EAB Silviculture Guidelines Draft

June 22, 2018

(Note: several 'highlight boxes' of important recommendations will be inserted later)

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Introduction

Purpose of the guide

This guide is intended to help resource managers make informed stand-level decisions to manage forests that are not yet infested by emerald ash borer (EAB), *Agrilus planipennis*, as well as implement salvage harvests and rehabilitation in stands that have already been impacted by EAB. The guidelines do not address landscape-level management or the treatment of individual trees with insecticides to prevent mortality from EAB. Landowners are strongly encouraged to consult with a professional forester about managing EAB in their forests. Sustainable forest management practices should be followed whenever possible.

Land managers should carefully review existing management plans, evaluate long-term management options, and determine which species and silvicultural practices are suitable for their properties. Preparing a stand for EAB impacts may allow a stand to remain adequately stocked with non-ash species, and able to meet management objectives if the remaining ash die or are harvested. In the short term, an ash component will help to maintain species diversity and provide ecological benefits.

History of EAB

The emerald ash borer (EAB), *Agrilus planipennis*, is an exotic insect that was first identified in southeast Michigan in 2002. In 2008, EAB was detected in Ozaukee and Washington Counties in southeast Wisconsin. Since then, EAB has been found in many areas of the state. EAB has also been found in numerous states and several Canadian provinces. Visit the Wisconsin EAB website to see where EAB has been confirmed.

The entire state of Wisconsin is now under a state-issued emerald ash borer quarantine even though the insect has not yet been found in all 72 counties. Quarantine restrictions may still apply to ash wood movement to another state. In addition, other quarantines to prevent the movement of gypsy moth are still applicable to wood movement into western Wisconsin counties. For more information, visit the Wisconsin EAB website.

Impact on ash

Emerald ash borer is expected to kill more than 99% of white, green and black ash in Wisconsin, regardless of a stand's size, ash density or species composition (e.g. Knight et al. 2010; Klooster et al. 2014; Smith et al. 2015). Emerald ash borer is capable of infesting trees more than one inch in diameter, and even healthy ash trees decline and die within a few years of becoming infested. In the absence of active management, EAB impacts will be proportional to the amount of ash in a stand. Insecticide treatments can prevent or reverse tree decline in moderately-infested ornamental trees, but are not practical for treatment of ash in forests.

White ash is reported to be less preferred by the insect than black or green ash, although studies in Michigan found nearly 100% mortality in all three species when EAB populations were high (Herms and McCullough 2014). Blue ash, which is present in a few southeast Wisconsin stands, has been observed to be more tolerant of EAB than other Wisconsin ash species (Herms and McCullough 2014).

Most mortality in an EAB-infested stand occurs within a period of a few years (Herms and McCullough 2014). Knight et al. (2013) found that ash trees died faster in stands with lower ash density, at mesic sites, in trees initially exhibiting dieback, and in intermediate and suppressed trees. The smallest susceptible ash trees tend to die last (Herms and McCullough 2014). The growth of non-ash species in mixed stands typically increases due to EAB mortality, filling in gaps created by dead ash (Burr and McCullough 2014; Costilow et al. 2017).

Scientific studies have found little natural resistance to EAB in the native ash population, but long-infested states report that some ash trees remain alive (e.g. Aubin *et al.* 2015; Kashian 2016; Robinett and McCullough 2016). At present, it is not practical for a forester to predict which individual trees will remain alive long-term. Ash regeneration from seeds and sprouts is present on the landscape, and ash may persist if it can sprout or produce seed before being killed by EAB. However, ash is unlikely to be as common as it currently is (e.g. Kashian 2016), and can be re-infested by EAB once it grows to a suitable size (e.g. Kashian 2016; Duan et al. 2017).

Once the initial wave of tree mortality has occurred, EAB populations decline dramatically. Low numbers remain in small, regenerating ash as well as surviving, larger trees (Burr and McCullough 2014; Klooster et al. 2014; Burr et al. 2018). Ongoing, low-level ash mortality continues in these areas. The long-term fate of ash will depend on the interactions between ash regeneration, EAB, and the natural enemies of EAB (Klooster et al. 2014). Studies are ongoing.

Signs and symptoms of an infestation

EAB-infested trees usually have multiple signs and symptoms of infestation if they have been infested for several years. These include thin foliage and/or dieback in the upper crown, epicormic sprouts on the stem or at the base, 1/8" D-shaped exit holes, S-shaped larval galleries under the bark, and heavy woodpecker activity. EAB larvae are up to 1.5" long and have distinctive bell-shaped segments. Similar signs and symptoms can be due to other causes, such as infestation by other wood and phloem-boring insects, phytoplasma infection, or root injury/infection. For more information, visit the Wisconsin EAB website. (note: images of signs and symptoms to be added later)

Ash in Wisconsin

Wisconsin's forests contain about 890 million ash trees greater than 1 inch in diameter, comprising approximately 8% of all forest trees of this size range. Ash is also a common street and yard tree. Approximately 20% of urban street trees and 12% of all urban trees are ash.

- White ash (*Fraxinus americana*) is present throughout the state, most commonly as a primary species within the northern hardwood cover type. White ash grows on a variety of sites but is most frequently found on fertile, well-drained soils. In general, white ash is less favorable for EAB than green or black ash.

