EAB RESPONSE:
An Ash Resource Inventory Field Manual

Wabanaki Tribes

July 2019

Inventory Spread Sheet CD

Contents:

- **Stage 2 Spreadsheet Template**
- **Stage 3 Spreadsheet Template**
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An Ash Resource Inventory Field Manual

State of Maine Indian Reservations

Passamaquoddy

Micmac

Maliseet

Penobscot

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Note from Author: Due to the rapid turnover in knowledge surrounding our ash resource and its management, I recommend this manual be updated and amended every 6 months. This manual is a useful tool in generating background on management options as well as generating useful data for the implementation of those management options. However, it is not any specific management recommendation; a licensed professional should be consulted in developing any such recommendation.

Acknowledgements

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Tom Newell, Basket Harvester and PFD Forester

Chapter 1: The Purpose and Importance of an Ash Resource Inventory

For many land managers and foresters, the goal to manage sustainably is often overarching many other goals and objectives. Sustainable management requires sources of information to make decisions based off. This information pertains directly to the resource they intend on managing. For foresters this data tends to come from forest inventories. Certain scenarios require a change in which forest inventory data is collected. For example, because ash in New England is typically a smaller component of the forest (less than 4-5% of all forestland in the state (FIA, 2018)), inventory techniques that undergo post stratification have been found to be successful in identifying rare species and are essential in being effective in your inventory approach of your ash resource. This manual can serve as the change and guide forest managers toward attaining the necessary data for formulating a management regime for their ash resource. The urgency to attain this data is apparent now, more than ever, and is explained throughout this chapter.

Emerald Ash Borer History

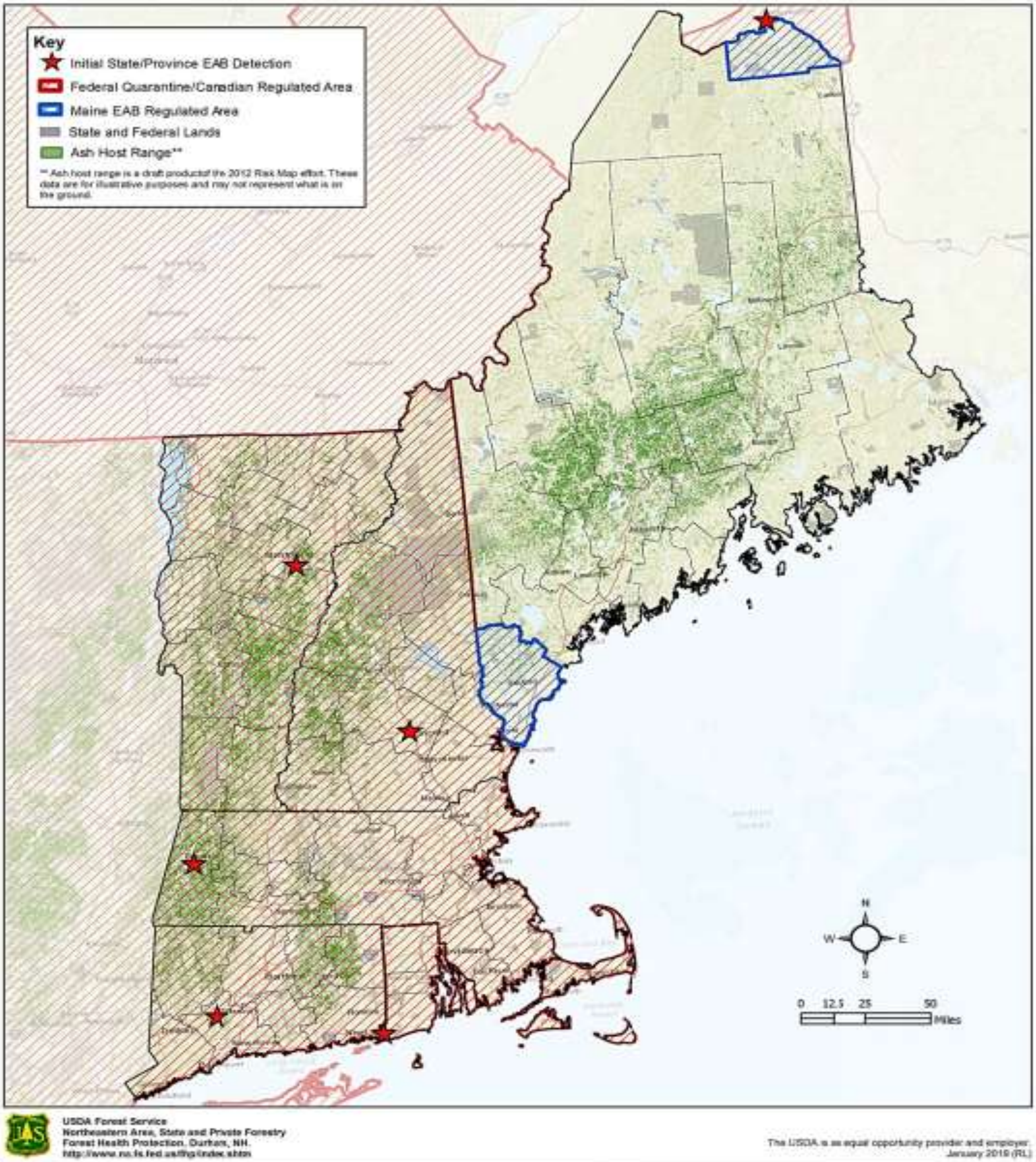
In order to set the context for this inventory manual understanding the pressing issue of Emerald Ash Borer (EAB; *Agrillus planipennis*) is a key first step. Currently our ash resource in North America is either under attack or pending a potential attack by EAB, an invasive forest pest from Asia. EAB came to North America in 2002, presumably on packing materials such as wooden crates and pallets. It has devastated ash stands in the central lakes region of the country leading to, in some cases, one hundred percent mortality. Management of the pest is controversial, and the most effective techniques are expensive and difficult or impossible for commercial operations to effectively implement. Continued research on prevention, mitigation, and restoration of North America's ash stands is a priority (D'Amato et al, 2018; USDA APHIS, 2018; Haack et al, 2015).

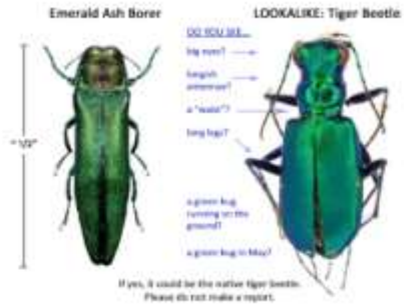
In the summer of 2002, EAB was first detected in central Michigan, and later in the same summer it was detected in Ontario, Canada. The infestation was assessed by the state of Michigan and they determined that the pest had been there since the 1990's based on the size of the infested area. By July and September of 2002, Michigan and Ontario had enacted quarantines on the affected areas. The United States Department of Agriculture responded to the discovery of EAB by enacting a federal quarantine on the affected counties of Michigan in October of 2003 (USDA APHIS, 2003) since the establishment of the federal quarantine it has expanded continually. It now includes 22 states in their entirety and specific counties of 12 states. (USDA APHIS, 2018). The last quarantine notice issued by USDA APHIS was on July 26, 2018 when Wisconsin was put under quarantine in its entirety.

It is important to note that the federal quarantine works domestically only, restricting the movement of particular restricted items of the *Fraxinus* family. Fortunately, Canada is also actively mitigating and limiting the impacts and spread of EAB so import of ash to the U.S. from within Canada's federally set quarantine areas is not a huge concern currently. In September of 2018, the Maine Forest Service issued an emergency order that restricted the movement of certain ash (*Fraxinus spp*.) products and or untreated firewood from towns that have had any EAB detection (MFS, 2018). This emergency order was put in place because the state of Maine was not listed in the federal quarantine area at the time of the detections. Shortly after the issuing of these emergency orders, USDA APHIS proposed the removal of the emerald ash borer domestic quarantine regulations. This was posted online for comment in Fall of 2018 and was open for comments until November 19th, 2018 (USDA APHIS, 2018). A quarantine is now in place for select counties in the state of Maine. York county in its entirety and a portion of Aroostook county are now under quarantine with restrictions on all ash products and hardwood firewood, these restrictions align with the standards set forth by USDA APHIS for the federal EAB quarantine. These quarantine areas are seen below in figure 1.1.

Figure 1.1

Maine's Current EAB Quarantine



Adult • small (1/2 inch) • metallic green • narrow, bullet-shaped • seen June-August • flying near canopies of ash trees • rarely on the ground	  (photo credits, left to right: Howard Russell, Michigan State University, PA Department of Conservation and Natural Resources (adapted))
Larva • is between 1/2 inch and 1 1/2 inches • creamy white • narrow with bell-shaped segments • may be seen year-round • in cambium layer of ash trees	  (photo credits, left to right: PA Department of Conservation and Natural Resources, David Cappaert, Bugwood.org)

(Data Source: MFS, 2018)

Emerald Ash Borer Biology and Host Species

Upon the arrival of EAB in North America research has been done to uncover the biology of the beetle. The finding show *A. planipennis* can complete a generation in just 1-2 years. The USDA Forest Service has found that eggs are laid in mid-June to late-August on the cracks and crevices of the ash trees. Two weeks after being laid eggs hatch and young larval beetles emerge. It is the larvae that do the majority of the damage to ash trees. They burrow into the cambium layer and feed on the nutrient transporting portion of the tree, the phloem. The intense feeding develops s-shaped serpentine feeding galleries that over time can girdle (preventing the transport of nutrients) and kill the ash tree. When larvae have been given enough time to grow and develop they fold up into pupation cells. Some less developed larvae simply overwinter in the feeding galleries and resume feeding when sap begin to flow in the ash tree the next growing season. Larvae in the pupation cells obviously pupate. This occurs in April-May of the next year and transform into adult beetles (USFS, 2018).

It is now that the adult beetles bore their way out of the ash tree causing the characteristic “D” shaped exit holes. Emerged adults are small in size being less than 0.5 inches in length (Kanoti, 2019). As adults, the feeding within the tree does not occur. Instead, some defoliation of the leaves can occur. But, as adults their primary focus remains with reproducing and laying eggs on the bark of ash trees to restart the life cycle (Wang, 2007; USFS, 2016). During this process the ash tree can show signs and symptoms forest managers can take notice of and potentially catch the infestations earlier rather than later and manage accordingly.

Let’s start with the signs. Signs refer to clues and indicators that point to EAB and EAB only, as they are a direct result of the pest’s activity (Livingston). For EAB, that refers to the characteristic “D” shaped exit holes, s-shaped serpentine feeding galleries, actual (positively identified) individual insects, and any egg mass that have been identified as EAB egg masses (USFS, 2016).

Figure 1.2

Art Wagner, USDA – APHIS, Bugwood.org

Woodpecker damage on white ash tree (*Fraxinus Americana*) causing blonding.

Steven Katovich, USDA Forest Service, Bugwood.org

Die-back being observed on canopy dwelling white ash trees (*Fraxinus Americana*).

Debbie Miller, USDA Forest Service, Bugwood.org

Characteristic "D" shaped exit hole with emerging adult EAB.

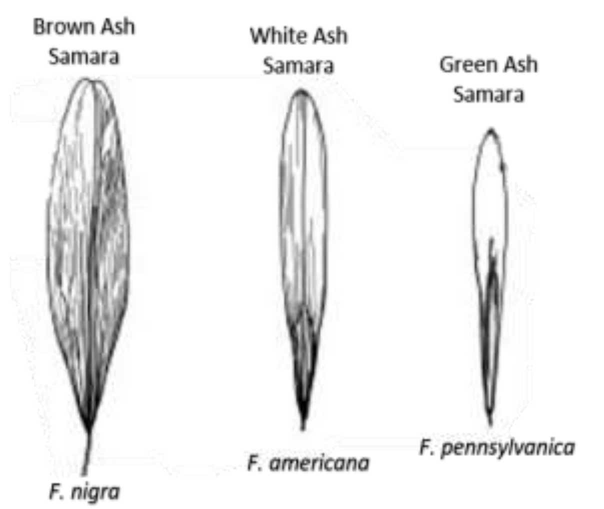
Then it comes to symptoms that might be attributed to EAB or an alternative cause. We are referring to the biological responses of the tree and its environment to the EAB attack. The important thing to consider here is that these symptoms do not absolutely point to an EAB infestation. They're still important to note and be on the lookout for in terms of forest health and monitoring for EAB. The symptoms include canopy die-back and "flagging" (premature yellowing of the leaves) due to the added stress of defoliation from EAB adults and the lack of nutrient transport due to EAB larval feeding. Excessive sprouting at the stump of the ash tree is another symptom. This is the biological response of the ash tree when stressors lead to a decline in the health or vigor of the tree. Unfortunately, these sprouts rarely survive to a seed bearing size before EAB has infested it (Petrice and Haack, 2011; Herms and Mccullough, 2014)). In addition to that detriment the ash seeds do not bank in the soil very long either (Benedict, 2003). So, it is unlikely that EAB will have left the area before what little ash seed source is available begins to sprout. Lastly, the most effective observation for the indication of EAB presence is the observation of what is known as blonding of the main stem. This occurs due to wood pecker activity which increases drastically when EAB is present. Blonding tends to occur higher up the tree and slowly work its way down as the infestation progresses. Blonding is characterized by a lighter reddish coloration on the bark from this increased wood pecker activity. But, when the tree is in serious decline this wood pecker activity progresses to the point of exposing the inner cambium of the ash tree. The earliest detection of EAB is often done through observation of woodpecker activity. (Liu, 2007; USFS, 2016). The spread of EAB is observed to be around 2-5 miles per year. But, studies show that the transport of firewood greatly increases the rate of spread (Kanoti; Daigle). On a positive note studies have begun to show genetic tolerance or resistance to the EAB infestation in some (1%) heritable genes of some white ash individuals. This genetic resistance is a future direction for research (Kanoti).

Background information on Ash species (*Fraxinus spp.*)

When managing a natural resource knowing the function and biology of that resource in its natural setting is essential to achieving sound management and silviculture. There are three ash (*Fraxinus*) species found in Maine. The White Ash (*Fraxinus Americana*), green ash (*Fraxinus pennsylvanica*), and black ash (*Fraxinus nigra*). White ash is the primary upland ash in the state where as black and green ash are the lowland ash species, occurring on flood plains, outwash plains, and shallow depressional wetlands across the state (WDNR, 2018).

The distribution of these ash species in the state of Maine varies species to species but overall ash tends to be most prevalent along a broad band across the state from the southernmost tip to the eastern half of the state as depicted above in figure 1.1 as "Ash Host Range" (in green) which uses the average measured basal area of all ash species to map the range for ash species in the state. This distribution is presumably driven by soil characteristics and climatic variables. But, white ash in particular is a fairly versatile species as it can thrive in a variety of settings restricted mostly by soil nutrient levels. White ash was commonly used, second only to green ash, as a replacement species for many of the ornamental elms that fell victim to Dutch elm disease for that reason (USDA, 2017).

Figure 1.3



Depicted above are the samaras of the three native ash species present in Maine. When collecting seed and identify your ash resource this figure can be a useful visual guide for distinguishing the three species from one another. Ash trees are either male, female, or polygamous so the presence of seed can rule out the possibility of a male individual.

(Data Source: Benedict, 2003; Line drawing by Amy Rediker)

When it comes to proper identification of these trees I find that the Forest trees of Maine book, put out by the Maine Forest Service, does a great job of singling out the characteristics that set the three species apart as well as set them apart from different families of forest trees in Maine; the essential excerpt from this publication has been scanned and added to the appendix of this manual.

All three of the ash species in Maine are dioecious plant specimens meaning that they require a male and female counterpart to successfully reproduce. Dioecious plant specimens can be observed as either a female (seed bearing individuals), male (individual having only male flowers), or polygamous individuals (bearing seed and having male flowers). A polygamous individual can successfully reproduce without the need of another individual, the seed produced would be genetically identical (Benedict, 2003).

Seeds can actually serve as a great way of distinguishing among the ash species a publication by Les Benedict outlined the propagation process for seed collected from brown ash and included a great diagram and information on distinguishing the "oar" shaped samaras of the three ash species; see figure 1.2

The scientific community is realizing their lack of understanding of many of the ash species, primarily the brown ash species. The brown ash species is the only ash species native to Maine that is essential in the traditional basket making practices of the Wabanaki people. The need to further our understanding of the brown ash species is a high priority as it is susceptible to invasion by EAB and is preferred during over the other two species (Seigert). The lack of knowledge on the species is largely because brown ash has not been viewed as an economically valuable species, in terms of timber production. For this reason, funding tended not to be used on brown ash research. Furthermore, the sites, in which brown ash tend to grow, are very mesic or wet. In some cases, to the point of inoperability for commercial harvest. Additionally, there tends not to be any species of value mixed in these stands as the sites tend to be characterized as less productive primarily due to their extended periods of water inundation (D'Amato, et al 2018).

Cultural Significance of Ash

Here in the state of Maine, the Native American tribes that are federally recognized refer to themselves collectively as the Wabanaki nations. This is because of the shared history between all the Wabanaki tribes. No matter the tribe, whether Penobscot, Passamaquoddy, Maliseet, or Micmac they have a connection that bonds them closely to their identities individually and as a group. One core connection is their spiritual identity as it refers to their creation story. The Wabanaki people share stories that have been told and retold for generations. A heroic figure that has stayed constant in them is Gluskap. The Wabanaki refer to him as one of them and he is a powerful and wise being. In their creation story, Gluskap comes to North America before any natives inhabited the area and fires his bow and arrow at the "trees, the basket-trees, the Ash. Then Indians came out of the bark of the Ash trees." (Wood, 2017). This tight connection between their creation and brown ash trees establishes the ash tree as part of who they are and as a culturally significant species to the Wabanaki people (Wood, 2017). But, the importance of this tree to them is even greater and hence considered a cultural keystone species.

For generations, the Wabanaki people have been using the brown ash and its particular special properties to make baskets. The production of a brown ash basket is truly an art starting with just the selection of a true basket quality ash tree in the forest (Greenlaw). Every generation of Wabanaki basket makers have taken the time to teach younger generations the art of basket making, and all the steps involved. This format of building knowledge and understanding forces those engaged to develop an unprecedented knowledge of the brown ash tree and serve as true stewards to ash species.

Background Information on Basketry

The art of basketry by the Wabanaki people has evolved over many generations. In terms of this inventory manual there are some essential aspects of the basket making process that should be known. Traditionally you have two key individuals in the development of a basket the harvester and the basket maker, in some cases one individual completes both of these tasks. The harvester enters an ash stand and assesses the area as well as the individual trees. Their assessment allows them to identify basket quality brown ash (BQBA). The stands hydrology, topographical setting, and species composition all appear to be significant factors in the determination of a BQBA site (Costanza et al.,2017). When they look at the individual trees they will assess their form, health, and annual growth increment which are all attributes that are significant in classifying a tree as a BQBA. These standards however are particular to each individual basket maker and they're difficult to determine without years of experience in the art of basketry. When determining whether a site is up to BQBA standards as a forester the best we can do at this point are use a few rules of thumb; you can use these few questions to assess them (Greenlaw; Newell).

- Is the diameter distribution shifted toward smaller diameters that would enable most individuals to carry 8-10 foot logs over their shoulder to a nearby accessible road?
- Are the stems straight and true or are there many defects and sweep associated with the ash on the site?
- In terms of site hydrology; is this site very "swampy" and flooded for most of the growing season or is the site draining fairly well and serving more as a flood plain or outwash area?

If the answer to the first two is yes and the hydrology is not "swampy", then notifying basket makers or harvesters of the sites location can help promote the continuation of the cultural art of basketry. Basket quality brown ash sites are the areas your management will likely work to protect and maintain so identifying and monitoring them is essential. Because these BQBA sites are hard to identify this area is a future direction for research. See the appendix item "Suzanne Greenlaw's Remote Sensing Work". For now, once a brown ash corridor is identified using stage 3 of this inventory use the above questions to identify whether or not it is a potential BQBA site and then have a basket maker or harvester check it out and see what their opinion is. When communication like this occurs, it can be very beneficial to the forestry department from a public relations standpoint but also it is the best way to acquire traditional ecological knowledge or TEK on basketry to help guide your management decisions.

Management Options

This section is a brief overview of some of the more widely accepted management regimes being applied on ash stand to combat or improve a stands resilience to an EAB infestation. These are not recommendations; in the case of any such recommendation a professional licensed forester should be consulted in regard to any particular stand's management. A forester should always have the best interest of the land owner in mind as well as stay true to their ethical obligation to responsibly "manage land for current and future generations" (SAF Principals and Pledges). Forecasting the impacts of EAB on our ash resource can often times push landowners toward a salvage or pre-salvage prescription. Although this can be sustainably done, the underlying issue is the potential loss of an ash species on the woodlot and creating greater impacts than the insect itself if harvests are not carefully planned. It is the responsibility of the forester to push for maintaining some component of ash for its importance and contributions to biodiversity, ecosystem services, cultural practices, and aesthetics.

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Upland Ash Stands

Upland ash stands are generally composed of white ash (*Fraxinus americana*). In Maine a majority of our ash timber is used for fuel wood, pulp wood, and lumber. Being a commercial species its loss on the landscape can have serious financial implications. Managing your ash resource ahead of EAB can better prepare your ash stand for an EAB invasion. It has long been accepted by many that reducing host abundance and transitioning your upland ash stand to some other commercial species was the best option. But, this technique fails miserably at controlling local EAB populations. This can clearly be seen as this technique has been in practice since the arrival of EAB in the US, and yet the continual spread of EAB across the northeast makes it safe to say, “36 states later...it hasn’t worked” (Damato). This technique has worked for the management of other forest pests and perhaps that is the reason it continues to be implemented on ash stands or maybe it is because of the alarming findings of nearly 100% ash mortality following an EAB invasion. Where entire ash stands are survived only by a few scattered “lingering” ash trees (Knight et al., 2013). Until recent, the only glimmer of hope for those “lingering” ash trees was that they displayed some degree of genetic resistance to EAB. Now, with findings by Molly Robinett and Deborah Mcullough the future is brighter. Robinette and Mcullough returned to the epicenter of the EAB invasion in southeast Michigan for inventory of the EAB aftermath forests that were previously dominated by ash. They found, on average across 28 different sites, that 75% of the white ash they inventoried were alive and in good health. Almost all of the white ash encountered had evidence of previous colonization of EAB with presence of feeding galleries, exit holes, and wood pecks. But, these damages to the tree were healing or were healed naturally by the tree with the production of callus tissue or periderm tissue re-establishing cambial integrity. There were even findings that suggested a strong potential for the recruitment of lower strata white ash into the overstory in these after math forests (Robinett and Mccullough, 2019). These findings show there is a promising potential survivorship with white ash, that can work to maintain an ash component on the landscape post-EAB. With this updated information experts are now pushing for landowners to maintain an ash component as it can increase management options down the line. As more silvicultural trials are performed on these EAB aftermath forests this new-found white ash survivorship can establish a brighter future for our ash resource. In the case of converting to an alternative species through the reduction of your stands ash component, this region of the country is at a great advantage. In Maine its particularly common to have a few replacement options available at a single site due to the high level of self-regeneration in the Maine forest (WDNR, 2018;Livingston). Artificial regeneration is another option, but, again due to Maine's ability to rely on natural regeneration there really is no need for artificial regeneration in these upland sites. The silvicultural techniques for promoting the alternative species can be achieved in a variety of ways such as an overstory removal, coppice, seed tree, or clear-cutting techniques for even-aged/two aged scenarios to single tree selection or group selection methods in pattern variations of strips, patches, etc. for the cases of multi-aged silviculture (Ray, 2019). The key to success in these active management approaches to EAB is early active management. If you are not ready to introduce this alternative species to the canopy or preemptively manage your ash resource to better aid in the survivorship of upland ash. Then when EAB comes through, the overall health and balance of the stand will feel the negative impacts of the infestation far more than if you are ready and actively managing to prepare for the arrival of EAB (WDNR, 2018). To further push away from the reduction in host abundance technique the reduction or elimination of an ash component in the forest has significant negative impacts due to the loss of the ecological benefits that having white ash present in an upland forest community provides. At the very least it provides species diversity. Because of those benefits as well as the potential genetic resistance to EAB found, in some cases, in 75%-90% of white ash, as suggested by Robinett and Mcculloughs study. The reduction should not eliminate the species entirely from the stand. At the very least, mature seed-bearing individuals should remain scattered throughout the stand if possible as legacy trees.

Lowland Ash Stands

The management of lowland ash stands is quite a bit more challenging. You tend to only have brown and green ash occurring on these sites due to their hydrology and site conditions. As previously mentioned black and green ash are the lowland ash species, occurring on flood plains, outwash plains, and shallow depressional wetlands across the state (WDNR,2018). When you're dealing with these areas you need to be aware of the hydrological features that surround you both from a regulatory standpoint and as well as an ecological standpoint. These features will also help guide your management decisions. Stage 3 of this inventory will focus on these areas and give you a well-rounded inventory from which to base management decisions.

In Wisconsin these habitats are broken into two cover types, bottomland hardwood and swamp hardwood. This designation is based on hydrology and species composition. Bottomland hardwoods experience "unrestricted flood pulse events" and are dominated by silver maple, birch, and green ash, with varying densities of brown ash. Swamp hardwood cover types typically experience an extended hydroperiod and are characterized by a low site productivity. These sites are often times dominated by brown ash (WDNR,2018). In either case the main purpose of management strategies for these cover types is to convert the stand from a mainly brown ash canopy to some alternative species in hopes of increasing its resilience to an EAB attack, another reduction in host species approach (WDNR,2018).

In Wisconsin, following the EAB invasion on the lake states, a series of experimental silviculture trials were executed. One focus of these trials was to find regeneration methods that were successful in promoting non-ash species. The most successful strategies for natural regeneration of bottomland hardwood cover types were one-cut shelterwood/overstory removal methods (OSR), and uniform shelterwood (SW) regeneration methods for cases where the desired conversion species has a shade tolerance of "mid-tolerant". Low intensity group/patch selection methods were seen to be very ineffective in terms of seedling establishment when done on either cover type. For that reason, it is suggested that if that method is chosen, group or patch sizes should be quite large. 0.5-2.0 acres and 0.1 to 0.5 acres respectively (WDNR, 2018). Swamp hardwood cover types are a bit more troublesome as there tends to be a risk of an observed rise in the water table following the harvest/mortality to brown ash. This is due to the ecological niche that brown ash is filling. Brown ash has hypertrophied lenticels that allow if to function at a much higher rate of evapotranspiration (ET). This high rate of ET, especially in stands dominated by brown ash, can be so influential on the water table throughout the season; that without its influence a significant increase in the water table is observed (Slesak et al.,2014; Van Grinsven et al., 2017). This can negatively impact the survivorship of any alternative species on the site (D'amato et al., 2018; WDNR,2018). Because of this issue, management strategies need to limit the impacts that a loss in ET can have on a sites water table.

The most successful strategy for natural regeneration of an alternative species in stands where this issue is possible appears to be strip clear-cuts/coppice methods which are also known as strip shelterwood (D'amato et al., 2018). The other issue with these sites is that because of the flooding, pulsed or not; the suite of species that can serve as an alternative are limited. In these cases, artificial regeneration can sometimes be the only option. A study done in Minnesota observed good seedling survival following planting in small group selection openings. In addition to that success they observed no significant increase in the water table following the establishment of the openings (Looney et al.,2015). When it comes to artificial regeneration there are many other approaches though.

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Seed Collection and Artificial Regeneration

Regarding the urge to sustain our ash resource in to perpetuity we can use a method called seed banking. By placing ash into a seed bank, or germplasm repository, then our ash species can be put into remediation/replanting strategies or experimentation of hybridized individuals in hopes that we may develop a hybrid ash species that can naturalize and show some defense or genetic resistance to emerald ash borer. Because of this potential future direction, research on how to effectively collect seed, store seed, and germinate seed is needed. Ash trees are polygamous as previously mentioned. This means some trees are female only and bear seed on all mature branches; some trees are male only and bear no seeds on any of their branches; then there are polygamous individuals that bear male flowers on certain branches as well as seed bearing branches, expressing female reproductive components (Benedict, 2003). This can make seed collection more difficult. Like the other topics surrounding ash there was a lack of knowledge in the field of seed collection and the seed germination of ash species, which forces us to start from square one. Many of the studies that have focused on seed collection have worked with ornamental white ash trees in residential areas. The crown structure of these trees aids to the ease of seed collection with low hanging, seed-bearing branches. In general, it appears white ash can more commonly have these low hanging, seed bearing branches whereas green and brown ash typically have higher crowns that generally never have these lower seed-bearing branches.

Because of this issue, experiments have looked at various strategies for collecting seed of brown and green ash trees. Strategies include small seed cages that are manually installed and checked later by tree climbers (Neptune). Experiments also are looking at long pruning brushes, commonly used in arborist work, to cut seed-bearing branches for collection on the ground. There are even attempts of catapulting sand bags up and over large branches, using a variety of launching mechanisms. Then shaking the rope that is looped over the branch vigorously to dislodge mature seeds for collection as they fall to the forest floor (Ellis, 2006). Dave Ellis, a Plant Geneticist in the Plant Genetics Resources Preservation Program at the National Center for Genetic Resources Preservation. Has produced an excellent document recommending the best ways to collect ash (*Fraxinus*) seed. I recommend this document be referenced before collecting any seed.

A huge potential threat discussed by Dr. Ellis in this document is the unintentional collection of seed infested with fungus or disease. The infested seeds can infect other seeds in the seed stock of many of these ash germination programs. Partnering with these programs can make your effort more effective. Its programs like this that make artificial regeneration possible. Brown and green ash or even white ash for that matter are not typical nursery stock due to their low economic value in comparison to other species. This requires research and trial and error for determining how to produce nursery stock for ash species. Les Benedict is a leading brown ash researcher with ties to the Saint Regis Mohawk tribe of New York state. In the appendix of this manual there is a write up he has made on the collection and germination of brown ash seed (Appendix 13). The process is in depth and alludes to the precision science behind successfully germinating a brown ash seed.

The planting of these trees can be challenging due to the high-water table associated with these sites. Due to the intense effort and resources associated in creating brown ash seedlings an inventory of microsites/microtopography or pits and mounds at various sites can be extremely helpful in successful artificial regeneration. It is also very useful to take note of the degree of herbivory at each site. It is important to select a sites where animal browse is less likely to cause issues. Nate Seigert, the USDA Forest Service entomologist, has spent many years studying and researching EAB since its arrival in North America. He notices that snags and blowdowns of ash and non-ash species following an EAB attack can create temporary deer exclusions around ash regeneration. In areas where these natural exclusions do not occur implementing a variety of man-made deer exclusions can be effective. Many studies that have explored this topic have looked at planting alternative non-ash species. Because of the ecological niche that brown ash is filling within these lowland sites, trying to determine the best species to replace it is an impossible task. Studies have looked at a variety of different species and the best results were observed using containerized spruce and white pine seedlings. But, yellow birch was seen to be an affective under-planting species (Haugen et al. 2016). The Wisconsin Department of Natural resources has created a checklist for evaluating lowland ash stands (Appendix 3) and it does an excellent job of out lining the various management strategies I've mentioned here in this section and provides some additional insight into their efficacy. There is much more research needed for developing specific strategies for effective ash seed collection as well as the artificial regeneration of ash and non-ash species in these EAB impacted forests.

USDA Aphis

Biological Controls

USDA APHIS proposed the removal of the emerald ash borer domestic quarantine regulations. This was posted online for comment in Fall of 2018 and was open for comments until November 19th, 2018 (USDA APHIS, 2018). The reasons for lifting this quarantine appears to point toward a focus of program funds and resources on developing and administering bio-controls. Biological controls for EAB utilize five parasitoid wasps. One of these parasitoids is native to North America and is very effective at attacking EAB. Unfortunately, a majority of the state of Maine is too far north and out of the range of this parasitoid wasp. Three of the wasps (*Spathius agrili*, *Tetrastichus planipennisi*, and *Spathius galinae*) are larval parasitoids from Asia. They co-evolved with EAB and for that reason attack and help to control their populations in Asia. These larval parasitoids lay their eggs inside the EAB feeding galleries using their ovipositors. Trees with thicker bark do not allow wasps with smaller ovipositors to lay their eggs. Once hatched they feed on the larvae of the borer in order to develop into an adult parasitoid. All of these wasps are under question in terms of their efficacy in colder temperatures.

All of these wasps are similar, but they differ in two areas. Their observed success in colder temps and the length of their ovipositor. The colder temperatures appear to effect *S. galinae*. This is fortunate for Maine as this wasp is also one with a larger ovipositor that can successfully lay eggs in the ash trees with thicker bark. However, the extent of this wasps' northern range is not confirmed to reach across the state in its entirety yet. The only other parasitoid currently approved by the USDA for use as a bio-control for EAB is *Oobius agrili*, an egg parasitoid. Egg parasitoids lay their eggs within the egg masses of the borer. The wasps' larvae overwinter in these egg masses feeding on the EAB larvae and emerging in the spring. In Asia, these wasps have been observed to parasitize 60% of EAB eggs. Many believe the best strategy for combatting EAB with bio-control agents is to utilize both an egg parasitoid and a laval parasitoid. The range of *O. agrili* has not been confirmed to include the state of Maine (USDA, 2017; Kanoti; MFS, 2018). Nate Seigert spoke in Littleton, Maine at an EAB meeting about bio-control agents in April, 2019. He mentioned a newly discovered *Oobius* species of wasp in Russia that would likely have a northern range and be able to withstand the colder temperatures of Maine. However, he, much like everyone else, he is a bit skeptical about the application of an invasive species to control the population of another invasive species. There are more examples in history where this strategy has gone wrong than there are examples of it being successful. This is an important consideration when deciding if bio-controls are a viable option on your ash stand. If it is a preferred management direction Seigert explained that these biological control agents are administered to state agencies from a rearing facility in Brighton, Michigan. Landowners within those states need to be in contact with their state agency, the equivalents of the Maine Forest Service.

They will provide you with information on bio-controls and a set of site evaluation criteria in order to obtain a local land use permit for introducing the wasps. Because this program is not in operation here in Maine these requirements are not clear currently and the process could be slightly different when the program is established. Staying in contact with the state entomologist and the Maine Forest Service as it is developed is the best course of action currently.

The USDA has a publication available for the EAB biological control release and recovery guidelines for 2017-2018 available online at the following link: https://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/EAB-FieldRelease-Guidelines.pdf

This publication outlines some of the site evaluation criteria landowners are required to provide to get approval for the release of parasitoid wasps on their woodlot. All of these criteria are addressed in this inventory manual. They include some general site characteristics, a percent composition and diameter distribution of ash species, an estimation of the density of EAB infestation. The density of infestation estimation is based off of monitoring efforts for EAB signs and symptoms, something all forest managers should be doing regardless as to whether bio-controls are management option. To aid in establishing that estimation of infestation they provide the following parameters.

Table 1.1

Rating	None	Low	Medium	High
Degree of Infestation	No confirmed EAB signs or symptoms have been observed.	EAB signs and symptoms confirmed, but difficult to find.	Trees are beginning to show frequent signs and symptoms of EAB.	Greater than 25% of ash trees are showing signs and symptoms of EAB

This is a useful table for deciding the relative intensity of your EAB infestation. There is site assessment data that this manual includes regarding bio-controls that the USDA guidelines do not require. That being an assessment of the dominant shrub layer species in the brown ash corridors. This is partly due to the need of a high sugar resource, commonly found in shrub species in Asia, for many of these parasitoid wasps (Hassett, 2015). Bio-controls can be effective and may be the best option for sustaining our ash resource into the future. Implementing this manual in managing EAB populations and this manual will provide you the necessary data for getting enrolled into EAB biological control programs.

David Cappaert, Bugwood.org

Insecticides

Insecticides can be effective in controlling local EAB populations and protecting the more valuable ash trees, even large diameter ones. However, some insecticides on the market are more effective than others. This section introduces some of the insecticide treatments available today and answers some common questions associated with EAB insecticide treatments.

As always, with insecticide chemicals, following the application directions on the bottle or packaging of the chemical is necessary to achieve desired results. Insecticide treatments are costly and should only be done when EAB is confirmed in the stand. In general, it has been thought that there is no need to apply insecticide when EAB is not around, it is a waste of money. However, Insecticide treatments can occur in advance of EAB infestations; in hope to lessen the impact on larger seed-bearing individuals. Following this early application of insecticide, and once EAB has arrived in the ash stand, a release of bio-control wasps is being looked at as a potential long-term management method for EAB populations. Insecticides can be a pollutant, but, fortunately the more successful injected systemic insecticides are not observed to enter the surrounding soil or pollen of treated ash trees and therefore is not a serious concern (Deborah McCullough). However, basal applications, soil drenches, or cover sprays of these chemicals are subject to drift and can adversely affect the environment and other insects in the area, and could adversely affect pollenators. Some studeies suggest that the use of many of these chemicals is linked to a decline in honey bee populations in the central part of the country. In the case of brown ash trees, their associated wetland complex is at high risk of pollution from these treatments. Local regulations may prohibit this management strategy on brown ash stands for that reason. Les Benedict, a member of the Saint Regis Mohawk tribe in upstate New York, has stated that the Mohawk tribe will not utilize insecticide treatments on their brown ash stands due to this risk of pollution in their associated sensitive wetland areas. The Mohawk tribe may be open the use of the less problematic, injected systemic insecticides. It is also important to note that some of the chemicals mentioned in this section may not be accepted in all states. Contacting your local arborist or state agency to determine the acceptance of some of these chemicals may be necessary. If the crown of your ash tree is showing greater than 50% die-back, then it is not recommended that insecticides be used on it. This is because majority of the chemicals being used to treat EAB are systemic insecticides that require the tree to move the chemical throughout its vascular system to reach EAB adult beetles and larvae. They're either impacted within the tree (i.e. feeding galleries) or via consumption of foliage containing the insecticide chemical. A tree with significant die-back will not translocate the insecticide chemical at a high enough rate to achieve the necessary level of effectiveness to protect the tree from EAB. These are all impacts and consideration you need to address before administering insecticide treatments on your ash stand.

A common concern is the cost and benefit of insecticide treatments. Many of the more effective treatments tend to be costlier and along with that cost they require application to be done by a licensed professional. The costs for application by a licensed professional vary from contractor to contractor and region to region. For that reason, it is difficult to determine a specific cost associated with EAB insecticide treatments. There are online cost estimators for EAB insecticide treatments. The Urban Tree Alliance has a cost estimator that uses a measure of a trees circumference to determine the cost to remove that tree as well as to treat that tree with insecticide, allowing landowners to make informed decisions on how to manage their ash resource. In all cases the calculator shows that the cost of insecticide is lower than the cost of removal. Many studies affirm that claim, having shown in landscape or residential settings, using a variety of insecticide chemicals, that the cost associated with bi-annual insecticide treatments (typically every 2 years, but in some cases 3-4 years) is less than the costs associated with removing and replacing trees. However, over time repeated bi-annual treatments will eventually exceed the costs of removing the tree. The Urban Tree Alliance's (UTA) "EAB cost calculator" estimates that a 20 in. DBH ash tree will cost $200.00 to treat with insecticide and cost roughly $1045.00 to remove, assuming no revenue is generated from the harvest of the tree. The difference in cost establishes that it would take 10 years of bi-annual treatments of the insecticide to equal the costs of removing the tree. It also states that the 20-inch ash tree would provide $198 annually in beneficial ecosystem services, this is an important consideration. A link for the EAB cost estimator is provided below. Before considering insecticides, I recommend getting a quote from a local arborist. This will allow you to better budget the cost associated with insecticide treatments.

How practical is treating a stand of ash though? In the case study for this manual, seen as appendix item 1, the area for which stage 3 of the inventory occurs is known as a brown ash corridor. It is an area where brown ash is confirmed and likely to be occurring in high density. The results from data analysis of the stage 3 inventory associated with the case study, returned that the brown ash corridor was 2.6 acres in size and had 178 ash trees recorded, mostly brown ash but a large amount of white ash as well. This gives you roughly 68 ash trees per acre in the corridor. The average DBH among those trees was calculated to be around 8 inches. According to the Urban Tree Alliance's EAB cost calculator an 8-inch DBH ash tree cost $79.00 to treat with insecticide. This cost is seen every two years for retreatment purposes. Below, organized in table 1.2, I have organized the bi-annual costs associated with treating an ash stand based on the case studies principal, 2.6 acre, brown ash corridor.

Table 1.2

Total Ash Recorded	Ash Recorded/Acre	Bi-annual Cost to Treat Stand ($)	Bi-annual Cost to Treat/Acre ($)
178	68.46	$14,062.00	$5,408.46

*Based on an 8 inch as tree. Costs calculated using UTA: EAB cost calculator.

Because Insecticides have been shown to be effective in combatting local populations of EAB and preserving high value ash trees, the market has been flooded with a variety of options that utilize one or a combination of two of the nine different active ingredients that have been proven to be effective in treating ash trees against EAB impacts. Many of the studies that have assessed the efficacy of these various active ingredients have claimed that emamectin benzoate is the most successful. It does still require bi-annual application to the tree, through trunk injection by a licensed professional which can have varying associated costs. The North Central Integrated Pest Management Center (NCIPMC) has a publication available online that provides a lot of detail on EAB insecticide treatments (Appendix 13) It can be accessed at the following link:

NCIPMC publication:
http://www.emeraldashborer.info/documents/Multistate_EAB_Insecticide_Fact_Sheet.pdf

UTA EAB cost calculator:

https://www.urbantreealliance.org/eab-costs/

In the NCIPMC publication there is a table (provided below) that list the insecticide options available to home owners and licensed professionals. Some of these chemicals, but not all, have been observed to consistently and effectively protect ash trees from EAB during periods of high insect pressure. Reference the publication for additional details on these options.

