Photo: John Ambrose

Blue Ash

(Fraxinus quadrangulata) in Ontario

Ontario Recovery Strategy Series

2017

Natural. Valued. Protected.

Ministry of Natural Resources and Forestry

Ontario

About the Ontario Recovery Strategy Series

This series presents the collection of recovery strategies that are prepared or adopted as advice to the Province of Ontario on the recommended approach to recover species at risk. The Province ensures the preparation of recovery strategies to meet its commitments to recover species at risk under the *Endangered Species Act 2007* (ESA) and the Accord for the Protection of Species at Risk in Canada.

What is recovery?

Recovery of species at risk is the process by which the decline of an endangered, threatened, or extirpated species is arrested or reversed, and threats are removed or reduced to improve the likelihood of a species' persistence in the wild.

What is a recovery strategy?

Under the ESA a recovery strategy provides the best available scientific knowledge on what is required to achieve recovery of a species. A recovery strategy outlines the habitat needs and the threats to the survival and recovery of the species. It also makes recommendations on the objectives for protection and recovery, the approaches to achieve those objectives, and the area that should be considered in the development of a habitat regulation. Sections 11 to 15 of the ESA outline the required content and timelines for developing recovery strategies published in this series.

Recovery strategies are required to be prepared for endangered and threatened species within one or two years respectively of the species being added to the Species at Risk in Ontario list. Recovery strategies are required to be prepared for extirpated species only if reintroduction is considered feasible.

What's next?

Nine months after the completion of a recovery strategy a government response statement will be published which summarizes the actions that the Government of Ontario intends to take in response to the strategy. The implementation of recovery strategies depends on the continued cooperation and actions of government agencies, individuals, communities, land users, and conservationists.

For more information

To learn more about species at risk recovery in Ontario, please visit the Ministry of Natural Resources and Forestry Species at Risk webpage at: **www.ontario.ca/speciesatrisk**

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Declaration

The recovery strategy for the Blue Ash was developed in accordance with the requirements of the *Endangered Species Act, 2007* (ESA). This recovery strategy has been prepared as advice to the Government of Ontario, other responsible jurisdictions and the many different constituencies that may be involved in recovering the species.

The recovery strategy does not necessarily represent the views of all of the individuals who provided advice or contributed to its preparation, or the official positions of the organizations with which the individuals are associated.

The goals, objectives and recovery approaches identified in the strategy are based on the best available knowledge and are subject to revision as new information becomes available. Implementation of this strategy is subject to appropriations, priorities and budgetary constraints of the participating jurisdictions and organizations.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy.

Responsible jurisdictions

- Ontario Ministry of Natural Resources and Forestry
- Environment and Climate Change Canada – Canadian Wildlife Service, Ontario
- Parks Canada Agency

Executive summary

Blue Ash (*Fraxinus quadrangulata*) is a medium-sized tree native to Ontario's Carolinian Zone. In Ontario, Blue Ash is designated as threatened under the *Endangered Species Act, 2007*. It has been documented from a total of 56 sites in southwestern Ontario, including sites on Pelee and Middle Islands in Lake Erie.

Although precise population estimates are not available, it has been estimated that the number of mature reproductive individuals in Ontario is less than 2500. Many more saplings and seedlings are present at some sites, and it is possible that more sites will continue to be found.

Blue Ash occurs in three main habitat types in Ontario: in moist deciduous forest, on stabilized dunes, and on limestone bedrock. Blue Ash is moderately shade tolerant, and will grow and even proliferate in open and semi-shaded conditions. It is the most drought-tolerant of native ashes.

Several threats to Blue Ash have been identified, although their impacts are not clear. The invasive Emerald Ash Borer (EAB, *Agrilus planipennis*) is now present throughout the Ontario range of Blue Ash. Although Blue Ash appears to exhibit greater resistance to EAB than other native ash species, it is possible that EAB may threaten Blue Ash over the long term. High levels of deer browse have also been observed at some sites, although the population-level effects of this are not known. Other causes of mortality or damage to trees include localized colonies of Double-crested Cormorants, habitat loss due to development, vegetation management, fire suppression and water management, and recreational pressure.

The recovery goal for Blue Ash in Ontario is to maintain or increase all current naturally-occurring populations within its known Ontario range, and to ensure its persistence as a functional, reproductive forest tree. The following protection and recovery objectives are proposed.

- Evaluate threats to Blue Ash through regular monitoring.
- Mitigate documented threats with management and stewardship.
- Encourage in-situ and ex-situ conservation to augment populations and conserve genetics.
- Conduct research to fill knowledge gaps related to Blue Ash mortality and management in Ontario.

It is recommended that a habitat regulation for Blue Ash protect the Ecological Land Classification (ELC) vegetation type in which naturally-occurring trees are found. In non-floodplain areas, the ELC vegetation type may be bounded by a distance of 75 m, since the probability of dispersal beyond this distance is relatively low. Where trees are close to the habitat edge or the habitat polygon cannot be easily described using ELC, a radial distance of 23 m is recommended to protect the tree's root zone, and a minimum

distance of 75 metres from the stem of native-grown trees is recommended to protect any suitable habitat into which seeds may disperse. Habitat regulation should not apply to Blue Ash trees planted as horticultural specimens in landscaped areas or gardens; however, regulation should apply to restoration plantings.

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1.0 Background information

1.1 Species assessment and classification

Table 1. Species assessment and classification of the Blue Ash (*Fraxinus quadrangulata*). The **Error! Reference source not found.** provides definitions for the bbreviations within, and for other technical terms in this document.

Assessment	Status
SARO list classification	Threatened
SARO list history	Threatened (2015) Special Concern (2008)
COSEWIC assessment history	Threatened (2014) Special Concern (2000) Threatened (1983)
SARA schedule 1	Special Concern
Conservation status rankings	GRANK: G5 NRANK: N3 SRANK: S2?