- Green ash (*F. pennsylvanica*) is most common in southern Wisconsin but is found throughout the state. It may form pure stands or grow in association with black ash, red maple, silver maple, swamp white oak and elm. Green ash is most common in and around stream banks, floodplains and swamps, although it may grow as an associate in upland hardwood stands.

- Black ash (*F. nigra*) is most frequently found in northern Wisconsin but is distributed over the entire state. It is most common in swamps where it is the most abundant species, although it is also found in other wet forest types.

- Blue ash (*F. quadrangulata*) is a threatened species that is only found at a few upland sites in Waukesha County, but is common in states farther south. It is not of commercial importance in Wisconsin. Blue ash is the native Wisconsin *Fraxinus* species most tolerant of EAB infestation, and many blue ash trees remain alive in long-infested states.

- Mountain ash (*Sorbus americana* and *S. decora*) is not a 'true' ash (*Fraxinus*) and is not attacked by EAB.

All ash species serve an ecological value of some kind. Seeds are eaten by several bird species and smaller rodents. Ash also provides browse opportunities, cavity and cover value for a wide variety of wildlife. Black and green ash, sometimes being the only significant tree species in wetlands, maintain evapotranspiration in the area and prevent swamping.

Economic uses

In Wisconsin, ash represents approximately 4% of pulpwood production and about 5% of sawlog production (2013 data). Ash is used for multiple purposes, including lumber, paper and woodworking pieces. Wisconsin's ash grade lumber is mostly sent to cabinet, flooring, trim and handle manufacturers in the Midwestern U.S. Ash log and lumber export is also a major market for many Wisconsin wood products companies. The low-grade lumber and cants go mostly to pallet manufacturers throughout the region. Other commerical uses for ash include firewood, animal bedding and baseball bat production. For more information about the uses of ash, see the links in the 'Additional Resources' section of this guide.

Management of Stands With Ash – Overview

The continued spread of EAB has increased the urgency to address ash management, especially in stands where ash is more than a minor component. Harvesting of ash is intended to capture economic value and establish suitable growing conditions for non-ash species. It is not done with the expectation of slowing EAB spread.

Pre-salvage and salvage of ash, as well as encouraging non-ash regeneration, will be a priority in many stands. Land managers will likely have more control over the future composition and structure of their stands if active management is started as soon as practical, as opposed to waiting until EAB impacts properties or local areas. Starting management activities early can help address the uncertainty about how quickly EAB will spread and impact a previously uninfested stand. When timing management activities, is important to consider factors that may cause an unexpected change in the financial value of ash timber. These factors include unpredictable winter access to lowland sites, fluctuating wood markets, and length of time required to set up and administer a timber sale. Prioritization of stand activity will be important to landowners with large, geographically-scattered properties.

It is important to harvest ash trees prior to EAB infestation if a land manager intends to capture maximum economic value. Published literature and local experience have found a loss of timber value following EAB infestation, primarily due to fungal staining. The amount of value loss increases with the length of time that the trunk of a tree is EAB-infested. Trees that have died from EAB have rapid wood degradation and value loss. Fungal decay may already be present. Dead trees have a significantly lower moisture content (Persad 2013), so wood that is sold by weight will typically have limited value. In addition, accelerated oxidation staining and fungal discoloration can occur in warm weather if trees are left on site too long after being harvested.

If EAB is known to be in the local area, it may be appropriate to accelerate harvesting schedules because there is not much time to pre-salvage ash before it becomes infested. EAB infestation may turn an economically-viable timber sale into one that is no longer financially viable, especially if the trees cannot be harvested before log degradation.

Ash retention

Even though EAB is expected to kill more than 99% of ash trees, this does not mean that they should all necessarily be harvested. Consider retaining scattered ash trees for ecological purposes, species diversity, wildlife habitat, or other ecological reasons. It may also be appropriate to retain smaller ash trees to temporarily provide growing conditions for non-ash regeneration, control wetland hydrology, or inhibit the growth of invasive plants. Small ash (<6" dbh) are more likely to produce basal sprouts than larger trees (e.g. Kashian 2016), and may help to retain the presence of ash on the landscape. Also, consider retaining some mature ash to provide a seed source for ash regeneration that may be aided by the introduced biological controls.

Stand Assessment

Before deciding on a management strategy for a forest stand, it is important to evaluate the characteristics of the stand and site in terms of stand growth, quality and potential. It is highly recommended that a forester assess a stand with the considerations found in Table 1 before deciding on a management strategy. Further information can be found in the DNR Silviculture Handbook, Checklist for Evaluating Lowland Ash Stands, Lowland Ash Replacement Species Guide, and Wetland Habitat Typing documents as well as in the 'Additional Resources' section of this guide.

Proximity to known EAB infestations

An important consideration affecting the choice of silvicultural alternatives for an ash stand is the proximity to known EAB infestations. Visit the Wisconsin EAB website for information about the known locations of the insect. If EAB is known to be in the local area, it may be appropriate to accelerate harvesting schedules. When EAB populations are high, spread can be several miles per year and ash impacts may become common within a few years of a first detection in the local area.