Table 1.3

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Products Intended for Sale to Professional Applicators			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Early to mid spring or mid fall
Safari™ (20 SG)	Dinotefuran	Soil injection or drench	Mid to late spring
Transtect™ (70WSP)	Dinotefuran	Soil injection or drench	Mid to late spring
Xylam® Liquid Systemic Insecticide	Dinotefuran	Soil injection or drench	Mid to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Early to mid spring or mid fall
Azasol™	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Arbormectin™	Emamectin benzoate	Trunk injection	Mid to late spring after trees have leafed out
Imicide®	Imidacloprid	Trunk injection	Mid to late spring after trees have leafed out
TREE-äge™	Emamectin benzoate	Trunk injection	Mid to late spring after trees have leafed out
TreeAzin®	Azadirachtin	Trunk injection	Mid to late spring after trees have leafed out
SafariTM (20 SG)	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Transtect (70 WSP)	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Zylam® Liquid Systemic Insecticide	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Astro®	Permethrin	Preventive trunk, branch, and foliage cover sprays	Two applications at 4-week intervals; first spray should occur at 450–550 degree days (50°F, Jan. 1); Coincides with black locust blooming
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Products Intended for Sale to Homeowners			
Bayer Advanced™ Protect and Feed II	Clothianidin + Imidacloprid	Soil drench	Early to mid spring
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Early to mid spring
Optrol™	Imidacloprid	Soil drench	Early to mid spring
Ortho Tree and Shrub Insect Control Ready to Use Granules®	Dinotefuran	Granules	Mid to late spring after trees have leafed out

For each of the insecticide options available, the application method is provided. For home owners that choose not to hire a professional, options include soil drenches, injections or granules. Studies indicate varying results with these methods, in some cases no positive impact was observed. The trunk injections appear to be the most effective with treatments lasting anywhere from 1-3 years (3 years is beginning to be the standard) depending on the insect pressure and product selected. These systemic injected pesticides also come in basal bark applications. These varieties are much more soluble and for that reason the potential for pollution is greater. With that being said, the efficacy of the basal bark varieties is similar to that of the injected systemic pesticides. Cover sprays also vary in efficacy dependent on insect pressure and product selection. Many do not recommend cover sprays because of this uncertainty associated with their efficacy as well as the potential for drift during application that can adversely affect adjacent vegetation, water sources, and non-target insects. Be sure to contact you state agency for recommendations on insecticide treatments and never move forward as an unlicensed individual with application of products that require a licensed professional.

Chapter 2: An Overview of The Inventory Strategy

This inventory is essentially a three-stage process. Three stages may sound costly, but the first stage will more than likely be pre-existing, meaning the group/individual interested in inventorying ash; will already have this data available. Forestry departments for tribal affiliations are actively engaging in timber harvests on tribal lands and the associated cruising data can serve as an existing dataset. These existing datasets are used here to localize the efforts of the more extensive inventory stages that follow in this manual. Doing this can allow land managers to be more cost effective in their approach to inventorying their ash resource. As a bench mark for this existing data reference, I will outline the current timber cruising process being implemented on Passamaquoddy Tribal Lands by the Passamaquoddy Forestry Department. It is important to note that because this existing data is for areas set to be harvested this approach is opportunistic and will not inventory areas that are not set to be harvested. However, the existing dataset could be number of things. Below are some of the more common datasets that may be at your disposal.

- Timber Cruising Data
- Continuous Forest Inventory Data (CFI)
- Stand Type Mapping
- LiDAR and Some Other Remote Sensing Strategies

The above options are all widely available and common on managed forest lands across the state, with the exception being LiDAR, although a majority of the state has been flown with LiDAR. LiDAR stands for light detection and ranging, it is a remote sensing technology that can be very useful in forest inventory and mapping strategies. LiDAR mapping can create very fine textured mapping of topography and provide input into the determination of depth to water table. These are very useful in determining areas in which brown ash are more likely to occur. Vegetation indices are another remote sensing tool used to distinguish various vegetation, there may be an index that is strongly correlated to ash (*Fraxinus*) species and provide input for delineating ash stands. This is not something that is known currently and is a future direction for researchers. Suzanne Greenlaw, a University of Maine Graduate Student, is working on developing a remote sensing model for mapping areas of basket quality brown ash. This could serve as a very useful tool in delineating ash stands and brown ash corridors and should be explored in the future as a potential mapping tool (Appendix 2).

Stage 1 of Inventory (An existing dataset example)

(Passamaquoddy Forestry Department Timber Cruising Protocol)

Outline: Plots are laid out in a systematic grid pattern across the landscape at a spacing of 1 plot for every 10 acres. This puts plots approximately 660 feet apart or 10 chains. Each individual plot is inventoried using a variable radius technique that utilizes a 15 basal area factor prism (BAF). Each plot visited, is assessed using a stand type coding system and operability is also assessed. Swinging the prism starting in the north facing direction each "in" tree encountered while spinning in a clockwise direction is measured/assessed for designation of acceptable growing stock (AGS) / unacceptable growing stock (UGS), species, DBH, and products; the product designation is applied to each 8ft section along the stem and can include the branches on larger trees. Product designations can be cull, pulpwood, stud wood, log, or veneer specs. Notes can be made on regeneration and certain site characteristics at the discretion of the inventory personnel (Carle). If ash is noted during the inventory process or if actual data on ash is collected, then a series of follow-up questions should be answered.

(If ash is present) follow-up questions:

- What is the estimated number of years until next harvest/development/land-use change or conversion?
- What is the relative level of human activity on or around the stand?
    - (ex. Hiking or biking trails, recreational trails, hunting and fishing access.) Think in terms of public visitation. If visits occur daily to weekly, then the rating is high; every other week to monthly is moderate, and every other month or longer between visits is a low rating.
- What are the nearby major roads, developed areas, open areas, or surface water features?
- What is the percent composition of ash? *
- Is the woodlot connected to adjacent woodlots or is isolated?
- What is the proximity of this stand to known EAB infestations? (measured in miles)
- What is the proximity of this stand to known EAB quarantined areas? (measured in miles)

* Metric derived from tree level data

The Must Have Information Moving Forward

Stage 1 is a pre-existing data set and can be a range of different things. What is important is that this pre-existing dataset is useful. Time is money, and inventory plots cost money to measure. So in the interest of time and money it is essential that you have certain information for moving forward to stage 2 of this inventory. Luckily this information is fairly minimal and most preexisting data sources will provide it. You need to have aerial imagery (preferably leaf off imagery) for the potential ash stand. You need a data source that can allude to the presence or lack thereof ash in the area and surrounding areas of the potential ash stand. If possible identify the percent composition of ash, as calculated in equation 2.1, for the given area. Lastly, if this pre-existing dataset is cruising data or CFI data you may have field notes from inventory personnel available, that indicate ash encounters. This can be very useful information in delineating ash stands. If this was not something practiced prior to the threats of EAB perhaps informing personnel of this practice can ensure that this resource is available in the future. What this existing dataset ultimately provides is a means of localizing the more extensive inventory stages that follow. With the PFD example a systematic spacing of 1 plot for every 10 acres will likely pick up any significant component of ash. Mapping out these areas can help to localize stages 2 and 3 of the ash resource inventory. Once this data is analyzed and you determine the area for which a significant ash component is present on your woodlot you can move on to stage 2. A significant ash component that would require a stage two inventory will typically have a percent composition of ash greater than or equal to 10%. As derived from the principal equation:

Equation 2.1

$$Ash\ Percent\ Composition(\%) = \frac{(Combined\ Ash\ Species\ Trees\ Per\ Acre)}{(Total\ Stand\ Trees\ Per\ Acre)}$$

Disclaimer: The data outlined in this inventory are not necessarily essential to the management of every ash stand. For example, an upland ash stand doesn't require a stage 3 inventory at all; a stand that does not ever want to implement artificial regeneration techniques or engage in the cooperative agreement associated with EAB bio-controls does not necessarily need to identify the species associated in the shrub layer. In order to avoid the collection of unnecessary data land managers should reference the back of this manual (Chapter 6), where each piece of data collected is justified and determine if the justification aligns with the management goals and objectives of the landowner(s).

Red Flags to Look For

Because of the variability of this existing data set, the usefulness of that dataset in setting up stage two of this inventory, is equally as variable. For that reason, it is important to be aware of data that is publicly available to you through the Maine office of GIS or federal and state agencies like the Maine Forest Service and the U.S. Forest Service. Additionally, Universities often will share data they are collecting and can provide tools and management information that can assist you in managing your ash resource. Much like any other career path, forest management and all other natural resource management, is a field in which you have signed up for a lifetime of learning. So, being up to date and caught up with the latest research will make you a better forester and natural resource manager.

Stage 2 of Inventory

Outline: Now that a significant ash component has been identified, as determined by the percent composition for all ash species combined. Inventorying it in order to formulate an EAB response plan is the essential next step to protecting your ash resource. To not over complicate the inventory process adopting the same inventory strategy as in stage 1, but using a 20 basal area factor prism (BAF) prism with a plot for every 1.5 acres, appears to be the easiest and most obvious choice in inventory scheme/strategy. We are using a 20 BAF prism for two reasons. The first being to improve efficiency, the other is to align with the area-based requirements for NRCS inventory standards. They will fund projects on woodlots that have a plot for every 1.5 acres when at most a 20 BAF prism is used. Regeneration data will consist of a tally count by species for saplings that occur within the nested 1/100th acre plots (radius of 11.78 feet); alternative plot sizes can be substituted here. It is common to use a 1/217th acre plot as it has a radius of around 8 feet, allowing for quick establishment of plot boundaries using a stick marked at the appropriate length; an 8-foot stick is easier to carry in the woods than a 12-foot stick. It may be useful to utilize a collapsible fishing rod in this circumstance. In either case saplings are defined as all stems >0.5 in DBH and <4.5 in DBH. Here there will be additional stand level info/data collected, additional plot level data collected, and additional tree level data collected. They are listed below.

<u>Stand Level:</u>

- All the follow-up questions from stage 1 should be associated with this ash stand.
- Map(s) showing depth to water table, drainage class, ponding frequency, and soil series
- The percent composition of ash should be updated for the specific delineated ash stand. *
- An overall product designation of cull, bolt wood, potential log, log, veneer, stud wood, and pulpwood on a per acre basis *
- An age class and or size class distribution by species *
- Percent composition of ash species on a per acre basis *
- Percent composition of EAB infestation on a per acre basis *

* Metric derived from tree level data

<u>Plot Level:</u>

- Overall Topography (Slope, Aspect, Elevation)
- Presence of any invasive species (note species if possible)
- Microtopography (degree of pits and mounds)
- Nested 1/100th acre circular regeneration survey plots

Tree level:

- Live crown ratio
    - *HCB* (Height to Crown Base), *Ht* (Total Height), *LCR* (Live Crown Ratio)
    - $\frac{(Ht-HCB)}{Ht} = LCR$
- Diameter at breast height
- Species
- Overall product designation for the tree (See chapter 4 for reference)

Tree Level (ash species only):

- Is it a Male, Female, or Polygamous individual?
- Monitoring: EAB signs and symptoms

Signs:

- Exit holes
- Serpentine feeding galleries
- Actual insect Identified (adult or larvae)
- Egg masses

Symptoms:

- Flagging and/or die-back
- Bark Splitting
- Evidence of wood pecker feeding or "blonding"

Takeaway for later stages: As you may have been able to assume, this stage sets up a focused inventory that will target brown ash. To do this brown ash corridors are identified using this stage two data and other publicly available data. Again, this focusing of efforts will allow natural resource managers and foresters to focus their efforts on inventorying the necessary areas only.

Disclaimer: The data outlined in this inventory are not necessarily essential to the management of every ash stand. For example, an upland ash stand doesn't require a stage 3 inventory at all; a stand that does not ever want to implement artificial regeneration techniques or engage in the cooperative agreement associated with EAB bio-controls does not necessarily need to identify the species associated in the shrub layer. In order to avoid the collection of unnecessary data land managers should reference the back of this manual (Chapter 6), where each piece of data collected is justified and determine if the justification aligns with the management goals and objectives of the landowner(s).

Stage 3 of Inventory

Outline: The data collected in stage 2 will provide an excellent set of data for developing management regimes for upland ash components like white and sometimes green ash. Although stage 2 may have picked up some brown ash it can be difficult to implement a management plan for brown ash or lowland ash sites without delineating the natural boundaries of the lowland ash corridor and determining the specific characteristics of that wetland.

In the case of no brown ash being picked up by field notes or the actual inventory data associated with stage 2 there would be no need to implement stage 3 of this manual. But if brown ash was noted during the stage 2 inventory or was picked up in the data collection; I recommend stage 3 be implemented on the areas you have identified as brown ash corridors.

Delineating the edge of this corridor can be done prior to the third entry to the field, see the section on “The Delineation of Ash Corridors” for reference. This is a particularly important stage for the tribal affiliates due to the cultural significance of brown ash. The better your understanding of these sites is, across your landscape, the better armed you will be for protecting and sustaining the longevity of the brown ash resource.

Stage three has some economic implications as many would view this as the third time inventorying the same area; a waste of funds. I understand this argument and have chosen to implement a 3P inventory in the delineated brown ash corridors for that reason. A 3P inventory is very quick, efficient, and accurate. It is particularly useful in this application as It has been found to be effective in the inventory of rare species and it requires that every tree in the ash corridor be visited. Each tree that is visited in the corridor will get an ocular measurement or visual estimation of species, and DBH. For the purposes of this inventory estimations only need to be made for trees that appear to have a DBH of 4.5 inches or lager.

For those trees that are visited, their DBH estimation will be transformed using Wykoff coefficients to give an estimated volume for the tree. If the transformed DBH yields a volume higher than some randomly selected number between 0 and the “KZ” value then the tree will be measured closely and is referred to as a “sample tree” in this manual, for additional information on 3P and the “KZ” value please see the “3P inventory section” of this manual.

As ocular estimations are made while walking through the corridor from one end to the other a few the trees, the “sample trees”, will be selected for actual measurement. In addition to the previously mentioned data to be collected there will also be some “plot level” data associated with each “sample tree” which will be taken according to the surroundings of each site tree. The limiting distance of this “surrounding” area is 10 feet. Tree level data will be analyzed to produce some per acre metrics. Regeneration data will be collected using 1/100th acre plots chosen at random from the ash corridor, these plots should occur once per every 1.5 acres. For efficiency as well as to avoid bias in the selection of regeneration survey areas, the plots should be selected prior to site visit and put on a GPS unit for ease of locating by inventory personnel.

Regeneration data will consist of a tally count by species for saplings that occur within the 1/100th acre plots, as previously mentioned alternative plot sizes can be substituted. Saplings are defined as all stems >0.5 in dbh and <4.5 in dbh. All data mentioned above in stage 2, is also collected during stage 3. Any data that is plot level in stage 2 is associated with the "sample trees" here in stage 3. The exception to that rule is the regeneration survey as that will be achieved with the random plots. The stage 3 "plot level", and tree level data that are collected in addition to the data from stage 2 are listed below.

"Corridor" Level

- All the follow-up questions from stage 1 should be associated with this brown ash corridor.
- The percent composition of ash should be updated for the specific delineated brown ash corridor. Reference equation 2.1 for calculation.
- Instead of AGS[1] and UGS[1] an overall product designation of cull, bolt wood, potential log, log, veneer, stud wood, and pulpwood on a per acre basis*
- An age class and or size class distribution by species*
- Percent composition of ash species on a per acre basis*
- Percent composition of EAB infestation on a per acre basis*

* Metric derived from tree level data

"Plot" Level (taken according to the surrounding area of each "site tree"):

- Hydrological classification
- Dominant shrub layer species 1,2, and 3
- Dominant ground vegetation species 1,2, and 3
- Presence of any invasive species (note species if possible)
- Microtopography (degree of pits and mounds)
- Randomly placed circular 1/100th acre regeneration survey plots*

* *Is "plot" level data not associated with the 10-foot circular "surrounding area" of sample trees*

Tree level (ocular estimates given for every tree and actual measurement given for each "sample tree"):

- Every tree in the corridor will be given ocular estimation of species and DBH
- Live crown ratio
  - *HCB* (Height to Crown Base), *Ht* (Total Height), *LCR* (Live Crown Ratio)
  - $\frac{(Ht-HCB)}{Ht} = LCR$
- Diameter at breast height
- Species
- Overall product designation for the tree (See chapter 4 for reference)

Tree Level (“sample trees” that are ash species only):

- Is it a Male, Female, or Polygamous individual?
- Monitoring: EAB signs and symptoms

  Signs:

  - Exit holes
  - Serpentine feeding galleries
  - Actual insect Identified (adult or larvae)
  - Egg masses

  Symptoms:

  - Flagging and/or die-back
  - Bark Splitting
  - Evidence of wood pecker feeding or “blonding”
- Increment bore to measure growth increment (done for every 5th brown ash “site tree”)*

** If the stand is being attacked by EAB or is at high risk of attack (less than 10 miles from a known infestation). Then boring trees for ring width data is not recommended.*

At the completion of stage 3 recall the three questions referenced in the section “Background Information on Basketry” for determining the sites potential for being a basket quality brown ash (BQBA) site. The three questions were:

- Is the diameter distribution shifted toward smaller diameters that would enable most individuals to carry 8-10 foot logs over their shoulder to a nearby accessible road?
- Are the stems straight and true or are there many defects and sweep associated with the ash on the site?
- In terms of site hydrology; is this site very “swampy” and flooded for most of the growing season or is the site draining fairly well and serving more as a flood plain or outwash area?

If the site has potential for being a BQBA site, then relay that information to basket makers and harvesters.

Disclaimer: The data outlined in this inventory are not necessarily essential to the management of every ash stand. For example, an upland ash stand doesn’t require a stage 3 inventory at all; a stand that does not ever want to implement artificial regeneration techniques or engage in the cooperative agreement associated with EAB bio-controls does not necessarily need to identify the species associated in the shrub layer. In order to avoid the collection of unnecessary data land managers should reference the back of this manual (Chapter 6), where each piece of data collected is justified and determine if the justification aligns with the management goals and objectives of the landowner(s).

A look at The 3P Inventory Technique

"3P" is a very versatile inventory strategy based on the principal of "probability proportional to prediction" (Iles 436). And has been said to have a wide range of potential application in all facets of natural resource management. It was first introduced in 1963 by L.R. Grosenbaugh at an annual Society of American Foresters meeting (Iles,2003; West, 2011). It is seemingly becoming more popular among forest inventory strategies over time, it is commonly implemented in areas that are small in size and have high value timber, and/or undiscernible boundaries (Bell, 1995). This essay will explore the basics of traditional or regular 3P inventory techniques and highlight the overall strengths and weaknesses of this inventory strategy. In closing this essay will summarize the use of 3P inventory techniques and their application in an Ash (*Fraxinus*) resource inventory strategy being implemented on the University Forest for the development of an emerald ash borer response plan for Native American tribes here in the state of Maine.

To start, we will look at the basic scheme that is executed when applying a 3P inventory technique. Let's use an example to do this. Let's say there is a 50-acre woodlot that needs to be inventoried. There are several reasons as to why you might choose a 3P inventory technique to accomplish this and I will explain those later. What choosing 3P as your approach requires, is that every tree (maybe determined by a break point diameter) within the stand is sampled. Sounds very timely and costly, doesn't it? But, it is in fact the opposite of that. Here is why. Every tree will receive an ocular or visual estimation of some metric, typically total volume / merchantable volume. The variable being estimated is sometimes referred to as the auxiliary variable and this can literally be any variable estimated in any units (West, 2011). This estimation is quick and efficient and allows the "estimator" to move through the stand quickly. No one person would estimate a tree the same volume as another; but that one person will typically be able to show consistency in their estimation of volume for that same tree. That consistency is what makes 3P possible. Now if an individual was consistent; they could most definitely still be wrong. But, that is okay because the estimates are adjusted using an average ratio between their estimate for the tree and the true measurement of the tree. To determine this ratio actual measurements, need to be taken. For this reason, all 3P inventory techniques are a 2-phase process. The second phase is done using a subset of the population, they're known as sample trees (Iles, 2003; West, 2011). Using the data from your sample trees and the ocular estimates for that tree you can determine the ratio for which the estimate was off from the true measurement. Doing this for all the sample trees and averaging those ratios gives you the average amount your estimates are off. Using this average ratio, you can adjust the rest of your estimates to get them closer to the true measurement. Totaling your adjusted estimates can give you an estimate of the total volume for the 50-acre parcel based on measures of every tree in the stand (Isles, 2003).

As I mentioned earlier the basic principal of a 3P inventory is "probability proportional to prediction". But, the example above doesn't allude entirely to this principal. So, what exactly does this mean? To answer this question, we must focus our attention on the selection of sample trees. Sample trees are selected using a comparison of your estimate to a random number. If your ocular estimate is larger than this random number, the tree is selected as a sample tree and you record the actual measurements. That random number ranges from 0 and your KZ or K+Z. This KZ range can be set arbitrarily or calculated based on a rough estimate of your expected total stand volume, or whatever metric you're looking at. Essentially what your KZ value does is set your sample size; the larger the KZ the fewer sample trees you will encounter during inventory and vice versa. You're sampling to correct as I mentioned above, and the selection of those samples are determined using probability proportional to prediction; hence "3P" (Ilse, 2003). Next, we will look at how to set your sample size.

In many cases you want to set your sample sizes due to a needed level of certainty / confidence interval or to meet the requirements set by your company or a cost share program. Because 3P is not widely accepted in forest inventory many cost share programs (Such as NRCS) and 3rd party certifications that have forest inventory standards do not accept 3P inventories. Unless a case is pleaded regarding the high level of accuracy executed by the 3P inventory. NRCS and other cost share programs that use an area-based assessment of inventories do not typically set a certain number of sample trees per acre for 3P inventories; but as this technique builds its popularity that may be a future direction (Weiskittel). To set your sample size a rough idea or estimate of the total for whatever metric you are estimating is needed. For example, if you know the 50-acre woodlot should yield near 30,000 BF and you want to sample 25 trees throughout the inventory process. You would want to use the principal equation of $KZ = \frac{(Expected\ Total)}{(Desired\ \#\ of\ Sample\ Trees)}$; this would yield a KZ of 1200. If the estimated volume of a given tree is equivalent to or greater than a randomly generated number between 0 and 1200, or the KZ value, than that tree is selected as a sample tree and an actual measurement is made (Iles, 2003).

When implementing a 3P inventory the random number and volume estimations may seem to be tedious and challenging to execute and compare in the field. This is an issue that has been trouble shot over the years and is well streamlined at this point. Most commercial level implementations of 3P utilize a program that will simply take the height and/or DBH estimates and produce a number via volume tables to be used in the comparison to a random number and advise you to measure or not (Iles, 2003). In the early years of 3P this wasn't available and random numbers were generated ahead of time and printed out as lists for in field comparison. The estimator crew would use their estimates and manually generate a number for comparison using the local volume tables. This can be a bit more time consuming and requires the estimator to keep track of what random numbers to use for comparison but just like any other strategy you become more efficient with practice.

Table 1. Interpolated and extended version of Gevorkiantz and Olsen's (1955) *Table 11* developed using the methods presented in Burk and Ek (1999).

	Assumed total height (ft) in constructing Gevorkiantz and Olsen's *Table 6* when the number of 8-foot bolts is									
dbh (in)	1	2	3	4	5	6	7	8	9	10
4	33	36								
5	38	40	44							
6	43	44	50	56						
7	47	47	51	60	65					
8	51	51	51	60	70	73				
9	56	56	56	60	68	77	81			
10	57	57	57	57	66	76	82			
11	62	62	62	62	65	73	82	84		
12	63	63	63	63	64	72	83	86	88	
13	67	67	67	67	67	72	81	100	100	100
14	67	67	67	67	67	70	79	90	95	95
15	70	70	70	70	70	71	78	88	90	95
16	71	71	71	71	71	71	76	87	90	95
17	72	72	72	72	72	73	76	85	88	90
18	74	74	74	74	74	74	76	84	86	90
19	75	75	75	75	75	75	77	83	84	88
20	77	77	77	77	77	77	77	82	84	88
21	78	78	78	78	78	78	78	82	84	87
22	80	80	80	80	80	80	80	82	84	87
23	80	80	80	80	80	80	80	82	84	87
24	81	81	81	81	81	81	81	81	84	87
25	83	83	83	83	83	83	83	83	84	87
26	83	83	83	83	83	83	83	83	84	86
27	84	84	84	84	84	84	84	84	84	86
28	84	84	84	84	84	84	84	84	84	86
29	84	84	84	84	84	84	84	84	84	86
30	84	84	84	84	84	84	84	84	84	86

A study by Thomas E. Burk used a very straight forward and versatile volume table to do this. The volume table can be seen below in table 1; Burk notes that it is an extended and interpolated version of Gervorkiantz and Olsens table 11 (1955). A table like this is useful in circumstances where volume estimates are not wanted as they're not needed or will be calculated at the computer following inventory. Instead all that is collected in the field are DBH measures; in these case Iles recommends utilizing a technique referred to as transformation of the random number. This allows you to use the DBH of a tree directly for the determination of its selection as a sample tree. The estimated DBH is compared to a T-value. Which is commonly generated using a volume table, such as the one Burk used, to indicate the DBH that would generate a volume equivalent to the random number generated from 0 to KZ. These transformed random numbers are printed on a list and used for easy comparison in the field (Burk,2012; Iles, 2003).

When choosing whether to implement 3P, it is important to first determine if the given area or situation is well suited for 3P. Here are some scenarios where 3P is an obvious choice. If the stand is already requiring that you visit every tree in the stand for marking purposes, then it would be an obvious choice to implement 3P. In addition, if the area is small in size the task of visiting every tree within the area is not as daunting a task as it would be in a large area. If the area is small and you're choosing to inventory it. Then a high level of precision is probably desired; 3P can deliver that high level of precision because you're visiting every tree within the stand. If there is a significant issue with edge effect in the stand 3P can account for that variability around the boundary as well as any other variability across the area by assessing every tree within the stand; assuming that the estimator can be consistent in their ratio of estimate to true measurement (Isles, 2003).

In the case of this inventory, it is brown ash corridors that are best inventoried using 3P. As mentioned before, brown ash has a serious cultural significance to the tribe and some basket makers even make an honest living producing baskets for basket shows throughout the year (Newell). But other than those select few basket makers there is little economic value in brown ash. Generating an inventory of these corridors as a result requires a cost benefit analysis that accounts for that cultural aspect. To make that analysis more favorable for the implementation of the inventory, using 3P which requires little time and resources to implement is an obvious choice. The other two major benefits for using 3P here are that you are visiting every tree in the area for EAB monitoring purposes and all the while capturing inventory of the rare species that occur in the area. As I have mentioned before Brown ash is a rare species but when you're inventorying a brown ash corridor, brown ash is no longer the minority, it is the majority. 3P will pick up many of the alternative species (the minority) that occur within the corridor and allow managers to determine what species to promote as a replacement of brown ash considering EAB impacts. This has been seen to be the most successful management strategy in improving a stands resilience to an EAB attack. Now in this example we are not interested in the volume of the of stand per say but that information is useful, we really just want to know the density of ash and develop a diameter distribution with that information. 3P does this wonderfully. The use of 3P as described above, makes a 3P inventory technique an obvious choice in the development of an EAB response plan for the Native American tribes of Maine.

The Delineation of an Upland Ash Stand

This is done using three data sources for a post stratification. The three data sources you will utilize will be:

1.) The pre-existing data source mentioned in the outline for stage 1. Which in the example for the stage 1 outline was cruising data.

2.) (When available) Any field notes taken traveling from plot to plot by inventory personnel

3.) And lastly aerial imagery, just to discern hardwood from softwood. (So preferably leaf off imagery.)

This information can be synthesized in a GIS to help in the delineation of an ash stand. The exact boundaries of the stand can be reestablished with a site visit. If a site visit isn't done it may make sense when implementing stage 2, to skip any measurements on plots where no ash species are present to improve efficiency, remember to make a note that no data was collected at the plot because of an absence of ash. Use these void plots to adjust the boundaries and area of the ash stand for mapping purposes. Because of previous timber harvests foresters and other staff that have been working the property for several years may know where these stands are, utilize that knowledge. Another source of information is basket makers and harvesters. They all have areas where they like to go and harvest their ash. The locations may be secretive but as the threat of EAB approaches for the sake of the ash resource these stand will likely become known. Inventorying them is a priority when that time comes. To help facilitate this interaction with basket makers and harvesters see the section "An Ash Harvest Protocol for Tribal Lands" in chapter 5 of this manual. There are a lot of similarities between this and the process for the delineation of brown ash corridors. But, there is some additional resources involved with brown ash corridors, I will elaborate on that in the next section. With that being said; the figures and maps used in the next section can be useful guides for delineating upland ash stands.

The Delineation of a Brown Ash Corridor

To focus efforts for stage 3, identifying the areas where brown ash is occurring is essential. This is done using 3 sources of information to post stratify your stage 2 inventory. Those data sources are shown below.

1.) Soils information
2.) National Wetlands Inventory Information
3.) Stage 2 data and field notes.

Brown ash is commonly associated with sites that have certain soil types that fall within the soil orders of Histosols and Entisols, both orders are present in Maine (Wright and Rauscher,1981). Typically map units for soil surveys use the broadest classification of soils, that being a soil series complex. Soil series can contain soil types from classified as Histosols/Entisols or not. This means it can be difficult to determine if the map unit classification of your soil series complex is predominantly a Histosol or Entisol.

As a rule of thumb we know that Histosols are "organic soils commonly known as peat bogs or mucky soils, but include shallow deposits of organic material above bedrock" and Entisols are "mineral soils in which there is very little evidence of soil development" (Ferwerda et al.,1997). Knowing this and knowing the area you are inventorying well, can help you determine which map units from a soil survey would most likely be predominantly a Histosol or Entisol. To help in that delineation the table below shows soil series that are common in Maine and that are typically associated with lowland sites and flood plains where brown ash is more likely to occur.

Table 2.1

	Lowland sites			Flood Plains
Map Unit Name	Swanville-Boothbay-Biddeford	Scantic-Lamoine-Buxton-Lyman	Nicholville-Buxton-Dixfield-Scantic	Cornish-Fryeburg-Podunk-Ondawa

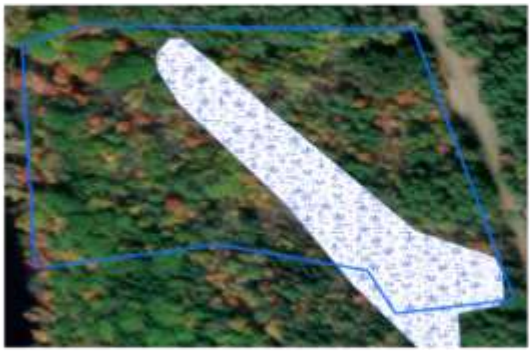
Data Source: Maine Department of Agriculture and Forestry and the U.S. Department of Agriculture

You should use the above table to determine where these soils occur on your ash stand. Soils information for your area can be acquired using the USDA web soil survey (WSS) application at the following link: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

Figure 2.1

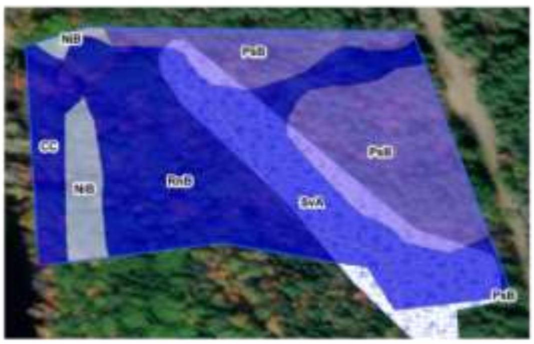
Delineating a Brown Ash Corridor

NWI – Wetland Classification



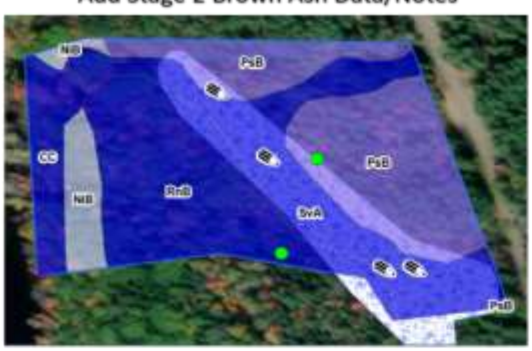
The National Wetlands Inventory provides a starting point by identifying wetland complexes and their associated surface water feature across the stand. These are areas that are more likely to have brown ash occurring.

Add Soils Information



Here the colors of the polygons indicate depth to water table and the letter labels indicate soil series. The blue being 15 cm above the water table and the Swanville silt loam complex (SvA) are indicators of ash occurrence for this stand.

Add Stage 2 Brown Ash Data/Notes



During the stage 2 inventory any plots that recorded brown ash are added here (green points). Additionally, inventory personnel noted any encounter with brown ash as the inventory took place (Pencil icon). Adding this data to a map provide insight into delineating the corridor.

Delineated Brown Ash Corridor

Using all of this information allows you to remotely delineate the brown ash corridor. This corridor is the area for which stage 3 of the inventory will occur. The boundaries do not need to be well defined as when you inventory with "3P" in stage 3 you visit all trees in the area in which brown ash is occurring, you visually decide that boundary during inventory at your discretion. That's a benefit of using "3P".

The web soil application can be very useful in making maps and delineating brown ash corridors for the purposes of this inventory. In the appendix of this manual you can find a publication that walks you through the process of accessing this information and downloading it for use in a GIS (Appendix 9). The primary data found on the USDA WSS that you would be interested in for this inventory, are soil series classifications, depth to water table, drainage class, and (if available for the area of interest) ponding frequency. When delineating the boundaries of an ash corridor you can use these soil series polygons and their associated depth to water table or drainage class rating/ponding frequency to aid in setting the boundaries for the corridor.

National wetlands inventory (NWI) data is publicly available online for download. These wetland delineations were done though visual assessment of aerial imagery primarily in the 1980's. Some small percent of the classified wetlands may be ground truth verified, but many are not. Even with that being so, NWI layers will identify many of the areas where brown ash is occurring simply due to their ties to the sites hydrology. The boundaries set by NWI layers can also be used in aiding in the delineation of brown ash corridor boundaries. In the appendix of this manual you can find a publication that walks you through the process of accessing this information and downloading it for use in a GIS (Appendix 10). Your stage 2 data, like in the delineation of an ash stand, serves as a vital resource in post stratification. Using the information from stage 2 plots you can run queries in a GIS to determine which plots had brown ash present. This information, along with GPS points tied to the locations of areas where inventory personnel noted brown ash encounters, can be used to further delineate the boundary of your brown ash corridor. Above on page 34, figure 2.1 displays a series of snapshots that visually explain the above process of using all three data sources to delineate the boundaries of a brown ash corridor. To show how successful this strategy can be in comparison to going out in the field and visually setting the boundaries for which ash is occurring, figure 2.2 shows a comparison of an in-field and remotely delineated ash corridor. The results highlight the efficacy of this process.

Figure 2.2

Efficacy of Using This Strategy to Delineate a Brown Ash Corridor

The image above shows three polygons and the stand boundary. The red outline shows the remotely delineated brown ash corridor that was established through the process that is visually represented in the **"Delineating a Brown Ash Corridor"** figure on the previous page. The yellow polygon is an in-field delineation of the brown ash corridor. The boundaries for that corridor were set in the field based on the confirmed presence of brown ash. The green polygon is the area of overlap between the in field and remotely delineated brown ash corridors. This figure displays the accuracy and efficacy of using the previously described strategy for remotely delineating a brown ash corridor. Below is a table showing the area of each polygon in acres.

Polygon	Remote Delineation	In-Field Delineation	Area of Overlap
Acres	2.6	2.8	2.07

Chapter 3: A Closer Look at Stage 2

Essential Equipment

To implement stage two, you will need the following equipment:

- A **GPS** and **Compass** for navigation
- **20 Basal Area Factor Prism**
- **Calipers or Diameter tape**
- **100-foot linear tape** for height estimations and measuring regen plot radius
- **Clinometer** for height estimations
- **Flagging** (assorted colors as needed)
- **Plot pins** (posts and tags for permanent plots)

Alternatives to this equipment do exist. It may be a good idea to carry **binoculars** for looking at the canopy of ash trees for determining male, female, or polygamous individuals as well as to distinguish the three ash species from one another. A stage 2 data spread sheet is shown below and is referenced in the step by step process below. For collection of this data printing out this provided datasheet is recommended. You can access the data sheet by downloading it from the CD that is included in the front of this manual.

A Step by Step Process at The Plot

This section will take you to through a chronological step by step process at the plot level.

1. Navigate to the GPS coordinate for plot center, mark it with a plot pin.
2. Record plot level data of aspect, % slope, elevation, Presence of Invasive species (Indicate species when possible), and lastly the microtopography of the plot. Put this info into columns B,C,D,E, and F of the stage 2 data sheet respectively.
    a. Common invasive species of Maine:
        - Japanese and Shrubby Honeysuckle
        - Autumn Olive
        - Bittersweet
        - Common and Glossy Buckthorn
        - Burning Bush
        - Japanese Knotweed
        - Japanese Barberry

    Data Source: Maine Natural Areas Program

    The following link has additional information on the above invasive species: https://www.maine.gov/dacf/mnap/features/invasive_plants/invasives_gallery.htm

    b. Microtopography chart:

    Table 4.1

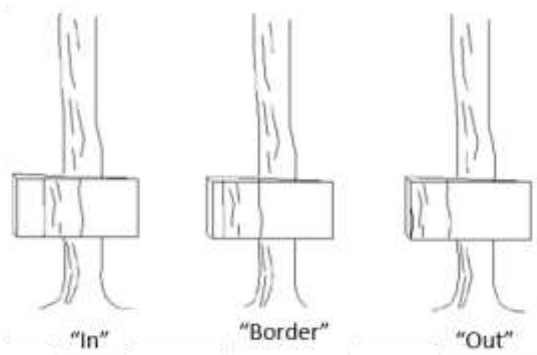
Code	Description:
SM	**Smooth** Few or no mounds; if present, less than 1 ft. high and more than 20 feet apart.
MO	**Moderately mounded** Mounds 1 ft. to 3 ft. high and 10 to 20 feet apart
ST	**Strongly mounded** Mounds 1 ft. to 3 ft. high and less than 10 feet apart
EX	**Extremely mounded** Mounds more than 3 ft. high

Data Source: Province of British Columbia; Resource Inventory committee

Note: Percent slope and elevation are often times available on your **GPS** unit. If it isn't you can determine it using a topographical map or in a GIS program. If necessary, the clinometer or your **compass** may be used to determine this. Remember the equation is, $\%\ slope = \frac{rise\ distance}{run\ distance}$, as long as the same units are being used for both rise and run.

3. Using a **20 BAF Prism** face the north direction and swing your prism clockwise to determine your first "in" tree. The figure below helps with determining an "In" tree.
   Figure 4.1

Prism Guidance Diagram:



When swing the prism "In" trees are chosen for measurement, and "Out" trees are not. "Border" trees need to be determined as either "In" or "out" by calculating the limiting distance. This is done with the following equation:

$$Limiting\ Distance = DBH \times PRF$$

Where DBH is diameter at breast height and PRF is the plot radius factor associated with the prism being used. In this circumstance the PRF for a 20 BAF prism is 1.944. After doing this calculation if the limiting distance is greater than your measured distance to that tree it is an "In" tree and vice versa.

Data Source: Dr. Tom Baribault, Forest Solutions inc; Dr. Weiskittel personal communication

4. An "In" tree is encountered, record species, DBH, and give an overall product designation for the tree, using it is appropriate number code. section into the stage 2 data spread sheet. The product designations are as follows:

Table 4.2

Number Code	1	2	3	4	5	6	7
Product Designation	Veneer	Saw log	pallet	bolt wood	pulp	Potential Log	Cull

5. If the "In" tree is an ash species indicate when possible if the individual is male, female, or polygamous by putting an M,F, or P into column M of the data sheet (**Binoculars** are useful here). Then check for any EAB signs or symptoms. If any of the symptoms seen in columns N through T are observed input a 1 in the stage 2 data sheet, otherwise leave it blank.
6. Every 10th "in" tree is assessed for height and height to crown base. This is done using the **clinometer** at some known distance from the tree, as measured using the **linear tape**. This data is recorded in columns K and L of the stage 2 data sheet.
7. Once all tree level data is collected the regeneration survey is done. From the plot center the linear tape is stretched out to 11.78 feet in all four cardinal directions (north, east, south, and west) where **flagging** is hung to establish the boundaries of the 1/100th acre circular regeneration plot.
8. The associated plot number, and a count of sapling stems for each species that occurs in the plot is tallied and recorded in the regeneration data sheet in columns A, B, and C respectively.
9. Move on to the next plot.

