DRAFT Recovery Strategy for the Black Ash (*Fraxinus nigra*) in Ontario

2022

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Cover illustration: Photo of a sapling Black Ash by Pauline K. Catling

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Declaration

The recovery strategy for the Black Ash (*Fraxinus nigra*) 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 individuals who provided advice or contributed to its preparation, or the official positions of the organizations with which the individuals are associated.

The recommended 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

Ministry of the Environment, Conservation and Parks
Environment and Climate Change Canada – Canadian Wildlife Service, Ontario
Parks Canada Agency

Executive summary

Black Ash (*Fraxinus nigra*) is listed as endangered under Ontario's *Endangered Species Act, 2007*. It has been assessed as threatened in Canada by the Committee on the Status of Endangered Wildlife in Canada, but it is not currently listed on Schedule 1 of the federal *Species at Risk Act, 2002*. It has a global conservation rank of G5 (Secure) and a subnational (Ontario) conservation rank of S4 (Apparently Secure). However, these ranks may not capture the ongoing expansion of Emerald Ash Borer (*Agrilus planipennis*), a destructive, invasive insect pest, and may overstate the security of Black Ash.

Black Ash is a broad-leaved deciduous hardwood tree in the Olive family (Oleaceae). It can attain a height of 15 to 27 m and a diameter at breast height of over 100 cm, although 50 cm is more typical. The leaves are opposite, pinnately compound with 7 to 11 leaflets and between 25 to 40 cm in length. Leaflets are toothed and stalkless.

Black Ash is found only in North America. Its northern range limit is in northwestern Ontario at approximately 53°N and it extends as far south as Virginia at 36°N. Its western range limit is in Manitoba at 100°W and its eastern range limit is on the island of Newfoundland at 56°W. In Ontario, Black Ash occurs from its northern range limit at 53°N, approximately the northern end of Lake Nipigon, to its southern extent on Pelee Island. It has declined significantly in the southern portions of its Ontario range due to the impacts of Emerald Ash Borer.

The current size of the Ontario population of Black Ash has been estimated at approximately 83 million mature individuals, which represents 51 percent of the Canadian population. It is estimated that between 53 and 99 percent of the Ontario range will be susceptible to infestation by Emerald Ash Borer and population declines of 44 to 82 million mature individuals are predicted over the next 80 years. It is strongly suspected that the susceptible area will increase as northern parts of Ontario experience warmer winters as a result of climate change. Projected declines in young regenerating ash have not been quantified.

Black Ash is a facultative wetland species that occurs in moist bottomland habitats such as swamps, fens, floodplain forests and shorelines. It is most commonly found and grows best in well-aerated flooded areas. It occasionally occurs in upland habitats, but upland occurrences are typically in depressions or other moist microsites. Black Ash occurs on a variety of soil types and can tolerate a wide range of pH and nutrient conditions.

Threats to Black Ash or its recovery vary throughout its range but include invasive pests and pathogens, changing environmental conditions (e.g., climate and hydrology), incidental and targeted harvesting, invasive plant species and habitat loss. The primary threat to Black Ash is the Emerald Ash Borer, an invasive beetle which was introduced to North America from Asia and first detected in Ontario in 2002. Adult beetles feed on the foliage of Black Ash while the larvae tunnel through the tree's cambium (under bark), girdling and eventually killing the tree. It has caused significant mortality (50 -

99%) of Black Ash in parts of southern Ontario. Emerald Ash Borer has a natural range expansion rate of 20 km per year. Additionally, long-distance human-assisted dispersal occurs via transportation of ash wood and nursery stock. Emerald Ash Borer is intolerant of temperatures below -26 to -30°C (depending on a multitude of factors including but not limited to individual fitness, life stage and microclimate within the tree), which is expected to limit its dispersal into northern Ontario, but climate change-induced warming is expected to shift its potential northern limit. Studies based on current climate change models suggest that nearly 100 percent of the Ontario range of Black Ash may be susceptible to Emerald Ash Borer over the next 80 years.

The recommended recovery goal for Black Ash in Ontario has been divided into separate recovery goals for two geographical regions based on the threat of Emerald Ash Borer. In areas within the presumed climatic range limit of Emerald Ash Borer the recommended recovery goal is to reduce the impact of Emerald Ash Borer and preserve an in-situ (in a natural location) and ex-situ (away from a natural location) gene bank for Black Ash. In areas beyond the presumed climatic range limit of Emerald Ash Borer the recommended recovery goal is to maintain or increase the current population abundance and distribution of Black Ash and preserve an in-situ (in a natural location) and ex-situ (away from a natural location) gene bank.

The recommended protection and recovery objectives for Black Ash are:

1. Assess threats and undertake actions to eliminate them or reduce the severity of their impact.
2. Protect and maintain Black Ash individuals and habitats.
3. Raise awareness about Black Ash and its habitat, threats to Black Ash, Emerald Ash Borer and the safe handling of infested ash trees.
4. Initiate or support inventories and research to fill knowledge gaps.

The recommended area for consideration in developing a habitat regulation for Black Ash is the entire Ecological Land Classification ecosite type in which one or more Black Ash tree is present and all of the area within a radial distance of at least 28 m from an individual Black Ash tree.

Table of contents

List of figures

List of tables

1.0 Background information

1.1 Species assessment and classification

The following list is assessment and classification information for the Black Ash (*Fraxinus nigra*). Note: The glossary and list of abbreviations provides definitions for abbreviations and technical terms in this document.

- SARO List Classification: Endangered
- SARO List History: Endangered (2022)
- COSEWIC Assessment History: Threatened (2018)
- SARA Schedule 1: No Status
- Conservation Status Rankings: G-rank: G5; N-rank: N5; S-rank: S4.

1.2 Species description and biology

Species description

Black Ash (*Fraxinus nigra*) is a medium to large deciduous tree in the Olive family (Oleaceae). Several other ash species, including White Ash (*F. americana*), Green Ash (*F. pennsylvanica*) and Manchurian Ash (*F. mandshurica*), were historically treated as subspecies of Black Ash, but this treatment is not recognized by modern taxonomists (Wallander 2008). No subspecific taxonomy of Black Ash is currently recognized.

Black Ash can attain a height of 15 to 27 m and a diameter at breast height (DBH) of over 100 cm, although 50 cm is more typical (Grimm 1962; Pardo 1978; Farrar 1995; American Forests 2012). The bark of mature Black Ash trees is grey and broken into flat, corky ridges. The leaves are oppositely arranged, pinnately compound, 25 to 40 cm long and with stalkless leaflets (Gucker 2005). This species is polygamo-dioecious (individuals may be male, female or bisexual). The flowers are small and appear in crowded clusters in early spring prior to leaf out. Male flowers are green to red clusters below the terminal bud. Female flowers lack petals and form small, red-branched clusters below the terminal bud. Fruits are single-seeded winged samaras. Black Ash can be distinguished from other ashes in Ontario by the combination of the following characteristics (Figure 1):

- leaves with 7 to 11 leaflets;
- leaflets sessile;
- leaves glabrous except for tufts of rusty hairs at the bases of leaflets;
- terminal bud separated from lateral buds by a visible gap;
- twigs round in cross-section;

- twigs glabrous; and
- bark of young trees soft and corky; bark of mature trees breaking into corky ridges.

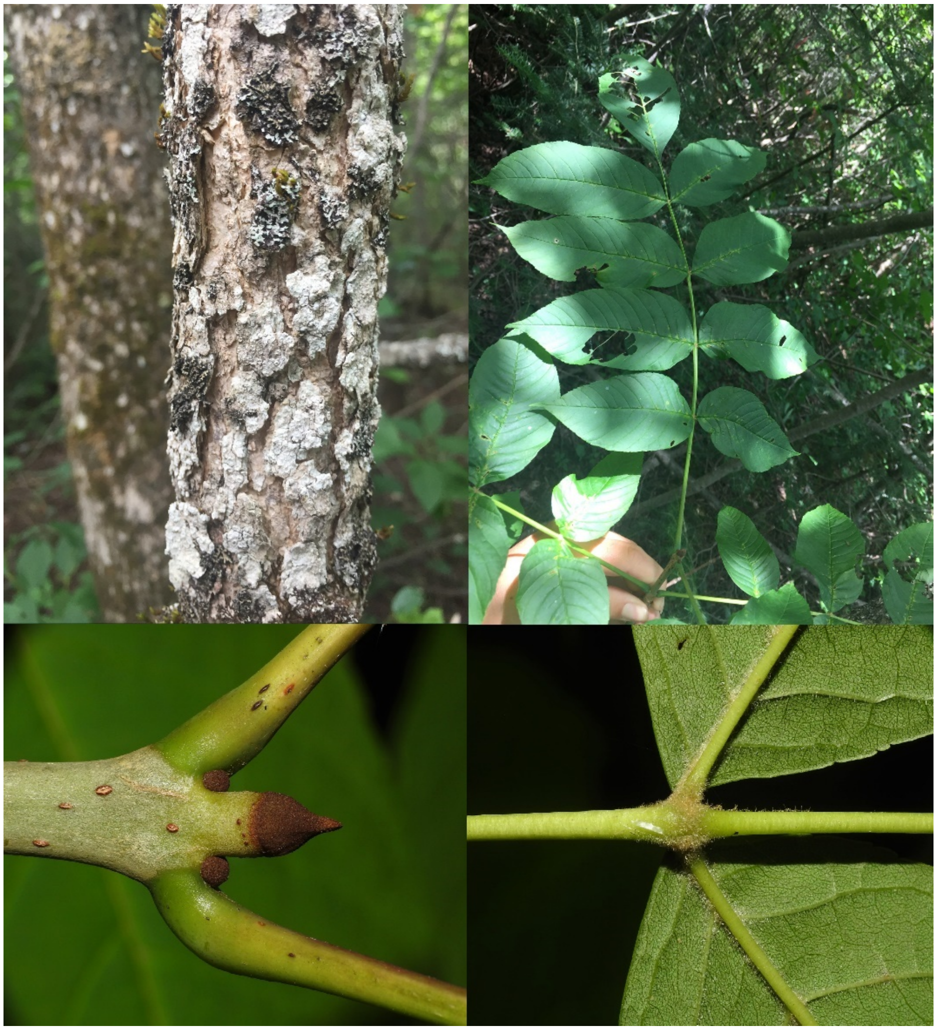

Figure 1. Identifying features of Black Ash (*Fraxinus nigra*). Photos by Pauline Catling and Will Van Hemessen.

Black Ash is comprised of a shallow and fibrous root system (Harlow et al. 1979), the roots are long and rarely branch measuring between 0.1 and 0.4 mm in diameter (Brundrett et al. 1990). Root spread distance of Black Ash has not been documented. Non-specific to Black Ash, tree roots can spread a considerable distance beyond the branch spread, extending outwards a distance equivalent or up to three times the tree height (Dobson 1995).

Biology

Black Ash is a long-lived tree species with an average life span of 150 years and potential longevity of over 300 years (Gucker 2005; COSEWIC 2018). Black Ash takes several decades to reach sexual maturity and it begins to produce fruit at between 30 and 40 years of age (Heinselman 1981). Although young trees (seedlings and saplings) can exhibit rapid growth under optimal conditions, Black Ash is generally a slow-growing tree, exhibiting an annual growth rate of 45 to 75 cm in height per year (Carmean 1978; Erdmann et al. 1987; Wright and Rauscher 1990; COSEWIC 2018).

Black Ash is polygamo-dioecious and has small, wind-pollinated flowers which emerge in May or early June at the same time or just before the leaves (Wright 1953; Wright and Rauscher 1990; Benedict and David 2003). The winged single-seeded samaras mature from July to October and are dispersed by wind and water in fall and winter (Erdmann et al. 1987; Lees and West 1988; Write and Rauscher 1990; Thébaud and Debussche 1991; Sutherland et al. 2000; Schmiedel and Tackenberg 2013). The number of seeds per individual tree may range from 2 to 1,500 (Hurlburt 2011) with each inflorescence producing up to 20 or more seeds in maximum crop years (COSEWIC 2018). The seeds exhibit physiological dormancy and need to be exposed to winter freezing followed by spring heat and sufficient moisture in order to germinate in the wild (Steinbauer 1937; Vanstone and LaCroix 1975; Benedict and David 2003). The seeds are relatively short-lived and do not persist in the natural seed bank for more than a few years, which may be a limiting factor for recovery (Sims et al. 1990; Wright and Rauscher 1990; BenDor et al. 2006; COSEWIC 2018). Reproduction by seed is more common in well-drained sites and vegetative shooting increases in areas with flooding (Tardif and Bergeron 1999).

Seed dispersal distance of Black Ash is unknown; however, studies on other ash species have recorded maximum dispersal distances of 1.4 km to 163 km (Bacles et al. 2006; Schmiedel et Tackenberg 2013). Sutherland et al. (2000) found that ash seed exhibits wind dispersal of 100 m or more from parent trees. Johnson (1988) found that Green Ash is able to disperse 150 m from the parent tree but with densities less than one seedling per meter square after about 110 m. Schmiedel et al. (2013) modeled the wind dispersal of Green Ash. Average dispersal distances varied between 47 and 85 m. Maximum dispersal values modeled along the prevailing wind direction ranged from 60 to 150 m, while that modeled in the opposite direction were estimated at 23 m (Schmiedel et al. 2013). A study on water dispersal found that mean floating time in Green Ash was two days and samaras were transported up to 163 km (Schmiedel et Tackenberg 2013); however, hydrological dispersal is dependent on habitat and water flow. Germination rate was positively correlated with the amount of time seeds were stored in water (Schmiedel et Tackenberg 2013).