Once EAB is detected in an area, it may take several additional years for the population to build to a level that will cause significant tree mortality. However, this length of time is variable and often difficult to predict because it depends on several factors such as infestation age, local spread rates, local climate, and the proximity of undetected infestations. At a county level, a significant increase in ash mortality generally begins 6–7 years after EAB is first detected, and continues until most ash are killed (Morin et al. 2017). Knight et al. (2013) found that ash mortality in stands was more than 99% within six years of first infestation, and half of the ash trees over 1.2 inches (3 cm) in diameter were dead within 2 years of first seeing D-shaped EAB exit holes in the stand.

Since timber harvests can take several years to complete (particularly in lowland stands), start management activities as soon as practical. This will maximize the amount of time available for management prior to expected heavy ash mortality, and additional silvicultural treatments to establish non-ash regeneration may be feasible. If EAB is already present in or near the stand, immediate management will likely capture more financial value and give a land manager more options for encouraging regeneration.

It is not easy to accurately predict when EAB will impact a stand in parts of the state where EAB is not yet common. In those areas, infestations are younger and less-established, spread rates are variable, and undetected infestations are likely present. In parts of Wisconsin where EAB is known to be common, EAB is already present in the stand or will soon be present. These stands will likely have fewer management options before EAB impacts them. If ash mortality is already occurring in a stand, active

❖ **<u>Species Composition</u>** • Canopy, shrub, and ground layers • Potential growth and competition	❖ **<u>Hydrology</u>** • Drainage issues, including drain tile, impediments, terrain and water flow • Potential rise in water table • Seedling flood tolerance • Road impacts, Best Management Practices • Seasonal inundation period • Depth to water table • Soils - drainage class, texture
❖ **<u>Regeneration Potential</u>** • Advance regeneration • Non-ash seed sources • Other non-ash regeneration sources • Interfering vegetation • Herbivory intensity	❖ **<u>Operational Considerations</u>** • Access • Volumes • Seasonal variability • Economic viability
❖ **<u>Stand Structure</u>** • Size class distribution and density • Age class distribution	❖ **<u>Surrounding topography and hydrology</u>** ❖ **<u>Presence of invasive plants (e.g., reed canary grass, phragmites and buckthorn)</u>** ❖ **<u>Presence of damaging insects and diseases</u>**
❖ **<u>Growing stock quality</u>** • Acceptable/Unacceptable Growing Stock • Vigor • Degraded vs non-degraded stand condition after ash mortality	

Table 1. Stand characteristics used to evaluate management options in stands potentially impacted by emerald ash borer.

management may be limited to salvage harvests and encouraging the regeneration of non-ash species.

Management Objectives

Management objectives should be identified within the practices of sustainable forestry. Maintaining forest productivity and improving forest resilience are desirable management goals. Evaluation of factors in the 'Stand Assessment' section of this guide will help determine whether active management is practical. Assessment outcomes may result in alteration of management goals, stand entry timelines, or the anticipated stand rotation age. This information may also provide an estimate of financial costs to meet management goals. It may be appropriate to alter an existing management plan if EAB is found in the stand or local area during the lifespan of the plan. Low-quality stands may have to be sold in combination with larger, more valuable stands in order to have active management completed.

Land managers should be aware that EAB impacts may affect eligibility for the Wisconsin tax law programs. For more information, visit the DNR forestry tax law website. State and Federal financial assistance for site conversion is limited.

Stand Alternatives

This guide contains several management alternatives based on whether the stand is located in an upland or lowland forest. In general, management in lowland forests is more complicated than that in upland forests. Aim for a species composition (typically less than 20% ash) that would leave a stand adequately stocked and able to meet landowner goals if all remaining ash were harvested or killed by EAB. The alternatives are based on the stand/site-level considerations and whether EAB is known to be present in the stand.

An assessment of degraded or non-degraded stand condition is based on a minimum level of non-ash Acceptable Growing Stock (AGS). The baseline is set at a common threshold of 40 non-ash AGS per acre or approximately 45% relative density. However, a forester may need to be flexible when setting a minumum baseline or determining what stocking is considered acceptable. Stands at or above this baseline should be able to be managed for non-ash species using 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., less than 40 non-ash AGS per acre) if regeneration options are limited.

The Ash Decision Model (Figure 1) is a tool to aid foresters and land managers in managing ash across many different landscapes in Wisconsin. This model will usually suggest several management options when used in conjunction with the DNR Silviculture Handbook, Checklist for Evaluating Lowland Ash Stands, and Lowland Ash Replacement Species Guide. It is up to the forester or land manager to make a final management decision. Stand and site conditions and capabilities, management goals, and past successes/failures with ash management on both upland and lowland sites were taken into consideration during model development.

Upland Stands

Upland ash (primarily white ash, although green ash can be found in minor amounts) is generally associated with the northern hardwood cover type, with most stands having less than 20% ash. Other species commonly associated with ash in these stands are sugar maple, beech, basswood and yellow birch, with sugar maple typically being the dominant species. Ash also grows as an associate species in other forest cover types, and only rarely occurs as a dominant component. Upland ash occurs on a wide variety of soil types, but grows best on mesic sites with well-drained to moderately well-drained loamy soils.