Stage 2 Data Sheet

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
	Stand Name:	University of Maine Ash Stand			Start Time:	12:00 PM							Key:	Columns	-Collected on all plots/"in" trees				
	Size (Acres):	12.35			End Time:	2:05 PM								Columns	-Collected on every 10th "in" tree				
BAF:	20	PRF:	1.944		Duration:	2 Hours, 5 minutes								Columns	-Collected on ash trees only				
	Location:	University Forest, Old Town ME, 04468												Columns	-EAB monitoring of signs and symptoms (ash trees only)				
	Inventory Date:	Friday, April 5, 2019							47					Columns	-Data Calculations to be done following inventory				
	Weather:	43 degrees fahrenheit, partly cloudy																	
Plot	Aspect	%Slope	Elevation	Invasives	Micro Top	Tree Count	Species	DBH	Products	Ht	HCB	M/F/Poly	Exit Holes	Galleries	Insect	Eggs	Dieback	Bark Splitting	Woodpecker feeding
1	NW	25%	112	None	MO	3	RM	9	6	71	24								
1	NW	25%	112	None	MO	1	RM	7.7	5										
1	NW	25%	112	None	MO	2	RM	13	5										
1	NW	25%	112	None	MO	4	BF	4.6	5										
1	NW	25%	112	None	MO	5	BT	13	5										
1	NW	25%	112	None	MO	6	BT	12	5										
1	NW	25%	112	None	MO	7	BT	12	5										
1	NW	25%	112	None	MO	8	RM	7	5										
1	NW	25%	112	None	MO	9	BT	14	5										
1	NW	25%	112	None	MO	10	BT	21	7										
1	NW	25%	112	None	MO	11	BF	5.5	5										

Regeneration Data Sheet

A	B	C	D	E	F
Plot Size:	1/100th acre	Exp Factor:	100		
Plot Radius (ft):	11.78				
Key:	Columns	-Collected on all regen plots			
	Columns	-Data Calculations to be done following inventory			
Sapling:	all stems >0.5 in dbh and <4.5 in dbh.				
Plot	Species	Sapling Count	ExpFactor	TPA	
1	RM	10	100	1000	
1	WP	3	100	300	
1	BF	1	100	100	
1	BA	1	100	100	

Red Flags to Look For

Although noting the occurrence of brown ash may seem to be a minor and somewhat optional practice in implementing this inventory, it can be a very vital resource in setting the boundaries of the brown ash corridor for stage 3. A simple note like “while traveling to plot 8 there were brown ash in the terraces associated with the stream dumping into the Stillwater River. At plot 8 the ash was at a low density but occurred once up stream toward college avenue and several times down stream of plot 8. No brown ash were sampled at plot 8.” takes no more than a 30 second to record once at plot 8 but it tells the individual creating the map of the brown ash corridor that the area just downstream of plot 8 can serve as an excellent boundary point for the brown ash corridor. That leads to less time inventorying areas where ash isn’t occurring, which means less money and resources are being used in the inventory of the ash resource and those resources can be used elsewhere.

It is also important to note that in many circumstances where a resource is under immediate danger of attack by a tree pest, effort to capture value and “salvage” harvest after attack can quickly get out of hand. In order to effectively manage the longevity of your ash resource it is ecologically and ethically responsible to maintain a population of ash in your stand. These trees that are kept are often referred to as legacy trees in silviculture (Ray, 2018). Legacy trees are a recommended component to an EAB response plan and are often chosen based on a trees dominance in the stand or their potential resistance to the pending forests pest or threat. In this case we have no proven genetic resistance, although roughly 1% of white ash has been seen to be defensive to attacks by EAB. Knowing this, it is recommended that certain seed bearing, and dominant individuals of any of the three ash species will make excellent legacy trees. I say seed bearing hoping that seedlings can establish in the aftermath zone of an EAB attack. These legacy trees are often chosen at an even distribution across the stand and can serve as a vital management tool known as a trap tree during an EAB attack.

Chapter 4: A Closer Look at Stage 3

Essential Equipment

To implement stage three, you will need the following equipment:

- **GPS** and **Compass** for navigation
- **Printed out list of random numbers** ranging from 0 to "KZ"
- **Local Volume Table** print out
- **marker**
- **Hand held Tablet with Excel "3P" Data sheet uploaded**
- **Calipers or Diameter tape**
- **100-foot linear tape** for height estimations and measuring regen plot radius
- **Clinometer** for height estimations
- **Flagging** (assorted colors as needed)
- **Log or Lumber Crayon** for marking trees that have been estimated

Alternatives to this equipment do exist. It may be a good idea to carry **binoculars** for looking at the canopy of ash trees for determining male, female, or polygamous individuals as well as to distinguish the three ash species from one another. An Excel "3P" data sheet is shown below and is reference in the step by step process below. If this spread sheet is not used on a hand-held tablet and there is not a "3P" inventory program at your disposal, it is recommended that you print the 3P excel sheet for recording data in the field. You can access this datasheet by downloading the file from the CD included in the front of this manual. To execute stage 3, it is useful to understand the core concepts of 3P as described in the section labeled "A look at the 3P Inventory Technique" in chapter 2 of this manual.

A Step by Step Process in the Ash Corridor

This section will take you to through the chronological step by step process you will execute at the ash corridor.

1. Navigate to the brown ash corridor using the **GPS** unit and / or **compass**.
2. Using the **hand-held tablet with the 3P Excel file** enter visual estimations of species, and DBH. Input this data into columns B and C respectively.
3. Column G will indicate whether the tree is a sample tree. "YES" indicates it is a sample tree and "NO" indicates it is not. Regardless as to whether it is a sample tree mark the tree with a **log or lumber crayon** to assure it isn't estimated twice. It is also useful to draw an "X" on dead standing trees.
4. If it is indicated as a sample tree wrap pink **flagging** around the stem. Record measurements of DBH, height, height to crown base, and an overall product designation as described in the table below. Use the **diameter tape** or **calipers** for DBH and the **clinometer** for height and height to crown base. Put this data in columns H, I, and J respectively of the Excel "3P" data sheet.

   The product designations are as follows:

   Table 5.1

Number Code	1	2	3	4	5	6	7
Product Designation	Veneer	Saw log	pallet	bolt wood	pulp	Potential Log	Cull

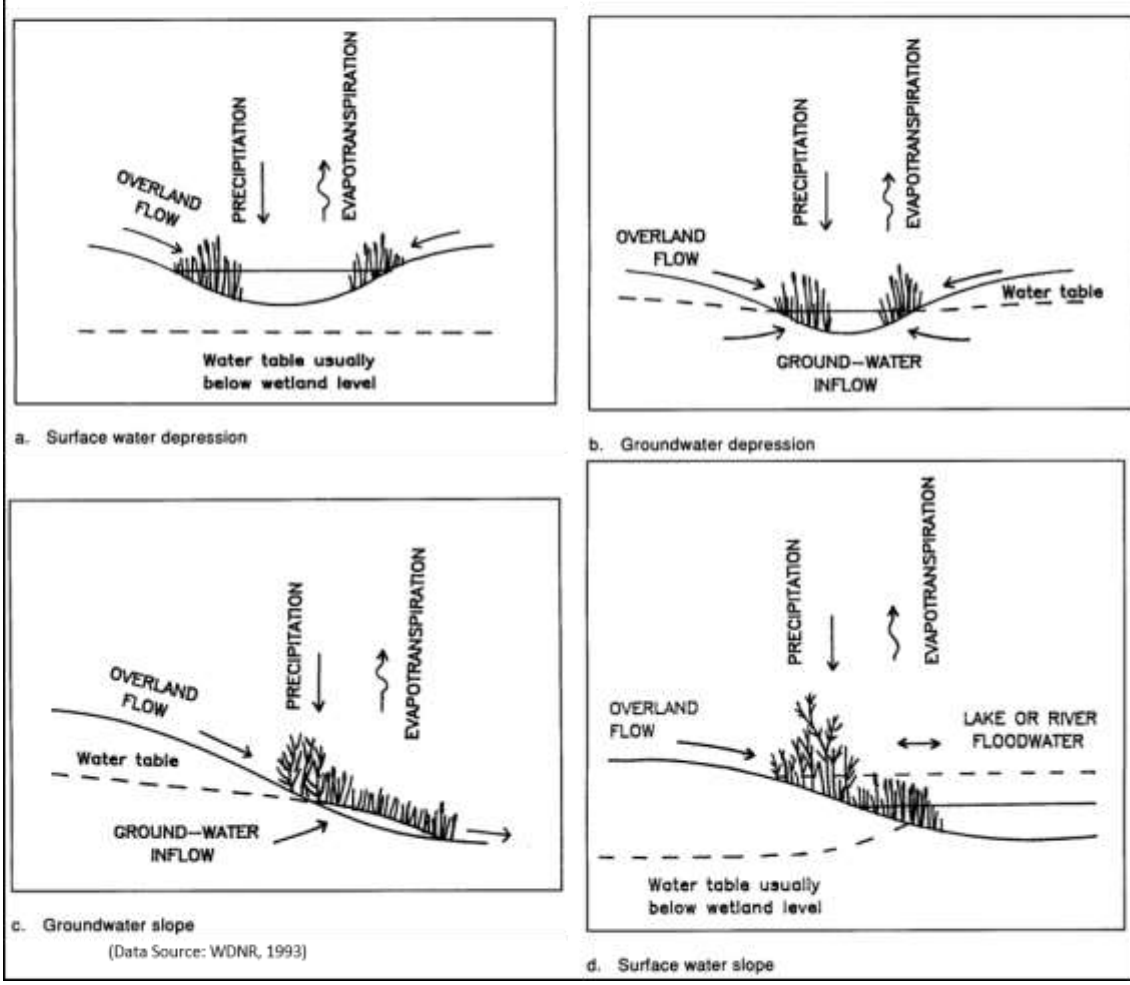
5. If the "In" tree is an ash species indicate when possible if the individual is male, female, or polygamous by putting an M, F, or P into column R of the data sheet (**Binoculars** are useful here). Then check for any EAB signs or symptoms. If any of the symptoms seen in columns R through X are observed input a 1 in the stage 2 data sheet, otherwise leave it blank.
6. After measurement is made plot level data will be collected in a 10-foot circle around the "Sample tree". Record the presence of any invasive vegetation (note species when possible), the three most dominant shrub and ground layer vegetation present, the hydrological classification, and lastly a microtopography code into columns M through Q respectively. Tables below are references for collecting the data described in this step.

Table 5.2

Code	Description:
SM	**Smooth** Few or no mounds; if present, less than 1 ft. high and more than 20 feet apart.
MO	**Moderately mounded** Mounds 1 ft. to 3 ft. high and 10 to 20 feet apart
ST	**Strongly mounded** Mounds 1 ft. to 3 ft. high and less than 10 feet apart
EX	**Extremely mounded** Mounds more than 3 ft. high

Figure 5.1

The Wisconsin Department of Natural resources designates four hydrologic types to their wetlands. The main driver of a wetlands designation across these four types is where the water source is coming from. The figures below show a visual representation of this classification system. This figure can be a very useful aid in the field when classifying the hydrology in the immediate are around "Sample Tree's".



(Data Source: WDNR, 1993)

The four hydrologic types described above are recorded for the 10-foot area around a "Sample Tree". When recording it in the data sheet the following 3 letter codes are used.

Table 5.3

Code	GWD	SWD	GWS	SWS
Hydrologic Type	Groundwater Depression	Surface Water Depression	Groundwater Slope	Surface Water Slope

10. At the end of the corridor use your GPS to navigate to the 1/100th acre regeneration plots. The associated plot number, and a count of sapling stems for each species that occurs in the plot is tallied and recorded in the regeneration data sheet in columns A, B, and C respectively. After all regeneration surveys are complete your brown ash corridor and stage 3 of the inventory are complete.

    Note: If paper lists are used, the transformation of the trees DBH for comparison to the random number can be done using a local volume table or with the table given as an example in the section called "A look at the 3P Inventory Technique" in chapter 2 of this manual. Printing out the data sheet for recording the data is required when paper lists are used.

Stage 3 "3P" Data Sheet

Stand Name: University of Maine Brown Ash Corridor | Start Time: 3:50 PM
Size (Acres): 1.812 | End Time: 6:20 PM
KZ range 0-267 (per acre volume) | Duration(H:MM): 2:30
Location: University Forest, Old Town ME, 04468
Inventory Date: Tuesday, April 16, 2013
Weather: 43 degrees fahrenheit, partly cloudy

Key:
Columns -Collected on all plots/"in" trees
Columns -Collected on/in the area of all **"Sample Trees"**
Columns -Collected on ash **"Sample Trees"** only
Columns -EAB monitoring of signs and symptoms (ash **"Sample Trees"** only)
Columns -Data Calculations to be done following inventory
Columns -Used for the determination of **"Sample trees"**

Tree Count	Species	DBH	Predicted Ht	VOL	0-KZ	Measure	Measured DBH	Ht	HCB	LCR	Products	Invasives	Dom. Shrub	Dom. Ground	Hydro	Micro Top	MF/Poly	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Bark Splitting	Woodpecker feeding
1	BA	11.5	60.88414489	18.48	38	NO																		
2	BA	7.5	53.32895756	7.162	155	NO																		
3	BA	5.5	47.02075492	3.513	196	NO																		
4	RM	17	66.40494107	42.84	180	NO																		
5	RM	6	48.84436815	4.3	77	NO																		
6	RM	17	66.40494107	42.84	231	NO																		
7	BA	10	58.58192357	13.61	220	NO																		
8	QA	14	69.86672476	33.01	128	NO																		
9	QA	14	69.86672476	33.01	13	YES	13.2	62	46		5	None	BF,WA,BA	N/A	GWS	MO								1
10	BA	9	56.73537775	10.78	179	NO																		

Stage 3 Regeneration Data Sheet

Plot Size: 1/100th acre | Exp Factor: 100
Plot Radius (ft): 11.78

Key:
Columns -Collected on all regen plots
Columns -Data Calculations to be done following inventory

Sapling: all stems >0.5 in dbh and <4.5 in dbh.

Regen. Plot #	Species	Sapling Count	ExpFactor	TPA
1	RM	1	100	100
1	BA	2	100	200
1	BF	3	100	300

Red Flags to Look For

It is important that you are weary of the area you're in. These brown ash corridors will commonly be forested wetland complexes. There are state regulations associated with some of these wetlands and associate surface water features. To ethically and actively manage your ash resource in those areas you need to remain in accordance to those regulations. Reference the Maine Forest Service publications "The Forestry Rules of Maine" 2017 edition, and the "Best Management Practices for Forestry: Protecting Maine's Water Quality" for guidance on staying in accordance to those regulations. Much like in stage 2 conversion to alternative species, or a salvage cut may be the management direction you intend to go. If this is the case be sure that legacy brown ash trees are held over for seed collection and species diversity purposes in your stand.

The hydrological classification tells you a lot about the function of the brown ash corridor in the forest landscape. It has also been observed to show an indication of a sites at risk of expressing a rise in the water table following ash mortality or in this case ash salvage or active management removal (Slesak et al,2014; Van Grinsven et al., 2017; D'Amato et al,2018). This rise in the water table can make it very difficult to promote any alternative species. You should be aware of this potential risk as you move forward with the active management of your brown ash corridor.

Robert Vidéki, Doronicum Kft., Bugwood.org

Chapter 5: Future Directions and Important Resources

Throughout the process of developing this manual thoughts, ideas, and potential future directions and next steps in terms of managing ash resources on tribal lands have been generated. The most useful and helpful one I found worthwhile noting are discussed here in this chapter.

An Ash Harvest Protocol for Tribal Lands

Currently Ash resources are harvested on tribal lands for a variety of reasons like fuelwood, pulp, lumber, and of course basket making materials. It is important to monitor this closely regardless as to what the use of the resource is. If a firewood or timber harvest is being done it would be simple to establish in the contract with the logger that all ash logs hauled to the landing need to be assessed for EAB infestation and any concerning ones are put to the side for closer evaluation by a tribal forester/ forestry employee. Flagging these ash trees that show potential signs and symptoms can help loggers identify them ahead of time. Having some protocol in place can go a long way toward protecting your ash resource during active timber and fuelwood harvests. Sometimes tribal members simply get firewood permits, if they intend on doing this they should be receiving a packet or some verbal explanation of information on EAB and its impacts to our ash resource. If any of the fuel wood being harvested is of ash species a form should be filled out that tracks this wood and requires the tribal member do an inspection of the wood before transporting it. It would be difficult to require a rigorous inspection. But, a quick check-off of the presence of not for the various signs and symptoms of EAB would be good. This form would need to make it back to the forestry office for their records. The use of this record is merely to serve as a monitoring tool. But, the real benefit is the outreach of EAB related information to tribal members and could help foster healthy relations between the tribal members and their affiliated forestry department.

Developing Characteristic Brown Ash Plant Communities

This manual requires data on the three dominant shrub and ground layer vegetation surrounding the "sample trees" in stage 3. This data is useful for a number of reasons. But, one potential benefit from it would be the development of characteristic plant communities for brown ash sites. The Minnesota Department of Natural resources included a broad suite of tree, shrub, herbaceous layer, and wildflower vegetation associated with "mesic hardwood systems" in their Ash management guidelines for private forest landowners. This is useful information for management and mapping of ash stands as many of these plant communities have specific environmental parameters that we could use to focus our efforts for identifying brown ash corridors. Additionally, the elusive basket quality brown ash is seemingly correlated with the specific hydrology of the site. These plant communities tend to occur on specific hydrologic types. If basket makers identify which brown ash corridors, that have been inventoried using this manual, are basket quality sites. A quick cross reference to the dominant vegetation associated with that site will allow us to begin generating data on plant communities associated with basket quality brown ash sites.

Wabanaki Basket Quality Legacy Forest: Insecticide Preservation

When considering the impacts of EAB on our ash resource it can be difficult to not be pessimistic about the situation. When EAB is not addressed with ethical active management the impact observed in other states has been very grim. For tribal communities it is easier to get an interest in finding resolution and maintaining an ash component in the forest due to the cultural significance of ash species. But, for many a transition from ash species on their woodlot to an alternative species is the best option in their eyes. If this is the common strategy. We could observe the spread of EAB at an accelerated rate due to unethical "pre-salvage" harvesting before quarantines are set in place to prevent just that. This would be a worst-case scenario and some would say even if the spread was localized and moved across the state at a much slower rate the end result would be the same. Regardless of the way this scenario comes about I think tribal entities at that point would be best off to pool their resources and utilize insecticide treatments to preserve the highest value ash stand found on tribal lands. Inventory, using a manual such as this one is the first step. This will identify those high value ash sites. High value is difficult to quantify here, they may be sites displaying exemplar basket quality brown ash, or having high cultural significance, or even just easy community access. Many different characteristics would make a particular site a candidate and for that reason it would need to be an active conversation between tribal communities to identify and choose this high value ash stand. Once identified the costly insecticide treatment can be administered and significantly pro-long the longevity of that ash stand into the future. Perhaps for long enough to control EAB populations in North America so that our ash resource can begin to make a comeback.

Tom Newell, Basket Harvester, PFD Forestry

Chapter 6: Justification of Data to be Collected and Glossary of Terms

This section of the manual is useful in determining whether all the data outlined in the chapters above are necessary for collection, given the management directions of your ash stand. Each piece of data or site characteristic that is defined in the above chapters is given a reason for its collection in the below sub-sections. If the reasons do not align with the management direction of your ash stand than it may not be necessary to ask inventory personnel to collect that data.

Questions on Stand Characteristics

What is the estimated number of years until next harvest/development/land-use change or conversion?

- The requirement for enrollment into a biological control program for EAB is that you answer this question. What they're concerned with is releasing these wasps, which are costly to rear, into an area that may be impacted by some management/land use change that decreases the likelihood of the establishing the parasitoid wasp.

What is the relative level of human activity on or around the stand?

- Similarly, this question needs to be answered for enrollment into an EAB bio-control program. Here the concern is with frequent recreation release sites can be compromised and public perception can sometimes be troublesome.

What are the nearby major roads, developed areas, open areas, or surface water features?

- In any natural resource management situation understanding the landscape features that surround the area can provide insight into how the forest system is functioning. It also is useful to bio-control folks who need access to the area and for knowing what features limit the wasps connection to adjacent woodlots.

What is the percent composition of ash/EAB infested ash?

- Many management recommendations use the percent composition (%C) of ash a way of quantifying its vulnerability to EAB impacts. There are also thresholds associated with enrollment into bio-control programs for the %C of ash and the R of EAB infested ash; for the specifics on those thresholds contact your state agency involved in EAB bio-controls.

What is the level of connection to adjacent woodlots; or degree of isolation? (i.e. 1,2,3…)

- Again another question associated with enrollment into EAB bio-control programs. They're interested in administering bio-controls in large continuously forested areas to increase the chances of establishing the parasitoid wasps.

What is the proximity of this stand to known EAB infestations?

- If you're going to actively manage your ash resource in preparation of the arrival of EAB knowing where it is can give you a time frame for which it might reach you. As a rule of thumb if you are greater than 10 miles from an infestation our woodlot is at low risk and less than 5 miles your woodlot is at high risk of EAB attack. Remember without any influence from anthropogenic transport EAB travels an average of 2-5 miles per year.

What is the proximity of this stand to known EAB quarantined areas?

- Nate Seigert, an entomologist for the U.S. Forest Service, explained quarantine areas as an effective means of minimizing long distance transport of EAB. Active management is effective at stopping the localized spread of EAB. We need to do both to effectively manage our ash resource. So, it is essential that you know where these quarantined areas are.

Stand Level Data

Map(s) showing depth to water table, drainage class, ponding frequency, and soil series

- These maps are important for establishing what areas are most likely to have brown and green ash occurring, your lowland ash species.

Instead of AGS and UGS an overall product designation of cull, bolt wood, potential log, log, veneer, stud wood, and pulpwood on a stems per acre basis

- AGS or acceptable growing stock and UGS or unacceptable growing stock have long been a designation given to trees that should be left to grow or be harvested right away. Many of the management recommendation for upland and lowland ash stands that came from the Wisconsin EAB silviculture trials recommend based on the AGS per of non-ash species and ash species. I personally see the vagueness associated with just two classes of AGS and UGS. For example, in situations where ash is a significant component of the stand waiting for potential logs to mature to log size before harvesting can result in a lot of economic value.

An age class and or size class distribution by species

- This data is required for enrollment into EAB bio-control programs. It is also useful for management decisions.

Plot/corridor Level Data

Overall Topography (Slope, Aspect, Elevation)

- Artificial regeneration and underplanting are focused on areas with certain topography based on the silvics of the seedling. Active management at sites with excessive slopes need to bring in equipment that can handle the broken terrain. Basket quality brown ash (BQBA) tend be associated in relatively flat areas; knowing the topography can allude to that sites likelihood of harboring BQBA. Bio-control folks want to know the topography of the site as it can affect the establishment of parasitoid wasps.

Presence of any invasive species (note species if possible)

- In artificial and natural regeneration invasive species can significant hinder the ability of sprouts and seedling from establishing on the site. In lowland sites invasive species are common and often require that site preparation be done before planting or planning for natural regeneration.

Microtopography (degree of pits and mounds)

- In the case of artificial regeneration microsites are essential to successful establishment of nursery stock. Having an idea of where these microsites already exist can help to focus planting efforts.

1/100th acre (radius of 11.78 feet) circular regeneration survey plots

- Understanding understory component is existing throughout the stand can help land managers identify alterative non-ash species to promote through active management. It can also tell us which areas ash species have regenerating naturally. A 1/100th acre plot will pick up regeneration in a variety of basal area levels; in the case of a very high basal area condition it may be in the best interest of time to go with a 1/1000th acre plot.

Hydrological Classification

- Many studies have looked at the impact EAB mortality has on the water table. In sites that have the hydrological type known as a groundwater depression or depressional wetland. There appears to be a higher risk of a rise in the water table following ash mortality. This rise in the water table can make management much more difficult as it limits the suite of species you can hope to replace ash following mortality. Ultimately, knowing the hydrology changes the management strategy for that lowland ash site.

Tree Level Data

Live crown ratio

- Live crown ratio (LCR) has been widely accepted for its correlation to tree vigor in the forestry community. If forest health is a concern, which is a definite when forming a response plan for EAB, then determining LCR is essential.

Diameter at breast height

- Diameter at breast height is the core data collection of most all forest inventories even when tree or stand volume is not a huge interest as it has a direct correlation to basal area.

Species

- An inventory needs to know what resource is available. In this case knowing where ash is occurring is a major interest and also know what species other than ash, your non-ash species, are present and available as potential replacement for ash species in light of EAB.

Overall product designation for the tree (See chapter 4 for reference)

- An overall product designation as opposed to AGS and UGS only, or a product designation for every 8-foot stick, appears to be the superior option in this inventory. If you have a forest inventory program that allows you to enter a product designation for every 8-foot section you will likely get more accurate merchantable volumes, as the program will employ a taper equation automatically. If you do not, which not all Wabanaki tribes do, then you can use the publicly available Forest Vegetation Simulator (FVS) to model your forest and get merchantable volumes and run management scenarios. Your merchantable volume will be more accurate as you can enter this data into the "tree_list" sheet of your FVS data base to correct any assumption FVS may make about your forest. You can still do merchantable volume from the data you collect with this manual without utilizing FVS.

Is it a Male, Female, or Polygamous individual?

- Many foresters that have growing concern for their ash resource have commented on the higher abundance of male ash trees in comparison to female ash trees. From a regenerative stand point this could be troublesome. Because they are easily distinguished by their branches having seed or not it can be a simple observation to get data on the ratio of male, female, and polygamous ash trees. This can influence artificial regeneration potentially by focusing planting of female seedings in areas where males are more prevalent in hopes to lead to more reproduction at maturity.

Presence of Exit holes

- Monitoring your forest for the signs and symptoms of the principal pest you are actively managing for is essential. There are only three signs that absolutely confirm EAB. This is one of them. EAB will leave characteristic "D" shaped exit holes when larvae have matured to adults and leave the tree.

Presence of Serpentine feeding galleries

- Monitoring your forest for the signs and symptoms of the principal pest you are actively managing for is essential. EAB larvae bore into the out cambial layer of ash trees to feed on the high sugar content. Their feeding galleries tend to show a characteristic “S” shaped serpentine pattern. This pattern is best observed when the borer is at low densities.

Presence of Actual insect Identified (adult or larvae)

- Monitoring your forest for the signs and symptoms of the principal pest you are actively managing for is essential. There are only three signs that absolutely confirm EAB. This is one of them the principal insect itself as an adult beetle or an immature larva.

Presence of Egg masses

- Monitoring your forest for the signs and symptoms of the principal pest you are actively managing for is essential. There are only three signs that absolutely confirm EAB. This is one of them. It is rare to identify a forest pests’ eggs but with identification keys and help from the state Entomologist EAB eggs can be a way of confirming EAB presence.

Glossary of Terms

A

Acceptable growing stock
: Growing stock that is classified as having potential to produce saw timber.

Active management
: Engaging in silvicultural and other forest management practices to improve wildlife habitat, forest health, or forest quality.

Aerial imagery
: Photographic images of the forest; Useful in analysis of forest cover types and stand type mapping.

Aesthetics
: a natural landscape value as established by visually appealing scenery.

Aftermath zone
: The condition of the forest following an emerald ash borer invasion. The density of EAB is very low at this condition, however, many of the ash trees are dead or in serious decline. Large seed-bearing ash are very few or non-existent. Any understory regeneration is borne from ash seed that was present in the seed bank prior to invasion. Parents to these ash seedlings are now dead. It is for this reason that scientist refer to this cohort of ash seedlings as the “orphan cohort’.

Animal browse
: Herbivorous fauna, such as deer or moose, prey upon the buds and sprouts of forest floor vegetation and seedlings. This can be very detrimental to regeneration efforts.

Annual growth increment
: In the northeast the spring and summer months are the growing season for trees. This growing season comes to an end in early fall. Growth rates decline throughout that time resulting in abrupt and distinct breaks in growth production. This abrupt change marks the annual growth increment. Basket makers are interested in annual growth width in terms of assessing its suitability for basket making.

Arborist
: Is a professional in the practice of arboriculture, a tree surgeon.

Artificial regeneration
: The regeneration of forested land through means of planting either direct seeding methods or with seedling stock.

Aspect
: The orientation of a slope in reference to its degree of solar radiation.

B

Bark splitting

A common symptom brought on by EAB feeding galleries.

Basal area

A measure of the density used in forestry. It is equated as the total cross-sectional area of all stems in a given stand, at breast height. Given as a per acre measurement.
Basal area factor

Basket quality brown ash

Brown ash that is exhibiting the characteristics and qualities of an ash tree usable in the art of basket making. Basket makers will often look at annual ring width, tree form, and size. In addition to that they look at various site conditions/characteristics associated with the tree.

Biodiversity

The variety of fauna present in a given ecosystem.

Biological control agent

A natural enemy to a given invasive pest. Introduction of this agent can be effective in controlling the invasive pests populations.

Blonding

Infested ash trees will have a high density of EAB larvae present. This presence attracts wood peckers and leads to excessive wood pecks along the stem of an ash tree. Early on this increased level of wood pecks creates a lightened bark along the stem of the tree and is referred to as blonding.

Break point diameter

During inventory procedures it is common to only require data collection on trees above a certain diameter. In this inventory it is 4.5 inches. This diameter is referred to as a break point diameter.

Brown ash corridor

Brown or black ash is often seen to occur in pockets, along streams, and throughout flood plains. Due to the small area of occurrence it can be commonly referred to as a corridor.

C

Cambium

The layer of a trees cross-section, just under the outer bark, and established around both the xylem and phloem of the tree.

Chain
A chain is linear measure of distance commonly used in the forestry industry. It is equivalent to 66 linear feet.

Characteristic plant communities
When describing the habitats and ecosystems common to a specific species it is useful to associate the plants that grow in its most favorable conditions to help locate areas that species is more likely to occur or locate areas to introduce that species to.

Clinometer
An instrument or tool commonly used to measure the slope and or the heights of trees in forestry settings.

Continuous forest inventory
A series of permanent plots used to monitor and follow the development, growth, and mortality of stands over time through periodic remeasurement.

Cooperative agreement
An agreement made with a governing agency to obtain funding or a thing of value. The application or use of these things by the recipient often has significant roles or influence played out by the government.

Coppice
A form of forest management that takes advantage of the natural ability of certain trees to prolifically sprout from the stump following harvest to regenerate a new cohort of trees in the forest.

Cultural practices
Are traditional and customary practices of a certain ethnic or cultural group. The art of basketry is a cultural practice of the Wabanaki people.

D

Defoliation
The loss of photosynthetic vegetation due to some external stressor.

Delineation
The setting or identification of a specific location for some sort of natural or manmade boundary. In the case of this manual it is a natural boundary set by the hydrological regime associated with the brown ash at a given site.

Depressional wetlands
A wetland established in a dip in the topography. The water associated with the wetland comes from the groundwater, precipitation, or inflow from adjacent upland areas.

Depth to Water table
The measure in centimeters through the soil until the natural water table for a given site is reached.

Diameter at breast height
: The measure of a standing trees diameter at 4.5 feet above the ground.

Die-back
: The loss of photosynthetic vegetation and death of twigs and branches due to some external stressor.

Dioecious
: An organism having the male and female reproductive organs present on separate individuals.

Drainage class
: Identifies the frequency and duration of wet periods for a given soil series.

Drought
: Extended periods of time without precipitation.

E

Ecosystem
: A biological community of organisms interacting with one another and the environment.

Ecosystem services
: The natural amenities provided by our natural world. They come in forms of provisioning, regulatory, supporting, and cultural services.

Efficacy
: The ability of something to produce a desired result or outcome.

Egg masses
: Invertebrates commonly lay multiple eggs in globulous structures on a variety of substrates. Female EAB beetles plant their egg masses on the bark of ash trees.

Elevation
: The relative level of vertical displacement for a geographical point in reference sea level.

Entomologist
: A scientist trained in the field of entomology or insects.

Evapotranspiration
: The process of water being transferred from land to the atmosphere. Can be done either through evaporation from the soil or other land surfaces or from the surfaces of leaves exhibiting transpiration.

Even aged stand
: A stand consisting of just one single cohort of trees. They may not be of the same species.

Exit hole

When adult EAB beetles have developed they must emerge from the tree. This is done by boring out through the cambium and outer bark. Resulting in “D” shaped exit holes

F

Feeding galleries

In the case of EAB, are “S” shapes or serpentine in shape. They are the areas where immature larvae feed before pupating.

Flagging

A term for referring to the yellowing or necrosis of leaves in a trees canopy. Often used as an indicator of low vigor or stressful conditions for a tree.

Floodplains

A low-lying area adjacent to a river that experiences pulsed or periodic flooding events generally seasonal.

G

Genetic resistance

The ability of certain individuals to withstand or remain unaffected by some external stressor that others of the same species are very negatively impacted by.

Germinate

The process for which a seed undergoes imbibition and begins to develop into a juvenile individual.

Germination programs

Programs set up for the propagation of collected seed for the purposes of nursery stock or planting efforts.

Ground vegetation

Herbaceous vegetation on the forest floor.

Group/patch selection

A systematic or randomly selected harvest layout used in forest management practices that typically work to promote natural regeneration.

H

Height to crown base

The height of a tree from the forest floor to the height of the first live branch.

Host species
A species in which some parasitic agent relies on for the harnessing of energy. The energy is harnessed, and the host is negatively impacted.

Hydrological setting
Is an area description that focuses on identifying the sources of water for the given site.

Hydrology
The study of earths water and its movement over land.

Hypertrophied lenticels
A physical adaptation of certain tree species for increasing oxygen exchange along the stem of the tree. This adaptation is often necessary when trees are growing in poorly aerated soils or water inundated soils.

I

Inoperability
A site that cannot sustain the operation of heavy equipment due to some characteristic.

Insecticide
A chemical treatment applied to vegetation to kill unwanted insect pests.

K

KZ value
A value falling between a range of numbers set by the expected total for a given metric that is being estimated in a 3P inventory process.

L

Larval beetles
Refers to the immature stage of an insect.

Larval parasitoid
Female parasitoids that use their ovipositors to inject their eggs into the bodies of larvae feeding in the phloem of a tree. These injected eggs develop by robbing the larvae of nutrients and eventually kill the larvae and emerge as juvenile parasitoids.

Leaf-off imagery
Aerial imagery that was taken following the leaf cast of deciduous trees.

Legacy trees
Trees that are left following forest harvests either for their unique contribution to biodiversity and/or genetic superiority.

LiDAR

A remote sensing technology that uses a laser to precisely measure elevation.

Live crown ratio

The measure of vegetated crown on a tree relative to its overall height.

Log

Is a product designation for trees greater than 10 inches in diameter and clear of defects on at least three sides. The diameters and number of clear faces can vary mill to mill and region to region.

M

Micro sites/Microtopography

The surficial features of a site on a microscopic scale. Often measured in degrees of pits and mounds present. These areas often serve as excellent sites for planting as they promote establishment for the planted seedling.

Multi aged stand

A stand consisting of multiple (3 or more) age classes or cohorts.

N

Natural regeneration

Newly established cohorts of trees that were not planted or seeded by man.

Nested regeneration plots

Smaller subplots that are often placed on or oriented around the center of an exist larger plot. They are used to survey the regenerative component present on the plot.

O

Ornamental tree

A tree planted for its aesthetic value. It may or may not be native to the given area. They most commonly occur in urban settings.

Outwash plains

Are plains formed from deposited materials that melted out of the terminal end of a glacier. These sites tend to be in low lying areas.

Over-story removal

A final harvest associated with a shelterwood sequence that is used to release a naturally regenerated understory component.

Overwintering

An extended period for which insects go dormant when climatic conditions are not favorable for development

P

Parasitoid

An insect whose larvae live as parasites that eventually kill their host.

Percent composition

A measure of abundance for some specific subset of something relative to the total of that thing.

Percent composition of EAB infested trees

A measure of abundance for infested ash trees relative to the total number of ash trees in a given area.

Phloem

The tissue within a tree correct that is responsible for the conduction of sugars and other solutes.

Plant geneticist

A scientist involved in the study of plant genetics in the discipline of botany.

Polygamous

An individual that exhibits both male and female reproductive organs.

Ponding frequency

A measure of the number of times surface ponding of water occurs on an annual basis.

Pre-salvage logging

Logging done to capture mortality that is expected to occur in the somewhat near future. It is never a sure thing that this expected mortality would ever have actually occurred.

Pulpwood

A grade of timber that serves its highest and best use in the production of paper.

Pupae

The stage of insect development between the immature larval stage and the adult stage.

Pupate

The act or process, in which an insect transforms from the larval stage to the adult stage.

Q

Quarantine

A geographic isolation of forestland that is subject to the infestation or potential infestation of a forest pest. Exportation of potentially infested materials is commonly regulated or prohibited in these areas.

R

Remediation
: The process of remedying a situation from some undesirable state to a more desirable state.

Remote delineation
: The remote or out of field setting/identification of a specific location for some sort of natural or manmade boundary. In the case of this manual it is a natural boundary set by the hydrological regime associated with the brown ash at a given site.

Remote sensing
: The scanning of the earths surface in order to obtain information about it.

Resilience
: The capacity of a tree to recover quickly to the impacts of some external stressor.

S

Samara
: The winged nut, seed, or achene of a tree.

Sapling
: Any stem greater than 0.5 inches at DBH, but, less than 4.5 inches at DBH.

Seed banking
: Facilities that store seeds for preserving genetic diversity or the natural storage of seeds in the duff layer and subsoil of a site, some species can store for longer than others in this natural storage setting.

Seed tree
: A mature and dominant seed-bearing tree capable of producing offspring.

Seed-bearing individuals
: Any tree that is capable of producing seed and eventual offspring.

Seedling
: A newly established individual tree coming from a germinated seed.

Shade-tolerance
: The relative ability of a tree species to withstand shaded or low light conditions.

Shelterwood
: A forest management strategy that establishes ideal light conditions for a target regenerative species and follows their establishment with a release cut that allows those regenerated individuals to infiltrate the canopy.

Shrub layer

The layer of wood stemmed vegetation that exist below that canopy. Generally no larger that 15 feet in height.

Signs

Signs are direct evidence of the presence of a specific principal tree pest of disease.

Silviculture

The art and science of growing trees for desirable size/volume, quality, health, and composition

Single tree selection

A silvicultural or forest management technique that targets specific trees for removal. If a silvicultural technique trees are targeted with some consideration to a catering the desired development of a younger cohort.

Slope

A setting in the terrain in which one end is at a higher elevation than the other.

Soil orders

The most general level of classification for soil types set forth by the U.S. Department of Agriculture.

Soil series

An intermediate level of classification for soil types as set forth by the U.S. Department of Agriculture.

Species diversity

Is the number of different species represented in a given area.

Sprouts

A juvenile stem that is borne from the roots or stumps of individuals undergoing increased levels of environmental stress.

Stand

The principal unit for which silvicultural prescriptions are derived for. A stand is composed of a community of trees sufficiently uniform in composition, spatial arrangement, site quality, and condition.

Stand type mapping

Aerial mapping that breaks the forest into various stand types based on the composition, management history, age, etc…

Strip cutting

A systematic harvest layout in evenly spaced strips. Commonly used in forest management practices that typically work to promote natural regeneration.

Studwood
A grade of timber that serves its highest and best use in the production of structural dimensional lumber.

Symptoms
The biological responses observed for trees impacted by some external stressor.

Systemic insecticide
Systemic insecticides are insecticide treatment that require transport throughout the tree from within its tissues. For this reason, they are very soluble and are often injected.

T

Topography
The arrangement of natural physical features in an area.

Total height
The overall height of tree from ground to the top of the crown.

Traditional ecological knowledge
Refers to the extensive knowledge of native or indigenous communities that has been acquired over hundreds of years through direct contact with their natural environment, this knowledge is passed down generation to generation.

Tree crown
The live or vegetated bowl of the tree.

Tree Vigor
A trees capacity to resist stress or strain in its natural environment.

Trunk injection
A method of applying insecticide treatment where needles allow for direct injection into the ash tree.

T-value
The transformed DBH value that is estimated is known as the t-value it is compared to a KZ value for it determination as a sample tree in the 3P inventory strategy.

Two-aged stands
A stand consisting of just two different age classes or cohorts.

U

Unacceptable growing stock
Growing stock that is classified as never having the potential to produce saw timber.

V

Veneer log

A grade of timber that serves its highest and best use in the production of high-quality saw timber. Veneer logs need to be at least 10 inches in diameter and be free of defect on all four sides. This diameter can vary species to species, mill to mill, and region to region.

W

Water Inundation

An overabundance or constant flooding of water.

Water Soluble

Able to dissolve in water.

Water Table

The level below which the ground is saturated with water.

Wykoff Coefficient

A Unitless coefficient specific to a certain species that is used in the Wykoff equation for determining the height of a tree.

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Appendices

Appendix 1: An Ash Resource Inventory Case Study: The DeMeritt Forest in Orono, ME

Case Study Introduction and Project Area Description:

With emerald ash borer looming in the background, forest managers are on high alert to monitor their ash resource and manage accordingly. The inventory strategy reviewed here is set to follow the recommendations set forth by the "EAB Response: An Ash Resource Field Inventory Manual" (referred from this point on as "ash manual"). The methods section of this report is broken into three sections highlighting the process associated with the three stages established by the ash manual; stage 1, stage 2, and stage 3. Similarly, the results section is broken into two sections to display the results following implementation of stage 2, and stage 3 of the ash manual. Stage 1, as the manual explains, is an existing dataset. Here that existing dataset was verbal confirmation of ash presence by the forest manager (Keith Kanoti) associated with this case studies principal ash stand. This inventory for obvious reasons requires a stand consisting of a strong ash (*Fraxinus spp.*) component.