Trees injured by Emerald Ash Borer (*Agrilus planipennis*) or other stressors frequently exhibit adventitious shooting from the roots, lower trunk or stump. This form of vegetative regeneration may be more important than seed dispersal for the persistence of Black Ash stands in parts of its range (Erdmann et al. 1987; Trial and Devine 1994; USDA 2006; COSEWIC 2018).

Black Ash occurs at low densities as scattered individuals across much of its Ontario range, but it is a dominant canopy tree in several types of swamp and forest ecosites and it has been described as a keystone and foundational species (Lee et al., 1998; Telander et al. 2015; Iverson et al. 2016; Youngquist et al. 2017). Black Ash abundance prior to European colonization is unknown, but it may have been widespread and in higher abundance before hydrological changes associated with settlement occurred (e.g. wetland drainage, damming watercourses). Local extirpation and widespread decline of Black Ash as a result of Emerald Ash Borer invasion is expected to cause significant structural, hydrological and biological changes in communities where it is dominant (Dayton 1972; Lenhart et al. 2012; Telander et al. 2015; Wagner and Todd 2015).

Black Ash, like other ashes, provides food, shelter and other habitat functions for a large diversity of wildlife (Martin et al. 1951; Dickerson 2002, 2006; Gandhi and Herms 2010; Wagner and Todd 2015). At least one insect species, the Canada Sphinx Hawkmoth (*Sphinx canadensis*), may rely almost exclusively on Black Ash (Tuttle 2007; Handfield 2011).

A variety of mammals and birds will feed on ash samaras generally, although this is not specific to Black Ash (Martin et al. 1951; Dickerson 2002, 2006; Wagner and Todd 2015; COSEWIC 2018).

Black Ash directly supports or is associated with several rare species or provincially listed species at risk. Flooded Jellyskin (*Leptogium rivulare*) is a provincially rare lichen which grows on the trunks of Black Ash at several locations (COSEWIC 2015a). Black Ash may be used as nesting sites or food source for birds, although no bird species exclusively use Black Ash for nesting or food. Bird species at risk that nest in forests and swamps include the Canada Warbler (*Cardellina canadensis*, special concern), Cerulean Warbler (*Setophaga cerulea*, threatened), Eastern Wood-pewee (*Contopus virens*, special concern), Louisiana Waterthrush (*Parkesia motacilla*, threatened), Prothonotary Warbler (*Protonotaria citrea*, endangered) and Wood Thrush (*Hylocichla mustelina*, special concern) (COSEWIC 2007; COSEWIC 2010a; COSEWIC 2012a; COSEWIC 2012b; COSEWIC 2015b; COSEWIC 2020).

Other species at risk that do not rely directly on Black Ash but occur in the same habitats include the Jefferson Salamander (*Ambystoma jeffersonianum*, endangered), Unisexual Ambystoma (Jefferson Salamander dependent population, *Ambystoma laterale-(2) jeffersonianum*, endangered), False Hop Sedge (*Carex lupuliformis*, endangered) and Blanding's Turtle (*Emydoidea blandingii*, threatened) (COSEWIC 2010b; COSEWIC 2011; COSEWIC 2016a COSEWIC 2016b).

Cultural significance

Indigenous people of North America have been using Black Ash wood for centuries. The properties of Black Ash wood (strongly ring-porous and highly pliable) make it an ideal material for basketry, snowshoe frames, canoe ribs, tool handles, furniture, framing, flooring and many other applications (Benedict 2001; Hill-Forde 2004; Benedict and French 2008; Benedict et al. 2010; Forbes 2012; Beasley and Pijut 2013). Black Ash is of significant cultural and economical importance to many North American Indigenous peoples and Black Ash basketry remains an important component of the histories, cultures and economies of many Indigenous peoples, including the Abenaki, Maliseet, Mi'kmaq, Mohawk, Ojibwe, Penobscot and Passamaquoddy (Smith 1928; Gilmore 1933; Speck and Dexter 1951, 1952; Rousseau 1947; Benedict and David 2000; Benedict 2001; Benedict and Frelich 2008). Additionally, Black Ash has been used medicinally and to develop a blue fabric dye (Hoffman 1891; Smith 1923, 1928, 1932; Gilmore 1933; Speck and Dexter 1951, 1952; Hamel and Chiltoskey 1975; Herrick 1977; COSEWIC 2018).

1.3 Distribution, abundance and population trends

Global distribution and status

Black Ash is considered globally 'Secure' with a conservation status rank of G5 (NatureServe 2016). It is the most northern species of ash in North America, reaching its northern limit at approximately 53°N in northwestern Ontario and extending as far south as 36°N in southwestern Virginia (Figure 2). Its western range limit is at 100°W in Manitoba and its eastern range limit is at 56°W on the island of Newfoundland. Most of the global distribution data for Black Ash predates the arrival of Emerald Ash Borer in North America so there is some uncertainty about its current range limits, particularly at the southern edge of its range where it may be locally extirpated from some areas (COSEWIC 2018). Black Ash is a dominant hardwood tree in a variety of swamp and forest communities throughout its range.

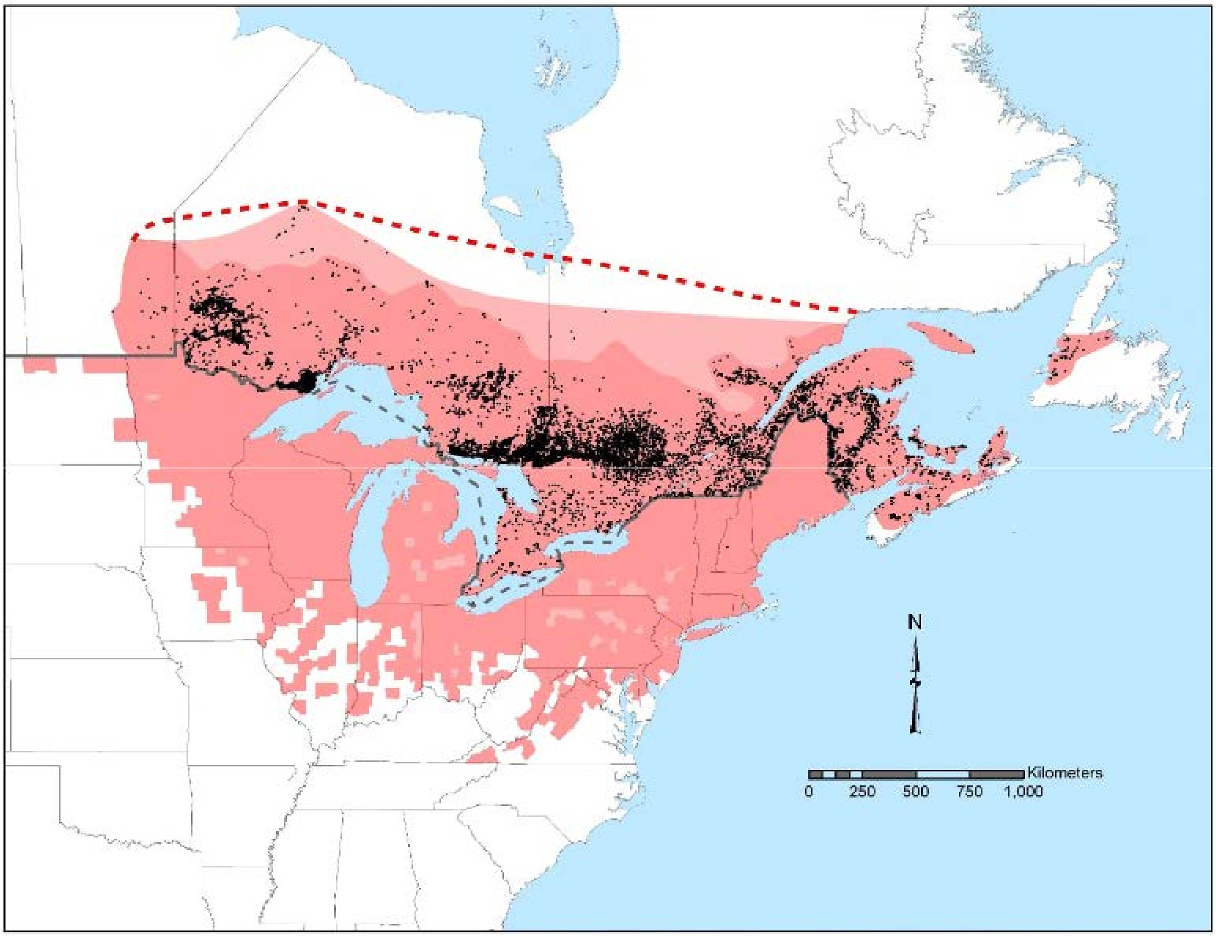

Figure 2. Global range of Black Ash showing known occurrence records for Canada (black dots), published range maps (darker shaded area), northern limit inferred from known occurrence records (lighter shaded area) and potential maximum northern limit (hatched line) (COSEWIC 2018).

Note: Figure 2 was developed for the COSEWIC status report (COSEWIC 2018) utilizing a dataset of roughly 25,000 occurrences compiled from the following sources: Baldwin (1958), Rousseau (1974), Riley (2003), Atlantic Canada Conservation Data Centre (AC CDC 2017), New Brunswick Department of Energy and Resource Development (NBDERD 2016), the New Brunswick Museum (NBM 2016), the Connell Memorial Herbarium (CMH 2016), Quebec Ministère des Forêts, de la Faune et des Parcs (MFFPQ 2016), the Ontario Natural Heritage Information Centre (ONHIC 2016), Ontario Ministry of Natural Resources and Forestry (OMNRF 2016a, b; OFRI 2017; OPIAM 2017), the Manitoba Conservation Data Centre (MCDC 2016), the Canadian Forest Service (CFS 2016) and Canadensys (2016).

In the parts of its range most affected by Emerald Ash Borer, Black Ash is either extirpated or exists only as seedlings and vegetative shoots from the roots of dead mature trees (COSEWIC 2018). Black Ash has been locally extirpated from a number of locations and is expected to be supplanted by other canopy tree species throughout much of its range (COSEWIC 2018).

Ontario distribution

The natural range of Black Ash occupies a substantial area of Ontario's landmass, being distributed from as far south as Pelee Island at 41°N to approximately 53°N in northwestern Ontario (Figure 3). The natural distribution of Black Ash in Ontario represents approximately 25 percent of the species' global range. It should be noted that Black Ash continues to be a widespread species in Ontario and its distribution is largely continuous between the dots illustrated on Figure 3 (i.e., the illustrated occurrences do not represent the only locations of Black Ash in Ontario).

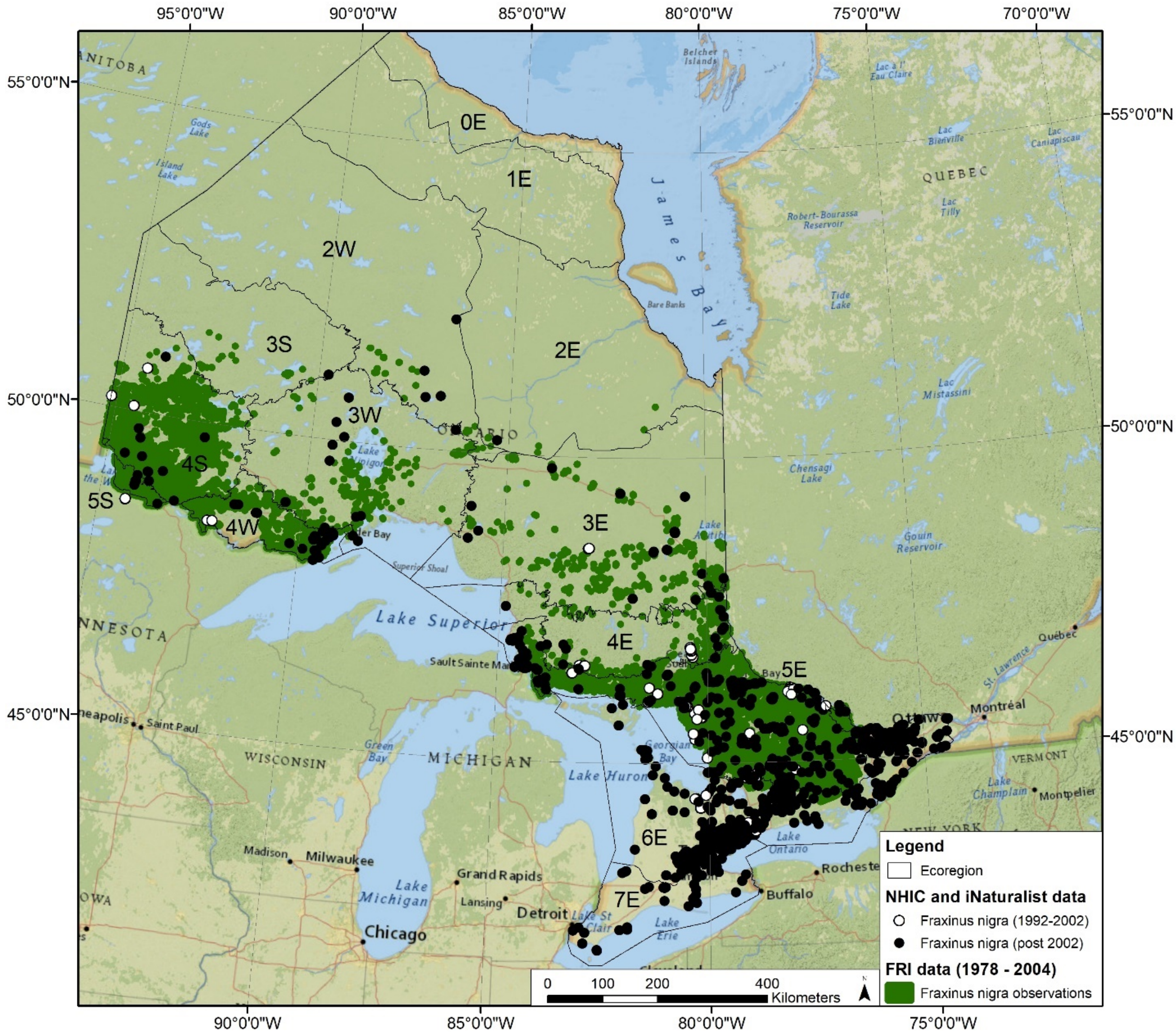

Figure 3. Occurrences of Black Ash in Ontario by ecoregion.

