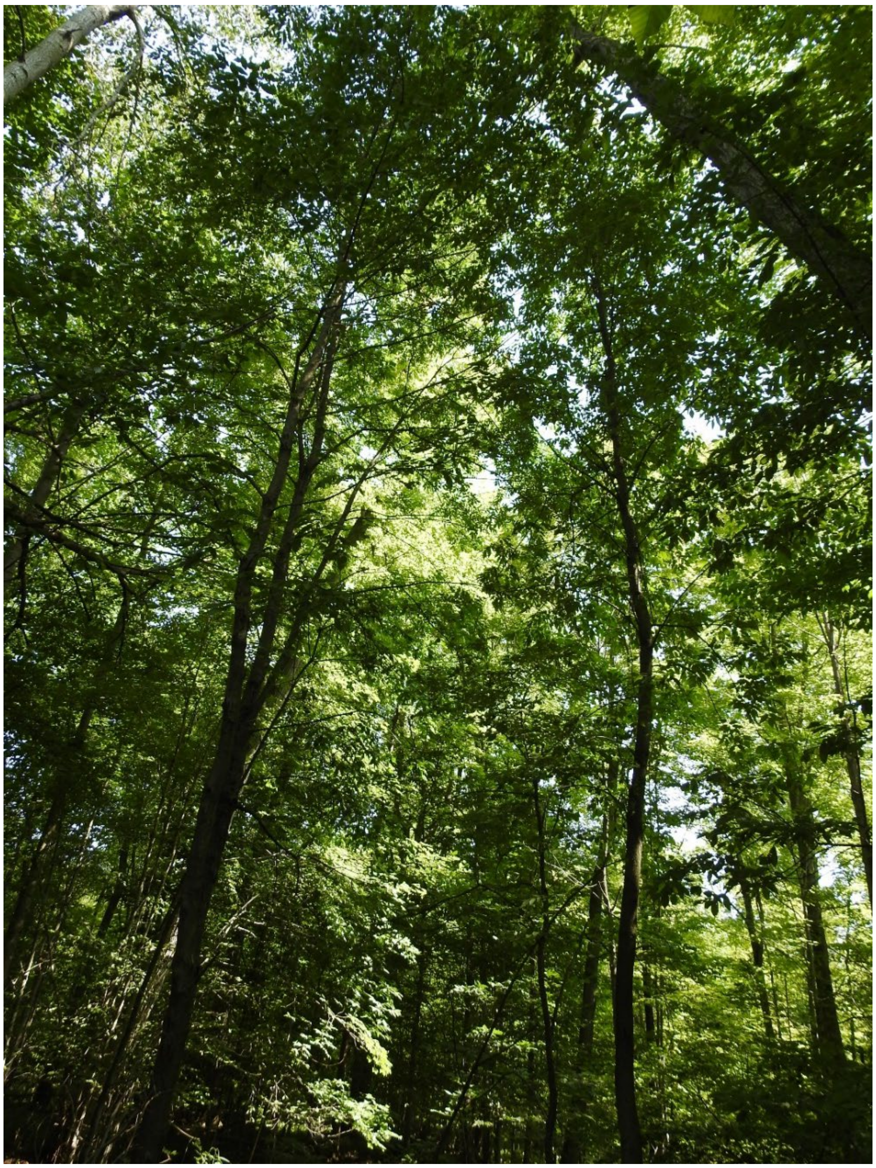
DRAFT Recovery Strategy for the Pumpkin Ash (*Fraxinus profunda*) in Ontario



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Declaration

The recovery strategy for the Pumpkin Ash (*Fraxinus profunda*) 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

Executive summary

Pumpkin Ash (*Fraxinus profunda*) is a medium to large deciduous hardwood tree in the Olive (Oleaceae) family which is native to the Carolinian Zone in Southwestern Ontario. The rest of its range is in the United States and occurs in a ring along the East Coast down to Florida, along the Gulf of Mexico coast to Louisiana and northwards towards the Great Lakes. It generally grows to a height of 15 to 35 m, can have a diameter at breast height of 173 cm and has a relatively narrow crown. Pumpkin Ash can be hard to distinguish from other Ash species. It has a tendency to form swollen bases when growing in saturated habitat, has bark with a furrowed texture and a gray-brown colour and pinnate leaves which are generally 20 to 50 cm long and composed of 7 to 9 leaflets with a distinctive rounded base.

Pumpkin Ash is listed as endangered under Ontario's *Endangered Species Act, 2007*. It has been assessed as endangered in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), but it is not currently listed on Schedule 1 of the federal *Species at Risk Act, 2002*. It has a global conservation rank of G4 (Apparently Secure) and national and subnational (Ontario) conservation ranks of N1 and S1 respectively (Critically Imperilled).

Pumpkin Ash is a bottomland species and prefers wet to very wet mineral soils. It is considered a flood tolerant species and is found across its range in coastal marshes, swamp margins, large river floodplains, deep sloughs and tidal estuaries. It is considered an obligate wetland species in Ontario.

Thirty-nine subpopulations of Pumpkin Ash have been identified in Ontario. Of these 39 subpopulations, 13 are considered extant, 3 are known to be extirpated, 12 are presumed extirpated and 11 are of unknown status. Since the 2021 COSEWIC report, additional potential subpopulations have been identified. It is estimated that there are fewer than 2,000 immature individuals of Pumpkin Ash remaining in Canada, with fewer than 10 sexually mature individuals.

The main threat to Pumpkin Ash is the invasive Emerald Ash Borer (*Agrilus planipennis*). This metallic green beetle which is native to Asia is dependent on Oleaceae trees to complete its lifecycle. It was first detected in Ontario in Windsor in 2002 but is believed to have been introduced to North America in the 1990s on wood packaging material. Emerald Ash Borer can cause the death of an ash stand within six years of initial infestation. Pumpkin Ash is considered particularly vulnerable to Emerald Ash Borer. It is unknown how many Pumpkin Ash were present in Ontario prior to the introduction of the Emerald Ash Borer, but the species has been decimated by the beetle, which is present throughout the entire range of Pumpkin Ash in the province.

The second main threat to Pumpkin Ash is habitat destruction and fragmentation. Prior to the introduction of Emerald Ash Borer to Ontario, Pumpkin Ash was already under threat by the draining and destruction of wetlands for large scale agriculture, which has been ongoing since the beginning of European settlement. Other threats to Pumpkin

Ash include other pests and diseases (both native and non-native), climate change, logging and wood harvesting and recreational activities.

A number of recovery actions are already under way, including legislative protection for Pumpkin Ash, genetic investigations and breeding programs, seed collection, the release of biological control agents in the form of parasitoid wasps, the use of systemic insecticides to protect high-value trees, restrictions within the Canadian Food Inspection Act regulated area for Emerald Ash Borer and education on Emerald Ash Borer and botanical inventories within the Carolinian Zone which are identifying new Pumpkin Ash subpopulations.

There are a number of knowledge gaps that need to be addressed with regards to Pumpkin Ash. As it is quite a rare species, and forms only a minor component of the hardwood forests it inhabits, there is little data on this species. General knowledge about this species is poor, including preferred Ecological Land Classification communities and crown spread. There is a lack of Pumpkin Ash-specific research, including Emerald Ash Borer dynamics with regards to this species, how well it responds to biocontrol and insecticides, how susceptible it is to other pests and diseases and how it will be affected by climate change. In addition, detailed location information still needs to be amassed for Pumpkin Ash.

The recommended recovery goal for Pumpkin Ash in Ontario is to maintain all current naturally-occurring subpopulations and genetic diversity within its known range in the province, reintroduce Pumpkin Ash to suitable sites if the threat of Emerald Ash Borer can be mitigated, and to ensure its persistence as a functional, reproductive forest tree. The following protection and recovery objectives are recommended:

1. Evaluate threats and undertake actions to mitigate their impact.
2. Identify, protect and maintain Pumpkin Ash subpopulations, individuals and habitats for in-situ conservation.
3. Investigate ex-situ conservation to preserve population genetics with an aim of improving Emerald Ash Borer resistance over the long term.
4. Engage in educating stakeholders and rightsholders about Pumpkin Ash and Emerald Ash Borer.
5. Initiate research to fill knowledge gaps on Pumpkin Ash biology, threats and management.

The recommended area for consideration in developing a habitat regulation for Pumpkin Ash is the entire Ecological Land Classification ecosite in which one or more Pumpkin Ash are present, as well as the area within a radial distance of 23 m from an individual Pumpkin Ash tree or sprouting trunk, including less suitable habitat.

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1.0 Background information

1.1 Species assessment and classification

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

- SARO List Classification: Endangered
- SARO List History: Endangered (2024)
- COSEWIC Assessment History: Endangered (2022)
- SARA Schedule 1: Under consideration for addition
- Conservation Status Rankings: G-rank: G4; N-rank: N1; S-rank: S1

1.2 Species description and biology

Species description

Pumpkin Ash (*Fraxinus profunda*) is a medium to large, deciduous hardwood tree in the Olive Family (Oleaceae). There are no recognized subspecies or designatable units, and no known records of hybrids with other ash species (Harms 1990; COSEWIC 2022). In the past Pumpkin Ash has been considered a subspecies of either White Ash (*Fraxinus americana;* (Bush 1897)) or Green Ash (*Fraxinus pennsylvanica;* (Nesom 2010)). Some authors claimed the morphology was not distinctive enough to support an independent species (Miller 1955; Wilson and Wood 1959). However, due to key differences from both White and Green Ash in ploidy, morphology and ecological niche, Pumpkin Ash is now considered an independent species (Wallander 2008; Whittemore et al. 2018).

Pumpkin Ash generally grows to a height of 15 to 35 m, with some rare trees growing up to 45 m (Harms 1990; Missouri Department of Conservation 2006; Nesom 2010; Atha and Boom 2017). The word ‘pumpkin’ in the name ‘Pumpkin Ash’ refers to the tendency of the trees to form swollen, buttressed bases when the trees grow in their preferred wet-bottomland habitat (Figure 1) (Harms 1990; Nesom 2010). The swollen base often used to characterize Pumpkin Ash cannot be used as an identifying feature, as other ash species, such as Green Ash, can produce a similar swollen base if growing in a flooded area (Harms 1990; COSEWIC 2022). Diameter at breast height (DBH) varies considerably but mature trees growing on ideal sites may have a DBH of up to 173 cm (Harms 1990). The bark of Pumpkin Ash is similar in appearance to White Ash, with a furrowed texture and a gray-brown colour (Nesom 2010). The appearance of the bark ridges ranges from almost parallel to a convoluted network (Figure 1) (Nesom

2010). The average crown spread of mature Pumpkin Ash is not well established. Green Ash and White Ash are closely related to Pumpkin Ash and may have average crown spreads similar to Pumpkin Ash (Whittemore et al. 2018). Green Ash has a crown spread of approximately 13.5 to 15 m, while White Ash has a crown spread of approximately 12.2 to 18.3 m (Gilman and Watson 1993b; Gilman et al. 2019). Pumpkin Ash is at risk of windthrow due to its shallow root system (COSEWIC 2022). This root system is characteristic of other bottomland species and may hamper the uptake of water and nutrients during droughts (COSEWIC 2022).

Pumpkin Ash has pinnate leaves characteristic of other ash species (Figure 2) (Nesom 2010). The pinnate leaves are generally 20 to 50 cm long and composed of 7 to 9 lanceolate leaflets with a distinctly rounded base (Nesom 2010; Atha and Boom 2017). The dimensions of each leaflet are roughly 9 to 20 cm long and 4 to 8 cm wide (Atha and Boom 2017). The upper surface of the leaves is smooth and dark green, while the underside is uniformly downy and paler in colour (Figure 2) (Nesom 2010). The margins or edges of each leaflet are essentially smooth (entire) but occasionally appear vaguely serrate (Nesom 2010; Atha and Boom 2017). The petiolules or stalks of each leaflet are 5 to 12 mm in length and slightly winged (Nesom 2010). The main stalk of the leaf is generally 8 to 15 cm long, though it can rarely be as short as 5 cm (Nesom 2010). Compared with other Ontario ashes, this species tends to have a tall bole, narrow crown, and somewhat droopy leaves (M. Gartshore pers. comm. 2024). The leaf scars of Pumpkin Ash are crescent to inverted cone shaped and not particularly distinctive from those of White Ash; however, the crescent tends to be more deeply notched in the leaf scars of Pumpkin Ash (Whelden 1934; Nesom 2010; Atha and Boom 2017). The leaf scar may also look convex due to the presence of raised bundle scars (Figure 1) (Whelden 1934).