The DeMeritt Forest is located on College Avenue Extension in Old Town, ME. It is managed by the University Forests of the University of Maine. For the case study, we focused on a 12.35 acre stand with the necessary strong ash component (minimum (10%) composition of ash). This mimics a stand that would be identified following a stage 1 inventory, as explained in the ash manual. A recent harvest was preformed up to the southern boundary of the stand. This report looks at the hydrological features, soils, variable radius cruising data, and some "3P" sampling data collected on this 12.35 acre stand on April 5th, 2019; April 17th, 2019; and April 18th, 2019.

Given that there is a significant component of ash (*Fraxinus*) species represented the primary concern in this woodlot is to formulate a response plan for the invasive insect emerald ash borer, *Agrilus planipennis.* The ash manual is supposed to serve as a guide for forest managers. A guide that will focus efforts toward attaining the necessary data for formulating a management regime for a landowner's ash resource in light of EAB. This paper will quantitatively analyze the efficacy of the inventory strategies recommended in the ash manual. This should allude to the overall usefulness associated with the data, that has been collected in accordance to the manual, in formulating an EAB management regime. The better the data summarizes the characteristics of the stand the easier it will be to implement the necessary active management activities that are mentioned in the ash manual.

Methods

Stage 1: An existing Dataset

As previously mentioned the principle stand of this case study mimics that of a stand identified using an existing dataset following stage 1 of the ash manual. The manual prompts the user to answer a series of follow-up questions before moving forward to stage 2 of the inventory. The answers to those questions as they pertain to this stand are as follows:

- **Question:** What is the estimated number of years until next harvest/development/land-use change or conversion?
- **Answer:** This woodlot has no current harvest plan in order for the next 5 years, according to Keith Kanoti, the Universities head forester.

- **Question:** What is the relative level of human activity on or around the stand?
- **Answer:** The woodlot is subject to moderate human activity. This is due to public visitation occurring every other week. There is a lack of recreational trails in the stand but due to the proximity to the University, students and the public do use the woodlot for recreational purposes.

- **Question:** What are the nearby major roads, developed areas, open areas, or surface water features?
- **Answer:** The only major road near this woodlot is the college avenue extension, which runs along the woodlot's eastern boundary. On the woodlot's western boundary, the Stillwater River can be observed with an inlet that runs through the center of this woodlot.

- **Question:** What is the percent composition of ash?
- **Answer:** In this case the exact percent composition of ash was acquired with a pre-cruise of the woodlot using four variable radius sample points, the PC was determined to be roughly 11% across the upland and lowland section of the stand.

- **Question:** Is the woodlot connected to adjacent woodlots or is it isolated?
- **Answer:** Due to the low level of development of the Old Town and Orono, Maine area the stand is not isolated and still has forested connections to adjacent woodlots on the university forest lands.

- **Question:** What is the proximity of this stand to known EAB infestations? (measured in miles)
- **Answer:** EAB infestations have been reported in Edmundston, NB, Canada; Sherbrooke QC, Canada; and Lebanon, ME, United States the distances to these known infestations are 169, 158, and 153 miles respectively.

- **Question:** What is the proximity of this stand to known EAB quarantined areas? (measured in miles)
- **Answer:** The known EAB quarantine areas, based off the above mentioned infestations, are a portion of Aroostook County, ME, United States; all of the Province of Quebec, Canada; and all of York County, ME, United States. Those quarantine areas are at a distance of 149, 100, and 124 miles respectively.

An assessment of soils using the USDA's web soil survey application is required in the ash manual following stage 1. Our soil survey revealed an exceptionally variable representation of soil series for a 12 acre stand. In total this stand is made up of 5 different series of varying drainage classes and depth to water table designations, this is displayed in map 2 of the supplemental materials section. This variability alone leads us to believe the stands species composition could be quite variable throughout. We can also see the previously mentioned stream appears to follow along the swanville silt loam complex, a common soil association of brown ash species (*Fraxinus nigra*), and dumps into the Stillwater River. Another requirement following stage 1 is importation of National Wetlands Inventory data into a GIS. Our NWI data revealed the southern portion of the above referenced stream is designated as a PFO1E wetland according to the National Wetlands Inventory database and can be seen on map 3 of the supplemental materials section.

Stage 2: A Variable Radius Technique

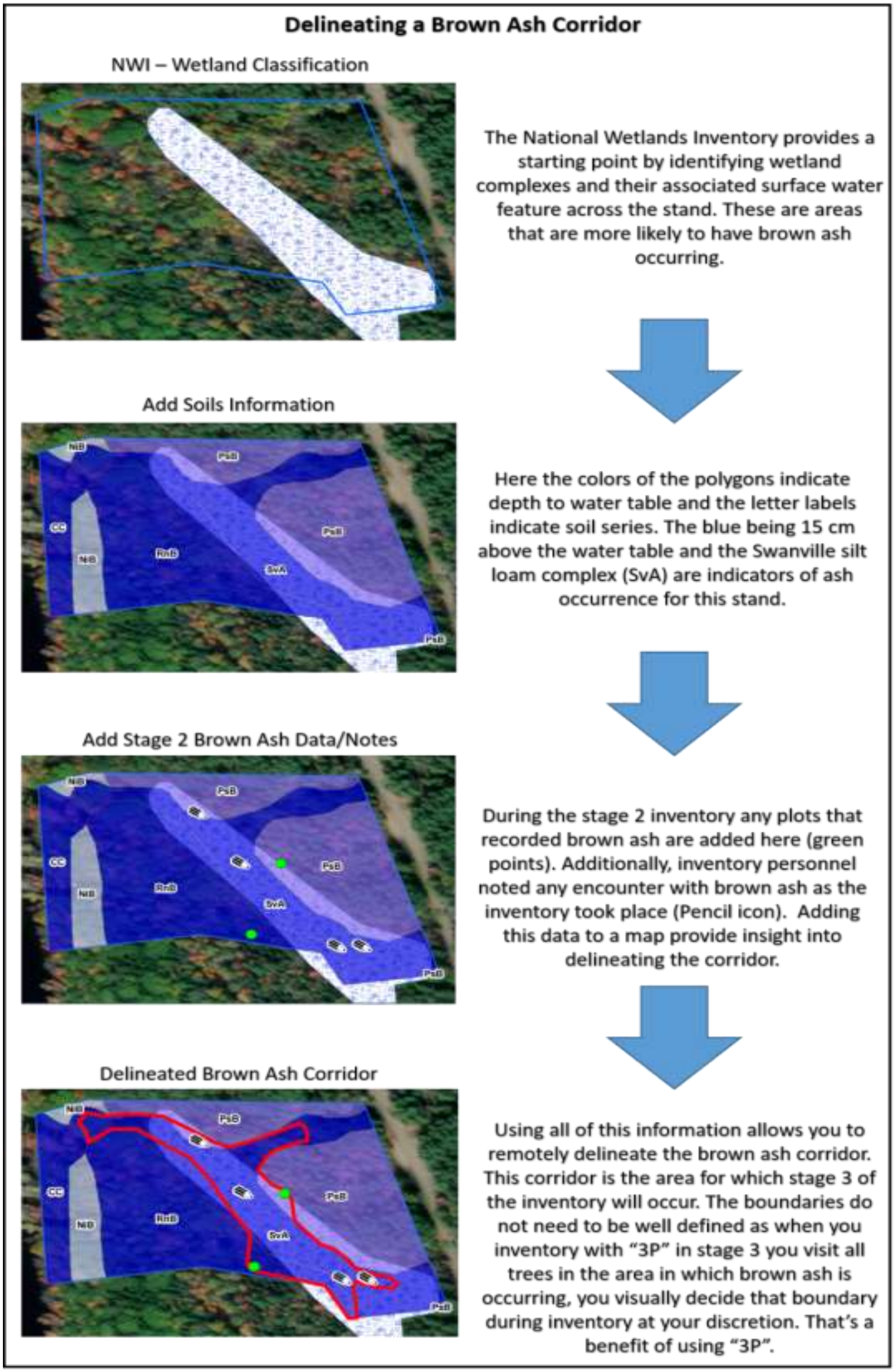
The site assessment information obtained in stage 1 brought us forward to stage 2, a variable radius inventory technique. The layout of these plots consisted of 8 systematically established plots throughout the stand, this can be seen in the aerial map labeled as Map 4 of the supplemental materials section. The systematic grid for this woodlot was laid out on a 15-degree northeast offset. The plots fall 4 chains apart, which works out to 1 plot for every 1.5 acres. This aligns with the area-based threshold for inventories accepted by the Natural Resource Conservation Service (NRCS) for variable radius techniques using a 20 basal area factor prism (BAF).

As the ash manual recommends, to stay in accordance with that inventory standard a 20 BAF prism must be used. So, starting in the north direction all "In" trees, according to a swing of the 20 BAF prism, were assessed for tree level data as suggested in the ash manual. A variety of stand level and plot level data were also collected. At the completion of each plot a regeneration survey using a 1/100th acre circular plot was performed. This required a stem count for all sapling size species represented in the plot. A sapling was defined as any stem >0.5 in DBH and <4.5 in DBH. For details on the data collected, reference the ash manual. On April 5th, 2019 a 5-man crew set out in the southeastern corner of the stand and began taking inventory for the 8 plots. Inventory procedures continued for approximately 2 hours and 5 minutes before all 8 plots were sampled to completion.

The stand level, plot level, and tree level data were collected in accordance to the ash manual. Data was recorded on printed out excel data sheets that were provided in the ash manual. Data was then transferred to that same excel file for analysis in Microsoft Excel.

Following this data analysis, a geographical analysis of the data using ESRI ArcMap allowed us to set boundaries of a corridor in which brown ash *(Fraxinus nigra marsh)*, is more likely to occur. This corridor will be sampled using a “3p” sampling technique as indicated in the ash manual. This process is outlined visually in figure A-1 on the next page.

Figure A-1


Delineating a Brown Ash Corridor
NWI – Wetland Classification
The National Wetlands Inventory provides a starting point by identifying wetland complexes and their associated surface water feature across the stand. These are areas that are more likely to have brown ash occurring.
Add Soils Information
PsB
NiB
CC
RnB
SvA
Here the colors of the polygons indicate depth to water table and the letter labels indicate soil series. The blue being 15 cm above the water table and the Swanville silt loam complex (SvA) are indicators of ash occurrence for this stand.
Add Stage 2 Brown Ash Data/Notes
During the stage 2 inventory any plots that recorded brown ash are added here (green points). Additionally, inventory personnel noted any encounter with brown ash as the inventory took place (Pencil icon). Adding this data to a map provide insight into delineating the corridor.
Delineated Brown Ash Corridor
Using all of this information allows you to remotely delineate the brown ash corridor. This corridor is the area for which stage 3 of the inventory will occur. The boundaries do not need to be well defined as when you inventory with "3P" in stage 3 you visit all trees in the area in which brown ash is occurring, you visually decide that boundary during inventory at your discretion. That's a benefit of using "3P".

Stage 3: A 3P Inventory Technique

The ash corridor was first remotely delineated using the process outlined above in figure A-1. It was then cruised using the 3P inventory technique; requiring visual estimations of DBH and species for all 146 trees, above 4.5 inches DBH, that occurred within the remotely delineated brown ash corridor. This resulted in a total of 6 sample trees using a KZ value of 267. For details on the 3P inventory technique reference the ash manual. Data was recorded using a handheld tablet in the field. This was done for convenience of comparing the random number to our estimates. Data analysis was done following inventory in Microsoft Excel. Following data collection and analysis the true extent of brown ash occurrence was delineated in the field. This in-field delineation was recorded using GPS for comparison to the remotely delineated brown ash corridor. This comparison can be seen in figure A-2.

The quantitative analysis of stage 2 and 3 data was done in Microsoft excel. Data analysis of both stages were used in conjunction with the suggested silvicultural prescriptions from the ash manual to develop a management regime for this 12.35-acre ash stand. The results from this case study are addressed below.

Results

Stage 2: A Variable Radius Technique:

Following the collection of the variable radius data it appears the sampling was sufficient enough to capture the variability associated with the stand. Our data results returned a very low allowable error as seen in table A-1 below.

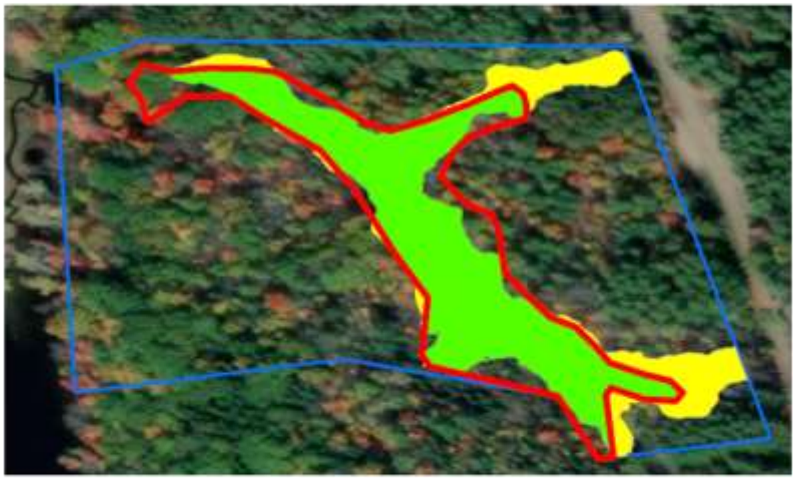
Table A-1

Arithmetic Mean (BA) ft^2 ac^{-1}	Standard Deviation (BA) ft^2 ac^{-1}	%Coefficient of Variation (BA)	Current % Allowable Error (BA)
117.5	45.9	39%	10%

Quantitative analysis of stage 2 data using the calculated basal area for each sample point. (i.e. (BA) indicates basal area)

After this quantitative analysis it appears that to effectively formulate an EAB response plan for this stand a 10 percent allowable error is acceptable for the variable radius inventory technique. This stage of the inventory is meant to set up the brown ash corridor for which the "3P" sampling is done. Below is a figure that alludes to the efficacy and accuracy associated with establishing the brown ash corridor. The remotely delineated corridor (red outline) is shown in comparison to an in-field delineation of confirmed brown ash occurrence (yellow polygon).

Efficacy of Using This Strategy to Delineate a Brown Ash Corridor



The image above shows three polygons and the stand boundary. The red outline shows the remotely delineated brown ash corridor that was established through the process that is visually represented in the **"Delineating a Brown Ash Corridor"** figure on the previous page. The yellow polygon is an in-field delineation of the brown ash corridor. The boundaries for that corridor were set in the field based on the confirmed presence of brown ash. The green polygon is the area of overlap between the in field and remotely delineated brown ash corridors. This figure displays the accuracy and efficacy of using the previously described strategy for remotely delineating a brown ash corridor. Below is a table showing the area of each polygon in acres.

Polygon	Remote Delineation	In-Field Delineation	Area of Overlap
Acres	2.6	2.8	2.07

This diagram was established in a GIS program and then edited for ease of viewing for the purposes of this case study and the ash manual. The original maps can be seen below as maps 4 and 5 of the supplemental materials section. Referencing them can provide visual clarity on the delineation process.

Stage 3: A 3P inventory Technique:

With this corridor established the stage 3, 3P inventory was executed. As previously mentioned the inventory resulted in 6 sample trees. For these sample trees a correction ratio was caculated by dividing the measured DBH by the estimated DBH. This ratio was averaged across the 6 sample trees.

Quantitatively analyzing these correction ratios has been accepted as a means for assessing the accuracy of a 3P inventory. That quantitative analysis can be seen below in table A-2.

Table A-2

Arithmetic Mean (CR)	Standard Deviation (CR)	%Coefficient of Variation (CR)	Current % Allowable Error (CR)
1.08	0.16	14%	4%

Quantitative analysis of stage 3 data using the calculated correction ratios for each sample tree. (i.e. (CR) indicates correction ratio)

This analysis of the stage 3 data reveals a high level of accuracy associated with the 3P data. It is important to note that these results can vary dependent upon the inventory personnel's ability to consistently estimate the DBH of the trees. Data that describes the true mean of the brown ash corridor can be utilized well in the development of an EAB response plan for this ash stand and its associated brown ash corridor.

Useful Management Data

Along with the accuracy of depicting the true mean of the stand, the data associated with these two stages can be easily post processed in excel to produce data and figures useful for making management decisions.

Below in figure A-3 is a diameter distribution for stage 2. Figure A-4 shows this for the stage 3 data. The ash manual explains this is a necessary piece of data to move forward in management prescriptions.

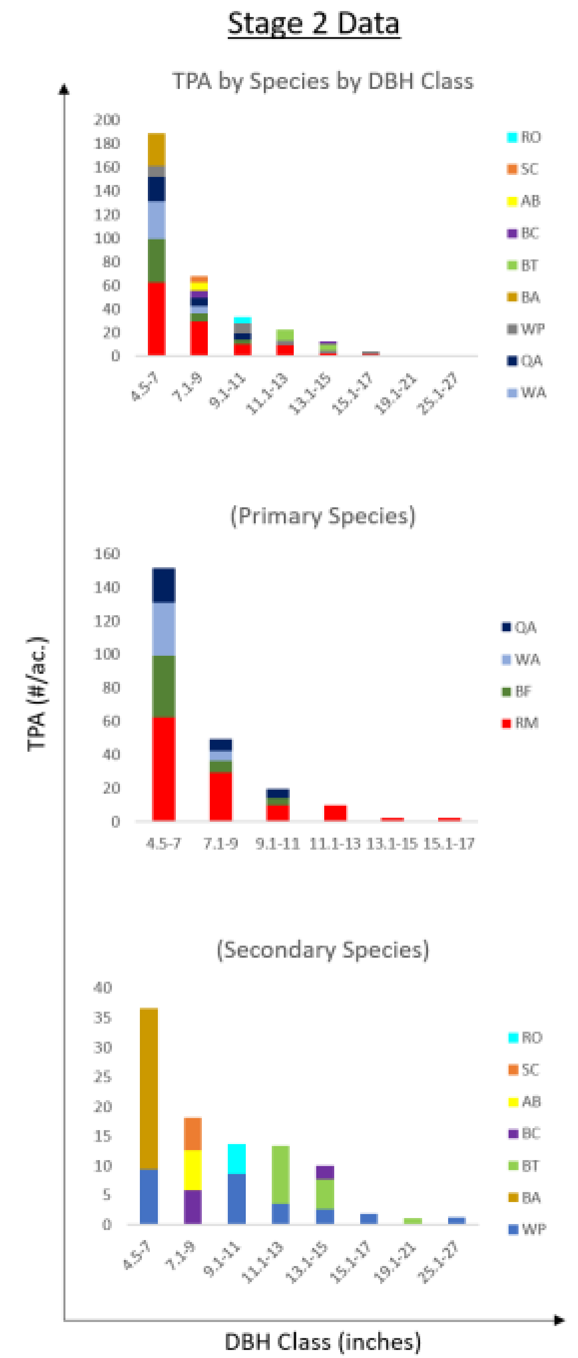


Figure A-3 The diameter distribution for all species recorded during the stage 2 inventory. Graphs are organized with diameter class on the x-axis and trees per acre on the y-axis. Species are color coded and their respective FVS alpha codes can be seen in the key, to the right of each graph. The top graph shows all species recorded. The middle graph shows the primary species recorded. The bottom graph shows the secondary species recorded. Their designation of primary and secondary was based on overall occurrence during inventory.

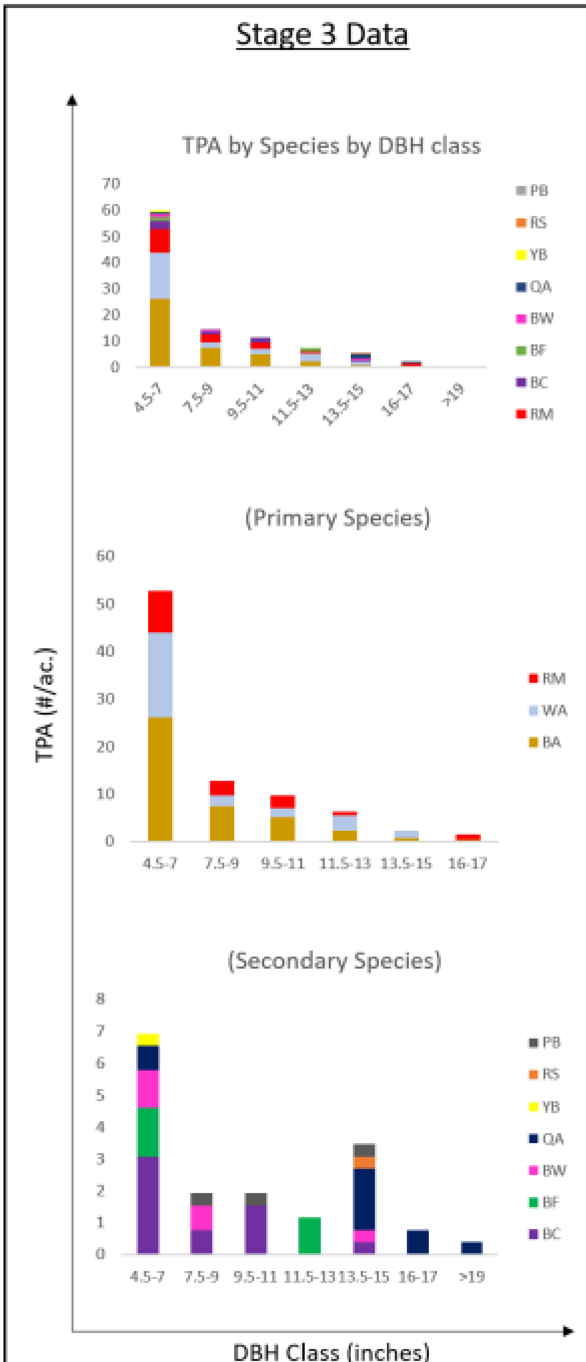


Figure A-4 The diameter distribution for all species recorded during the stage 3 inventory. Graphs are organized with diameter class on the x-axis and trees per acre on the y-axis. Species are color coded and their respective FVS alpha codes can be seen in the key, to the right of each graph. The top graph shows all species recorded. The middle graph shows the primary species recorded. The bottom graph shows the secondary species recorded. Their designation of primary and secondary was based on overall occurrence during inventory.

Table A-3

Stand Table for the 12.35 acre mixed species ash (*Fraxinus*) stand stand in Old Town, Maine. Data sourced from stage 2 of inventory. Data was generated from the U.S. Forest Service program, forest vegetation simulator (FVS). Volumes given in cubic feet.

		No. of Trees		Cubic-foot volumes (per acre basis)			Cubic foot volumes (stand totals)		
DBH Class, in.	Basal Area	Stand Total	Per acre	Pulp/ac.	Saw Log/ac.	Total/ ac.	Pulp	Saw Log	Total
04	20.0	1752	142	142.3	0.0	142.3	1757.7	0.0	1757.7
08	41.3	1596	129	961.2	13.6	974.8	11871.4	167.7	12039.1
12	30.7	521	42	465.3	440.6	905.9	5746.4	5440.9	11187.3
16	17.3	165	13	86.3	501.0	587.3	1065.8	6187.1	7252.9
20	2.7	14	1	7.0	91.4	98.4	86.3	1128.6	1215.0
28	2.7	9	1	1.8	108.5	110.3	22.5	1340.1	1362.7

Table A-4

Stock table for the 12.35 acre mixed species ash (*Fraxinus*) stand stand in Old Town, Maine. Data sourced from stage 2 of inventory. Data was generated from the U.S. Forest Service program, forest vegetation simulator (FVS). Volumes given in cubic feet.

		No. of Trees		Cubic-volumes (per acre basis)			Cubic-volumes (stand totals)		
Species	Basal Area	Stand Total	Per acre	Pulp/ac.	Saw Log/ac.	Total Vol./ac.	Pulp	Saw Log	Total Vol.
AB	1.3	44	4	36.6	0.0	36.6	451.4	0.0	451.4
AE	1.3	90	7	13.8	0.0	13.8	170.5	0.0	170.5
BA	5.3	240	19	121.4	0.0	121.4	1499.6	0.0	1499.6
BC	4.0	80	6	83.1	31.1	114.2	1026.3	383.5	1409.8
BF	6.7	400	32	78.6	20.7	99.4	971.0	256.1	1227.1
BT	8.0	105	8	93.9	188.1	282.0	1159.5	2323.5	3483.0
PB	6.7	403	33	131.4	0.0	131.4	1622.5	0.0	1622.5
QA	10.7	448	36	120.7	134.6	255.3	1491.2	1662.0	3153.2
RM	33.3	1085	88	554.5	241.4	796.0	6848.4	2981.8	9830.2
RO	4.0	189	15	55.1	29.1	84.2	680.2	359.1	1039.3
SC	1.3	37	3	20.5	13.6	34.1	253.5	167.7	421.2
WA	16.0	708	57	258.6	59.2	317.8	3193.3	731.5	3924.7
WP	16.0	229	19	95.8	437.2	533.0	1182.9	5399.2	6582.1
Total	114.7	4056	328	1664.0	1155.0	2819.0	20550.2	14264.5	34814.7

In many management scenarios basic metrics describing the stands density and value in terms of volume are useful. In tables A-3 and A-4 a stand and stock, respectively, can be seen for the stage 2 data. The stand and stock data was generated with the Forest Vegetation Simulator. Additionally, table A-5 displays a variety of stand level metrics generated from the stage 2 data. Discrepancies between volume estimations in stage 2 tables is due to methodology differences in calculation. Table A-5 uses the VBAR method and FVS has another standard method for volume calculations in place.

The stand and stock data for stage 3 data can be seen in tables A-6 and A-7, respectively. The same stand level metrics were generated at a "corridor level" for this stand's associated brown ash corridor. This data can be seen in table A-8. Discrepancies between total volume and basal area in stage 3 tables is due to the manipulation of 3P data for FVS input as well as the addition of regeneration data when entered in the FVS.

Table A-5

QMD (in.)	Basal Area	Total Vol. (ft^3)	Vol./Ac (ft^3 ^{-1}ac)	Total Vol. (cords)	Vol./Ac (cords ^{-1}ac)
8.1	114.7	40726.1	3297.7	479.1	38.8

Table A-6

Stand Table for the 2.6 acre brown ash (*Fraxinus nigra*) corridor in Old Town, Maine. Data sourced from stage 3 of inventory. Data was generated from the U.S. Forest Service program, forest vegetation simulator (FVS). Volumes given in cubic feet.

		No. of Trees		Cubic-foot volumes (per acre basis)			Cubic foot volumes (stand totals)		
DBH Class, in.	Basal Area	Stand Total	Per acre	Pulp/ac.	Saw Log/ac.	Total/ ac.	Pulp	Saw Log	Total
4.0	4.6	94	36	23.4	0.0	23.4	60.8	0.0	60.8
8.0	12.3	107	41	250.4	0.0	250.4	651.0	0.0	651.0
12.0	13.0	47	18	191.0	140.3	331.3	496.6	364.8	861.4
16.0	9.1	18	7	45.0	213.1	258.1	117.0	554.1	671.1

Table A-7

Stock table for the 2.6 acre brown ash (*Fraxinus nigra*) corridor in Old Town, Maine. Data sourced from stage 3 of inventory. Data was generated from the U.S. Forest Service program, forest vegetation simulator (FVS). Volumes given in cubic feet.

		No. of Trees		Cubic-volumes (per acre basis)			Cubic-volumes (stand totals)		
Species	Basal Area	Stand total	per acre	Pulp/ac.	Saw Log/ac.	Total Vol./acre	Pulp	Saw Log	Total Vol.
BA	14.1	109	42	223.8	92.4	316.2	581.9	240.2	822.1
BC	2.6	16	6	29.4	27.5	56.9	76.4	71.5	147.9
BF	1.9	8	3	8.5	34.6	43.1	22.1	90.0	112.1
BW	0.5	5	2	7.4	0.0	7.4	19.2	0.0	19.2
PB	0.4	3	1	11.4	0.0	11.4	29.6	0.0	29.6
QA	3.9	10	4	18.8	86.8	105.6	48.9	225.7	274.6
RM	5.8	42	16	85.7	35.0	120.7	222.8	91.0	313.8
RS	1.0	3	1	3.5	23.1	26.6	9.1	60.1	69.2
WA	8.8	70	27	121.3	54.0	175.3	315.4	140.4	455.8
Total	39.1	265	102	509.8	353.4	863.2	1325.5	918.8	2244.3

For the stage 2 data, the overall product designations were calculated out to a per acre basis in excel. This data was explained useful in generating management regimes for both lowland and upland ash stands. Stage 3 being only 2.6 acres is difficult to describe using per acre values for product designations, as there were only 6 sample trees. In a larger corridor these may be more useful. The per acre product designations are displayed in table A-9.

Table A-8

Basal Area	Total Vol. (ft^3)	Vol./Ac (ft^3 ^{-1}ac)	Total Vol. (cords)	Vol./Ac (cords ^{-1}ac)
114.7	40726.1	3297.7	479.1	38.8

Table A-9

Product Designation	Pulp	Saw Log	Potential Saw Log	Cull
TPA (#/ac.)	260	35	35	1

Conclusion

Conclusions can only be drawn on the effectiveness of these inventory strategies (stage 2 and 3) at deriving accurate data with exceptional stand errors for the 2.6-acre stand used in the case study. This conclusion is affirmed in tables A-1 and A-2. It cannot be claimed effective on all ash stands. Modifications and alterations to the data collection and inventory scheme may be necessary to replicate this level of accuracy in data collection on other ash stands.

The inventory for stage 2 was quick and efficient, a common benefit of variable radius inventories. The overall inventory took just 2 hours and 5 minutes to be completed by a 5-man crew. Given the data needed for collection this is an acceptable length of time to spend on inventory. For stage three the inventory took too long. Completion of the inventory was not achieved until 3 hours and 12 minutes had passed. This is far too long to spend on inventory, when the area of interest is just 2.6 acres in size. This extended period was caused largely by the inventory personnel's need to mark every tree in the corridor with a lumber crayon, as well as the slow rate for which the inventory personnel were able to confidently estimate the tree's DBH. Over time, with practice, these issues will be minimized, and the efficiency associated with the stage 3, 3P technique, will not take nearly as long to execute.

When it came to the tree level data, tree heights were the limiting factor in efficiency. Many of the stand level data was collected with a quick observation of the surrounding area. Topography was very easily calculated using a topographical layer in a GIS platform. A solution to the issues around height measurements was suggested in the ash manual. The solution was to flag trees that are indicated as a sample tree for a crew designated with the task of taking measurements follows behind.

Overall this inventory strategy is very effective in providing data to describe the stand. Is that the necessary data for formulating an EAB management response plan though? The only way test that is to come up with a management regime based off the data collected in accordance to this ash manual.

Management Recommendation

The above results from inventory of this 12.35-acre ash stand make a management recommendation complex. This is because across the small 12.35 acre stand there are two different ash stands. The upland stand and the lowland stand. Each need to be managed differently. But, in addition to being managed differently the management decisions on one affect the other. For that reason, it is easiest to prioritize management and then manage secondary components accordingly.

Because the ash manual puts emphasis on protecting the culturally significant brown ash species, this recommendation starts with the 2.6-acre brown ash corridor. The hydrology of any brown ash site is a primary concern in terms of management. For this brown ash site the hydrology, according to inventory, is a ground water slope. This indicates that water for this site is sourced from precipitation and the Still Water River primarily; but it also uses ground water inputs during the drier parts of the season. These wetland systems have not been seen to show correlation to a rising water table following an EAB attack. This is a good thing, as it means shifting toward in alternative species is not as demanding of a potential issue as it could be.

With a rise in the water table a non-issue, I do not recommend the use of active management to promote an alternative species for this brown ash site. The corridor is dominated by brown ash currently but the understory, according to regeneration surveys, seems to be heavily favored by red maple and white ash. Red maple, although it has no cultural significance to the Wabanaki people, will serve as a naturally regenerated "alternative species" at this site, without any active management efforts. To help along with that shift creating some dialogue between forestry staff at the University and ash harvesters/basket makers can facilitate some harvests of basket quality brown ash from this site. With those BQBA erased from the canopy, a majority of the available growing space will be captured by the faster growing red maple saplings in the understory. This shift should help maintain stocking on this stand during the impacts it may receive during an EAB attack. The only concern would be with those areas where invasives or competing shrub vegetation were recorded in the corridor. Some site preparation may be required in these areas to control the growth of these shrub species, herbicides will likely not be permissible due to local regulations in these areas, nor do I recommend their use in this site preparation due to the potential for pollution. It is important to note the need to shift to alternative species like red maple would be more pressing if a known EAB infestation were closer. Once within 10 miles of an infestation the shift should be well underway as just 2-4 years remain before the area will likely be infested. Like the ash manual stresses, it is important to maintain an ash component within the corridor for a variety of benefits that are provided. This is why it is important to monitor the harvests by the basket makers/harvesters to be sure that a component of brown ash remains on the site. In order to effectively do this keeping a presence not enough, the brown ash that remain should be in healthy condition and preferably seed bearing. Keeping an eye on the male to female ratio of ash trees can be useful here.

If it is a primary concern to maintain a brown ash component in the corridor, there are management activities in the upland stand that can be done to help this effort. First, although this is labeled an ash stand the upland site has a much smaller component of ash than the corridor does. The upland sites have an ash percent composition of just 11% whereas the corridor has a percent composition of 67% this can be seen in the diameter distributions as well. This is expected but should be carefully considered when determining a management strategy. Of course, it would be counter intuitive to promote white ash in the upland sites because it is at risk of attack by EAB. But, maintaining a component of ash in the upland area is important, for this reason no white ash should be harvested in the upland sites except in the case of salvage after attack by EAB has occurred, and in the case of a salvage harvest it must be done in accordance to any quarantines for the area. The importance in maintain an upland ash population is two-fold. It provides biological diversity and it provides a management tool. These upland ash trees can be girdled and used a trap trees to control local beetle populations, hopefully pulling them away from the more desirable brown ash in the corridor. Trap trees are selected relative to there position to the corridor but also their relative health. A tree that is in a good healthy condition may be a white ash tree that has a genetic resistance to EAB. For this reason, white ash that are showing sign of decline or die-back should be selected as trap trees.

Species	Avg. TPA (#/ac.)
WP	25
RM	88
QA	25
BF	63
BA	38
RO	25
WA	138
Total	400

Table A-10
Regeneration data for stage two. Data is presented in a stems per acre basis. FVS alpha codes for each species are used.

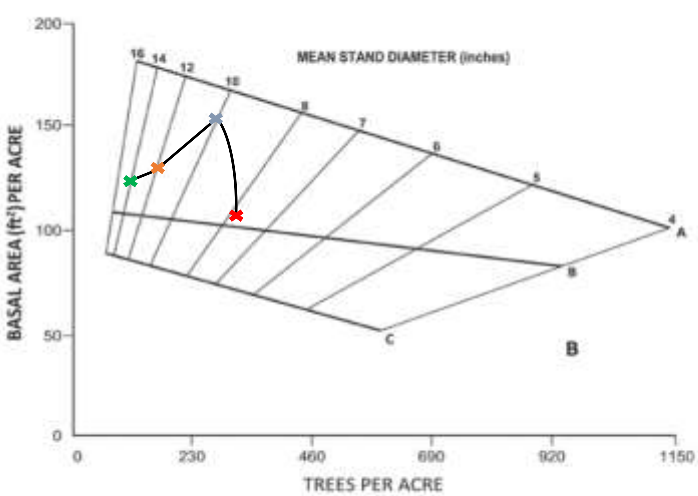


Figure A-5
Northern hardwood stocking chart (Leak et al.,2014) displaying proposed management for the 12.35 acre ash stand in Old Town, Maine. Red "X" indicates current stocking. Blue "X" indicates stocking at time of shelterwood preparatory cut. Orange "X" indicates residual stand after thinning. Green "X" indicates stocking prior to overstory removal.

Being sure to maintain those white ash trees in the upland component allows you the freedom to exercise some silvicultural creativity. Currently the stand needs additional time to grow. The stands QMD, the TPA by product designation, DBH distribution, and stand and stock tables show this. Using a stocking diagram/chart or putting the data into FVS (which projects out the volume) can be helpful in establishing a time frame for when to enter the stand for harvest.

The current stocking for the 12.35-acre stand is marked with a red "X" on the northern hardwood stocking chart in figure A-5. Allowing this stand to grow into a QMD of 10 before harvest should push majority of the 35 TPA of potential saw logs into the saw log category. You may even observe some recruits from the pulp category as well. This can be projected in stand stock tables through FVS. But, monitoring the stand and taking inventory down the road will allow you to have a better idea of what's actually playing out. Where this is a 12.35-acre stand you can manage to do that quite easily. Once to a QMD of 10 you can observe a blue "X" on the stocking chart, FVS predicts this will occur in 10 years or the year 2029. This is followed by a shelter wood preparatory cut or a thinning from below. This will bring the residual trees per acre to 160 and the basal area down to 120 square feet. What this does is allows you to promote a particular understory component by providing an environment most suitable to your desired regenerative species. Looking at the regeneration data for stage 2 (sapling stem counts by species) in table A-10 below you can see that red maple, white ash, and brown ash appear to be the most commonly occurring species in the saplings size cohort of this stand. Smaller components of aspen, white pine, and red oak exist though. It is a challenge to promote red oak in this situation due to deer browse pressure. Oak will be preferred over red maple by deer in most cases which makes the challenge even more trialing. None the less I recommend promoting red oak as it adds to species diversity and richness in the stand. For that reason, the thinning from below should be done in small patches that surround dominant seed-bearing red oak. Majority of the sapling size red oak likely occur near these mature oaks as this species commonly sprouts at the roots. To establish more oak seedlings, this thinning should be done on a good mast year.

The southwest portion of the stand had no oak observed. This is where the white pine saplings were recorded. Here the small groups/patches associated with the thinning should establish canopy openings over areas of high-density white pine regeneration. It is unlikely that a white pine seed year will correlate with the red oak mast year but if this timing is possible it should be done. I recommend favoring the red oak mast year over the white pine mast year as the University forest has many other highly productive white pine stands scattered throughout their ownership and not many red oak stands. Red oak masts or acorns are also an excellent food resource to wild life. Once the red oak seedlings have reached a height of around 1-2 ft tall. An over story removal should be done to release this younger cohort of red oak (Leak et al.,2014). FVS predictions indicate this will occur 10 years after the shelter wood establishment cut in the year 2039. This final over story removal will occur while the stand is at a basal area of 115 square feet per acre and approximately 114 trees per acre.

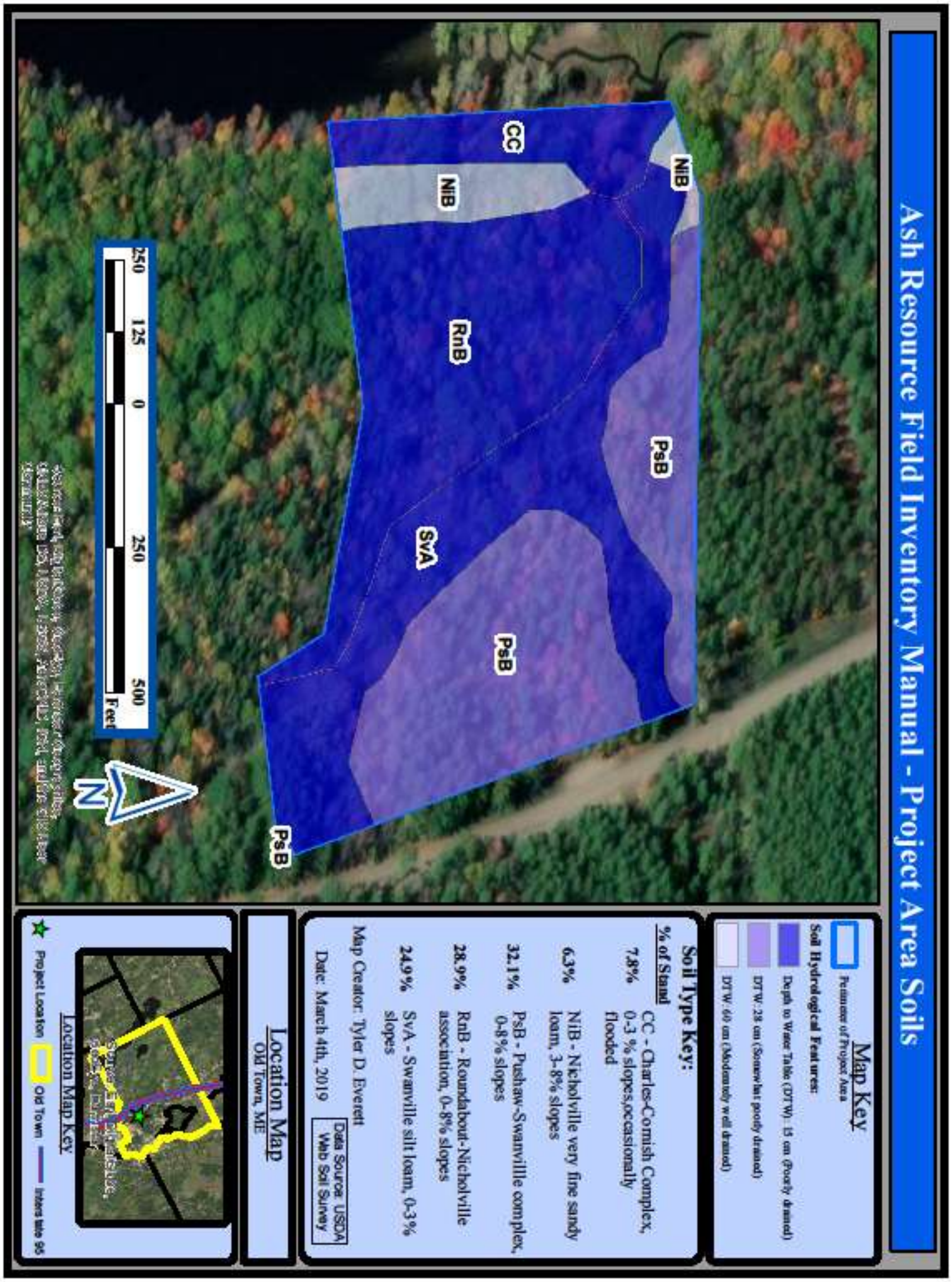
Following the harvest, the residual and future stand will have a stocking of 65 square feet of basal area and 91 trees per acre with a strong regenerative component of red oak infiltrating the understory. Mature white ash will be scattered throughout the stand and many low vigor white ash will exist as potential trap trees. The brown ash corridor will slowly and sustainably be utilized by basket makers to continue the culturally significant practice of basketry.

