlot ash trees through biological control. By comparison, Preemptive Management or No Action approach would eliminate all white ash from the park while resulting in tree removal cost ($56,120) immediately or 2-3 years down the road, whereas the window for Aggressive Management approach may have passed when more than 60% infested ash trees with a crown dieback rate >30%, the commonly accepted upper threshold for chemical treatment.

Results of cost/benefit analysis support the selection of Selective Management approach for Greenwood Furnace State Park.

11. Fiscal Planning

A variety of funding sources will be necessary to implement the prescriptions outlined in this EAB management plan. Greenwood Furnace will annually submit the estimated cost of tree removal and restoration planting as part of the park's annual budget process. The estimated cost could be the figure that appears in the plan or a refined estimate generated by the park. The Bureau of State Parks will explore opportunities for planting stock donations. FPM, Bureau of Forestry, on behalf of the park will work to secure awards and grants from federal , state, and local agencies to fund a portion or the entirety of the chemical treatment. At this time the parasitoids are available at no cost to federal cooperators.

12. Time Table

This is a joint project between Bureau of State Parks and FPM. All proposed activities listed below will be carried out by personnel from both units during the project period.

Year	Proposed activities
2012	Tree inventory, chemical treatment, tree removal, site selection, parasitoid release, community outreach, progress report
2013	Tree removal, efficacy evaluation, parasitoid recovery, replanting, community outreach, progress report
2014	Tree removal, chemical treatment, parasitoid recovery, replanting, community outreach, progress report
2015	Tree removal, efficacy evaluation, replanting, community outreach, progress report
2016	Tree removal, parasitoid recovery, replanting, community outreach, progress report
2017	Chemical treatment, replanting, community outreach, progress report
2018	Parasitoid recovery, efficacy evaluation, community outreach, progress report
2019	Chemical treatment, community outreach, progress report
2020	Parasitoid recovery, efficacy evaluation, community outreach, progress report
2021	Chemical treatment, community outreach, final report

13. Data Collection

Field data will be collected at a timely fashion and submitted to FPM forest entomologist for processing and analysis. A centralized electronic database will be established to store the data. All data and results will be shared among involved parties. Final results will be used in annual progress report and final report.

14. Reporting

Progress report is required by the end of each year for the entire project period. The annual report is used to report the progress of the project for the current year and to guide project activities in the next year. Modification will apply to project when fully justified. A final report will be issued to summarize the entire project by the end of 2021.

15. References

Council of Tree and Landscape Appraisers (CTLA). 2000. Guide for plant appraisal. 9th edition. International Society of Arboriculture, Champaign, IL. 143 pp.