This species is dioecious (individuals may be male or female) (Nesom 2010). The long calyx of the petalless flowers remains present and visible at the base of the samaras (Nesom 2010; Atha and Boom 2017). Pumpkin Ash samaras range from 5 to 8 cm long and 7 to 12 mm wide, with a wing that extends over 1/3 of the length of the fruiting body (Nesom 2010; Atha and Boom 2017). Pumpkin Ash can be difficult to identify but can be differentiated from the other ashes of Ontario using a combination of the following features:

- underside of leaflets lacking tiny nipple-like bumps (papillae) or with only a few sparse papillae at greater than 40x magnification (COSEWIC 2022)
- average length of unwinged portion of petiolules greater than 7 mm (COSEWIC 2022)
- petiole, main leaf stalk and underside of leaflets hairy (COSEWIC 2022)
- base of leaflets are rounded and truncate, petiolules are unwinged for most of their length (COSEWIC 2022)
- calyx 2 to 5 mm (usually 4 mm) long when examined on samaras (Waldron et al. 1996; Waldron 2003)

Figure 1. Bark, twig and samara features of Pumpkin Ash. Distinctive samaras with long persistent calyx (Top Left, scale = cm; photo by William van Hemessen). Winter twig showing leaf scars, terminal bud and lateral buds (Top Right; photo by Brynn Varcoe). Dead Pumpkin Ash with a swollen base (Bottom Left; photo by Mary Gartshore). Bark (Bottom Right; photo by Brynn Varcoe).

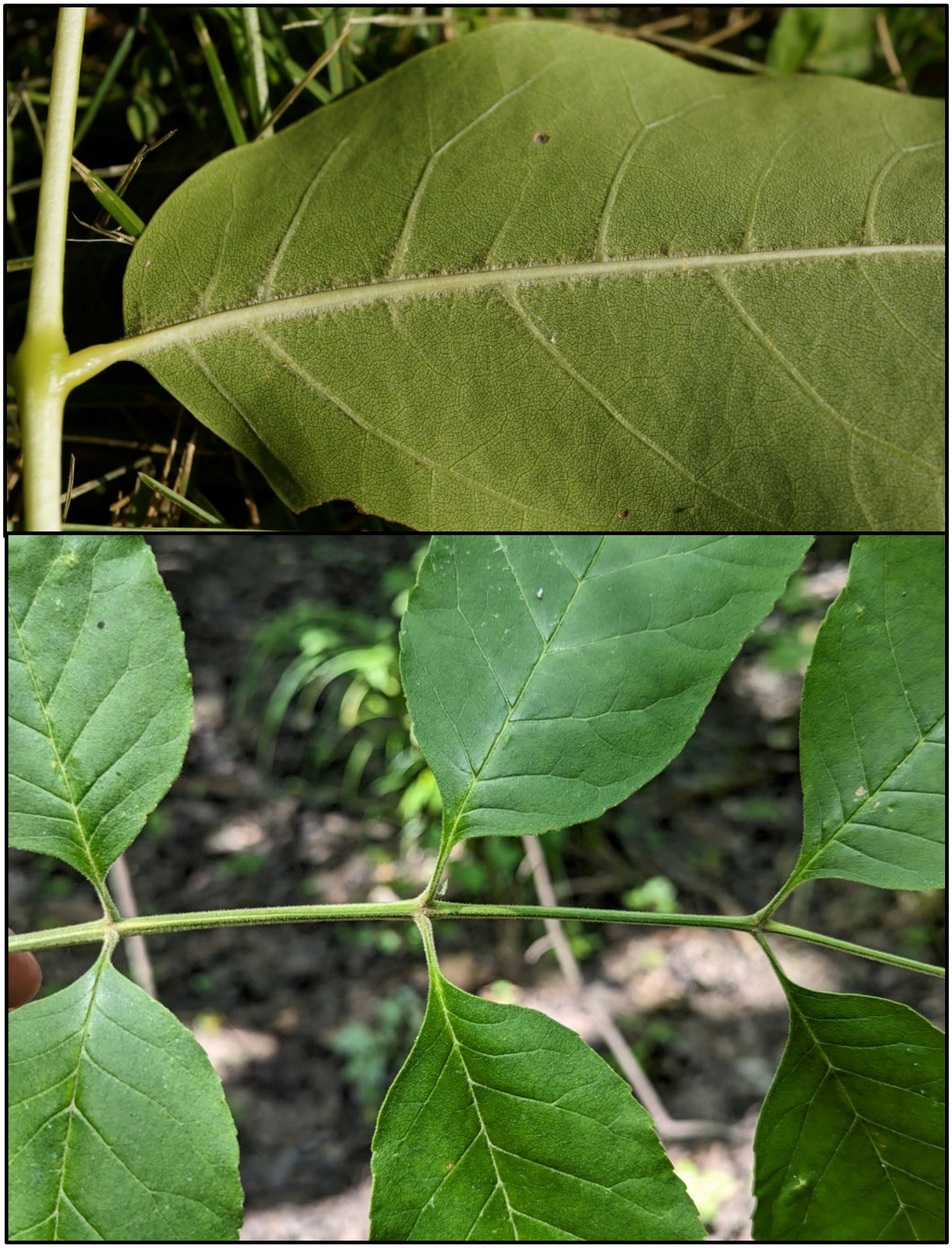

Figure 2. Underside and upper side of the compound leaf of Pumpkin Ash. Underside (Top; photo by Sean Fox). Upper side (Bottom; photo by William van Hemessen).

Alternative names and synonyms

Pumpkin Ash has only one recognized scientific name *Fraxinus profunda* (Bush 1897); however, there have been other names proposed and/or used. Other names include *Fraxinus tomentosa* (Michaux 1812-1813), *Calycomelia profunda* (Bush) Nieuwl., *Calycomelia tomentosa* Kostel., *Fraxinus americana* var. *profunda* Bush, *Fraxinus michauxii* Britton, *Fraxinus pennsylvanica* subsp. *profunda* (Bush) A.E. Murray, *Fraxinus pennsylvanica* var. *profunda* (Bush) Sudw., and *Fraxinus profunda* var. *ashei* E.J. Palmer (Royal Botanic Gardens Kew 2024). No specific word for Pumpkin Ash in Ojibwe, Munsee or any Iroquoian language was found during the background review.

Species biology

Flowering occurs from April to May, before the leaves of the tree emerge (Harms 1990; Wallander 2008; Nesom 2010). Seeds become mature in late August to October and fall between October and December (Harms 1990; Knight et al. 2010). The fruit or samaras are single seeded but are produced in clusters (Harms 1990). Pumpkin Ash can reach sexual maturity at a relatively young age, with trees as young as 10 years old producing seeds (Harms 1990). It is believed that Pumpkin Ash takes longer to reach sexual maturity in its northern range; however, research on this is lacking (COSEWIC 2022). As Pumpkin Ash are dioecious they can only cross-pollinate not self-pollinate, and both male and female plants are needed for sexual reproduction (COSEWIC 2022). Pumpkin Ash are wind-pollinated, so males and females must be in relatively close proximity of each other for successful reproduction. While there are no studies on pollen dispersal of Pumpkin Ash, Wright (1952) found that for Green and White Ash pollen counts decreased from 2502 grains at 25 ft (8 m) to 2 grains at 400 ft (122 m) from the source, while captured pollen of European Ash (*Fraxinus excelsior*) was found to have decreased by 50 percent at a distance of 200 m from the source (Eisen et al. 2022). The Forest Stewards Guild recommends distances of less than 400 ft (122 m) between male and female ash trees to increase the likelihood of pollination (D’Amato et al., 2020).

Pumpkin Ash is not known to be a prolific seed producer (Sterrett 1915; Harms 1990). Like other ash species Pumpkin Ash may produce large seed crops during mast years; however, there is not enough data to provide an estimate on the periodicity of these mast years (Bonner 2008). The seeds of Pumpkin Ash are winged, which serves to decrease fall speed and increase dispersal distance (Norberg 1973). Wind dispersal is the primary method by which Pumpkin Ash seeds, known as samaras, are spread (Harms 1990). The dispersal distance of Pumpkin Ash samaras has not been researched. There is dispersal distance data for the most closely related ash species to Pumpkin Ash, White Ash and Green Ash. White Ash samaras have been recorded travelling up to 140 m from the parent tree, while Green Ash samaras have been modelled as having a long-distance dispersal of 150 m downwind and 23 m upwind using the most appropriate model (Fowells 1965; Schlesinger 1990; Schmiedel et al. 2013). European Ash have recorded dispersal distances of up to 1.4 km (Wardle 1961). Pumpkin Ash samaras are quite a bit larger (anywhere between 0.5 cm to 5.5 cm larger) than the samaras of both of the aforementioned ash species, which may impede their wind dispersal ability (Atha and Boom 2017). Some Pumpkin Ash samaras are spread via water and while in water remain viable for several months (Harms 1990). The Manna Ash (*Fraxinus ornus*) was found to spread along the Hérault River system where it is invasive at an average rate of 970 m/yr, which was attributed to the water transport of the samaras during periodic fall flooding (Thébaud and Debussche, 1991). Both Green Ash and European Ash have also demonstrated spread by water transport, with Green Ash proving the most successful of the two species. Green Ash samaras had a longer mean floating time than European Ash, and showed improved germination rates when they are stored in water for a period of time (Schmiedel and Tackenberg 2013). In dry seed bank collections that are intentionally preserved, viability estimates and expectations may be up to several decades (Knight et al. 2010, L. Liston pers. comm. 2024). Limited data is available regarding seed viability in natural environments, though it is expected to vary depending on environmental factors.

Fully developed embryos in a state of physiological dormancy are present within the shed seeds of Pumpkin Ash (COSEWIC 2022). Seed germination occurs above ground and is most successful on bare, wet soil (Harms 1990). Germination occurs more readily within openings in the canopy, though Pumpkin Ash can be moderately shade tolerant (Harms 1990). Overall, young Pumpkin Ash is considered a fast grower when compared to other North American ash species, in some cases even outgrowing Green Ash (Sterrett 1915; Harms 1990). Though Pumpkin Ash prefers moist soils and tolerates saturation, it grows less rapidly in areas with high levels of saturation such as the margins of swamps (Harms 1990).

Epicormic shoot production was noted in Pumpkin Ash by Harms (1990) and William van Hemessen (pers. comm. 2024) though no specific estimates of shoot viability or quantity were given. The ability of Green Ash to produce regenerative epicormic shoots was documented in Michigan by Kashian (2016). In fact, epicormic sprouting was the dominant mode of regeneration, accounting for 40 to 57 percent of all regeneration within Emerald Ash Borer (*Agrilus planipennis)* damaged ash stands (Kashian 2016). A mean of 62 percent of the trees that had been top-killed by Emerald Ash Borer produced root generated shoots, and 27 percent of shoots greater than 4 cm DBH produced seeds during the mast seeding year (Kashian 2016). As Pumpkin Ash is closely related to Green Ash, it is possible that epicormic sprouting could result in a similar level of regeneration in Pumpkin Ash. Coppicing of ash trees and encouraging epicormic shoots as a method of silviculture management has been utilised to perpetuate elm in the UK during the Elm Bark Beetle outbreak and may also be applicable in Canada to Pumpkin Ash and Emerald Ash Borer (Mark Brown pers. comm. 2024). Epicormic ash sprouts from the root collar will form new roots, allowing for ash regeneration without seeds (Sterret 1915).

While no studies were found on Pumpkin Ash seed banks, research on other ash species has found variable results regarding seed viability. Klooster et al. (2014) found that Black, White, and Green Ash seeds do not form a persistent seed bank in the soil or on the forest floor. However, other studies have found that Ash seeds can remain viable in the soil up to eight years (Schopmeyer 1974; Wright and Rauscher 1990;

Sutherland et al. 2000). Studies have found that once mortality of mature ash trees is largely complete, new ash seedlings are either greatly reduced or completely missing from the forest tree community (Kashian and Witter 2011; Klooster et al. 2014).