As you can see the ash manual has provided me with an endless amount of information for me to make technically sound management decisions with. This manual has a lot of data that was not used and that does not necessarily mean it isn’t useful. In certain stands other pieces of data that were collected would come into play. This is why the ash manual explicitly states that there are certain data that should be removed from protocol if there is no intention of implementing certain management activities. These data would be unnecessarily collected if that step was not taken. Inventory can be very costly to implement and that makes the decision of whether or not to collect additional data a critical one.

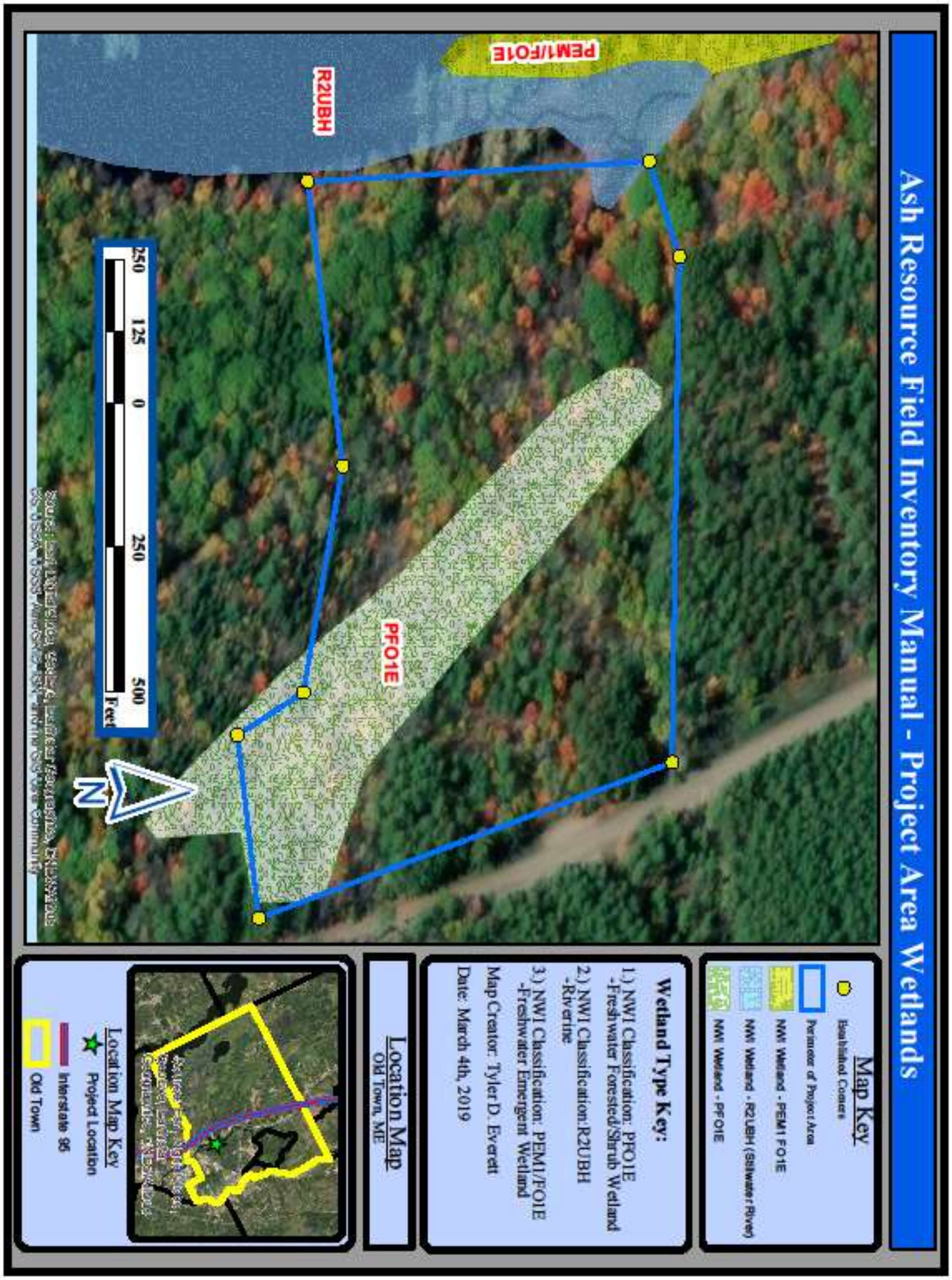
Supplemental Materials for Case Study

Map 1: Ash Resource Field Inventory Manual – Project Area

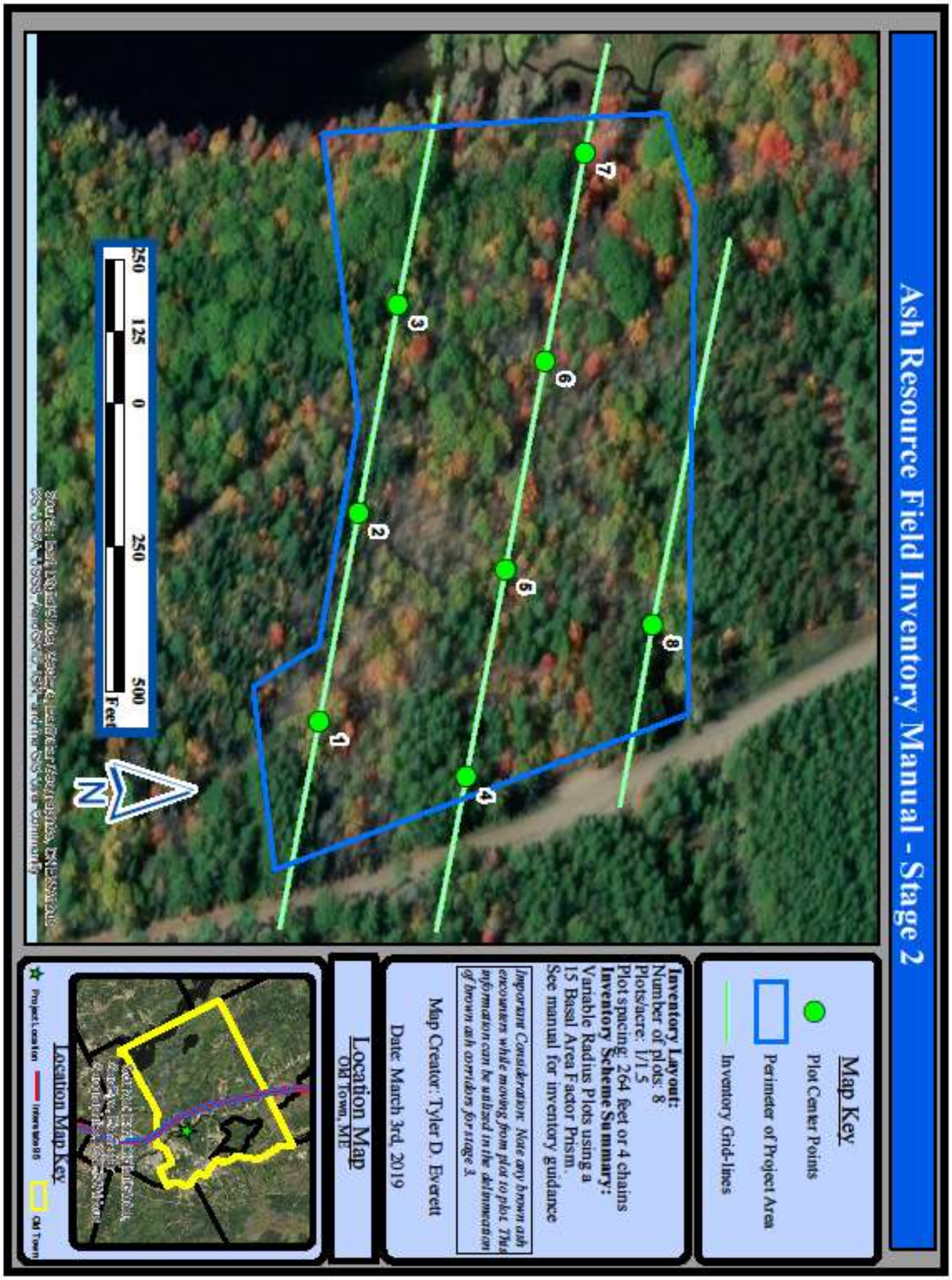
Map 2: Ash Resource Field Inventory Manual – Project Area Soils



Map 3: Ash Resource Field Inventory Manual – Project Area Wetlands

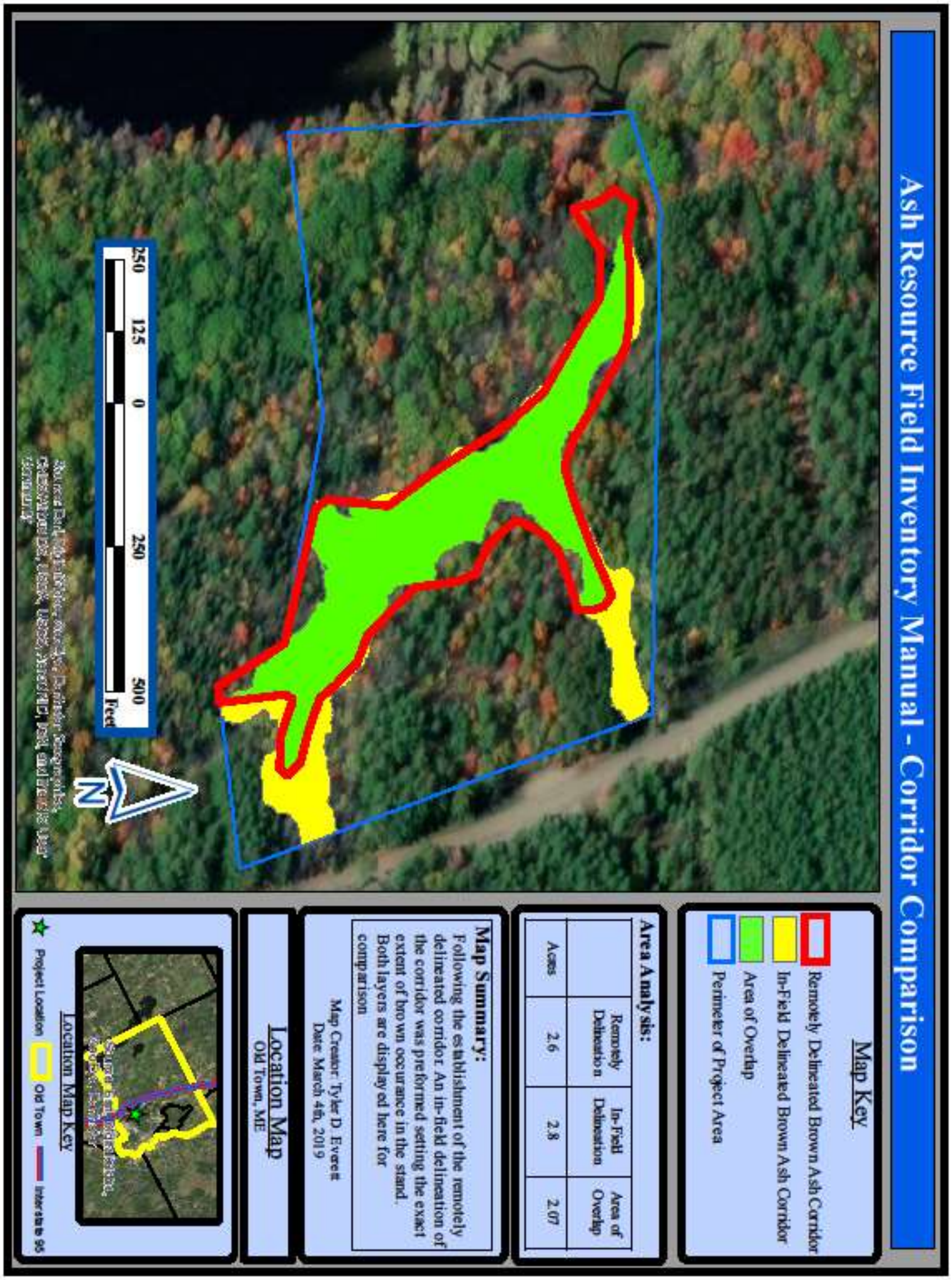


Map 4: Ash Resource Field Inventory Manual – Stage 2



Map 5: Ash Resource Field Inventory Manual – Delineating the Brown Ash Corridor

Map 6: Ash Resource Field Inventory Manual – Corridor Comparison



Map 7: Ash Resource Field Inventory Manual – Stage 3

Appendix 2: Suzanne Greenlaws Remote Sensing Work

Author: Suzanne Greenlaw

A Brown Ash Habitat Suitability Model

Introduction and Background

Through native people's long standing relationship with brown ash comes extensive ecological knowledge of the tree and its habitat. This knowledge is denoted as traditional ecological knowledge (TEK). TEK is "a working body of knowledge, an adaptable, dynamic system based on skills, abilities, and problem solving techniques that change over time depending on environmental conditions" (Battiste 2002). Locating brown ash suitable for basket making is a specialized knowledge held within Native American brown ash harvesters. Brown ash is found in a small proportion of the total forest and only about 5%-20% of brown ash trees are suitable for basket making (Benedict & Frelich 2008). Brown ash, over other tree species used in basketry, has specific characteristics that allow the wood to split along its growth ring with repeated pounding. The width of the growth ring is a dominant factor in choosing the appropriate tree and the ideal ring width ranges from 5 to 2 mm (personal communication Richard Silliboy 2009). Basket makers have a body of knowledge they employ to identify brown ash trees for basket making. Basket makers have reported specific characteristics associated with basket quality brown ash such as soil drainage, landform, hydrology source, and forest type in predicating basket quality brown ash shown in Table 1.

Study Area

My model focus is in Houlton, Maine, which is located in South-Eastern Aroostook County, in Northern Maine (Fig.1). For the model, the Meduxnekeag River, extending from Houlton to Littleton, Maine, was chosen due to availability of information for known basket quality ash locations.

Objective

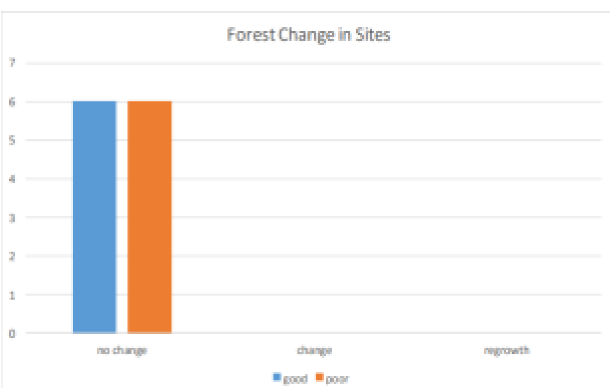
The goal of my research is address Wabanaki harvester's decreased access to basket quality brown ash and change how land owners and harvesters communicate. Creating a habitat suitability model to predict basket quality brown ash sites is the first step of the research.

Data Generation

Ethnographic research has been conducted to understand the ecological variables correlated with basket quality brown ash. Ecological and socio-ecological factors from the ethnography are included in the TEK column . Map parameters corresponding with TEK, data sources and the resulting model thresholds are shown in Table 1. Model thresholds were determined through analysis with known ash sites. Examples of the analysis are shown in the graphs. The habitat suitability model was created using ARC GIS software, version 10.4 (ESRI. 2016). I obtained data layers to construct the model through Maine GIS Data Catalog, the Natural Resource Conservation Service Geospatial Data Gateway, and the USGS Earth Explorer website. I acquired the political layers-state, county, roads, hydrology, and Digital Elevation Model in 10 meters from Maine GIS catalog. Soil data from the Soil Survey Geographic Database (SSURGO) for Aroostook County, Maine were downloaded from the Geospatial Data Gateway. From the USGS Earth Explorer I downloaded Landsat 5 Path 11 Row 28 for September 11, 2011. All data layers were projected in the Universal Transverse Mercator, Zone 19N, North American Datum of 1983 coordinate system. Twelve brown ash stands within the Houlton, Maine region were identified and Wabanaki ash harvester evaluated each site as either good quality or poor quality. Six sites were identified as poor quality, six sites were identified as good quality. These twelve sites were used to identify each data layer's threshold to predict basket quality ash sites and determined reclassification values.

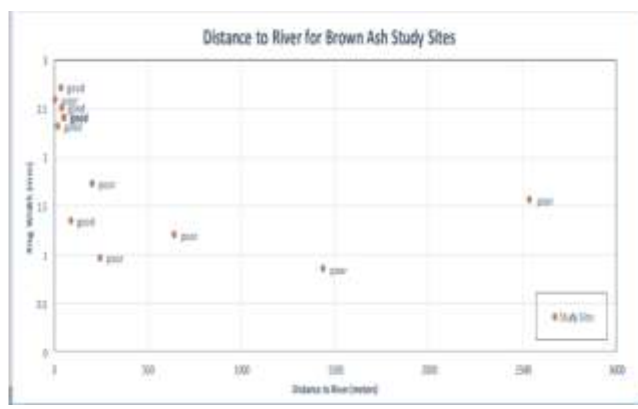
TEK	Map Parameters	Data Source	Threshold Value
Ash grows near flowing water	Flow Accumulation	Digital Elevation layer	Cell values <10
Ash grows in flood plains	Distance to River	River layer from MEGIS	Area > 75 meters from River
Ash grows with hardwoods	Hardwoods companion species	Landsat	Hardwood and mixed forest type
soils are wet but not too wet	Well -moderately drained soils	USDA soil layers	drained soils
Ash is at least 5" DBH	Stand age	Landsat-time series	forest with no disturbances within 30 yrs

Graph 1.



Graph 1. A forest change map was created from conducting a 3 date NDVI between three dates of 1987, 1999, and 2011. . All 12 ash sites were found in a forest that experience no change in the last 30 years.

Graph 2.



Graph 2. Ash stands distance to the river. Each ash stand was designated as good quality or poor quality by an ash harvester. Each stand is represented by the average ring width of that stand. Basket makers prefer a ring width of 2 mm or greater.

Flow accumulation represents the accumulated flow of water downslope as water moves via gravity. The Arc/Info program "flow accumulation" basically counts the number of cells sending water downslope to the cell being evaluated. Ridge tops would have a flow accumulation of only one while the valley bottoms would have maximum accumulation. With the DEM in 10 meters, flow accumulation, slope, and hill shade was created. I reclassified the flow accumulation for all values up 10 had a value of zero and the rest of the values from 10 to 5,600,000 had 1.

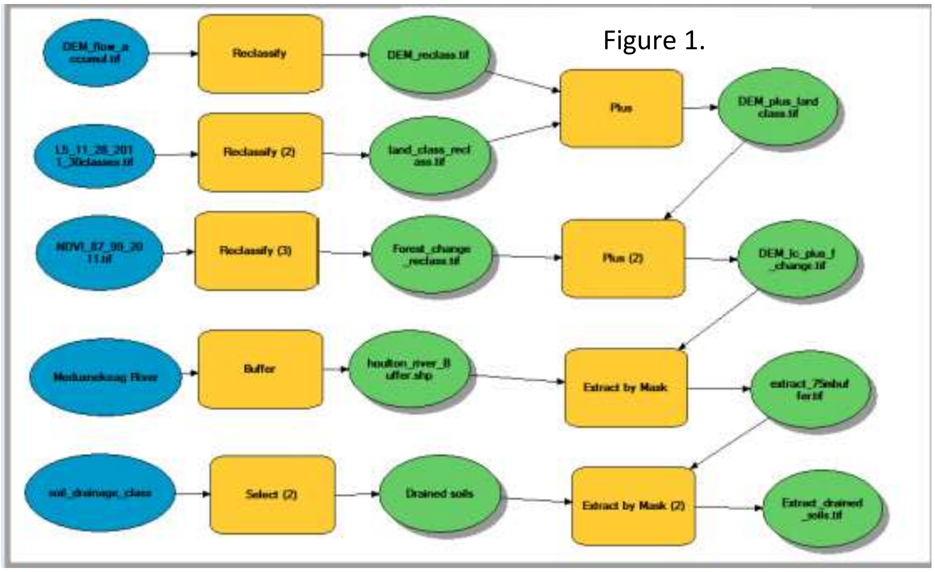


Figure 1. Geoprocessing model for Basket Quality Brown Ash Habitat Suitability Map.

A Landsat 5 TM Path 11 Row 28 image of September 11, 2011 was used for analysis. I clipped the aerial imagery to the study area. An unsupervised classification was conducted due to the lack of training data and ability for fast analysis. Initial classification had 30 classes. I assessed the land class with the aerial imagery and convert the 30 classes to 10 classes; wetland, water, softwoods, hardwoods, mixed forest, impervious surface, grassland, farmland, disturbed (forest regrowth). I reclassified each wetland, softwood, impervious surface, grassland, farmland, water to a value of zero. Hardwood, and mixed forest was reclassified to 1. I conducted a time series analysis through a 3 date NDVI with Landsat 5 TM Path 11 Row 28 images. The dates of the Landsat images are June 21, 1987, September 3, 1999, and September 11, 2011. An unsupervised classification was conducted with 30 classes. I converted the 30 classes to 5 classes; no changed, water, regrowth, disturbances, and non forest. All 12 ash stands were found within no change as shown in graph 1. I reclassified no change to a value of 1 and the rest of the classes to a value of zero.

I created a buffer of 75 meters around the river vector layer. This distance was determine by the data shown in graph 2. The six known “good” sites were within a 75 meter distance to the river. Basket quality brown ash was found in drained soils as shown. I created an individual map for drainage using Soil Data Viewer. I selected the polygons with the drainage classes for moderately well drained to excessively well drained and created a new shapefile.

Figure 1.

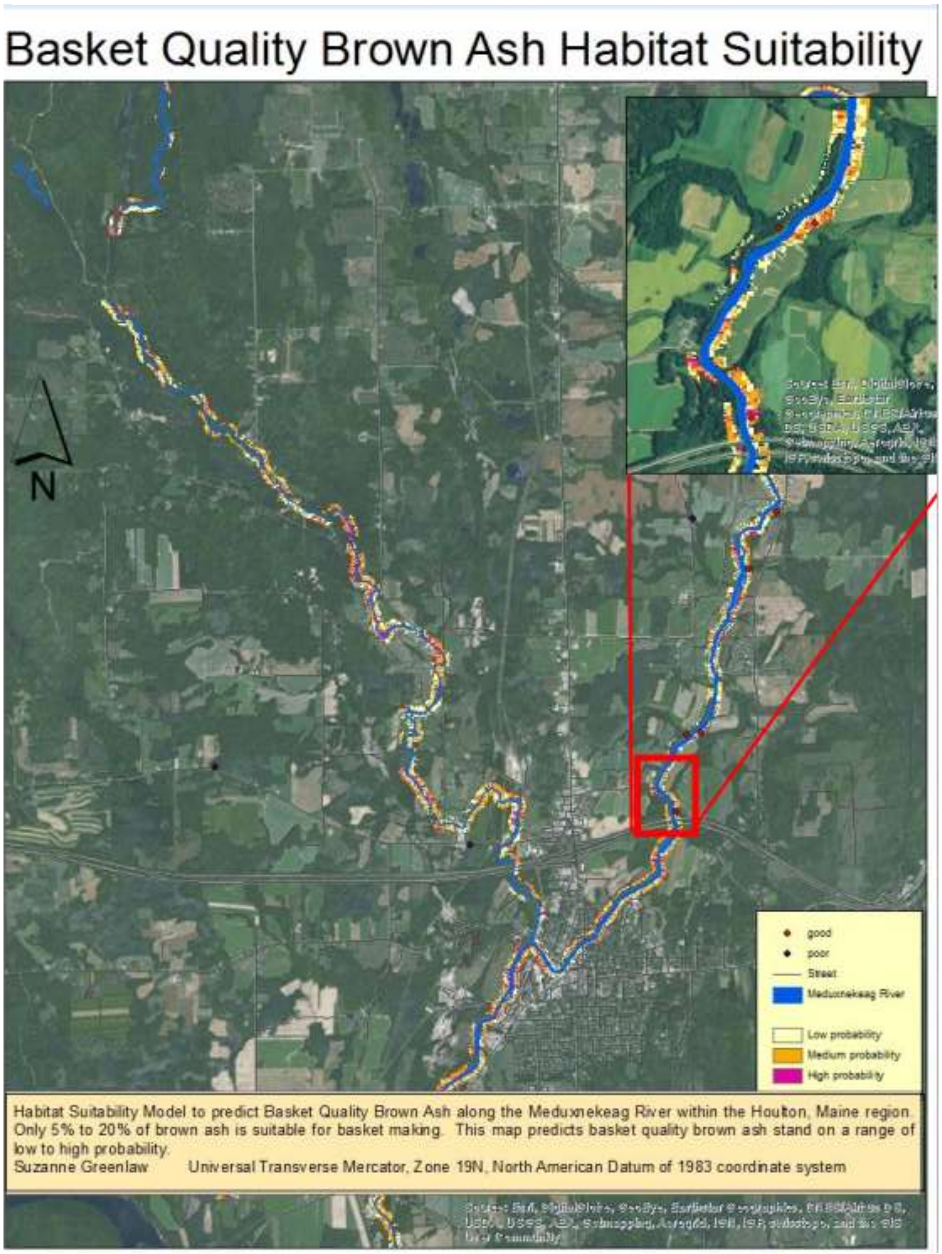


Figure 2. Basket Quality Brown Ash Habitat Suitability map for the Meduxnekeag

Using the plus tool in Raster Calculator function of Spatial Analyst toolbox, I calculated suitability by adding the Land classification, Forest change map, and flow accumulation layers and created values of 0 to 4. Cells with a zero value predicts no basket quality ash. Cells with the values 1 to 3 indicate a range of probability with 3 being the high probability of basket quality brown ash. I extracted the habitat suitability map by the buffer of 75 meters. I then extract the map by the drained soils layer. The geoprocessing workflow model for the brown ash habitat suitability map is show in figure 1. The resulting basket quality brown ash habitat suitability map is show in figure 2. This is the first iteration of the map using study sites to generate threshold. Further steps will include collecting more study sites.

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Appendix 3: Wisconsin Dept. of Natural Resources: Checklist for Evaluating Lowland Ash Stands

https://dnr.wi.gov/topic/Forestmanagement/documents/checklistevaluatelowlandash.pdf

Checklist for Evaluating Lowland Ash Stands (WDNR 04/2017): This checklist/decision tool is for use in lowland ash stands that will potentially be impacted by emerald ash borer (EAB). The checklist is designed to assist with site and stand evaluation prior to developing a prescription. Due to the complex nature of these sites the checklist results should be considered collectively, along with other stand data, landowner objectives, and professional judgment when evaluating management alternatives.

Landowner:	**County:**	**Town:**
Section-Town-Range:	**Cruiser:**	**Date:**
Compartment:	**Stand:**	**Acres:**

SITE QUALITY and/or TIMBER SALE OPERABILITY:

Low -
- ☐ Wetland FHT – very poor to poor (Habitat Type:______)
- ☐ SI < 40 ft.* (SI Species / Site Index: _____ / _____)
- ☐ Drainage Class – very poorly drained
- ☐ Soil – deep organic/sphagnum bog
- ☐ Vigor – Poor tree and stand vigor
- ☐ Sale Volume – limited (e.g., <100 cords or 10 MBF)
- ☐ Sale Access - poor

Medium to High –
- ☐ Wetland FHT – poor to rich (Habitat Type:______)
- ☐ SI > 40 ft.* (SI Species/ Site Index: _____ / _____)
- ☐ Drainage Class – poorly drained or better
- ☐ Soil - non-sphagnum organic or organic over mineral
- ☐ Vigor – moderate to good tree and stand vigor
- ☐ Growing Stock Quality - acceptable (evaluate AGS)
- ☐ Sale Volume - acceptable (e.g., >100 cords or 10 MBF)
- ☐ Sale Access – fair to good

* It may be difficult to obtain an accurate SI in lowland ash stands. It is not recommended to rely on SI alone for site quality evaluations.

ADVANCE REGENERATION (NON-ASH SPECIES):

Adequate –
- ☐ Non-ash, desirable species
- ☐ 2000+ stems/acre (advance + projected coppice)
- ☐ 2-4 ft. tall
- ☐ Distribution > 50% stocking

Present but Inadequate –
- ☐ Non-ash, desirable species
- ☐ 200-2000 stems/acre (advance + projected coppice)
- ☐ 2-4 ft. tall
- ☐ Distribution < 50% stocking, grouped

No Potential –
- ☐ Mostly ash or undesirable species
- ☐ <200 stems per acre (advance + projected coppice)
- ☐ < 2 ft. tall (e.g., 1st year germinants)
- ☐ Distribution – limited

POTENTIAL EAB IMPACT TO STAND CONDITION:

Non-Degraded –
- ☐ ≥ 40 non-ash AGS (Acceptable Growing Stock) trees per acre or > 45% relative density of non-ash AGS

Degraded –
- ☐ < 40 non-ash AGS trees per acre or < 45% relative density of non-ash AGS

ALTERNATE SEED SOURCES:

Good -
- ☐ 5-10+ non-ash AGS/seed trees per acre
- ☐ Dominant or codominant crown class
- ☐ Reproductively mature
- ☐ Dispersed

Poor -
- ☐ <5 non-ash AGS/seed trees per acre
- ☐ Intermediate and suppressed crown classes
- ☐ Reproductively immature
- ☐ Poorly distributed

HERBIVORY:

Low –
- ☐ Browse severity index 1-3

High -
- ☐ Browse severity index 4-6

HYDROLOGICAL RISK:

Low –
- ☐ Seasonal inundation of limited duration (< 60 days)
- ☐ Depth to water table > 30cm during majority of growing season
- ☐ Ponding infrequent
- ☐ Drainage Class poorly drained or better, convex surfaces
- ☐ Shallow organic or mineral soils
- ☐ Limited impediments to drainage

High –
- ☐ Seasonal inundation common, well into growing season (> 60 days)
- ☐ Depth to water table < 30cm during majority of growing season
- ☐ Ponding frequent
- ☐ Drainage Class very poorly drained, concave surfaces, limited water flow
- ☐ Deep organic soils / sphagnum bog
- ☐ Impeded drainage due to roads, culverts, other impounding factors

INTERFERING VEGETATION:

Low –
- ☐ <25% coverage RCG, buckthorn, alder, other _________

High -
- ☐ ≥25% coverage RCG, buckthorn, alder, other _________

STAND COMMENTS:

Site Quality/Operability	EAB Stand Impact	Hydrological Risk	Advance Regeneration	Alternate Seed Sources	Herbivory	Interfering Vegetation	Prescription Alternatives
Low	n/a	n/a	n/a	n/a	n/a	n/a	**Limited Management Potential** - low priority stand, potential for non-timber management objectives (e.g., wildlife habitat)
Medium-High	Not Degraded	n/a	n/a	n/a	n/a	n/a	Alternative Cover Type - Manage for non-ash species according to appropriate cover type guidance
Medium-High	Degraded	Low	Adequate	n/a	n/a	n/a	OSR, TA
Medium-High	Degraded	Low	Present but Inadequate	Good	Low	Low	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-O
Medium-High	Degraded	Low	Present but Inadequate	Good	Low	High	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-R
Medium-High	Degraded	Low	Present but Inadequate	Good	High	Low	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-O, BP
Medium-High	Degraded	Low	Present but Inadequate	Good	High	High	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-R, BP
Medium-High	Degraded	Low	Present but Inadequate	Poor	Low	Low	OSR (advance regen. sufficient), SCC, GPS, P-R, R-O
Medium-High	Degraded	Low	Present but Inadequate	Poor	Low	High	OSR (advance regen. sufficient), SCC, GPS, P-R, R-R
Medium-High	Degraded	Low	Present but Inadequate	Poor	High	Low	OSR (advance regen. sufficient), SCC, GPS, P-R, R-O, BP
Medium-High	Degraded	Low	Present but Inadequate	Poor	High	High	OSR (advance regen. sufficient), SCC, GPS, P-R, R-R, BP
Medium-High	Degraded	Low	No Potential	Good	Low	Low	SCC, SW, GPS, P-R, SP-O
Medium-High	Degraded	Low	No Potential	Good	Low	High	SCC, SW, GPS, P-R, SP-R
Medium-High	Degraded	Low	No Potential	Good	High	Low	SCC, SW, GPS, P-R, SP-O, BP
Medium-High	Degraded	Low	No Potential	Good	High	High	SCC, SW, GPS, P-R, SP-R, BP
Medium-High	Degraded	Low	No Potential	Poor	Low	Low	SCC, GPS, P-R, SP-O
Medium-High	Degraded	Low	No Potential	Poor	Low	High	SCC, GPS, P-R, SP-R
Medium-High	Degraded	Low	No Potential	Poor	High	Low	SCC, GPS, P-R, SP-O, BP
Medium-High	Degraded	Low	No Potential	Poor	High	High	SCC, GPS, P-R, SP-R, BP
Medium-High	Degraded	High	Adequate	n/a	n/a	n/a	SCC, GPS
Medium-High	Degraded	High	Present but Inadequate	Good	Low	Low	SCC, GPS, P-O, R-O
Medium-High	Degraded	High	Present but Inadequate	Good	Low	High	SCC, GPS, P-O, R-R
Medium-High	Degraded	High	Present but Inadequate	Good	High	Low	SCC, GPS, P-O, R-O, BP
Medium-High	Degraded	High	Present but Inadequate	Good	High	High	SCC, GPS, P-O, R-R, BP
Medium-High	Degraded	High	Present but Inadequate	Poor	Low	Low	SCC, GPS, P-R, R-O
Medium-High	Degraded	High	Present but Inadequate	Poor	Low	High	SCC, GPS, P-R, R-R
Medium-High	Degraded	High	Present but Inadequate	Poor	High	Low	SCC, GPS, P-R, R-O, BP
Medium-High	Degraded	High	Present but Inadequate	Poor	High	High	SCC, GPS, P-R, R-R, BP
Medium-High	Degraded	High	No Potential	Good	Low	Low	SCC, GPS, P-R, SP-O
Medium-High	Degraded	High	No Potential	Good	Low	High	SCC, GPS, P-R, SP-R
Medium-High	Degraded	High	No Potential	Good	High	Low	SCC, GPS, P-R, SP-O, BP
Medium-High	Degraded	High	No Potential	Good	High	High	SCC, GPS, P-R, SP-R, BP
Medium-High	Degraded	High	No Potential	Poor	Low	Low	SCC, GPS, P-R, SP-O
Medium-High	Degraded	High	No Potential	Poor	Low	High	SCC, GPS, P-R, SP-R
Medium-High	Degraded	High	No Potential	Poor	High	Low	SCC, GPS, P-R, SP-O, BP
Medium-High	Degraded	High	No Potential	Poor	High	High	SCC, GPS, P-R, SP-R, BP

Key to Prescription Alternatives: Overstory Removal (OSR), Strip Clearcut/Coppice (SCC), Two-Age (TA), Shelterwood (SW), Group/Patch Selection (GPS), Supplemental Planting – Optional (P-O), Supplemental Planting – Recommended (P-R), Release – Optional (R-O), Release – Recommended (R-R), Site Preparation for Natural Regeneration – Optional (SP-O), Site Preparation for Natural Regeneration – Recommended (SP-R), Browse Protection (BP)

Developing Silvicultural Rx Alternatives for Lowland Ash Stands: The following guidance is based on current research and silvicultural case studies from the Lake States and is specifically directed at ash-dominated lowlands that will be heavily impacted by EAB. Ash-dominated lowlands encompass both the swamp hardwood and bottomland hardwood cover types, where the primary tree species may include black ash, green ash, red maple, silver maple, swamp white oak, and elms. Current silvicultural guidelines for the regeneration of these cover types is tentative and incomplete, due in part to our limited knowledge and experience managing these complex ecosystems for species other than ash. The threat of EAB has increased the urgency to find management strategies that maintain forest productivity and improve forest resilience. This guidance will highlight some of the important stand assessment considerations and regeneration methods that have shown the most promise for increasing species diversity in lowland ash stands. Many of these recommendations are based on lessons learned through a series of 29 swamp hardwood silvicultural trials conducted over the past 40 years in Wisconsin and draws from other emerging research in the Lake States (WDNR 2017). Additional management information can be found in the Swamp Hardwood and Bottomland Hardwood chapters of the Silviculture Handbook.

STAND ASSESSMENT CONSIDERATIONS

Proximity to EAB Infestations – An important consideration affecting the choice of silvicultural alternatives for an ash stand is the proximity to known EAB infestations and the amount of time available for management prior to major ash mortality. EAB was first detected in Wisconsin in 2008 and currently slightly over half of the state's counties are under quarantine for EAB. Once EAB is detected in an area it may take several more years for the population to build to a level that will cause significant tree mortality. A study using FIA and county-level quarantine data found this lag time to be 7-10 years (Morin et al. 2016). EAB may actually be present in an area for years prior to detection, so the actual lag time between establishment and mortality is likely greater. If mortality is already occurring in a stand, management options may be limited to salvage operations. A management window of several years or longer however will allow for more flexibility, such as the use of alternative regeneration methods and/or multiple stand entries. The goal should not be to remove all ash in every situation, without first carefully considering management time frames and site opportunities to improve future stand conditions.

Site Quality/Wetland Forest Habitat Type – A careful assessment of site quality will help prioritize which stands will respond best to management treatments in terms of growth, regeneration, and hydrology. Low quality sites as defined within the checklist generally have lower productivity and it may not be practical to invest in extensive management treatments. The Forest Habitat Type Classification System has commonly been used in Wisconsin to assess upland site capability based on the floristic composition of plant communities, and now that system has been extended to wetland forests in northern Wisconsin. Based on the swamp hardwood trials, habitat types that are slightly richer in nutrients (e.g., FNArl and FnUb in Regions 3 and 4, respectively) seem most capable of supporting higher proportions of non-ash tree regeneration, but post-harvest shrub competition on these sites is proportionately higher creating the potential need for follow-up release treatments (Pszwaro et al. 2016). Less rich habitat types were also found to support moderate to high proportions of non-ash tree regeneration, particularly under the strip clearcut/coppice and strip shelterwood regeneration methods, and generally proportionately lower shrub densities. Site quality of wetland forests may also be reflected in the depth to mineral soil, as well as influenced by the influx of nutrients from adjacent landforms.

Timber Sale Operability – Sale operability considerations are particularly important in ash-dominated lowlands due to both the seasonally saturated soil conditions and the generally low value of associated forest products. Stands with very poor drainage classes, long seasonal inundation periods, deep organic soils, and/or impeded drainage may have limited harvest windows and be more susceptible to site damage due to rutting and swamping. Harvesting during frozen conditions, using logging mats and driving over tops/branches can minimize site damage. Road systems and other infrastructure can have long-lasting impacts on wetland hydrology and site productivity by impeding water flow, and therefore need to be carefully located and constructed. Foresters should also evaluate potential sale volumes relative to local markets when assessing timber sale feasibility. Small stands with difficult access will have limited marketability and may need to be sold with adjacent upland stands or forgo management.

Hydrological Risk – Hydrological risk refers to the risk of "swamping," or a water table rise following harvest due to tree removal and/or site damage. The risk is considered greatest for clearcutting and overstory removal treatments where all trees and the main sources of evapotranspiration are removed in a single operation, but swamping can occur with other silvicultural treatments as well if site factors are high risk. Swamping was noted in three of the 29 swamp hardwood trials; a clearcut, a 120' strip clearcut/coppice harvest and a diameter-limit harvest. Swamping can lead to tree regeneration delays, failures, and shifts in the vegetation to wetland obligate species, such as alder and grasses/sedges. A water table response study of black ash wetlands in Minnesota found water table increases greatest in simulated EAB mortality (i.e., girdling down to 4" DBH) and clearcutting treatments, and lowest in group selection treatments (Slesak et al. 2014). Partial harvest treatments will generally mitigate the water table impacts by maintaining tree canopy. Predicting the risk of swamping is difficult however and will vary depending on site hydrology, annual precipitation, and the period of time necessary to re-establish vegetation (Slesak et al. 2014). The checklist provides a partial list of factors to consider when assessing site hydrology and swamping risk. Also consider the landscape context of the wetland forest being managed. Larger watershed issues, such as major road impoundments or beaver dams, may impact the hydrology over extensive areas.

