

Emerald Ash Borer Response Plan for the City of Bangor, ME

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A special thank you to the members of the Ash Protection Collaboration Across Wabankik for helping address the cultural impacts of this management plan on the Indigenous peoples of the greater Bangor area. Also, to Allison Kanoti, Jan Santerre, and Michael Parisio of the Maine Forest Service, who offered advice on compliance with state regulations regarding invasive pests and whose emerald ash borer resources were influential to the content of this management plan. A final thanks to the City of Bangor Forestry Division employees, without whom none of this work would get done.

Executive Summary

Emerald ash borer (EAB) has been present in the United States since 2002, when it was introduced to the Midwest from its native range of Asia via shipping channels in the Great Lakes. Since then, it has been introduced to several other seaports within the U.S., including on the East Coast. It was discovered in Maine in 2018, in Portland in 2019, and in 2023, in Hermon, which borders the City of Bangor, making the need to prepare for EAB in Bangor even more salient.

EAB is a wood-boring beetle that targets ash tree species. About 20% of Bangor's publicly owned trees are ash trees. Once EAB infests a tree, there is a mortality rate of about 98%. Losing this significant portion of the urban canopy can lead to the loss of many ecosystem services that are often overlooked but actively provide monetary value to the public. Fortunately, EAB has not yet been identified within the city itself. However, because of the proximity of the Hermon infestation, now is the time to plan. The impact of this insect will also include ash in city forests and on private property, for which we do not have extensive data at this time.

This response plan has been developed in collaboration with the University of Maine, Orono, to address this pressing issue. It includes details regarding the treatment of eligible ash trees with insecticides, the preemptive removal of ash trees that are already considered hazardous to public safety, and the proposed course of action for ash trees whose future is still undetermined. Further work is needed to explore all facets of this complex issue. However, what is presented here are the current known impacts and the recommended actions based on the most recent information available regarding EAB in urban areas.

Two hundred and fifty ash trees have already been selected for chemical treatment across the City of Bangor (Selected Treatment Trees). These trees are currently in good health and are appropriately located so as not to threaten public safety or infrastructure. It was determined that over a nine-year treatment period (see p. 24 for more details) discounted at 5% there would be a \$107 per tree cost to chemically treat these trees, which would preserve a per tree benefit of \$1,846, or a cost-benefit ratio (BCR) of 17. This means that the treatment of these trees is financially viable over nine years, and the benefits they provide far outweigh the estimated cost of treatment. The total discounted cost of chemically treating these trees over this period is estimated at \$26,864. As of July 1st, 2025, 85 of the 250 Selected Treatment Trees have been injected with the chemical insecticide emamectin benzoate.

Four hundred and thirty-six ash trees have been identified by the Forestry Division as hazardous and needing removal before EAB detection in Bangor (Required Removal Trees). These trees are not eligible for treatment because of their condition or location, so there is no other option but to remove them. For this reason, the cost of chemical treatment and the benefit they provide to the city were not calculated. Four distinct hazard groups within these trees were identified, and it was determined that one group must be removed per year to prevent them from becoming even more hazardous when they become actively infested. For this reason, the cost of removing these trees was discounted by 5% over four years and was determined to be \$1,221 per

tree removed by a contractor and \$572 per tree removed by the Forestry Division staff. This is a total discounted removal cost of \$330,022 and a total discounted replacement cost of \$164,743. A BCR was not calculated for this group because the avoided cost of the threat to public safety could not be accurately estimated.

One thousand one hundred and sixty-eight ash trees remain without a plan (Remaining Trees). A cost-benefit analysis determined that these trees will provide a discounted benefit of over \$7 million across the next ten years, or \$6,025 per tree. Across the same period, it would cost \$36,058 to chemically treat all these trees, or \$31 per tree. It would cost \$582,100 to remove them and \$381,530 to replace them, or \$498 and \$327 per tree, respectively. The BCR for treating these trees is 194, which means chemically treating them is highly financially viable to preserve their benefits. The BCR for removing them all is zero because their benefits would be entirely lost, and we cannot accurately estimate the avoided cost of the threat to public safety. This means removing all these trees is not financially viable. Based on this information, this plan recommends chemically treating between 750 and 1,000 ash trees including the already selected 250 and depending on eligibility.

It is also recommended that there be a robust public outreach and education initiative around EAB in Bangor. Citizens can often become alarmed when many significant landscape trees are quickly removed. Their alarm can be ameliorated when conversations are had, and there is transparency between them and the city's managers. Continued monitoring for EAB should occur in the future, and additional partnerships for this effort should be explored. If successfully executed, this plan will ensure ash trees in Bangor's urban canopy in the future, mitigate public safety hazards and property damage from falling ash trees, and create an urban area that continues to benefit greatly from its trees.

Purpose

This document serves the following purposes:

1. To present the results of the City of Bangor 2024 Complete Urban and Street Tree Inventory to the public and how it was used to inform decisions made in this response plan.
2. To propose a proactive response plan for EAB in Bangor to mitigate disruption to the city's urban canopy and forests and prevent public safety hazards and property damage. The initial plan is limited to publicly owned trees.
3. To assess the economic impacts of the proposed EAB management plan to determine the financial viability of implementation.
4. To educate the public about EAB, how it affects ash trees, the importance of ash, and the impacts of its loss from the urban canopy.

Introduction

Since 2002, with the introduction of emerald ash borer (*Agrillus planipennis*) to the U.S., there has been a widespread loss of ash trees across the country. The insect was thought to be introduced through the Great Lakes shipping channels, as a stowaway in pallet wood. After a secondary introduction event in the mid-Atlantic region and a predicted trend of outward expansion, the ash trees of New England have been succumbing to EAB at a rapid and alarming rate. With little to nothing to do to prevent the almost complete loss of ash trees, it is becoming evident that the only thing to do is plan. Particular attention should be paid to the urban centers of these states, as the loss of urban ash trees poses an additional risk to public health and safety due to falling debris and reduction in the urban forest canopy. It has been shown that increased canopy cover in cities and towns improves stormwater management, air quality, and overall community health, so the loss of a large portion of this canopy will have devastating effects not limited only to the aesthetic qualities of cities.

The City of Bangor, ME, will be heavily impacted by this spreading infestation. The identification of an infestation in Hermon, ME, in 2023, which borders Bangor to the west, increases the level of concern for Bangor's ash trees. A complete urban and street tree inventory conducted in the summer of 2024 indicates that about 20% of the city's urban canopy is made up of ash species. This highlights the need for a comprehensive management plan to respond to the EAB threat. Due to the rapid development of the EAB situation in New England, towns and cities typically have little time to make necessary preparations. Management plans are often retroactively authored in response to a developing infestation instead of preemptively.

Fortunately, no known cases of EAB infestations exist within the City of Bangor at the time this document was published. Ash trees in the city will likely begin showing signs and symptoms of infestation within the next one to two years. They will significantly decline and die within the next five to seven years without intervention. Bangor needs to immediately implement a plan for removing, protecting, and replacing ash trees while also considering diversifying the urban canopy to mitigate similar circumstances in the future.

Background Information

What is Emerald Ash Borer (EAB)?



Figure 1. An adult emerald ash borer. Image collected from the *University of Maine News website*¹.

EAB adults are iridescent green beetles and about the size of a penny. The larvae are legless, white, and segmented. The larvae feed on the inner bark of ash trees before emerging as adults in late spring. Their feeding creates “galleries” or passages through the inner bark, where nutrient and water transport occurs within the tree. This girdles the tree and prevents resources from reaching the upper canopy, after which photosynthesis declines, leading ultimately to death. These galleries are serpentine or S-shaped– a unique identifier of the insect. Since EAB is a non-native insect species, they have no natural predators in North America. However, some woodpecker species are known to feed on the larvae. Adults can fly limited distances, but spread most often occurs when humans transport infested wood away from the initial infestation site.

After being introduced into an uninfested area, the adults lay their eggs in the furrows of the exterior bark through the summer months, and upon hatching, the larvae burrow into the inner bark, also known as the phloem and cambium. They can remain feeding in the inner bark and create galleries for one to two years, overwintering inside a pupation chamber. After pupating, the new adults emerge from the cambium, creating D-shaped exit holes in the outer bark, and the cycle begins again (Wisconsin Department of Natural Resources, n.d.).

¹ <https://umaine.edu/news/blog/2024/07/19/for-umaine-emerald-ash-borer-researchers-preparing-for-the-inevitable-is-an-act-of-hope/>

Adults typically will remain on the same tree from which they emerged unless the tree has been completely infested, and their offspring can no longer obtain the required amount of food to develop. When infesting a new tree, adults usually fly to and lay their eggs in the upper canopy since the exterior bark is thinner, and it is easier for larvae to enter the cambium. As the larvae run out of food and room for growth in the upper canopy, they wind further down the tree. This creates the appearance of a “top-down” decline in the tree. Because of this behavior and the larvae's one to two-year growth period, infestations are challenging to detect in the early stages.

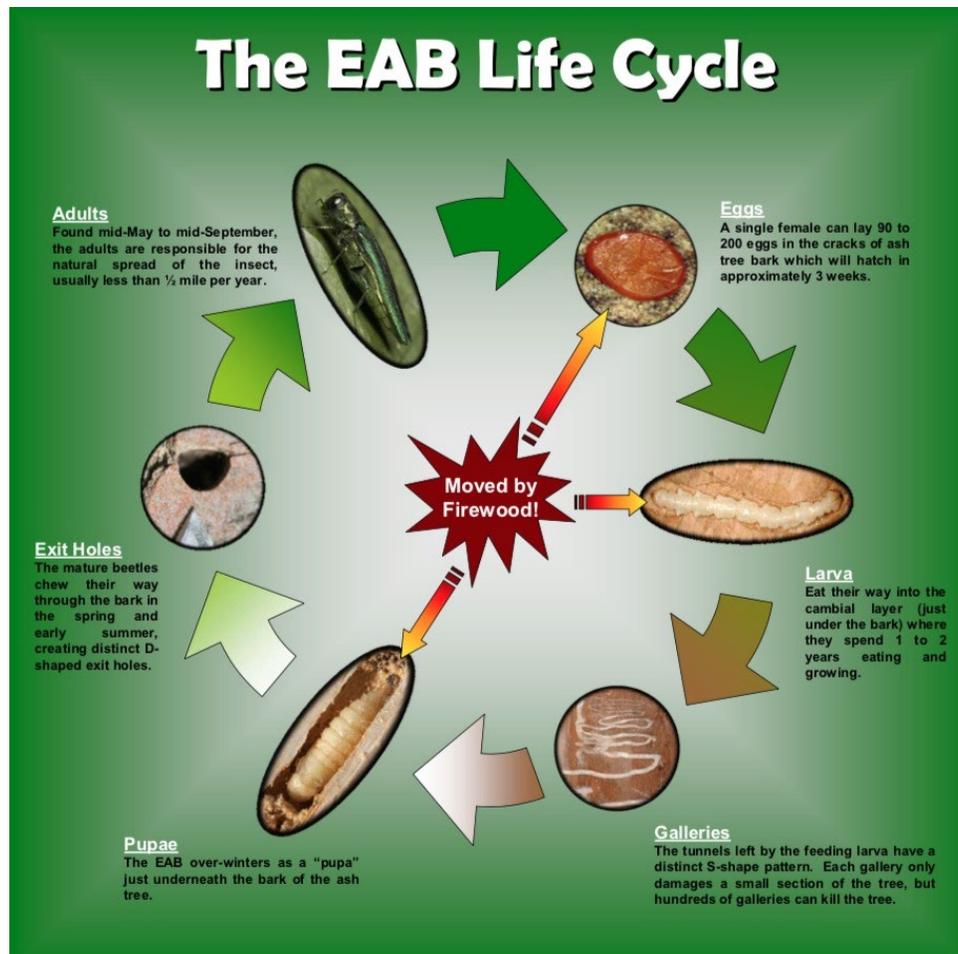


Figure 2. Emerald ash borer life cycle graphic produced by WI-DATCP and collected from the University of Wisconsin-Madison Extension [website](#)².

EAB infestations have an almost 100% mortality rate, and little can be done to prevent EAB from becoming established. Detecting early infestations is difficult because insects first attack the upper crowns of trees and are hard to detect in the early stages of infestation. Often, by the time the insects are noticed, the tree is too damaged to be saved. A study by Knight et al. (2013) in Ohio found that there may be some variability in the mortality rate, depending on the

² <https://eab.russell.wisc.edu/identifying-eab-and-potential-look-alikes/>

hydrology of the site they are growing on, stand density, and canopy position. Unfortunately, however, by publication, there was an almost complete loss of ash trees in the study, with death occurring four to five years after EAB was first detected (Knight et al., 2013). One estimate suggests that in a predicted U.S. invasive pest “hotspot” that encompasses Milwaukee, Chicago, and New York City, there will be 98.8% mortality of all ash trees by 2050 (Hudgins et al., 2022). In the decades since the discovery of EAB in the U.S., there have been significant advances in preventative treatments, the most notable being trunk injections of emamectin benzoate insecticides, which have been shown to protect trees from infestations for up to three years (McCollough, 2019).



Figure 3. Close-up of the S-shaped galleries produced by EAB larval feeding in the inner bark of an ash tree and a pre-pupal larva in a pupation chamber. Photo credit: Tawny Simisky. Image collected from the University of Massachusetts Amherst Extension Landscape, Nursery and Urban Forestry [website](https://www.umass.edu/agriculture-food-environment/landscape/fact-sheets/emerald-ash-borer)³.

The signs and symptoms of EAB infestations in ash trees are typically noticeable about two to five years post-initial infestation. The signs include the D-shaped exit holes created by emerging adults, bark blanding from woodpecker activity, and the serpentine galleries that can sometimes be seen beneath the outer bark. The symptoms are crown dieback from the upper canopy downwards, excessive sprouting along the trunk or at the tree's base (known as water sprouts), vertical bark splitting along the trunk due to the attempted formation of callus tissue, and mortality.

³ <https://www.umass.edu/agriculture-food-environment/landscape/fact-sheets/emerald-ash-borer>

Ash Trees and Their Importance in Maine

White (*Fraxinus americana*), green (*F. pennsylvanica*), and black ash (*F. nigra*) are the three species of ash native to Maine. White and green ash are commonly planted as street trees, but are native to Northern hardwood forests. Each plays a unique role in the state's urban and rural forests.