1.2 Species description and biology

Species description

Species description

The Blue Ash is a medium-sized tree in the olive (Oleaceae) family, often growing up to 20 metres in height. Like other ashes, Blue Ash has opposite, compound leaves, in this case with 5-11 leaflets on short stalks[1]. The leaflets are coarsely toothed with long-tapering tips. The seeds are contained within keys, called samaras, which have a broad, twisted wing that extends along the body to the base (Waldron 2003; Voss and Reznicek 2012).

[1] Opposite refers to the arrangement of leaves along branches: two opposite leaves are placed opposing each other at a leaf node (whereas alternate leaves have a single leaf at each node, alternating along a branch). Compound leaves are composed of more than one part, i.e., a leaf with two or more leaflets (see Voss and Reznicek 2012).

The young branchlets have four distinct corky ridges along their length ("four-angled"), and can even be slightly winged (Waldron 2003, Voss and Reznicek 2012). This is usually the most diagnostic feature of Blue Ash, leading to the species' scientific name *Fraxinus quadrangulata*. On more mature branchlets, the ridges may be obscure, and should be sought on the most vigorous growth (Waldron 2003). In the absence of clearly ridged twigs, the toothed, short-stalked leaves and light reddish gray, often scaly or platy bark can be useful identifying characters (Waldron 2003).

Further botanical description, illustrations, and technical keys to separate the Blue Ash from other native ashes can be found in references such as Voss and Reznicek (2012), Waldron (2003), Holmgren (1998), and Farrar (1995). It is possible that Blue Ash has been underreported in the past since the diagnostic features may be missed.

Species biology

The information available on the biology of Blue Ash is relatively minimal, and in some cases conflicting.

In Ontario, the flower clusters of Blue Ash appear in April and May, before the leaves emerge. Unlike other North American ashes, most flowers are "perfect," meaning that they have both male and female parts. Thus, most Blue Ash trees are capable of bearing fruit (i.e., keys or samaras), whereas other ash species typically have separate male and female trees. The flowers are wind-pollinated, and good seed crops ("mast crops") in ashes are generally produced every 3-4 years or more (Prasad et al. 2007, Sutherland et al. 2000). Trees first bear fruits at about 25 years of age (Prasad et al. 2007). Some authors suggest that Blue Ash typically lives for 125 to 150 years (Waldron 2003, Prasad et al. 2007), while others suggest a maximum age of 200 to 300 years (Strobl and Bland 2013).

The winged seeds of related ashes are dispersed in late fall primarily by gravity and wind (McEuen and Curran 2004 Prasad et al. 2007). Modelling of seed dispersal of Green Ash (*Fraxinus pennsylvanica*) in Germany showed mean dispersal distances of between 47 and 66 m. Wind direction plays a role in dispersal, with high seed densities occurring exclusively against the direction of the prevailing winds (i.e., NE-E). The same study estimated long-distance (95th percentile) wind dispersal of *F. pennsylvanica* at between 60 and 150 m in the direction of the prevailing winds (Schmiedel et al. 2013). A second recent model predicted that the majority of *F. pennsylvanica* seeds would land at a distance of 100 m from the parent tree (Schmiedel and Tackenberg 2013). For *F. pennsylvanica* in Germany, it has been concluded that there is a high probability of regeneration establishment in areas <50 m from a seed source (Schmiedel et al. 2013).

In colder climates, seeds shed in winter may disperse through secondary transport on snow (Greene and Johnson 1997). During winter, Sutherland et al. (2000) estimate that ash samaras can be blown "100 metres or more" from the parent tree. Dispersal by water along floodplains may carry seeds even further. In France, the related *F. ornus* was found to disperse at an average rate of 970 m per year (Thébaud and Debussche 1991).

Landscape fragmentation increases the likelihood of long-distance dispersal of winged seeds by wind. Studies of European Ash (*F. excelsior*) found that seeds could be transported tens of kilometers in highly fragmented Scottish landscapes. These rare long-distance dispersal events may be important to maintaining genetic connectivity across fragmented landscapes (Bacles et al. 2006).

Seeds may also be dispersed longer distances on the flowing water of rivers and creeks. Ambrose and Aboud (1983) observe that the species' strong association with floodplain and shoreline habitats suggest that water was likely important for the long-distance dispersal of seeds following glaciation. Birds and small mammals also consume the seeds and can transport them varying distances (see COSEWIC 2014).

Although evidence is conflicting and may be site-dependent, Blue Ash seeds probably do not form a persistent long-term seed bank. Ash seeds have been reported to be viable for up to eight years (Sutherland et al. 2000). However, in studies in a deciduous forest, the density of viable seeds across 18 stands infested with the invasive Emerald Ash Borer was found to decline almost to zero within two years (Klooster et al. 2014). Ash samaras lack a protective thick coat, and the majority of ash seeds likely do not survive to their second season due to predation and fungi (D. Simpson, pers. comm. 2016).

Blue Ash is moderately shade tolerant, and as the forest canopy closes, regeneration decreases (Ambrose and Aboud 1983, Strobl and Bland 2013). Like many other deciduous forest species, Blue Ash can proliferate following canopy thinning, showing increased vigour and regeneration (Ambrose and Aboud 1983).

1.3 Distribution, abundance and population trends

Blue Ash is found in Ontario's Carolinian Zone[2], occurring naturally at Point Pelee, Pelee Island and other Lake Erie Islands, and in valleys along the Thames and Sydenham Rivers. There is a single isolated occurrence along Catfish Creek in Elgin County. Blue Ash is also grown commercially and has been planted in many urban and natural areas in southern Ontario, especially in the City of Windsor (Waldron 2003, COSEWIC 2014).