Potential EAB Impacts to Stand Condition – The checklist provides an assessment of degraded verses non-degraded stand condition based on a minimum level of non-ash AGS (Acceptable Growing Stock). The baseline is set at 40 non-ash AGS per acre or approximately 45% relative density. Stands at or above this baseline should be able to be managed for non-ash species according to the appropriate cover type guidance. Stands below this baseline will be considered degraded after EAB kills the ash component and may require silvicultural treatments to increase non-ash tree regeneration. Foresters may decide to continue to manage understocked stands below this baseline (i.e., <40 non-ash AGS per acre) if regeneration options are limited.

Regeneration Potential – Maintaining the resilience of ash-dominated lowland stands in the face of EAB will require increasing tree diversity, specifically increasing non-ash tree regeneration. The checklist assesses the non-ash regeneration potential of a stand by evaluating several factors; non-ash advance regeneration density and stocking, alternate seed sources, herbivory pressure, and interfering vegetation. Based on the trials, all silvicultural treatments produced abundant ash regeneration due to this species ability to easily reproduce from seed and stump sprouts. Ash regeneration as small as 1" DBH however will likely experience near complete mortality by six years after infestation (Knight et al. 2013) and cannot be relied on as a viable species to restock the stand. Evaluating the regeneration potential of alternate species will help in the selection of prescription alternatives geared towards increasing the non-ash tree component. However the initial abundance of ash and shrub regeneration following all silvicultural treatments in the trials suggests follow-up release treatments may be necessary to maintain the non-ash regeneration over time.

Landowner Objectives – All silvicultural prescriptions must be considered within the context of compatible landowner objectives. Defining your landowner's objectives becomes even more critical for ash-dominated lowlands because of the challenges and potential costs associated with managing these systems. A significant investment may be needed to implement some of the management treatments described below. Foresters can help landowners prioritize where to make these investments in management through careful stand assessments, using tools such as the checklist. Prioritization may be based on multiple considerations such as stand size, accessibility, ecological importance, probability of treatment success, impacts to hydrology, and several other factors discussed here. Many ash-dominated lowland stands will have limited options and EAB mortality will be allowed to run its course. Other stands will have greater opportunities and silvicultural treatments can be used to build resilience to EAB impacts, improve future stand productivity, as well as utilize the ash resource that is being lost.

REGENERATION METHODS

Overstory Removal (aka, Natural or One-Cut Shelterwood) – An overstory removal is a regeneration method in which the stand overstory is removed in one cut to provide release of established seedlings and saplings. Important considerations when using this method include having adequate density, distribution, height, vigor, and desirability of established non-ash advance regeneration. Overstory removal is a generally accepted practice in the swamp hardwood and bottomland hardwood cover types as long as density and stocking are maintained with at least 2-5,000 well-distributed trees per acre that are 2-4' in height. This advance regeneration needs to be desirable non-ash species in order to avoid understocking the stand once EAB kills the ash component. Because the entire overstory is being removed in one cut there may be a risk of swamping, so this method may be best on sites with low risk factors. If the advance regeneration is well established and deep rooted, there are some indications that rapid re-vegetation of a site can mitigate some of the water table rise (Slesak et al. 2014). Swamping risk may also be mitigated through patch or strip overstory removals that retain a portion of the forest canopy.

Strip Clearcut/Coppice (aka, Strip Shelterwood) – In a progressive strip clearcut/coppice the stand is removed in a series of strips harvested over 2-3 entries, usually covering an equal area on each occasion. The entire stand level strip removal process is completed within a period of time not exceeding 20% of the intended rotation. In lowland stands, this method may be chosen to reduce the risk of swamping and windthrow, as well as improve equipment operability. The mode of regeneration in ash-dominated lowland stands is often from both seed and coppice. In Wisconsin, these strips have generally been 50'-200' in width and remove approximately 1/3 to 1/2 of the stand at each entry. This method may also be defined as a strip shelterwood, as narrow strips (i.e., 120' and less) will have growing conditions that are significantly modified by the adjacent uncut strips. The strips are often oriented at right angles to the prevailing winds in order to aid in seed dispersal. In the swamp hardwood trials, strip clearcut/coppice generally provided the best balance between establishing regeneration (including a high proportion of non-ash species) and maintaining site hydrology.

Shelterwood (Uniform) – The shelterwood regeneration method is designed to regenerate a stand by manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. The overstory serves to modify understory conditions, create a favorable environment for reproduction, and provide a seed source. The method is characterized by a preparatory cut (optional), seeding cut(s), and overstory removal. The variation of strip shelterwood was discussed above. Uniform shelterwood, where the residual trees are uniformly distributed, has also been utilized in both swamp hardwood and bottomland hardwood stands to encourage more mid-tolerant species, such as yellow birch, red maple, silver maple, swamp white oak, and white pine. Successful application of this method is often tied to creating proper seedbed conditions and timing relative to the production of good seed crops. Site preparation for natural regeneration on these sites can be difficult due to the wet conditions and further development of interfering vegetation. Promising chemical site preparation treatments have been demonstrated in bottomland hardwood stands with the late fall application of pre-emergent herbicides to control reed canary grass, allowing for a window of seedbed exposer (Thomsen et al. 2012). The seeding cut should generally leave a uniform crown cover of 50-75% of vigorous dominant and codominant trees, favoring non-ash seed sources. Uniform shelterwood may be most applicable on medium to high quality sites with better drainage, where equipment operability improves allowing access throughout the stand.

Group/Patch Selection – The group and patch selection methods maintain an uneven-aged stand by removing groups/patches of trees at regular intervals. In Wisconsin these canopy openings are defined as 0.1 to 0.5 acre for group selection and 0.5 to 2.0 acres for patch selection. These methods are appropriate for encouraging many mid-tolerant species and the retention of a partial canopy may help mitigate swamping risk. Consideration needs to be given to the percent of the stand regenerated at each entry, given the likely short timeframe until EAB infestation. There may be not enough time available for multiple entries prior to significant EAB caused mortality. Based on the swamp hardwood trials, regeneration response was also most limited for low intensity treatments (i.e., single-tree and group selection), resulting in the lowest seedling densities. Aggressive patch selection could be used to speed the regeneration process by harvesting larger areas of the stand; however consideration will need to be given to increased swamping risk and further development of interfering vegetation. Group and patch selection have been coupled successfully with site preparation and supplemental planting in order to increase species diversity in stands with limited alternate seed sources. A Minnesota study found that trees planted within group selection openings had better overall survival than clearcuts, suggesting that group selection may be a good compromise for maintaining site hydrology while supporting seedling development (Looney et al. 2015).

Two-aged Methods – Broadly speaking two-aged methods retain scattered trees or groups of trees following a harvest (i.e., standards or reserves), while initiating a new age-class. The result is a stand of trees with two distinct age classes, separated in age by more than 20% of the rotation. Trees can be retained for several reasons including, additional growth, wildlife habitat, aesthetics, or as an alternate seed source to slowly convert a stand to a different composition. Coppice with standards has been the most common two-aged method applied to Wisconsin lowland ash stands. When applied to black ash swamps this regeneration method is designed to naturally regenerate the stand using vegetative reproduction from stump sprouts, while retaining standards or reserve trees of a desirable seed source (e.g., yellow birch, red maple, silver maple, white pine, white spruce, tamarack, and cedar) to maintain site hydrology and promote the conversion to alternate species. Depending on the degree of canopy removal this method can present a swamping risk and therefore may be best on sites with low risk factors. Retained trees will also be more susceptible to windthrow due to the shallow rooting zone and wet soil conditions. In ash-dominated lowlands, significant coppice ash reproduction should be expected.

Impacts of Clearcutting – Clearcutting, or the removal of most or all woody vegetation during a harvest leading to natural regeneration from seed, is not a generally accepted practice in swamp hardwoods or bottomland hardwoods, primarily due to the removal of most seed sources and the risk of swamping. Based on the swamp hardwood trials, clearcutting generally produced the lowest density of non-ash tree regeneration and the highest shrub density. Slesak (2014) found that clearcutting black ash stands produced a significant water table rise compared to group selection and control treatments. Clearcutting has also been found to lead to a greater abundance of sedges, grasses, and shrubs that may necessitate vegetation control treatments to establish artificial regeneration (Looney et al. 2017). Given these risks, other regeneration methods are recommended if EAB has not yet infested the stand or if alternative tree species are available to manage. Once EAB caused mortality has begun in an ash-dominated stand there may be few options other than salvage harvesting/clearcutting and artificial regeneration.

INTERMEDIATE TREATMENTS

Release **–** The swamp hardwood trials found a strong regeneration response from ash and shrub species across all habitat types and prescriptions, suggesting that follow-up release treatments may be necessary to maintain non-ash regeneration over time. Ash stumps sprouts in particular demonstrate rapid juvenile growth and may overtop other regeneration quickly if not controlled. EAB caused mortality may help release other species over time, but regenerating stands should be monitored for release needs.

Site Preparation for Natural Regeneration **–** Depending on the regeneration method proper seedbed conditions may be necessary to encourage natural regeneration, especially for species preferring an exposed humus or mineral soil, such as yellow birch, red maple, silver maple, swamp white oak, tamarack and white pine. Site preparation for natural regeneration can be accomplished via mechanical or chemical methods, prescribed burning, or a combination of these techniques. Site preparation may be difficult on these sites due to swamping, rutting potential and further development of interfering vegetation. Promising chemical site preparation treatments have been demonstrated in bottomland hardwood stands with the late fall application of pre-emergent herbicides to control reed canary grass, allowing for a window of seedbed exposure (Thomsen et al. 2012). The checklist defines low levels of interfering vegetation at less than 25% coverage, where site preparation treatments may be optional depending on the aggressiveness of the existing interfering vegetation and the seedbed requirements. High levels of interfering vegetation (i.e., ≥25%) may require site preparation treatments to be successful, but the vegetation should be further evaluated in terms of percent coverage, species, light levels, and seedbed requirements.

Thinning **–** Thinning is often difficult on wet sites due to equipment operability concerns and economic limitations. It may be prudent to initiate regeneration treatments rather than thinning in ash-dominated stands, given the relatively rapid spread of EAB in Wisconsin. Thinning resulted in low regeneration densities in the swamp hardwood trials, as with other low intensity treatments. In mixed stands, thinning may be more appropriate to increase the proportion of non-ash species, while utilizing the ash resource. Stands at or above 40 non-ash AGS per acre or 45% relative density may be appropriate for thinning treatments using the alternative cover type guidance.

Impacts of Diameter-limit Cutting **–** Diameter-limit cutting is sometimes proposed for the pre-salvage of ash-dominated lowland stands as a way to harvest the greatest economic value prior to EAB caused mortality. This cutting practice however may have unintended negative consequences on future productivity and resilience in lowland stands. Slesak (2014) found that water table increases were greatest in EAB simulated mortality treatments that girdled trees down to 4" DBH, similar to how a diameter-limit treatment would retain only smaller diameter classes. This response was attributed to the reduced transpiration coupled with the presence of a partial canopy that reduced vegetation establishment. Leaving a partial canopy of unacceptable growing stock may inhibit the development of desired tree regeneration. Decades of experience with diameter-limit cutting in other forest types has shown this practice degrades overall stand conditions and is a largely haphazard approach to regenerating forest systems (Nyland 2005).

ARTIFICIAL REGENERATION

Supplemental Planting **–** Artificial regeneration is an option to maintain forest cover in ash-dominated stands with poor natural regeneration potential. Due in part to the difficulty and expense of reforesting entire lowland stands, more often tree planting is used to supplement natural regeneration methods. Supplemental or enrichment planting requires a careful evaluation of existing advance regeneration (including potential coppice reproduction), interfering vegetation, as well as species and stock type selection. Seedlings can be planted within harvest openings or underplanted below existing ash stands in anticipation of EAB losses. Generally large bareroot or containerized seedlings are needed to compete with the advance regeneration and interfering vegetation, as well as survive periods of water inundation on wet sites. In Wisconsin foresters have experimented with fall planting in order to avoid spring inundation periods that can last until mid-summer. Survival can be improved by planting seedlings on drier micro-sites, avoiding wet depressions. Interfering vegetation from both native and invasive species can be particularly severe in lowland sites, so site preparation is often required to ensure survival of planted stock. Deer browse may also have significant impacts on planted seedlings and can make those seedlings less able to survive long periods of flooding (De Jager et al. 2013). Follow-up release is often required as planted stock typically lags behind natural regeneration in height growth.

Reforestation experience of lowland forests in the Lake States is limited. A 2010 swamp hardwood trial in Sawyer County attempted reforestation of a former tag alder and black ash swamp using a variety of bareroot and containerized stock, including tamarack, white pine, white spruce, black ash, yellow birch, red maple, quaking aspen, hemlock and balsam fir. Survival and growth of the conifers was superior to deciduous species, with tamarack and white pine performing best. Deer browse impacted the deciduous seedlings most, yet some yellow birch seedlings showed exceptional height growth. A 2013 American elm reforestation trial in Minnesota, Wisconsin, and Iowa planted elm and swamp white oak seedlings on a variety of bottomland hardwood sites ranging from former fields to clearcut and group selection openings. Survival of the 1-0 bareroot stock was generally excellent after two growing seasons, however height growth was poor with deer browse evident on more than 75% of elm seedlings across all sites and prolonged water inundation and interfering vegetation were limiting factors on some sites (Haugen et al. 2016). A larger scale American elm underplanting trial was started on the Avon Bottoms Wildlife Area in Rock County in 2014; however the results have not yet been reported. A 2011 study in Minnesota black ash swamps planted a variety of bareroot and containerized stock (i.e., yellow birch, balsam poplar, tamarack, black spruce, eastern cottonwood, quaking aspen, white cedar, basswood, red maple, American elm, hackberry, swamp white oak, Manchurian ash) within clearcut, group selection, girdling and control treatments (Looney et al. 2015). This study found that trees planted within group selection openings had better overall survival than clearcuts, suggesting that group selection may be a good compromise for maintaining site hydrology while supporting seedling development. Mortality was generally high with the majority of species having less than 50% survival in the first growing season; however the best performing species were Manchurian ash, swamp white oak, American elm, and hackberry – all of which were large bareroot stock. Conifer survival was poor in this study. Fall planting was preferred over spring planting due to improve accessibility, but survival results were mixed between spring and fall planted seedlings, depending on species and overstory treatment. A pair of artificial regeneration studies in black ash wetlands on the Ottawa National Forest and Superior Municipal Forest planted a variety of species with a focus on using natural and constructed hummock microsites (i.e., mounding) (Bolton et al. 2016). Trees planted on both natural and constructed hummocks had better survival, with American elm, silver maple, white cedar and red maple performing the best.

Species and Stock Selection – Species and stock selection are critically important for successful tree planting, especially in lowland stands where there is a limited number of adapted species to choose from and overall growing conditions can be challenging. The tree species selected must be compatible with the landowner's management goals and biologically suited to the planting site. Non-ash species considered for reforestation of bottomland and swamp hardwood stands in Wisconsin have included silver maple, red maple, river birch, yellow birch, paper birch, swamp white oak, bur oak, American elm, cottonwood, quaking aspen, hackberry, basswood, tamarack, white cedar, black spruce, hemlock, and white pine. Species from this list that have generally shown the best survival and growth in local studies and field trials have included silver maple, yellow birch, swamp white oak, American elm, cottonwood, tamarack, black spruce and white pine. Additional non-local species tested successfully on lowland sites in southern Wisconsin have included American sycamore and Kentucky coffeetree. A controlled flooding experiment testing the flood tolerance of planted seedlings found that swamp white oak and eastern cottonwood maintained the best growth and vigor over prolonged periods of water inundation (Kabrick et al. 2011). The Swamp Hardwood chapter of the Silviculture Handbook includes an analysis of local species that were historically present in public land swamp hardwood stands based on data from the Public Land Survey of the mid-1800s. In many locations in northern Wisconsin, it appears that the representation of conifers, particularly white cedar and tamarack, in these stands is much less now than it was historically. Seed source is also an important consideration to ensure climatic suitability and long-term stand productivity. Climate change will complicate the determination of appropriate seed sources due to potential shifts in suitable habitat. Some studies have experimented with the use of seed sources from southerly locations, however at this time there is limited seed movement guidance for most lowland species. In Wisconsin, we have generally considered hardwood seed sources suitable if they are from no more than 100-150 miles south of the planting site. Other tree species, such as American elm, have their own forest health challenges. At this time there are no American elm seed sources tested that are both Dutch Elm Disease resistant and appropriate for wide-scale reforestation based provenance suitability, but research and field trials continue in this area.

Stock selection includes both the propagation method (i.e., bareroot, containerized, cuttings) and the plant size (e.g., stock age class, container size, cutting size). All of the propagation methods may be appropriate for lowland sites depending on the species and planting method, but generally larger stock size has been favored for better survival on lowland sites because of high levels of interfering vegetation and periods of water inundation. It has been observed that seedlings with portions of the stem that remain above the water during periods of flooding have better survival rates. Large containerized stock is expensive, but generally demonstrates high survival rates and superior initial height growth. Bareroot stock is lower cost and is generally easier to transport and can have a competitive advantage over weeds. The American elm trial cited above observed that younger 1-0 elm stock had a better root to shoot balance and grew exceptionally well if not damaged by browse. Further trials are needed to help refine species and stock selection guidelines for lowland stands.

Browse Protection – Deer browse is often a significant barrier to successful tree planting in lowland stands. Small scale plantings, such as those within group and patch selection openings, can be particularly susceptible. Nursery grown stock is also considered more susceptible to browse due to the higher plant nutrient concentrations. If browse is expected to be a limiting factor, consider applying browse protection measures. Options include both physical barriers (e.g., tree shelters, bud caps, fencing, tree tops) and repellents. In areas with severe browse, more foresters in Wisconsin have been experimenting with polypropylene fencing around harvest gaps and patches. Costs for this fence are currently running around $1-2 per linear foot. Lowland stands with moving flood waters may present fence maintenance challenges however.

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Note – Development of this checklist was led by Greg Edge (Wisconsin DNR), with input from Colleen Matula (Wisconsin DNR), Brad Hutnik (Wisconsin DNR), Bill Ruff (Wisconsin DNR), Anthony D'Amato (University of Vermont), and Justin Pszwaro (The Nature Conservancy). Work contributing to the development of this checklist was supported by funding through the USDA Forest Service Northeastern Area State and Private Forestry, the Department of Interior Northeast Climate Science Center, the Upper Midwest and Great Lakes Landscape Conservation Cooperative, and the Wisconsin Department of Natural Resources.

Appendix 4: Personal Essay by the Author: "Wabanaki Traditional Ecological Knowledge in Emerald Ash Borer Management and the Implications of State and Federal Regulation"

Wabanaki Traditional Ecological Knowledge in Emerald Ash Borer Management and the Implications of State and Federal Regulation

Report Prepared by: Tyler D. Everett

Date Prepared: 3/12/2018

There is value to be seen in the knowledge of the Native American community. Value to the progression of science, policy, and overall management in natural resources. The scientific community has in the past disregarded this asset; but in recent years the acceptance of this asset has grown and led to the appreciation of what is now known as traditional ecological knowledge or TEK (Greenlaw). There are many examples in which western science and TEK have met and worked cooperatively to advance our understanding of the natural world and be more effective in our management of it. Here in the state of Maine, the Native American tribes that are federally recognized refer to themselves collectively as the Wabanaki nations. This is because of the shared history between all the Wabanaki tribes. No matter the tribe, whether Penobscot, Passamaquoddy, Maliseet, or Micmac they have a connection that bonds them closely to their identities individually and as a group. One core connection is their spiritual identity as it refers to their creation story. The Wabanaki people share stories that have been told and retold for generations. A heroic figure that has stayed constant in them is Gluskap. The Wabanaki refer to him as one of them, but he is powerful and wise. In their creation story, Gluskap comes to North America before any natives inhabited the area and fires his bow and arrow at the "trees, the basket-trees, the Ash. Then Indians came out of the bark of the Ash trees." (Wood, 2017). This tight connection between their creation and brown ash trees establishes the ash tree as part of who they are and as a culturally significant species to the Wabanaki people (Wood, 2017). But, the importance of this tree to them is even greater.

For generations the Wabanaki people have been using the brown ash and its particular special properties to make baskets. The production of a brown ash basket is truly an art starting with just the selection of a true basket quality ash tree in the forest (Greenlaw). Every generation of Wabanaki basket makers have taken the time to teach younger generations the art of basket making, and all the steps involved. This format of building knowledge and understanding forces those engaged to develop an unprecedented knowledge of the brown ash tree and serve as true stewards to ash species. This knowledge may not be backed by statistics and extrapolating it may be difficult, but this knowledge can serve as an asset of traditional ecological knowledge that the scientific community can use to better their understanding of the brown ash species (Greenlaw;Newell).

Currently the scientific community is realizing their lack of understanding of many of the ash species, primarily the brown ash species. The brown ash species is the only ash species native to Maine that is essential in the traditional basket making practices of the Wabanaki people. The need to further our understanding of the brown ash species is a high priority as it is susceptible to invasion by an invasive forest pest known as the emerald ash borer (EAB). The lack of knowledge on the species is largely because brown ash has not been viewed as an economically valuable species, in terms of timber production. For this reason, the use of funds to research brown ash has not always been there. Furthermore, the sites in which brown ash tend to grow are very mesic to the point of inoperability for commercial harvest. There tends not to be any species of value mixed in these stands either as the sites tend to be characterized as less productive primarily due to their extended periods of water inundation (D'Amato, et al 2018). The Wabanaki people realize the importance of managing and protecting this resource for future generations, given the current situation of brown ash and other ash species in the light of EAB. EAB is an invasive pest that came to North America in 2002, presumably by packing materials such as wooden crates and pallets. It has devastated ash stands in the central lakes region of the country leading to, in some cases, one hundred percent mortality. Management of the pest is controversial, and the most effective techniques are expensive and difficult or impossible for commercial operations to effectively implement. Continued research on prevention, mitigation, and restoration of these brown ash stands is a priority (D'Amato et al,2018; USDA APHIS,2018; Haack et al, 2015).

Forest management regarding EAB has generated concern from various parties. At the University of Maine, it has led to the reincarnation of the Brown Ash Task Force (BATF). The BATF is a group that was brought together to begin generating some knowledge on the brown ash species. The initial event that brought them together was not EAB related but instead a concern among basket makers that were observing a pattern of decline in brown ash trees. They voiced their concern with forestry and tree health professionals at the University of Maine in Orono. The response was to get together and discuss these concerns and focus research efforts on identifying the issues and providing solutions. They determined the die back at that time was an environmental scenario stemming from the long-term effects of an intense ice storm experienced across the state in 1998. As the group meetings progressed, the attendance widened to professionals in other fields, students, state officials, and even representatives working with federal agencies. With the rapid spread of EAB, the BATF reestablished in 2015. Their goals and how they operate highlight them as a primary example of western science and traditional ecological knowledge coming together. This group is now working together on following the progression and changes in policy surrounding EAB and continued research on brown ash and emerald ash borer (Daigle). The Wabanaki people are open to adopting western science knowledge and silvicultural techniques for EAB management and have pushed their forestry departments to continue their involvement with the BATF as well as many other applicable conferences and meetings so that that they can better educate themselves on EAB management (Neptune).

The Wabanaki people also work to spread their traditional ecological knowledge to the public and researchers by regularly attending public meetings and holding demonstrations in which they explain their traditional basket making practices. The value of the BATF group is that it brings so many different viewpoints to the same table to discuss some of the more specific questions and concerns they might have (Daigle). I was fortunate enough to attend the previous meeting in which I was able to develop an idea for my masters project. Being Native American and a member of the Wabanaki people, I find it important to understand the traditional ecological knowledge of my people. This knowledge and the scientific knowledge I have acquired through the University of Maine will fuel this project, making it another example of TEK and western science meeting. My project will be to develop an ash resource inventory manual for the tribal forestry departments of the Wabanaki people. The manual will be tailored to provide the data necessary for determining the areas that are most susceptible to EAB impacts, and allow natural resource professionals and foresters to formulate EAB response plans in the best interest of the tribe. Suzanne Greenlaw is a graduate student here at the University of Maine working on developing a habitat suitability model for basket quality brown ash. She provides another example of a Wabanaki working to bring TEK and western science together in managing brown ash. Her research includes multiple interviews with basket makers from various tribes to generate qualitative data that is used to model the habitat suitability of brown ash (Greenlaw). In addition to finding the inspiration for my master's project at the latest BATF meeting, I was also enlightened about some more serious short comings of policy on the state and federal levels.

In the summer of 2002 EAB was first detected in central Michigan, and later in the same summer it was detected in Ontario, Canada. The infestation was assessed by the state of Michigan and they determined that the pest had been there since the 1990's based on the size of the infested area. By July and September of 2002, Michigan and Ontario had enacted quarantines on the affected areas. The United States Department of Agriculture responded to the discovery of EAB by enacting a federal quarantine on the affected counties of Michigan in October of 2003 (USDA APHIS, 2003) since the establishment of the federal quarantine it has expanded continually. It now includes 22 states in their entirety and specific counties of 12 more. (USDA APHIS, 2018). The last quarantine notice issued by USDA APHIS was on July 26, 2018 when Wisconsin was put under quarantine in its entirety. It is important to note that the federal quarantine works domestically only; restricting the movement of particular restricted items of the *Fraxinus* family. Fortunately, Canada is also actively mitigating and limiting the impacts and spread of EAB so import of ash to the US from within Canada's federally set quarantine areas, is not a huge concern currently. In September of 2018 the Maine Forest Service issued an emergency order that restricted the movement of certain ash species (*Fraxinus spp*.) products and or untreated firewood from towns that have had any EAB detection (MFS, 2018). This emergency order was put in place because the state of Maine was not listed in the federal quarantine area at that time as the detections within the state were so recent. Shortly after the issuing of these Emergency Orders, USDA APHIS proposed the removal of the emerald ash borer domestic quarantine regulations. This was posted online for comment in Fall of 2018 and was open for comments until November 19th, 2018 (USDA APHIS, 2018). A state-wide quarantine is not in place for the state of Maine, should the federal quarantine be terminated. There currently isn't even a proposed state-wide quarantine in Maine. When the federal quarantine is lifted the movement of currently restricted products from quarantined areas surrounding Maine can import them to the state without any regulation. Studies have shown that one of the fastest and largest threats to the spread of EAB is the movement of firewood. Without any sort of quarantine on the federal level this threat is far more likely to encroach on the state of Maine. Forestry professionals and natural resource managers from across the state recognize the negative impact lifting this federal quarantine could have. For this reason, Maine was very well represented in the comments on this proposed regulation change with a substantially higher number of comments against the quarantine being lifted in comparison to comments for the lifting of the quarantine (Daigle).

When looking at the relationship between the United States and Native American tribes we often look to the terms described for the US trust responsibilities to Native American tribes. The U.S. Supreme Court has established and reinforced this trust responsibility throughout many instances of reviewing treaties between the U.S. and tribes. Within this description of trust responsibilities there is language of "providing for the well-being of tribes" and "an obligation to provide those services required to protect and enhance tribal lands, resources..."(ANA, 2014). For the Wabanaki people, the brown ash is not only a resource for the tribe on tribal lands but also a culturally significant resource, in which its very presence is vital to the well-being of tribal members. Therefore, lifting the federal quarantine and increasing this resources' susceptibility to infestation by EAB is a prime example of the U.S. not fulfilling their trust responsibility to Native American tribes. Furthermore, part of the trust responsibilities for the United States is to includes "those economic and social programs which are necessary to raise the standard of living and social well-being of the Indian people to a level comparable to the non-Indian society." (ANA, 2018, p.X). Wabanaki basket makers have perfected their trade for so long that their baskets are true art pieces that catch values upwards of $10,000 at basket shows across the country. The time and effort to get to that level is substantial and those tribal members really rely on that source of income as their livelihood. They are also the tribal members most responsible for sustaining this cultural livelihood through time (Newell). So once again, lifting the federal quarantine and increasing this resources susceptibility to infestation by EAB is a prime example of the U.S. not fulfilling their trust responsibility to Native American tribes.

The state of Maine does not hold the greatest track record of responding to forest pest breakouts. In the 1970's Maine was subject to a widespread outbreak of spruce budworm. This outbreak was forecasted well in the industry, like what we're observing with EAB, and as a result stimulated excessively high cutting levels for spruce and fir in the state. Many landowners permitting cutting far past their annual allowable cuts. Some of these observations were made in areas not affected by the outbreak either bringing about public scrutiny and changing the dynamic of Maine's forest for years thereafter (Irland et al, 1988). Today we have more programs and regulations in place to prevent these issues from reoccurring, but there is a risk that we could observe some controversial harvesting of ash species in the light of an EAB invasion.

Another area of concern surrounding these topics of regulation are how they influence protocol at the Maine and Canadian border. I reached out to Samantha Anderson, the agricultural specialist for U.S. Border Patrols, Jackman office regarding this issue. She explained that currently with the federal quarantine in place they are ordered to not allow any ash products across the border. That being said, searches on logging trucks coming from Canada occur at random and not all are searched in regard to the species of wood being transported. The only record for imported products documented by the U.S. Border Patrol is the "Import Manifest Documentation". These forms are tied to every shipment across the border. When it is a logging truck the specifics of what is being hauled are generally described in vague detail by the trucker on this form. Examples of these descriptions would be "HW Pulp, SW Pulp" or even as vague as simply "Logs". This system does little to mitigate the spread of ash products, in that it is rare that any product is defined down to the species. The agricultural specialist commented that she does not think the federal quarantine will be lifted anytime soon. But, if it were she would hope the state of Maine would have a quarantine in place at the state level. She says this because regardless as to whether the state regulates the movement of ash products or not, border patrol will only enforce regulation from a federal quarantine on ash products. That is, unless advised by their superiors in Boston to continue stopping the movement of ash species across the border, which she believes will likely happen if the quarantine is lifted (Anderson).

With the federal quarantine lifted, Maine would likely enact quarantines within the state to limit the spread from infected areas to uninfected areas in the state. Hopefully this is done in a timely manner. There are opportunities to implement programs to strengthen the effectiveness of any strategy for limiting the spread of EAB. A program I have recently come across is being implemented in Canada. The program works to limit the spread of EAB by tracking the movement of any restricted products within the country and it requires this for products taken from and mills/other facilities housing ash products to enroll in this program. The incentive for enrolling is simply job security, if you will. The closer of an eye we can keep on ash products which they rely on as a source of income the better off everyone is. The Canadian Food Inspection Agency (CFIA) developed this program. They refer to it as their Emerald Ash Borer Approved Facility Compliance Program (CFIA, 2017). In their overview of the program they establish that this data also follows any ash products imported into the United States. This would be an effective strategy that the U.S. and/or Maine could adopt from, or partner with the CFIA on. The platform is already there and would be fairly easy to implement. This may be a future program we utilize here in Maine.

Appendix 5: Emerald Ash Borer Information for Maine Landowners (Information Sheet 28)

file:///C:/Users/tyman_000/Downloads/28_eab_info_for_me_landowners.pdf

INFORMATION SHEET 28
May 2017

Emerald Ash Borer Information for Maine Landowners

Maine Forest Service, DEPARTMENT OF AGRICULTURE, CONSERVATION & FORESTRY
22 State House Station, Augusta, ME 04333

What is emerald ash borer?

Emerald ash borer (EAB) is a non-native beetle that that attacks and kills ash trees. Native to China, eastern Russia, Japan, and Korea, it was first detected in North America near Detroit, Michigan, in the early to mid-1990's.

What kind of damage does it do?

EAB feeds on all species of ash. None of Maine's native ash trees (***Fraxinus*** spp.) are resistant to the insect. Mountain-ash is not a host because it's not a true ash species.

It takes 3-5 years for infested trees to die. Research suggests that some low level of tree resistance may occur, though less than 1% of ash trees are expected to survive the EAB invasion. Tree mortality is widespread in areas where EAB is established

EAB damages trees by boring through the inner bark. Heavy feeding by the larvae disrupts the movement of water and nutrients.

Branches less than 1" in diameter can be infested. EAB infestations often begin in the canopy.

EAB-infested trees die in 3-5 years

Will it spread to Maine?

EAB is expected to spread to Maine. With over 100 million ash trees in Maine, it will have a significant impact.

EAB has NOT been detected in Maine yet. No EAB adult beetles have been caught on the hundreds of purple panel traps that have been deployed throughout Maine or by any other detection methods, such as visual surveys, girdled trap trees, and monitoring predatory wasp colonies.

There are several known EAB infestations, however, within 50 miles of Maine's border. Examples include the greater Montreal area, south-central NH, Massachusetts, Connecticut and New York. People spread EAB much farther and faster than it spreads on its own.

Moving firewood is the #1 cause of EAB spread. Other new infestations have been traced to shipments of nursery trees and logs. But all stages of the insect can travel 65 mph down the interstate inside infested wood!

EAB will easily survive Maine's winters. It is a cold-hardy insect, native to northern China, Mongolia, and the Russian Far East. It has already become established in Quebec, Ontario and northern Michigan.

Avoid spreading EAB to non-infested areas by using only locally-sourced firewood.

How can I tell if I have EAB?

Woodpecker damage to live trees may be the first sign that a tree is infested. When feeding on EAB, woodpeckers scrape off outer bark, leaving smooth, light colored patches. If the bark is removed, S-shaped galleries weaving back and forth on the surface of the wood may be visible. The D-shaped exit holes are good EAB indicators, but are small and can be hard to see.

Other health problems can kill ash trees in Maine. Ash trees are susceptible to drought. An infectious disease called ash yellows is common in parts of the state. Not all declining ash trees are necessarily infested with EAB.

Adult beetles are ½" long and metallic green. Under the wing covers, their abdomen is purple. Adult beetles may be present between June and August. Information about lookalike insects is available at http://www.maine.gov/DACF/php/caps/EAB/EABid.shtml

If you think you might have EAB, report it. Collect and/or photograph any suspect insects. If you can't reach someone at the contact numbers below, call the EAB hotline at 1-866-322-4512

Woodpecker damage may be the first sign that a tree is infested with EAB.

What will happen when EAB is found in Maine?

The first step will be to determine the size of the infested area. Most state and federal management decisions will depend on the results of this on-the-ground delineation survey.

We won't get rid of EAB by removing ash trees. Early eradication attempts have been costly and unsuccessful. While some ash tree removal may be a component of a broader, integrated EAB management approach, Maine will not implement widespread tree removal to try to eradicate EAB.

In forest stands, most ash trees die in 3-5 years. Once the trees die, additional sunlight reaches the forest floor, stimulating growth of young trees and other plants, including non-native invasive species if they are present. While they're standing, dead ash trees fall apart fairly quickly. They are more likely to become coarse woody debris than long-term snags, but still provide some benefits for wildlife. Landowners should look out for hazardous situation caused by dying ash trees for recreational users, loggers and firewood cutters.

Landowners will be able to sell ash logs, but there will be restrictions. When a new EAB infestation is detected, a quarantine zone will be established. Under current rules, ash logs can be transported out of the quarantine zone, but only to a sawmill with a "compliance agreement" to follow shipping restrictions. No restrictions apply if your woodlot is outside the quarantine zone, or if both your woodlot and the destination sawmill are within it.

In other states, log prices have been minimally affected. Researchers have tracked log prices before, during and after EAB, and have found prices remained steady or increased slightly. This may be due to a larger quarantine area, resulting in additional markets available to landowners, a spike in demand by mills stockpiling logs, and or a combination of factors.

Should I cut my ash trees now?

It could be many years before EAB shows up in your woodlot. Consider the ecological, aesthetic, and economic value of your ash, your tolerance of risk, and your objectives for ownership. Stay abreast of new information to avoid short-sighted decisions. Visit http://www.maine.gov/DACF/php/caps/EAB/index.shtml for the latest news on EAB.

Work with a consulting forester to protect your interests and your forest. Studies have shown that woodland owners who use professional forestry services before they cut make more money and are more satisfied with the results than owners who sell timber on their own.

Plan for EAB now if you have ash trees in your woods. It may take a while to carry out your plan, especially on large ownerships. Know what's at risk: how much ash you have, its size and quality, and where it's located. Your potential losses may be minimal and require little to no additional management.

Growing ash sawlogs is a riskier long-term investment than it used to be. During scheduled harvests, take steps to limit your exposure to loss. Reduce the percentage of large ash trees.. Review your diameter target (how big to grow trees before cutting them) with your forester, discussing site quality, tree condition, and markets. To keep from degrading your woodlot, retain good quality trees of a variety of species.

If you're growing trees for timber income, don't cut immature ash too early. If the trees are too small to yield high value sawlogs, you may get a better return if you allow them to grow. They will increase in volume, and may improve in grade, which will lead to a better return.

If you decide to cut, consider leaving scattered ash trees in the woods. The last trees standing will be the last to produce seed.

Reassess your plan if EAB is detected in or near your county. Keep abreast of news about the insect. The threat of imminent tree mortality increases when EAB is detected within 10 miles of your property.

What else can I do?

Spread the "Don't Move Firewood" message in your town. Visitors who bring infested firewood to second homes or campgrounds near you put your trees at risk. Talk with neighbors and campground owners. Post leaflets, available through the contacts below, in your community.

Know when EAB arrives near you by supporting detection efforts. Help spread the word in your community; a variety of outreach materials are available. Participate in more formal monitoring efforts through http://www.maine.gov/DACF/php/caps/EAB/index.shtml

Think big. Take action. Encourage your town to plan ahead for EAB. By addressing issues before EAB arrives, the loss associated with an infestation can be spread over a longer period of time. Neighboring communities can coordinate to share resources and reduce costs. Please visit http://www.maine.gov/DACF/php/caps/EAB/index.shtml for more information.

Is there any hope?

We've only known about EAB since 2002. Our knowledge about the insect is rapidly expanding. A substantial research effort is underway to improve insect management and tree survival.

Scientists are investigating natural enemies of EAB. Parasites and predators significantly reduce EAB populations. Several parasites from China have been released, and are now becoming established in the US. As these efforts continue, the impact of EAB may be reduced, making it more manageable in the future.

Many healthy ash trees are still growing in every infested state. Even where mortality has been severe, the occasional "lingering" ash has survived. Partial resistance has been found in North American blue ash. White ash is thought to be genetically diverse, providing hope that some genetic resistance may occur in that species as well.

For additional information:

Maine Forest Service:
http://www.maine.gov/DACF/php/caps/EAB/index.shtml

Emerald Ash Borer Information Network
http://emeraldashborer.info/

US Forest Service, Northeastern Area
https://www.na.fs.fed.us/fhp/eab/

State of Maine – Invasive Species
http://www.maine.gov/portal/about_me/invasives.html

Facebook – Maine Bug Watch
https://www.facebook.com/Maine-Bug-Watch-286814954695063/?hc_ref=PAGES_TIMELINE

Twitter – Maine Bug Watch
https://twitter.com/mainebugwatch?lang=en

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For more information, please contact:
Maine Forest Service
DEPARTMENT OF AGRICULTURE, CONSERVATION & FORESTRY
22 State House Station
Augusta, ME 04333-0022
(207) 287-2791 or 1-800-367-0223
forestinfo@maine.gov

Be Woods Wise!

www.maineforestservice.gov

Appendix 6: Dr. Kim Iles "A Sampler of Inventory Topics": 3P Ordering Information

The current series of books is as follows :

(Book 1) ***A Sampler of Inventory Topics*** *(3d printing)*

(860 pages, **17 chapters**) This is a technical book, oriented to forest sampling and Timber Cruising. It has chapters #16 *Regression* & #17 *Hypothesis Testing* on a CD, (otherwise the book is too large to print) along with Excel programs showing computation methods (as do all the other books). The statistics are dealt with as logical issues, with very few equations, and lots of examples.

(Book 2) ***The Compassman, The Nun, and The Steakhouse Statistician***

359 pages, **40** short chapters (≈5 pages each), very few equations or math. This is a more philosophical book, with technical solutions to practical statistical and sampling problems, and some advice to young samplers. It includes the two chapters from the *Sampler* book on Regression and Hypothesis Testing, just so the chapters do not disappear (print lasts - CD's will not), and those chapters are easier for most people to read in printed form. One of the 3 main characters in the book, "OH", is from chapter 6 of the *Sampler*. Example chapters can be viewed at my website.

(Book 3) ***The Retread, The Reject, and the Tower Statistician***

417 pages, **61** short chapters, in much the same style as the *Compassman*. OH and another character from that book are continued here. It has more advice on the practical and psychological issues of a career in forest sampling, running an inventory department and making measurements (with several current and newer techniques used as examples). Just as the other books do, it emphasizes the underlying ideas of statistics and sampling.

Prices (as of Jan 2018

Sampler **$60** plus shipping
Compassman **$35** plus shipping
Retread **$45** plus shipping

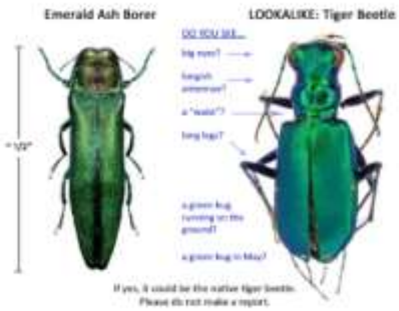
For shipping **<u>outside North America</u>** you can check with me first on the postage.