Current estimates of generation time and the maximum age of Pumpkin Ash are primarily produced from other ash species in combination with the sparse data related to the average reproductive age of Pumpkin Ash. The current generation length estimates from the International Union for Conservation of Nature (IUCN) and COSSARO is 40 to 50 years (or 60 years according to the COSEWIC report from 2022), with a maximum age of 200 to 300 (Westwood et al. 2017; COSSARO 2022). Sterrett (1917) tested the lumber qualities of North American ash species and sampled wood from three Pumpkin Ash trees. The three trees had ages of 180, 220 and 230 (Sterrett 1915). Given the age of these trees it is likely that the maximum age of Pumpkin Ash is greater than 200.

Little is known about the physiology of Pumpkin Ash. Research on the physiological adaptations of Green Ash to flooded conditions may be applicable to Pumpkin Ash, as it is closely related and grows in habitat that undergoes similar if not greater flooding (Nesom 2010). Research by Gomes and Kozlowski (1980) indicates that Green Ash undergoes adventitious rooting during flooding which was correlated with higher absorption of water and stomatal (pores that act as gas exchange valves) reopening. Another potential adaptation towards flood tolerance that Pumpkin Ash could exhibit is maintaining high concentration of root starch, although this is not an adaptation exhibited by Green Ash (Gravatt and Kirby 1998).

The interspecific interactions and ecological role of Pumpkin Ash are largely unknown and understudied. Only one arthropod was identified as making use of Pumpkin Ash in a study completed by Wagner and Todd (2015). The mite that was identified is not a specialist on Pumpkin Ash; however, based on records from similar species, such as Green Ash, there are likely other arthropod species that make use of Pumpkin Ash that have yet to be recorded (Gandhi and Herms 2010; Wagner and Todd 2015). Pumpkin Ash samaras are eaten by a variety of birds such as Wood Ducks (*Aix sponsa*), while the twigs and leaves are occasionally browsed on by White-tailed Deer (*Odocoileus virginianus*) (Harms 1990; Waldron 2003). In general, ash seeds are considered a moderately important food source for woodland songbirds and ground foraging birds such as grouse and turkeys (Wagner and Todd 2015). Rodents, ungulates and lagomorphs also forage and feed on the foliage and seeds of ash species (Harms 1990; Wagner and Todd 2015).

Cultural significance

Ash trees were and are used by the Indigenous people of North America for a variety of purposes, the most well documented of them being basketry (Densmore 1928; Jourdan 2013). Based on review of the literature and consultation with Indigenous communities within the historical range of Pumpkin Ash in Ontario, there are no known uses of Pumpkin Ash specifically (S. Lunham Jr. pers. comm. 2024; P. General. pers. comm

2024). However, it is possible that it was not distinguished from White and/or Green Ash and was used in similar ways. It is also likely that at some point it was used as a source of firewood. Other uses of ash by Indigenous people in North America include; snowshoe frames (wood), sleds (wood), cradle boards (wood), bows and arrows (wood), wig-wams (bark), medicinal treatments (leaves, inner bark, smoke) and food (cambium layer) (Densmore 1928; Uprety et al. 2012).

1.3 Distribution, abundance and population trends

Global distribution

Pumpkin Ash is solely found within Eastern North America (COSEWIC 2022). Southern Ontario is the most northern portion of Pumpkin Ash's global range, while its most southern subpopulations exist in Louisiana and Florida (COSEWIC 2022). The most easterly population lies within New York, while the most westerly is within Louisiana (COSEWIC 2022). It is not evenly distributed across this range, but instead has several core areas, including one within the lowlands of the Mississippi and Ohio river valleys and another within the Gulf and Atlantic coastal plains (COSEWIC 2022). The only suspected introduced or non-native Pumpkin Ash populations occur in Connecticut (COSEWIC 2022).

Ontario distribution and population trends

Within Canada, Pumpkin Ash has a very limited range that is restricted to the Carolinian Zone of Southern Ontario (COSEWIC 2022). This zone accounts for only 0.8 percent of the global range of Pumpkin Ash and contains relatively few recorded Pumpkin Ash (Figure 3) (COSEWIC 2022). The historic extent and distribution of Pumpkin Ash is largely unknown. Pumpkin Ash was not identified in Ontario until 1992 (Waldron et al.1996). This was after large swaths of suitable habitat and wetland within Southern Ontario had been converted to agriculture and housing (Penfound and Vaz 2022). Since its official discovery in Ontario through to the introduction of the destructive and invasive Emerald Ash Borer (see **Threats to survival and recovery** for more detail), no expansive effort was made to survey the species. Because of the lack of survey data, there are no baseline distribution or population estimates prior to European colonization or even prior to the introduction of Emerald Ash Borer. It is unknown whether Pumpkin Ash was more widespread or relatively rare before both major threats were introduced, although Waldron et al. (1996) describes Pumpkin Ash as a common associate of Southwestern Ontario swamp communities.

The COSEWIC report from 2022 identifies 419 Pumpkin Ash individuals occupying approximately 1,800 ha of habitat. Thirty-nine subpopulations were investigated via field work in 2021, of which 13 are considered extant, 3 are known to be extirpated, 12 are presumed extirpated and 11 are of unknown status. The locations of these subpopulations are provided in Figure 3. Almost all individuals fell within the seedling or sapling class (350 individuals at <5 cm DBH), while 56 trees were classified as saplings (5 to 10 cm), 11 were classified as immature trees (10 to 20 cm) and only two were greater than 20 cm and classified as mature (COSEWIC 2022). Both of these mature trees were sexually mature; however, they were both female (COSEWIC 2022). The larger of the two trees was a split stem tree with DBHs of 20 and 24 cm (COSEWIC 2022). This tree was heavily infested with Emerald Ash Borer at the time of the survey, with one trunk being almost completely dead (COSEWIC 2022).

Since the release of the 2022 COSEWIC report, there have been several additional element occurrences confirmed by the Natural Heritage Information Centre (NHIC). These are shown in Figure 3. Other observations reported to the NHIC are considered candidate element observations, but have yet to be confirmed as an occurrence or are pending review by the NHIC. Many of these candidate occurrences are either not recent (i.e., not from within 5 years), lacking details on maturity and health or overlap with confirmed extant observations from the COSEWIC document. These candidate element occurrences, along with seven research grade iNaturalist records, and four additional locations identified by the co-author of the COSEWIC report after its publication (W. Van Hemessen pers. comm. 2024) are not shown on Figure 3 as they are unverified. Targeted sampling should occur at these locations and at other sites in Ontario with suitable habitat to confirm the status of Pumpkin Ash.

The total number of Pumpkin Ash across the province is unknown; however, based on habitat availability, there may be up to 1,257 individuals that have yet to be discovered (COSEWIC 2022). The maximum provincial estimates produced in the COSEWIC report are 2,000 immature trees and 10 sexually mature trees (COSEWIC 2022). Population decline is hard to estimate due to sparse historical distribution and abundance data; however, estimated population decline is a minimum of 97.5 percent, as of 2022 (COSEWIC 2022). One cultivated specimen is known to be maintained at the University of Guelph Arboretum and was not included within the map below.

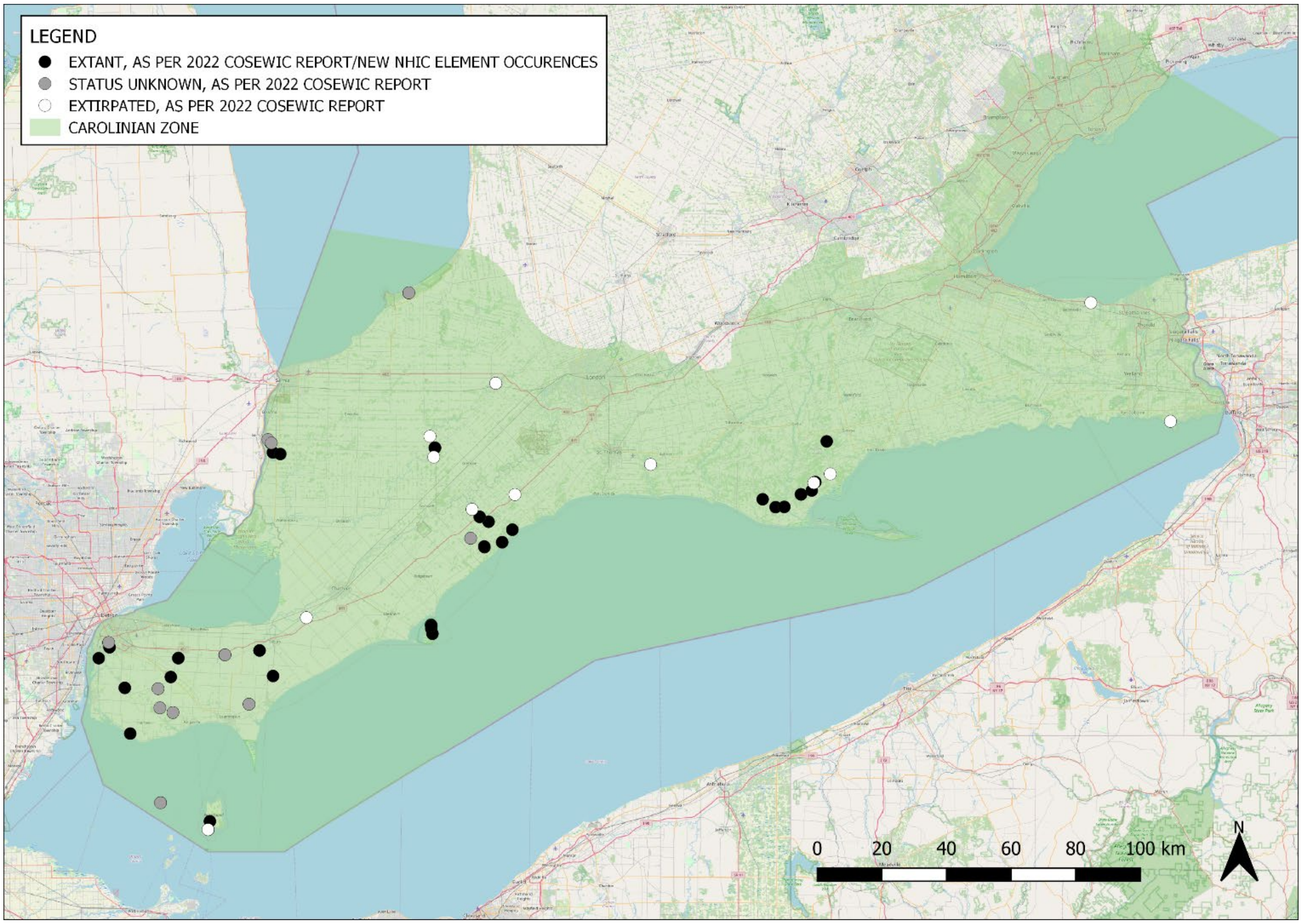

Figure 3. Historical and current distribution of the Pumpkin Ash in Ontario.

1.4 Habitat needs

The bottomland habitat of Pumpkin Ash varies across its global range, but almost always has wet to very wet mineral soils (Harms 1990; MacFarlane and Meyer 2005; Nesom 2010). Soil texture varies but is usually somewhere in between silt loam and clay loam, with a surface of muck or peat (Harms 1990). Along the East Coast of the USA, it is found in coastal marshes, swamp margins, large river floodplains, deep sloughs and tidal estuaries (Harms 1990). It is often found in habitat that is seasonally flooded and is considered a flood tolerant species (Nesom 2010). In the Atlantic coastal plain, it is found within the edges of swamps and in river bottoms (Harms 1990). This habitat use is characteristic of Pumpkin Ash that grow in Southern Maryland, Southeastern Virginia to Northern Florida and west to Louisiana (Harms 1990). Very little is known about the habitat requirements of Pumpkin Ash, particularly within the northern portion of its range.