White ash is one of Maine's most valuable hardwood timber species. It is notably used for peavey handles, baseball bats, and hockey sticks. It is typically found on upland sites and favors high-quality soil. Because of its straight trunk and ability to grow quickly, it is often made into veneer-quality wood.



Figure 4. *Flower-top Basket, 2012, made by Molly Neptune Parker, a Passamaquoddy Tribal Member and basketmaker. The basket is made of brown ash and sweetgrass. Acquired by the Peary-Macmillan Arctic Museum at Bowdoin College in 2018. Image collected from the Bowdoin College Museum of Art [website](#)⁴.*

Black or brown ash grows in areas with high soil moisture, primarily in swamps and along streams. It has a rich cultural significance in the state, specifically to the Wabanaki people, who have been using it for basket-making for as long as they have an oral tradition. The tree also plays a prominent role in the Wabanaki people's origin story (Neptune and Neuman, 2015). These baskets are made using the wood beneath the inner bark that EAB feeds on. The Ash Protection Collaboration Across Wabanakik (APCAW) was founded before EAB reached Maine. It has focused on protecting ash in the state and public education around its cultural importance. APCAW has close ties with the tribal community, basketmakers, and the University of Maine.

Green ash is among U.S. towns and cities' most planted street trees (Nielsen et al., 1985). This is due to its ability to form full canopies to produce shade, adaptability to different environmental conditions, and the ability to survive flooding. Before the mid-1900s, elm trees

⁴ <https://www.bowdoin.edu/art-museum/exhibitions/digital/innovation-resilience/project1.html#images-1>

served this purpose. In the 1930s, Dutch elm disease was introduced to the U.S., and most of the elm street trees were wiped out and primarily replanted with green ash.

In addition to human use of white, black, and green ash, these trees also play a significant role in Maine's forested ecosystems. Often growing in riparian areas, their shade can offer temperature control for freshwater streams, an essential factor in the life cycles of many benthic macroinvertebrates, a crucial food source for freshwater fish species. Cool, clear water for spawning is also a requirement of anadromous fish species like Atlantic salmon and alewives. There is also concern regarding changes in organic matter levels in freshwater systems and how this may impact litter consumers (Kreutzweiser et al., 2018). Because of its height and diameter growth, white ash can create critical habitat for cavity-nesting birds such as woodpecker species.

Loss of overstory ash from any of the three species across all forest types creates openings that can promote the recruitment of invasive plant species, specifically Glossy Buckthorn (*Frangula alnus*), which is known to germinate after sudden exposure to high light levels and is present in Bangor's forested recreation areas. High densities of invasive plant species make it difficult for important native plant species to regenerate, drastically reducing the biodiversity and health of forests in the long run.

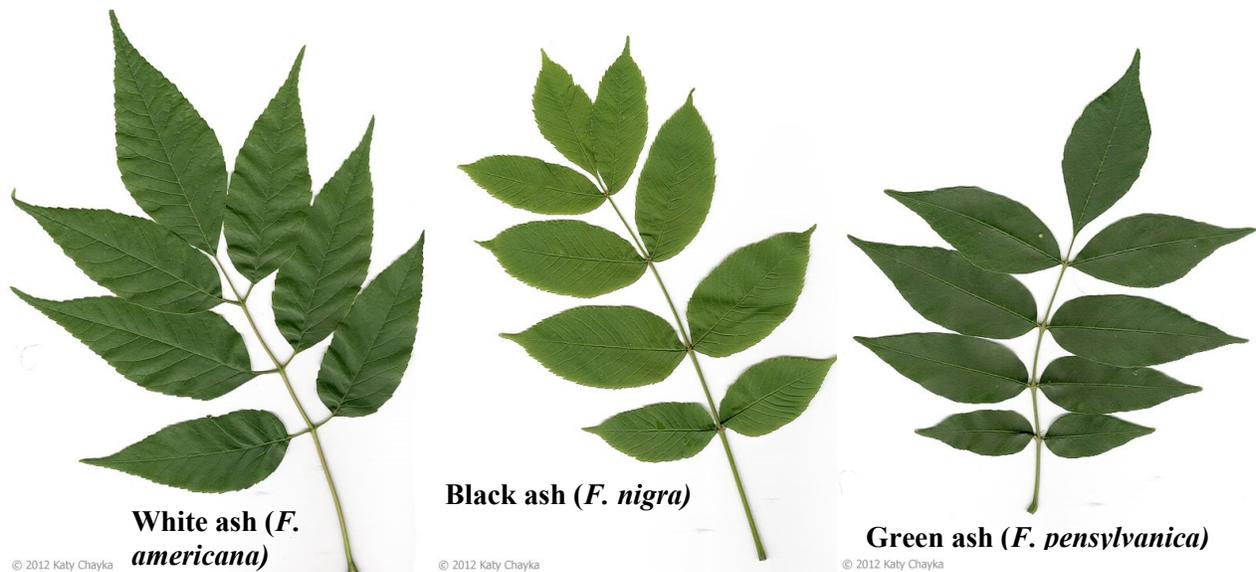


Figure 5. Leaves of white, brown, and green ash trees. Images collected from the [Minnesota Wildflowers website](https://www.minnesotawildflowers.info/page/trees)⁵.

In urban areas, ash planted as street trees are essential for capturing stormwater, reducing the “urban heat island” effect, and improving air quality (Schrader et al., 2021). Urban trees, in general, enhance outdoor recreation, which can be correlated to residents' improved mental and physical health, especially concerning conditions linked to obesity. They also capture and store

⁵ <https://www.minnesotawildflowers.info/page/trees>

carbon the urban community produces, an incredibly important feature as global climate change progresses.

The City of Bangor Tree Inventory and EAB

City of Bangor 2024 Complete Urban and Street Tree Inventory (CUSTI)

From May 2024 to August 2024, the City of Bangor Forestry Division—a division of the Bangor Public Works Department—hired four student interns from the University of Maine. Their primary responsibility for the summer was to conduct a complete public tree inventory for the city. With the supervision of Ben Arruda, the City Forest Manager, they collected data for approximately 8,600 publicly owned trees. This number includes trees in esplanades along public roadways or within the right-of-way and trees in public parks, cemeteries, public schools, or open areas. It does not include privately owned trees or trees in forested areas (Brown Woods, Essex Woods, Prentiss Woods, or the City Forest).

ArcGIS Field Maps was used for data collection, and a data input table was explicitly developed by the GIS technician for the city and Ben Arruda before the beginning of the inventory process. Each pair of interns carried a Samsung tablet with them, and using the Field Maps application, GPS points were created for each tree inventoried, and individual TreeIDs were generated. The GPS accuracy of these tablets is about 30 feet. Using a physical map of all city streets, the interns kept track of already inventoried areas and started in Downtown Bangor, eventually working their way out to the city limits. Right-of-way distances are different for each road within the city, so the interns also had access to the city's Parcel Viewer, a complete database of the parcels in the city with accurate right-of-way distances. Rights-of-way were measured using a 100-foot tape to determine if trees were publicly or privately owned. The interns also used on-the-ground boundary evidence (corner pins, granite corner posts, survey markers, etc.) to help determine what was city-owned property and what was privately owned.

Tree species were determined, and the diameter at breast height (DBH) was measured and recorded in association with the GPS points. The date and time that each tree was inventoried were automatically recorded, and the interns assessed each tree's health on a scale of 0 to 4, 4 being excellent and 0 being dead or failed. Health was determined based on canopy density, bark appearance, limb death, etc. Intrusions across utility lines, over buildings, or into roadways or sidewalks were also recorded for each tree. Based on these observations, trees could be marked for pruning, removal, or other maintenance via yes or no prompts. This allowed for the formation of three lists of TreeIDs that can be referred to for future management purposes.

If a tree was scored as 0 on the health scale, interns automatically marked it for removal in the inventory database. If scored as a 1 on the health scale, determinations on whether to prune or remove were made on a case-by-case basis regarding proximity to roads, utility lines, sidewalks, or buildings. They are as follows:

- Yes, to pruning if:
 - The tree has multiple dead branches, but is a species that can benefit from and be revived by a heavy prune (e.g., crab apples or plums).

- The tree appears to be in borderline decline, but only has a few limbs over man-made structures.
- There is no significant risk to the structural integrity of the trunk.
- Yes, to removal if:
 - Large portions of the declining tree are over man-made structures and could cause severe damage and be a public safety risk should it fall.
 - The tree is leaning at a significant angle/the roots are overly exposed, and there is a risk of tip-up/wind throw during storm events.
 - There is a significant risk to the structural integrity of the trunk (hollow, trunk splits/seams, butt rot, etc.).
 - A large ash tree showing decline or poor form (over 20 inches DBH) that could fall or drop limbs over sidewalks, roads, utility lines, or buildings if infested with EAB.
 - It is a smaller ash tree (under 20 inches DBH) with significant blanding, upper limb death, or general decline that could be linked to an early EAB infestation.

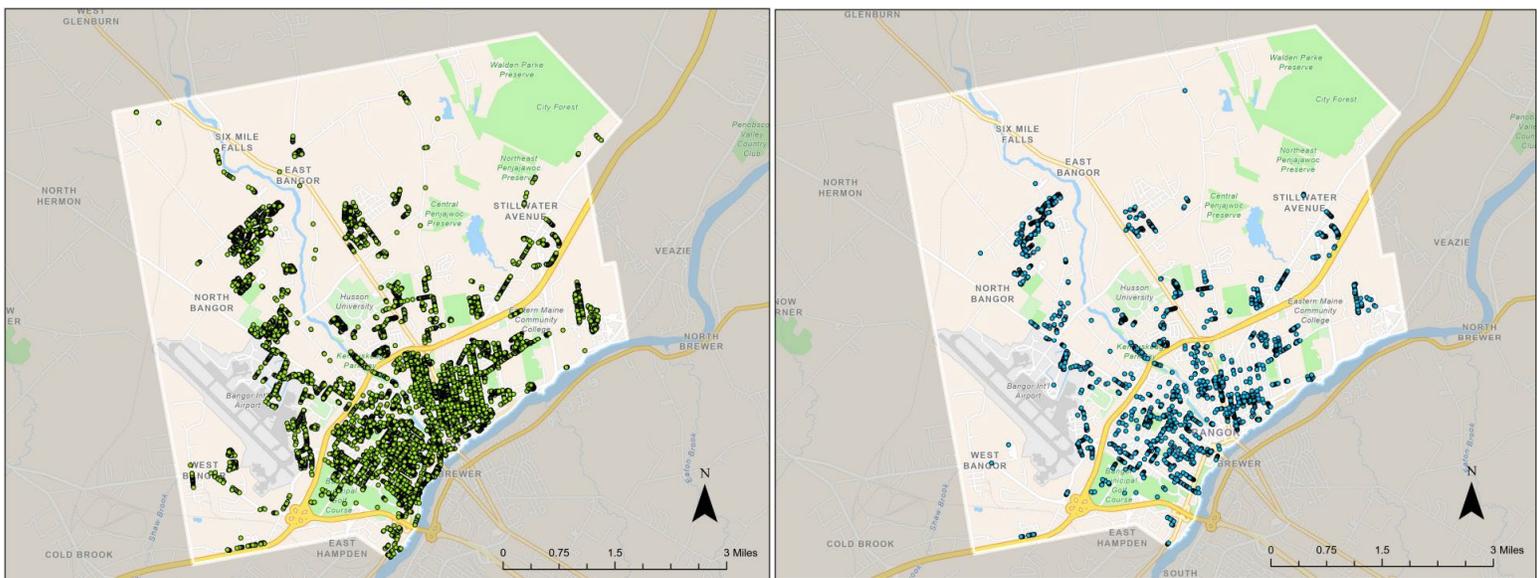


Figure 6. On the left, a dot-density map showing the location of all publicly owned trees collected in the 2024 CUSTI. On the right, a dot-density map showing the location of all the publicly owned ash tree species collected in the 2024 CUSTI. Prepared by Sophia Cameron.

For trees that were 2 to 3 on the health scale, removal determinations are made on a per-case basis regarding proximity to roads, sidewalks, buildings, and utility lines, as well as whether or not the tree is an invasive species (e.g., Callery pear trees that are a 2 were often selected for removal), tree location (e.g., growing directly through utility lines or leaning over the sidewalk or street), and size (e.g., larger than 30-inch DBH trees growing in an esplanade). If a tree rated 2 to 3 had intrusions over buildings, roads, sidewalks, or utilities that were not a significant portion

of the crown, they were marked for pruning. Trees marked as 4 on the health scale were never marked for removal but may be marked for pruning depending on individual tree circumstances and limb positioning.

A digital public tree inventory was attempted previously but never completed. The points generated from these previous attempts were integrated into Field Maps with their associated information. This allowed the interns to match trees with these points and update diameters, add health scores, intrusion, and management information, validate species, and mark whether these trees had been removed since they were last recorded without creating new points and TreeIDs.

Application of the 2024 Complete Urban and Street Tree Inventory (CUSTI) to EAB Management in Bangor

Given the pressing nature of an expected EAB infestation, particular attention was paid to any ash trees encountered during 2024 CUSTI. Each ash tree encountered was inspected for visible signs and symptoms of an EAB infestation. This included looking for boreholes in the upper canopy, noting bark seams or blanding, and looking for serpentine galleries if there was damaged outer bark. The interns also paid attention to the quality of the canopy of each ash tree and noted defoliation or browning of leaves.

If a particular ash tree appeared to have very good form, was a 3 to 4 on the health scale, had no intrusions, and had no visible damage to the trunk, roots, or canopy, the interns would note that it may be eligible for treatment. This aided in the selection of treatment trees later on. Inversely, if a particular ash tree was deemed a hazard during the inventory process, this was also noted and used to select trees that require removal regardless of whether or not they are infested with EAB.

Analysis of the 2024 Complete Urban and Street Tree Inventory (CUSTI)

Upon completion of the 2024 CUSTI, data cleanup was performed. This included adding missing information such as addresses, verifying species when necessary, and taking additional DBH measurements if some appeared inaccurate. Because of the resulting dataset's size and inability to seamlessly integrate previously collected data, data cleanup should continue as the CUSTI is updated. These difficulties may also contribute to slight inaccuracies when reporting urban forest metrics here, so it is important to remember that all values are approximations.

To better understand the city's urban canopy composition, the CUSTI was imported into i-Tree Eco, a free-to-use tool produced by the USDA Forest Service. The tool allows you to import complete or partial inventories for urban or rural trees to generate information at the forest and individual tree levels. This includes estimates about the trees' ecosystem services, canopy structure, composition analysis, and even forecast prediction modeling to predict the impact of certain disturbances.