Orders can be made at :
http://www.island.net/~kiles/
My email is :
kiles@island.net

Appendix 7: Insects in Maine that may be confused with EAB

Adult

- small (1/2 inch)
- metallic green
- narrow, bullet-shaped
- seen June-August
- flying near canopies of ash trees
- rarely on the ground

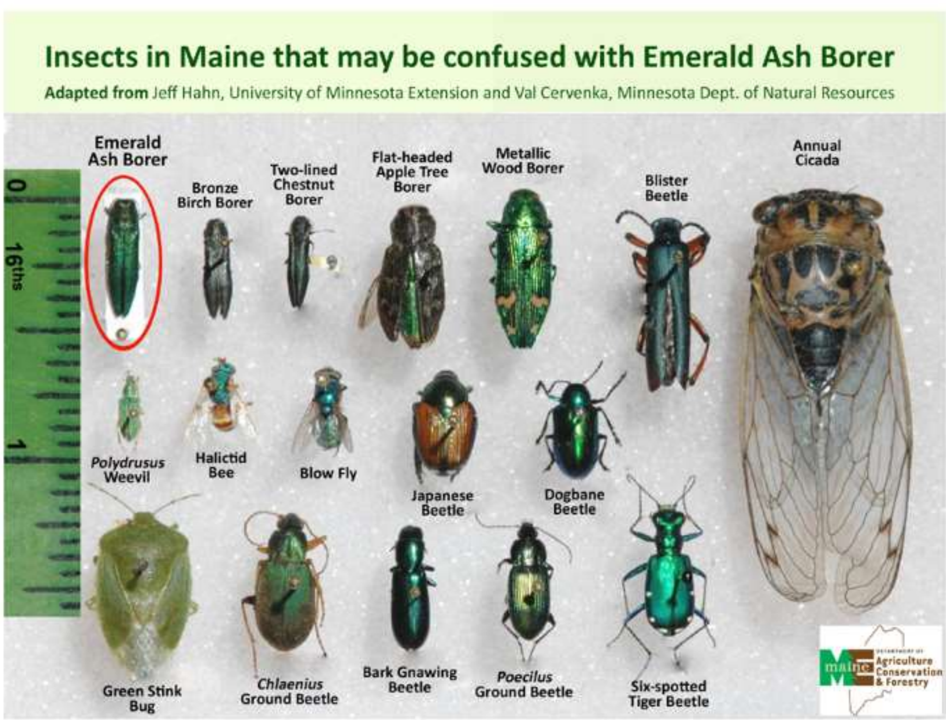


(photo credits, left to right: Howard Russell, Michigan State University, PA Department of Conservation and Natural Resources (adapted))

Larva

- is between 1/2 inch and 1 1/2 inches
- creamy white
- narrow with bell-shaped segments
- may be seen year-round
- in cambium layer of ash trees

(photo credits, left to right: PA Department of Conservation and Natural Resources, David Cappaert, Bugwood.org)



https://www.maine.gov/dacf/php/caps/EAB/EABid.shtml

Appendix 8: Resources for Distinguishing Various Ash Species

Forest Trees of Maine Excerpt

https://www.maine.gov/dacf/mfs/publications/handbooks_guides/forest_trees/pdf/Ashes.pdf

ASHES *The Important Distinctions*

ASH

	**White Ash** *Fraxinus americana*	**Green Ash*** *Fraxinus pennsylvanica*	**Black Ash** *Fraxinus nigra*
LEAVES			
LEAFLETS	5–9, usually 7	7–9	7–11
DESCRIPTION	Leaflets are mostly entire, borne on stalks, without hairs below. Turn purple in autumn	Leaflets borne on stalks. Hairy below and on rachis. Turn yellow or bronze in autumn.	Toothed leaflets which are without stalks except the one at the end. Hairs lacking below except for buff-colored hairs at the junction of the leaflets and the rachis. Turn yellow in autumn.
BUDS			
SIZE	⅛ inch	⅛ inch	Less than ¼ inch
SHAPE	Blunt-pointed	Cone-shaped	Sharply-pointed
COLOR	Brown	Brown with rusty or dull red hairs	Black or very dark
FRUIT			
WINGS	Wing terminal	Seed body grading gradually into wing	Flat, completely surrounds seed body
SEED BODY	Cigar-shaped	Funnel-shaped	Slightly twisted, less than half the length of the fruit
TWIGS			
TEXTURE	Smooth and shiny, often with slight bloom, very brittle	Somewhat covered with downy hairs	Smooth, not shiny
COLOR	Gray or greenish-brown, inner bark bright brick red	Greenish-gray, inner bark cinnamon-colored	Pale gray, inner bark dirty white

*Specimens of green ash which lack hairs on the twigs or leaflets, but otherwise fit the above description, were formally designated as var. lanceolata. They are now designated under the species due to the many gradations of the hairiness character.

ASHES 127

WHITE ASH *Fraxinus americana* L.

White ash is one of Maine's valuable timber trees and is found commonly throughout the state.

White ash is one of Maine's valuable timber trees and is found commonly throughout the state. Best growth occurs on rich, rather moist soil of low hills. It grows to a height of 60–70 feet and a diameter of 15–30 inches. The branches are upright or spreading, forming a narrow top in the forest.

The **bark** pattern resembles a woven basket; it is broken into broad, parallel ridges by deep furrows, and is dark brown or deep gray.

The **leaves** are opposite, 8–12 inches long and consist of 5–9 (usually 7) leaflets. The leaflets are 3–5 inches long, oval to lance-shape, borne on short stalks, edges remotely toothed towards the tip, dark green and often shiny on the upper surface. In fall, they turn to a soft, velvety purple.

The **fruit** is a single samara occurring in clusters. The seed body is cigar-shaped and has a terminal wing.

MAINE REGISTER OF BIG TREES 2008
White Ash
Circumference: 244"
Height: 95'
Crown Spread: 70'
Location: South Waterford

White ash twigs are hairless and have deeply notched leaf scars.

The **twigs** have a smooth, shiny bark which is grayish, greenish or maroon on the surface. The inner layer of the bark is brick red. The terminal buds are rounded or dome-shaped.

The **wood** is hard, strong and tough. It is used for agricultural implements, tool handles, oars, furniture, interior finish, dowels, pulp and firewood, and sporting goods including baseball bats, hockey sticks and snowshoe frames.

GREEN ASH *Fraxinus pennsylvanica* Marsh.

Green or red ash occurs over much of the state, particularly along the major rivers. It is not as abundant as the white and black ash, but is fairly common in central Maine. Sometimes mistaken for black ash, it grows near the banks of streams and lakes on rich, moist soil. It has stout branches that bend downward on older trees and form an irregular, compact head in the forest. It seldom exceeds a height of 50–60 feet and a diameter of 16–20 inches.

The quality of green ash wood is not as good as white ash.

Green ash twigs are often hairy and do not have deeply notched leaf scars.

MAINE REGISTER OF BIG TREES 2008
Green Ash
Circumference: 115"
Height: 63'
Crown Spread: 65'
Location: Mechanic Falls

The **bark** on the trunk of old trees is dark gray or brown, and firm and furrowed like that of the white ash.

The **leaves** are 10–12 inches long, opposite, with 7–9 leaflets borne per stalk. Leaflets are 4–6 inches long, entire or wavy, or sometimes toothed, particularly on the upper-half of the leaflets, yellow-green on the upper surface, hairy below and on the rachis, and oval to elliptical.

The **fruit** has a funnel-shaped seed body gradually blending into the terminal wing.

The current year **twigs** are greenish-gray and covered with numerous hairs, although sometimes there are no hairs. Inner bark is cinnamon red.

The **wood** is hard, heavy, fairly strong, coarse-grained and brittle. It is used in the same ways as white ash.

BLACK ASH *Fraxinus nigra* Marsh.

Black or brown ash occurs statewide. It grows almost entirely on rich, moist ground or in cold, wet swamps and along the banks of streams.

It is a tall, slender tree with a short, narrow head. It grows to a height of 50–60 feet and a diameter of 10–20 inches. The trunk is often without branches for a considerable distance from the ground.

The **bark** is gray to dark gray, corky and spongy, with more or less parallel ridges. It rubs off freely with the hand.

Black ash wood is used for interior finishing, cabinet work, baskets and, to a limited extent, pulp.

The wing of black ash fruit completely surrounds the seed body.

The **leaves** are 12–15 inches long, opposite, and have 7–11 leaflets that are 4–5 inches long, and without stalks except the one at the tip. Leaflets are lance-shape and have remotely-toothed margins. The upper surface is dark green. There are buff-colored hairs at the junction of the leaflets and rachis.

The **fruit** is a single samara occurring in clusters. The seed is flattened and completely surrounded by the wing.

The **twigs** are smooth, gray to olive-green. The buds are black or brown and pointed at the tip. The inner layer of the bark is dirty white.

The **wood** is coarse-grained, heavy, tough, durable and pliable. It is used for interior finishing, cabinet work, baskets and, to a limited extent, pulp. It the past it was used to make barrel hoops.

MAINE REGISTER OF BIG TREES 2008

Black Ash

Circumference: 139"

Height: 82'

Crown Spread: 56'

Location: Waterboro

AMERICAN BASSWOOD *Tilia americana* L.

American basswood or linden occurs as scattered specimens throughout the state. It grows to a height of 50–70 feet and a diameter of 2–3 feet. The branches are slender, somewhat pendulous, comparatively small and numerous, forming a broad and rounded head.

The **bark** on the trunk of old trees is deeply and irregularly furrowed. On young trees, it is smooth or slightly fissured and has a grayish appearance.

The **leaves** are alternate, 5–6 inches long with uneven bases. They are broadly egg-shaped to heart-shaped in outline, and toothed; the upper surface

Light, soft, easily worked and carved, American basswood is used for molding, yardsticks, veneer, dowels, furniture, carvings and pulp.

The fruit of American basswood is attached to a distinctive leaf-like bract.

is dark green, while the lower is yellow-green and shiny.

The **flowers** are greenish-yellow, borne on a slender stalk that is attached to a rather long, yellowish, leaf-like bract. They are fragrant, contain an abundance of nectar and open in July.

The **fruit** is clustered, spherical, covered with short buff-colored hairs, woody and about as large as a pea. It remains attached to the leaf-like bract when it falls.

The **twigs** have a zigzag pattern and bright red buds.

The **wood** is light, soft, easily worked and carved. It is used for molding, yardsticks, veneer, dowels, furniture, pattern stock, carvings and pulp. Traditionally it was used to make butter box molds, dough bowls and other kitchen items that touched food.

In Germany, basswood is called the bee tree. Bees make an excellent grade of honey from the flowers. The young fruit and flowers ground into a paste make an excellent substitute for chocolate.

The **European linden** (*Tilia europaea* L.) and **Little-leaf linden** (*Tilia cordata* Mill.) are commonly planted as shade trees. They are smaller in height than our native species and with smaller leaves. Baxter Boulevard in Portland is lined with both of these species.

MAINE REGISTER OF BIG TREES 2008
American Basswood **Circumference:** 224" **Height:** 85' **Crown Spread:** 63' **Location:** Strong

American Elm *Ulmus americana* L.

American elm is one of our largest and most graceful trees; it occurs throughout the state, although its numbers have been severely reduced by Dutch elm disease. It is found most often on rich bottomland and moist soil along streams, but sometimes grows on higher ground. It grows quickly, attaining a height of 60–70 feet and a diameter of 2–4 feet.

The trunk often divides into numerous limbs, which form a vase-shaped or spreading, round-topped head with graceful, drooping branches.

The number of American elms in Maine has been severely reduced by Dutch elm disease.

ELM

The **bark** on the trunk is separated into broad ridges by deep fissures and is ashy-gray on the surface. It shows alternate layers of chocolate brown and buff coloration beneath.

The **leaves** are alternate, 3–6 inches long, with coarsely doubly-toothed margins and uneven bases. The upper surface is dark green and sandpaper-like.

The **flowers** appear in April before the leaves.

The **fruit** consists of a small, winged seed which ripens about the end of May, before the leaves have fully developed. It has a wide, open notch at the apex and a hairy margin.

The **wood** is spiral and coarse-grained, hard, heavy, strong, tough and hard to split. It is used for flooring, railroad ties and pulp. In the past it was used to make barrel hoops, barn stall flooring, door thresholds and wheel hubs.

Slippery elm, *Ulmus rubra* Muhl, has been recorded in Franklin and York counties, but these records are historical. A few specimens have been found in association with cultural settings, but it is not known if these populations are native or escaped. If it still occurs naturally in the state, it is undoubtedly quite rare. Slippery elm is most easily distinguished from American elm by the winter buds which are covered with rusty hairs. In the past, the inner bark of the slippery elm was chewed to relieve sore throats.

American elm twigs have a zigzag pattern and slightly flattened buds.

MAINE REGISTER OF BIG TREES 2008
American Elm Circumference: 244" **Height:** 110' **Crown Spread:** 120' **Location:** Yarmouth

Appendix 9: Accessing and Downloading USDA Web Soil Survey Data

You are here: Web Soil Survey Home / Getting Started

Getting Started With Web Soil Survey

Soil surveys are being completed and published in printed form on an ongoing schedule. As time passes, the data in printed surveys can become out of date. The up-to-date official information about the soils in a given area is now available in electronic form for each of the Soil Survey Areas. Web Soil Survey provides interactive access to the most current information for a user-defined Area of Interest. Click the following link to go to the Web Soil Survey home page: Web Soil Survey Home Page. If spatial soil data are available for your Area of Interest, Web Soil Survey also generates soil maps. Web Soil Survey also provides the capability to download official Soil Survey Geographic Database (SSURGO) soil data for whole soil survey areas. Generalized soil data (State Soil Geographic Database or STATSGO2) can also be downloaded in individual state datasets or the whole U.S.

Information about how to use Web Soil Survey, including a link to this **Getting Started** document, is available on the Web Soil Survey home page. Look on the right side of the home page in the **I Want To...** and **I Want Help With...** sections.

Here's a brief overview to get you started using Web Soil Survey:

1. Browse to the Web Soil Survey home page at the following link: Web Soil Survey Home Page.
2. To start the application, click the large round green button labeled **Start WSS**.
3. To work with Web Soil Survey interactively, jump to step 4 below. To download soils data for a full survey area or for State Soil Geographic Database (STATSGO2) data, click the **Download Soils Data** tab.
4. After the map refreshes, you can use the **Zoom In** map tool.

Click on the **Zoom In** tool to put the map in **Zoom In** mode. Then either click on the map to zoom in, or click and drag the map to zoom to the rectangle you've drawn. Zoom in as close as you need.

5. Or alternatively, on the left side of the browser window, in the **Quick Navigation** panel, click on one of the forms — **Address**, **State and County**, **Soil Survey Area**, etc. Enter the information, and click **View**.
6. Before you can view any soil data, you must define your Area of Interest or AOI. You can set your AOI by drawing a rectangle or a polygon on the map, or you can set your AOI to a whole Soil Survey Area. You can also create a multi-part AOI using the Create AOI from Shapefile or Create AOI from Zipped Shapefile options under the Import AOI menu. AOIs created using the **AOI Rectangle** and **AOI Polygon** tools are limited to a maximum of 100,000 acres, but Soil Survey Area AOIs are not.
   - To set your AOI to a rectangle, click the **AOI Rectangle** map tool. Then click and hold the left mouse button, and drag a rectangle on the map. When you release the mouse button, the rectangle you've drawn will be set as your Area of Interest.
   - To set your AOI to a polygon, click the **AOI Polygon** map tool. Then click points on the map to define your AOI. To finish, either double click the last point, or hold down the Control key while clicking the last point.
   - To set your AOI to a whole Soil Survey Area, in **Quick Navigation**, open the **Soil Survey Area** form. Choose a state and Soil Survey Area using the dropdowns. Then click **Set AOI**.
7. Once you have set your AOI, click the **Soil Map** tab to see the soil map and map unit information.
8. To create a printable document containing the map and information on the **Soil Map** tab, click the **Printable Version** button, and then click the **View** button.
9. To run soil ratings or soil reports, click the **Soil Data Explorer** tab, then the one of the inner tabs: **Suitabilities and Limitations for Use**, **Soil Properties and Qualities**, or **Soil Reports**.
10. On the left side of the browser window, click the **Open All** button to expand all the folders, or click an individual folder to list the items within it.
11. Click one of the items to open the form, then set options as desired, and click **View Rating** or **View Soil Report**. This will show the data in tabular form and, for the Ratings, in color-coded map form. Click the Legend tab at the left side of the map to see a legend of the Rating values.
12. To create a printable version of the soil data, click **Printable Version** or **Add to Shopping Cart**:
    - **Printable Version** generates a Portable Document Format (PDF) document containing the rating or report that you just ran.
    - **Add to Shopping Cart** adds the report or map to the shopping cart. You can add multiple ratings and reports to the shopping cart and then create a Portable Document Format (PDF) document containing all the items you added to it. The AOI soil map and the list of map units and their descriptions are added to the shopping cart by default.

      Once you're done adding content to the shopping cart, click the **Shopping Cart (Free)** tab, and then click the **Check Out** button. This will generate a single Portable Document Format (PDF) document containing all the items you added. By default, the **Soil Map** content is automatically included in your Portable Document Format (PDF) document.

      For best results, limit the number of items you add to the shopping cart to ten or fewer.

13. There is a **Search** function that you can use to search for where specific keywords occur in the application. The **Search** form is located in the upper left corner of each tab. Set your Area of Interest, then click **Search** and enter keywords, such as "hydric rating" or "KCl", and then click the **Search** button. The search results are links that navigate to the place in the application where the keywords were found.
14. After you have defined your AOI, you can also click the **Download Soils Data** link to download tabular and spatial soils data for your AOI. You will need Microsoft Access software to make use of the tabular data, and ArcGIS software to make use of the spatial data.
15. Throughout Web Soil Survey, context-specific help is available by clicking the following question mark icon: ?. For more information, see "How can I get help using Web Soil Survey?" on the Frequently Asked Questions page by clicking the following link: How can I get help using Web Soil Survey?
16. For assistance with specific soil data questions, you may click the following Contact Us link: Contact Us. The Contact Us link is also located beneath the USDA logo in the upper-left corner of Web Soil Survey.

    For further assistance, you can also click the following email link: soilshotline@lin.usda.gov.

Last Modified: 08/21/2017

Additional Steps:

17. Once the necessary data is downloaded, you can access database files for depth to water table, ponding frequency, and drainage class through the downloaded web soil survey folder.

18. Navigate to the "spatial folder". The table you're interested in for the above mentioned excel files, are labeled "soil_mu_a_aoi.dbf". Add this data into a GIS for the generation of useful maps for creating the brown ash corridor associated with stage 3 of the ash manual.

19. Once in your GIS the table will need to be joined to the existing table of data associated with the soil series polygons that were imported into a GIS by following the above steps.

20. The other option is to manually input the soil information into the existing table for your soil series polygons, if you have a large land base this can be very time consuming.

21. Once this data is in your GIS adjusting the labeling and symbology in your soil can create maps that visually display the characteristic of your soil that you are interested in.

Appendix 10: Accessing and Downloading National Wetlands Inventory Data

Download Data

The Get Data button will open a new dialog box with options for downloading seamless wetlands data as viewed on the Wetlands Mapper. The Wetlands Mapper provides users enhanced access to the wetlands data with the capability to download geospatial wetland map data by state and watershed (HUC8) in shapefile and file geodatabase format; and to connect to the wetlands dataset via web services (WMS, KMZ and REST). Connecting to Web services allows users to dynamically interact with the data on their desktop and web-based applications. You can view the Shapefiles by using ESRI's ArcGIS Explorer free software[5], among others. Geodatabases require a full ESRI ArcDesktop license.

By Watershed - The Download by Watershed option allows users to select individual watersheds in the mapper for data download. This tool gives you the option of downloading a Shapefile or File Geodatabase.

By State - You can also download data by State. Each State data download is available as either a compressed File Geodatabase or a Shapefile.

Web Services – Web Services option allows direct connection to the NWI web map service, for either wetlands data, wetlands status, or riparian data. For detailed information on how to connect to these services please visit our website at: https://www.fws.gov/wetlands/Data/Web-Map-Services

Once downloaded un-zipping the ".zip" file gives you access to the shapefiles associated with the data you collected. You may need to clip the area of extent down to your area of interest. But, this can easily be done within a GIS platform.

Appendix 11: Dr. Ellis Fraxinus Seed Collection Protocol

http://www.emeraldashborer.info/documents/Fraxinuscollection.pdf

RECOMMENDATIONS FOR THE COLLECTION, STORAGE, AND GERMINATION OF ASH (*FRAXINUS SPP.)* SEED

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Seed that is harvested when mature and processed immediately has the greatest life span during storage. Seeds infested with fungus or insects do not survive very long and may potentially infect other seeds. The recommendations below will help to acquire the highest quality seed for long term storage.

Identifying trees for collection

1) There are several species of interest: *F. americana* (white ash), *F. nigra* (black ash) and *F. pennsylvanica* (green ash) are among the ash native to the Lake States.
2) It is always a good to collect leaf samples along with seed samples so that identity can be confirmed.
3) Collect seed when it is mature. Seed maturation dates differ among ash species: Sept-Oct is generally a good time to collect black and white ash, while green ash can be collected into December. Also note that ash trees may only produce large seed crops once every 3 to 5 years.
4) Seeds are contained within fruiting bodies called *samaras*, with the seeds are at the thicker base end of the samara.
5) Collect seeds when the samaras are faded from green to yellow or brown. Seeds within samaras should be firm, crisp, white and fully elongated. Avoid collecting samaras that have signs of mold or insect infestation.
6) Record date, location (lat/long data from topo map and relevant landmarks and/or GPS coordinates) for sampled tree in field notes. Use one bag for each tree
7) Collect seeds on a non-rainy day

Collecting seeds (samaras)

1) Ash trees can be very tall. Make sure proper safety protocols are used.
2) You may want to spread sheets under the tree to collect seed that falls.
3) Clusters of samaras from low lying branches can be clipped with pruning sheers. Rope, pole pruners, shotgun or bow and arrow can be used to dislodge samaras from higher branches.
4) Pick seeds (samaras) off tree as late in the year as possible to ensure collection of mature seed. Avoid picking seed up off the ground. The trick may be to pick as late as possible but once mature, the longer you wait, the more prone the seed is to weathering, insects or fungal contamination. It is more efficient to harvest the seeds as clusters rather than picking individual seeds..
5) If leaves are available on the tree, prepare a pressed dry herbarium sample for positive identification of the species at a later date. See websites for proper preparation of herbarium samples.
6) Samaras should be a natural brown and no longer green (if seed is pale green it is ok where you cannot get back to the site in a week or two).
7) Visually inspect seed prior to collecting. When possible **do not collect seed which**:
   A) is black or dark green.
   B) has evidence of insect damage. This would appear as tiny entrance or exit holes in the seed.
   C) is non-uniform – avoid distorted, twisted seed.
   D) does not have a solid base which is thicker than the wing.
   E) is mildewed or has evidence of fungal infection (spotted/mottled-looking seed).
   F) is on the ground.
8) Once seed is picked off the tree, place the seed in a paper lunch bag and label the collection information (see number 10 below). A paper bag open at the top will provide necessary air flow to naturally dry seeds. Do not place in plastic bag or other container which does not allow air flow.
9) One paper lunch bag full of seed (4-6 cups of seed) is plenty from any one tree.
10) Use a separate bag for each batch of seed (usually seed from a single tree/bag).
11) Collection notes are usually kept in a field book with collection numbers written on the bag containing the seed. However, since multiple people will be collecting seed over many years and storage will be long-term, we recommend labeling the bag (and any pressed leaves) so that the location and identification of the source is clearly marked. The portion of the paper bag containing the label can remain with the sample in storage for positive identification of the collection decades from now. The labeling should include:
    A) The species – place question marks around the species when identification is not certain (*Fraxinus ?pennsylvanica?*).
    B) A description of where the seed was collected. Examples include:
       i) Just inside gate to Bear Park - left side of the road in Lightfoot County, MI.

ii) Right side of Elk Creek Rd, ~2.7 miles N. from the traffic light in Red Deer, WI.

iii) Moline National Park, Brookside campgroup, behind campsite #7, OH.

C) GPS/GIS coordinates and elevation when possible.

D) Description of tree:

i) Shrub or tree.

ii) Healthy or sick looking.

iii) Any Emerald Ash Borer (EAB) evidence ("D"-shaped exit holes, dead branches, lesions in bark).

iv) Evidence of other borers or insect damage.

v) Approximate height of tree.

E) Date of collection.

F) Name and contact information of person(s) collecting the seed.

12) Once collected, keep seed out of direct sunlight but in an area that allows airflow (i.e. not in a sealed cooler). Do not leave in hot car or box in the back of a pick-up truck or car in the sun.

13) Leave seeds (samaras) in paper bags open at the top for about 3 days in a dark, cool, dry location. After 3 days, clean the seed. Break apart the seed clusters so that seed is individualized and remove any branches and debris.

14) Dry samaras by spreading them thinly in a single layer on newspaper in a shallow tray. Use one tray/seed collection to avoid any chance of mixing two different seed collections.

15) Place the trays with the seed in a dark, cool, dry location. If the weather is humid, place trays in a dehumidified room with lots of airflow. They will dry out within about a week or two.

16) When samaras are dry, seeds can be cleaned. Seeds can be isolated from dried samaras by rubbing them through your palms. Remove samara fragments by shaking sample through screens. Spread cleaned seed out on tray and inspect for insect or microbial damage

17) Place the seed in an air-tight moisture-proof container containing with the collection information written on the outside of the container and the original labeling information from the collection bag inserted into the container with the seed. The portion of the collection bag with the information can be cut and inserted in with the seed.

A) Air-tight moisture-proof containers include:

i) A kitchen "seal-a-meal" self-sealing bags.

ii) A screw-top bottle or jar.

iii) A plastic zip-lock bag (least preferred as they often do not seal tight).

B) To label the outside of the container use a permanent marker – Sharpie's work great.

18) To test moisture content of the seed, place the seeds in a screw cap container containing a small package of *indicating silica gel*. If silica gel turns pink within a few hours, seeds should be removed and dried in a drier environment. If silica gel turns pink in 1-3 days, replace it with freshly activated silica gel. If silica gel remains blue for a week in the screw cap jar, the seeds are sufficiently dry for storage. Many silica gels can be reactivated by

putting it in the oven at about 250F overnight – the granules should turn from pink (moist) back to blue (dry).

19) Place the air-tight container containing the seed in a cardboard box in a freezer. Locate the freezer where someone looks at it at least weekly (preferably daily). This way any problem with the freezer will be noticed immediately. May freezers can also be equipped with an audible alarm to notify you if it is not keeping things cold.

Testing ash seed (samara) viability

When possible it is always preferable to know how good the seed is that you are storing. There are two primary reasons for this. 1) You want to ensure you are storing good, live seed and 2) you will to know if the seed deteriorates during storage to enable you to pull the seed out of storage and germinate it prior to complete loss of viability. Below we mention two methods. The first requires specialized laboratory equipment that can be found in most high school biology classes. The second method relies on germination of the seed. We recommend testing a minimum of 100 seed. In collections where few seed are available, testing 5-10 seed will suffice.

There are other methods for testing seed viability that are available and used in seed testing laboratories, yet these generally require advanced laboratory facilities. These methods include terazolium staining of the embryos and x-raying the seed. For *Fraxinus*, both methods are used, with x-raying of the seed the quicker and easier method for facilities with the equipment.

1) Physical examination of the seed. Fresh or dried seed can be examined with a microscope or magnifying glass.
   A) The narrow, pointed end of the seed is where the embryo is.
   B) Carefully cut this end open by slicing length-wise and observe the embryo
      i) The embryo should be white, solid and fill the entire seed cavity. Is the seed "fresh and filled"? If the embryo looks wilted or off color, this is not a favorable sign.
      ii) You can also observe the presence of seed insects – these are usually gray with segmented bodies and a brown head.
      iii) Basically anything other than an embryo in the seed cavity is an indication of poor seed.
2) Germination tests. This is done in 2 phases: Phase1 - stratify to break dormancy; and Phase 2 actually germinate the seed. Stratification can be done in a common refrigerator (about 45°F) for 2 to 3 months, while germination can be done in a greenhouse or cold frame.
   A) Place 100 seed in a thin layer of moist sand or moist paper towels and let this sit for 60-90 days in a refrigerator.
   B) After the cold stratification treatment, place the seed in an area with 68°F nights and 86°F days. If moist paper towels were used for the cold stratification, spread these towels out in a thin layer of sand prior to placing in a greenhouse or cold frame. Keep the seed moist during this time
   C) The number of seed germinated should be counted after 40 and 60 days. The percent of seed germinated should be recorded and kept with the seed sample.
   D) Germinated seed can be planted and grown in pots.

WEBSITES FOR INSTRUCTIONS FOR MAKING HERBARIUM SPECIMENS

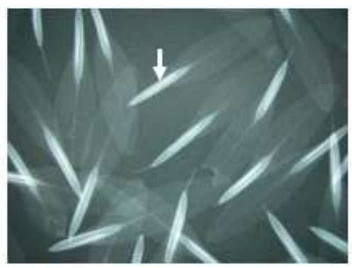
http://www.mobot.org/MOBOT/Research/Library/liesner/pressing.html
http://www.herbarium.unc.edu/chpt18.html
http://www.siu.edu/~ebl/prepare.htm
http://www.une.edu.au/botany/plant_collecting.htm
http://www.rmh.uwyo.edu/prelude/intro/rmcoll.htm
http://herbarium.usu.edu/K-12/Collecting/specimens.htm
http://www.uaf.edu/museum/herb/howtocoll.html
http://herbarium.ucdavis.edu/herbarium.html
http://www.montana.edu/wwwpb/pubs/mt8359.pdf
http://www.flmnh.ufl.edu/herbarium/voucher.htm
http://www.virtualherbarium.org/collecting.htm
http://www.herbarium.lsu.edu/makingherbspecimen.html
http://www.auburn.edu/academic/science_math/botany/herbarium/collecting.html
http://www.life.uiuc.edu/ib/335/CollectingPlants/CollectingPlants.html
http://www.montana.edu/wwwpb/pubs/mt8359.html
http://artemis.austincollege.edu/acad/bio/gdiggs/collecting.htm

The National Arboretum has offered to store herbarium voucher specimens for you. For more information or questions on herbarium specimens you should contact:

Kevin Conrad
Curator
Woody Landscape Plant Germplasm Repository
U.S. National Arboretum
ARS-USDA
10300 Baltimore Ave
Building 010A Room 233
Beltsville, MD 20705
Cell Phone 240 832 9415
ConradK@usna.ars.usda.gov

Ash seed clusters.

X-ray of filled ash seed
Note large white area which is the embryo.



X-ray of empty ash seed
Note light white area where embryo should be. Small under developed embryos are also noted (arrow).

X-ray of filled and insect damaged ash seed
Note segmented embryos (arrow) where insects have eaten.

Close-up of X-ray of insect damaged ash seed.

Evidence of insect damage to seed (arrow). Note also deformed seed (bottom).

Close up of insect entrance hole in seed.

Empty seed due to insects. Rip in seed is due to insect exiting.

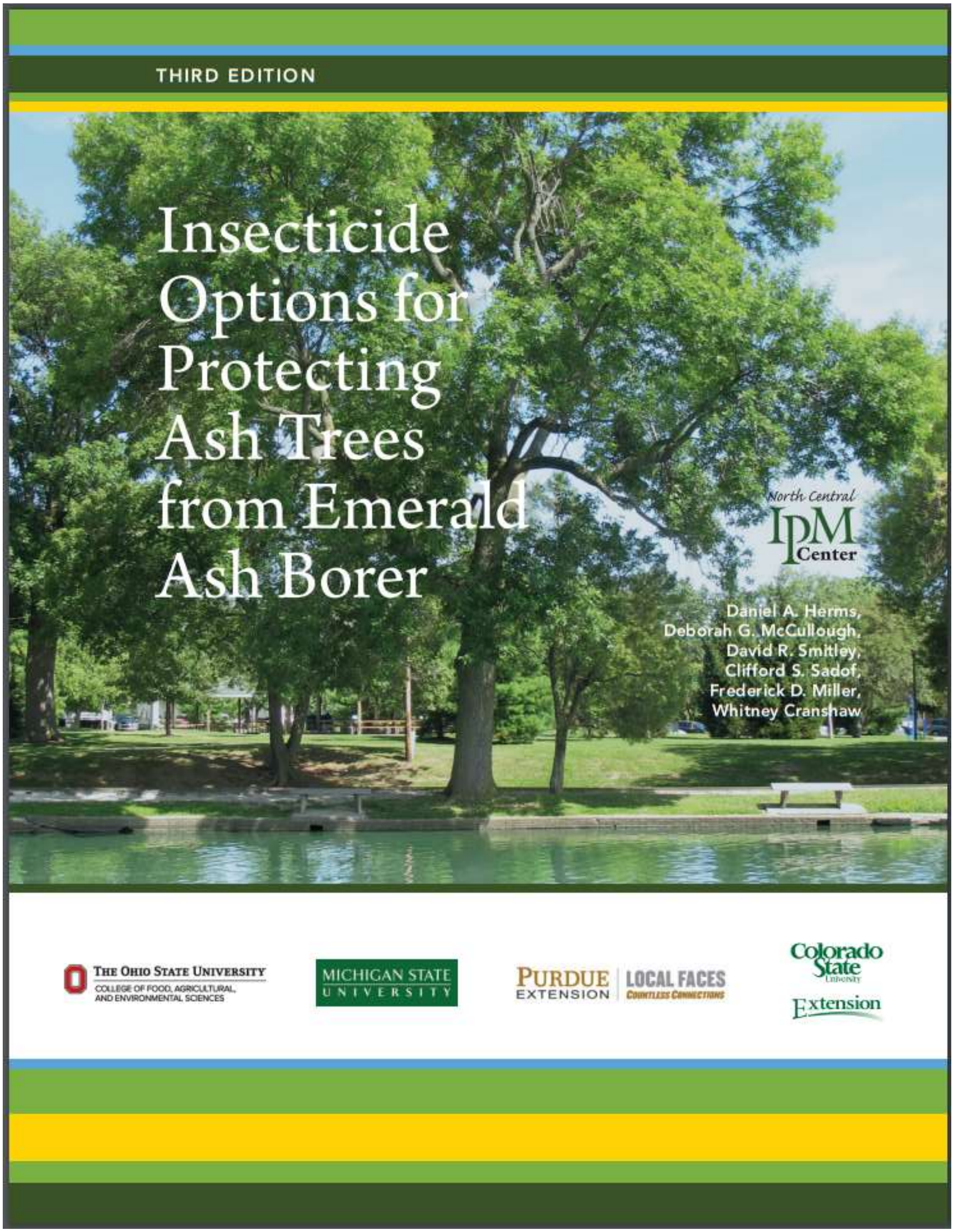
Close up of grub found in ash seed.

Tetrazolium stained ash embryo. Red color indicates good (live) embryo.

Ash seed sliced longitudinally to examine the embryo. Middle embryo is good while top and bottom have insect damage.

Appendix 12: "Insecticide Options for Protecting Ash Trees from Emerald Ash Borer"

http://www.emeraldashborer.info/documents/Multistate_EAB_Insecticide_Fact_Sheet.pdf



THIRD EDITION

Insecticide Options for Protecting Ash Trees from Emerald Ash Borer

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Insecticide Options for Protecting Ash Trees from Emerald Ash Borer

Emerald ash borer (*Agrilus planipennis* Fairmaire), an invasive insect native to Asia, has killed untold millions of ash trees (*Fraxinus* species) in urban, rural and forested settings. This beetle was first identified in 2002 in southeast Michigan and Windsor, Ontario. As of December 2018, emerald ash borer (EAB) infestations were known to be present in 35 states as well as five Canadian provinces. Surveys continue and additional infestations will be found as EAB continues to expand its range in North America. Ash trees are common in urban landscapes and residential areas across much of the continental US. Many homeowners, tree care professionals, and municipalities would like to protect valuable ash trees from EAB.

Since EAB was first identified in 2002, our ability to control this pest and effectively protect ash in the landscape has progressed substantially. Scientists have learned much about this insect and how it interacts with its host trees. New insecticide products and application methods have been developed and tested. Results of field trials have shown that ash trees of all sizes can be effectively and consistently protected over multiple years, even in areas with high densities of EAB. Recent economic analyses have concluded that treating landscape ash trees with effective systemic insecticides is much less costly than removing trees.

Our understanding of how EAB can be managed successfully continues to advance. This bulletin addresses frequently asked questions and reflects the current state of knowledge about insecticide options for controlling EAB. It is important to note that research is an ongoing process. Scientists from universities, government agencies and companies will continue to make discoveries to advance EAB management and ash conservation.

Answers to Frequently Asked Questions

What options do I have for treating my ash trees?

Several insecticide options are available to protect landscape ash trees threatened by EAB. Products listed in Table 1 have been evaluated by university and government scientists in field trials. Keep in mind, however, that controlling insects that feed under the bark with insecticides has always been challenging. This is especially true with EAB because most of our native North American ash trees have little natural resistance to this pest. Effective control of EAB requires that the insecticide product applied with the proper method and at the correct time.

I know my tree is already infested with EAB. Will insecticides still be effective?

It is best to begin using insecticides while ash trees are still relatively healthy. By the time most people notice canopy thinning or dieback, EAB has already caused considerably injury to the vascular system of the tree. An effective insecticide may stop additional damage, but it cannot reverse damage that has already occurred and it takes time for trees to recover. Most insecticides used for EAB control act systemically, meaning that the insecticide is transported within the tree. Therefore, a tree must be healthy enough to move a systemic insecticide up the trunk and into the branches and canopy.

Trees are damaged by EAB larvae feeding under the bark in "tunnels" called galleries. Galleries injure the inner bark, called phloem, which affects the transport of nutrients within the tree. The galleries also score or "etch" the outer wood, called xylem, affecting the ability of the tree to transport water. Systemic insecticides are carried in xylem tissue up the trunk to the branches and leaves in the canopy A few galleries have little effect on most trees. As EAB populations build and the tree becomes more infested, the injury becomes more severe. Canopies become thin because branches are too damaged to produce a full set of leaves. Large branches and even the trunk can be girdled and killed by the larval galleries.

Multi-year studies have shown that if more than 50 to 60% of the canopy has been killed by EAB, or if the canopy appears to be thin and is carrying less than half as much foliage as it should, it is probably too late to save the tree. The ability of trees to recover from low to moderate EAB injury can vary, depending on the extent of the damage and which control options are used. Studies have also shown that if the canopy of a tree is already declining when insecticide treatments begin, the condition of the tree may continue to deteriorate during the first year of treatment. If treatment is effective, the tree canopy will usually begin to improve in the second year of treatment. This lag in the reversal of canopy decline probably reflects the time needed for the tree to repair its vascular system after the density of EAB larvae has been reduced.

My ash tree looks fine but EAB has been detected in the vicinity of my property. Should I start treating my tree?

Detecting new EAB infestations and identifying ash trees that have only a few larvae is very difficult. Ash trees with a low density of EAB larvae usually have few or even no external symptoms or signs of infestation. In addition, scientists have learned that most EAB females lay their eggs on nearby trees, i.e. within 100 yards of the tree from which they emerged. A few female beetles, however, appear to disperse much further, anywhere from 0.5 miles to 2–3 miles. Therefore, if your property is within 30 miles of trees with noticeable EAB damage, then ash trees on your property are probably at risk. Signs of EAB damage include woodpecker holes or epicormic sprouts on the trunk or large branches, noticeably thin canopies or bark cracks above old larval galleries.

Treatment programs that begin too early waste money and result in unnecessary use of insecticide. However, treatment programs that begin too late will not be as effective. Trees must be healthy enough to carry the systemic insecticides to the leaves and branches in the canopy.

New EAB infestations continue to be discovered and existing EAB populations will build and spread over time. From 2002 to 2018, federal regulatory officials posted maps of quarantined states and counties on the www.emeraldashborer.info website. Federal regulatory surveys to detect EAB, however, have ended and state and local survey efforts vary. Therefore, maps of EAB detections may not adequately reflect the current distribution of EAB. City foresters, county extension offices or state departments of agriculture, forestry or natural resources may have information on the status of local EAB infestations. The www.emeraldashborer.info website provides links to specific information about EAB and regulations within individual states.

When is the best time to treat my trees?

As with any pest management effort, optimal timing is important to ensure insecticides provide effective EAB control. Your application of systemic insecticide should allow for uptake and distribution of the insecticide within the tree to ensure adult beetles and very young larvae encounter the toxin.

Two life stages of EAB are targeted by treatments: adult beetles and young larvae. Adult EAB feed on ash foliage throughout their life span and females must feed on leaves for at least 14 days before they begin laying eggs. This provides a window of opportunity to control the adults before any new eggs or larvae are produced. Beetle emergence usually begins sooner in the south than in northern areas. For example, the onset of adult beetle emergence begins in early May in southern Indiana and Ohio and in early June in central Michigan. Peak beetle emergence typically occurs two to three weeks after the first beetles exit the tree.

Regardless of location, emergence of adult EAB consistently begins at 450–550 growing degree days, based on a threshold of 50°F and a starting date of January 1. Beetles are most abundant at about 1,000 growing degree days. Cumulative growing degree days are tracked and posted on websites of many land grant universities as well as the NOAA website. First emergence of EAB also closely coincides with the period when black locust trees bloom. This phenological indicator is a reliable predictor of EAB

Ash trees on a street in Toledo in 2006 and 2009 before and after being impacted by EAB.

emergence across a wide region, ranging from northern Michigan to Kentucky and Maryland.