In Ontario, Pumpkin Ash is considered an obligate wetland species found in deciduous forests and swamps with a coefficient of wetness of -5 (Oldham and Bakowsky 1995;

COSEWIC 2022). The Ontario range of Pumpkin Ash lies entirely within the Carolinian zone/Lake Erie Lowland ecoregion within the Mixedwood Plains Ecozone (Nature Conservancy of Canada 2019). Pumpkin Ash in its Ontario range is sometimes found in drier mesic sites, though it is still considered drought intolerant (Harms 1990; Waldron et al. 1996). This may be a result of the artificial drainage associated with heavy agricultural activity that is characteristic of the region (Waldron et al. 1996).

Pumpkin Ash is generally considered a minor component of forest communities and cover types throughout its range (Harms 1990). Common associate tree species with ranges in Ontario include: Red maple (*Acer rubrum*), Silver Maple (*Acer saccharinum*), Freeman's Maple (*Acer* x *freemanii*), Black willow (*Salix nigra*) and other willows, Swamp Cottonwood (*Populus heterophylla*), Pin Oak (*Quercus palustris*), Swamp White Oak (*Quercus bicolor*), Black Gum (*Nyssa sylvatica*), and Kentucky Coffee-tree (*Gymnocladus dioicus*). On dryer sites associate tree species include American Elm (*Ulmus americana*) and other elms, and Green Ash (Harms 1990; Waldron et al. 1996; Waldron 2003; COSEWIC 2022).

Information on Ecological Land Classification (ELC) communities utilised by Pumpkin Ash is limited. Investigation of the Great Lakes Shoreline Ecosystem (GLSE) inventory, which includes data for the Canadian side of the Great Lakes shoreline from the land to water or wetland interface to 2 km inland, found some overlap between ecosites identified in this inventory and identified Pumpkin Ash trees (MNRF, 2022). The most common ecosites containing Pumpkin Ash were Dry to Fresh and Moist Hardwood Treed communities (ELC codes beginning with TRT-HNd and TRT-HNf) and Hardwood Treed Swamp communities (ELC codes beginning with SWT-Hm), along with instances of Hardwood Plantation, Deciduous Thicket, Mixedwood Treed, Hedgerow and Marsh communities. The most common ecosites were Moist Carolinian Coarse Mineral Hardwood Treed, Moist Hickory +/ Maple +/ Oak Fine Mineral Hardwood Treed, Moist Red Maple Fine Mineral Hardwood Treed, Ash +/ White Elm Coarse Mineral Hardwood Swamp and Silver Maple +/ Freeman's Maple Fine Mineral Hardwood Swamp. These communities are found in lower slope areas, seepage areas, bottomlands, tablelands with poor drainage, and swamps with seasonal inundation and short flood duration. Many of the Hardwood Treed communities contained Hardwood Treed Swamp inclusions (MNRF, 2022). Common species associated with these ecosites include Silver Maple, Red Maple, Freeman's Maple, Sugar Maple (*Acer saccharum*), Black Maple (*Acer nigrum*), Eastern Hop-hornbeam (*Ostrya virginiana*), Green Ash, Black Ash, White Ash, American Elm, Northern Red Oak (*Quercus rubra*), White Oak (*Quercus alba*), Black Oak (*Quercus velutina*), Bur Oak (*Quercus macrocarpa*), Shagbark Hickory (*Carya ovata*), Bitternut Hickory (*Carya cordiformis*), Willow species, Paper Birch (*Betula papyrifera*), and Yellow Birch (*Betula alleghaniensis*).

The Critical Root Zone (CRZ), or area around a single tree that has the highest root density, of Pumpkin Ash is not known. Based on the methods outlined by Coder (2018) and the maximum DBH estimate provided by Harms (1990), the CRZ diameter on a large Pumpkin Ash would be 51.8 m. Because of the extremely limited information regarding average DBH, crown spread and root system of Pumpkin Ash, this estimate may not be a reliable value of the CRZ.

1.5 Limiting factors

Environmental Factors

Pumpkin Ash is at the very northern end of its range in Southwest Ontario, as it is restricted to the Carolinian Zone. There are no confirmed occurrences of Pumpkin Ash above ~43.2 °N (COSEWIC 2022), although the similarity of Pumpkin Ash to Green Ash may have led to misidentifications and the range may be greater. Due to its limited range within the Carolinian Zone, Pumpkin Ash is confined to the most developed area of Ontario, particularly due to the presence of large swathes of agricultural land, much of which is drained former wetland, previously Pumpkin Ash habitat (Ducks Unlimited 2010; Penfound and Vaz 2022). The large size of the samaras may also limit its ability to spread large distances across a fragmented landscape (Atha and Boom 2017). As Pumpkin Ash range is so limited and the subpopulations are so fragmented, the ability of Pumpkin Ash to expand outside of its current range due to climate change-induced range shift is severely limited (see **Habitat needs** for further detail).

Pumpkin Ash, like all ash species, has shallow, widespread roots due to their preference for moist sites. This leaves them susceptible to both excessive flooding and drought, as well as freeze-thaw injury in the winter, as they are minimally frost hardened and winter active (Ward et al. 2009; Auclair et al. 2010; Palik et al. 2011). Damp soils like those preferred by Pumpkin Ash are a particular cause of freeze-thaw injury in northern hardwood trees, as is a reduction in the size of the snowpack (Auclair et al. 2010). Pumpkin Ash has previously been noted to be susceptible to dieback when drought occurs at its wettest sites (Harms 1990). The shallow widespread roots also make Pumpkin Ash susceptible to windthrow (COSEWIC 2022).

Lack of Genetic Diversity and Gene Exchange

The National Seed Tree Centre has seed collections from three Ontario Pumpkin Ash, with one collection from 2006 and the others collected from the two mature Pumpkin Ash identified during surveys in 2021 (COSEWIC 2022; D. McPhee pers. comm. 2024). This is a poor genetic background with which to re-establish Ontario Pumpkin Ash (M. Spearing pers. comm. 2024). In addition, the remaining subpopulations of Pumpkin Ash within Ontario are highly fragmented, which will limit the exchange of genetic material between them due to the limited wind-dispersal of pollen and samaras (Wright 1952; COSEWIC 2022).

1.6 Threats to survival and recovery

Pumpkin Ash is highly understudied compared to other ash species across its range both in Ontario and the United States, due to its relative scarcity when compared with other ash species, the ease with which it is misidentified and its high susceptibility to Emerald Ash Borer. It was already in serious decline prior to the introduction of Emerald Ash Borer to Southwest Ontario, due to habitat fragmentation, urban sprawl and wetland loss (Marchant 2007; Ducks Unlimited 2010; Penfound and Vaz 2022). Emerald

Ash Borer is currently the most serious threat to Pumpkin Ash survival in Southwestern Ontario and across its range (Westwood et al. 2017).

Emerald Ash Borer

Emerald Ash Borer is an iridescent metallic green beetle which is native to Asia (Herms and McCullough 2014; Hope et al. 2020). It was first identified in North America in Detroit, Michigan and Windsor, Ontario in 2002, but is believed to have been introduced to North America in the 1990s on wood packaging material, prior to the implementation of stringent regulations (CFIA 2014c; MacQuarrie et al. 2015). Since it was first identified in Windsor, it has spread across Canada, and is now present not only in Ontario, but also Manitoba, Quebec, New Brunswick and Nova Scotia, with these areas now part of the regulated area for Emerald Ash Borer in Canada (Figure 4) (Hope et al. 2020; CFIA 2024b).

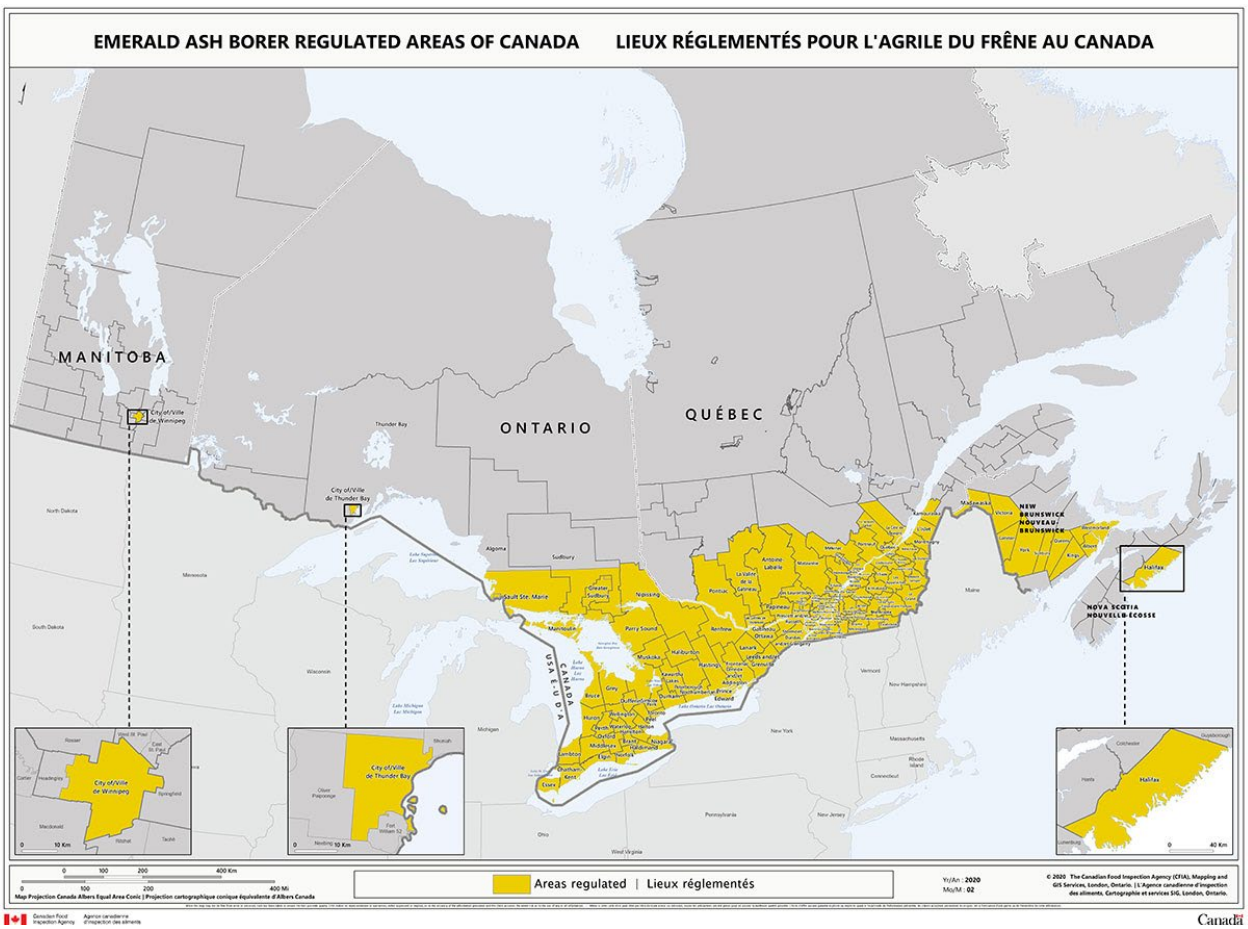

Figure 4. Areas regulated for Emerald Ash Borer within Canada (CFIA 2024a)

Trees infested with Emerald Ash Borer exhibit a number of symptoms. Initial symptoms include a significant thinning of the tree’s foliage, which is sometimes accompanied by yellowing of the remaining foliage, particularly in the upper canopy (Marche II 2012). Another initial symptom is the presence of unusual epicormic shoots (Marche II 2012).

Symptoms that develop as infestation progresses are serpentine, frass-packed tunnels through the outer sapwood and lower bark caused by the feeding of the larvae, and small D-shaped holes approximately 3 to 4 mm in width, which are exit tunnels created by the adult beetles when they emerge (Poland and McCullough 2006; Rebek et al. 2008; Marche II 2012). Although adult beetles also feed on foliage, it is the tunnels that will eventually lead to the crown death of the tree, as they cause massive damage to the tree's vascular system (Rebek et al. 2008; Marche II 2012; Catling et al. 2022). Both stressed and healthy trees are attacked by Emerald Ash Borer, and an ash stand is likely to see almost complete mortality within six years of the initial infestation (Poland and McCullough 2006; Knight et al. 2013).