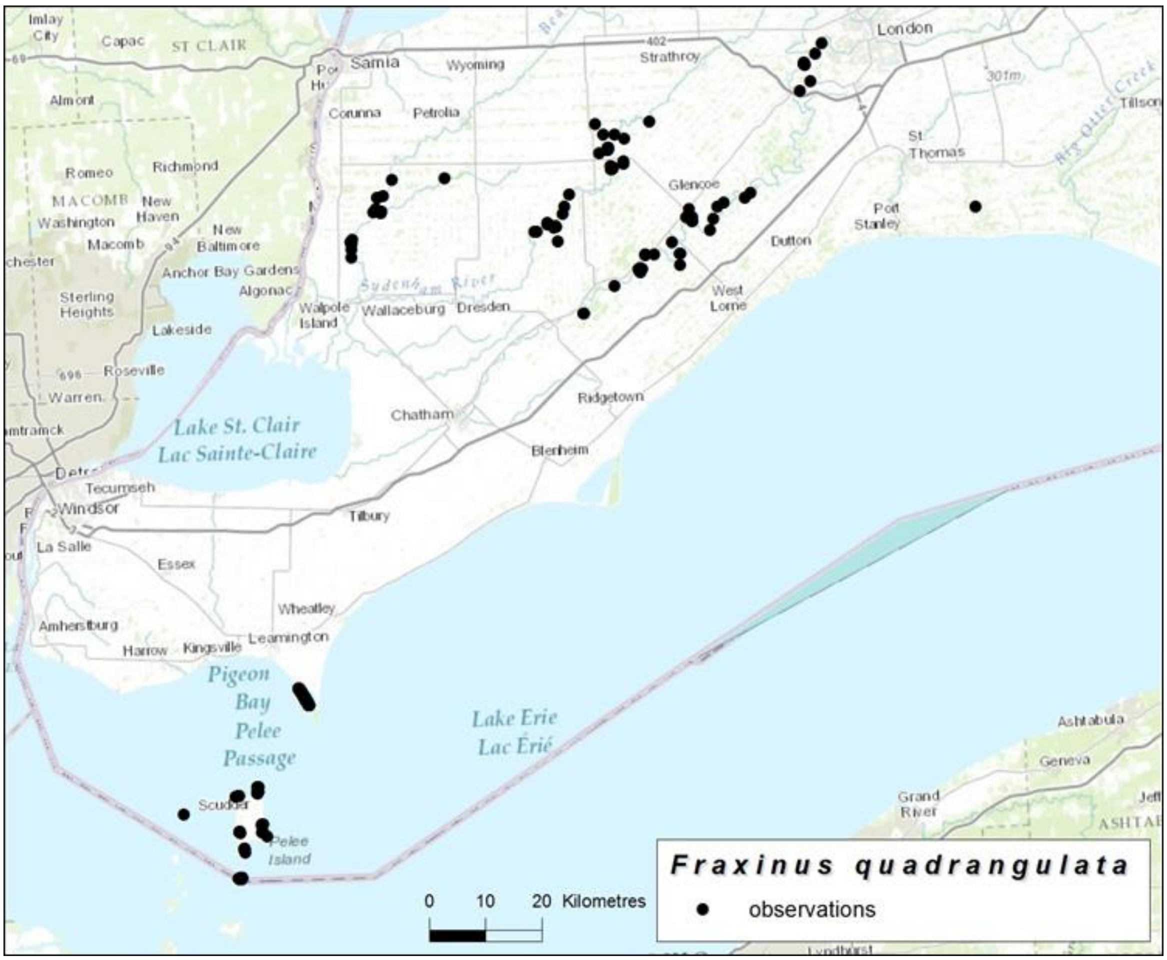
Approximately 56 naturally-occurring sites are known in Ontario, although many of these have not been recently confirmed (COSEWIC 2014). In 2012-13, about half the known naturally-occurring sites were surveyed. These surveys resulted in a total count of 1806 trees (both mature and immature). Overall, the number of mature individuals in

[2] Ontario's Carolinian Zone is known internationally as the Eastern Deciduous Forest Region.

Ontario is estimated at less than 2,500[3]. There are large numbers of seedlings and saplings (i.e., immature trees) at some sites, such as Point Pelee National Park (PPNP) and the McAlpine Tract on the Sydenham River (COSEWIC 2014).

Blue Ash occurs more commonly in Ontario than previously thought, largely due to increases in survey effort and awareness. However, the population is believed to be declining overall, due to a number of threats (see Section 1.5).

Figure 1. Current distribution of the Blue Ash in Ontario (source: COSEWIC 2014).



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[3] Trees greater than 10 cm in diameter at breast height were considered "mature individuals" for the purpose of assessing abundance (COSEWIC 2014). The count focused on trees in natural settings that were presumed native, and did not include trees in horticultural situations.

1.4 Habitat needs

Blue Ash occurs in three main habitat types in Ontario. Most commonly, it is found in moist deciduous forest, especially along floodplains. However, it also occurs on stabilized dunes at Point Pelee National Park, and on alvar or limestone bedrock on the Lake Erie islands. Although Blue Ash can persist in a range of soil types, it grows best on well-drained, rich bottomland soils. The species is highly resistant to drought, which is especially evident at sites on Pelee Island (Waldron 2003).

<u>Deciduous floodplain forests</u>
The majority of Ontario sites occur on floodplains of the Sydenham and Thames River watersheds. In these areas, Blue Ash is usually found in rich bottomland deciduous forests with deep alluvial soils, usually silt to clay loams, but sometimes on heavy clay. Associated tree species in this habitat include Black Maple (*Acer saccharum* ssp. *nigrum*), Common Hackberry (*Celtis occidentalis*), Basswood (*Tilia americana*), White Ash (*Fraxinus americana*), Green Ash (*Fraxinus pennsylvanica*), Black Walnut (*Juglans nigra*), White Oak (*Quercus alba*), Red Oak (*Quercus rubra*), Chinquapin Oak (*Quercus muehlenbergii*), Shagbark Hickory (*Carya ovata*) and Bitternut Hickory (*Carya cordiformis*) (Ambrose and Aboud 1983, Mills and Craig 2008). Blue Ash probably occurs in several ELC[4] vegetation forest and woodland types in these areas (Lee et al. 1998, and updates), although these have not been documented to date.