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Appendix A. **Ash Tree Inventory in Plot A**										
Date	***Tree #***	***Tag #***	***Species***	***DBH (Inches)***	***Latitude***	***Longitude***	***EAB infestation***	***Crown Dieback (%)***	***Observers***	***Note***
3/12	1	301	White ash	8.7	N 40.65050	W 77.75528	No	10	PW, TP, HL	To be removed in 2016
3/12	2	302	White ash	18.9	N 40.65053	W 77.75536	No	10	PW, TP, HL	To be removed in 2016
3/12	3	303	White ash	22.0	N 40.65057	W 77.75523	No	5	PW, TP, HL	To be removed in 2016
3/12	4	304	White ash	19.0	N 40.65054	W 77.75520	No	10	PW, TP, HL	To be removed in 2016
3/12	5	305	White ash	14.6	N 40.65049	W 77.75560	No	20	PW, TP, HL	To be removed in 2015
3/12	6	306	White ash	13.0	N 40.65052	W 77.75536	No	5	PW, TP, HL	To be removed in 2016
3/12	7	307	White ash	9.0	N 40.65040	W 77.75566	No	40	PW, TP, HL	To be removed in 2014
3/12	8	308	White ash	6.0	N 40.65040	W 77.75568	Yes	60	PW, TP, HL	To be removed in 2013
3/12	9	309	White ash	5.1	N 40.65058	W 77.75525	Yes	90	PW, TP, HL	To be removed in 2012
3/12	10	310	White ash	5.4	N 40.65053	W 77.75557	Yes	50	PW, TP, HL	To be removed in 2014
3/12	11	311	White ash	10.0	N 40.65050	W 77.75575	Yes	40	PW, TP, HL	To be removed in 2014
3/12	12	312	White ash	10.8	N 40.65045	W 77.75577	Yes	85	PW, TP, HL	To be removed in 2013
3/12	13	313	White ash	7.2	N 40.65040	W 77.75577	Yes	85	PW, TP, HL	To be removed in 2013
3/12	14	314	White ash	9.6	N 40.65042	W 77.75577	Yes	30	PW, TP, HL	To be removed in 2014
3/12	15	315	White ash	11.0	N 40.65043	W 77.75575	Yes	30	PW, TP, HL	To be removed in 2014
3/12	16	316	White ash	25.1	N 40.65048	W 77.75592	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	17	317	White ash	14.3	N 40.65048	W 77.75592	Yes	50	PW, TP, HL	To be removed in 2014
3/12	18	318	White ash	15.5	N 40.65045	W 77.75600	Yes	80	PW, TP, HL	To be removed in 2013
3/12	19	319	White ash	16.1	N 40.65047	W 77.75608	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	20	320	White ash	16.0	N 40.65043	W 77.75605	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	21	321	White ash	11.4	N 40.65040	W 77.75608	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	22	322	White ash	9.9	N 40.65038	W 77.75613	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	23	323	White ash	10.9	N 40.65038	W 77.75622	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	24	324	White ash	9.3	N 40.65038	W 77.75618	Yes	10	PW, TP, HL	To be removed in 2016
				8.7			Yes	80	PW, TP, HL	2nd trunk
3/12	25	325	White ash	7.6	N 40.65042	W 77.75625	Yes	95	PW, TP, HL	Dead - to be removed in 2012
3/12	26	326	White ash	11.2	N 40.65045	W 77.75625	No	80	PW, TP, HL	To be removed in 2013
3/12	27	327	White ash	13.5	N 40.65048	W 77.75628	No	30	PW, TP, HL	To be removed in 2014