Note: Occurrence records in Figure 3 are a compilation of 48,759 records from Ontario's Natural Heritage Information Centre (NHIC; 1,397 records), Ontario's Forest Resources Inventory (FRI; 46,208 records) and research grade observations from iNaturalist (1,154 records). Black Ash was historically common in Ontario and was not well-tracked prior to the introduction of Emerald Ash Borer in 2002. No data prior to 1992 was reported to NHIC. Figure 3 was developed using NHIC data and does not accurately represent the historical (over 30 years) or pre-Emerald Ash Borer (pre-2002) range due to a lack of data from that period. Black Ash is expected to occur between the known records illustrated in Figure 3.

No significant changes in the extent of the natural distribution of Black Ash have been observed in Ontario, but it has experienced considerable declines and local extirpation from several locations in southern Ontario as a result of Emerald Ash Borer (COSEWIC 2018).

Population size and trends

The percentage of the global population of Black Ash that occurs in Ontario is unknown due to a lack of information on the United States population of Black Ash (COSSARO, 2020). The current size of the Ontario population of Black Ash has been estimated at approximately 83 million mature individuals which represents 51 percent of the Canadian population according to 15 datasets from 1958 to 2017 (COSEWIC 2018). Population dynamics (size and age composition) in Ontario are largely unknown.

Although Emerald Ash Borer currently affects only a portion (estimated as over 25 percent) of the Black Ash range in Ontario, it is recognized as the most important driver of Black Ash population size in Canada and is expected to be an increasingly important factor in declines of the species in Ontario (COSEWIC 2018; COSSARO 2020). It is estimated that 53 percent of the Ontario range of Black Ash is currently susceptible to Emerald Ash Borer and will suffer significant mortality over the coming decades (Desantis et al. 2013; Blaney et al. 2018; COSEWIC 2018). Assuming a 99 percent mortality rate of mature Black Ash trees, which is consistent with observations in Michigan and Ohio (Klooster et al. 2014), it is estimated that the Ontario population of Black Ash will decline by approximately 43 million mature individuals over the next 60 years. This might be a conservative estimate because increasing winter temperatures due to climate change may result in a greater area of the Black Ash range becoming susceptible. It is estimated that an increase in winter minimum temperatures of one to four degrees Celsius will result in up to 99.98 percent of the Ontario range of Black Ash being susceptible to Emerald Ash Borer by the year 2100 (Desantis et al. 2013; Blaney et al. 2018; COSEWIC 2018). Under this scenario, it is estimated that Ontario's Black Ash population will decline by approximately 82 million mature individuals over the next 80 years.

1.4 Habitat needs

Black Ash is a facultative wetland species adapted to long periods of inundation. It occurs primarily in moist bottomland habitats such as swamps, fens, floodplain forests and shorelines (Erdmann et al. 1987; Wright and Rauscher 1990; Oldham et al. 1995; Gucker 2005; MacFarlane and Meyer 2005; Ehrenfeld 2012; OMNRF 2014a; OMNRF 2014b). It is most commonly found and grows best in well-aerated flooded areas. It occasionally occurs in drier upland habitats, but upland occurrences are typically in depressions or other moist microsites (Ehrenfeld 2012; Lichvar et al. 2016). Black Ash occurs on a variety of soil types and can tolerate a wide range of pH and nutrient conditions, but it is most abundant on alkaline, nutrient-rich and finer-textured soils (Heinselman 1970; Godman and Mattson 1976; Hosie 1979; Brand 1985; Kurmis *et al*. 1989; Zogg and Barnes 1995; Loo and Ives 2003; Gucker 2005; MacFarlane and Meyer 2005; ACCDC 2017). Black Ash saplings and seedlings have been described as very shade tolerant, but they become less shade tolerant with age and shade is a limiting factor for growth (Erdmann et al. 1987; Gucker 2005).

Like all trees, the roots of Black Ash extend well beyond the crown width/dripline of an individual tree (Gilman 1988; Hruska et al. 1999; Lilly 2010). The area around an individual tree that contains the highest root density is frequently called the Critical Root Zone (CRZ) and is defined as the ratio of root spread to crown spread (Hruska et al. 1999). The typical CRZ for Black Ash is unknown, but conservative estimates of CRZ can still be provided based on the largest known Black Ash tree. Applying the method of Coder (2014) to the typical maximum DBH of 50 cm for Black Ash gives a CRZ of approximately 15 m. This area is considered to have the highest sensitivity to habitat modification, since any activities within the CRZ have the potential to directly harm the health of an individual Black Ash. According to the method of Coder (2014) the total rooting area for Black Ash would be estimated as approximately 24 m.

Another methodology for estimating CRZ and root spread utilizes radial crown spread. For other tree species the CRZ has been quantified as 1.68:1 where 95 percent of roots are within 1.68 times the radial crown spread (Hruska et al. 1999). The remaining five percent of roots may extend up to three times the radial crown spread (Lilly 2010). Based on estimates from other trees it is expected that 95 percent of roots of an individual Black Ash would also occur within an area 1.68 times the radius of the crown width/dripline (i.e., the CRZ). The largest recorded crown spread for a mature Black Ash was a radius of 9.15 m, which results in a CRZ radius of 15.37 m and a maximum root distance of 27.45 m. Note that these conservative estimates were based on the largest canopy size recorded for Black Ash in combination with root size estimates of a difference tree species. Species-specific knowledge gaps such as this are further discussed in Section 1.7.

Black Ash occurs in a wide variety of vegetation communities (MacFarlane and Meyer 2005). Mass mortality of Black Ash trees may result in long-term changes to forest composition and structure (Hoven et al. 2014), which may influence other habitat characteristics such as soil moisture or nutrients. Black Ash has been noted to have a role in regulating hydrology where it occurs as a dominant species (Slesak et al. 2014).

1.5 Limiting factors

Environmental factors

In the northern part of its range, Black Ash may be limited by a short growing season because it is one of the last trees to leaf out in the spring and one of the first trees to lose its leaves in the fall (Ahlgren 1957; COSEWIC 2018). A short growing season and cool spring temperatures in the northern part of its range may also limit seed germination since the seeds require cold stratification followed by spring temperatures warmer than 20°C to stimulate germination (Steinbauer 1937; Vanstone and LaCroix 1975; Benedict and David 2003; Morin et al. 2007). Based on predicted climate warming, range expansion of Black Ash may occur in the northern part of its range due to climate change making these factors less limiting.

Although young Black Ash trees (seedlings and saplings) are shade tolerant, light levels are a limiting factor and they exhibit slower growth rates in shady conditions (Erdmann et al. 1987; Gucker 2005). Canopy gaps created by the death of mature Black Ash trees may therefore promote the growth of young individuals. However, replacement of Black Ash in the canopy by other tree species (e.g., Red Maple [*Acer rubrum*], Silver Maple [*Acer saccharinum*], White Elm [*Ulmus americana*], Balsam Poplar [*Populus balsamifera*] and Willows [*Salix* spp.]), may limit the recovery of Black Ash at some locations since saplings are sensitive to competition and exhibit suppressed growth in shady conditions (Stewart and Krajicek 1978; Benedict and Frelich 2008; Forbes 2012).

Native pathogens

It is noted that native pathogens may be of little significance considering the level of threat posed by Emerald Ash Borer; however, because it is uncertain how impact of native pathogens may compound with Emerald Ash Borer they have been included as a limiting factor.

A number of fungi have been frequently associated with ash species including trunk rot (*Stereum murrayi*), butt rot (*Armillarea mellea*), heartwood rot (*Polyporus hispidus*), leaf spot (*Mycosphaerella effigurata*), anthracnose (*Gloeosporium aridum*), canker (*Nectria galligena*) and Ash Rust (*Puccinia peridermiospra*) (Wright and Rauscher 1990; Hurlburt 2011). The extent and severity of impact that these fungi have on Black Ash in Canada is unknown; however, the effect of fungi may be more significant after tree health has already declined due to biotic or abiotic factors (COSEWIC 2018).

Ash Yellow, caused by the phytoplasma ‘Candidatus’ *Phytoplasma fraxini* (Pokorny and Sinclair 1994; Griffiths et al. 1999) which is spread by leafhoppers and other hemipteran insects, is a disease of unknown origin that impacts ash in North America. Ash Yellow has been observed in Ontario and Quebec (Sinclair et al. 1996; Griffiths et al. 1999).

White Ash Mosaic Virus is of unknown origin and has been observed on Black Ash, causing irregularly mottled leaves (Machado-Caballero et al. 2013). The potential impacts of the virus on Black Ash are unknown (COSEWIC 2018).

Other interspecific interactions

Cauliflower Gall Mite (*Aceria fraxinivorus*) causes deformation of the female flower and prevents seed formation (COSEWIC 2018). The mite has been observed in Ontario and New Brunswick but its origins are unknown. The effects on Black Ash are currently unknown (COSEWIC 2018).

Ash trees are the host species of a diversity of fauna including gall-forming invertebrates, folivores, subcortical feeders, sap feeders and seed predators. Eleven specialist invertebrate herbivores associated with Black Ash have been identified (Todd 2015). Many ash-dependent insects parasitize seeds and may limit recovery potential and seed collection efforts (D. McPhee pers com. 2021). The impact of these interspecific interactions on Black Ash in Ontario is unknown.

Low reproductive rate and dispersal rate

It is unknown what the typical reproductive rate is for Black Ash. Black Ash may have low rates of sexual reproduction (Hurlburt 2015), with bumper crop occurring every five to nine years (FGCA 2014; D. McPhee pers. com. 2021). Dispersal is typically within 150 m of the parent tree (Hurlburt 2015). Black ash has one of the lowest reproductive rates in northern hardwoods for seed crop intensity over time and area (Godman and Mattson 1976; M. Spearing pers. com. 2021).

It is to early to tell how Emerald Ash Borer affects reproduction rate because Emerald Ash Borer has only recently entered the core range of Black Ash (M. Spearing pers. com. 2021). There is anecdotal evidence that individuals may produce extra seed after becoming infested by Emerald Ash Borer; however, there is no data on the viability of this seed crop and it is hypothesized that reducing any nutrient or water flow to developing seed crop is likely to have an impact on viability and long-term storage potential (M. Spearing pers. com. 2021).

1.6 Threats to survival and recovery

A decline of abundance in ash was noted in literature as early as the 1920s (Palik et al. 2011, 2012). The severity, scope and causes of declines prior to Emerald Ash Borer is uncertain and presently the primary cause of decline in ash is due to Emerald Ash Borer.

Emerald Ash Borer

Emerald Ash Borer is a buprestid wood-boring beetle native to northeastern Asia (CFIA 2019; OISAP 2020). The larvae feed on the conductive tissue in the sapwood and inner bark of ash trees, which causes canopy dieback and ultimately the death of the tree through girdling (BenDor 2006; Poland and McCullough 2006). Emerald Ash Borer was introduced to North America in the 1990s and was first documented in Ontario in 2002 (Haack et al. 2002; Cappaert et al. 2005; Herms and McCullough 2014). The insect can complete its life cycle in all ash species native to Ontario, but the susceptibility of each species differs and Black Ash appears to be highly susceptible to infestation (COSEWIC 2018).

Emerald Ash Borer attacks both healthy and stressed ash trees; however, unhealthy trees may experience more rapid decline (Knight et al. 2013). Adult beetles feed on the foliage while the larvae tunnel through the tree’s above-ground vascular system which obstructs the flow of water and nutrients causing a decline in tree health (Hope et. al.

2020; OISAP 2020). Beetles are able to infest trees as small as 2.5 cm in diameter, which means that trees are frequently killed before reaching reproductive maturity (COSEWIC 2018; McCullough et al. 2008; Klooster et al. 2014). Signs and symptoms of Emerald Ash Borer damage may not become visible until three or four years after infestation (Streit et al. 2012). Large-scale mortality (50 - 99%) of ash trees occurs within 4 to 10 years of Emerald Ash Borer's arrival to an area (Knight et al. 2008; Klooster et al. 2014; Hodge et al. 2015; Cuddington et al. 2018; Duan et al. 2018; Hope et al. 2020). High-density stands experience slower mortality after infestation although it is uncertain what causes this trend (Knight et al. 2014). Decline and mortality of Black Ash occurs more rapidly compared to Green Ash or White Ash (Smith et al. 2014).