<u>Stabilized sand dunes and savannas</u>
Blue Ash is found at Point Pelee National Park and Fish Point (Pelee Island) on calcareous sands. It occurs on open shores, stabilized dunes, and in open woodlands and forests. To date, it has been identified within the following ELC vegetation types at PPNP (Dougan and Associates 2007):

- SHOM1-2 Sea Rocket Sand Open Shoreline
- SBOD1-1 Little Bluestem-Switchgrass-Beachgrass Open Graminoid Sand Dune
- SBSD1-2 Hop-tree Shrub Sand Dune
- SBTD1-3 Red Cedar Treed Sand Dune
- WODM4-x Dry-Fresh Hackberry Deciduous Woodland
- FODM4-3 Dry-Fresh Hackberry Deciduous Forest

Typical associated ground flora varies a great deal among these communities. In dune communities at PPNP, associates may include Little Bluestem (*Schizachyrium scoparium*), American Beachgrass (*Ammophila breviligulata*), Common Juniper (*Juniperus communis*), Poison Ivy (*Toxicodendron radicans*) or Fragrant Sumac (*Rhus aromatica*). In woodland and forest communities at PPNP, typical associates are Dutchman's Breeches (*Dicentra cucullaria*), Smooth Sweet Cicely (*Osmorhiza longistylis*), Lopseed (*Phryma leptostachya*), and Wild Blue Phlox (*Phlox divaricata*).

[4] ELC: Ecological Land Classification (Lee et al. 1998) is a standard framework for describing vegetation communities in southern Ontario.

Several non-native invasive species, including English Ivy (*Hedera helix*), Periwinkle (*Vinca minor*), and Garlic Mustard (*Alliaria petiolata*), are also common at some shaded sites in PPNP (Dougan and Associates 2007).

Alvars and limestone bedrock

On Pelee Island, Middle Island and Hen Island, Blue Ash grows on shallow soil over limestone bedrock. More open habitats are characterized as alvars or rock barrens; shaded sites may grade into forested vegetation types. Blue Ash has been found in the following ELC vegetation types at sites managed by the Nature Conservancy of Canada (Environment Canada 2016):

- RBSA1-x Alvar Shrub Rock Barren
- RBTA1-7 Red Cedar Alvar Woodland grading to FOCS3-2 Dry Red Cedar Calcareous Bedrock Coniferous Forest
- RBTA1-1 Chinquapin Oak-Nodding Onion Treed Alvar
- RBTB1-2 Hackberry Calcareous Treed Rock Barren
- FOCS3-2 Dry-Fresh Red Cedar Calcareous Bedrock Coniferous Forest
- MEMM3 Dry-Fresh Mixed Meadow (former agricultural fields)
- FODM3-2 Dry-Fresh White Birch Deciduous Forest

On Middle Island sites managed by Parks Canada, Blue Ash occurs in the following vegetation types:

- FOD7-5 Hackberry - Sugar Maple Forest
- FOD4-3 Hackberry Forest
- CUM - CUT Cultural Meadow - Cultural Thicket
- Hackberry-Blue Ash-Common Hoptree Forest (No ELC Code)
- Thicket/Young Hackberry Forest (No ELC Code).

Common understory associates in these limestone bedrock communities include Hairy Wild Rye (*Elymus villosus*), Bottlebrush Grass (*E. hystrix*), Virginia Wild Rye (*E. virginicus*), Short's Aster (*Symphyotrichum shortii*), Grassland Sedge (*Carex divulsa*), Fragrant Sumac (*Rhus aromatica*), Chinquapin Oak, Black Walnut and dead White Ash (Environment Canada 2016).

1.5 Threats to survival and recovery

A number of threats to Blue Ash have been identified and are described below. The relative impact of these threats is uncertain because there is little empirical information available for Ontario sites.

Browsing by White-tailed Deer

Ash twigs and leaves are a favoured food of White-tailed Deer (*Odocoileus virginanus*) which are present in high numbers in many areas of southern Ontario (Waldron 2003).

High browsing pressure can result in reduced plant diversity and shrub cover, local extirpation of native plants, and increased cover by exotic species (Hynes et al. 2002). It is also possible that browsing pressure on Blue Ash may increase as other ash species are reduced or extirpated by Emerald Ash Borer.
During COSEWIC surveys in 2012-13, there was evidence of deer browsing observed at several Ontario sites. Abundant regeneration of Blue Ash is observed at sites where deer are absent or relatively less abundant (e.g., some islands and possibly at PPNP), and less frequently at other sites (COSEWIC 2014; N. Paleczny, pers. comm. 2016). The overall effects of deer browsing on Blue Ash populations are probably high at certain sites (COSEWIC 2014).

Even following deer exclusion, regeneration of the forest understory may take many years, and native species will recover only if seeds remain available in the soil (Pendergast et al. 2015. Recovery of Blue Ash following deer exclusion may therefore require seeding, due to the inability of ashes to form long-term seed banks.

<u>Emerald Ash Borer</u>
The Emerald Ash Borer, an invasive beetle native to Asia, has been present in Ontario since 2002 and has now been detected in most areas of southern Ontario (Haack et al. 2002; USDA 2016). Adult beetles lay eggs under ash bark; the larvae feed on the inner bark and can cause tree death within one to three years (Poland et al. 2015). Mortality of most ash trees is virtually complete within 3-6 years (Knight et al. 2013). To date, Emerald Ash Borer has killed millions of ash trees across North America (Herms et al. 2014, EAB Information Network 2016).
When compared to other native ashes, Blue Ash appears to show some resistance to EAB (Anulewicz et al. 2008, Tanis and McCullough 2012). The reasons for the observed resistance are unknown, but may be due to the presence of phenolic compounds, or structural differences in the inner bark (Tanis 2013). At a Michigan study site, 63% of the Blue Ash survived, while only 11% of White Ash remained, and these were all young (<11 cm DBH). Blue Ash trees may be colonized by EAB, and yet may continue to appear healthy (Anulewicz et al. 2008, Tanis and McCullough 2012). Experimental studies have also shown that both adult and larval beetles have lower rates of survival on Blue Ash than on other native ashes (Tanis 2013, Tanis and McCullough 2012). In recent surveys of Ontario Blue Ash sites, EAB was present at almost half of sites, but infestation on Blue Ash was found at only 3.7% of these sites. Of the infested Blue Ash, only 11% (i.e., eight trees) had died (COSEWIC 2014). In the 2016 season, many Blue Ash trees at PPNP, in Essex County and on Pelee Island continued to survive and even thrive, sometimes despite EAB infestation (J. Ambrose, pers. comm. 2016, M. MacFarlane, pers. comm. 2016, N. Paleczny, pers. comm. 2016, G. Waldron, pers. comm. 2016).