Date	*Tree #*	*Tag #*	*Species*	*DBH (Inches)*	*Latitude*	*Longitude*	*EAB infestation*	*Crown Dieback (%)*	*Observers*	*Note*
3/12	28	328	White ash	11.9	N 40.65045	W 77.75643	Yes	90	PW, TP, HL	Dead - to be removed in 2012
3/12	29	329	White ash	7.8	N 40.65037	W 77.75647	Yes	30	PW, TP, HL	To be removed in 2014
3/12	30	330	White ash	20.1	N 40.65043	W 77.75652	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	31	331	White ash	6.0	N 40.65047	W 77.75660	No	40	PW, TP, HL	To be removed in 2014
3/12	32	332	White ash	19.4	N 40.65060	W 77.75647	Yes	95	PW, TP, HL	Dead - to be removed in 2012
3/12	33	333	White ash	19.0	N 40.65063	W 77.75617	Yes	60	PW, TP, HL	To be removed in 2013
3/12	34	334	White ash	13.3	N 40.65017	W 77.75655	No	10	PW, TP, HL	To be removed in 2016
3/12	35	335	White ash	37.0	N 40.65008	W 77.75671	No	20	PW, TP, HL	To be removed in 2015
3/12	36	336	White ash	15.8	N 40.65017	W 77.75667	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	37	337	White ash	14.8	N 40.65005	W 77.75690	Yes	10	PW, TP, HL	To be removed in 2016
				10.5			Yes	40	PW, TP, HL	2nd trunk
3/12	38	338	White ash	10.6	N 40.65002	W 77.75697	Yes	90	PW, TP, HL	Dead - to be removed in 2012
3/12	39	339	White ash	15.0	N 40.65041	W 77.75670	Yes	90	PW, TP, HL	Dead - to be removed in 2012
3/12	40	340	White ash	8.2	N 40.65042	W 77.75678	No	20	PW, TP, HL	To be removed in 2015
3/12	41	341	White ash	3.0	N 40.65036	W 77.75677	No	0	PW, TP, HL	To be removed in 2016
3/12	42	342	White ash	6.8	N 40.65045	W 77.75674	No	10	PW, TP, HL	To be removed in 2016
3/12	43	343	White ash	5.9	N 40.65059	W 77.75671	No	40	PW, TP, HL	To be removed in 2014
3/12	44	344	White ash	27.3	N 40.65068	W 77.75662	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	45	345	White ash	22.0	N 40.65068	W 77.75667	Yes	60	PW, TP, HL	To be removed in 2013
				20.0			Yes	70	PW, TP, HL	2nd trunk
3/12	46	346	White ash	16.4	N 40.65050	W 77.75618	Yes	100	PW, TP, HL	Dead - to be removed in 2012
3/12	47	347	White ash	7.3	N 40.65086	W 77.75628	No	0	PW, TP, HL	To be removed in 2016
3/12	48	348	White ash	7.0	N 40.65084	W 77.75615	No	0	PW, TP, HL	To be removed in 2016
3/12	49	349	White ash	6.1	N 40.65079	W 77.75597	No	10	PW, TP, HL	To be removed in 2016
3/12	50	350	White ash	5.8	N 40.65079	W 77.75598	No	10	PW, TP, HL	To be removed in 2016
				4.7			No	10	PW, TP, HL	2nd trunk
3/12	51	351	White ash	32.0	N 40.65060	W 77.75583	Yes	80	PW, TP, HL	to be removed in 2013
3/12	52	352	White ash	5.5	N 40.65075	W 77.75593	Yes	95	PW, TP, HL	To be removed in 2012
3/12	53	353	White ash	12.0	N 40.65080	W 77.75567	Yes	80	PW, TP, HL	Removed on 6/12/2012