Emerald Ash Borer adults are strong fliers and have been recorded to fly up to six kilometres in a day (Taylor et al. 2010). Emerald Ash Borer range expansion rates are typically 20 km per year (Prasad et al. 2010); however, studies on the Emerald Ash Borer estimated expansion rate suggest an expansion of approximately 50.2 km per year in Canada (Webb et al. 2021). Estimates by Webb et al. (2021) may be higher than actual expansion rate due to a lack of reporting and accurate location information after the initial record of Emerald Ash Borer in Ontario. Long-distance dispersal events due to storm events with strong winds or human-aided dispersal (e.g., through transport of lumber, firewood or nursery stock) can greatly increase dispersal distance beyond 20 km (Muirhead et al. 2006; DeSantis et al. 2013; COSEWIC 2018). Emerald Ash Borer is currently widespread throughout the south and central regions of Ontario, which has resulted in the death of millions of ash trees in the province (CFIA 2019; CFIA 2021b; Invasive Species Centre 2020; Government of Canada 2020). There is evidence that following an Emerald Ash Borer invasion, regeneration from seed is low in ash populations and niche of seedlings is reduced in area due to the dominance of the shrub layer where the overstory has died back and possibly also due to coppicing from surviving ash stumps (Aubin et al. 2015; Erdmann et al. 1987).

As of 2018, aerial surveys by the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) estimated that 601,672 ha of ash trees have been injured or killed by Emerald Ash Borer in Ontario (Rowlinson pers. comm. 2021; Figure 4). Species specific data on the number of ash trees killed by Emerald Ash Borer is unavailable, so it is unknown how many individuals of Black Ash have been affected in the province as a whole. Significant mortality has been observed in the City of Ottawa (L. Adderley pers. com. 2021), the United Counties of Prescott and Russell; and Stormont, Dundas and Glengary (S. Hunter pers. com. 2021) and the City of Toronto (N. Leach pers. com. 2021). Conversely, observations in the counties of Renfrew and Haliburton describe Black Ash as common with no notable mortality observed to date (L. Rose pers. com. 2021; M. Cockwell pers. com. 2021).

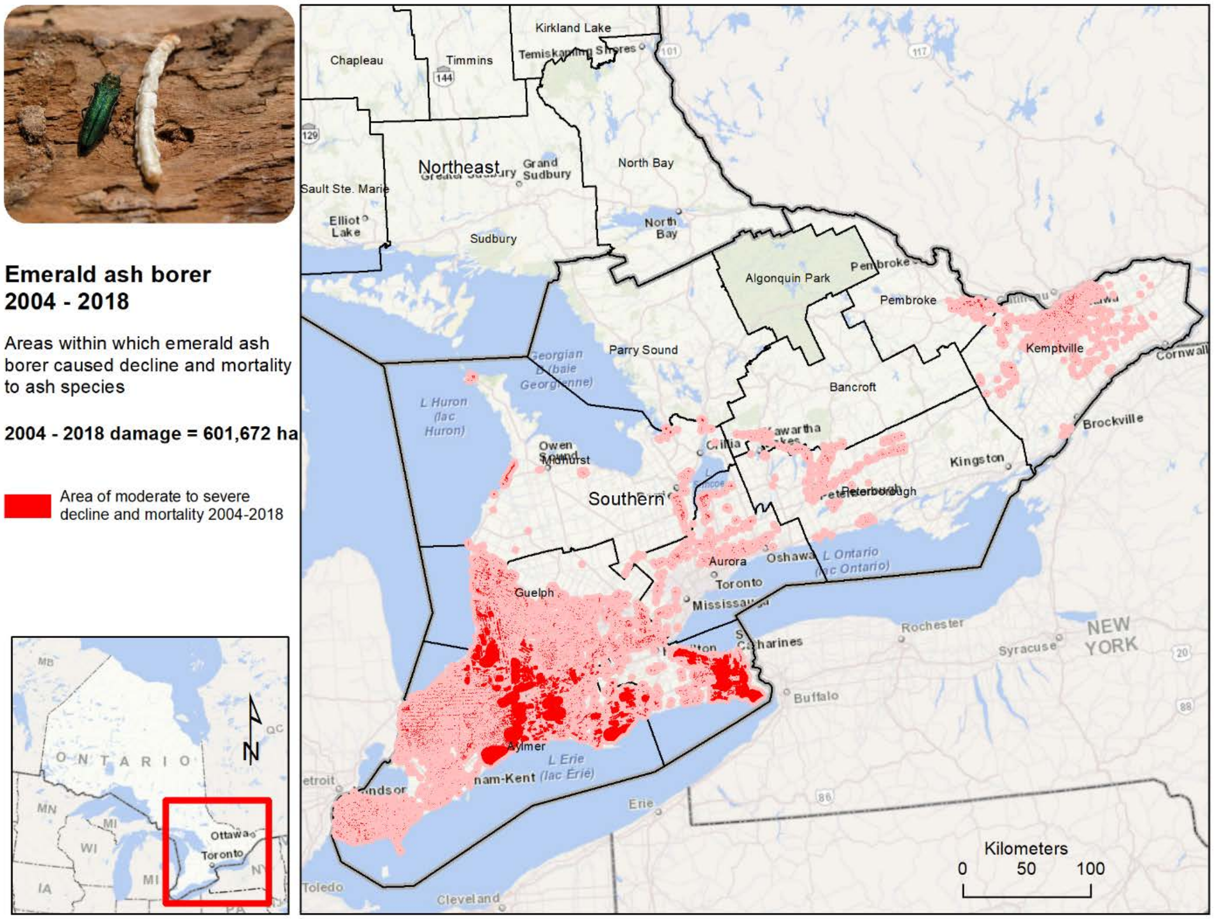

Figure 4. Extent of Emerald Ash Borer caused decline and mortality of ash trees in Ontario (Map developed by Dan Rowlinson 2021 using NDMNRF data).

Note: Due to COVID-19 the 2018 results were the most recently available to develop Figure 4. Additional expansion of Emerald Ash Borer into northern Ontario has occurred in Thunder Bay and Sault St. Marie and is thought to be restricted in northern Ontario to those cities and their immediate vicinities at this time.

Emerald Ash Borer is not currently known to be widespread in northwestern Ontario and Black Ash is assumed to remain abundant on the landscape in the Ontario Shield Ecozone (M. Wilkie pers. comm. 2021). Its expansion into northern Ontario is currently restricted by seasonally low temperatures that are below the tolerance of Emerald Ash Borer (i.e., between -26°C and -35°C, depending on the amount of insulation provided by bark and snowfall) (Blaney et al. 2018). Figure 5 shows the areas of the Ontario range of Black Ash that are currently susceptible to Emerald Ash Borer based on seasonal minimum temperatures. Susceptible areas are predicted to expand due to climate change (i.e., increasing winter temperatures), which may result in up to 99.98 percent of the Ontario range of Black Ash being susceptible to Emerald Ash Borer by the year 2100 (Desantis et al. 2013; Blaney et al. 2018; COSEWIC 2018).

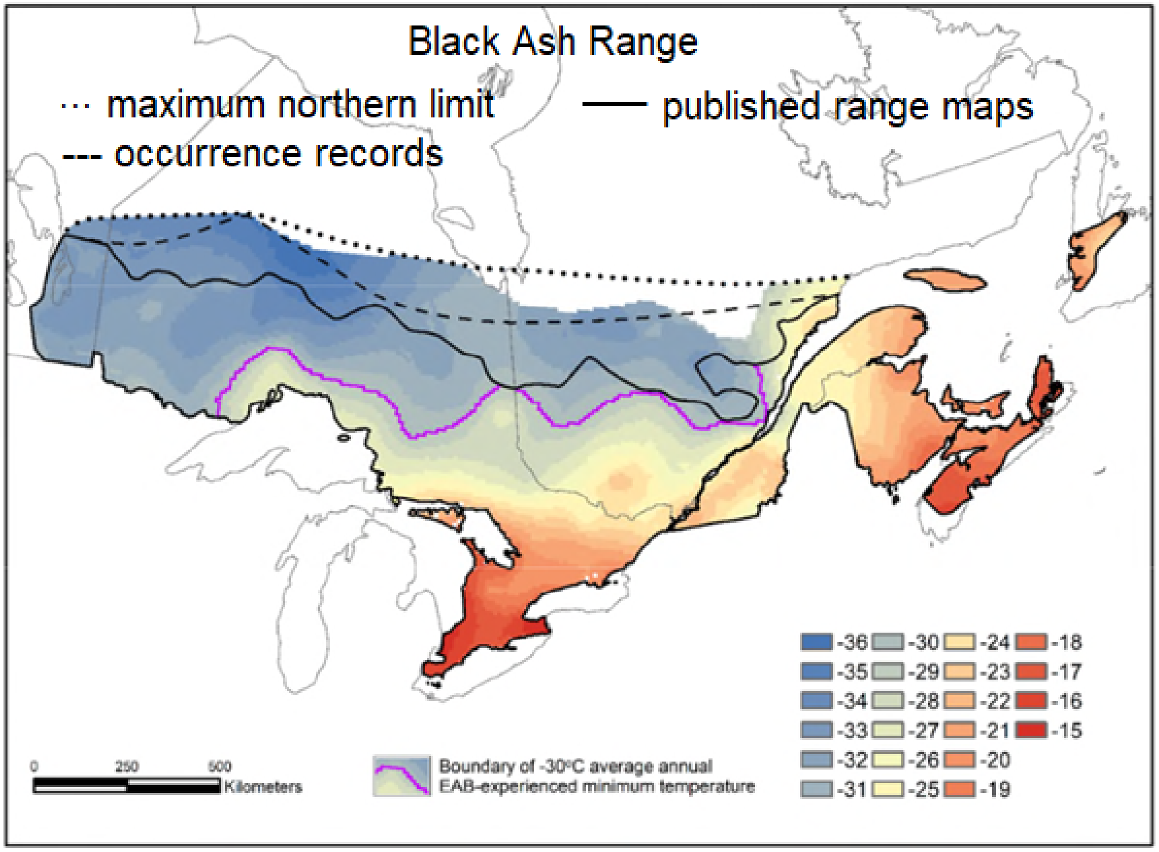

Figure 5. Extreme minimum air temperature zones within the Black Ash range in Canada represented by a colour gradient (COSEWIC 2018).

Black Ash is threatened by the persistence of Emerald Ash Borer in the south and central regions of Ontario and its expansion into northern Ontario (COSEWIC 2018). Emerald Ash Borer can persist in surviving and regenerating trees even where large-scale ash mortality causes the insect's population density to collapse (Prasad et al. 2010; Klooster et al. 2014; Bauer et al. 2015; Hodge et al. 2015; Sadof et al. 2017; Cuddington et al. 2018; Hope et. al. 2020). In parts of southern Ontario which have experienced large-scale ash mortality, 7 to 43 percent of regenerating saplings have been found to be infested with Emerald Ash Borer (Aubin et al. 2015). Mortality of regenerating trees before they can reach sexual maturity combined with the short lifespan of ash seeds in the seed bank means that the opportunity for a second regeneration of ash from seed has been lost in some areas (Klooster et al. 2014; COSEWIC 2018). Black Ash can persist at some locations as epicormic shoots from the roots and trunks of infested trees (Kashian 2016).

Habitat conversion

Habitat conversion, especially conversion of wetlands to agricultural and urban land uses, was historically the primary threat to Black Ash. In Ontario's Mixedwood Plains

Ecozone, it is estimated that 72 percent of wetlands larger than 10 ha have been lost since European settlement (Ducks Unlimited 2010). Conversion of Black Ash habitat to agricultural, industrial and urban land uses is currently ongoing (C. Craig pers. com. 2021), but to a lesser extent because of regulatory protections for wetlands and woodlands through provincial and local laws. Habitat has also been lost to the creation of reservoirs upstream of hydroelectric dams (Lee et al. 2012). Ash stands are still being impacted by infrastructure projects such as transportation or utility corridors (S. Young pers. com. 2021). Habitat conversion represents a permanent loss of individuals and habitat.

If habitat loss leads to habitat fragmentation, then gene flow and the species evolutionary capacity may be impacted.

Climate change

Climate change is expected to result in considerable changes to forest composition and ecosystem processes throughout North America (Iverson et al. 2002, 2008, 2016).

Climate change is predicted to increase the average annual temperature in southwestern Ontario by five to six degrees Celsius and four to five degrees Celsius throughout the rest of the province by 2071-2100. Warming will be greater in the winter than the summer, and greater in the north than the south (Colombo et al. 2007).

Potential impacts of climate change on Canada's boreal forest ecosystems include loss of permafrost, warmer temperatures, changes to the distribution and timing of annual precipitation, increased length of growing season, increasing atmospheric carbon dioxide, increased frequency of fires and increases in insect pests (Price et al. 2013). Changes are expected to vary based on geographical area. Predicted changes to occur by 2100 within the boreal regions where Black Ash occurs in Ontario are an increase in annual mean air temperature by approximately 3.6 to 3.7 degrees Celsius, increase in annual precipitation by approximately 49 to 73 mm and an increase in the growing season length by approximately 21 to 31 days (Price et. Al 2013).