Studies of Blue Ash at PPNP indicate that trees in this area remain in relatively good health. In 2006, 82% of individuals surveyed were either healthy (<10% crown foliage decline), or showed light to moderate (11-49%) decline in crown foliage. Of these trees, 41% showed some signs of EAB infestation. Continued monitoring will determine whether trees continue to decline in later stages of infestation (N. Paleczny, pers. comm. 2016).

While there are promising indications that Blue Ash harbours some resistance to EAB, there is still reason for concern. For example, some Blue Ash at PPNP and at certain sites on Pelee Island appeared to be infested and exhibiting crown dieback and/or epicormic growth in the summer of 2016 (J. Crosthwaite, pers. comm. 2016, N. Paleczny, pers. comm. 2016). Some crown dieback is also occurring at sites within the St. Clair watershed (T. Payne, pers. comm. 2016). While these are isolated observations, it is possible that Blue Ash decline may be delayed, because Blue Ash is a less-preferred host of EAB. It has been speculated that damage and even mortality may increase once the more common species of ash are reduced or locally extirpated (COSEWIC 2014). At PPNP, Blue Ash infestation and subsequent decline and mortality has occurred following the mortality of other ash species due to EAB (N. Paleczny, pers. comm. 2016).

Overall, EAB may present a threat to the health of Blue Ash in some areas, although observed resistance and the possibility of effective biological control may help to limit mortality.

<u>Double-crested Cormorants</u>
High densities of colonial tree-nesting Double-crested Cormorants (*Phalacrocorax auritus*) are present on Middle Island and several other Lake Erie islands (Hebert et al. 2014). In high numbers, nesting cormorants can cause physical damage to trees, nitrification of surrounding soils by accumulated guano, and reduction or elimination of seedlings (Hebert et al. 2005, Korfanty et al. 1999). Of 240 Blue Ash on Middle Island examined in 2012, 19% were either dead or severely damaged, and most others were in some stage of decline (T. Dobbie pers. comm. 2012 cited in COSEWIC 2016).

<u>Fire suppression and water management</u>
Blue Ash is probably susceptible to changes in natural systems. At some sites, recruitment may depend on the creation of openings in the forest canopy, allowing seedling establishment (Ambrose and Aboud 1983). Such gaps may be less frequently created than historically, because natural fire is often suppressed, and extreme flooding events are now controlled through management. Shoreline hardening, extensive tile drainage, and flood control structures may all have altered the local hydrology within existing habitats, potentially having an effect on recruitment.

<u>Habitat loss due to development</u>
Incremental loss of Blue Ash habitat is ongoing in southwestern Ontario (J. Ambrose, pers.comm. 2016). Habitat loss is caused by forest clearance for a variety of reasons, including development, transportation, agricultural intensification, and landscaping.

<u>Vegetation management</u>

Throughout its range, Blue Ash can occur along roadsides, hydro corridors, drainage canals, and in other public areas that are subject to maintenance. In some areas, roadside brush and tree cutting have been observed where Blue Ash is present. In some cases, this may be due to misidentification. The effect on the Blue Ash population is local, but may be significant, especially on Pelee Island (J. Ambrose, pers. comm. 2016). Since the arrival of EAB to Ontario, extensive removal of EAB-infested trees has also been undertaken in many areas in an attempt to contain EAB. It is likely that potentially healthy Blue Ash have been and continue to be removed for EAB control.

<u>Other threats</u>

Recreational vehicles (e.g., ATVs) and trampling probably have a local impact at some publicly accessible sites. Loss of genetic diversity is a risk arising from habitat fragmentation, but has not been studied in this species (Ambrose and Aboud 1983). Some activities previously considered as threats probably rarely affect existing native populations. For example, livestock grazing in woodlots was historically widespread, but this practice is now fairly rare in southwestern Ontario (COSEWIC 2014). Land development caused extensive past declines due to habitat loss, but much of the remaining Blue Ash habitat is now either protected, or is found in areas generally unsuitable for development (e.g., floodplains).

1.6 Knowledge gaps

The main threats to Blue Ash in Ontario are not well understood. For example, the population-level effects of both reportedly high levels of deer browse and EAB infestation remain unclear. In particular, determining the effects of these threats on Blue Ash reproduction, demographics, and population structure would provide information useful to prioritize recovery efforts.

A level of resistance of Blue Ash to EAB-caused mortality has been reported from the United States (Anulewicz et al. 2008, Tanis and McCullough 2012). Although there are both informal, site-based monitoring projects and anecdotal observations from various locations in Ontario, no targeted monitoring program exists to determine the potential long-term effects of EAB on this species at risk in Ontario. Considering the status of this species in Canada, this represents a significant knowledge gap.

In both the U.S. and Canada, researchers are evaluating potential biological control methods for use in forested habitats (Bauer et al. 2008, Herms and McCullough 2014, Lyons 2016, Ryall 2016). Because of the time required for parasitoid wasps to establish, the ability of their populations to slow or stop the spread of EAB in North America remains unknown.

Ecological research could help support management for this species. It is known that Blue Ash seedlings can proliferate following canopy openings. The effects of prescribed burning and/or manual vegetation clearing have not been documented, and would be helpful to guide restoration efforts.

There continues to be a need to identify new locations, and to provide further information on the population, range and area of occupancy of Blue Ash in Ontario.

1.7 Recovery actions completed or underway

A number of site-specific surveys of Blue Ash have been completed over the past decade and are summarized in COSEWIC (2014). Most recently, a total of 27 sites were surveyed by different observers between 2007 and 2013 (Mills and Craig 2008, COSEWIC 2014).

To date, there have been few effective control methods available to reduce the effects of Emerald Ash Borer within woodland habitats. Insecticide injections are available to protect individual ash trees, although these are costly and typically require multiple applications to be effective; as a result, they are mainly used on high-value urban trees (Herms et al. 2014).