Date	*Tree #*	*Tag #*	*Species*	*DBH (Inches)*	*Latitude*	*Longitude*	*EAB infestation*	*Crown Dieback (%)*	*Observers*	*Note*
3/12	54	354	White ash	7.0	N 40.65082	W 77.75565	Yes	80	PW, TP, HL	Removed on 6/12/2012
3/12	55	355	White ash	10.0	N 40.65082	W 77.75560	Yes	80	PW, TP, HL	Removed on 6/12/2012
3/12	56	356	White ash	8.0	N 40.65083	W 77.75560	Yes	80	PW, TP, HL	Removed on 6/12/2012
3/12				11.0			Yes	80	PW, TP, HL	2nd trunk. Removed on 6/12/2012
3/12	57	357	White ash	7.0	N 40.65070	W 77.75550	Yes	50	PW, TP, HL	Removed on 6/12/2012
3/12	58	358	White ash	5.8	N 40.65085	W 77.75555	Yes	70	PW, TP, HL	To be removed in 2013
3/12	59	359	White ash	9.0	N 40.65073	W 77.75555	Yes	50	PW, TP, HL	Removed on 6/12/2012
3/12	60	360	White ash	11.0	N 40.65078	W 77.75542	Yes	50	PW, TP, HL	To be removed in 2014
3/12	61	361	White ash	28.2	N 40.65088	W 77.75540	Yes	60	PW, TP, HL	To be removed in 2013
3/12	62	362	White ash	6.2	N 40.65128	W 77.75505	No	10	PW, TP, HL	To be removed in 2016
3/12	63	363	White ash	7.6	N 40.65123	W 77.75502	No	10	PW, TP, HL	To be removed in 2016
3/12	64	364	White ash	8.2	N 40.65144	W 77.75522	Yes	40	PW, TP, HL	To be removed in 2014
3/12	65	365	White ash	8.4	N 40.65147	W 77.75498	Yes	40	PW, TP, HL	To be removed in 2014
3/12	66	366	White ash	9.6	N 40.65134	W 77.75496	No	20	PW, TP, HL	To be removed in 2015
3/12	67	367	White ash	5.4	N 40.65150	W 77.75462	No	10	PW, TP, HL	To be removed in 2016
3/12	68	368	White ash	5.5	N 40.65152	W 77.75465	No	10	PW, TP, HL	To be removed in 2016
3/12	69	369	White ash	7.6	N 40.65152	W 77.75463	No	10	PW, TP, HL	To be removed in 2016
3/12	70	370	White ash	7.3	N 40.65157	W 77.75468	No	10	PW, TP, HL	To be removed in 2016
3/12	71	371	White ash	8.8	N 40.65158	W 77.75466	No	10	PW, TP, HL	To be removed in 2016
3/12	72	372	White ash	28.0	N 40.65177	W 77.75610	Yes	50	PW, TP, HL	To be removed in 2014
3/12	73	373	White ash	6.7	N 40.65177	W 77.75623	No	10	PW, TP, HL	To be removed in 2016
3/12	74	374	White ash	6.0	N 40.65177	W 77.75625	Yes	90	PW, TP, HL	To be removed in 2012
3/12	75	375	White ash	20.3	N 40.65192	W 77.75558	Yes	80	PW, TP, HL	To be removed in 2013
3/12	76	376	White ash	17.3	N 40.65147	W 77.75385	Yes	90	PW, TP, HL	To be removed in 2012
3/12	77	377	White ash	17.6	N 40.65137	W 77.75382	Yes	60	PW, TP, HL	To be removed in 2013
3/12	78	378	White ash	9.0	N 40.65170	W 77.75411	No	5	PW, TP, HL	To be removed in 2016
				7.8			No	10	PW, TP, HL	2nd trunk
3/12	79	379	White ash	21.0	N 40.65177	W 77.75417	No	10	PW, TP, HL	To be removed in 2016
				20.0			No	10	PW, TP, HL	2nd trunk

Date	*Tree #*	*Tag #*	*Species*	*DBH (Inches)*	*Latitude*	*Longitude*	*EAB infestation*	*Crown Dieback (%)*	*Observers*	*Note*
3/12	80	380	White ash	10.4	N 40.65163	W 77.75428	No	10	PW, TP, HL	To be removed in 2016
3/12	81	381	White ash	12.0	N 40.65157	W 77.75430	Yes	100	PW, TP, HL	To be removed in 2012
				14.0			Yes	80	PW, TP, HL	2nd trunk
				10.0			Yes	70	PW, TP, HL	3rd trunk
3/12	82	382	White ash	17.8	N 40.65127	W 77.75428	Yes	70	PW, TP, HL	To be removed in 2013
3/12	83	383	White ash	11.3	N 40.65007	W 77.75493	Yes	30	PW, TP, HL	To be removed in 2014
3/12	84	384	White ash	12.5	N 40.65001	W 77.75510	Yes	90	PW, TP, HL	To be removed in 2012
3/12	85	385	White ash	7.8	N 40.64993	W 77.75535	Yes	30	PW, TP, HL	To be removed in 2014
3/12	86	236	White ash	13.3	N 40.65118	W 77.75572	No	60	PW, TP, HL	Tree-age rinse tree on 06/19/2012
3/12	87	237	White ash	12.4	N 40.65112	W 77.75563	No	70	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	88	238	White ash	10.8	N 40.65125	W 77.75545	Yes	50	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	89	239	White ash	12.0	N 40.65220	W 77.75472	Yes	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	90	240	White ash	9.5	N 40.65222	W 77.75470	Yes	40	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	91	241	White ash	17.4	N 40.65222	W 77.75450	No	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	92	242	White ash	22.0	N 40.65230	W 77.75445	Yes	40	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	93	243	White ash	12.0	N 40.65202	W 77.75437	No	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	94	244	White ash	13.0	N 40.65215	W 77.75420	Yes	20	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	95	245	White ash	11.0	N 40.65203	W 77.75440	Yes	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	96	246	White ash	8.4	N 40.65203	W 77.75455	No	0	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	97	247	White ash	11.5	N 40.65217	W 77.75468	Yes	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	98	248	White ash	6.5	N 40.65232	W 77.75473	No	0	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	99	249	White ash	9.0	N 40.65222	W 77.75462	No	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	100	250	White ash	12.0	N 40.65202	W 77.75475	Yes	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
3/12	101	251	White ash	14.0	N 40.65192	W 77.75463	No	10	PW, TP, HL	Treated w/ Treeage on 06/19/2012
Total	101		1346.9	12.2			Yes = 61 No = 40	46.2		
	Crown condition was evaluated based on dieback rate (0-100%) at an increment of 5% on 7/24 by observers Paul Weiss (PW), Tim Price (TP), and Houping Liu (HL) with help from Tim Marasco(TM); whereas chemical treatment was carried out on 6/19 by PW and HL with help from Tim Frontz (TF).									