A northward expansion of Black Ash's climate niche is predicted based on climate warming models (Iverson and Prasad 2002; McKenney et al. 2007a,b; McKenney et al. 2011; McKenney et al. 2014; COSEWIC 2018). However, this expansion will not offset the predicted declines in Black Ash as a result of Emerald Ash Borer, habitat loss and other threats (COSEWIC 2018). For example, warmer winter temperatures are predicted to promote the dispersal of Emerald Ash Borer into regions where it cannot currently survive (Tluczek 2011; Desantis et al. 2013; Price et al. 2013; Iverson et al. 2016; Blaney et al. 2018; COSEWIC 2018). Additionally, modeling predicts that only a small portion of expanded climatic niches for tree species can be colonized due to migration rates (Prasad et al. 2020). Although Black Ash was not one of the species studied, seed dispersal distance may limit the speed of migration and thus limiting potential for range expansion.

Black Ash is sensitive to drought, excessive soil moisture, winter root kill and late spring frosts (Tardif and Bergeron 1997; Ward et al. 2006; Auclair et al. 2010; Palik et al. 2012). Climate change is predicted to result in greater frequency of extreme weather conditions that can result in Black Ash dieback from stresses such as fires, drought, heatwaves, late spring frosts and erratic winter weather (which can result in root injury) (Tardif and Bergeron 1997; Ward et al. 2006; Auclair et al. 2010; Palik et al. 2012). Changes in drought regimes can result in severe dieback where high water tables result in shallow rooting (Prasad et al. 2007). Studies focused on the global range of Black Ash predict an average decline of 65.3 percent by 2100 under five different climate change modelling scenarios (Iverson and Prasad 2001; Iverson et al. 2011). Morin et al. (2008) completed an in-depth study based on two International Panel on Climate Change (IPCC) climate change scenarios for 2100. It was predicted Black Ash will see a greater level of extirpation of over 97.8 percent of the species' global range, a decreased probability of occurrence within over half of its remaining range, and the migration to the north and northeast was predicted to be very modest (Morin et al. 2008).

Hydrological changes caused by climate change or habitat conversion may cause local declines in Black Ash or impact tree health. Changes in the amount and timing of precipitation could directly cause mortality of Black Ash since it is sensitive to changes in water availability (i.e., through flooding or drying of its habitats) (L. Rose pers. comm. 2021). Water stress can also make Black Ash more susceptible to infestation by Emerald Ash Borer. Hydrological changes may make plant communities more susceptible to invasion by non-native plants, such as European Buckthorn (*Rhamnus cathartica*). This species could compete with Black Ash for water, nutrients and light, making it more vulnerable to Emerald Ash Borer. The scope and severity of impact of climate change is unknown.

Black Ash, like many other wetland trees, has a shallow root system and is particularly susceptible to windthrow (Erdmann et al. 1987; USDA 2006). Increases in severe weather events including winter storms, torrential rain storms, tornadoes and windstorms are becoming more frequent and intense in Ontario (Gough et al. 2016). Exact predictions of the severity and number of storm events have not been made but increased severe storm events may increase the number of Black Ash affected by windthrow.

In southern Ontario, severe storm events, high lake levels and a lack of winter ice have contributed to severe shoreline erosion, which may directly impact Black Ash or its habitat in these areas. This may not influence a large portion of the Ontario population; however, at sites like Point Pelee National Park, this threat has potential to extirpate the population within the park (T. Dobbie Pers. com. 2021). Accelerated erosion due to shoreline conversion and climate change has already removed a portion of the park area and an additional 50 ha is expected to be lost within the next 50 years (Zuzek Inc. 2018). Shoreline erosion is expected to cause a decline of swamp forests at Point Pelee, which are a major vegetation community in the park (BaMasoud and Bryne 2011) and habitat for Black Ash.

Logging and wood harvesting

Black Ash is considered a commercially important species (McPherson pers. com. 2021). Black Ash is not targeted as a major source of lumber or pulpwood in Ontario, but it is believed that Black Ash trees are harvested incidentally through commercial forestry (COSEWIC 2018). Black Ash may be cleared or brushed during logging for safety and accessibility, or Black Ash trees could be accidentally injured during logging (L. Rose, pers. comm. 2021). Removal of canopy trees through harvest can provide increased light penetration and may promote the regeneration of Black Ash (M. Wilkie pers. comm. 2021). Sustainable forestry practices are not a main threat to Black Ash but may cause incidental harm or morality of individuals (S. Blaney pers. com. 2021).

Indigenous peoples selectively harvest Black Ash for basketry (Smith 1928; Gilmore 1933; Speck and Dexter 1951, 1952; Rousseau 1947; Benedict and David 2000; Benedict 2001; Benedict and Frelich 2008); however, the extent of this harvesting is unknown.

Wood and pulp plantations

All forest stands treated for the control of broad-leaved hardwoods is considered under this section. This includes wood and pulp plantations and stands planted for forest regeneration after clear cutting silviculture has removed conifer-dominated areas. Although these areas would not be considered plantations by foresters, this fits with the IUCN categorization of threats.

Wood and pulp plantations within the range of Black Ash are managed to promote the growth of conifers, which may involve the use of herbicides to control broad-leaved trees (COSEWIC 2018). In the absence of fire to control hardwood competition in the boreal forest (specifically Trembling Aspen [*Populus tremuloides*] and White Birch [*Betula papyrifera*]) herbicide application may be used to maintain conifer species on the landscape. Herbicide treatment may incidentally harm individual Black Ash despite Black Ash not being the primary target of herbicide applications. The impact of this threat in Ontario has not been quantified but it is expected to be small in scope and low impact to the Canadian population as a whole (COSEWIC 2018).

Invasive non-native plant species

A variety of invasive non-native plants such as European Buckthorn, Glossy Buckthorn (*Frangula alnus*), European Common Reed (*Phragmites australis australis*), Garlic Mustard (*Alliaria petiolata*), Dog-strangling Vine (*Vincetoxicum rossicum*) and non-native honeysuckles (*Lonicera* spp.) have been observed growing with or near Black Ash (P. Catling pers. obs. 2021; M. Hudolin pers. com. 2021; T. Dobbie pers. com. 2021). These species may negatively impact Black Ash and its habitat by altering soil moisture and porosity, altering light levels, direct competition and allelopathy (Klionsky et al. 2011; Warren et al. 2017). The berries of European Buckthorn, which frequently grows with Black Ash, contain chemicals that inhibit seed germination of neighbouring plants, which could limit regeneration of Black Ash from seed (Seltzner and Eddy 2003).

Ash dieback

'Ash dieback' refers to dieback in ash species not known to be directly related to insect damage or disease, though those factors, environmental factors and climate change may contribute or compound to cause dieback. Ash dieback is poorly understood but occurs on a large geographic scale and can cause locally high mortality rates. Factors such as drought, excessive soil moisture, altered hydrology, road salt, pollution, winter root kill and late spring frosts are thought to contribute to dieback with root damage caused by erratic winter weather being proposed as the main cause (Tardif and Bergeron 1997; Ward et al. 2006; Auclair et al. 2010; Hurlburt 2011; Palik et al. 2012; COSEWIC 2018). Observed dieback in the United States suggests that ash dieback may be a threat in Ontario and across Canada (COSEWIC 2018). The severity of ash dieback may increase with climate change (Allen and Breshears 2007).

Problematic species/diseases of unknown origin

Cottony Ash Psyllid (*Psyllopsis discrepans*), an aphid-like insect, has been found in Ontario and elsewhere in North America (Ossiannilsson 1992; Hodkinson 1988; Culliney and Koop 2005). The nymphs of this pest feed on foliage which can cause curling and yellowing of leaves and gradual crown dieback (COSEWIC 2018). The extent of infestation and impacts of Cottony Ash Psyllid in Ontario have not been quantified (COSEWIC 2018).

Black Ash trees with curled leaves and crown dieback have been observed in Newfoundland, Nova Scotia and New Brunswick. The cause of these symptoms is unknown but is suspected to be an introduced insect or disease (COSEWIC 2018). These unexplained declines have not yet been observed in Black Ash in Ontario.

Native mammals

White-tailed Deer (*Odocoileus virginianus*), Moose (*Alces americanus*) and Beaver (*Castor canadensis*) have been noted to browse Black Ash twigs and branches (Burns and Honkala 1990). Browsing by White-tailed Deer is reported to have a negative effect on regenerating ash and could have important implications for ash regeneration and persistence in North American woodlands (Kashian et al. 2018). Suppression of ash regeneration due to deer browsing has been noted in the United States and an unnaturally high abundance of deer may limit regeneration of Black Ash in southern Ontario (Bressette et al. 2012; White 2012). Browsing by Moose is not believed to be a major limiting factor.

Beavers are believed to be more abundant than they were historically in Ontario and are often observed in the same flooded lowlands as Black Ash (M. Wilkie pers. com. 2021).

Beavers may have a positive or negative impact on Black Ash through flooding existing habitat beyond tolerable levels or creating new areas of flooded habitat that are suitable for Black Ash.

Targeted harvesting

The characteristics of Black Ash wood make it ideal for basketry, canoe ribs, snowshoe framing and barrel making (COSEWIC 2018). Targeted harvesting is believed to be ongoing and may impact the species on a local scale but is not believed to be a significant threat to the Ontario population of Black Ash. This species is considered economically and culturally important; however, Black Ash often occurs in difficult to access areas and is not commercially in demand so target harvesting on a commercial scale is rare (L. Rose pers. com. 2021). Protections afforded to wetland habitats are further discussed in Section 1.8. Existing protections are expected to limit targeted commercial harvesting of Black Ash.

Forest fires

Forest fires naturally occur in the boreal and Great Lakes-St. Lawrence forests where Black Ash occurs. Forest fires are not expected to have a negative impact on the species overall; however, extensive forest fires may temporarily reduce the abundance of mature Black Ash on a local scale. This may impact seed collection recovery actions aiming to collect representative genetics from across Ontario.

Chalara dieback

Chalara dieback, caused by an ascomycete fungus (*Chalara fraxinea*), has not yet been observed in North America but has caused extensive declines of ash in Europe. It is thought to have originated in Asia and affects trees of all ages, causing leaf discolouration and wilting, formation of epicormic shoots, longitudinal bark cankers and xylem necrosis. If introduced to Ontario, the impacts of Chalara dieback on Black Ash are predicted to be severe (Pautasso et al. 2013; COSEWIC 2018). This potential threat should be considered so that early-detection and rapid-response may occur if it is introduced.

1.7 Knowledge gaps

Species biology

There is limited species-specific information available for Black Ash. Certain aspects of this recovery strategy have been based on available research on similar species (other ashes). In order to develop science-based recommendations for habitat regulation it would be beneficial to have accurate information on the CRZ radius for Black Ash based on tree size.

Black Ash occurs in a wide range of Ecological Land Classification (ELC) ecosite types. A list of all ecosites Black Ash has potential to occur in and how abundant Black Ash is within each has not been developed. This information may assist in further refining a habitat regulation and provide insight into the identification of key significant habitats where Black Ash is most abundant.

Detailed occurrence information

Black Ash is still considered a relatively common species in Ontario and detailed occurrence data has not been a focus for this species prior to the invasion of Emerald Ash Borer. Due to this, the pre-Emerald Ash Borer abundance in Ontario cannot be accurately quantified. The current distribution, abundance and health of Black Ash is poorly known.

A quantitative assessment of the Black Ash population in Ontario as well as an analysis of population fluctuations (e.g., regeneration of many individuals causing an abundance increase following invasion by Emerald Ash Borer, natural survival rate of regenerating individuals and reinvasion by Emerald Ash Borer caused declines) would assist in informing recovery. Once an assessment has been completed recovery approaches should be updated to include a measurable target based on what is expected to be the long-term state of Black Ash in Ontario.

Accurate occurrence records would also assist in identifying the largest (e.g., top five percent by size within each ecodistrict) remaining subpopulations and potentially resistant individuals/stands in order to better prioritize in-situ protection of Black Ash.

Emerald Ash Borer

The distribution and population dynamics of Emerald Ash Borer are currently being monitored; however, additional information would be beneficial. Monitoring to determine the rate and location of range expansion should continue. Accurate modeling to forecast long-term trends of Emerald Ash Borer expansion based on more recent knowledge of movement patterns would be useful to inform more specific recovery goals for certain geographic locations.

Parasitic biological control agents have been released in various locations within North America (see Section 1.8 for further information). The population dynamics and spread of parasitic biological control agents is still poorly reported at this time and the long-term impact of these biological controls on Emerald Ash Borer is uncertain. Short-term and long-term studies are required to provide additional information on these trends.

The potential of biological controls at reducing the impact of Emerald Ash Borer is unknown. The information regarding location and spread of biological controls that have been implemented has not been synthesized and information of the effectiveness of biological controls is not reported. The climate niche of biological controls utilized so far has not been mapped in relation to the potential climate niche of Emerald Ash Borer. Therefore, the geographical range within which biological controls may offer protection is unknown.

Indicators of Emerald Ash Borer resistance

It would be beneficial to determine what factors promote resistance to Emerald Ash Borer and determine if this can be induced in some way.

Threats

Due to the prevalent threat of Emerald Ash Borer, distinguishing impacts or mortality caused by other threats may be challenging. How many individual Black Ash are impacted due to threats other than Emerald Ash Borer has not yet been quantified.

The threat of habitat loss and fragmentation on Black Ash in southern Ontario is poorly understood and has not been quantified. Impacts to gene flow and subpopulation persistence warrant future study.

The impact of pathogens and insects that impact flower or seed development on recovery is unknown. This may impact recovery by making collection of viable seed with representative genetics from all subpopulations more challenging.