The 2024 CUSTI was converted into Excel format, including the unique TreeID, the most recent DBH, and the condition of each tree. The condition was aligned with the health measurement used by i-Tree Eco, which is the percent dieback of the canopy. A failed tree (health score of 0) would have 90-100% dieback, a poor tree (health score of 1) would have 60-80% dieback, a fair tree (health score of 2) would have 40-50% dieback, a good tree (health score of 3) would have 20-30% dieback, and an excellent tree (health score of 4) would have 0-10% dieback. The Excel file was then imported into i-Tree Eco and submitted for processing. Again, it is important to remember that all values are approximated at this time. i-Tree's calculation methodology can be found [here](#)⁶.

Table 1 below shows the approximate percentages of the top ten species in the 2024 CUSTI, the approximate leaf area percentage, and the importance value. It shows that ash species and Norway maples combined comprise about 40% of the urban tree population in Bangor. While Norway maples are a higher percentage of the composition, ash species have a higher importance value (IV) because they have a higher leaf area percentage in the urban canopy. It is worth noting that these two species are the only ones in the inventory that are over 10% of the urban canopy.

Table 1. Approximate percentage of each species in the 2024 CUSTI, their leaf area percentage, and their importance value.

Species Name	Percent Population	Percent Leaf Area	IV
Ash spp	21.1	19.5	40.6
Norway maple	22.6	17.4	40.0
Eastern white pine	3.5	24.5	28.0
Silver maple	6.4	9.6	16.0
Littleleaf linden	6.5	5.5	12.0
Japanese flowering crabapple	6.6	1.3	7.9
Northern red oak	3.1	4.5	7.5
Red maple	3.5	2.8	6.3
Sugar maple	2.6	2.6	5.2
Pin oak	1.6	2.6	4.3

Figure 7 displays the diameter distributions (three-inch diameter classes) for the top ten species in the 2024 CUSTI. Different species of trees grow at different rates and achieve maturity at different diameters (e.g., Japanese tree lilacs are small trees and do not reach large

⁶ <https://www.itreetools.org/support/resources-overview/i-tree-methods-and-files/i-tree-eco-resources>

diameters even at maturity). However, the low percentage of trees in the smaller diameter classes likely represents fewer new tree plantings within the city in recent years.

Species Distribution by DBH Class

Location: Bangor, Penobscot, Maine, United States of America
 Project: City of Bangor CUSTI 2024, Series: CUSTI 2024, Year: 2024
 Generated: 3/18/2025

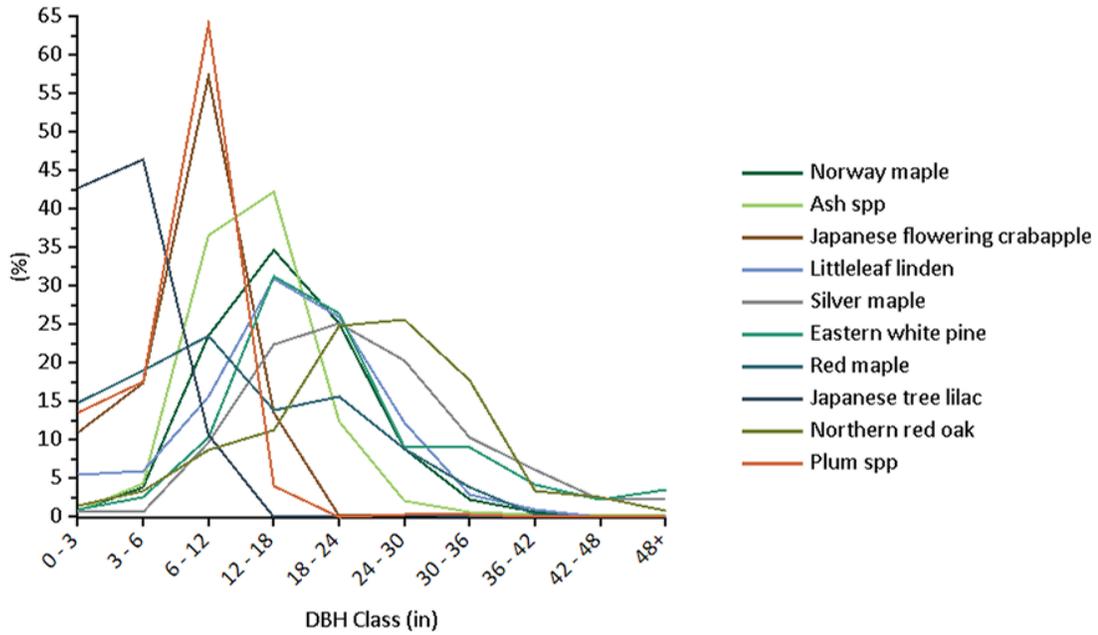


Figure 7. Species distribution in the 2024 CUSTI by three-inch size classes.

Proposed EAB Response Plan for the City of Bangor

Scope

This proposed EAB response plan applies to all publicly owned properties in the City of Bangor where ash trees may grow, including public parks, cemeteries, public school grounds, and rights-of-way. The EAB management of privately owned properties within the city limits will be determined separately. At some point soon, a complete inventory of each city-owned forest should be performed, focusing on identifying stands containing ash trees and selecting possible seed trees for chemical treatment. Amendments will be made to the response plan to address these areas after the additional inventories are completed. For the current document, the response plan includes strategies for maintaining ash in the urban canopy, removing high-hazard trees, replacing trees that have been removed, and monitoring the EAB status in the city.

Administration

The City Forestry Manager will be responsible for implementing this plan and ensuring its completion through the Department of Public Works in conjunction with other departments based on tree placement through separately managed properties within the city (Parks and Recreation Department, Bangor School Department, etc.). He will oversee Forestry Division employees, hired interns, and contractors conducting EAB management work. All management work will be performed internally when possible. However, given the scope of the issue, hiring contractors may be necessary.

Budgeting for this management plan will be determined by the Director of Public Works and approved by the City Council yearly. The Forestry Division will regularly consult with the Parks and Recreation and Planning Departments regarding management plans to ensure cooperation and efficiency.

Management of Healthy Ash

Justification: Importance of Maintaining Ash in Bangor's Urban Canopy

Ash is the second most abundant tree species in Bangor's 2024 Complete Urban and Street Tree Inventory at approximately 20%. The city must remove trees threatening public safety and infrastructure, but it should also plan to maintain some ash trees in the urban canopy. This will reduce removal expenses and retain the ecosystem services provided by urban ash trees, including reducing temperatures, sequestering carbon, enhancing recreation and city aesthetics, increasing property values, reducing heating and cooling costs for property owners, and helping to manage stormwater runoff.

It is also necessary to consider the importance of maintaining ash in Bangor's canopy as a genetic repository for the species. While Asian ash species and other related tree species (the native hosts of EAB) have evolved to have some resistance to the insect, the North American ash have not, which makes them incredibly susceptible to infestations. There is hope that as the killing front— a term commonly used to describe the first wave of an insect infestation or pathogen infection of a large population— continues to progress across North America, more and more individual trees will be identified as resistant to EAB. The discovery of resistant North American ash trees has already allowed researchers to inspect the genetics and possible causes of resistance in green ash (Koch et al., 2015), and there is continued investigation into the evolved resistance of Asian ash species (Gossner et al., 2023). This gives us hope that in the future, there will be progress in the selective breeding of EAB-resistant ash trees, as there has been with American chestnuts. However, in the meantime, preserving genetic diversity within the species is essential, which means preserving as many seed-producing trees of the three native North American species as possible.

Complete ash removal from Bangor's urban canopy is not recommended. Removing all ash trees would eliminate the risks of property damage or public safety; however, doing so in a relatively short time would shock the urban environment and may have grave consequences. Preemptively removing all ash trees, even over an extended period, reduces the overall economic value of the urban canopy (Vanatta et al., 2012). These economic implications will be further explored later in this document. Therefore, strategies for keeping some ash trees alive are needed.

Insecticide Treatment Options

Since EAB was first introduced in the U.S., there have been incredible strides in preventing initial infestations of ash trees and effectively killing EAB in already-infested trees. There are currently no effective management strategies for protecting trees from EAB that do not require the use of insecticides. Systemic insecticides applied as foliar or branch cover sprays,

lower trunk sprays, soil drenches or injections, and trunk injections have all been effective methods of controlling EAB (Herms et al., 2019). In Maine, effective insecticide products used to control EAB must be applied by professional pesticide applicators. The products include imidacloprid, dinotefuran, emamectin benzoate, azadirachtin, permethrin, bifenthrin, cyfluthrin, and carbaryl (Herms et al., 2019).

All these insecticide application methods—excluding foliar sprays—function through translocation. This is the movement of water, nutrients, and, in this case, insecticides from one part of the tree to another part of the tree. For example, if an insecticide is injected at the base of a tree's trunk into the inner bark (phloem and cambium) and wood (xylem), it will move through the vascular tissue of the tree (phloem and xylem) either up into the canopy and leaves or down into the roots, depending on the time of year. Through the spring and summer months, nutrients from the soil move upwards to facilitate canopy growth and leaf function. Whereas in the late summer and fall months—as deciduous trees prepare to lose their leaves—the starches used to produce energy through the winter are translocated into the roots and trunk for storage, so the movement in the phloem is downwards. Because of these physiological changes, it is vital to consider the timing of insecticide applications, their intended mode of delivery throughout the tree (should the product go to the roots or the leaves?), and the target pest's lifecycle. Trees infested with EAB can be treated only if they still have 60% of their canopy remaining, indicating that there is still sufficient undisturbed phloem for product translocation (Herms et al., 2019).

The timing of the insecticide depends heavily on the EAB life cycle. The adults feed on the leaves from late May to September. To control adult populations, you would either apply insecticides directly to the leaves or use a product that will be translocated into the leaves. Adult females lay their eggs in bark crevices during the same periods, and larvae immerse in about three weeks. Treatment is most effective in killing actively feeding larvae in mid to late spring when translocation movement is upward through the trunk. In early infestations, the products must reach the upper canopy effectively so that adults feeding on leaves and larvae in the smaller branches can also be killed.

In urban settings, there is concern regarding human and animal exposure to insecticides. Spraying insecticides also has a negative public perception and could promote the public's resistance to treating ash trees. For this reason, trunk and foliar cover sprays are not recommended in urban areas. Foliar sprays would be challenging for the city, as the application of the products should cover most of the canopy of each tree (Herms et al., 2019). Effectiveness studies have been based on two applications per year, so the scale of coordinating this effort and the amount of product needed would likely make this method not financially viable (Herms et al., 2019). Foliar sprays are also only effective as a preventative treatment option and cannot effectively remove an EAB infestation. Dinotefuran is the recommended product when performing trunk sprays to prevent EAB (Herms et al., 2019). Because of their toxicity to pollinators, neonicotinoids like imidacloprid and dinotefuran should only be used as trunk or soil injections to avoid the drift or spread of the product to other insects. Their use is also restricted

within Maine (130th Maine Legislature, 2021). The concerns around drift, unintentional exposure, and the high treatment rates exclude foliar and trunk sprays as viable EAB treatment options within the City of Bangor.

Soil drenches are performed by diluting insecticides in water and pouring the solution around the base of a tree directly into the soil. Soil injections are similar, but special equipment injects the solution two to four inches into the soil around the tree's base (Herms et al., 2019). Both are done to allow for root uptake of insecticides and prevent damage to the bark of a tree, as would occur with trunk injections (Herms et al., 2019). Soil injections also help to reduce insecticide runoff, like what can happen with soil drenches (Herms et al., 2019). Research on the effectiveness of soil-applied insecticides has varied, likely because of the differing application methods and rates (Herms et al., 2019). Dinotefuran and imidacloprid are used for soil drenches and injections, so the same concerns around pollinator exposure apply to these methods. Additionally, there is no research on the effectiveness of soil-applied insecticides on trees over 22 inches in diameter (Herms et al., 2019). Several trees of this size are included in the list of trees already selected for treatment within the city. These methods are effective when the highest rates of products are applied, so there would also be an increased cost to treating via soil drenches or injections (Herms et al., 2019).

Trunk injections are performed by drilling one injection hole for every two to three inches of diameter of the trunk at the base (ex., A 20-inch diameter at breast height tree would have 10 injection holes drilled) and then using specialized equipment to inject the insecticides directly into the inner bark where the larvae feed. A licensed pesticide applicator must do this, and great caution should be taken when injecting, as high-pressure injections can cause separation of the outer bark from the inner bark, which can severely damage a tree (Herms et al., 2019). The insecticides used are emamectin benzoate, azadirachtin, or imidacloprid. This method of application of imidacloprid reduces the risk of exposing pollinators because the insecticides remain contained entirely within the tree. Of the three, emamectin benzoate is the most effective at controlling EAB and the most long-lasting. Azadirachtin and imidacloprid must be injected annually for effective control, while emamectin benzoate, even at lower application rates, can control EAB reliably for two years (Herms et al., 2019). If pest pressure is lower and emamectin benzoate is applied at a higher rate, studies suggest that it could protect for up to three years (Herms et al., 2019, Smitley et al., 2010).

Treatment Recommendations

The official recommendation of this response plan is to inject the 250 selected treatment trees with emamectin benzoate, specifically the Arborjet product Tree-age R10. Tree-age R10 is faster acting than Arborjet's Tree-age G4. The higher concentration means a lower application rate, reducing the time required to inject each tree. A licensed pesticide applicator must inject it, and protective equipment should be worn to reduce the risk of exposure to the product. Members

of the Forestry Division are seeking their pesticide applicator's license, and maintaining these licenses will reduce the overall cost of treatment.

There is concern about the damage done by drilling into the trees, as it causes stress and may make them more susceptible to other pests and pathogens. However, trees have been found to recover quickly and generate new wood over injection sites the summer following spring injections (Herms et al., 2019). Additionally, injections will be performed every two to three years, so there will be a longer recovery period between injections. Any breach of the outer bark creates an entrance for other pathogens, so injected trees should be monitored closely in the months following treatment for any signs of decline.

The Forestry Division has already acquired an Arborjet Quickjet Air-2 injection system, significantly reducing the time needed to inject each tree. Injection caps will be inserted into each drilled injection site so that they do not need to be drilled for the following injections, and damage to the tree is reduced. Injection sites will be evenly spaced around the tree trunk within 24 to 48 inches of the root collar, and the drill holes will be $\frac{5}{8}$ "-1 $\frac{5}{8}$ ".