All North American ash species have proven to be susceptible to Emerald Ash Borer to some degree, with Blue Ash (*Fraxinus quadrangulata*) demonstrating some level of resistance and Pumpkin Ash demonstrating high susceptibility (Rebek et al. 2008; COSEWIC 2014; Bickerton 2017; Kelly et al. 2020; COSEWIC 2022; R. Buggs, pers. comm. 2024). This high susceptibility of Pumpkin Ash to Emerald Ash Borer, as well as its limited range in Ontario, has put it at particular risk of extirpation by the beetle (COSEWIC 2022). Emerald Ash Borer can infest and kill ash trees as small as 2.5 cm DBH, although this has not been confirmed in Pumpkin Ash specifically (Poland and McCullough 2006; McCullough et al. 2019).

There is conflicting research as to whether the density of ash trees, either the same or different species, within an area causes increased or decreased tree mortality by Emerald Ash Borer. It is likely that there are multiple factors at play that dictate the dynamics of Emerald Ash Borer infestation, including the phase of the infestation and the scale at which it is occurring (Kappler et al. 2018). In some studies, more rapid mortality was found in stands with lower ash density (Knight et al. 2013), while in others, trees with the healthiest canopies were in areas with lower ash density (Kappler et al. 2018). These studies occurred during different phases of Emerald Ash Borer infestation, with the former study occurring during the growth stage of infestation, and the latter during the post-invasion stage. Smith et al. (2015) found that ash density was not related to percentage mortality, either positively or negatively. Some studies have suggested that pure ash stands are more resistant to Emerald Ash Borer than mixed hardwood forests (Kashian 2016). As Pumpkin Ash does not form large, pure stands, but occurs as a minor component in hardwood forest communities, this may put it at higher risk of Emerald Ash Borer (Harms 1990; Stevens 2012; COSEWIC 2022).

There are native predators to Emerald Ash Borer that may help to control populations of the beetle. Woodpeckers and other bark-foraging birds, particularly Hairy Woodpecker (*Picoides villosus*), Downy Woodpecker (*Picoides pubescens*), Red-bellied Woodpecker (*Melanerpes carolinus*) and White-breasted Nuthatch (*Sitta carolinensis*), will consume Emerald Ash Borer. One study found that predation by bark-foraging birds significantly reduced densities of the insect by upwards of 85 percent and that predation intensity increased with increasing Emerald Ash Borer infestation levels (Flower et al. 2014). Woodpecker predation was found to be the most important cause of natural mortality for Emerald Ash Borer within the study area, accounting for nearly all natural mortality of late-instar larvae and was particularly prevalent in winter when late-instar larvae are most abundant (Jennings et al. 2016; McCullough et al. 2019). Emerald Ash Borer has been credited with an increase in populations of bark-foraging bird species due to enhanced survival and reproduction related to increased food availability (Koenig et al. 2013; Koenig and Liebhold 2017).

While survival of large mature Pumpkin Ash trees infested with Emerald Ash Borer is unlikely, the species will likely persist for some time in the form of orphaned juveniles and epicormic sprouting (Kashian 2016). These sprouts may form adventitious roots and become independent from the tree from which they formed (Kashian 2016). This will be particularly important for ash trees in Emerald Ash Borer impacted areas where the seed bank has been depleted. Regeneration from epicormic sprouting and the survival of the orphaned cohort of established seedlings and saplings becomes the main method of maintaining ash presence in these areas, although regeneration through seedlings may continue if mast years occur relatively frequently (Klooster et al. 2014; Kashian 2016). Epicormic shoots as young as seven years old have been found to be important contributors to mast years for Green Ash (Kashian 2016), which may be the case for Pumpkin Ash.

Habitat Loss and Fragmentation

Second to Emerald Ash Borer as the greatest threat to Pumpkin Ash is habitat loss and fragmentation. Prior to the establishment of Emerald Ash Borer in Ontario, Pumpkin Ash was already under threat by rampant wetland and forest clearing in the Carolinian Zone, largely for agricultural land, but also for urban sprawl (Ducks Unlimited 2010; Environmental Commissioner of Ontario 2018a; Environmental Commissioner of Ontario 2018b; Penfound and Vaz 2022). Prior to European settlement 200 years ago, Southern Ontario was almost continuously forested, and 25 percent was covered in wetland (Environmental Commissioner of Ontario 2018a; 2018b). Following the establishment of European settlements, Southern Ontario has seen an estimated loss of 72 percent of its wetlands to an average of 6.8 percent wetland cover and has an average of about 25 percent forest cover (Environmental Commissioner of Ontario 2018a; 2018b). In Southwestern Ontario in the Carolinian Zone, forest cover averages at only 12.1 percent, with some municipalities in the most western part of the Ontario Peninsula having less than 5 percent forest cover (Environmental Commissioner of Ontario 2018b). Approximately 85 percent of wetland loss in Southern Ontario from pre-settlement to 2002 was due to conversion to agricultural uses (Ducks Unlimited 2010; Environmental Commissioner of Ontario 2018a). The draining of wetlands reduces or destroys both wetland area and function, and removal of the water from the soil destroys the habitat of obligate wetland species like Pumpkin Ash (Environmental Commissioner of Ontario 2018a). While Pumpkin Ash is unlikely to have been present in every single wetland which has been cleared from the Carolinian Zone, it is likely that it was much more widespread throughout its range prior to European settlement (COSEWIC 2022). Widespread habitat fragmentation caused by forest and wetland clearance also isolated Pumpkin Ash subpopulations, preventing gene exchange and cross pollination (Penfound and Vaz 2022; COSEWIC 2022).

Contemporary trends in forest and wetland loss typically involve less wholesale clearing of woodlands, and more incremental degradation due to the gradual expansion of urban sprawl through development and infrastructure projects, as well as the gradual encroachment of agricultural activities (Environmental Commissioner of Ontario 2018b; 2018a). Two Ontario Pumpkin Ash subpopulations have been documented to have been lost to incremental conversion of woodland to agriculture; one between 2007 and 2009, and one between 2019 and 2021 (COSEWIC 2022). Woodlands and wetlands are offered some protection under the Provincial Policy Statement 2020 (PPS) when designated as Significant Woodlands or Provincially Significant Wetlands. (Environmental Commissioner of Ontario 2018b; 2018a). However, not every municipality designates Significant Woodlands and Significant Wetlands; as a result, wetlands and woodlands are unprotected when unevaluated or if they fail to meet the criteria for significance.

In addition to agriculture, road and rail construction was responsible for a high proportion of wetland loss, both historically and in recent years (Penfound and Vaz 2022). Some extant Pumpkin Ash subpopulations have been identified as being close to roads and transmission lines and are a risk of removal or pruning due to infrastructure maintenance, particularly when they are in an advanced state of decline due to Emerald Ash Borer infestation (COSEWIC 2022).

Other Pests and Diseases (native)

Browsing by White-tailed Deer is likely putting pressure on regenerating juvenile Pumpkin Ash (Kashian et al. 2018), as deer have been noted to browse on this species and are considered a threat to other endangered ash species in Southern Ontario (Harms 1990; Waldron 2003; COSEWIC 2014; 2018;). Black Ash (*Fraxinus nigra*) is considered palatable to White-tailed Deer. When deer exclusion fences were installed around study plots, it was observed that Black Ash in the fenced plots experienced significantly higher mean density gains compared to those in unfenced plots (White 2012). As other species of ash are considered palatable to deer, it is likely that Pumpkin Ash is too.

Currently there is no specific information on other diseases and pests that specifically affect Pumpkin Ash (Harms 1990). However, in North America there are multiple other pests and diseases that can cause harm to ash trees in general, including ash anthracnose disease, ash yellows, verticillium wilt, ash rust and powdery mildew. How these affect Pumpkin Ash is unknown.

Other Pests and Diseases (non-native)

Cottony Ash Psyllid (*Psyllopsis discrepansis*) is a small phloem-feeding insect native to Europe, which has now been identified in Nova Scotia and the Prairie Provinces (Wamonje et al. 2022). Infestation with Cottony Ash Psyllid has been associated with infections of the bacterium '*Candidatus* Liberibacter solanacearum', which is likely to exacerbate the negative effects of insect infestation and lead to tree death (Wamonje et al. 2022). Black Ash has proven to be susceptible to this insect and associated bacterial infection, but it is unknown what affect it may have on Pumpkin Ash.

In Europe, Chalara Ash Dieback caused by the fungus *Hymenoscyphus fraxineus*, likely native to Asia, has decimated populations of European Ash (*Fraxinus excelsior*) (Nielsen et al. 2017; Plumb et al. 2020). Studies performed to investigate the susceptibility of North American Ash trees to this fungus have shown that while Pumpkin Ash is susceptible to the fungus, it shows relatively low susceptibility (Nielsen et al. 2017; Plumb et al. 2020). It should be noted, however, that these assessments were based on a very small number of individuals (L. Kelly, pers. comm. 2024). Chalara Dieback tends to affect small ash trees more than larger ones which, in combination with Emerald Ash Borer which targets the larger trees, could be disastrous for North American ash trees (K. Knight, pers. comm. 2024). A risk management assessment for Chalara Dieback has been produced by the CFIA, with the decision to implement phytosanitary import requirements for ash plant material (CFIA 2014b).

Climate Change

Canada is warming at twice the global average, with Southwestern Ontario estimated to warm 5 to 6 °C between the time periods of 1971-2000 and 2071-2100 (Colombo et al. 2007; Bush and Lemmen 2019). Summer and winter precipitation over that time is expected to be reduced by up to 10 percent (Colombo et al. 2007). Pumpkin Ash is susceptible to fire and drought and grows best in saturated soils (Harms 1990). Increased temperatures and a reduction in precipitation will be harmful for this species. Pumpkin Ash is considered to have moderate vulnerability to climate change due to its distribution relative to anthropogenic barriers, its historical hydrological niche and its physiological hydrological niche (Brinker et al. 2020; COSEWIC 2022).

With reduced precipitation and increased temperatures, reduced snowpacks and increased soil saturation are likely, increasing the risk of freeze-thaw injury and associated ash dieback (Auclair et al. 2010; Palik et al. 2011). As winter storms, tornadoes and windstorms increase alongside droughts and heat waves, there is increased likeliness that shallow-rooted trees like Pumpkin Ash will be more likely to experience windthrow (Gough et al. 2016; Catling et al. 2022).

Logging and Wood Harvesting

Pumpkin Ash has limited commercial value in Canada given its rarity, and is therefore not a target species. However, the timber can be used to generate high-valued lumber and is used in the manufacture of tool and implement handles (Harms 1990; Stevens and Pijut 2012; 2014). Ash is also considered a high-quality firewood, the transportation of which allowed for the fast rate of spread of Emerald Ash Borer before restrictions were placed on its movement (COSEWIC 2022). In addition, the pre-emptive removal of healthy and non-hazardous ash trees by both municipalities and private landowners may be negatively impacting Pumpkin Ash (COSEWIC 2022). Logging and wood harvesting occurs throughout the Carolinian Zone, and Pumpkin Ash subpopulations may be at risk, including those in the Walsingham properties, which are owned by the

LPRCA and have been confirmed to contain Pumpkin Ash, which are slated for logging (COSEWIC 2022; M. Gartshore, per. comm. 2024).

Recreational Activities

All Terrain Vehicle (ATV) trails within forested swamps with Pumpkin Ash present can cause severe damage, particularly to young seedlings and sprouts which may be growing around dying mature trees (Figure 5). ATVs can compact the soil and crush young seedlings and saplings (COSEWIC 2022).

Figure 5. ATV damage within the South Walsingham Rolling Sand Ridges Area of Natural Scientific Interest, an area where Pumpkin Ash are known to occur. Photo by Mary Gartshore.