There is much uncertainty around the threat climate change poses to Black Ash and its habitat. The severity, scope and probability of impacts from climate change are uncertain. Modeling of climate-moisture index changes due to climate change may be beneficial due to the sensitivity of Black Ash to drought.

Modeling of climatic niche expansion and changes to plant hardiness zones has been completed for a variety of species (McKenney et al. 2007a, b; Natural Resources Canada 2021). However, the predicted climatic niche expansion of Black Ash has not yet been compared to biological constraints that impact its range expansion potential (D. McKenney pers. com. 2021). This has been completed for White Ash (*Fraxinus americana*) (Prasad et al. 2020). A species-specific analysis for Black Ash would be beneficial to allow for comparison of Black Ash range expansion and Emerald Ash Borer range expansion based on climatic modeling and dispersal trends.

Regeneration

Regeneration of Black Ash from seed and from epicormic shoots off stumps has been observed. It has not been reported if epicormic shoots can reach maturity or if their growth rate differs compared to individuals growing from seed. A study on ash regeneration has been completed in southeastern Michigan (Kashian and Witter 2011).

The amount of regeneration occurring in Ontario has not been quantified and the survival rate of regenerating individuals is uncertain, as is whether regenerating individuals have any resistance to Emerald Ash Borer or if they will experience decline once they are large enough to host Emerald Ash Borer. The natural survival rate of these regenerating trees is unknown, making it difficult to determine if mortality is due to Emerald Ash Borer or other factors. Whether Black Ash subpopulations can regenerate and whether these individual trees can survive to maturity is a vital question that can help inform the development of a measurable recovery goal. Without knowing what is reasonably possible considering the ongoing threat of Emerald Ash Borer and the difficulty in its eradication, an accurate measurable goal cannot be determined at this time.

Epigenetic effects

Epigenetic effects are changes in gene function that do not involve changes to the DNA sequence. Trees have a great ability to survive through various stresses for prolonged periods and it is believed epigenetics play a key role in this resilience and resistance (Amaral et al. 2020). Mageroy et al. (2019) applied phytohormone methyl jasmonate (MeJA) on a stand of 48-year-old Norway Spruce (*Picea abies*) 35 days before exposing the species to a tree-killing bark beetle; this resulted in a primed state or immunological memory, which allowed trees to resist insect attack. Further studies are needed, but it is believed the subsequent priming memory is related to epigenetic mechanisms such as DNA methylation and histone modifications as in the genus *Arabidopsis* (Wilkinson et al. 2019). Studies may provide a greater understanding of how epigenetics relate to the response of Black Ash to biotic stresses, such as insect invasions. Studies on epigenetic effects may also assist in locating Black Ash with higher resistance to Emerald Ash Borer.

Forest management and recovery actions

Forest management actions and recovery actions focused on ash trees, but not Black Ash specifically, have occurred across Ontario. This information has not been synthesized in a manner that allows one to track the success of these actions on a provincial scale. It would be beneficial to synthesize the history of management and recovery actions taken to combat Emerald Ash Borer across Ontario in order to determine the short-term and long-term success of these actions in relation to the protection and recovery of Black Ash.

Forestry management practices have been recommended that maintain the health of the forest community overall; however, the long-term impact on Black Ash from these practices has not been quantified.

Other diseases/pests

The predominant threat from Emerald Ash Borer has largely overshadowed research on other diseases and pests that impact Black Ash. Additional information is required on how the impact of other diseases and pests compounds with the impacts of Emerald Ash Borer.

Community classification

Canopy dieback of ash trees in ash-dominated communities has caused many of these forest or swamp communities to no longer fit within their previous classifications according to the existing ELC system for southern Ontario (Lee et al. 1998). These communities may regenerate with young ash, invasive species or a diversity of tree species. The change in community classification has the potential to alter protection afforded to these communities because they may be classified as cultural communities, which do not receive the protections afforded to forests, before they have the opportunity to mature. A classification system for regenerating or successional communities would more accurately represent the existing vegetation conditions. A revised classification system could be used to afford these communities protection.

1.8 Recovery actions completed or underway

Legislation in place to protect species at risk

Ontario's ESA and Canada's *Species at Risk Act, 2002* (SARA) provide legal protection for species at risk. The purpose of the ESA is:

1. "To identify species at risk based on the best available scientific information, including information obtained from community knowledge and aboriginal traditional knowledge.
2. To protect species that are at risk and their habitats, and to promote the recovery of species that are at risk.
3. To promote stewardship activities to assist in the protection and recovery of species that are at risk."

With a SARO List classification of endangered, the ESA prohibits killing, harming, harassing, transporting, trading and selling of live or dead Black Ash. Additionally, this legislation sets the requirements for the Ministry to produce a recovery strategy, a government response statement that sets out the policy with respect to the actions that the Government of Ontario intends to take in response to the recovery strategy, and a review of progress towards the protection and recovery of Black Ash.

Species listed as endangered under Schedule 1 of the SARA are afforded both individual and habitat protection. Generally, compliance with provincial ESA legislation will satisfy the requirements under the SARA; however, the SARA applies to all federal lands.

Habitat protection and conservation in policy

Forests, wetlands and other habitats in Ontario containing Black Ash may be protected under the *Forestry Act, 1990, Crown Forest Sustainability Act, 1994* (CFSA)*, Planning Act, 1990* (through the Provincial Policy Statement), *Municipal Act, 2001*, and/or the *Conservation Authorities Act, 1990*. A variety of other policy instruments facilitate wetland conservation, including but not limited to those under the *Great Lakes Protection Act, 2015*, *Far North Act, 2010*, *Provincial Parks and Conservation Reserves Act, 2006*, *Municipal Act, 2001*, *Environmental Assessment Act*, *1990*, *Conservation Lands Act, 1990*, and *Invasive Species Act, 2015* (Government of Ontario 2015; OMNRF 2017). Emerald Ash Borer is currently not listed under the *Invasive Species Act* (Government of Ontario 2012).

Forest Management Plans prepared under the CFSA for Ontario's 39 Forest Management Units contain policies and practices which afford protection to wetlands and habitats of species at risk on crown land. These protections within forestry provide protection for Black Ash through the protection of wetland habitat (V. Brownell pers. com. 2021). According to Forest Management Plans, individual Black Ash trees may still be removed or harmed.

The Provincial Policy Statement (OMMAH 2020) under the *Planning Act* may afford protection to habitats of Black Ash by prohibiting development and site alteration of provincially significant wetlands and restricting development and site alteration of other significant natural heritage features which may contain Black Ash. Wetlands that contain Black Ash are candidate provincially significant wetlands since the Ontario Wetland Evaluation System assigns a high score to the presence of species at risk (Ontario 2014a; Ontario 2014b). Wetlands are also protected under provincial growth plans, including the Greenbelt Plan, Niagara Escarpment Plan, Oak Ridges Moraine Conservation Plan and Lake Simcoe Protection Plan. Some municipalities have natural heritage policies which are more restrictive than the Provincial Policy Statement and apply to wetlands and woodlands which contain Black Ash.

The *Conservation Authorities Act* allows Ontario's 36 conservation authorities to regulate development interference with wetlands and alterations to watercourses within their watersheds. Conservation authority policies typically restrict development and site alteration of wetlands.

Federal legislation, namely the *Fisheries Act, 1985*, may provide regulatory protection for Black Ash in riparian and swamp habitats which are also habitat for fish. The *Canada National Parks Act, 2000*, would provide habitat protection within National Parks in Ontario. Incentive programs such as the Aboriginal Fund for Species at Risk, Environment and Climate Change Canada has supported Indigenous-led conservation projects specific to Black Ash in Ontario.

Restricting movement of Emerald Ash Borer

The Canadian Food Inspection Agency (CFIA) is responsible for monitoring Emerald Ash Borer in Canada and restricting activities which disperse Emerald Ash Borer, such as the movement of firewood. CFIA currently enforces a regulated area for Emerald Ash Borer which covers approximately one-third of the Ontario range of Black Ash (CFIA 2021b). International restrictions on the movement of ash materials are enforced by CFIA and the United States Department of Agriculture Animal and Plant Health Inspection Service (Hope et al. 2020).

Emerald Ash Borer is not listed under Ontario's *Invasive Species Act*, which restricts the possession and distribution of invasive species, including products which may contain Emerald Ash Borer.

Monitoring for Emerald Ash Borer

In Ontario, the spread of Emerald Ash Borer is monitored at a province-wide scale every two years through aerial surveys by NDMNRF (Rowlinson pers. comm. 2021). Monitoring has also been completed by some municipalities and conservation authorities. The City of Thunder Bay, which includes the northwesternmost occurrence of Emerald Ash Borer in Ontario, was previously inventoried using pheromone sticky traps to detect the species but that technique was determined to be ineffective at detecting Emerald Ash Borer (M. Wilkie pers. com. 2021). Monitoring using traps has also been conducted in North Bay and Mattawa which are at the northern margins of the central Ontario Emerald Ash Borer distribution in Ontario (S. McPherson pers. com. 2021).

Modeling of Emerald Ash Borer movement has been completed in the United States (Iverson et al. 2006; Iverson et al. 2010). However similar modeling hasn't been completed for Ontario.

Insecticide control of Emerald Ash Borer

Systematic insecticide control of Emerald Ash Borer can be completed with TreeAzin (BioForest 2020). Fungal insecticide control of Emerald Ash Borer has also been tested (Stevens and Pijut 2014). Insecticide control has been focused on street trees in urban areas, species representatives within arboretums or ornamental trees (Streit et al. 2012; K. McLoughlin pers. com. 2021). Point Pelee National Park is planning to utilize TreeAzin on Black Ash as an experimental interim conservation effort once healthy trees have been located (T. Dobbie pers. com. 2021).

Insecticide control using TreeAzin costs approximately $4/cm DBH, making it a costly method for protecting individual trees. Insecticide control can be an effective means of preventing mortality of individual trees due to Emerald Ash Borer. Trees treated every one or two years have been noted to survive for over ten years (K. McLoughlin pers. com. 2021). However, the injection process of utilizing TreeAzin is not an optimal long-term solution because drilling in the base of the tree is an entry point for decay and drilling disrupts cambium. Typically drill locations are not reused and with each treatment additional wounds are created leading to disruption of the cambium around the base of the tree. Impacts from drilling can lead to mortality of the tree through introduction of decay or disruption of the cambium (K. McLoughlin pers. com. 2021).

Promoting resistance to Emerald Ash Borer

Research programs include collection of seeds and breeding of remnant native trees, which may have some resistance to Emerald Ash Borer (Koch et al. 2012; Herms et al. 2014). There are also backcross breeding programs aiming to introduce resistance genes from Asian ash species into native ash (Koch et al. 2012; Herms et al. 2014; Villari et al. 2014), *in vitro* mass propagation programs (Stevens and Pijut 2012; 2014) and genetic transformation studies (Stevens and Pijut 2014). These programs and studies are largely being undertaken in the United States and have not been implemented in Ontario.

Biological control of Emerald Ash Borer

Four parasitic wasp species known to affect Emerald Ash Borer have been introduced to North America as biological control agents: the egg parasitoid *Oobius agrili* (Hymenoptera: Encyrtidae) and the larval parasitoids *Tetrastichus planipennisi* (Hymenoptera: Eulophidae), *Spathius galinae* and *S. agrili* (Hymenoptera: Braconidae) (Bauer et al. 2015; CFIA 2018; Duan et al. 2018). In Canada, the biological control program for Emerald Ash Borer is led by the Canadian Forest Service's Great Lakes Forestry Research Centre (Ryall 2017). As of 2018, parasitic wasps had been released at 19 sites in Ontario and Quebec (CFIA 2018). Releases of *T. planipennisi* began in Ontario in 2013 and *O. agrili* was released in Ontario in 2015 (Bauer et al. 2015; Ryall 2017). By 2017, over 60,000 individuals of *T. planipennisi* had been released at 12 sites in Ontario and Quebec (Ryall 2017). Monitoring results indicated that *T. planipennisi* dispersed from the point of introduction and were able to locate trees infested with Emerald Ash Borer (Ryall 2017). Outcomes of the release of *O. agili* are unknown at this time. *S. galinae* has also been released in Ontario (Duan et al. 2018) but the outcomes of these releases are unknown. *S. agrili* has been approved for use as a biological control in Canada but has not yet been released because it is intolerant of winter temperatures north of 40°N (Bauer et al. 2015; CFIA 2018; Duan et al. 2018). Longer-term and more detailed studies are needed to assess the effectiveness of biological controls for managing Emerald Ash Borer and promoting ash recovery in Ontario.

Seed banks

The National Tree Seed Centre maintains seed collections of Black Ash to preserve the genetic diversity of the species in Canada. Additionally, the Ontario Forest Research Institute has a provincial seed archive. The National Tree Seed Centre's collections include samples of Black Ash seeds from across Ontario, but with limited specimens from southern and northern limits of the Black Ash range (Figure 6). A total of 669 specimens of Black Ash seeds have been collected (D. McPhee pers. com. 2021). The entirety of the range of Black Ash is not yet represented in the National Tree Seed Centre (D. McPhee pers. com. 2021) and additional collection of Black Ash seeds from southwestern Ontario and the northernmost portions of its range will help to preserve its genetic diversity in Ontario.