Because of the active infestation confirmed in Hermon, the first round of treatment should begin immediately, as there could be active infestations in Bangor that have gone undetected. While adults cannot fly far distances, it is not unlikely that ash wood products have been transported from Hermon into Bangor, increasing their distance of spread. Bangor shares its western border with Hermon, so starting injections on the west side of the Kenduskeag Stream is recommended.

The current recommended timeline of treatment is as follows:

- About a third of the 250 selected treatment trees (85 trees) should be injected in the **Spring 2025**. These trees are considered **Treatment Group 1**.
- In **Spring 2026**, 84 more trees will be treated, moving west to east within the city. These trees are considered **Treatment Group 2**.
- In **Spring 2027**, 81 trees will be treated to complete the initial treatment of all 250 selected treatment trees. These trees are considered **Treatment Group 3**.
- **Between 2025 and 2027**, as the initial treatments are being completed, the trees that remain untreated will continue to be monitored by the Forestry Division to ensure that the selected trees are still eligible for treatment. Should they become ineligible, they will be removed from the list, and trees not on the original list will be inspected and added as replacements. If the EAB infestation spreads across the city faster than anticipated, Public Works and the Forestry Division will discuss changing the treatment timeline, and an amendment will be made to this document.
- The treatment cycle will restart in **Spring 2028**, so Treatment Group 1, treated in 2025, will be inspected for treatment efficacy and treated again. Treatment Group 2, treated in Spring 2026, will be treated again in **Spring 2029**, and Treatment Group 3, treated in Spring 2027, will be treated again in **Spring 2030**.

- The treatment cycle will start once again in **Spring 2031**, in the same order for the third round.
- Upon completion of the third round of treatment in **2033**, the status of the EAB infestations across the city will be assessed, likely during an updated CUSTI. Depending upon the infestation's activity level and spread across the city, the Forestry Division can determine if another round of treatment is required or if treatment can be stopped and the trees monitored.

Throughout the nine-year treatment period, there may be discoveries regarding the best practices for protecting ash trees from EAB. Should the recommendations presented here change, an amendment will be made to this document explaining the changes in treatment methods.

Treatment Tree Selection Process

The terms “Selected Treatment Tree” or “Treatment Tree” are used in this document to refer to ash trees in good health that are chosen to be treated with chemical insecticides. The 2024 CUSTI of Bangor allowed for the ease of treatment tree selection. As the inventory was being completed, the interns were instructed to make a note in the comments section to be revisited later if they saw ash trees of particularly good form with few or no intrusions. These, along with trees marked as 3 or 4 on the health scale that did not intrude on utility lines, buildings, streets, or sidewalks, were selected and added to an Excel spreadsheet of potential treatment trees. Attention was also paid to the location of these trees so that every neighborhood with eligible trees across the city had several eligible ash trees for treatment to promote urban canopy equity.

Every tree on this spreadsheet was revisited in the same summer to confirm that it had at least 40% of its canopy, no significant or dangerous intrusions, and no structural defects of the trunk that could cause it to fall or be removed within the nine-year treatment period. They were also closely inspected for any other signs or symptoms of EAB. No size preference was given, as a multi-age class urban canopy ensures that ash trees will be in Bangor’s canopy into the future, and there is no limit on the diameter of trees that can be injected. These rechecks created the final list of 250 trees. The trees were sorted into separate lists depending on which municipal budget would pay for treatment (e.g., Treatment of trees located in rights-of-way would be paid for out of the Public Works budget, while those in parks would be paid for out of the Parks and Recreation budget). These trees were explicitly used to calculate chemical treatment costs. They are mapped in Figure 8.

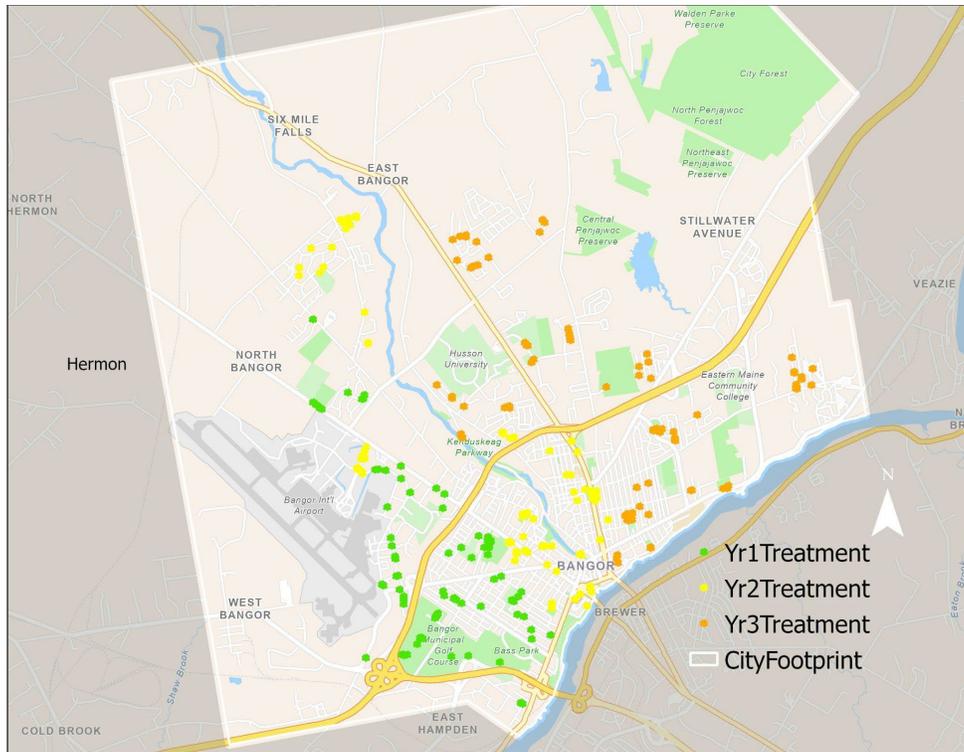


Figure 8. Map showing the three treatment groups described in the treatment timeline (p. 24), which were used to calculate the ten-year treatment budget.

Management of Unhealthy, Infested, and Dead Ash

Risks Posed by EAB-Infested Ash Trees

Any dead or dying tree in the urban environment risks public safety. When trees die, their wood becomes very brittle, and water stops moving through their tissues. Think of the ease with which you can split dried firewood. Additionally, dead trees are more prone to fungi that cause rot or insects that make their homes in dead wood. These factors further compromise a tree's structural integrity, leading to broken branches, an increased risk of windthrow, and total trunk collapse.

Because of how EAB feeds on ash trees, infested trees are even less structurally sound. Since EAB infests trees from the top down, branches 30 to 40 feet in the air are the first to die. The galleries prevent water movement into the upper canopy, so these branches dry out and become brittle quickly, even if the lower canopy appears alive (Sadof et al., 2023). This can result in large branches falling from great heights, posing a significant risk to those walking underneath these trees. There is also the risk of damage to utility lines, roofs, and cars parked underneath them. If an ash tree is left standing and dies completely, the galleries in the main trunk generate the same drying effects, and there have been claims of entire trees collapsing under their weight, seemingly unprovoked. This combination of factors creates particularly hazardous and unpredictable standing dead trees, especially in densely populated areas.

Justification: Importance of Preventative Removal of Ash Trees

The increased wood brittleness from infestation, combined with current defects (leaning trunks, root lifting, damage to branches or the trunk, etc.), creates incredibly structurally unsound and dangerous trees. Ash trees that are damaged or stressed (e.g., hit by a snowplow or growing in an esplanade) produce stress pheromones that EAB adults are attracted to (McCullough et al., 2009). This means that trees that are considered high-risk are also actively attracting insects. For these reasons, removing ash trees that already show signs of stress, structural damage, or defects before an EAB infestation is wise.

Required Removal Tree Selection Process

Ash trees that displayed significant damage or defects were added to the list of trees that require removal ahead of an active infestation in Bangor. These trees are ineligible for treatment and pose a high risk to public safety. Similarly to how treatment trees were selected, notes were made in the comments section during the 2024 CUSTI for trees that the interns believed to be in poor condition or had significant intrusions that could not be resolved with pruning. These trees

and those 0 to 2 on the health scale with intrusions were added to an Excel sheet for removal. Examples of trees on the required removal list are shown in Figure 9.

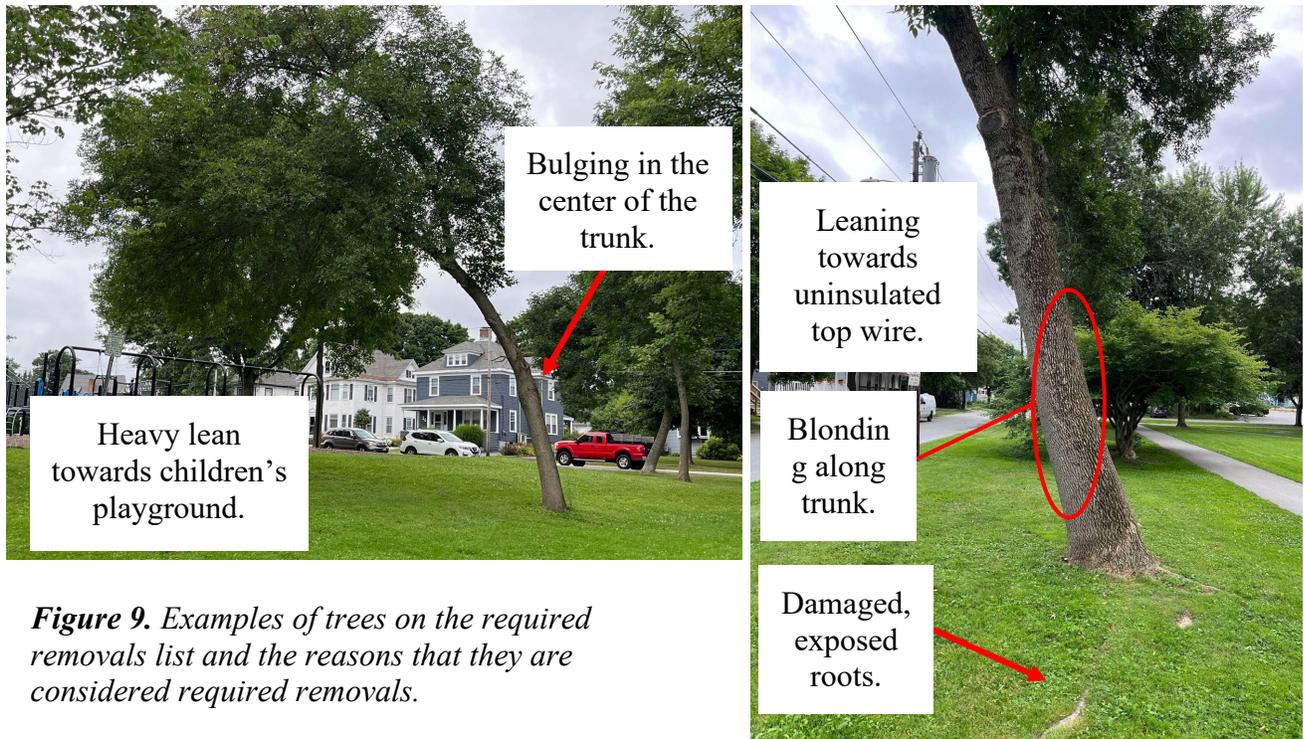


Figure 9. Examples of trees on the required removals list and the reasons that they are considered required removals.

The interns inspected each tree to confirm its noted defects or damage, health score, and intrusions. Trees with a health score of 2 were specifically scrutinized to determine if they belonged on the required removal list. If each tree was determined to be in poor condition with damage or defects, they were put through the flowchart in Figure 10. This was designed collaboratively with the Forestry Manager and interns to accurately categorize trees into “risk groups.” Group 1 must be removed as soon as possible because they are high risk, and Group 4 can wait to be removed because they are lower risk. The purpose of the flow chart was to standardize decision-making across the interns. It also allowed for the creation of an ordered removal list of ash trees, with the hopes that their efficient removals will reduce risks in the urban environment.

All the ash trees in Group 1 of the required removals had photos taken, which were added to the inspections in the CUSTI. When the interns visited trees determined to be in Group 1, International Society of Arboriculture (ISA) Basic Tree Risk Assessment forms were also completed. These additional steps will allow the Forestry Manager to quickly reference why each tree is being removed should members of the public enquire. Each tree on the required removals list was also categorized as needing to be removed by a contracting arborist or if it could be removed using the in-house forestry staff. This was determined based on the tree's proximity to a building or uninsulated top wires on utility lines. Large trees close to these features will need to be removed by contractors.

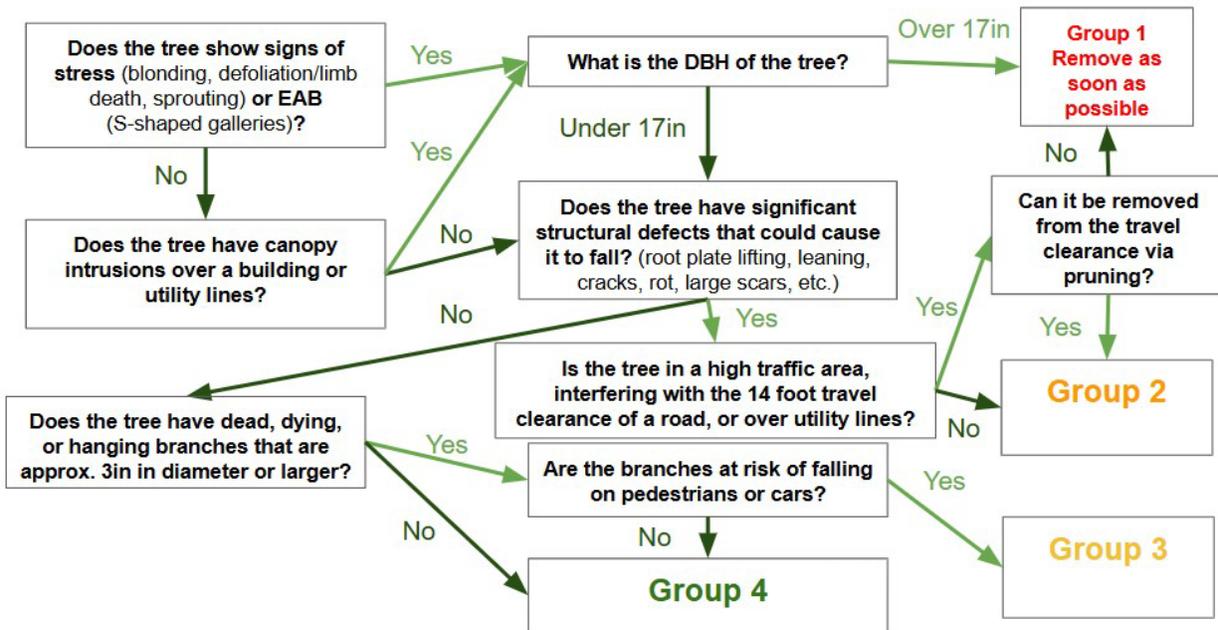


Figure 10. Flowchart developed to standardize decision-making for sorting required removal trees into removal groups.