Peak egg hatch and larval establishment occur between early June and early to mid August, depending on location and weather. As a general rule, young larvae are more susceptible to insecticides than are older larvae. Moreover, controlling young larvae prevents damage to the tree caused by older, larger larvae that feed in larger galleries and thus injure more area on the tree. Data from several university studies have shown that spring insecticide treatments are consistently more effective than the same treatments applied in fall.

Imidacloprid soil treatments generally require four to six weeks for uptake and distribution of the insecticide within the tree. In the upper Midwest, for example, applications should be made in mid-March to late April, depending on the region and spring weather. Treatments should be applied on the earlier side of these schedules in more southerly locations and later side in more northerly regions. To minimize effects on pollinators such as honeybees that might collect pollen from male ash trees (female trees do not produce nectar), soil-applied systemic insecticides can be applied just after ash trees flower. Ash flowering occurs for a few days in spring just before buds break leaves begin to emerge from buds.

Soil applications of dinotefuran can be applied 2–3 weeks later than imidacloprid. This compound, which is much more soluble than imidacloprid, is taken up and transported through the tree more rapidly. When dinotefuran is applied as a basal trunk spray, the insecticide moves into trees even faster. Basal trunk sprays of dinotefuran can be applied between late May and mid-June in much of the upper Midwest.

Optimal timing for trunk injections of emamectin benzoate occurs after trees have flowered and leaves are expanding. This period typically occurs from mid-May through mid June in much of the upper Midwest.

Sometimes a tree is not known to be infested until July or even August. In this situation, it is still possible to get some benefit from an insecticide treatment in the fall, but not as much as from a spring application. When emamectin benzoate is injected in September, for example, enough insecticide will move into the canopy the next spring to control leaf-feeding EAB adults and young larvae during the summer. However, control of EAB may not persist as long when emamectin benzoate is applied in the fall. Similarly, applying the 2× rate of imidacloprid in autumn, e.g., between early October and early November, will generally control EAB the following summer. A large field study showed, however, that over time, fall applications do not protect ash trees as effectively as spring applications of the same product.

How can I convince my community that action must be taken before it is too late to save the ash trees?

The first step is to educate your community about the threat posed by EAB and the value of the ash trees in the community. Members of some communities have acquired permission to mark ash trees with visual tags. This allows residents to clearly see the extent of the resource at risk. Other suggestions for organizing communities can be found in the "Neighbors Against Bad Bugs" fact sheet. You will want to cooperate with your city forester who may already have an inventory of street trees. An inventory will help identify where the ash trees are located, the size and species of the ash trees, and the proportion of the public forest at risk. Some cities use sophisticated inventory systems that even calculate the value of the services provided by the ash trees. In Milwaukee, WI, for example, the capacity of ash trees to filter storm water saves the city more than enough money to justify the cost of treating the trees. Other cities use similar programs to create visible tree tags that tally the dollar value of the services provided by each tree. The National Tree Benefits Calculator website provides information on calculating the value of trees for professional arborists and urban foresters. You may also wish to estimate or compare costs of different management responses to the EAB invasion over time. The EAB Cost Calculator website at Purdue University, for example, allows users to enter their own tree inventory, compare local costs of treatment options or tree removal, and print reports. Links to these websites are available at www.emeraldashborer.info or by using the website name in a google search.

I realize that I will have to protect my ash trees from EAB for several years. is it worth it?

Several factors can influence treatment decisions, including the condition, size and location of trees. Numerous studies have compared costs of removing urban ash trees versus costs of treating the same trees with emamectin benzoate. These studies assumed trees would need to be treated with emamectin benzoate every other year. Results consistently showed treatment costs are much lower than removal costs.

Recent work, however, shows emamectin benzoate applied in spring can provide effective EAB control for up to three years. New tools are also available now to substantially reduce the time it takes to inject a tree. Annualized costs of treating trees at 3 year intervals and more efficient applications obviously increase the ratio of benefits to costs even further.

Protecting ash trees in landscapes also ensures the trees continue to provide ecological services including storm water capture and shade. Economic value of these services increases the benefit to cost ratios even further. Of course, not all tree decisions are based on economics. Many people are sentimental about their trees. These intangible qualities are also important and warrant consideration when developing EAB management strategies.

It is worth noting that the density of an EAB population in a given area changes over time. Populations initially build slowly, but later increase rapidly as more trees become infested. As EAB populations reach peak densities, a high proportion of the untreated ash trees in the area will decline and die. This usually occurs over a 3–5 year period. Once untreated ash trees succumb, however, the local EAB population will decrease substantially. Several studies have found that EAB populations still persist, but at much lower densities on the few mature ash trees alive in the area. Young ash saplings in forests, right-of-ways or woodlots may be colonized by EAB and serve as a persistant source for infesting ash trees in the landscape. Suspension of treatments on protected ash trees after the untreated trees are dead may be a way to reduce protection costs. However, the decision to stop treatment or to extend the interval between treatments should include the initiation of a monitoring program to evaluate tree condition. This ensures that treatments can be resumed when local EAB activity increases well before trees sustain serious injury.

My customers want to know about the environmental impacts of systemic insecticides used to protect ash trees from EAB.

People often have questions about whether systemic insecticide products used to protect ash trees will harm the environment or other organisms such as woodpeckers and pollinators. A bulletin entitled "Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used to Control Emerald Ash Borer" is available on the www.emeraldashborer.info website. The four page bulletin can be viewed on the website or downloaded and printed for distribution.

Insecticide Options for Controlling EAB

Insecticides that can effectively control EAB fall into four categories: (1) systemic insecticides that are applied as soil drenches or soil injections; (2) systemic insecticides applied as trunk injections; (3) systemic insecticides applied as lower trunk sprays; and (4) insecticides applied as cover sprays to the trunk, main branches, and (depending on the label), foliage.

Insecticide formulations and application methods that have been evaluated for control of EAB are listed in Table 1. Some are marketed for use by homeowners while several others are intended for use only by professional applicators. The "active ingredient" refers to the compound in the product that is actually toxic to the insect.

Formulations included in Table 1 have been evaluated in multiple field trials conducted by the authors and other university or government researchers. Inclusion of a product in Table 1 does not imply endorsement by the authors.

Strategies for the most effective use of these insecticide products are described below. It is important to note that pesticide labels and registrations change constantly and vary from state to state. It is the legal responsibility of the pesticide applicator to read, understand and follow all current label directions for the specific pesticide product used.

Using Insecticides to Control EAB

Soil-Applied Systemic Insecticides

Imidacloprid and dinotefuran are systemic insecticides that can be applied as soil drenches or soil injections. Both are sold under numerous brand names for use by professional applicators and homeowners. Soil applications can applied as a drench by mixing the product with water, then pouring the solution directly on the soil around the base of the trunk, or injecting the solution a few inches below ground at multiple locations near the base of the tree. The insecticide is taken up by the roots of the tree and then moves (translocates) up the tree to canopy branches and foliage.

Products designed for homeowners have some restrictions that do not apply to professional products. Homeowner products can be applied as a soil drench or as granules that are watered into the soil, but not as a soil injection. Homeowners are also restricted to making only one application per year.

Professionals can apply these products as a soil injection as well as a soil drench. Soil injections require specialized equipment, but offer the advantage of placing the insecticide below mulch or turf and directly into the root zone of the tree. This also can help to prevent runoff on slopes.

Injections should be made just deep enough to place the insecticide beneath the soil surface (2–4 inches). Soil injections should be made within 18 inches of the trunk.

Uptake is higher and the treatment more effective when the product is applied around the base of the trunk where the density of fine tree roots is highest. As you move away from the tree, large radial roots diverge like spokes on a wheel and fine root density decreases. Soil drenches offer the advantage of requiring no special equipment for application other than a bucket or watering can. However, imidacloprid can bind to surface layers of organic matter, such as mulch or leaf litter, which can reduce uptake by the tree. Before applying soil drenches, it is important to remove, rake or pull away any mulch or dead leaves so the insecticide solution is poured directly on the mineral soil.

Rates of soil applied insecticides needed to provide effective control may vary depending on the size of the tree and the intensity of pest pressure at the site. Some imidacloprid products available to professionals and homeowners can be applied at higher rates to large trees with trunk diameters (DBH) greater than 15 inches. Lower rates may be effective on smaller trees and when EAB populations are relatively low. Not all imidacloprid products can be applied at the higher rate so be sure to review the label when selecting a product.

Treatment programs must also comply with the limits specified on the label regarding the maximum amount of an insecticide that can be applied per acre during a given year. This restricts the number of trees that can be treated in an area in a given year, especially when relatively high application rates are used or when large trees need treatment.

Soil applications should be made when the soil is moist but not saturated nor too dry. Insecticide uptake will be limited when soil is excessively dry. You may need to irrigate the soil surrounding the base of the tree before and possibly after the insecticide application if soils are dry. However, waterlogged soil can result in poor uptake if the insecticide becomes excessively diluted and

TABLE 1. Insecticide options for professionals and homeowners for controlling EAB that have been tested in multiple university trials. Some products may not be labeled for use in all states. Inclusion of a product in this table does not imply that it is endorsed by the authors or that it has been consistently effective for EAB control. Additional products that have not been tested in multiple university trials may be available in your area. See text for details regarding effectiveness.

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Products Intended for Sale to Professional Applicators			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Early to mid spring or mid fall
Safari™ (20 SG)	Dinotefuran	Soil injection or drench	Mid to late spring
Transtect™ (70WSP)	Dinotefuran	Soil injection or drench	Mid to late spring
Xylam® Liquid Systemic Insecticide	Dinotefuran	Soil injection or drench	Mid to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Early to mid spring or mid fall
Azasol™	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Arbormectin™	Emamectin benzoate	Trunk injection	Mid to late spring after trees have leafed out
Imicide®	Imidacloprid	Trunk injection	Mid to late spring after trees have leafed out
TREE-äge™	Emamectin benzoate	Trunk injection	Mid to late spring after trees have leafed out
TreeAzin®	Azadirachtin	Trunk injection	Mid to late spring after trees have leafed out
SafariTM (20 SG)	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Transtect (70 WSP)	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Zylam® Liquid Systemic Insecticide	Dinotefuran	Systemic basal bark spray	Mid to late spring after trees have leafed out
Astro®	Permethrin	Preventive trunk, branch, and foliage cover sprays	Two applications at 4-week intervals; first spray should occur at 450–550 degree days (50°F, Jan. 1); Coincides with black locust blooming
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Products Intended for Sale to Homeowners			
Bayer Advanced™ Protect and Feed II	Clothianidin + Imidacloprid	Soil drench	Early to mid spring
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Early to mid spring
Optrol™	Imidacloprid	Soil drench	Early to mid spring
Ortho Tree and Shrub Insect Control Ready to Use Granules®	Dinotefuran	Granules	Mid to late spring after trees have leafed out

may also result in puddles of insecticide that could wash away, potentially entering surface water or storm sewers. To further protect surface and ground water, soil applications should not be made to excessively sandy soils with low levels of organic matter that are prone to leaching, especially where the water table is shallow, or where there is risk of contaminating gutters, ditches, lakes, ponds, or other bodies of water.

EAB adults must feed on foliage before they become reproductively mature.

No soil applications should be made where roots of flowering plants can be visited by bees and other pollinators. This situation is most likely to occur when flowering plants are growing around the base of an ash tree. In these situations, the flowering plants should either be destroyed or insecticide should be applied via trunk injection to ensure the toxins will not be taken up by the flowering plants.

Trunk-injected Systemic Insecticides

Several systemic insecticide products can be injected directly into the base of the tree trunk, including formulations of azadirachtin, emamectin benzoate, and imidacloprid (see Table 1). An advantage of trunk injections is that they can be used on sites where soil treatments may not be practical, effective or appropriate, including trees growing on excessively wet, sandy, compacted or restricted soil environments. Trunk injections generally involve drilling through the bark and into the outer sapwood at the base of the tree. Drilling wounds could cause long-term damage, especially if treatments and applied annually in late spring. Recent studies of emamectin benzoate (TREE-äge™) injected using Arborjet plugs and imidacloprid applied with Mauget capsules®, however, showed ash trees rapidly recovered and began producing new wood over the wounds in late summer. Application methods that rely on high pressure injections of insecticide through needles inserted into small holes in the bark may damage the tree if the pressure causes the bark to bulge and separate from the cambium. This is most likely to occur in spring and can cause larger wounds that result from death of the vascular tissue at the point of separation.

Products applied as trunk injections are typically absorbed and transported within the tree more quickly than soil applications. Rate of transport within trees varies among products. Imidacloprid moves more slowly than emamectin benzoate while azidirachtin and dinotefuran products move relatively rapidly. Imidacloprid usually takes 2–3 weeks to reach the canopy while other products reach the canopy within a week. Optimal timing of trunk injections occurs after trees have leafed out in spring but before EAB adults have started to lay eggs. This timing generally between mid-May and mid-June in the upper Midwest. Uptake of trunk-injected insecticides will be most efficient when trees are actively transpiring. Best results are usually obtained by injecting trees in the morning when soil is moist but not saturated. Uptake may be slowed by hot afternoon temperatures as well as dry soil conditions. Irrigating trees during droughty conditions will help with insecticide uptake and translocation within the tree.

Noninvasive, Systemic Basal Trunk Sprays

Dinotefuran is labeled for application as a noninvasive, systemic trunk spray for EAB control. It belongs to the same chemical class as imidacloprid (neonicotinoids) but is much more water soluble and moves more readily through plants. The formulated insecticide is sprayed on the lower five to six feet of the trunk using a common garden sprayer and low pressure. The insecticide penetrates the bark and is transported systemically throughout the tree. The basal trunk spray offers the advantage of being quick and easy to apply and requires no special equipment other than a garden sprayer. This application technique does not wound the tree, and when applied correctly, little insecticide enters the soil. Sprayers must be calibrated to ensure the appropriate amount of the formulated product is applied to each tree.

Dinotefuran can be mixed with surfactants that may facilitate its movement into the tree, particularly on large trees with thick bark. However, in field trials, adding a surfactant did not consistently increase the amount of insecticide recovered from leaves of treated trees or improve effectiveness of the application.

Protective Cover Sprays

Although control is possible with protective cover sprays, it is not recommended because of problems with spray drift, coverage and effects on nontarget species. Cover sprays applied to the trunk, branches and foliage can kill adult EAB beetles as they feed on ash leaves, and newly hatched larvae as they chew through the bark. Thorough coverage is essential for this to work. Products that have been evaluated include some specific formulations of permethrin, bifenthrin, cyfluthrin and carbaryl (see Table 1). Be careful to read the label because some products can be applied to bark but not to foliage.

Protective cover sprays are designed to control EAB adults and might control some of the very young larvae that hatch from eggs laid after pesticide has been applied. Sprays will have no effect on larvae feeding under the bark. Cover sprays should be timed to occur when most adult beetles have emerged and are feeding on ash leaves. For best results, consider two applications, one at 500 DD_{50} (as black locust approaches full bloom) and a second spray four weeks later.

How Effective Are Insecticides for Control of EAB?

Extensive testing of insecticides for control of EAB has been conducted by researchers at Michigan State University (MSU) and The Ohio State University (OSU) (Purdue University and Morton Arboretum). The following sections summarize key results of these trials.

Healthy ash trees that have been protected with imidacloprid soil drenches in 2009 growing next to untreated ash trees injured by EAB. The same street in 2011 following six consecutive years of treatments during a peak EAB outbreak. Untreated trees declined and were removed.

Soil-Applied Systemic Insecticides

Efficacy of soil-applied systemic insecticides for controlling EAB has been inconsistent. In some OSU and MSU trials, EAB control was excellent, while others yielded poor results. Application protocols and conditions of the trials have varied considerably, making it difficult to reach firm conclusions about sources of variation in efficacy.

Some imidacloprid formulations can be applied to trees with a trunk diameter greater than 15 inches at a rate that is twice as high (2× rate) as the rate used for smaller trees (1× rate). In an OSU study in Toledo conducted from 2006–2014, imidacloprid soil drenches effectively protected ash trees ranging from 15–22 inches in diameter when applied at the 1× rate in spring, or at the 2× rate when applied in either the spring or fall. These treatments were effective even during years of peak pest pressure when all of the untreated trees died. Trees treated in fall with the 1× rate, however, declined and had to be removed.

EAB larvae damage the vascular system of the tree as they feed, which interferes with movement of systemic insecticides in the tree.

In another OSU multi-year trial with trees up to 22 inches DBH, dinotefuran soil applications, as well as basal trunk sprays (see below) were effective when applied at the highest labeled rate. However, lower rates were less effective. Soil applications of imidacloprid at a lower rate (the rate recommended for turf insects) did not protect ash trees.

Results from several studies in MI, OH, IL, and IN since then have similarly indicated that high rates of imidacloprid must be applied to protect larger trees. Adding either clothianidin or fertilizer to the formulation of imidacloprid products did not provide any additional protection from EAB.

Researchers have found that soil drenches and injections made at the base of the trunk result in more effective uptake than applications made in grid or circular patterns under the canopy away from the trunk.

Trunk-injected Systemic Insecticides

Emamectin benzoate • In several intensive studies conducted by MSU and OSU researchers at MSU, OSU, Morton Arboretum and Purdue, a single injection of emamectin benzoate (TREE-äge™) in mid-May or early June provided excellent control of EAB for up to three years, even during years of peak EAB densities. For example, in a highly-replicated study conducted on trees ranging in size from 5 to 21-inch DBH at three sites in Michigan, untreated trees had an average of 68 to 132 EAB larvae per m^2 of bark surface, which represents very high pest pressure. In contrast, trees treated with low rates of emamectin benzoate (0.1–0.2 g ai or 2.5 ml per inch DBH) had, on average, only 0.2 larvae per m^2, a reduction of >99 percent. When additional trees were felled and debarked two years after the emamectin benzoate injection, there were still virtually no larvae in the treated trees, while adjacent, untreated trees at the same sites had hundreds of larvae.

In two Ohio studies with street trees ranging in size from 15- to 25-inch DBH, a single application of emamectin benzoate provided excellent control for two years, even at the lowest rate. There was no sign of canopy decline in treated trees and very few emergence holes, while the canopies of adjacent, untreated trees exhibited severe decline and extremely high numbers of emergence holes. In another trial, large trees, ranging from 32 to 53 inches DBH, were treated in alternate years with emamectin benzoate at medium- low or medium-high rates. Canopies of all treated trees remained healthy six years later (after three treatment cycles) despite high pest pressure and numerous declining (untreated) trees in the immediate vicinity.

In a six year Purdue study, trees with DBH ranging from 28 to 62 inches were effectively protected from EAB when injected in June with a medium rate (0.2 g ai or 5 ml per DBH inch) of emamectin benzoate once every three years. By the end of the study in 2018, untreated trees were dead or dying. Trees treated in June had less than 15% canopy thinning. When treatment was delayed until September, however, trees sustained unacceptable levels of canopy thinning by 2018.

Two of the most recent studies have shown that even when TREE-äge™ is applied at the lowest rate on the label (0.1 g ai or 2.5 ml per DBH inch), trees are protected from EAB for three years. A six year MSU study quantified EAB larval densities on trees treated annually, at 2 year intervals or at 3 year intervals with a low (2.5 ml per DBH inch) or medium (5 ml per DBH inch) rate of TREE-age, dinotefuran basal trunk sprays or imidacloprid applied with Mauget capsules. Treated and untreated control trees were felled and debarked to assess efficacy. Results showed that both rates of TREE-äge provided nearly complete EAB control for three years post-treatment. Biennial and annual TREE-äge injections, as well as annual basal trunk sprays of dinotefuran provided similarly high levels of control, while imidacloprid injections were less effective, even when applied annually. In other trials with side-by-side comparisons of insecticide products, emamectin benzoate has been consistently more effective than other systemic insecticides.

Between 2008 and 2014, a study with 205 green ash trees ranging from 12 to 15 inches DBH was conducted outside of Chicago by a researcher at the Morton Arboretum. By 2014, untreated trees had lost 93% of their canopy. Trees treated with of 2.6 gm ai/ inch of emamectin benzoate (6 ml per DBH inch) every two years had less than 25% canopy thinning in 2014. In contrast, trees treated with annually with soil injections of neonicotinoids in the spring or fall at 1× or 2× rates had lost > 50% of their canopies by 2014.

Azadirachtin • Results from a two-year study in Michigan replicated at three sites showed azadirachtin products affect EAB differently than other insecticide products. In this study, adult EAB beetles fed for six days on leaves from trees treated with a high rate of azadirachtin (TreeAzin®), then fed on leaves from untreated trees for the remainder of their life span. In contrast to trees treated with either emamectin benzoate (trunk injection) or dinotefuran (basal trunk spray), leaves from the azadirachtin trees were not acutely toxic to adult beetles. However, azadirachtin reduced the ability of mature female beetles to produce viable eggs that successfully hatched. Young females, conversely, appeared to recover and were able to reproduce normally.

When the trees in this study were felled and debarked after two years of exposure to EAB, it was apparent that numerous EAB larvae had begun feeding on trees treated with TreeAzin. Most of the larvae died while still young and small. Very few live larvae were present on the trees treated in both years with TreeAzin. When trees were treated only the first year but not the second year, density of live larvae was 75–80% lower than on untreated control trees. Results from this study suggest that in most years, TreeAzin will effectively protect ash trees for two years, but when EAB densi- ties are high, annual applications are necessary.

Imidacloprid • Trunk injections with imidacloprid products have provided varying degrees of EAB control. In an MSU study, larval density in trees treated annually with Imicide® injections were reduced by 60 to 96 percent, compared to untreated controls.

Healthy ash trees protected with emamectin benzoate trunk injections behind an untreated, declining tree.

There was no apparent relationship between efficacy and trunk diameter or infestation pressure. In another MSU trial, imidacloprid trunk injections made in late May were more effective than those made in mid-July, and IMA-jet® injections provided higher levels of control than did Imicide®, probably because the IMA-jet® label calls for a greater amount of active ingredient to be applied on large trees. In an OSU study, IMA-jet® provided excellent control of EAB on 15- to 25-inch trees under high pest pressure when trees were injected annually. However, trees that were injected every other year were not consistently protected.

In a discouraging study conducted in Michigan, ash trees continued to decline from one year to the next despite being injected in both years with either Bidrin (Inject-A-Cide B®) or imidacloprid. The imidacloprid treat- ments consisted of two consecutive years of Imicide® (10% imidacloprid) applied using Mauget® micro-injection capsules (3 ml), or an experimental 12% formulation of imidacloprid in the first year followed by Pointer™ (5% imidacloprid) in the second year with both applied using the Wedgle™ Direct-Inject™ System. All three treatment regimens suppressed EAB infestation levels in both years, with Imicide® generally providing best control under high pest pressure in both small (six-inch DBH) and larger (16-inch DBH) caliper trees. However, larval density increased in treated and untreated trees from one year to the next. Furthermore, canopy dieback increased by at least 67 percent in all treated trees (although this was still less than the amount of dieback observed in untreated trees). Even consecutive years of these treatments only slowed ash decline under severe pest pressure.

In a head-to-head comparison of products conducted by OSU researchers, emamectin benzoate trunk injections (0.4 g a.i. / inch DBH applied during the first year in May) and imidacloprid soil drenches (applied in both years in May at the highest labeled rates) provided effective control of EAB. In contrast, trees treated with Pointer™ (5% imidacloprid applied in both years in May at the highest labeled rate) and the untreated trees declined substantially over the two-year study period. In another MSU study, ACECAP® trunk implants (active ingredient is acephate) did not adequately protect trees > 15-inch DBH under high pest pressure.

Noninvasive Systemic Basal Trunk Sprays

Studies to date indicate that the effectiveness of dinotefuran basal trunk sprays are similar to soil applications of dinotefuran or imidacloprid. MSU and OSU studies have evaluated residues in leaves from trees treated with the basal trunk spray. Results showed that the dinotefuran effectively moved into the trees and was translocated to the canopy at rates similar to those of other trunk-injected insecticides, and faster than soil-applied neonicotinoid products. As with imidacloprid treatments, control of EAB with dinotefuran has been variable in research trials. Several MSU studies ranging from two to six years have shown annual dinotefuran basal trunk sprays effectively protect ash trees and significantly reduce EAB larval densities compared to the heavily infested untreated trees. As with dinotefuran and imidacloprid soil applications, the basal trunk treatment was effective for only one year and would have to be applied annually.

In a five-year OSU study with trees up to 22 inches DBH, dinotefuran basal bark sprays provided effective protection when applied at the highest labeled rate (average of less than 5% canopy decline compared with nearly 80% average canopy decline for untreated trees). A lower rate was less effective (almost 20% average canopy decline).

Protective Cover Sprays

MSU studies showed that a cover spray of Onyx™, Tempo® or Sevin® SL provided good control of EAB, especially when the insecticides were applied in late May and again in early July. Acephate sprays were less effective. BotaniGard® (Beauvaria bassiana) was also ineffective under high pest pressure. Astro® (permethrin) was not evaluated against

EAB in these tests, but has been effective for controlling other species of wood borers and bark beetles.

In another MSU study, spraying Tempo® just on the foliage and upper branches or spraying the entire tree were more effective than simply spraying just the trunk and large branches. This suggests that cover sprays may be especially effective for controlling EAB adults as they feed on leaves in the canopy. A single, well-timed spray was also found to provide good control of EAB, although two sprays may provide extra assurance, given the long period of adult EAB activity.

It should be noted that spraying large trees is likely to result in a considerable amount of insecticide drift, even when conditions are ideal. Drift and potential effects of insecticides on non-target organisms should be considered when selecting options for EAB control.

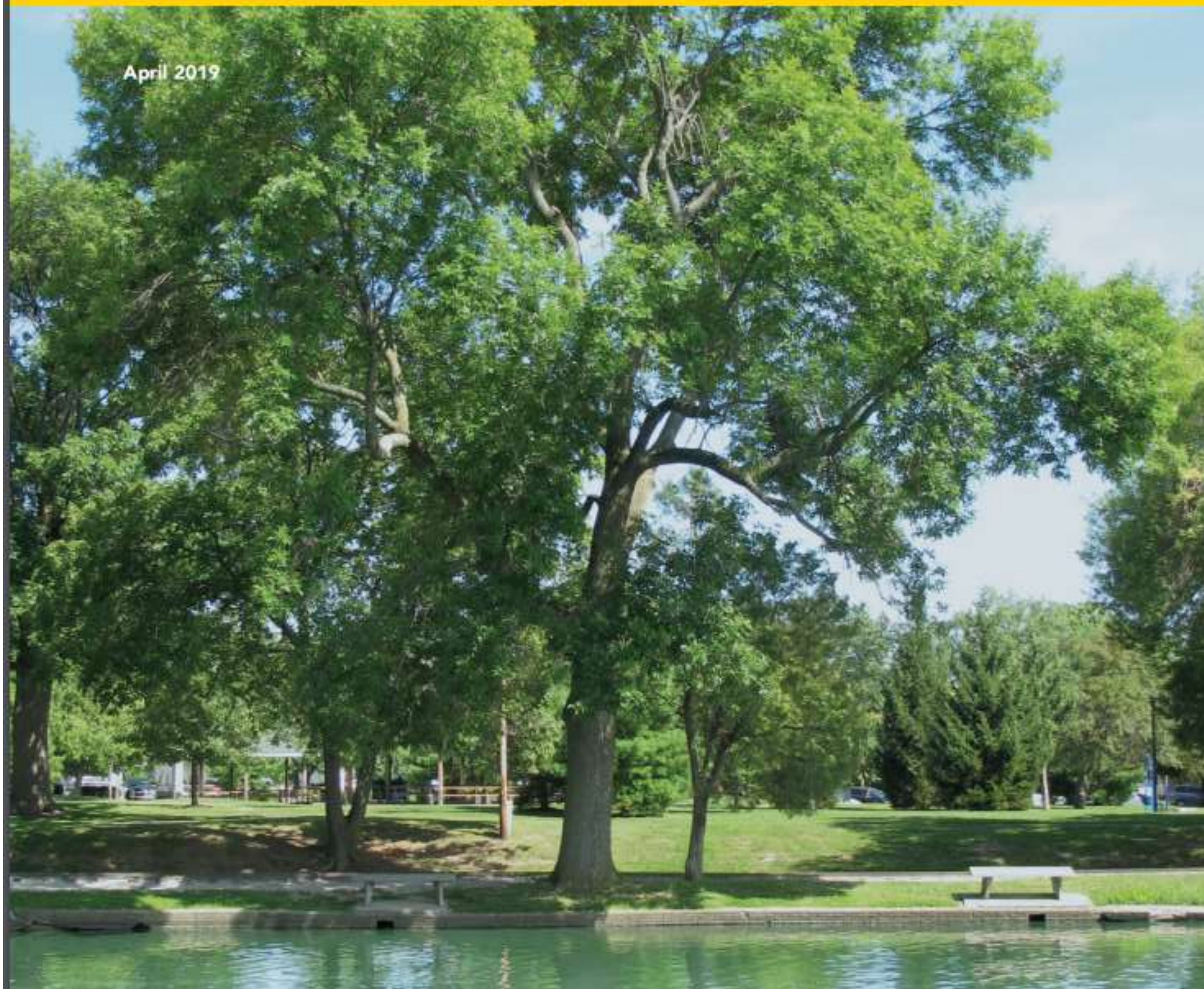
Key Points and Summary Recommendations

- Insecticides can effectively and consistently protect ash trees, including very large trees, from EAB, even under intense pest pressure.
- Drought stress inhibits uptake and transport of systemic insecticides. Supplemental irrigation will be needed during dry periods.
- Unnecessary insecticide applications waste money. However, survey activities to detect or monitor EAB infestations vary considerably among and within states. In addition, EAB infestations are very difficult to detect when populations are low. Nearly all EAB infestations have been at least four to six years old before they were detected. If ash trees with obvious signs of EAB infestation are within 30 miles, you should consider beginning treatment. It is important to stay aware of the status of EAB in your location. Check the www.emeraldashborer.info website for current maps of known EAB distribution AND links to other websites with information specific to your state, county or municipality.
- Trees that are already infested and showing signs of canopy decline when treatments are initiated sometimes continue to decline the first year after treatment, then begin to improve the second year, as the trees recover. Effectiveness of products varies considerably, however, depending on the product applied, the extent of injury already sustained by the tree and the pest pressure. Trees with lower levels of canopy decline may not recover despite treatment.
- Emamectin benzoate has consistently provided highly effective EAB control for two and even three years with a single application. This level of efficacy has been consistently recorded even in sites where large and very large trees were under intense pest pressure. This insecticide also provided greater EAB control than other products in side-by-side studies.
- Trunk injections of azadirachtin affect EAB differently than other systemic insecticides. Results from a recent study indicate azadirachtin should provide effective protection for one to two years, depending on EAB pressure.
- Basal trunk sprays with dinotefuran applied annually have effectively protected ash trees in several studies. It is important to calibrate sprayers to ensure the proper rate of the formulated product is applied.
- Soil applications of imidacloprid and dinotefuran yielded mixed results. In some studies, soil drenches or soil injections of imidacloprid effectively protected trees while in other studies, they failed. Yet these products remain the only option for many homeowners who choose not to hire a professional. Individuals who want to try this option should apply these products at the highest labeled rate. Soil drenches should be applied at the base of the trunk where fine roots are concentrated. Soil injections should be no more than 2–4 inches deep, to avoid placing the insecticide beneath feeder roots of the tree. Users must comply with all restrictions on application frequency and the amount of insecticide that can be applied per acre per year.

The Cooperative Emerald Ash Borer Program

For more information and to download additional copies of this bulletin:

www.emeraldashborer.info



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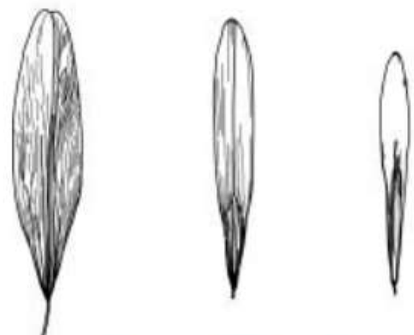
Appendix 13: Les Benedict "Propagation protocol for Black Ash"

http://npj.uwpress.org/content/4/2/100.full.pdf+html



Propagation protocol for BLACK ASH

Fraxinus nigra Marsh.

Les Benedict and Richard David |

Figure 1. Left to right: Seeds of black ash (*Fraxinus nigra*), white ash (*F. americana*), and green ash (*F. pennsylvanica*).

Line drawing by Amy Rediker

KEY WORDS

Oleaceae, seed propagation, seed collection, bareroot production

NOMENCLATURE

ITIS (2002)

Black ash (*Fraxinus nigra* Marsh. [Oleaceae]) is native to the northeastern portion of North America, from Nova Scotia and New Brunswick east to Ontario and eastern Manitoba, and south through the Midwest and New England to Minnesota, northern Iowa, Indiana, Ohio, and Pennsylvania. Black ash is a shallow-rooted tree commonly found growing in moist to wet muck or shallow organic soils. Habitats include small hummocks within swamps, along small streams in gullies, and in small, poorly drained depressions. It also grows on fine sands and loams underlain by clays and on other poorly drained sites with high water tables. In mesic hardwood upland sites, black ash is restricted to sites with impeded drainage, where it grows on wetter than normal mineral soils. Soil pH ranges from 4.1 to 8.2, depending on site conditions.

Most black ash trees are polygamous, having male, female, and hermaphroditic flowers on the same plant or on separate plants. Small inconspicuous flowers emerge during spring with, or just before, leaf emergence. The fruit is an elongated, winged, single-seeded samara that is borne in terminal or axillary clusters.

HISTORY AND USES

Black ash (Mohawk name: *Ehsa*) has many notable qualities but is especially important for basket making. The wood is used for basket splints, which are obtained by pounding a log with a mallet or axe until it separates along the annual growth rings. Outer sapwood has an attractive satiny, creamy white color and is frequently used for delicate fancy baskets. Inner heartwood has a golden brown color and is slightly brittle. This wood is commonly used for handles, rims, and splints for more robust baskets. The light and unusually strong splints obtained from black ash make the tree of great cultural and economic importance to the Mohawk and other Northeastern native peoples.

The quantity and health of black ash has generally declined in the Northeast and Great Lakes region. Today, the species makes up less than 1% of forest cover in the Northeast. Decline is due to loss of habitat and long-term effects of pollution. Declining trees are also subjected to many pests, such as carpenterworm (*Prionoxystus robiniae* Peck [Lepidoptera: Cossidae]) and fall webworm (*Hyphantria cunea* Drury [Lepidoptera: Arctiidae]), among others. Diseases include leaf spots, cankers, powdery mildew, and rusts.

In the past, Mohawk (Akwesasne) basket makers obtained their black ash material locally, however, recently they have traveled as far as Maniwaki, Quebec, to find live, suitable trees. The Mohawk Council of Akwesasne's Department of Environment, with its Model Forest Program, has been working on black ash restoration for several years. In 1999, 1000 black ash trees were planted throughout the community.

SEED COLLECTION AND PROPAGATION

Seed collection requires scouting for female and polygamous trees in May and June during flowering. Seeds mature from July to October, depending on elevation, latitude, and aspect. Good seed crops are seen on average of every 5 to 7 y, and they disperse from July to October in the Northeast.

The most important factor for seed collection is recognizing black ash seeds, because green ash (*F. pennsylvanica* Marsh) and white ash (*F. americana* L.) are sometimes found growing in the same vicinity (Figure 1). This is especially important in late fall after leaves have fallen. Black ash seeds are elongated and blunt on the terminal tip and gradually pointed on the end. White ash and green ash samaras are narrower through their length and have a pronounced pointed tip on the end.

We use 3 collection methods. The first method is the use of pruning poles and ladders. Fruit-bearing twigs are pruned closely so that fruit clusters do not disperse during cutting. Seed maturity should be assessed before using this method. Collect fully elongated seeds when they are yellow to brown in color and the endosperm is firm and white.

The second method is to use canvas tarps spread around the base of a seed-bearing tree. If the tree is small enough it can be shaken vigorously to collect seeds. And third, tie a canvas tarp at its 4 corners beneath a good seed-bearing tree. The canvas should be high enough that small animals do not become trapped or persons do not walk into them, and have a drain hole to allow rainwater to pass through easily. This method requires that you check the seed trap daily and separate out other seeds that are caught on the tarp.

After collection, seeds are dried in shallow trays and further cleaning can be accomplished by breaking dried clusters apart by hand, by flailing in paper sacks, or by using a macerator if the seeds are completely dry. Stems can then be removed by fanning or by air screen cleaners with openings of 1 x 1 cm (0.38 x 0.38 in) or slightly larger. We have seen no advantage to de-winging seeds. Desired seed moisture content after drying and processing is 7% to 10% and averages 17 820 seed/kg (8100 seeds/lb). Seeds of *Fraxinus* species can be stored up to 8 y in sealed containers at 5 °C (41 °F) (WPSM 2002).

In nature, black ash seeds go through a natural stratification and after-ripening process as a result of being exposed to warm and cold temperatures over the progression of the season. Seeds exhibit deep simple morpho-physiological dormancy and take up to 2 y to germinate. High summer temperatures followed by warm but slightly cooler autumn temperatures are required to break 1 type of physiological dormancy, and winter temperatures are required to break the second physiological dormancy. Morphological dormancy cannot be broken until high temperatures overcome the first physiological dormancy and seeds are subjected to autumn temperatures. Embryo growth occurs during winter months (Baskin and Baskin 1998).

Using seed sources from a site in New York, we use a 90-d warm stratification, followed by a 90-d cold stratification. Seeds are placed in moistened sphagnum peat moss in aerated plastic boxes. Stratification medium is carefully monitored using a soil moisture probe and moistened when needed. Warm-stratified seeds are kept at room temperature ranging from 16 to 22 °C (61 to 72 °F) during the warm stratification period and then placed under refrigeration for 90 d at 5 °C (41 °F).

BAREROOT SEEDLING PRODUCTION

For field production of seedlings, seed beds are prepared by a spring topdressing of $15N{:}15P_2O_5{:}15K_2O$ fertilizer at the rate of 169 kg/ha (150 lb/ac). Fields should have a pH of 6 to 6.5 and adequate calcium levels. The seedbed surface is raked smooth prior to sowing.

For highest germination rates, we sow artificially stratified seeds in May or sow freshly collected seeds from mid-October to early November. Seeds are sown 6 cm (1 in) apart and covered with 6 mm to 1.9 cm (0.25 to 0.75 in) of topsoil and mulched with bark chips at a depth of 7.5 cm (3 in). Mulch provides moisture retention, which is needed during germination and initial establishment, and reduces the need for weeding later in the growing season.

The desired plant density on emergence is 30 to 45 plants/m^2 (10 to 15 seedlings/ft^2). Seed germination continues during the second year and those germinants are transplanted to new seedling beds. Seedlings are susceptible to damping off disease (*Fusarium* and *Rhizoctonia* spp.) during emergence, and disease is controlled by the use of fungicides such as Captan, or preferably, by ensuring adequate air movement around seedlings and by careful irrigation practices at this stage.

Additional fertilizer is supplied during the spring of years 2 and 3 and seedlings are irrigated as needed. Roots are pruned by a horizontal blade mounted on a tractor during June or July. The root pruning zone is 22.5 to 25 cm (8 to 9 in) below soil line. Bareroot seedlings (Figure 2) are ready for lifting 2 to 3 y after initial sowing. For harvest, trenches are dug 38 to 45 cm (15 to 18 in) deep, just below the last root-pruning zone and 30 cm (12 in) from the seedling stems. Roots are combed with a

Figure 2. 1+0 black ash seedling.

spading fork to remove soil and wrapped in wet burlap to prevent desiccation. Seedlings are 16 to 42 cm (6 to 16 in) in height with an average caliper of 5 mm (0.25 in).

OUTPLANTING

We find that soil maps are useful tools for selecting outplanting sites. Seedlings are planted 3 to 4.5 m (10 to 15 ft) apart for reforestation and basket materials projects. If needed, competing vegetation is thinned or removed as black ash is shade intolerant. Weed control may be necessary during the first year of establishment. Because black ash grows in wetland and in areas adjacent to wetlands, we do not use herbicides for weed control but manage weeds through cultivation or hand pulling.

At Akwesasne, tree shelters from Treesentials® have been used with excellent results. During the first year of growth, black ash seedlings grew to the length of the 1 m (3 ft) tube. For larger plantings, however, fencing the area from browsing wildlife is a more cost effective alternative.

Basket makers and log pounders have observed black ash regenerating from stumps of previously cut trees. Although we have no information on propagating this species from cuttings, we plan to explore experimental techniques from callus cultures and stem cuttings. This is desired especially if the species continues to decline in the Northeast.

SUMMARY

The future is bright for black ash in spite of many obstacles that threatened its survival and health. Many are taking action to learn more about the tree and how to preserve it, including researchers and basket makers who wish to ensure a plentiful source for basket making in the future. As more information is gained, the hope is that it will be shared with those who desire to preserve and restore this species. Our intention is to restore black ash trees within suitable habitats and on experimental sites within the Akwesasne community. We hope to learn more about the trees' biology and to employ other propagation techniques to ensure its survival, which is vital to Mohawk culture and economy.

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