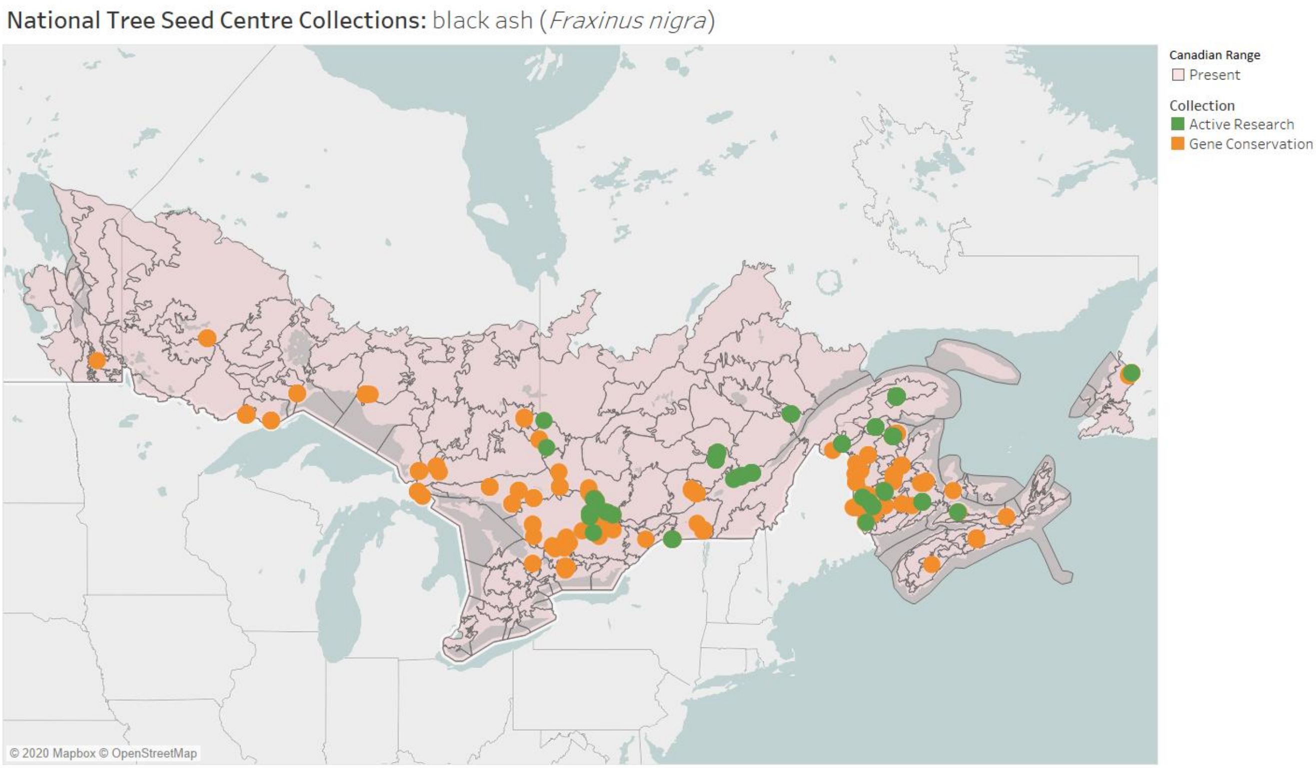

Figure 6. Locations where Black Ash seed has been collected that is within the National Tree Seed Centre (National Tree Seed Centre 2021).

The United States Department of Agriculture Forest Service began ash germplasm preservation in 2005, through seed collections for long term seed storage. As of 2017 approximately 4,000 seed lots had been collected, including seed lots from Black Ash (Karrfault 2017).

Although seed collection and preparation is time consuming (D. McPhee pers. com. 2021), seed viability can be maintained for 15 to 25 years (Smith et al. 2000; M. Spearing per. com. 2021) If the seedlot tests above 80 percent viability initially 40 to 50 years of reasonable viability can be expected (M. Spearing pers. com. 2021). The use of cryopreservation can extend that viability period beyond 100 years. Viability is contingent on all current seed banking steps being followed (M. Spearing pers. com. 2021):

1. That initial collections are done at optimal natural maturity in masting seed years

with good cross-pollination and minimal ash weevil (various species of *Myllocerus*) damage.
2. Seed is handled properly after harvest and shipped quickly.
3. Equilibrated to 25 to 30 percent relative humidity as soon as possible.
4. Stored in hermetic containers at -20°C.

The potential for stored seeds to remain viable for 40 to 50 years makes seed banks a useful tool for preserving Black Ash genetics and future rehabilitation. Seed collection primarily occurs during bumper crop years, which occur every seven to nine years and may not be predictable (D. McPhee pers. com. 2021). To increase the chances of preserving resistant genes, the National Tree Seed Centre is working with the International Lingering Ash Program, which identifies putatively resistant ash trees (D. McPhee pers. com. 2021).

2.0 Recovery

2.1 Recommended recovery goal

The recommended recovery goal for Black Ash in Ontario has been divided into separate recovery goals for two geographical regions based on the threat of Emerald Ash Borer.

In areas within the presumed climatic range limit of Emerald Ash Borer the recommended recovery goal is to reduce the impact of Emerald Ash Borer and preserve an in-situ (in a natural location) and ex-situ (away from a natural location) gene bank for Black Ash.

In areas beyond the presumed climatic range limit of Emerald Ash Borer the recommended recovery goal is to maintain or increase the current population abundance and distribution of Black Ash and preserve an in-situ (in a natural location) and ex-situ (away from a natural location) gene bank.

2.2 Recommended protection and recovery objectives

The recommended protection and recovery objectives for Black Ash are:

1. Assess threats and undertake actions to eliminate them or reduce the severity of their impact.
2. Protect and maintain Black Ash individuals and habitats.
3. Raise awareness about Black Ash and its habitat, threats to Black Ash, Emerald Ash Borer and the safe handling of infested ash trees.
4. Initiate or support inventories and research to fill knowledge gaps.

2.3 Recommended approaches to recovery

Table 1. Recommended approaches to recovery of the Black Ash in Ontario.

Objective 1: Assess threats and undertake actions for threat mitigation, reduction and/or elimination.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Inventory, Monitoring and Assessment	**1.1** Continue to monitor Black Ash declines and causes in Ontario. • Monitor the ongoing spread of Emerald Ash Borer. • Monitor for the presence of other pests and diseases to allow for early detection-rapid response mitigation.	Threats: • Emerald Ash Borer • Problematic species/diseases of unknown origin • Chalara dieback Knowledge gaps: • Threats • Detailed occurrence information • Emerald Ash Borer • Other diseases/pests

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Protection, Management, Education and Outreach, Communication	**1.2** Continue to restrict the movement of firewood and other dispersal vectors of Emerald Ash Borer. • Work with other agencies to inform the public of restricted vector movement regulations. • Prepare education materials and/or signage and distribute these materials. • List Emerald Ash Borer as a prohibited invasive species under the *Invasive Species Act* and develop exceptions that allow/specify the proper disposal of infested wood.	Threats: • Emerald Ash Borer • Problematic species/diseases of unknown origin
Critical	Ongoing	Protection, Management, Inventory, Monitoring and Assessment, Research	**1.3** Support the release of biological controls and monitoring and research on their effectiveness. • Research effectiveness of biological controls at protecting Black Ash in Ontario.	Threats: • Emerald Ash Borer Knowledge gaps: • Threats • Emerald Ash Borer

Critical	Ongoing	Protection, Management, Inventory, Monitoring and Assessment, Research	**1.4** Protect an in-situ living collection of Black Ash trees across its range in Ontario. • Determine the number of individuals required to represent a genetically diverse sample of Black Ash trees. • Locate and protect individuals or genotypes which are potentially resistant to Emerald Ash Borer across the range of Black Ash. • Locate and protect a genetically diverse living gene bank of Black Ash across its native Ontario range through protection of significant healthy trees and larger stands representing local diversity with biological controls, insecticide controls (such as TreeAzine) or other newly determined methods. Subpopulations should be each sufficiently large to represent the genetic diversity of the species, and strategically located across the range to conserve the adaptive variation of the species. • Develop a protocol for consistent assessment of Black Ash trees potentially resistant to Emerald Ash Borer. • Clone trees and archive genetic materials (seeds, etc.) of Black Ash individuals that are potentially resistant to Emerald Ash Borer with a goal of archiving at least 10 trees per ecodistrict. • Support seed and vegetative propagule collection from individuals potentially resistant to Emerald Ash Borer where possible.	Threats: • Emerald Ash Borer • Problematic species/ diseases of unknown origin • Chalara dieback • Ash dieback Knowledge gaps: • Detailed occurrence data • Indicators of resistance

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Short-term	Protection, Management, Research, Education and Outreach, Communication, Stewardship	**1.5** Support efforts, including those of the National Tree Seed Centre and Forest Gene Conservation Association to collect and preserve Black Ash seeds ex-situ. • Maintain a genetically diverse ex-situ seed bank representing the full range of Black Ash in Ontario including collections of seeds from a minimum of 15 trees per ecodistrict. • Ensure rapid permit approval or exemptions for conservation efforts, including seed collection. • Develop a contingency fund to support seed collection efforts and seed forecasting (studies to determine if collected crop is viable) that can be made available during bumper crop years when collection takes place.	Threats: • Emerald Ash Borer • Problematic species/diseases of unknown origin • Chalara dieback Knowledge gaps: • Detailed occurrence information • Emerald Ash Borer • Threats • Other diseases/pests
Beneficial	Long-term	Protection, Management, Communication, Stewardship	**1.6** Maintain the protection of, and habitat quality in, vegetation communities impacted by Emerald Ash Borer. • Support invasive plant species control and rehabilitation of degraded habitats containing Black Ash. • Promote healthy forests, woodlots and wetlands where Black Ash occurs.	Threats: • Emerald Ash Borer • Invasive non-native plants

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Beneficial	Long-term	Research	**1.7** Explore the potential for a breeding program or genetic manipulation to promote Emerald Ash Borer resistance in Black Ash.	Threats: • Emerald Ash Borer
Beneficial	Long-term	Research	**1.8** Develop or update climate change models to monitor the potential impact environmental changes may have to Black Ash in Ontario.	Threats: • Climate change

Objective 2: Protect and maintain Black Ash individuals and habitats.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Protection, Management, Education and Outreach, Communication, Stewardship	**2.1** Amend relevant industry guidelines to reflect current scientific knowledge and the designation of Black Ash as endangered; develop best management practices for activities for maintaining and protecting Black Ash and its habitat.	Threats: • Habitat conversion • Logging and wood harvesting • Wood and pulp plantations

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Protection, Management, Education and Outreach, Communication, Stewardship	**2.2** Update and/or develop best management practices for the removal and salvage of Black Ash trees infested with Emerald Ash Borer based on current scientific knowledge, with specific attention to how to reduce the spread of Emerald Ash Borer. • Provide clear guidance on the permitting and compliance requirements for removal and salvage.	Threats: • Habitat conversion • Logging and wood harvesting • Wood and pulp plantations • Emerald Ash Borer
Beneficial	Short-term	Protection, Management, Education and Outreach, Communication, Stewardship	**2.3** Implement a habitat regulation under the ESA and provide clear direction on regulated habitat for Black Ash. • Circulate materials to the forestry sector, land developers, the agriculture sector and other private sectors with information on habitat regulations for Black Ash. • Establish regulatory standards on the basis of the best available scientific information and methods which are reasonably expected to ensure land uses and development affecting Black Ash will not result in net negative outcomes for the species, and monitor the effectiveness of their application against appropriate performance measures. • Clarify any regional differences or exemptions for the habitat regulation.	Threats: • Habitat conversion • Logging and wood harvesting • Wood and pulp plantations • Targeted harvesting

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Beneficial	Long-term	Protection, Management, Inventory, Monitoring and Assessment, Research	**2.4** Ensure appropriate protection of Black Ash within all parks and protected areas. • Assess threats and determine site-specific management needs within parks and protected areas to protect Black Ash and its habitat. • Design trail and road systems to minimize harm to Black Ash and to prevent introduction of invasive species to its habitat. • Complete periodic monitoring to prevent unsanctioned activities (e.g., moving firewood, tree cutting). • Prepare educational signage to increase public awareness of Black Ash and its threats. • Perform active management of Black Ash trees/stands including use of pesticides to protect trees from Emerald Ash Borer and conserve the gene bank.	Threats: • Habitat conversion • Invasive non-native plant species Knowledge gaps: • Detailed occurrence information

Objective 3: Raise awareness about Black Ash and its habitat, threats to Black Ash, Emerald Ash Borer and the safe handling of infested ash trees.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Short-term	Protection, Education and Outreach, Communication, Stewardship	**3.1** Consult with and provide the forestry, aggregate and resource extraction, agricultural and land development sectors as well as private landowners with informational material about the identification, habitat, conservation status, threats, conservation mechanisms, regulated habitat, health indicators, impacts of development, where to report observations and recommended management of Black Ash. • Support these sectors in research and policy development of sustainable forest management practices for protection of Black Ash. • Encourage these sectors to report observations of Black Ash or trends in Black Ash health and regeneration. • Develop/improve and maintain a reporting system for observations of Emerald Ash Borer where it may be expanding its range.	Threats: • Habitat conversion • Targeted harvesting • Logging and wood harvesting • Wood and pulp plantations Knowledge gaps: • Detailed occurrence information • Emerald Ash Borer • Regeneration