Ash Tree Required Removal Timeline

Trees on the required removals list are there because they pose a certain level of risk even without being infested by EAB. This means that to prevent the damage they may cause, they should be removed as soon as possible. Because the groups created using the flowchart are sorted by risk level, Group 1 trees should be removed first. The timing of this may be variable, as some of these trees will need to be removed by contractors because of their proximity to buildings or utility lines. However, once Group 1 is removed, Group 2 can be removed, etc., so they are not constrained to a yearly basis like the treatment trees. Ideally, each group will be removed within less than a year. While it may not always be feasible because of other circumstances, it is recommended that these ash trees be prioritized over removing other species because of the impending infestation.

Management of Remaining Ash Trees

Remaining Publicly Owned Ash Trees

There are approximately 1,800 ash trees in the 2024 CUSTI. Two hundred fifty trees are already determined to be treatment trees, and 436 require removal. This leaves over a thousand publicly owned ash trees that do not have a determined course of action. This number also does not include any ash trees found in the public forests across the city.

Three routes could be taken: treat more, remove more, or do nothing. Treating more eligible trees would allow the city to maintain the ecosystem services these urban ash trees provide and incur the cost of treatment every three years for a somewhat indefinite period. Removing more trees would forfeit these ecosystem services but may prevent future damage or injury and their associated costs. This route would also require increased spending on removing each additional tree. Doing nothing would also forfeit the ecosystem services these trees provide, as there is a high likelihood that they would succumb to EAB without intervention. Additionally, doing nothing would increase the possibility of costs associated with property damage and injury to citizens.

Based on the economic analysis of the ecosystem services these trees provide (p. 41), the official recommendation of this response plan is to treat additional eligible trees with emamectin benzoate injections. The total number of trees chemically treated should be between 750 and 1,000 including the already selected 250 trees and depending on eligibility. These trees can be added after the first three-year treatment cycle to spread out treatment costs if necessary. This will also allow for more insight into the effectiveness of the treatments and provide time for correction if needed.

Private Ash Trees

At the time of this document's publication, no determined course of action has been established for ash trees found on private property throughout the city. The Forestry Division intends to work with other city offices and the Maine Forest Service to determine the best methods of dealing with EAB on private property. See the EAB Monitoring section (p. 37) to learn how to report ash on private property to the city for future management opportunities.

Urban Canopy Maintenance, Expansion, and Diversification

Justification: Importance of Maintaining, Expanding, and Diversifying Bangor's Urban Canopy

With the anticipated loss of so many ash trees across Bangor, it is essential to consider the broader impacts of a reduced urban canopy. As stated, urban trees provide many ecosystem services that are not always considered, making towns and cities far more livable overall.



Figure 11. A graphic produced by the [Nature Conservancy](https://www.nature.org/en-us/about-us/where-we-work/united-states/washington/stories-in-washington/voice-for-healthy-urban-trees/)⁷ outlining the many ecosystem services urban trees provide.

Dark, impervious surfaces attract light and retain heat, increasing the temperatures within more developed towns and cities by an estimated two to four degrees Fahrenheit compared to rural areas. Additionally, tall buildings can create the same effect as what you would experience standing at the bottom of a valley because long-wave heat radiation cannot escape the area, and increased particulate matter in the air also traps heat (Kleerekoper et al., 2012). This is known as the urban heat island effect. As climate change progresses, the temperature gap between rural and urban areas will widen as global temperatures increase. This can increase cooling costs

⁷ <https://www.nature.org/en-us/about-us/where-we-work/united-states/washington/stories-in-washington/voice-for-healthy-urban-trees/>

through the summer and endanger the lives of the chronically ill (particularly those with cardiovascular disease) or the elderly (Cleland et al., 2023). Even those in these vulnerable groups with climate-controlled homes may have difficulty being outdoors or performing daily tasks like grocery shopping. The urban heat island effect has also been found to disproportionately affect low-income and minority populations because of their inability to access climate-controlled spaces (Hsu et al., 2021).

The total population of Bangor is between 29,000 and 32,000 people, based on the 2023 American Community Survey five-year estimate provided by the Community Development Officer for the City of Bangor, Robyn Stanicki. Approximately 14.9% of the population meets the Federal Poverty Limit (FPL), and 24.9% have incomes that fall between 1-1.5 times the FPL. About 25% of the population is estimated to be 62 or older. This means that over 60% of the Bangor population is at greater risk of being negatively impacted by the urban heat island effect.

Impervious surfaces also generate more stormwater runoff and carry pollutants from roads into waterways since the water cannot flow into the soil and be naturally filtered. In a study conducted in 2020 in the Midwest, 29 green ash were removed from a medium-density urban area, and it was found that there was a 4% increase in stormwater runoff, which was about 52,000 gallons of additional water entering the sewer systems across the study period (Selbig et al., 2022). Bangor is currently at risk of losing over 1,800 ash trees within the next five to seven years, and there is concern that their loss will drastically increase the amount of runoff entering the sewer systems and freshwater bodies. Maine's precipitation rates are also expected to increase as climate change progresses, as are the yearly extreme weather events (Arnold et al., 2024).

In the U.S., there are an estimated 100,000 to 200,000 deaths related to air pollution per year (Thrakrar et al., 2020). One of the most efficient ways of decreasing air pollution in urban centers is to plant trees. The large surface areas of tree canopies allow particulate matter to settle onto leaf surfaces instead of continuing to be suspended in the air until they reach the ground, preventing them from being inhaled. Then, when it rains, this particulate matter is washed off the leaves and filtered through the soil, preventing it from re-entering the air. The rate at which urban trees remove air pollutants in urban environments varies depending on the proximity of pollutant production and other environmental factors (Grylls & Reeuwijk, 2022). However, one annual estimate for total air pollution removed (O₃, PM₁₀, NO₂, SO₂, and CO) by urban trees in the U.S. was over 700,000 metric tons, which equates to a \$3.8 billion value (Nowak et al., 2006).

Urban trees have also been shown to increase property values (Morales, 1980), improve overall health (Wolf et al., 2020), and may even reduce crime (Wolfe & Mennis, 2012; Lin et al., 2021). The urban canopy must be maintained, expanded, and diversified for Bangor to benefit from these ecosystem services.

Urban Canopy Maintenance and Replacement

To maintain the urban canopy, some eligible ash trees must be treated to protect against EAB, and removed ash trees must be replaced. Ideally, replacement would occur during the soonest planting season (Fall or Spring), but there is flexibility. The initial removals in response to EAB will reduce the benefit of the ecosystem services that the ash component of the urban canopy provides. However, replacing them means that, eventually, those services will be restored.

Urban Canopy Expansion

Maintaining Bangor's urban canopy by replacing removed trees will allow the city to preserve the value of the ecosystem services it currently provides, but expanding the urban canopy will allow the city to maximize its value. While this response plan does not include data on privately owned trees, we acknowledge that these trees equally contribute to the overall ecosystem benefits as the publicly owned trees included in the 2024 CUSTI and encourage private landowners to explore the best ways to increase their tree cover when possible.

Increasing Bangor's urban canopy can be accomplished through several avenues. Bangor Beautiful—an organization founded by Bangor citizens in 2022—has a program where residents of Bangor can donate a tree to be planted by their volunteers, called [Buy Bangor a Tree](https://www.bangorbeautiful.org/projects/buy-bangor-a-tree)⁸. Other donations have also already contributed to city plantings, such as a large donation from the Wason Tree Physiology research lab at the University of Maine, Orono, coordinated by Laura Pinover, which donated over 100 trees previously used for research. The Forestry Division has a yearly budget for buying new trees to plant to replace those that have been removed, and increasing this budget would greatly help in the urban canopy expansion effort. It is also recommended that the city take advantage of grants specifically for tree planting and replanting efforts in urban areas and look to other municipalities in the state for tree planting program inspiration (e.g., Lewiston's [Treebate](https://www.lewistonmaine.gov/796/Treebate-Program)⁹ program).

The city recently applied for and was awarded a Project Canopy grant through the Maine Forest Service. The grant will fund the construction of a new city nursery, including deer fencing, irrigation, and soil amendments using city-produced compost. This nursery will house seedlings and saplings to be planted across the city. This will increase the likelihood of successful plantings and provide a temporary “quarantine” location for newly purchased trees.

When planting new trees in Bangor, significant consideration should be given to ensuring the right tree is planted in the right place. Oftentimes, urban land managers of the past did not consider the futures of each of the trees planted and did not continue to monitor their growth over the years. Different tree species have different growth patterns, with some growing tall with

⁸ <https://www.bangorbeautiful.org/projects/buy-bangor-a-tree>

⁹ <https://www.lewistonmaine.gov/796/Treebate-Program>

thinner stems and others growing wide but remaining reasonably short. Others even take on a more shrublike appearance. These growth forms are essential when determining where to plant certain trees. Trees that grow 40 to 60 feet tall can be planted in the middle of a park, but would be less appropriate directly underneath utility lines. Being mindful of the locations of new plantings and the surrounding areas will lead to greater success for these plantings, as it will reduce the need for early removals of mature trees to prevent damage to infrastructure.

To further increase the success of new plantings so that they are recruited into and remain in Bangor's urban canopy into the future, it is important to monitor their growth and health continually. It is recommended that a member of the Forestry Division perform yearly inspections on trees for at least five years following their planting to monitor for adequate growth and check for damage or disease. It would also be helpful to mark these trees with reflective stakes to prevent damage from snowplows in the winter and to apply bark guards when planting so that string trimmers and lawn mowers do not damage their trunks. Discussions with those operating this equipment on preventing tree damage may also be helpful. Each tree should be planted following the best practices used by the Forestry Division, so contribute to their successful growth.

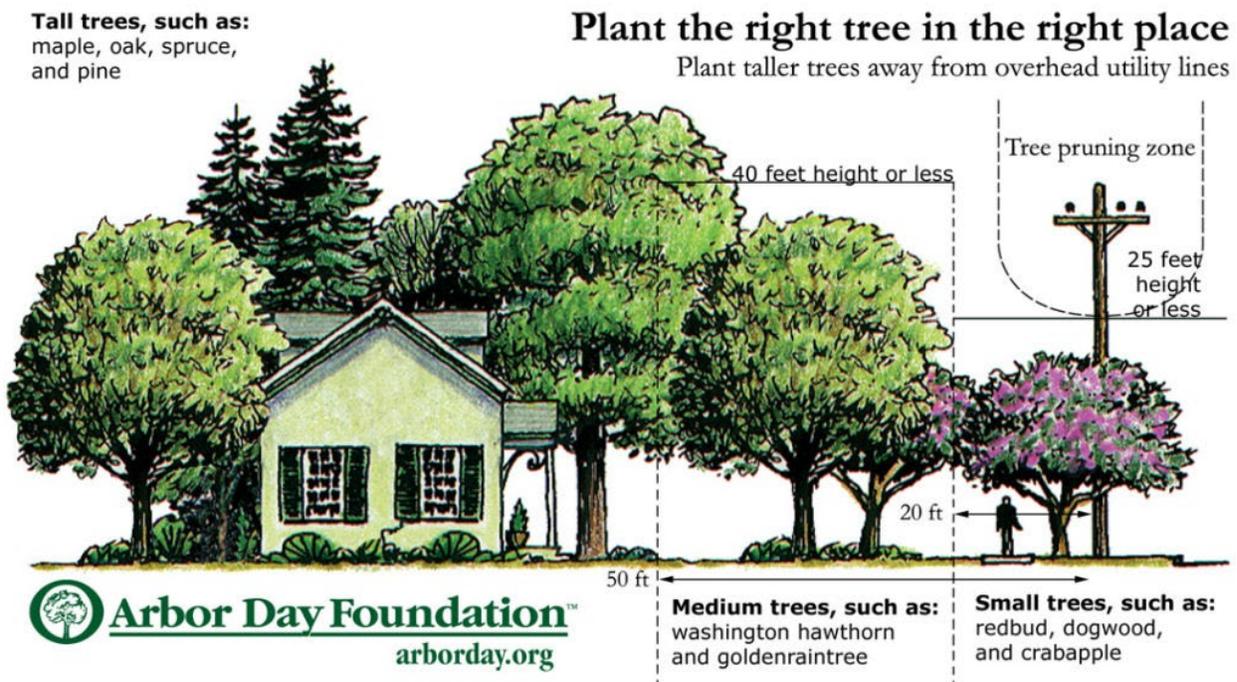


Figure 12. A schematic produced by the Arbor Day Foundation shows where appropriate locations for different tree species may be in an urban or suburban setting. Image collected from the Arbor Day Foundation [website](https://www.arborday.org/perspectives/planting-right-tree-right-place)¹⁰.

¹⁰ <https://www.arborday.org/perspectives/planting-right-tree-right-place>

Urban Canopy Diversification

Species-specific pests and diseases are incredibly detrimental to urban forests that are low in species diversity, like Bangor. Increased diversification is also expected to create more resilient urban forests as climate change progresses because you have different species in different functional groups (e.g., drought-tolerant or flood-tolerant species) (Wood & Dupras, 2021), while also acting as a genetic refuge for tree species that are most at risk due to a changing climate (Woodall et al., 2010). A diverse urban canopy is an insurance policy for urban land managers, ensuring that it will remain robust and healthy long into the future, regardless of what disturbance may affect it. The threat EAB poses to Bangor's urban ash has also created a new opportunity through the 2024 CUSTI to assess the current diversity of its urban canopy and work towards improvement.