1.7 Knowledge gaps

General Species Knowledge

As mentioned in **Species description and biology**, there is a lack of general knowledge on Pumpkin Ash physiology, including habitat tolerances and growth patterns. The taxonomic descriptions of this tree are relatively limited, particularly in comparison with other ash species. One variable that is largely unknown is the crown diameter of Pumpkin Ash. While height, DBH and circumference can be found in species descriptions, crown diameter is often missing. Crown diameter is used to calculate the radial distance from the stem of a tree to provide root protection, as in the recovery strategies for Black Ash and Blue Ash (Bickerton 2017; Catling et al. 2022). The only reference to crown diameter of Pumpkin Ash is in records of unusually large or champion trees. The National Champion Pumpkin Ash in Big Oak Tree State Park, Missouri, had a spread of 77 ft (23 m) (Missouri Department of Conservation 2006), while the largest Pumpkin Ash in Michigan had an average crown spread of 50 ft or 15.2 m (Campbell and Ehrle 2004). However, data from more representative Pumpkin Ash trees are lacking and data from the closely related Green Ash and White Ash will need to be consulted.

Information on ELC communities where Pumpkin Ash occurs is not directly available. The GLSE has provided information on coastal ecosites where Pumpkin Ash may be found, many of which are also ecosites found inland. An investigation of these ecosites and similar ecosites with similar plant communities and soil moisture will hopefully identify more potential ecosites that either contain Pumpkin Ash or suitable habitat for this species for future reintroductions. This information would aid in refining the habitat regulation and may help in identifying potential sites where Pumpkin Ash may be present.

Lack of Pumpkin Ash-specific Research

Most of the research done on threats facing Pumpkin Ash has been performed on other North American ash trees (Green, White and Black), as they are much more common and more economically important. Pumpkin Ash is a minority component of forest communities, while Green, White and Black Ash can form large single-species stands which are relatively easy to identify and study (Harms 1990; Stevens 2012; Kashian 2016).

Investigating the vigor of Pumpkin Ash epicormic shoots and their potential for becoming independent from the parent tree after succumbing to Emerald Ash Borer is important. This research is particularly significant given the observed importance of epicormic sprouting in Green Ash following infestation (Kashian 2016). It is also unknown how long Pumpkin Ash seeds form viable seedbanks in the soil, another important aspect as to how well Pumpkin Ash will be able to regenerate following Emerald Ash Borer infestation, although it is likely to be similar to the closely related Green and White Ash.

Research on Emerald Ash Borer dynamics and Pumpkin Ash is non-existent outside of its confirmed high susceptibility. How quickly Pumpkin Ash succumbs once infested, how well parasitoid wasps can parasitise larvae inside the tree, how effective insecticides are and the other knowledge gaps highlighted, need to be filled to give a more complete idea on how this species needs to be managed with respect to the Emerald Ash Borer.

Information is required on how susceptible Pumpkin Ash is to other diseases and pests, both native and non-native. There is no information on Pumpkin Ash susceptibility to diseases and pests besides Chalara Dieback. Additionally, there is a lack of information on the impact of deer browse on Pumpkin Ash, aside from its known occurrence.

Detailed Location Information

Further information on the species abundance and distribution is needed. Investigations into historical sites were undertaken to complete the COSEWIC assessment for this species (COSEWIC 2022). Additionally, Rondeau Provincial Park, the largest site investigated, was too large to be fully examined, leading to a probable underestimate. However, additional surveys should be undertaken in other potential sites within the Carolinian Zone to see if there are currently unknown subpopulations in existence. This will be particularly important in identifying other mature trees, with the hopes of collecting seed to bolster existing seed collections. Any identified Pumpkin Ash should be reported to the NHIC, so that the known population size may be monitored.

1.8 Recovery actions completed or underway

Legislative Protection

Pumpkin Ash is listed provincially in Ontario as Endangered under the *Endangered Species Act, 2007* (ESA), which protects both the plant and its habitat. Pumpkin Ash was assessed by COSEWIC as Endangered in May 2022 and is under consideration for listing under Schedule 1 of the *Species at Risk Act, 2002* (SARA).

Forests and wetlands that contain Pumpkin Ash habitat may be protected by a number of different legislation, including the Forestry Act, 1990, Crown Forest Sustainability Act, 1994, Planning Act, 1990, the Conservation Authorities Act, 1990, Great Lakes Protection Act, 2015, Provincial Parks and Conservation Reserves Act, 2006, Municipal Act, 2001, Environmental Assessment Act, 1990, Conservation Lands Act, 1990 and Invasive Species Act, 2015 (Catling et al. 2022).

Genetic Investigations and Breeding Programs

Investigations into the genetics of North American ash trees and the development of breeding programs to develop Emerald Ash Borer resistance are occurring in both Canada and the United States, although with limited work conducted specifically on Pumpkin Ash. As this species is so rare, more focus has been placed on the more abundant Black Ash, White Ash and Green Ash species.

The United States Department of Agriculture (USDA) has made progress in their ash resistance breeding program, focusing mainly on Green Ash and more recently on White Ash (T. Poland, pers. comm. 2024). The USDA has implemented a “lingering ash” definition, which are the ash trees that are used for resistance breeding programs and genetic analysis (Knight et al. 2012). Lingering ash trees are “healthy ash trees with a diameter at breast height (DBH) greater than 10 cm that have survived for at least two years after the initial ash mortality rate reached 95 percent from Emerald Ash Borer" (Kappler et al. 2018). While in some cases these trees may simply be the last to be infested, others have demonstrated rare phenotypes that provide them with resistance to Emerald Ash Borer (Kappler et al. 2018). As Pumpkin Ash is both rare and highly susceptible to Emerald Ash Borer, finding individuals that meet this definition has been challenging. The USDA has only identified one individual of this species that met the lingering ash definition, which has been grafted and will be tested in the next couple of years (J. Koch, pers. comm. 2024). Additionally, as Pumpkin Ash are so susceptible to Emerald Ash Borer, specimens showing even partial resistance (i.e. surviving slightly longer than their peers in the same location) are a useful starting point for a breeding program (K. Knight, pers. comm. 2024). The Canadian Forest Service (CFS) is also working on breeding programs using the same approach as the USDA, as well as characterising genetic diversity, although currently only for Black Ash (N. Isabel, pers. comm. 2024).

It is likely that the two mature Pumpkin Ash discovered in Elgin County in 2021 meet this description of lingering ash, given that Emerald Ash Borer have been present in the county since at least 2007, and these trees were still producing seed in 2021 (K. Knight, per. comm. 2024; J. Koch, pers. comm. 2024). Collecting scion from these trees, grafting them using hot callus grafting, and planting clonal replicates somewhere they can be protected from Emerald Ash Borer would be a good start for an Emerald Ash Borer resistance breeding program. However, co-operation with the USDA would likely be needed for this, as there is currently no-one in Canada that can perform the required grafting work (C. MacQuarrie, pers. comm. 2024; D. McPhee, pers. comm. 2024).

In vitro regeneration of Pumpkin Ash has been investigated as a method for the mass propagation and genetic transformation of the species to preserve it. As such, a plant regeneration protocol for the species was developed, and has since been utilised to produce Pumpkin Ash hypocotyls which were successfully transformed with a strain of *Agrobacterium tumefaciens* (Stevens and Pijut 2012; 2014). The transformation and regeneration protocol could form the basis for future genetic improvement of Pumpkin Ash, alongside the breeding programs already mentioned to produce insect-resistant trees (Stevens and Pijut 2014). However, Pumpkin Ash has proved to be a very easy woody plant to micropropagate and could be produced very easily through tissue culture (M. Stevens, pers. comm. 2024). As such, propagating and planting more resistant individuals of genetically diverse stock through breeding programs with genetically diverse backgrounds could be a good strategy for preserving Pumpkin Ash, with or without associated genetic transformations.

Seed Collections

Seed collections from three Ontario Pumpkin Ash trees are stored at the National Tree Seed Centre (NTSC) in New Brunswick (D. McPhee pers. comm. 2024; M. Spearing pers. comm. 2024). One collection was made in 2006 from a tree in Wallaceburg, Chatham-Kent, Ontario, while five collections were made in 2021 from the two mature trees identified in the field work for the COSEWIC report (COSEWIC 2022; D. McPhee pers. comm. 2024). An estimate of the viability of these seed collections was undertaken using an x-ray assessment (L. Liston, pers. comm. 2024). The number of estimated viable seeds is high for the 2006 collection. However, in 2021 fewer seeds were collected, which is in keeping with findings that seed production is considerably reduced following Emerald Ash Borer infestations (Kashian 2016). The seeds collected in 2021 also had a much lower percentage estimated viability, such that there are less than 100 estimated viable seeds from the 2021 collections. Any Pumpkin Ash trees in Ontario found with seeds present should be assessed for potential for seed collections for preservation.

Biological Control

Efforts to control Emerald Ash Borer using parasitoid wasps present in its native range have been attempted in both the United States and Canada. In the United States, the following four parasitoid species have been released: *Oobius agrili* (Encyrtidae), *Tetrastichus planipennisi* (Eulophidae), *Spathius agrili* (Braconidae) and *Spathius galinae* (Braconidae) (Duan et al. 2022). *O. agrili* is an egg parasitoid, while the remaining three species are larval parasitoids (Duan et al. 2022). In Canada, all but *S. agrili* have been released, as releases of *S. agrili* in the Northern United States have not been successful, suggesting a lack of suitability to the northern climate (Butler et al. 2022).

O. agrili, *T. planipennisi* and *S. galinae* have all been released in Ontario, although only *O. agrili* and *T. planipennisi* were released within the range of Pumpkin Ash (Butler et al. 2022). Three-thousand-two-hundred *O. agrili* were released in the Carolinian Zone in 2015 and 2016, and 8,687 *T. planipennisi* were released in 2013 and 2014, with a further 3,200 *O. agrili* and 19,030 *T. planipennisi* released in sites near the boundary of the Carolinian Zone in the same years (Butler et al. 2022). Early establishment of *T. planipennisi* was high, with adult parasitoids recovered at 81 percent of sites one to two years after release, although the number recovered for all three species was low, especially considering the number of parasitoids that had been released (Butler et al. 2022). There have been no releases in Southern Ontario since 2016, and no sites in Southern Ontario have been assessed for parasitoid establishment since then, as parasitoid releases are now being concentrated on the front line of Emerald Ash Borer infestation in the Maritimes (Butler et al. 2022, C. MacQuarrie, pers. comm. 2024). However, it is the intention of the CFS to assess Southern Ontario to see if the parasitoids have moved from their release sites and become established (C. MacQuarrie, pers. comm. 2024).

Native species of parasitoid wasps can also use Emerald Ash Borer as a host. *Atanycolus* spp. and *Phasgonophora sulcata* have been noted using Emerald Ash Borer larvae as hosts (Butler et al. 2022). While they were not actively released in Canada along with the non-native parasitoids, they were recovered from harvested trees, with *Atanycolus* spp. identified at 87 percent of the sampled release sites, and *Phasgonophora sulcata* identified at 50 percent (Butler et al. 2022). Emergence rates were much lower for the native parasitoids than for *T. planipennisi*, suggesting that while native parasitoids can use Emerald Ash Borer as a host, they are not as successful as the non-native species (Butler et al. 2022).

The use of parasitoid wasps does have implications for predation of Emerald Ash Borer by woodpeckers. Woodpeckers have shown a preference for non-parasitized larvae, such that when they encounter moderate to high parasitism rates in ash stands they will reduce their predation (Murphy et al. 2018). The reduction in the reproductive potential of Emerald Ash Borer in small regenerating ash forests in eastern New York and the complete cessation of reproduction of Emerald Ash Borer from such forests in Western New York has been attributed to the combined effects of biocontrol and woodpecker predation (Gould et al. 2022).

Insecticide Control

There are a number of different insecticides with different application methodology that are used to combat Emerald Ash Borer. Insecticide treatment should begin as soon as possible while the tree is still relatively healthy, as it will only prevent further damage to the tree and will be unable to reverse the damage caused by the serpentine galleries of the Emerald Ash Borer larvae (Herms et al. 2019). Most insecticides work systemically, and are transported throughout the tree via the vascular system, which must therefore be in sufficiently good condition for the insecticide to be taken up effectively (Herms et al. 2019).