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Short-term	Protection, Education and Outreach, Communication, Stewardship	**3.2** Develop or update stewardship and outreach materials informing the public of the identification, habitat, conservation status, conservation mechanisms, habitat regulation, where to report observations and recommended management of Black Ash. • Provide guidance to the public on if and when infested ash trees should be removed.	Threats: • Habitat conversion • Targeted harvesting Knowledge gaps: • Detailed occurrence information
Beneficial	Short-term	Protection, Education and Outreach, Communication, Stewardship	**3.3** Develop and/or update stewardship materials to raise awareness of Emerald Ash Borer in Ontario and the proper handling of infested ash trees. • Provide guidance to the public on if and when infested ash trees should be removed and how to properly dispose of infested wood.	Threats: • Emerald Ash Borer

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Beneficial	Long-term	Protection, Management, Inventory, Monitoring and Assessment, Research	**3.4** Engage Indigenous communities to gather and share traditional ecological knowledge of Black Ash to support protection and recovery goals.	Threats: • Emerald Ash Borer • Problematic species/diseases of unknown origin • Chalara dieback Knowledge gaps: • Indicators of resistance • Seed periodicity • Seed quality • Seed pests/ diseases

Objective 4: Initiate or support inventories and research to fill knowledge gaps.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Inventory, Monitoring and Assessment, Research	**4.1** Support studies to determine locations and health of Black Ash across Ontario. • Identify the largest remaining subpopulations of Black Ash in Ontario. • Identify locations of potentially resistant or high-value individuals or stands in each ecodistrict of Black Ash's range. • Implement citizen science programs to collect and compile Black Ash and Emerald Ash Borer occurrence data from private landowners, conservation organizations, naturalists and the general public. • Model the viability of Black Ash populations subject to Emerald Ash Borer infestations of differing severity and duration. • Model demographic changes in infested Black Ash populations and associated shifts in ecological role or dominance. • Conduct genetic or genomic studies of Black Ash populations across Ontario, and across its natural distribution.	Threats: • Habitat conversion • Logging and wood harvesting • Wood and pulp plantations • Emerald Ash Borer Knowledge gaps: • Detailed occurrence information • Regeneration • Threats • Indicators of Emerald Ash Borer resistance

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Long-term	Protection, Management, Inventory, Monitoring and Assessment, Research	**4.2** Determine ash diseases or pests (other than Emerald Ash Borer) that are causing or may cause declines of Black Ash in Ontario. • Determine additional causes of decline (other than Emerald Ash Borer). • Assess the potential impacts of ash diseases or pests (other than Emerald Ash Borer) on Black Ash or its recovery. • Monitor for diseases known from outside Ontario to enact early detection-rapid response mitigation.	Threats: • Problematic species/ diseases of unknown origin • Chalara dieback Knowledge gaps: • Other diseases/ pests • Threats

Beneficial	Long-term	Monitoring and Assessment, Research	**4.3** Research Black Ash biology to inform knowledge gaps. • Study anemochorous and hydrochorous seed dispersal in Black Ash. • Investigate the nature and strength of dependency of Black Ash populations on inhabited ecological areas and associated ecological or environmental processes, and changes to these resulting from stress caused by Emerald Ash Borer infestations. • Investigate whether any ecological conditions are positively correlated with the tolerance of Black Ash populations or subpopulations to Emerald Ash Borer. • Identify optimal site conditions for future planting of the progeny of Black Ash represented in living collections or gene banks. • Identify reliable indicators of irreversible decline or a poor prognosis in an infested Black Ash tree. • Investigate how epicormic shoot formation relates to crown die-back and tree health prognosis and the survival potential of epicormic shoots to maturity. • Investigate Black Ash performance in different vegetation communities or in association with different overstory dominants, with and without Emerald Ash Borer. • Conduct trials with putatively resistant trees to evaluate the level of resistance,	Knowledge gaps: • Species biology • Indicators of resistance

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
			characterize its ontogenetic variability, identify underlying mechanisms, and heritability. • Investigate options for producing resistance into Black Ash through genetic modification.	

Narrative to support approaches to recovery

Based on the ongoing threat posed by Emerald Ash Borer and other ongoing or potential threats discussed in this document, the abundance of Black Ash in Ontario is expected to continue to decline. However, northern subpopulations of Black Ash are not currently susceptible to Emerald Ash Borer due to winter low temperatures that Emerald Ash Borer cannot survive. The recommended recovery goal therefore reflects the different threat levels experienced in the northern and southern portions of the Ontario range of Black Ash. The recommended recovery goal incorporates the importance of protecting Black Ash not yet affected by Emerald Ash Borer and supporting the protection of healthy Black Ash in regions that have experienced high mortality due to Emerald Ash Borer. The recommended geographical areas are based on current susceptibility to Emerald Ash Borer. The boundaries of these are subject to change over time due to predicted winter warming. The areas are:

- Region 1: areas that are severely affected by Emerald Ash Borer, areas in the early stages of infestation and areas that are susceptible to invasion based on current winter low temperatures (south of the purple line in Figure 5).
- Region 2: northern areas beyond the presumed climatic range limit of Emerald Ash Borer (north of purple line in Figure 5).

In implementing recovery goals and objectives and a habitat regulation for Black Ash, adequate protection for pollen and seed producing trees (in-situ gene bank) and their habitat should be a major consideration. These trees play an important role in securing the future of Black Ash in Ontario because they are the remaining reproductive source and some surviving trees may be a source of Emerald Ash Borer resistant genes. If the remaining mature trees are not adequately protected, opportunities for recovery of the species will be lost. Seed banks will also be a valuable tool for long-term recovery.

2.4 Area for consideration in developing a habitat regulation

Under the ESA, a recovery strategy must include a recommendation to the Minister of the Environment, Conservation and Parks on the area that should be considered if a habitat regulation is developed. 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, including information that may become newly available following the completion of the recovery strategy should a habitat regulation be developed for this species.

Habitat of Black Ash trees should be protected in order to provide sufficient space and habitat conditions to promote their growth and reproduction (i.e., space should be provided where regenerating young trees can persist). These trees play an important role in securing the future of Black Ash in Ontario because some surviving trees may be a source of Emerald Ash Borer resistant genes. If the remaining trees are not adequately protected, opportunities for recovery of the species will be lost.

The recommended area for consideration in developing a habitat regulation for Black Ash is the entire ELC ecosite type in which one or more Black Ash tree is present and all of the area within a radial distance of at least 28 m from an individual Black Ash tree.

Due to the potential for hydrological change to impact Black Ash and the vulnerability of wetland habitats to disturbance and development the recommended regulated habitat for Black Ash is the entire ELC ecosite type (according to published ecosystem classification guides such as Lee et al 1998 and Sims et al. 1987) in which one or more Black Ash trees is present. Black Ash may occur in a wide range of ecosites and a complete list of all ecosite types in which this species may occur has been identified as a knowledge gap so that a habitat regulation area can be further refined in future. The ELC ecosite type boundary may exclude dry or upland areas with more than two metre depth to the water table, which is considered unsuitable for Black Ash (Nova Scotia Department of Natural Resources and Renewables 2021).

If an individual is close to the ELC ecosite polygon edge or the ELC ecosite is unable to be determined, a minimum distance of 28 m from the stem of the tree (or sprouting stump) is recommended for inclusion in the area prescribed as habitat in the habitat regulation. This is a precautionary measure based on CRZ estimates to ensure that a minimum distance is met for any ground disturbance that could affect trees. As discussed under *Habitat Needs*, the largest recorded crown spread for a mature Black Ash was a radius of 9.15 m, which results in a CRZ radius of 15.37 m and a maximum root distance of 27.45 m. The CRZ is considered to have the highest sensitivity to habitat modification, since any activities within the maximum root zone have the potential to directly harm the health of an individual Black Ash. Based on this, the area required to protect an individual Black Ash tree from any harm would be a radius of approximately 28 m, as measured from the base of the trunk. It is therefore recommended that the regulated area for Black Ash is a radial distance of 28 m from the base of individual trees in order to protect individual trees. It is acknowledged that these estimates are based on the maximum recorded canopy size of Black Ash and root distances of Green Ash. Species-specific information required to inform a recommended habitat regulation to protect individual trees is lacking and has been identified as knowledge gap. If, in the future, new species-specific scientific evidence indicates that an altered distance may reasonably contribute to achieving the protection of individual Black Ash from harm, then this information should be considered in revising the habitat regulation.

If future scientific studies indicate that additional areas of habitat are necessary to achieve the recovery goals for this species, the habitat regulation should be updated accordingly.

Glossary

Aerated: With air or oxygen present in the liquid.

Bumper crop: A crop that has yielded an unusually productive harvest.

Buprestid: Members of the family Buprestidae, which is a family of beetles known as jewel beetles or metallic wood-boring beetles because of their glossy iridescent colors. Larvae of this family are known as flatheaded borers.

Butt: A tree's "butt" is above the roots but separated from the trunk which continues upward toward the terminal bud.

Cambium: A cellular tissue layer in plants, located between the phloem (vascular tissue that conducts sugars and other metabolic products) and xylem (vascular tissue that conducts water) layers, where phloem, xylem and cork grows by division resulting in secondary thickening.

Canadian Food Inspection Agency (CFIA): A federal agency dedicated to safeguarding food, animals and plants, which enhances the health and well-being of Canada's people, environment and economy.

Canopy: The layer of a tree or trees formed by the branches, stems and leaves or needles. The canopy extends to the outermost edge of the branches.

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* that is responsible for assessing and classifying species at risk in Ontario.

Compound leaf: A leaf that is comprised of smaller leaflets arranged on the leaf’s central stalk.

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 (2021) 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 one to five, preceded by the letter G, N or S reflecting the appropriate geographic scale of the assessment. The numbers mean the following:

1 = critically imperiled
2 = imperiled

3 = vulnerable
4 = apparently secure
5 = secure
NR = not yet ranked

Critical Root Zone (CRZ): Area around an individual tree that contains the highest root density.

Deciduous: A tree or shrub that sheds its leaves annually.

Diameter at Breast Height (DBH): Measurement of a straight line passing through the centre of a tree trunk. Typically measured at 1.4 m from the base of the tree.

Ecodistrict: Ecoregions can be further subdivided into ecodistricts. Each ecodistrict is characterized by relatively homogeneous biophysical and climatic conditions.

Ecoregion: Ecologically and geographically defined area that contain distinct assemblages of natural communities and species. Ecoregions within Ontario have been illustrated in Figure 3.

Ecosite: Ecosites are sub-divisions of the Ontario Ecological Land Classification system that characterizes vegetation communities.

Ecological Land Classification (ELC): The Ontario Ecological Land Classification system provides a classification of vegetation communities by class, series, ecosite and type based on biotic and abiotic features.

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

Epicormic shoot: A shoot growing from an epicormic (previously dormant) bud, which lies underneath the bark of a trunk, stem, or branch of a plant.

Facultative wetland species: A species that usually occurs in wetlands (estimated probability 67 to 99 percent), but occasionally found in non-wetlands (estimated probability 1 to 33 percent).

Folivore: Animal that eats leaves.

Girdling: Severs the bark, cambium, and sometimes the sapwood in a ring extending entirely around the trunk of the tree

Glabrous: Describing something smooth; free from hair or down.

Heartwood: The dead, central wood of trees.

iNaturalist: A citizen science website for submission of all plant and animal observations (https://www.inaturalist.org/).

Natural Heritage Information Centre (NHIC): This provincial conservation data centre that manages data about the location of species of conservation concern, plant communities, wildlife concentration areas, and natural areas in Ontario.

Ontario Shield Ecozone: The shield ecozone is a broad region rock formation covering two-thirds of Ontario that is comprised of Precambrian rock. This ecozone has a relatively thin soil layer, exposed bedrocks and is rich in mineral deposits.

Phytoplasma: Obligate intracellular parasites of plant phloem tissue and of the insect vectors that are involved in their plant-to-plant transmission.

Pinnate: Having leaflets arranged on either side of the stalk that attaches the leaf to the stem.

Polygamo-dioecious: One individual that has female and bisexual flowers and another has male and bisexual flowers.

Putatively: Assumed to be.

Rachis: The stem of a plant. This is the attachment point for leaflets on a compound leaf.

Samara: A winged nut or achene containing a single seed.

Sapwood: The outer, living layers of the secondary wood of trees, which engage in transport of water and minerals to the crown of the tree.

Sessile: Attached directly by its base without a stalk or peduncle.

Silviculture: The practice of controlling the growth, composition, structure and quality of forests.

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.

Vascular tissue: Complex conducting tissue, formed of more than one cell type, found in vascular plants.

Vegetative shooting: The growth of new stems from the base of the trunk or root system.

Xylem: The vascular tissue in plants that conducts water and dissolved nutrients upward from the root and also helps to form the woody element in the stem.

List of abbreviations

COSEWIC: Committee on the Status of Endangered Wildlife in Canada
COSSARO: Committee on the Status of Species at Risk in Ontario
CWS: Canadian Wildlife Service
DBH: Diameter at Breast Height
ELC: Ecological Land Classification
ESA: Ontario's *Endangered Species Act, 2007*
ISBN: International Standard Book Number
MECP: Ontario's Ministry of the Environment, Conservation and Parks
NDMNRF: Ontario's Ministry of Northern Development, Mines, Natural Resources and Forestry
OMNRF: Ontario Ministry of Natural Resources and Forestry
SARA: Canada's *Species at Risk Act*
SARO List: Species at Risk in Ontario List

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