However, research on biological control is underway in both Canada and the U.S. The Great Lakes Forestry Centre of the Canadian Forest Service (CFS) is conducting research on the EAB, its ecological effects, and biological control. Beginning in 2013, CFS researchers released parasitoid wasps, originally from China, in an attempt to establish populations on the Emerald Ash Borer. A larval parasitoid, *Tetrastichus planipennisi*, was first released in 2013 at 12 sites across southern Ontario and Quebec. An egg parasitoid, *Oobius agrili*, was first released in 2015. Initial results are promising, with established parasitoid populations having been detected at all release sites in 2016 (Ryall 2016).

Similar biological control programs using these and other parasitoids have been undertaken in the United States since 2007, and parasitoids have also become established (Bauer et al. 2008; Duan et al. 2012). These parasitoids are considered likely to play an important role in EAB suppression as their populations increase (Duan et al. 2013), although it is still unclear whether established populations will be sufficient to slow or control the spread of EAB. Parasitism of EAB by some native parasitoids has also increased, probably in response to high densities of EAB, and interactions between native and introduced parasitoids are still unknown (Duan et al 2012). Some researchers have observed that there remains a high mortality of North American ash trees planted in China, where natural populations of parasitoids exist, and doubt that introduced parasitoids will effectively prevent EAB from building to high densities in North America. In fact, these authors suggest that biological control may be most successful at sites containing Blue Ash or other relatively resistant species (Herms and McCullough 2014).

Parks Canada has undertaken several concurrent efforts to conserve Blue Ash at Point Pelee NP and on Middle Island. Park staff began controlling cormorants on Middle Island in 2009, and efforts are ongoing. Both cormorant numbers and tree mortality rates have declined, although cormorant damage to Blue Ash and other species continues (T. Dobbie, pers. comm. 2016). Blue Ash trees at PPNP have been located and mapped, and park staff has completed health assessments on a portion of the population to assess the effects of EAB. (N. Paleczny, pers. comm. 2016). White-tailed deer populations are regularly managed at PPNP. (T. Dobbie, pers. comm. 2016). Since 2011, over 23 hectares of savanna have been restored at PPNP through clearing, invasive species removal, and prescribed burning (T. Dobbie, pers. comm. 2016). A detailed strategy guides the restoration project, which aims to create a total of 50 ha of sand spit savanna at PPNP by 2026 (Parks Canada 2012). Removal of invasive species and canopy thinning will likely benefit Blue Ash by promoting regeneration.

The National Tree Seed Centre (CFS) in New Brunswick collects and stores seeds of native woody plants, and currently holds 20 collections of Blue Ash. Of these, 17 originate from trees in an open-pollinated seed orchard at the University of Guelph Arboretum. Although these trees all originated from sites across southern Ontario, their seed is inter-provenance hybrid seed. The remaining three seed collections are from Point Pelee NP (D. Simpson, pers. comm. 2016).

The Nature Conservancy of Canada (NCC) has continued to survey for and informally monitor Blue Ash at their properties on Pelee Island. Staff are also continuing to manage these properties, including Blue Ash habitat, by removing invasive plant species. There is an opportunity to seed Blue Ash into canopy gaps created by invasive species removal and in other restoration areas (J. Crosthwaite, pers. comm. 2016).

In addition to having completed Blue Ash surveys on 32 properties in 2008, the St. Clair Region Conservation Authority (SCRCA) has opened forest canopies near Blue Ash stands, to encourage natural regeneration. This has been very successful, with Blue Ash saplings now abundant in some of these areas (T. Payne, pers. comm. 2016).

2.0 Recovery

2.1 Recovery goal

The recovery goal for Blue Ash in Ontario is to maintain or increase all current naturally-occurring populations within its known Ontario range, and to ensure its persistence as a functional, reproductive forest tree.

2.2 Protection and recovery objectives

The recovery objectives for Blue Ash place emphasis on evaluating the true effects of apparent threats, especially Emerald Ash Borer and deer browsing, so that these can be effectively controlled (Table 2). Additional objectives are aimed at preserving existing populations, promoting natural regeneration and restoration plantings.

Table 2. Protection and recovery objectives.

Number	Protection or recovery objective
1	Evaluate threats to Blue Ash through regular monitoring.
2	Mitigate documented threats with management and stewardship.
3	Encourage in-situ and ex-situ conservation to augment populations and conserve genetics.
4	Conduct research to fill knowledge gaps related to Blue Ash mortality and management in Ontario.

2.3 Approaches to recovery

Table 3. Approaches to recovery of the Blue Ash in Ontario.

Objective 1: Evaluate threats to Blue Ash through regular monitoring.

Relative priority	Relative timeframe	Recovery theme(s)	Approach to recovery	Threats or knowledge gaps addressed
Critical	Long-term	Monitoring and Assessment, Research	**1.1** Regularly complete and analyze standardized health assessments of representative Blue Ash stands in Ontario • develop and consistently use standardized survey method • analyze and publish results	Threats: • Emerald Ash Borer • Browsing by White-tailed Deer Knowledge gaps: • Effects of EAB • Severity of deer browsing
Beneficial	Ongoing	Monitoring and Assessment, Communication , Protection	**1.2** Communicate the need for Blue Ash conservation with landowners and land managers, and encourage assistance with health monitoring	Threats: • Emerald Ash Borer • Browsing by White-tailed Deer • Vegetation management Knowledge gaps: • Effects of EAB • Severity of deer browsing
Beneficial	Ongoing	Inventory	**1.3** Continue to locate and inventory new Blue Ash sites across southern Ontario	Threats: • All Knowledge gaps: • Population and range

Objective 2: Mitigate documented threats with management and stewardship.