As stated, ash species comprise about 20% of Bangor's inventoried urban canopy and are the second most important species in the city. The most prevalent species in Bangor's inventoried urban canopy is Norway maple (*Acer platanoides*), which is approximately 22% of the total tree population and has an importance value of 40 (Table 1). Norway maples are susceptible to Asian long-horned beetles (*Anoplophora glabripennis*), another wood-boring, invasive insect species. While Asian long-horned beetles (ALB) are not currently a species of concern in Maine, infestations have been reported as far north as Massachusetts (Parker et al., 2021), and the Maine Forest Service continues to monitor for their presence in the state. The susceptibility of another high percentage of Bangor's urban trees to yet another non-native insect pest species further highlights the need to increase the diversity of the urban canopy.

In addition to being susceptible to invasive pests, Norway maples are an invasive species in the U.S. themselves. They are native to Europe and western Asia and were introduced to North America as an ornamental species. They are outcompeting their native counterpart, sugar maples (*Acer saccharum*), in Northeastern forests (Webb et al., 2000). Their high number in Bangor highlights another critical issue that the city faces: the introduction of invasive plant species. Like Norway maple, most invasive plant species are introduced into areas because of ornamental plantings on public or private property, significantly reducing diversity as they take over. To prevent this, it is recommended that the city only plant trees native to the Northeastern U.S. or exotic species that are not known to be invasive. Examples of trees that should no longer be planted in Bangor are the Japanese tree lilac (*Syringa reticulata*) and Callery pears (*Pyrus calleryana*). Removing these species growing in the city is also recommended to prevent their continued spread. For more information on what species are considered invasive in Maine, you can find the Maine Department of Agriculture, Conservation, and Forestry invasive plant lists [here](https://www.maine.gov/dacf/php/horticulture/invasiveplants.shtml#rules)¹¹.

One of the most promising tools urban land managers have to mitigate the effects of climate change and preserve their urban canopies in the face of it is the concepts of assisted

¹¹ <https://www.maine.gov/dacf/php/horticulture/invasiveplants.shtml#rules>

migration and assisted range expansion of native tree species. Both are the movement of tree species by humans to mimic and increase the speed at which they would naturally migrate in response to changes in climate (Handler et al., 2018). Assisted migration is the movement of tree species far beyond their historical range. Assisted range expansion is the movement of tree species just outside of their historical range (Handler et al., 2018) (Fig. 13). These methods create a northern genetic refugia for more southerly tree species that may not be able to tolerate the more extreme temperature changes expected in the mid-Atlantic and southern New England, and introduce new species populations and genetics to northern New England that may better tolerate the changing climate here, and possibly preventing climate change induced urban canopy loss (Woodall et al., 2010).

It is recommended that to increase species diversity in Bangor's urban canopy, different trees native to the Eastern U.S. are planted in quantities that generate more even species percentages across the city. Due to climate change, it is also recommended that during tree selection, the concepts of assisted migration and assisted range expansion are considered, and that invasive tree species components are reduced or altogether removed. This means:

- 1) increasing the percentages of Maine's native species already planted in Bangor, such as red maples (*Acer rubrum*), sugar maples (*Acer saccharum*), Northern red oaks (*Quercus rubra*), or cultivars of these species;
- 2) decreasing the percentages of non-native, invasive tree species already planted in Bangor through removals, and no longer planting any invasive species in the city;
- 3) and adding species with more southerly ranges (specifically from southern New England and the mid-Atlantic region) that will be better adapted to the warmer climate that is expected in Maine as climate change progresses, such as shagbark hickory (*Carya ovata*), Northern catalpa (*Catalpa speciosa*), and swamp white oak (*Quercus bicolor*).

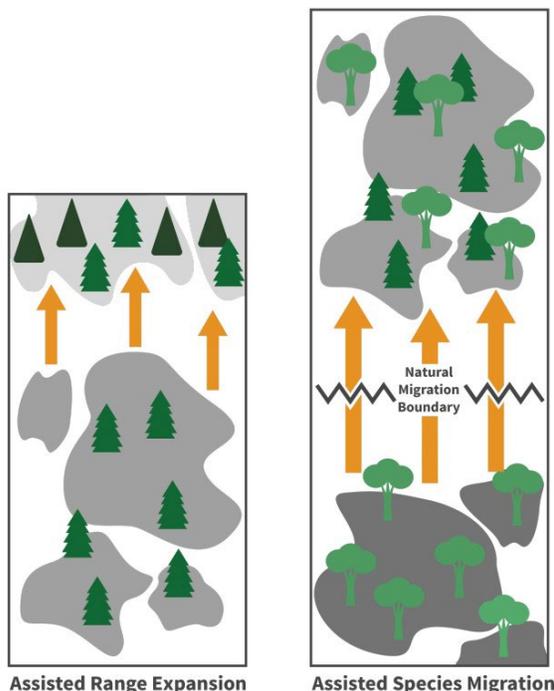


Figure 13. A diagram illustrating the difference between the concepts of assisted range expansion and assisted species migration. Taken from the Climate Change Resource Center's [Assisted Migration resource](#) (Handler et al., 2018) and adapted for use in this document.

EAB Monitoring

Maine Forest Service EAB Monitoring

The Maine Forest Service (MFS) has installed several purple prism traps across the city after they were alerted to a possible sighting of EAB bore holes in a Bangor neighborhood near I-95. These traps are used as an early detection tool in areas where EAB has not yet been detected. To learn more about the MFS EAB monitoring efforts, you can visit their website [here](#)¹².

City of Bangor EAB Monitoring

The Forestry Division intends to continue monitoring for EAB across the city. This includes using a tool created by CivicPlus called [SeeClickFix](#)¹³. The city already uses it to allow public reporting of things like graffiti and potholes. Recently, an additional feature was added that allows for reporting privately owned ash trees to better understand the privately owned ash component. There are plans to create another reporting feature to enable citizens to report possible EAB sightings, which a member of the Forestry Division can then verify.



Figure 14. A purple prism trap is on the left, and a properly girdled black ash trap tree is on the right. Images collected from the [USDA APHIS Trapping Protocol](#)¹⁴ and the MFS Trap Tree [website](#)¹⁵.

¹² https://www.maine.gov/dacf/mfs/forest_health/invasive_threats/purpletraps.htm

¹³ <https://seeclickfix.com/bangor>

¹⁴ <https://www.aphis.usda.gov/sites/default/files/eab-trapping-protocols.pdf>

¹⁵ https://www.maine.gov/dacf/mfs/forest_health/invasive_threats/eab_trap_trees.htm

Last summer, several EAB trap trees were created. This involved removing a portion of the outer bark and the first layer of the inner bark of an ash tree in fair health. This promotes the production of the stress pheromone that attracts EAB adults if they are nearby. These trees will be removed this coming summer (2025), and their upper limbs will be inspected for insects.

The Forestry Division also intends to develop public outreach programs around EAB monitoring in partnership with other local organizations.

Wood Utilization and Disposal

Maine Forest Service Best Management Practices (BMPs) for Ash Use and Disposal

While adult EAB can fly from tree to tree, their distance is limited. The long-range spread of EAB can be attributed to the transportation of their larvae and pupae in ash wood products, primarily firewood. For this reason, the MFS has developed a series of Best Management Practices (BMPs) for ash wood use and disposal. These BMPs apply to ash within regulated areas, which are shown in the map in Figure 14 below. It is not always possible to tell whether or not an ash tree is infested, so the key is always to assume a tree is infested. The BMPs include grinding, chipping, burning, or composting ash wood waste, only transporting ash wood products within five miles of where they were initially cut, seasoning ash wood where it is cut for at least 12 months before transportation, or transporting it during the winter months and using it before May. You can access the BMPs [here](#) to review them. It is also essential to adhere to the established wood quarantine zones (Fig. 14) to slow future spread. Bangor is currently a part of the active quarantine zone.

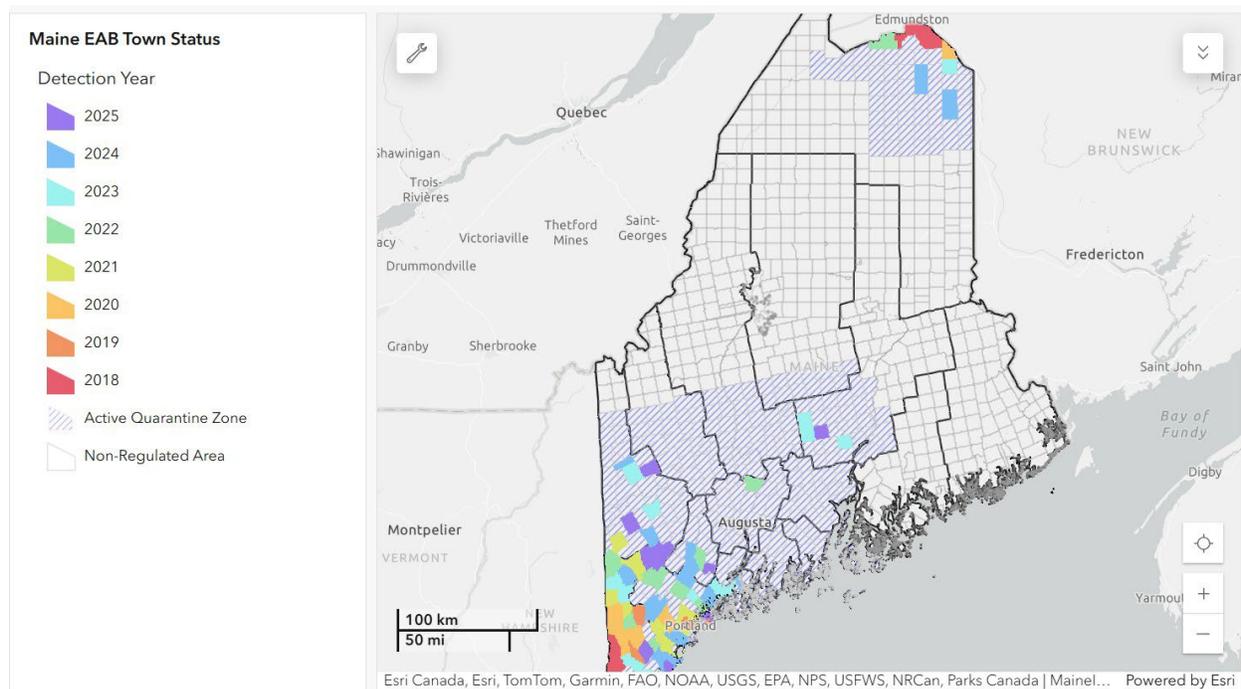


Figure 15. A screen capture of the MFS interactive EAB Dashboard shows the towns that have confirmed EAB infestations, the year they were detected, and the current quarantine zones. You can access the complete interactive EAB Dashboard [here](#)¹⁶.

¹⁶ https://www.maine.gov/dacf/mfs/forest_health/invasive_threats/eab/index.shtml

Recommendations for Ash Wood Disposal in Bangor

There are many strategies for managing the use and disposal of ash wood in Bangor's urban environment. Typically, trees under 18 inches can be chipped at the site of their removal by either contractors or members of the Forestry Division. This chipped material is then transported to the yard at the Public Works Department, where it is later run through an additional horizontal grinding on site to ensure uniform chip size and picked up by a contractor and taken for biomass. Trees larger than 18 inches are too large to be put through the chipper, so they are transported back to the yard by a contracted log truck. Independent timber producers have taken these large logs in the past. While these are the current methods for dealing with wood disposal, they may be unable to accommodate the volume of wood produced by the required removals of ash trees over the next several years.

Alternative solutions should be explored. Because of the cultural significance of ash for basket making in the Wabanaki culture, it is recommended that basketmakers and tribal members be given the right of first refusal for all ash trees that are required removals. This would allow these trees to be purposefully used. Preliminary discussions have been had with local Maine basket makers, who have expressed interest in this idea.

Trees that are not eligible for basket-making could be used to create a community firewood bank. Like a food bank, firewood banks provide free firewood to community members for home heating (Vivian and Leahy, 2015). Ash wood is particularly good for heating, so it would be appropriate for this use. Following the MFS BMPs would require that only ash trees in Bangor be accepted, and the logs to be seasoned for at least a year before their distribution. Volunteers could then split the logs and distribute the firewood to Bangor residents. This would be like the structure of the composting program the city already has in place. To learn more about the details of firewood banks and the process of creating one, you can review the [Community Guide to Starting & Running a Wood Bank](https://digitalcommons.library.umaine.edu/sfr_studentpub/1/)¹⁷.

¹⁷ https://digitalcommons.library.umaine.edu/sfr_studentpub/1/

Economic Analysis and Estimated Response Budget

To understand the financial impacts of Bangor's impending EAB infestation, the 2024 CUSTI, the selected treatment trees, and the required removal trees were used to estimate management costs and benefits of these management options to the City of Bangor. This is known as a Cost-Benefit Analysis (CBA). This CBA aims to determine the most cost-effective management strategy in dealing with the city's impending EAB infestation so that it can later be used to develop an EAB Response Budget.

This requires first identifying the costs and benefits associated with the infestation. The obvious associated costs are treating trees with chemical injections, removing trees, and replacing trees. Chemical injections preserve the benefits of the ecosystem services and the benefit of avoiding the cost of removal and replacement. Removing trees or allowing them to be killed by EAB results in the additional cost of losing their ecosystem services. The benefit of doing nothing (no treatment, no removals, no replacements) is the avoided cost of active management, but allowing dead trees to remain in the city incurs the cost of possible property damage and public safety risk, and an increased cost of later removal once the trees are more hazardous.

Therefore, we will assess the costs and benefits of active management (treating, removing, and replacing) and of maintaining ecosystem services. The risk of possible property damage and to public safety cannot be easily quantified and will not be included in this CBA. It is important to remember that the costs of removals and treatment depend on each tree's diameter at breast height (DBH). All cost and benefit values were generated per tree and then summed up to produce the values shared in the following sections. All these values were discounted by 5% over whatever time period was appropriate. This is because money spent today is worth more than money spent later, so this generates a more accurate estimate. These discounted total values are then used to make recommendations of the best course of action for the city.

The ash trees classified as “Selected Treatment Trees” are currently in good health and were selected to be chemically treated with emamectin benzoate to continue providing ecosystem services to the city. Those classified as “Required Removal Trees” are ash trees that are currently hazardous and will become even more so when they become infested by EAB and should be removed as soon as possible. The remaining healthy ash trees not presently assigned a plan for their future are classified as “Remaining Trees”.