Treatment options in Canada are more limited compared to those in the United States, due to the federal Pest Control Products Act, as well as a ban on the use of pesticides for cosmetic purposes in lawn and garden applications in Ontario, which includes ornamental ash trees (Davey Resource Group 2011). The Health Canada Pest Management Regulatory Agency has registered five different chemical pesticides containing three different active ingredients for the control of Emerald Ash Borer: TreeAzin (Azadirachtin), Ima-jet 10, Ima-jet and Confidor 200 SL (Imidacloprid), and Acecap 97 (Acephate) (Pest Management Regulatory Agency 2024). All of the above chemical insecticides have been registered for use via trunk injection for systemic protection only. In addition, a sixth fungal insecticide, Fraxiprotec (*Beauveria bassiana* strain CFL-A), was registered for use in Canada in 2022 (Pest Management Regulatory Agency 2024).

Insecticide control programs have been used to varying levels of success to protect Pumpkin Ash and other ash species. Two Pumpkin Ash trees at The Arboretum at The University of Guelph were both chemically treated, with one succumbing to Emerald Ash Borer six to seven years ago and one still healthy (S. Fox, pers. comm. 2024). In the Five Rivers MetroPark in Dayton, Ohio, 26 mature Pumpkin Ash trees have been treated with TREE-äge, an Emamectin Benzoate-based insecticide that is administered via trunk injection. These trees are currently healthy with good canopies and are among approximately 500 ash trees that are treated every two years within the park district (L. Zoromoski, pers. comm. 2024). Testing of multiple insecticide treatments in Michigan found that trunk injections of Emamectin Benzoate were the most successful insecticide treatment against Emerald Ash Borer when compared with basal trunk sprays of Dinotefuran and trunk-injections of Imidacloprid (McCullough et al. 2019). Emamectin Benzoate is one of six active ingredients in insecticides used to control Emerald Ash Borer in the United States that are not approved in Canada (Herms et al. 2019). Given its successful protection of ash trees in the United States, consideration of this insecticide for registration for use in Canada would be beneficial for Pumpkin Ash.

Treatment of urban trees in London, Ontario has been less successful. A TreeAzin treatment plan was initiated in 2013 for ash located in Environmentally Significant Areas in the city, all of which were native natural ash of known origin, with street trees having been injected prior to the development of the Environmentally Significant Areas treatment plan (S. Rowland, pers. comm. 2024). The treatment plan was not successful as it took too long for the already compromised trees to take up the insecticide. Around 15 percent of injected trees were lost between each two-year injection cycle. The program was discontinued within ten years due to mounting costs and fewer viable trees, and the last of the injected ash trees are scheduled to be removed in 2024 (S. Rowland, pers. comm. 2024).

One disadvantage to the use of trunk-injected insecticides is that they require drilling into the tree, which results in wounds that can cause long-term damage (Herms et al. 2019). Additionally, holes cannot be reused, so new ones must be drilled each injection cycle. While studies have found that ash trees are capable of producing new wood over the wounds (Herms et al. 2019), these wounds may cause problems for trees in particularly poor health. Given the large costs and multiple applications needed to maintain an insecticide treatment program, treatment should be limited to those trees considered to be particularly high-value.

Controls and Education on Emerald Ash Borer

While Emerald Ash Borer is capable of flying up to 2.5 km per day, with populations spreading at a rate of 20 km per year, the establishment of new populations is generally the result of people moving infested ash wood products such as firewood and nursery stock (Taylor et al. 2006; Herms and McCullough 2014; Hope et al. 2020). To prevent Emerald Ash Borer from spreading across the country, the CFIA restricted the movement of all firewood and ash materials within the regulated area (Hope et al. 2020). Regulations were first established in Southern Ontario in 2002 following the identification of Emerald Ash Borer, but the CFIA regulated area has since expanded as the beetle has spread from its original area of identification (Hope et al. 2020; CFIA 2024a).

The CFIA has also been involved in a number of education initiatives aimed at the general public, in order to facilitate awareness of the threat of Emerald Ash Borer. These initiatives include the launch of the “Don’t Move Firewood” campaign in 2008, which involves the production of brochures, posters, road signage and other communication products which are distributed annually with the help of partners, as well as participation in public shows and exhibits (CFIA 2014a).

Botanical Inventories within the Carolinian Zone

While not occurring with the specific intent of identifying Pumpkin Ash, conservation authorities, First Nations, municipalities and other organisations within the Carolinian

Zone have been performing botanical inventories and ELC surveys on their properties (A. Biddle, pers. comm. 2024; M. Brown, pers. comm. 2024; A. Heagy, pers. comm. 2024; L. Jones, pers. comm. 2024; V. McKay, pers. comm. 2024; C. Reinhart, pers. comm. 2024). These surveys have led to the identification of species at risk, including Pumpkin Ash, and may enable protective measures. The Long Point Region Conservation Authority (LPRCA) performs botanical inventories every year on their properties, which have identified locations of Pumpkin Ash subpopulations (C. Reinhart, pers. comm. 2024). Norfolk County undertakes botanical inventories of its forested properties to document the presence of Species at Risk and Provincially Significant Species, including Pumpkin Ash, and keep georeferenced data for future monitoring, although there are currently no efforts underway to preserve specific individuals (A. Biddle, pers. comm. 2024). ELC surveys of the Six Nations of the Grand River, the largest First Nations reserve in Canada, did not identify any Pumpkin Ash, but provides non-detection data for the range of this species (L. Jones, pers. comm. 2024).

Preservation of Known Pumpkin Ash Specimens

The Arboretum at the University of Guelph has been working with a number of Species at Risk or rare woody plants since the 1970s under the Rare Woody Plants of Ontario Program, archiving them onsite in gene bank seed orchards to represent the genetic diversity of these species from across the province (S. Fox pers. comm. 2024). The Arboretum currently has one specimen of Pumpkin Ash on the premises that was accessioned there in 1994 from seed collected in Devonwood Conservation Area, Windsor, Ontario, which is healthy and treated for Emerald Ash Borer, although it has never produced seeds (S. Fox, pers. comm. 2024). There are a number of small potted specimens that were provided to The Arboretum by Mary Gartshore, grown from seeds collected in Norfolk County prior to the establishment of Emerald Ash Borer (M. Gartshore, pers. comm. 2024). The Arboretum is currently planning on keeping some of these in pots, keeping them more protected from Emerald Ash Borer while maintaining the genetics of the population and hopefully producing some seeds from these in later years (S. Fox, pers. comm. 2024). While these specimens have not demonstrated resistance to Emerald Ash Borer, they could provide genetic diversity to a Pumpkin Ash breeding program.

2.0 Recovery

2.1 Recommended recovery goal

The recommended recovery goal for Pumpkin Ash in Ontario is to maintain all current naturally-occurring subpopulations and genetic diversity within its known range in the province, reintroduce Pumpkin Ash to suitable sites if the threat of Emerald Ash Borer can be mitigated, and to ensure its persistence as a functional, reproductive forest tree.

2.2 Recommended protection and recovery objectives

The recommended protection and recovery objectives for Pumpkin Ash are:

1. Evaluate threats and undertake actions to mitigate their impact.
2. Identify, protect and maintain Pumpkin Ash subpopulations, individuals and habitats for in-situ conservation.
3. Investigate ex-situ conservation to preserve population genetics with an aim of improving Emerald Ash Borer resistance over the long term.
4. Engage in educating stakeholders and rightsholders about Pumpkin Ash and Emerald Ash Borer.
5. Initiate research to fill knowledge gaps on Pumpkin Ash biology, threats and management.

2.3 Recommended approaches to recovery

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

Objective 1: Evaluate threats and undertake actions to mitigate their impact.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Long-term	Protection, Monitoring and Assessment, Research	**1.1** Monitor decline of Pumpkin Ash in Ontario and assess the causes. • Monitor the levels of Emerald Ash Borer infestation in Southwest Ontario. • Monitor White-tailed Deer populations in areas where Pumpkin Ash are present and take effective measure to prevent deer browse. • Monitor for the presence of other pests and diseases, both native and non-native, within the Carolinian Zone for proactive rather than reactive management.	Threats: • Emerald Ash Borer • Other pest and diseases (native and non-native) Knowledge gaps: • Lack of Pumpkin Ash-specific research
Critical	Short-term	Protection, Management	**1.2** Prevent damaging activities in areas where there are known Pumpkin Ash subpopulations. • Ensure any logging activities are conducted in a manner that do not impact Pumpkin Ash or it’s habitat. Prevent ATV damage through the use of signage, fencing etc.	Threats: • Logging and wood harvesting • Recreation activities

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Short-term	Protection, Management, Education and Outreach	**1.3** Encourage the use of insecticides to protect high-value trees (mature trees >20 cm DBH), if viable. • Identify any mature trees or trees nearing maturity for insecticide use, particularly those which are not showing high infection levels. • Identify any threats to the site and attempt to mitigate them. • Educate landowners and land managers as to why insecticide treatment is beneficial and when it should be used. • Investigate whether insecticides currently licensed for use against Emerald Ash Borer in the United States (particularly Emamectin Benzoate) are suitable for registration for use in Canada.	Threats: • Emerald Ash Borer

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Long-term	Monitoring and Assessment, Research	**1.4** Continue research into biological controls for Emerald Ash Borer. • Research effectiveness of biocontrol agents at controlling Emerald Ash Borer infestations in Pumpkin Ash. • Research how widespread biocontrol agents have become since their introduction to Ontario. • Develop or support the creation or maintenance of a repository for data collected on the distribution and population of biocontrol agents.	Threats: • Emerald Ash Borer Knowledge gaps: • Lack of Pumpkin Ash-specific research
Beneficial	Long-term	Research	**1.5** Develop climate models that investigate the potential impacts that climate change may have on Pumpkin Ash in Southwestern Ontario.	Threats: • Climate change Knowledge gaps: • Lack of Pumpkin Ash-specific research

Objective 2: Identify, protect and maintain Pumpkin Ash subpopulations, individuals and habitats for in-situ conservation.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Inventory, Monitoring and Assessment	**2.1** Continue to locate and inventory new Pumpkin Ash subpopulations across Southwestern Ontario for in-situ conservation. • Support municipalities, conservation authorities, First Nations and other landowners to perform biological inventories on their lands. • Produce a plain language identification guide for Pumpkin Ash to make identification more inclusive. • Encourage all Pumpkin Ash occurrence data to be provided to the NHIC. • Support municipalities and conservation authorities to develop sustainable forest management practices for the benefit of Pumpkin Ash.	Knowledge gaps: • Detailed location information
Critical	Ongoing	Protection, Management, Inventory, Monitoring and Assessment	**2.2** Monitor existing known subpopulations of Pumpkin Ash to promote the continued existence and health of the site. • Develop and/or consistently use standardized survey method, as well as tree health and impact and compensation assessments.	Threats: • All Knowledge gaps: • Detailed location information • Lack of Pumpkin Ash specific research

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Education and Outreach, Communication or Stewardship	**2.3** Communicate with landowners and land managers when a subpopulation is known or discovered to promote conservation and gain assistance with monitoring or treatment.	Threats: • All
Necessary	Short-term	Protection, Research	**2.4** Identify additional ELC communities that are associated with Pumpkin Ash in Southwestern Ontario to make it easier to identify and protect potential habitats and identify sites for reintroduction.	Threats: • Habitat loss and fragmentation Knowledge gaps: • General species knowledge

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Short-term	Protection, Management, Education and Outreach, Communication or Stewardship, Research	**2.5** Implement a habitat regulation for Pumpkin Ash under the ESA and provide clear guidelines on how these regulations should be implemented. • Provide materials to agricultural sector, land developers, consultants, proponents, contractors, engineers, etc. with information on Pumpkin Ash habitat regulations. • Carry out additional research on Pumpkin Ash so that the habitat regulation can be based on the best scientific information. • Monitor the effectiveness of the habitat regulation on protecting Pumpkin Ash.	Threats: • Habitat loss and fragmentation • Logging and wood harvesting • Recreational activities Knowledge gaps: • General species knowledge • Lack of Pumpkin Ash-specific research