Relative priority	Relative timeframe	Recovery theme(s)	Approach to recovery	Threats or knowledge gaps addressed
Necessary (possibly Critical)	Ongoing	Management, Monitoring and Assessment, Communication	**2.1** Where necessary (see 1.1), select and take effective measures to protect Blue Ash from deer browsing (e.g., fenced exclosures, reductions in local deer populations)	Threats: • Browsing by White-tailed Deer
Necessary	Long-term	Management	**2.2** Continue control of Double-Crested Cormorants on Middle Island, and elsewhere if necessary	Threats: • Double-crested Cormorants
Necessary	Ongoing	Management, Stewardship	**2.3** Communicate with municipalities and utilities to: • identify Blue Ash on roadsides, hydro corridors and other managed lands • ensure protection of plants during regular vegetation management, and EAB management	Threats: • Vegetation management
Necessary	Short-term	Protection, Management	**2.4** Reduce or eliminate local ATV damage and trampling through signage, fencing, etc.	Threats: • Trampling and ATV use

Objective 3: Encourage in-situ and ex-situ conservation to augment populations and conserve genetics.

Relative priority	**Relative timeframe**	**Recovery theme(s)**	**Approach to recovery**	**Threats or knowledge gaps addressed**
Beneficial	Ongoing	Management	**3.1** Use locally-sourced Blue Ash seed or seedlings in restoration plantings to augment existing populations within suitable habitat	Threats: • All
Beneficial	Ongoing	Management, Monitoring	**3.2** Promote natural regeneration of Blue Ash through canopy opening and/or vegetation removal, and document results	Threats: • All
Beneficial	Short-term	Protection, Management	**3.3** Develop an ex-situ conservation program for Blue Ash in Canada: – Identify representative, naturally-occurring sites across the range of Blue Ash in Ontario that adequately represent the genetic diversity of the species – Collect, document and deposit seed at a conservation facility	Threats: • All
Beneficial	Ongoing	Research, Management	**3.4** Identify EAB-infested but apparently healthy trees for use in future restoration efforts	Threats: • Emerald Ash Borer

Objective 4: Conduct research to fill knowledge gaps related to Blue Ash mortality and management in Ontario.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Long-term	Monitoring and Assessment, Research	**4.1** Study the effects of EAB on Blue Ash health, mortality, demographics and population viability in Ontario	Threats: • EAB Knowledge gaps: • Effects of EAB
Critical	Long-term	Management, Monitoring and Assessment, Research	**4.2** Continue experimental release of parasitoid biological control within Blue Ash habitat across southern Ontario, and evaluate effects on Blue Ash infestation and mortality specifically	Threats: • EAB Knowledge gaps: • Effects of EAB • Efficacy of biological control
Beneficial	Long-term	Research, Management	**4.3** Determine the effects of disturbance to Blue Ash in a variety of habitats, i.e., response to fire and manual removal of woody vegetation.	Threats: • All Knowledge gaps: • Ecological information

2.4 Area for consideration in developing a habitat regulation

Under the ESA, a recovery strategy must include a recommendation to the Minister of Natural Resources and Forestry on the area that should be considered in developing a habitat regulation. A habitat regulation is a legal instrument that prescribes an area that will be protected as the habitat of the species. The recommendation provided below by the author will be one of many sources considered by the Minister when developing the habitat regulation for this species.

It is recommended that areas where natural populations of Blue Ash occur be prescribed within a habitat regulation. For trees located in a definable ELC vegetation type, the contiguous ELC vegetation type polygon (Lee et al. 1998 and updates) within which the species is found is recommended for protection.

Because most wind-dispersed seeds are likely deposited within 75 m of a parent tree, a contiguous ELC vegetation type polygon that is not within a regulated floodplain may be bounded by a distance of 75 m in any direction from a parent tree (see rationale below). However, Blue Ash trees within a regulated floodplain may be dispersed longer distances by water, and the maximum dispersal distance is not known. In these areas, the contiguous ELC vegetation type (with no maximum distance) is recommended for protection.

For trees close to a habitat edge, or trees where the ELC vegetation type cannot be ascertained (e.g. along fencerows and roadsides),

- To protect root zones of existing trees, a radial distance of **at least 23 m** around each tree is recommended for protection. This is based on the estimated root zone of the Blue Ash trees, of three times the maximum crown width (see rationale below).
- To protect seed dispersal zones and regeneration habitat, a secondary area around each Blue Ash tree should be protected for seed dispersal by gravity and wind of **at least 75 m**, to allow for possible seedling establishment (see rationale below). Potentially suitable habitat within this radius should receive protection, because although it may be unoccupied, research shows that there is still a reasonable likelihood that seeds may disperse into such areas, perhaps especially in more open areas where wind speeds are higher.

Vegetation types may include those listed within Section 1.4 of this document, or any other ELC vegetation type (Lee et al. 1998 and updates) where the species is found.

It is recommended that trees planted as horticultural specimens in landscaped areas be excluded from habitat regulation. The area surrounding restoration plantings should be considered as regulated habitat following the recommendations above, in order to contribute to the recovery of the species.

If future studies indicate that additional areas of habitat are necessary to achieve the recovery goals for this species, the area prescribed as habitat within a regulation should be revised.

Rationale for recommendation

The recommended regulated area includes considerations of a) the habitat of individual trees and b) habitat for seed dispersal and regeneration.

Regulation of habitat of individual trees

Protection of individual trees is based on protecting the tree's root zone. Various arboricultural methods have been developed to determine the extent of a tree's root zone, using diameter at breast height (DBH, Coder 1995) and tree height (Matheny and Clark 1998). More recent findings have determined that most tree roots extend laterally rather than vertically, and that in unconfined soils they can spread up to three times the diameter of a tree crown (Jim 2003). Thus, protecting a diameter width of three times the diameter of a large tree crown is considered important to protect the tree's root zone.

The crown diameter or spread of Blue Ash is estimated at 10 to 15 metres (Hightshoe 1987; some American sources suggest a spread of 18 meters (Missouri Botanical Gardens 2017). In a more northerly climate in Ontario, a reasonable estimate to capture the diameter of a large crown is likely 15 metres (based on scale drawings in Kershaw 2001 and Waldron 2003). Three times this diameter equals 45 m surrounding each tree, or a 22.5 m radial distance from the stem of each tree. Rounding up, a minimum **23 m** radial distance from the stem of each Blue Ash is recommended for root protection.