White ash is generally the fastest growing of all the northern hardwood species and often exceeds other associate species in Site Index by 3-10 feet. It is also a reliable seed producer, with large and abundant seed crops every 3-5 years. For ash that is a component of a northern hardwood stand, consider the silviculture alternatives for this cover type. Follow the stand prescription when selecting trees to remove or retain, keep the stand adequately stocked, and encourage species diversity by promoting non-ash tree species.

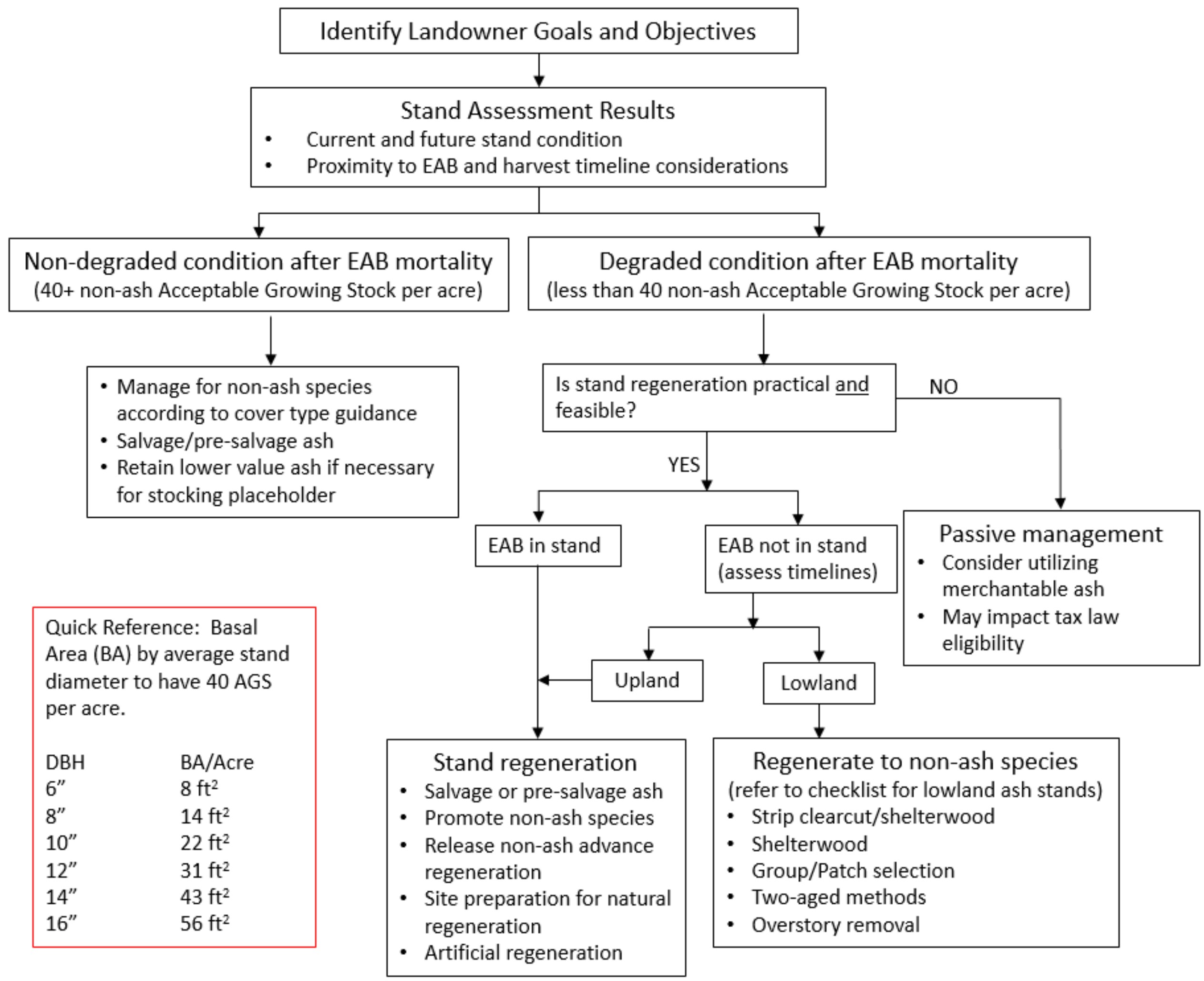

Figure 1. Ash decision model. Refer to the upland and lowland sections of these guidelines for more details. (Note: graphic design of this model will be altered)

Upland ash management will be similar whether or not EAB is present. Pre-salvage harvesting will reduce EAB impacts by removing vulnerable trees before they decline and die, and can be used to increase species diversity. Salvage harvesting will capture economic value by harvesting dead or dying trees, although trees may no longer be suitable for sawtimber.

- If pre-salvage or salvage harvesting of ash will not result in a degraded stand (i.e., more than 40 Acceptable Growing Stock (AGS) per acre remain, or the residual stocking of non-ash trees will be above C-line (approximately 45% relative density)), manage according to cover type silvicultural guidelines and encourage regeneration of non-ash species in the gaps. Monitor and address factors such as invasive plant occurrence and deer browse.

- If pre-salvage or salvage harvesting of ash will result in a degraded stand (i.e., less than 40 AGS per acre, or residual stocking will be below C-line (less than 45% relative density)), regenerate the stand to non-ash species according to cover type silvicultural guidelines using natural or artificial methods.