Costs and Benefits of Selected Treatment Tree

Cost of Treating the Selected Treatment Trees

The 250 selected treatment trees will be treated with TreeAge R10, an emamectin benzoate insecticide. The recurrent costs for this treatment across the nine-year treatment period include the chemical itself and the hourly labor cost for the time it takes to inject each tree. The labor cost consists of the hourly pay of the licensed pesticide applicator and the hourly pay of the master pesticide applicator who must supervise. The City Forest Manager, Ben Arruda, provided the hourly pay rates, which are publicly shared information. The amount of chemical used per tree depends on the tree's DBH, and the injection rate is 3mL/inch DBH.

The one-time costs for this treatment include purchasing the Arborjet Quickjet Air-2 injection system, two rebuild kits for the injection system, 2,000 Arborplugs to be inserted into the injection sites on each tree, and two Arborplug setters to install them. Table 2 summarizes all the costs associated with tree treatments.

<i>TreeAGE-R10 (Repeated)</i>	<i>Cost</i>
Pint	\$ 420.00
1 mL (568mL/pint)	\$ 0.74
3mL	\$ 2.22
<i>Labor (Repeated)</i>	<i>Cost (\$/hour)</i>
Licensed Pesticide Applicator	\$ 28.90
Master Pesticide Applicator	\$ 36.99
<i>Additional Items (One-time)</i>	<i>Cost</i>
Arborplugs (2000)	\$ 830.71
Arborplug Setter (2)	\$ 43.31
Quickjet Air Rebuild Kit (2)	\$ 46.65
Quickjet Air-2	\$ 2,500.00

Table 2. A breakdown of the values used to calculate the per tree cost of treatment across both the nine-year treatment timeline, and ten-year duration of this response plan (Table 4 and Table 7). The cost of the TreeAGE-R10 is based on the price at which it was purchased in the Fall of 2024 and is subject to change year by year based on changing markets. The labor costs for the Licensed Pesticide Applicator and Master Pesticide Applicator are based on the current hourly rates for equivalent positions employed through Bangor Public Works. These are also subject to change year by year.

The method of calculating the per-tree treatment cost is as follows:

$$(rDBH*\$2.22) + (t_1*\$28.90) + (t_2*\$36.99) = \text{Cost per tree, per treatment}$$

Where:

$rDBH$ = the rounded-up diameter at breast height of each tree in inches

t_1 = Amount of time the Licensed Pesticide Applicator spends injecting each tree

t_2 = Amount of time the Master Pesticide Applicator spends supervising injections at each tree

For the first round of injections, the amount of time the Licensed Pesticide Applicator and the Master Pesticide Applicator spend at each tree was assumed to be 20 minutes, or 0.3 hours. This includes the time to drill the injection holes and place the Arborplugs, as well as the time to inject each tree. For the following injections across the nine-year treatment period, the time they spent at each tree was assumed to be 10 minutes, or 0.16 hours, because new holes would not need to be drilled because of the placement of the Arborplugs.

To determine the total cost for the selected treatment trees across the treatment period, per-tree costs of the initial installation and treatment, and the per-tree costs of the subsequent treatments were summed by treatment groups. These summed costs were then spread across the nine-year treatment timeline outlined in the Treatment Recommendations section (p. 24). The annual treatment costs were discounted by a standard 5%, resulting in a discounted total of \$26,864.44 over the nine-year period, equivalent to \$107 per tree treated. The yearly discounted totals of treatment are summarized in Table 4.

Cost of Removing and Replacing the Selected Treatment Trees

The cost of removing and replacing each tree was also estimated to determine if treatment is the most financially viable course of action for the 250 selected treatment trees. It was assumed that the Forestry Division would remove these trees, or “in-house,” as they were chosen as treatment trees because they have no intrusions that would require them to be removed by a contractor.

The estimated costs per tree for in-house removals are shown in Table 3. The amount of time to remove each tree was estimated based on the time it currently takes a two-person crew to remove a tree of that size. The equipment costs are the hourly cost of using a chipper and a bucket truck, which are \$21/hour and \$22/hour, respectively, and the number of hours they would be used for each sized tree, which was estimated to be about a third of the total time of removal (i.e. a small tree is removed in six hours, but the chipper and bucket truck are only used for two of those hours). The labor costs are estimated based on the hourly rate of a single Heavy Equipment Operator (\$51.97/hour) currently listed for the City of Bangor. These values would increase if more crew members were needed, but the more crew members there are, the less time it would take to remove each tree, so it would even out. The cost of a log truck is only included in the total cost if the tree is greater than 18 inches DBH, as a log truck contractor needs to be hired to move the logs to the Public Works yard. This cost is \$150/hour, and it was estimated that it would take 1.5 hours to transport each tree, totaling \$225 per tree.

The total cost, discounted at 5% over three years (one treatment group removed per year), would be \$158,415, or \$634 per tree. To determine the cost of replacing each treatment tree with a tree of similar growth form, the average cost of a comparable tree was estimated based on price lists provided by several local nurseries. The average tree cost was \$423. The total discounted cost at 5% across three years to replace all the selected treatment trees is \$96,076, or \$385 per tree. So, the total discounted cost of removing and replacing the 250 treatment trees is \$254,492,

or \$1,018 per tree that is removed and replaced. All of this is summarized in Table 4, including yearly costs.

Table 3. *Estimated removal costs per tree for in-house removals, including the time it would take to remove each size class of tree, the equipment and labor costs for that amount of time, and the cost of a contracted log truck if the tree is over 18 inches DBH. How these costs were estimated is summarized on p. 43.*

Tree Size Class	Time to Remove (hours)	Equipment Costs	Labor Costs (by removal time)	Log Truck Cost (if >18in DBH)	Total
<i>Small (1-9 inches DBH)</i>	6	\$ 86.00	\$ 311.82	\$ -	\$ 397.82
<i>Medium (10-18 inches DBH)</i>	9	\$ 129.00	\$ 467.73	\$ -	\$ 596.73
<i>Large (19-29 inches DBH)</i>	18	\$ 258.00	\$ 935.46	\$ 225.00	\$ 1,418.46
<i>Extra Large (30+ inches DBH)</i>	24	\$ 344.00	\$ 1,247.28	\$ 225.00	\$ 1,816.28

Benefits of the Selected Treatment Trees

The benefit of chemically treating the Selected Treatment Trees includes the trees' yearly ecosystem services, such as reducing energy costs or increasing urban aesthetics, as shown in Figure 11. Benefits can also be interpreted as avoided costs. For example, by treating these trees, the higher cost of removing and replacing them is avoided, which is also a benefit of treatment.

The annual benefit value per tree for public trees provided by Kovacs et al. (2010) was adjusted for inflation using the [Federal Reserve Inflation Calculator](https://www.federalreserve.gov/econres/notes/2010/01/20100101.html)¹⁸. This value was then used to calculate the total value of the benefits the 250 treatment trees provide. The total benefit of these trees, discounted by 5% across the nine-year treatment period, is \$461,406, or \$1,845 per tree. By treating, you also avoid the \$254,492 total cost of removing and replacing the trees. The yearly discounted benefit the 250 treatment trees provide is shown in Table 4.

¹⁸ <https://www.minneapolisfed.org/about-us/monetary-policy/inflation-calculator>

Table 4. Summary of the yearly benefits and costs of the 250 selected treatment trees broken out into their treatment groups (1, 2, or 3). See the recommended treatment timeline on p. 24 for an explanation of the treatment groups. These values are discounted across the nine-year treatment timeline at 5%. The total discounted values were then divided by the total number of treatment trees (250) to generate the per-tree benefit or cost over the nine-year treatment period. Costs of removal and replacement only occupy the first three years because the assumption is that one treatment group will be removed per year.

Removal or Treatment Year	Discounted Benefit (Kovacs et al., 2010)	Discounted Cost of Treatment	Discounted Cost of Removing (assuming all in-house)	Discounted Cost of Replacement
<i>Year 1 (Treatment Group 1)</i>	\$ 60,717.26	\$ 4,118.50	\$ 55,070.63	\$ 34,245.29
<i>Year 2 (TG 2)</i>	\$ 59,316.24	\$ 3,868.23	\$ 54,574.79	\$ 32,230.86
<i>Year 3 (TG 3)</i>	\$ 56,746.67	\$ 3,598.31	\$ 48,770.44	\$ 29,599.77
<i>Year 4 (TG 1)</i>	\$ 52,449.85	\$ 2,912.64	-	-
<i>Year 5 (TG 2)</i>	\$ 51,239.60	\$ 2,734.39	-	-
<i>Year 6 (TG 3)</i>	\$ 49,019.90	\$ 2,550.79	-	-
<i>Year 7 (TG 1)</i>	\$ 45,308.15	\$ 2,516.05	-	-
<i>Year 8 (TG 2)</i>	\$ 44,262.70	\$ 2,362.07	-	-
<i>Year 9 (TG 3)</i>	\$ 42,345.24	\$ 2,203.47	-	-
<i>Discounted Total</i>	\$ 461,405.61	\$ 26,864.44	\$ 158,415.86	\$ 96,075.91
<i>Discounted per Tree</i>	\$ 1,845.62	\$ 107.46	\$ 633.66	\$ 384.30

Required Removal Tree Costs

Trees classified as “required removal trees” cannot be treated because they are in poor health and have defects or intrusions that make them dangerous to keep. For this reason, only the removal costs were calculated for these trees. During the inspection process, it was noted whether a tree had to be removed by a contractor because of its proximity to uninsulated top wires or buildings. This allowed us to calculate removal costs based on who will remove them—contractors or in-house.

Table 3 shows the in-house removal costs per tree, and Table 5 shows the contractor removal costs per tree. For contractor removal cost estimates, a tree less than 20 inches DBH was considered to be “small” and would take an estimated four hours for the contractor to remove, and a tree greater than 20 inches DBH was considered “large” and would take an estimated eight hours to remove. The hourly cost for a contracted arborist crew is \$195/hour. These time and labor cost estimates are based on previous invoices for contracted removals received by the Forestry Division. They are subject to change based on changes in the contractor or their pricing.

Depending on the location of each tree, a flagging crew may be required for the contractor to remove the tree safely. For example, a tree in the middle of a park or at a school would not need a flagging crew, but a tree within a road's right-of-way would. Fortunately, during the 2024 CUSTI, the locations of each tree were determined, and the nearest address was recorded. For park trees, trees on school property, or trees in cemeteries, the nearest address was the name of the park, school, or cemetery. The closest street address was recorded for trees along roads or in the rights-of-way. Because of this, we can determine whether a tree would require a flagging crew and apply this additional cost. A flagging crew was estimated to cost \$35/hour.

Contracted arborists do not necessarily take responsibility for wood disposal post-removal, so a log truck may need to be used for trees over 18 inches DBH removed by contractors. These different variables create distinct cost groups for contractor-removed trees: those over 18 inches DBH along roads or within rights-of-way that require both a flagging crew and a log truck, those over 18 inches DBH but that do not require a flagging crew, those below 18 inches DBH but along roads or within rights-of-way that require a flagging crew, and those that are below 18 inches DBH but do not require a flagging crew. This is reflected in Table 5, and these cost groups were assigned to each required removal tree to generate the values shown in Table 6.

Table 5. Estimated costs of contractor removals per tree as determined by size class. All costs are calculated from previous invoices from contracted arborists to the City of Bangor and were applied to each tree on the required removals list as the appropriate cost group, shown here and explained on p. 46.

Tree Size Class	Time to Remove (hours)	Labor Costs	Flagger Cost	Log Truck Cost (if >18in)	Total for Flagger and Log Truck	Total for Log Truck Only	Total for Flagger Only	Total for Labor Only
<i>Small (>20in)</i>	4	\$ 780.00	\$ 140.00	\$ 225.00	\$ 1,145.00	\$ 1,005.00	\$ 920.00	\$ 780.00
<i>Large (<20in)</i>	8	\$1,560.00	\$ 280.00	\$ 225.00	\$ 2,065.00	\$ 1,785.00	\$ 1,840.00	\$ 1,560.00

Under the assumption that one required removal group will be removed each year (see p. 29 for a reminder about the required removal groups), making the total time for removal four years, the 5% discounted total cost for the 124 trees that will need to be removed by contractors is \$151,460, and the total discounted removal cost for the 312 trees that can be removed in-house is \$178,562. The discounted total cost for both groups over four years is \$330,022. The total discounted cost of replacing these trees over four years will be \$164,743. So, the total discounted cost of removing and replacing these trees over four years is \$494,765. This is summarized in Table 6.

Table 6. Summary of the discounted yearly costs of removal and replacement of the required removal trees by removal group, with the assumption that one group will be removed per year. Includes the method of removal and the number of trees to be removed by each method. The cost of replacement is for all the trees in each group. The values are discounted over a four-year removal period at 5%. Values were calculated using Tables 3 and 5.

Removal Year	Method of Removal	Number of Trees to be Removed	Discounted Cost of Removal	Discounted Cost of Replacement
<i>Yr 1 (Removal Group 1)</i>	Contractor	73	\$ 108,185.71	-
	In-house	73	\$ 62,955.67	\$ 58,821.31
<i>Yr 2 (RG 2)</i>	Contractor	28	\$ 25,927.44	-
	In-house	91	\$ 48,807.31	\$ 45,660.38
<i>Yr 3 (RG 3)</i>	Contractor	11	\$ 8,379.22	-
	In-house	32	\$ 16,517.83	\$ 15,713.46
<i>Yr 4 (RG 4)</i>	Contractor	12	\$ 8,967.46	-
	In-house	116	\$ 50,281.56	\$ 44,547.56
<i>Discounted Totals</i>	-	436	\$ 330,022.20	\$ 164,742.71

Remaining Tree Costs and Benefits

How the remaining ash trees will be handled is yet to be determined. For this reason, the total cost of treatment over 10 years for all the remaining trees and the total cost of removing and replacing them over 10 years were calculated. This will allow us to determine the most cost-effective management method for the remaining trees.

The total cost of treatment was calculated using the same methods as the treatment trees, using the values in Table 2. However, they weren't divided into strategic treatment groups like the treatment trees. The total cost of treatment for all the remaining trees was divided by 10, so they could be discounted over 10 years, assuming that an even number of trees would be treated each year. The annual costs were discounted by 5% over 10 years and summed to get the total discounted cost of treating the remaining trees, which is \$36,058.