Regulation of habitat for seed dispersal and regeneration

Blue Ash seeds are primarily wind-dispersed. Although the vast majority of seeds are deposited close to the parent tree, a smaller proportion of seeds will disperse longer distances, depending on the tree's location, wind velocity, and wind direction. A habitat regulation should aim to capture the area into which a reasonable majority of seeds will be dispersed, and within which regeneration may occur.

It should be noted that ash trees can produce a large number of seeds (*F. pennsylvanica* in Germany: 220,000 seeds/year; Schmiedel et al. 2013). Also of note is that seed rain and seedling establishment are not necessarily correlated (Clark et al. 1998, McEuen et al. 2004). In studies of forest fragments in Michigan, McEuen et al. (2004) found that many species dominating the seed rain had few to no successful recruits. While recruitment is limited to a degree by the abundance of parent trees for dispersal, it is also influenced by seed predation, germination, and early seedling survival. Only a small fraction of most seeds will germinate and survive beyond the first year (Clark et al. 1998).

There are a number of studies estimating wind dispersal in ash trees. Studies of Green Ash (*F. pennsylvanica)* in Germany showed a mean dispersal of 47-66 m, with wind direction and speed playing important roles in the variation. Dispersal distances are greater downwind of the prevailing winds (N and NE) and lower upwind. Based on distance-density dispersal models, a distance of 75 m captures 100% of the upwind-dispersed seed, and more than 75% of the downwind-dispersed seed (approximated from Figure 3 in Schmiedel et al. 2013). Schmiedel and Tackenberg (2013) also report there is a "high probability of regeneration" in areas less than 50 m from a seed source.

Wagner et al. (1997) used modelling of European Ash (*F. excelsior)* seeds to determine that most fruits fell within 20 m of the tree, high fruit densities were found within 40 m of the parent tree, and 84% of seeds fell within 84.5 m of the parent tree. With this in mind, they recommended an 80 m protection distance into which seeds may be dispersed.

Longer distances are also recorded with decreasing probability. Downwind of parent trees, Schmiedel et al. (2013) estimated long-distance (95^{th} percentile) wind dispersal of Green Ash at between 60 and 150 m, with the longest distances in the direction of the prevailing winds.

Based on modelled curves of seed density and dispersal in related ashes, protecting a distance of at least 75 m from each tree in all directions is recommended to allow Blue Ash trees sufficient opportunity for dispersal and regeneration. This distance will likely capture the entire seed rain upwind of the parent tree, and the vast majority of seed rain downwind of the parent tree (see Figure 3 in Schmiedel et al. 2013).

Accounting for water dispersal in regulation is more challenging, since research on this form of dispersal is lacking. Thébaud and Debussche (1991) found that Flowering Ash (*F. ornus),* which is invasive in Europe, was spread by water transport along a high-energy river system in southern France at an average rate of approximately 970 m per year. However, it is unclear whether this environment could be considered comparable to that of Blue Ash in Ontario. Based on present information, it is recommended that Blue Ash trees found within a regulated floodplain be protected using the ELC vegetation type alone, without bounding by an estimated dispersal distance, which is unknown.

In summary, protecting Blue Ash habitat by ELC vegetation type is the recommended standard method of delineation, and is likely to protect existing trees and their habitat, and allow for dispersal and recruitment. In non-floodplain areas where seeds are wind-dispersed, evidence suggested that the vast majority of seeds will be dispersed within a 75 m radius of a parent tree, and protecting an area of this size should protect most opportunities for dispersal and establishment. The habitat of trees within floodplains should be protected by the ELC vegetation type alone, with no maximum dispersal distance.

Glossary

Alluvial: derived from loose, unconsolidated soil or sediments that have been eroded and deposited by rivers.

Alvar: Alvars are natural communities centred around areas of glaciated horizontal limestone or dolostone bedrock pavement. They are characterized by distinctive flora and fauna with less than 60 percent tree cover that is maintained by associated geologic, hydrologic, and other landscape processes (adapted from Reschke et al. 1999).

Committee on the Status of Endangered Wildlife in Canada (COSEWIC): The committee established under section 14 of the Species at Risk Act that is responsible for assessing and classifying species at risk in Canada.

Committee on the Status of Species at Risk in Ontario (COSSARO): The committee established under section 3 of the *Endangered Species Act, 2007* that is responsible for assessing and classifying species at risk in Ontario.

Conservation status rank: A rank assigned to a species or ecological community that primarily conveys the degree of rarity of the species or community at the global (G), national (N) or subnational (S) level. These ranks, termed G-rank, N-rank and S-rank, are not legal designations. Ranks are determined by NatureServe and, in the case of Ontario's S-rank, by Ontario's Natural Heritage Information Centre. The conservation status of a species or ecosystem is designated by a number from 1 to 5, preceded by the letter G, N or S reflecting the appropriate geographic scale of the assessment. The numbers mean the following:
1 = critically imperilled
2 = imperilled
3 = vulnerable
4 = apparently secure
5 = secure
NR = not yet ranked

Endangered Species Act, 2007 (ESA): The provincial legislation that provides protection to species at risk in Ontario.

Epicormic growth: Epicormic shoots sprout from normally-dormant buds underneath the bark of some trees. This type of growth often appears following injury (e.g. cutting, pruning, or deer browsing) or stress.

Parasitoid: A parasitoid is an insect that spends a significant portion of its life attached to or within a host organism. Unlike a true parasite, parasitoids ultimately kill their hosts, which are usually other insects.

Samara: a dry, nut-like fruit with a well-developed wing, e.g., the keys of maple or ash.
Species at Risk Act (SARA): The federal legislation that provides protection to species at risk in Canada. This act establishes Schedule 1 as the legal list of wildlife species at risk. Schedules 2 and 3 contain lists of species that at the time the Act came into force needed to be reassessed. After species on Schedule 2 and 3 are reassessed and found to be at risk, they undergo the SARA listing process to be included in Schedule 1.

Species at Risk in Ontario (SARO) List: The regulation made under section 7 of the *Endangered Species Act, 2007* that provides the official status classification of species at risk in Ontario. This list was first published in 2004 as a policy and became a regulation in 2008.

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