If ash is more than 10% of all regeneration, especially in gaps, consider reducing the ash component with release operations and favor non-ash species. Active treatment of ash regeneration through cutting or herbicide may be needed, especially if ash regeneration is predominant. Supplemental planting of non-ash species is another option to increase the non-ash component. Treatment of invasive plants prior to EAB impacts is recommended due to the likelihood of increased prevalence as ash die. Treatment options can be found in the DNR Silviculture Handbook.

Lowland Stands

Lowland ash (primarily black and green ash) occurs in shallow depressions, floodplains and associated terraces. Sites are seasonally wet, although the water table is almost always close to the surface and reaches the tree rooting zone. Soils can be wet mineral or organic muck over mineral. Other tree and shrub species, such as white cedar, red maple, spruce, alder, mountain maple and dogwood, can occur depending on the type of lowland stand. Many of these types, however, are predominantly ash with a heavy understory of ash regeneration. Wetland habitat typing is a good indicator of stand characteristics such as quality, site potential and site hydrology.

The establishment of EAB in Wisconsin has increased the importance of finding management strategies to maintain forest productivity and resilience in lowland stands, where silvicultural knowledge has been limited. Important goals will include diversifying overall stand composition and structure. Community responses to EAB are not well-understood, especially in hardwood swamps with few non-ash replacement species (Slesak et al. 2014; Iverson et al. 2016). Studies have found increased growth in residual non-ash species following the death of ash from EAB (Flower et al. 2013; Burr and McCullough 2014; Costilow et al. 2017).

Intensive site preparation, deer fencing, release treatments and invasive plant control may be required for successful establishment of regeneration. Timber sales can take several years to complete and site access can be unpredictable, so postponing management activities is not recommended. In addition, stand conversion costs will be high without a guarantee of success. Consult a forester to discuss management objectives before any decisions are implemented.

Guidance for lowland stands is based on silviculture case studies from the Lakes States, the Swamp Hardwood and Bottomland Hardwood chapters of the DNR Silviculture Handbook, the Checklist for Evaluating Lowland Ash Stands, and the Lowland Ash Replacement Species Guide. The Checklist for Evaluating Lowland Ash Stands is designed to assist with site and stand evaluation prior to developing a management prescription, and can be found in the 'Additional Resources' section of this guide. The Lowland Ash Replacement Species Guide can be used in selecting suitable species for a site, and considers a variety of suitability categories, such as habitat type, soil characteristics, flood tolerance and browse tolerance for each listed species. Due to the complex nature of these sites, it is recommended that the collected data be considered in combination with landowner objectives.

In 2002, DNR staff began collecting detailed information about 29 timber harvests in black ash stands across the state. They have regularly added this information to the DNR Silviculture Trials database.

The trials have indicated stand assessment considerations and regeneration methods that increased species diversity in lowland stands while minimizing site impacts.

In general, lower-intensity treatments such as single tree selection resulted in less tree regeneration along with lower diversity of non-ash species. Strip shelterwood and strip clearcut trials typically produced more diverse, non-ash regeneration (e.g. red maple, yellow birch, balsam fir, and basswood) as long as a seed source was present. Swamping occurred in diameter-limit and clearcut trials, whereas hydrological changes were less dramatic when the strip shelterwood/clearcut and single tree selection methods were used.

The considerations discussed below should be evaluated before selecting a silvicultural practice to manage these lowland stands. If stand regeneration is not practical or feasible, consider utilizing merchantable ash and letting the stand convert. Alternatively, no active management could be considered. Both of these options may impact tax law program eligibility.

Site Potential

A careful assessment of site potential will help predict which stands will best respond to management treatments in terms of growth, regeneration, and hydrological balance. Intensive management may not be practical in less productive, low quality stands.

The Forest Habitat Type Classification System is commonly used in Wisconsin to assess site capability in both upland and lowland stands. Based on the swamp hardwood trials, wetland habitat types that are slightly richer in nutrients (e.g., FnArI and FnUB in Regions 3 and 4, respectively) seem most capable of supporting higher proportions of non-ash tree regeneration. Post-harvest shrub competition on these sites creates a 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, with proportionately lower shrub densities, particularly under the strip clearcut and strip shelterwood regeneration methods. 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.

Operational Considerations

In ash-dominated lowlands, operational considerations are particularly important due to the seasonally-saturated soil conditions and the generally low value of associated forest products. Foresters should evaluate potential sale volumes relative to local markets when assessing timber sale feasibility. Small stands with difficult access will have limited marketability.

Stands with very poor drainage classes, long seasonal inundation periods, deep organic soils, and/or impeded drainage may have limited or unpredictable harvest windows, and be more susceptible to site damage due to rutting and swamping. Road systems and other infrastructure can impede water flow and have long-lasting impacts on wetland hydrology and site productivity. Thus, they need to be carefully located and constructed. More information can be found online at the DNR Forestry Best Management Practices website.

Regeneration Potential

Maintaining the resilience of ash-dominated lowland stands will require increased non-ashregeneration. Evaluation of regeneration potential should consider factors such as the density and stocking of non-ash advance regeneration, alternate seed sources, herbivory pressure and presence of competing vegetation.