Appendix B. Basal Area in Plot B

Site	Total	White ash		Black cherry		Black birch		Eastern white pine		Red maple		White oak		Red oak		Misc. (e.g. musclewood)	
		DBH	*Growth*	*DBH*	*Growth*	*DBH*	*Growth*	*DBH*	*Growth*	*DBH*	*Growth*	*DBH*	*Growth*	*DBH*	*Growth*	*DBH*	*Growth*
1	11	8.0	UG	16.0	AG	15.0	AG	39.0	UG								
		12.0	UG	21.0	AG	6.0	AG										
		16.0	UG			8.0	AG										
		9.0	UG														
		13.0	UG														
Basal area (ft^2/acre)	110	50.0		20.0		30.0		10.0									
Basal area (m^2/ha)	25.3	11.5		4.6		6.9		2.3									
2	12	23.0	UG	19.0	AG			18.0	AG	15.0	AG	25.0	AG			4.0	AG
		16.0	UG	17.0	AG					23.0	AG					3.0	AG
										10.0	AG					5.0	AG
Basal area (ft^2/acre)	120	20.0		20.0				10.0		30.0		10.0				30.0	
Basal area (m^2/ha)	27.6	4.6		4.6				2.3		6.9		2.3				6.9	
3	15	16.0	UG					19.0	AG					20.0	AG	4.0	AG
		11.0	UG					28.0	AG						AG	5.0	AG
		12.0	UG													4.0	AG
		23.0	UG													6.0	AG
		12.0	UG														
		10.0	UG														
		10.0	UG														
		11.0	UG														
Basal area (ft^2/acre)	150	80.0						20.0						10.0		40.0	
Basal area (m^2/ha)	34.4	18.3						4.6						2.3		9.2	
Average (ft^2/acre)	126.7	50.0		13.3		10.0		13.3		10.0		3.3		3.3		23.3	
Average (m^2/ha)	29.1	11.5		3.0		2.3		3.0		2.3		0.8		0.8		5.4	
		UG - Unacceptable growth, AG - Acceptable growth								Basal area converter: 1 ft^2/acre = 0.2296 m^2 ha							
		White ash, *Fraxinus americana* L. (Oleaceae)								Black cherry, *Prunus serotina* L. (Rosaceae)							
		Black birch, *Betula lenta* L. (Betulaceae)								Eastern white pine, *Pinus strobus* L. (Pinaceae)							
		Red maple, *Acer rubrum* L. (Aceraceae)								White oak, *Quercus alba* L. (Fagaceae)							
		Red oak, *Quercus rubra* L. (Fagaceae)								Musclewood, *Carpinus caroliniana* Walter (Corylaceae)							