Because we do not know the number of remaining trees that will need to be removed by a contractor and which can be removed in-house, the cost of removing them all through each method was calculated. The costs in Table 3 and Table 5 were used. The total costs for each of these were then divided by 10, and this value was discounted by 5% over 10 years and summed to get the total discounted cost of removing all the remaining trees. The total discounted cost of removing them all using a contractor is \$882,347, and the total discounted cost of removing them all in-house is \$582,100. The discounted cost of replacing all these trees was also calculated using the average tree cost of \$423. The total cost of replacing each of these trees was divided by 10 and discounted by 5% over 10 years, and summed to get the total discounted cost, which is \$381,530.

The third possible course of action for these remaining trees is to do nothing. This would require no outright spending, but because of the high mortality rate of EAB, the ecosystem services they currently provide would be forfeited. These trees' total discounted lost benefit if they are not treated and left standing or removed is \$7,036,959. This, combined with the lower price of treating these trees over removing them, provides a convincing argument to treat these remaining trees rather than removing them or doing nothing. All the yearly discounted values calculated for this section and their totals are summarized in Table 7.

Table 7. Summary of the yearly discounted costs and benefits of the remaining trees in the city, or those not being treated or removed. This includes the possible cost of removal of these trees, either by contractors or in-house, the cost of replacement, and the possible cost of treatment. All are discounted over 10 years at 5%. The discounted totals and per-tree costs and benefits are shown at the bottom.

Removal or Treatment Year	Method of Removal	Cost of Removal	Cost of Replacement	Annual Benefits (Kovacs et al., 2010)	Cost of Treatment
<i>Yr 1</i>	Contractor	\$ 108,826.67	-	-	-
	In-house	\$ 71,794.91	\$ 47,057.05	\$ 867,922.29	\$ 4,447.36
<i>Yr 2</i>	Contractor	\$ 103,644.44	-	-	-
	In-house	\$ 68,376.11	\$ 44,816.24	\$ 826,592.65	\$ 4,235.58
<i>Yr 3</i>	Contractor	\$ 98,708.99	-	-	-
	In-house	\$ 65,120.10	\$ 42,682.13	\$ 787,231.10	\$ 4,033.89
<i>Yr 4</i>	Contractor	\$ 94,008.57	-	-	-
	In-house	\$ 62,019.14	\$ 40,649.65	\$ 749,743.90	\$ 3,841.80
<i>Yr 5</i>	Contractor	\$ 89,531.97	-	-	-
	In-house	\$ 59,065.85	\$ 38,713.95	\$ 714,041.81	\$ 3,658.85
<i>Yr 6</i>	Contractor	\$ 85,268.54	-	-	-
	In-house	\$ 56,253.19	\$ 36,870.43	\$ 680,039.82	\$ 3,484.62
<i>Yr 7</i>	Contractor	\$ 81,208.13	-	-	-
	In-house	\$ 53,574.47	\$ 35,114.70	\$ 647,656.97	\$ 3,318.69
<i>Yr 8</i>	Contractor	\$ 77,341.08	-	-	-
	In-house	\$ 51,023.30	\$ 33,442.57	\$ 616,816.16	\$ 3,160.66
<i>Yr 9</i>	Contractor	\$ 73,658.17	-	-	-
	In-house	\$ 48,593.62	\$ 31,850.06	\$ 587,443.97	\$ 3,010.15
<i>Yr 10</i>	Contractor	\$ 70,150.64	-	-	-
	In-house	\$ 46,279.64	\$ 30,333.39	\$ 559,470.44	\$ 2,866.81
Discounted Totals for 10 Years					
	Contractor	\$ 882,347.21	-	-	-
	In-house	\$ 582,100.34	\$ 381,530.18	\$7,036,959.12	\$ 36,058.40
Discounted per Tree Totals					
	Contractor	\$ 755.43	-	-	-
	In-house	\$ 498.37	\$ 326.65	\$ 6,024.79	\$ 30.87

Summary of Economic Analysis

Table 8. Summary of the discounted total costs and benefits for each tree group. Includes the number of trees that make up each group. (*This is the removal cost for the Remaining Trees group if contractors remove them. **This is the removal cost for the Remaining Trees group if they are removed in-house.)

<i>Tree Treatment Group</i>	<i>Number of Trees</i>	<i>Total Discounted Benefit (Kovacs et al., 2010)</i>	<i>Total Discounted Treatment Cost</i>	<i>Total Discounted Removal Cost</i>	<i>Total Discounted Replacement Cost</i>
<i>Selected Treatment Trees</i>	250	\$ 461,405.61	\$ 26,864.44	\$ 158,415.86	\$ 96,075.91
<i>Required Removal Trees</i>	436	-	-	\$ 330,022.20 \$ 882,347.21*	\$ 164,742.71
<i>Remaining Trees</i>	1,168	\$ 7,036,959.12	\$ 36,058.40	\$ 582,100.34**	\$ 381,530.18

Table 8 summarizes the discounted totals for the CBA performed for the City of Bangor's EAB response plan. It shows all the ash trees, broken out into their treatment groups as either Selected Treatment Trees, Required Removal Trees, or Remaining Trees.

There are currently 250 Selected Treatment Trees chosen because of their good conditions and lack of interference with utilities, roads, or buildings. The total discounted benefit they will provide the city over the nine-year treatment period is \$461,406. If they are injected with TreeAGE-R10 before they are too damaged by EAB, this benefit will be preserved, and it can be assumed that they will continue to provide annual benefits until they reach the end of their natural life cycle, typically 100 to 120 years. The total discounted cost of treating these trees over the nine-year treatment cycle is \$26,864. Treating these trees would also avoid the costs incurred if they become hazardous due to EAB infestation. If these trees were to be removed instead, the benefits they provide would be forfeited, and their discounted removal costs (assuming they are all performed in-house) would be \$158,416, over three years. If they were replaced in the same years they were removed, their total discounted replacement costs would be \$96,076. The cost-benefit ratio (BCR) for chemically treating these trees to preserve their benefits over nine years is 17, which means it is financially viable to do so. The BCR of removing these trees would be zero, because all their benefits would be lost, and we cannot accurately estimate the avoided costs of public safety risk if they are removed.

Four hundred and thirty-six ash trees across the city were identified as Required Removal Trees, ahead of the EAB infestation of Bangor. For various reasons, these trees are already hazardous without being infested and can be expected to become even more so once the insect arrives. Because of this, their benefits were not calculated, nor was the cost of treating them or a BCR. The only option for these trees is to be removed and replaced. The total discounted cost of the combined removals performed by contractors and in-house is \$330,022 over the four-year removal period. Under the assumption that these trees will be replaced within the same year they're removed, the total discounted cost of replacing them over four years is \$164,743. This

means there is a total discounted cost of \$494,765, but the costs if these trees become even more hazardous will be avoided because they will be removed.

This leaves 1,168 publicly owned ash trees in the city that have not been assigned a management strategy. While there would be no upfront cost of doing nothing for these trees, over a thousand trees can potentially become highly hazardous should they be infested. Many of these trees are in good health now, but have intrusions over roads, utilities, or buildings. Once the insect arrives, damage to property or risk to public safety from the brittle, falling limbs of these trees would likely have significant costs for the city. Alternatively, if these trees were removed to mitigate those issues, the total discounted cost of removing them via a contractor is \$882,347 over ten years; if they are all removed in-house, it will be \$582,100. This approximately \$300,000 cost difference for removals provides a reasonable cause to prioritize the development of a robust Forestry Division with capable arborists. However, should all these trees be removed, the city would forfeit greater than \$7 million over ten years in the benefits they provide. The city could treat some or all these trees to maintain this benefit, costing \$36,058 over the same ten-year period, while still avoiding the costs associated with them becoming hazardous. The BCR of chemically treating these trees to preserve their benefits over ten years is 194, which means treating them is highly financially viable. The BCR of removing these trees is zero because all of the benefits they provide would be lost, and we cannot accurately estimate the avoided costs to public safety.

From an economic perspective, the path forward seems obvious. Increasing the number of ash trees treated across the city would be most cost-effective and retain the highest value of ecosystem services these trees currently provide. This may require increased staffing of the Forestry Division for at least the initial nine-year treatment cycle to keep up with the yearly treatment rotations and monitor treatment effectiveness and tree health. The total discounted cost of treating all these remaining trees, treating the already selected treatment trees, and removing and replacing the required removal trees would be \$557,688 over the estimated ten-year infestation period. This final value may be subject to change depending on the timing of each of these response activities. This action will allow the city to retain \$7,498,365 worth of ecosystem services over the same ten-year period.

Public Outreach and Education

One of the best ways to ensure the public's cooperation with this proposed response plan is to prioritize public outreach and education. This includes engaging with the public in public forums and listening sessions, sharing plans transparently with media outlets, and interacting with the public daily. Many of these efforts are already underway. During the completion of the 2024 CUSTI, the interns interacted with members of the public. They took these opportunities to share the city's concerns about EAB and why the completion of an inventory was so pressing.

Interactions with members of the Wabanaki tribal communities and the Ash Protection Collaboration Across Wabanakik (APCAW) have also been conducted to determine the best way to involve them in this process. APCA member Ella McDonald has already collected black ash seeds from the Bangor City Forest for research into ash genetics. Initial conversations have been had with local basket makers to determine their interest in and thoughts on this response plan. In the future, the city hopes to collaborate with Wabanaki youth organizations as well.

Members of the Forestry Division have also engaged with public news outlets like the Bangor Daily News and NewsCenter Maine to spread awareness about the threat EAB poses to Bangor's trees. This is an excellent way to inform the public of the actions the city is taking to mitigate the issue, and it should continue. Other methods of public outreach are social media posts, tabling at local events, and continuing to add EAB content to the city's webpages.

The Forestry Division also works with the Bangor High School science department, and their students have previously created Public Works-based science projects for the Maine State Science Fair. The city intends to maintain this relationship and has several students working on EAB-related projects. Educating high school-aged students about EAB prompts interest and passion in the next generation of potential researchers and problem solvers.

Postponed Work

The Forestry Division will continue prioritizing any tree of any species that becomes highly hazardous due to weather or other circumstances. The next priority level will be ash trees in Removal Group 1 of the required removal trees list. The purpose of this list, which was created in the summer of 2024, is to serve as guidelines for which trees will need to be removed. While the removal flow chart shown in Figure 10 helped standardize decision making across the interns doing inspections, trees are unpredictable, and their conditions can change quickly. For this reason, the ash removals list is somewhat fluid and subject to change, though every ash tree on it will need to be removed at some point within the next four to five years.

Because of the urgent nature of EAB in Bangor, some forestry work may need to be postponed. The city forest manager will create a system for this backlog so that all tree-related work orders can be addressed efficiently and based on their level of importance. In the future, it may be necessary to increase the staffing levels of the Forestry Division to accomplish this goal.

Other Departments

It is requested that other municipal departments in Bangor cooperate and collaborate with the Department of Public Works and the Forestry Division to best respond to an EAB infestation.

Summary of Recommendations

The official recommendations of this EAB Response Plan for the City of Bangor are as follows:

- I. Begin initial chemical treatment of the already selected 250 treatment trees in the Spring of 2025, following the treatment timeline provided on p. 24 of this plan. These trees will be injected at 3mL/inch DBH of Arborjet's TreeAGE-R10 by a licensed pesticide applicator and supervised by a master pesticide applicator. These trees should be monitored year to year to assess the effectiveness of treatment, and adjustments can be made accordingly. At the end of the nine-year treatment cycle, evaluate the status of the EAB infestation in Bangor and determine whether another treatment cycle should be completed. Continue status evaluations and reassessments until the killing front of EAB has been determined to have passed out of Penobscot County.
- II. Remove the 436 required trees as soon as possible to prevent public safety risks and property damage. This will require significant coordination between the Forestry Division and contracted arborists. The Forestry Division may also need to increase its staffing to accomplish all in-house removals efficiently.
- III. Monitoring and assessment of the remaining ash trees should be performed over the next one to two years to A) determine when EAB arrives in Bangor and B) determine which may be eligible to be added to the treatment tree list. Treating additional trees will reduce the overall cost of removals and replacement throughout this infestation and maximize the benefits these trees provide through their ecosystem services.
- IV. Select an additional 500-750 trees that are eligible for chemical treatment within the next one to two years to add into the existing treatment timeline.
- V. Replant lost ash trees with trees that will improve overall diversity and resilience of Bangor's urban canopy. Also, work to increase the size of Bangor's urban canopy to maximize the benefits trees provide to urban communities, paying particular attention to ensure that it is equitably distributed.
- VI. Encourage Bangor citizens to follow state-regulated wood quarantines and explore options for ash wood use and disposal, prioritizing community engagement with Bangor citizens and Wabanaki groups.
- VII. Continue developing a robust public outreach and education program regarding EAB to keep the public well-informed of the response actions utilized throughout the infestation and continue providing education on EAB and the importance of a healthy urban canopy.

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Amendments

July 1st, 2025—**Updates:** The following are updates after the completion of emamectin benzoate injections of the first group of Selected Treatment Trees on June 18th, 2025.

- Eighty-five of the 250 Selected Treatment Trees were injected by a contracted Master Pesticide Applicator (Ron Lemin) and an in-house Licensed Pesticide Applicator (Benjamin Arruda).
- These trees are located on the western side of the Kenduskeag Stream nearest the Hermon border, and were marked at the base of their trunk with either orange or blue tree paint for ease of location. This paint should be refreshed the next time these trees are scheduled to be treated in 2028.
- A health recheck of each of these trees have been completed to ensure that there were no immediate negative repercussions of the chemical injections. It is recommended that these rechecks continue each year of both the newly injected trees and the already injected trees.

July 1st, 2025—**Correction:** After a discussion with Ron Lemin, a contracted Master Pesticide Applicator, it was made clear that Arborplugs for emamectin benzoate injections are not reusable because the trees' callous tissue will grow over them. This means that new Arborplugs will need to be installed for each round of treatment. When calculating the costs of treatment in this plan, it was assumed that these plugs could be reused, which meant that the cost of new plugs each treatment round were not included, and the time of injection for subsequent injections was reduced. While this does change cost estimates, the price of Arborplugs is minor, as is the difference in the amount of time to inject each tree. For this reason, this is not anticipated to drastically change the cost of treatment for either the Selected Treatment Trees or for the Remaining Trees, so the recommendations based on the original BCA still stand.

July 14th, 2025—**Update:** With the changes made in this edition, the city Tree Board has recommended that this response plan be put forward to the Finance Committee for approval and adoption.

July 24th, 2025—**Update:** This plan has been officially approved and adopted as the governing document for the City's response to future Emerald Ash Borer infestations by the City Council.