Treatment of invasive plants prior to EAB mortality is recommended due to the likelihood of increased prevalence when understory light levels increase. Treatment options can be found in the DNR Silviculture Handbook.

In lowland silviculture trials, all treatments produced abundant shrub regeneration as well as abundant ash regeneration, due to the ability of ash to easily reproduce from seed and stump sprouts. However, ash regeneration as small as 1" in diameter is susceptible to EAB infestation and cannot be relied on to restock the stand. It is important to note that follow-up release treatments may be necessary to maintain non-ash regeneration over time.

It may be necessary to use a variety of silviculture techniques to maintain adequate forest cover at these sites. Bolton et al. (2018) used mounding techniques, deer repellents and fencing to test a variety of tree species in Michigan and Wisconsin. The study found that silver maple, red maple, American elm and other species were viable replacements for black ash. In addition, planting on natural or artificial hummocks was successful at increasing survival rates of several species. More information about suitable species is available from the DNR Silviculture Trials website.

Hydrological Risk

In these forest systems, it is important to protect hydrological and soil function, and perpetuate the forest canopy so that maximum evapotranspiration can occur. Hydrological risk refers to the risk of 'swamping,' when a water table rises following harvesting due to tree removal and/or site damage. Assessing hydrological risk should include factors such as length of seasonal inundation, depth to water table, likelihood of ponding, drainage class, type of soil and depth to mineral soils, and drainage impediments such as beaver dams.

Partial harvest treatments will generally mitigate the water table impacts. The risk is considered greatest for clearcutting and overstory removal treatments, where the primary sources of evapotranspiration (larger trees) are removed in a single operation. However, swamping can also occur with other silvicultural treatments if site factors are high risk, and from impeded drainage due to site damage.

EAB not observed in the stand

In lowland ash stands, there are several silvicultural alternatives that are recommended in the Swamp Hardwood and Bottomland Hardwood Chapters of the Silviculture Handbook, DNR Silviculture Trials website, and Checklist for Evaluating Lowland Ash Stands. Encourage the regeneration of non-ash species and/or consider non-ash supplemental planting when evaluating a silvicultural method. The Lowland Ash Replacement Species Guide can help select appropriate species to plant.

- **Shelterwood** – This method can help maintain hydrological balance while encouraging non-ash species if alternate seed sources (red maple, yellow birch, northern white cedar, etc.) are present. Site preparation for natural regeneration can be difficult on these wet sites, and minimizing competition can be challenging.

- **Strip clearcut/shelterwood** – This method can also help maintain hydrological balance and encourage non-ash regeneration if a seed source is present. The harvested strip may be 50 to 200 feet wide with residual strips left unharvested. In lowland systems, this method may also reduce windthrow and improve access within the stand. Deer browsing may be heavier in the regenerating areas.

- **Group/patch selection** – A group may be 0.1 to 0.5 acre in size, and a patch may be 0.5 to 2.0 acres in size. This method encourages the regeneration of mid-tolerant species and has been shown to reduce the risk of swamping. It can also be coupled with site preparation and supplemental, post-harvest planting of non-ash species to increase species diversity.

- **Single tree selection** – In the past, this method was recommended to encourage and perpetuate black ash. However, recent Wisconsin silviculture trials and other research have indicated that this method is less likely to encourage non-ash regeneration. The hydrological balance of the site is likely to be retained.

- **Clearcutting** – Based on silviculture trial results and research studies, clearcutting is not recommended except in limited circumstances. Clearcutting increases the risk of swamping and duration of ponding, and produces a greater abundance of sedge and grass that may compete with establishing seedlings. Both the Wisconsin Silviculture trials and Minnesota research (Slezak et al. 2014; Looney et al. 2015) have found that water tables rise after harvest and initial establishment of tree species is limited.

  The coppice method could be considered if there was an aspen component that would successfully regenerate within the stand. If the stand is a minimum of 3 acres and contains at least 20 ft^2/acre of uniformly-spaced aspen, consider coppice harvesting to promote aspen regeneration. Harvest boundaries can be extended a tree length away from the nearest aspen to allow for additional sunlight and aspen regeneration opportunities.

- **Overstory removal** – This method has been implemented in a few Wisconsin silviculture trials with mixed results. Important considerations include adequate density, size, distribution and desirable species of non-ash regeneration. This method can increase the risk of swamping and additional planting may be necessary to maintain adequate stocking. One study site had adequate non-ash regeneration, but hydrology was impacted and led to the establishment of cattails and other undesirable vegetation.

<u>EAB observed in the stand</u>

Management options will be more limited in lowland ash stands that are already impacted by EAB. If salvage harvesting of ash will not result in a degraded stand (i.e., more than 40 Acceptable Growing

Stock (AGS) per acre remain, or the residual stocking of non-ash trees will be above C-line (approximately 45% relative density)), manage according to cover type silvicultural guidelines and encourage regeneration of non-ash species.

If salvage harvesting of ash will result in a degraded stand (i.e., less than 40 AGS per acre, or residual stocking will be less than the C-line (less than 45% relative density)), regenerate the stand to non-ash species if practical and feasible, according to cover type silvicultural guidelines using natural or artificial methods.