Appendix C. **Chemcial Treatment of EAB-Infested Ash Trees in Plot A**										
Tree #	**Tag #**	**DBH (inches)**	**Treatment Date**	**Treatment Method**	**Rate (ml/in)**	**Volume (ml/tree)**	**No. Injection sites**	**Applicators**	**Weather**	**Note**
85	251	14.0	6/19/2012	IV	10	140	7	TF, HL, PW	Overcast	
86	250	12.0	6/19/2012	IV	10	120	6	TF, HL, PW	Overcast	
83	249	9.0	6/19/2012	IV	5	45	4	TF, HL, PW	Overcast	
82	248	6.0	6/19/2012	IV	5	30	3	TF, HL, PW	Overcast	
81	247	11.0	6/19/2012	IV	10	110	6	TF, HL, PW	Overcast	
80	246	8.0	6/19/2012	IV	5	40	4	TF, HL, PW	Overcast	
84	245	11.0	6/19/2012	IV	10	110	6	TF, HL, PW	Overcast	
88	244	13.0	6/19/2012	IV	10	130	7	TF, HL, PW	Overcast	
94	243	12.0	6/19/2012	IV	10	120	6	TF, HL, PW	Overcast	
93	242	22.0	6/19/2012	IV	10	220	12	TF, HL, PW	Overcast	
92	241	17.0	6/19/2012	IV	10	170	8	TF, HL, PW	Overcast	
91	240	9.0	6/19/2012	IV	5	45	4	TF, HL, PW	Overcast	
89	239	12.0	6/19/2012	IV	10	120	6	TF, HL, PW	Overcast	
64	238	11.0	6/19/2012	IV	10	110	6	TF, HL, PW	Sunny, hot & humid	
62	237	12.0	6/19/2012	IV	10	120	6	TF, HL, PW	Sunny, hot & humid	
63	236	13.0	6/19/2012	IV			6	TF, HL, PW	Sunny, hot & humid	Rinse injection tree
Total		192.0				1630				
	TF - Timothy Frontz, HL - Houping Liu, PW - Paul Weiss									

Appendix D . Parasitod Release Trees in Plot B

Tree#	Tag#	Species	DBH (in)	Latitude (N)	Longitude (W)	EAB infestation	Crown dieback (%)	Note
1	3701	White ash	6.4	40.64927	-77.75567	Yes	40	
2	3702	White ash	8.7	40.64943	-77.7555	Yes	50	
3	3703	White ash	6.3	40.64927	-77.75561	Yes	40	
4	3704	White ash	7.7	40.64944	-77.75528	Yes	25	
5	3705	White ash	7.1	40.64938	-77.75517	Yes	60	
6	3706	White ash	7.4	40.64937	-77.75513	Yes	50	
7	3707	White ash	7.5	40.64922	-77.7551	Yes	30	
8	3708	White ash	9.3	40.64907	-77.75523	Yes	70	
9	3709	White ash	6.5	40.64921	-77.75525	Yes	75	
10	3710	White ash	5.7	40.64915	-77.75531	Yes	65	
11	3711	White ash	6.3	40.64944	-77.75492	Yes	20	
12	3712	White ash	5.6	40.64944	-77.75497	Yes	25	
Average			7.0					

Selection of parasitoid release trees is based on USDA APHIS Emerald Ash Borer Biological Control Release Guidelines. EAB parasitoid release is targeted at 12 pre-selected release trees (3 in each cardinal direction from the epicenter) in the plot. Parsitoids are released on weekly basis depending on availablity. All species are released on the same day upon receiving, with approximately the same number of parasitoids on each tree. Weather conditions (e.g. wind, temperature, clouds, and percipitation) and duration are recorded for each release. Dead parasitoids are left inside the original containers and excluded from the final number released in the field.