Several resources are available to identify options that can potentially rehabilitate degraded lowland ash stands. Resources include the Checklist for Evaluating Lowland Ash Stands and the Lowland Ash Replacement Species Guide. In addition, a number of Silviculture Trials have been conducted in lowland sites throughout the Lakes States.

No Active Management Option

In many ash-dominated lowland stands, it will not be practical to actively harvest ash because of economic considerations, harvesting impacts, silvicultural options or suitable site access. Thus, there will be numerous sites where EAB will be allowed to run its course and management will focus on non-timber objectives. Mortality from EAB may lead to understocking, conversion to undesirable tree species or non-forest cover, elevated water tables or an increase in invasive plants such as reed canary grass and phragmites. These outcomes are less likely to occur if active management is selected.

Stands that currently have a predominance of ash may have abundant ash regeneration, but in many cases, regeneration will be poor or non-existent. In either case, this regeneration will become susceptible to EAB as it grows. Bowen and Stevens (2018) predicted that swamps with the least amount of ash will likely experience a proportional increase in non-ash species, whereas the sites with the most ash will likely transition to a shrubby, herbaceous swamp with scattered trees.

Artificial Regeneration

In many cases, natural regeneration will not be adequate to fully stock a future stand. Planting trees may be the only viable option to reasonably ensure the successful establishment and growth of non-ash species. Land managers are encouraged to work with a forester to develop a reforestation plan and estimate financial costs. More information about artificial regeneration techniques can be found in the DNR Silviculture Handbook and DNR Forest Management Guidelines.

Species Selection

Species selected for planting must meet management objectives and be suitable for each site. After evaluating the site characteristics, select a mixture of species that emphasize positive traits and overcome limiting factors. Factors that should be considered when selecting species as ash replacements include: Cover type, habitat type, soil texture and drainage, flood tolerance, shade tolerance, cold hardiness, browse susceptibility and presence of competing vegetation.

Detailed information about species selection and potential planting methods is available from the Lowland Ash Replacement Species Guide, the Checklist for Evaluating Lowland Ash Stands, and the DNR

Silviculture Trials website. In general, using larger planting stock has been more successful than using smaller stock. Additional planting techniques are in development. More information can be found the 'Additional Resources' section of these guidelines.

Site Preparation

Preparing a site for planting is a critical element of planting success, and is intended to improve growing conditions and control competing vegetation. Site preparation methods vary greatly, depending on the site characteristics and the degree to which competing vegetation interferes with planting. Site preparation treatments can involve chemical and/or mechanical methods. The timing of treatment, herbicide selection, application rates and mechanical treatment methods are all important to success and should be coordinated under the guidance of a forester.

Upland sites will typically be easier to prepare for planting than lowland sites. Common issues on upland sites include undesirable tree species, competition from grasses and sedges, and control of invasive plants such as honeysuckle, buckthorn and barberry.

Lowland sites will be the most difficult to prepare for tree planting. Undesirable tree species, invasive plants such as reed canary grass, and the seasonally wet nature of these sites can make site preparation challenging. Many sites will only be accessible for site preparation, planting and follow-up maintenance during a few months of the year.

Multiple treatments to prepare a site can quickly become expensive. Making site preparation part of the harvesting activities can keep costs down without discouraging seedling survival. For example, skidding of large trees can expose mineral soil and drop seed. Combining the activities can reduce total expenses, but does require increased planning, an experienced contractor, and development of contract specifications to meet objectives. Reduced timber sale revenue may result but expenses would also be lower.

Planting

Most sites will be hand-planted using a shovel or planting bar since mechanical planting is usually impractical. A rough estimate is that an inexperienced but physically fit person can hand-plant 300 to 500 trees per day. Recommended tree density can vary greatly, but typically will be 500 to 900 trees per acre.

Another option to consider is direct seeding, although very little direct seeding has been done in a forested setting. This cost-effective method can be used where planting is difficult, and can regenerate small areas or quickly reforest large acreage. Use of this method requires a knowledge of species/site combinations and proper seed handling. When compared to planted seedlings, seeded trees often have better root systems and are better suited to their microsites. However, small areas can be more susceptible to seed predation by rodents and deer. Forester assistance is recommended when planning direct seeding.

One disadvantage of direct seeding is a lower success rate, though many of these failures can be attributed to improper planning. Losses of seeds and small seedlings can be high. Hardwood seed is difficult to obtain in most years and does not store well. This uncertainty has led many land managers to select natural regeneration or tree planting instead of direct seeding.

Follow-up Maintenance

Once trees are planted, it is essential to periodically monitor them and evaluate growth. Typically, plantings will require maintenance and several years of monitoring in order to conclude that establishment was successful. Periodic spraying and/or mowing is recommended to reduce rodent cover, increase the amount of sunlight reaching the trees, and prevent weeds and grasses from smothering the trees until they have grown above the competition.

In addition, protection from deer browsing will often be required to obtain successful results. Many forest sites are now being fenced prior to planting in order to exclude deer. Other methods of browse prevention include bud caps and chemical deterrents. As with site preparation, the methods and timing of treatments, herbicide selection and chemical application rates are all important to success and should be coordinated under the guidance of a forester.

Glossary

Acceptable growing stock (AGS) – Live trees of an appropriate species, vigor and form that can be expected to contribute significantly to a future stand as high-quality stems.

Advance regeneration – Seedlings or saplings that are present in the understory in advance of stand rotation.

Basal area – The cross-sectional area of all stems in a stand expressed per unit of land area.

Clearcutting – A silvicultural system in which all merchantable trees are removed in one operation, to create an even-aged stand.

Coppice – Regeneration that is derived from vegetative sprouting, usually from smaller-diameter stumps.

Direct seeding – Broadcast sowing of tree seeds through aerial or manual means.

Epicormic sprout – A shoot arising from an adventitious or dormant bud on the stem or branch of a woody plant, often following exposure to fire or increased light levels.

Evapotranspiration – The water loss occurring from the processes of evaporation and transpiration from leaves.

Habitat type classification – A site classification system based on the floristic composition of plant communities.

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.

Herbivory – The consumption of plant material by animals.

Overstory removal – A regeneration method in which a stand's overstory is removed in one entry, to release established seedlings and saplings.

Oxidation staining – Discoloration that occurs following significant exposure to air.

Ponding – The retention of flowing water to form a pond.

Pre-salvage – The harvesting of highly vulnerable trees before they are damaged, decline or die.

Pulpwood – Trees that are between a sapling and a sawtimber tree in size. Typically, these are hardwood trees between 5 and 11 inches in diameter at breast height (dbh), and conifers between 5 and 9 inches dbh.

Quarantine – A system of regulations intended to help prevent the spread of a forest pest or disease. The EAB quarantine restricts the movement of untreated firewood and unprocessed ash products out of quarantined areas to non-quarantined areas.

Rehabilitation – The restoration of species composition and structure to a desired state following degradation such as mortality from emerald ash borer.

Relative density – Stand density expressed as a percentage of the average maximum for stands at a similar stage of development.

Rotation – In even-aged silvicultural systems, the period between regeneration establishment and final cutting. Rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, and biological condition.

Salvage – The removal of damaged, dead or dying trees to recover economic value that would otherwise be lost.

Sawlog – Trees with minimum diameter, length and stem quality suitable for processing into lumber. Typically, these are hardwood trees larger than 11 inches (dbh) and conifers larger than 9 inches (dbh).

Shelterwood – A silvicultural system characterized by multiple cuts, designed to encourage the regeneration of desirable tree species under the shade of residual trees until the residual trees are harvested.

Site index – A species-specific measure of actual or potential forest productivity, usually for even-aged stands, expressed in terms of the average height of trees included in a specified stand component (dominants, codominants, or the largest and tallest trees) at a specified index or base age.

Site potential – The sum total of all the factors (moisture, nutrients, heat, light, etc.) affecting the capacity of a site to produce forests or other vegetation. Different potentials facilitate growth of some species and limit growth of others.

Site quality – The productive capacity of a site, usually expressed as volume production of a species.

Strip clearcut (aka strip shelterwood) – A silvicultural system in which the stand is removed in a series of strips harvested over 2-3 entries, usually covering an equal area on each occasion. The entire removal process is completed within a period of time that does not exceed 20% of the intended rotation interval.

Unacceptable growing stock (UGS) – Live trees that are low vigor, low quality, high risk, or an undesirable species, and are not expected to contribute significantly to a future stand.

Additional Resources

- Emerald Ash Borer Resources
    - Wisconsin Emerald Ash Borer website
    - Emerald Ash Borer Information Network
- Silviculture Information
    - Checklist for Evaluating Lowland Ash Stands – actual document expected to be inserted
    - Lowland Ash Replacement Species spreadsheet – actual document expected to be inserted once completed this spring
    - DNR Silviculture Trials website
    - DNR Silviculture Handbook
    - Wisconsin DNR Forest Management Guidelines
    - Wetland Forest Habitat Type Classification System for Northern Wisconsin
    - Silvics of North America Handbook
    - NRCS Soil Survey data
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- Landowner Programs and Financial Incentives
    - DNR forestry assistance locator (DNR/cooperating foresters)
    - DNR Forestry financial help
    - Wisconsin Forest Landowner Grant Program (WFLGP)
    - Federal Government cost share programs
- Forest Products
    - Effects of EAB on wood quality
    - Wisconsin forest products information
- Artificial planting Links
    - Caring for planted trees
    - Herbicides for invasive plant control
    - Deer browse prevention

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Contributors

The stand-level EAB Silviculture Guidelines were originally implemented in 2007, with periodic reviews and updates since then. The guidelines were developed by evaluating multiple areas, including recent research findings, experience gained in implementation of the existing guidelines, and economic considerations. The EAB Silviculture Guidelines were revised in 2017-18 with the help of the following groups:

Advisory Committee – representatives from affected stakeholder groups including industry, government and landowners.

- Shawn Hagen, Forestland Operations
- Don Nelson, Domtar
- Jim Kerkman, US Army
- Chris Thies, CASL Forestry Service, LLC
- Scott Koerner, Koerner Forest Products
- Lee Rahlf, Lincoln County Forestry Department
- Chuck Wagner, Wisconsin Woodland Owners Association
- Greg Edge, DNR Forest Silviculturist
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