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Beneficial	Long-term	Protection, Management, Inventory, Monitoring and Assessment, Research	**2.6** Work with Provincial Parks and other protected areas (conservation authorities, Nature Conservancy of Canada, small land conservation groups, etc.) to ensure that Pumpkin Ash on their property are effectively protected. • Determine site-specific management needs to manage the threats faced by Pumpkin Ash at each site. • Develop educational materials such as signage to alert the public to threats faced by Pumpkin Ash. • Manage recreation activity so that it is directed away from known Pumpkin Ash locations (e.g. trail design and location). • Manage these habitats with a view to reintroduction. • List Emerald Ash Borer as a prohibited invasive species under the *Invasive Species Act*.	Threats: • Habitat loss and fragmentation • Emerald Ash Borer • Recreational activities Knowledge gaps: Detailed location information

Objective 3: Investigate ex-situ conservation to preserve population genetics with an aim of improving Emerald Ash Borer resistance over the long term.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Protection, Management, Inventory	**3.1** Visit confirmed extant sites during the fruiting season to investigate for the presence of seeds. • If seeds are present, they should be collected as per Knight et al. (2010) and sent promptly to the NTSC for assessment and storage. • Support the maintenance of seed collection data. • Engage with First Nations within the Carolinian zone to work with the NTSC to develop seed collections managed under the principals of Ownership, Control, Access and Possession (OCAP®; First Nations Information Governance Centre 2024). • Ensure rapid permit approval or exemptions for conservation efforts, including seed collection. • Develop a contingency fund to support seed collection and forecasting in anticipation of mast years.	Threats: • All Knowledge gaps: • Detailed location information

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Critical	Ongoing	Protection, Management, Inventory, Monitoring and Assessment, Research	**3.2** Carry out research on Pumpkin Ash genetics and diversity for a breeding program. • Determine the number of individuals required to represent a genetically diverse sample of Southwestern Ontario's Pumpkin Ash. • Utilise the USDA's "lingering ash" criteria to assess identified Ontario Pumpkin Ash for resistance to Emerald Ash Borer, as well as juveniles that display some level of resistance. • Utilise these individuals as the basis for a breeding program for resistance within Pumpkin Ash in Ontario via the collection of scion and seed from these individuals. • Determine the feasibility of micropropagation for use in the breeding program.	Threats: • Emerald Ash Borer Knowledge gaps: • General species knowledge • Lack of Pumpkin Ash-specific research

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Ongoing	Protection, Management, Inventory, Monitoring and Assessment, Research	**3.3** Determine the feasibility and appropriateness of augmentation/ reintroductions from sources within and outside of Ontario. • Encourage collaboration with Pumpkin Ash researchers in the United States to take advantage of their techniques and expertise. • Engage with the USDA for assistance with grafting resistant individuals found in Ontario • Engage with Ohio MetroParks for access to their treated Pumpkin Ash for increased genetic diversity. • Develop and/or utilise best practices for translocation, including disease and pathogen screening, both inter-provincially and internationally. • Ensure that all federal/provincial/state regulations or policies are abided by.	Threats: • Emerald Ash Borer Knowledge gaps: • General species knowledge • Lack of Pumpkin Ash-specific research

1068 Objective 4: Engage in educating stakeholders and rightsholders about Pumpkin Ash and Emerald Ash Borer.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Short-term	Protection, Education and Outreach, Communication or Stewardship	**4.1** Engage with stakeholders and rightsholders (including the public, First Nations, industry, the agricultural sector, private landowners and land managers) about Pumpkin Ash. • Provide information and outreach material on Pumpkin Ash biology and a plain language identification guide, as well as information on habitat regulation under the ESA should one be developed, symptoms of Emerald Ash Borer infestation and how to report occurrence data to the NHIC.	Threats: • Emerald Ash Borer • Habitat loss and fragmentation • Logging and wood harvesting • Recreational activities Knowledge gaps: • General species knowledge • Lack of Pumpkin Ash-specific research • Detailed location information
Beneficial	Long-term	Education and Outreach, Communication or Stewardship	**4.2** Encourage the public to get involved with Pumpkin Ash conservation via citizen science projects, including surveys and monitoring, habitat conservation and stewardship.	Threats: • Emerald Ash Borer • Habitat loss and fragmentation • Logging and wood harvesting • Recreational activities

Objective 5: Initiate research to fill knowledge gaps on Pumpkin Ash biology, threats and management.

Relative priority	Relative timeframe	Recovery theme	Approach to recovery	Threats or knowledge gaps addressed
Necessary	Long-term	Research	**5.1** Research Pumpkin Ash biology, such as average size and crown width, ELC communities that the species is present in, quantitative data on habitat requirements that can be linked to how habitats may change with climate change.	Threats: • All Knowledge gaps: • General species knowledge
Necessary	Long-term	Research	**5.2** Research how Emerald Ash Borer affects Pumpkin Ash specifically, including tree survival time once infected, effectiveness of biological control, suitability of specific insecticides, influence of ash species density and survival mechanisms for infected Pumpkin Ash (e.g. epicormic shoots).	Threats: • Emerald Ash Borer Knowledge gaps: • Lack of Pumpkin Ash-specific research
Necessary	Long-term	Research	**5.3** Investigate the susceptibility of Pumpkin Ash to other pests and diseases, both native and non-native.	Threats: • Other pests and diseases (native and non-native) Knowledge gaps: • Lack of Pumpkin Ash-specific research

Narrative to support approaches to recovery

Throughout all recommended approaches to recovery, a common thread is the number of knowledge gaps related to Pumpkin Ash. Of all the native ash trees in Canada, it is the most poorly studied across its range, both in Canada and the United States. Unlike other species of ash, it does not form large stands that are easy to study, rather forming a minor component of hardwood forests (Harms 1990; Stevens 2012). Due to its relative rarity and the destruction of much of its habitat in Ontario, as well as across other areas of its range, knowledge of Pumpkin Ash general biology is poor. Specific work assessing Pumpkin Ash response to Emerald Ash Borer, biocontrol and insecticide measures, Pumpkin Ash genetics and resistance and how susceptible the species is to other pests and diseases is largely non-existent. Further investigations into Pumpkin Ash subpopulation locations and health, how Emerald Ash Borer directly affect this species, other pests and how climate change will impact Pumpkin Ash and its habitat will allow for better recovery approaches to protect this species. While Emerald Ash Borer is very widespread across the Carolinian Zone in Ontario, maintaining restrictions on the movement of firewood may be beneficial to any small, fragmented populations which may have escaped large-scale infestation.

Given the large costs and multiple applications needed to maintain an insecticide treatment program, treatment should be limited to those trees considered to be particularly high-value (mature trees >20 cm DBH). The two seed-producing mature trees identified during the 2021 field surveys would be good candidates if they are still in sufficiently good condition to benefit from insecticide treatment, but as they are on private land treatment of these trees may be complicated (W. Van Hemessen, pers. comm. 2024).

Another overarching thread is the need for outreach and communication with the public, private landowners, First Nations, land managers, the agricultural sector, land developers, consultants and other members of the private sector regarding this species, particularly with respect to education regarding identification, conservation and protection. A plain language identification guide would be particularly useful to give to the public, as most identification information for Pumpkin Ash currently is aimed at botanists and full of specialized terminology.

2.4 Performance measures

The performance measures described below outline ways to define and measure progress toward achieving the recovery goal and objectives presented in this document.

- Additional locations of Pumpkin Ash have been identified via targeted sampling of unverified sites and sites of appropriate habitat, and protection measures implemented accordingly

- Mature trees that can be used as the basis of a grafting or seed collection program based on the “lingering ash” criteria have been identified, and genetic material has been collected
- The 13 confirmed extant subpopulations have been maintained
- Increased numbers of Pumpkin Ash are observed in locations where threat mitigation has occurred
- The status of the 11 subpopulations of unknown status has been confirmed, and protection measures implemented accordingly
- Health of chemically treated trees has been maintained or improved post-insecticide treatment
- Assessing engagement with and success of citizen science programs to identify and protect Pumpkin Ash
- Pumpkin Ash management plans have been developed and implemented by appropriate municipalities, parks, protected areas and conservation authorities
- Representative genetics of Ontario Pumpkin Ash have been safeguarded

2.5 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 for Pumpkin Ash should be protected to allow for trees already present to persist, and support subpopulations of a size sufficient to ensure viability for the foreseeable future. Protecting an area around mature trees will also provide protection for seed dispersal zones and establishment of a seed bank for future regeneration, should trees produce seeds.

The recommended area to be protected for this species is the ELC ecosite in which one or more Pumpkin Ash is present, along with a radial distance of at least 23 m from each individual Pumpkin Ash to protect trees growing on the edge of the ecosite. If an ELC ecosite is unable to be determined, a minimum radial distance of 23 m from each individual shall be utilised, even if there is habitat in that radius that is considered unsuitable. This radial distance is to protect the estimated root zone of the tree and is discussed further below.

It is recommended that the habitat regulation not include Pumpkin Ash that have been planted as horticultural specimens in landscaped areas or gardens. Pumpkin Ash that are planted from seeds, restoration plantings or individuals produced from breeding programs that are planted in natural and naturalised areas to increase the Pumpkin Ash subpopulations are recommended to be protected under the habitat regulation.

Data produced from future scientific studies should be used to update this habitat regulation as needed, particularly if they indicate that there are additional habitat features that should be taken into account for the habitat regulation.

Rationale for recommendation

The recommendations for the regulated area take into consideration habitat for individual trees and habitat for seed dispersal and regeneration.

Regulation of habitat for individuals

In order to promote the health of individual Pumpkin Ash, survival of the tree should be ensured as much as possible, particularly when faced with the threat of Emerald Ash Borer.

The radial area recommended for inclusion in a habitat regulation is based on protecting the substrate which contains the root system of each individual tree, and which supports its ecological functioning. A tree's roots can spread up to three times the diameter of the tree's canopy and damage to the roots can lead to the premature decline and death of otherwise healthy trees (Jim 2003). Given that most if not all Pumpkin Ash in Southwestern Ontario will be affected by Emerald Ash Borer, protecting the roots of these trees will help them to survive long enough to produce seeds which can either be collected for preservation or form a seed bank in the soil.

As mentioned previously, data on the crown spread (or diameter) of Pumpkin Ash was very sparse. The largest Pumpkin Ash in the United States has a crown spread of 77 ft or 23.5 m, while the largest Pumpkin Ash in Michigan had a crown spread of 50 ft, or 15.2 m (Campbell and Ehrle 2004; Missouri Department of Conservation 2006). Data on average Pumpkin Ash spread is not available. As Pumpkin Ash is closely related to Green and White Ash, information on the average crown spread of these trees was consulted. Green Ash have a crown spread of 45 to 50 ft (13.7-15.2 m), while White Ash have a crown spread of 40 to 60 ft (12.2-18.3 m) (Gilman and Watson 1993b; 1993a; Gilman et al. 2019). Given the similarities in crown spread between Green Ash and White Ash, two closely related species to Pumpkin Ash, the crown spread of 15.2 m demonstrated by the Michigan Pumpkin Ash is likely a good representative of a large Pumpkin Ash tree. As tree roots can spread up to three times this diameter, that means that the root zone may be up to 45 m in diameter, or 22.5 m radius from the trunk of the tree. This has been rounded up to 23 m for the recommended habitat regulation for this species.

As this area has been calculated from sparse Pumpkin Ash data, and utilising comparisons with the closely related ash species, this recommended area may change with future study.

Regulation of habitat for seed dispersal and regeneration

Pumpkin Ash habitat is now severely fragmented, with subpopulations largely isolated from each other (Environmental Commissioner of Ontario 2018b; COSEWIC 2022).

Movement of genetic material between subpopulations is now highly unlikely without outside assistance. The large samaras of Pumpkin Ash may prevent them from dispersing by wind as far as those of other species, although they may be carried by water. The wetland habitats of Pumpkin Ash, besides being vulnerable to development, are often surrounded by drained land which is either developed or farmed, meaning there are limitations in the surrounding lands outside of the ecosites in which the Pumpkin Ash are located for seeds to grow. Therefore, it is recommended that the regulated habitat include the whole ELC ecosite polygon in which at least one individual of this species is identified, as this will provide space and habitat for seeds produced to grow or form a seed bank within the soils, providing this species with an enhanced chance to persist in the landscape.

Glossary

Arthropod: an invertebrate animal of the phylum Arthropoda, such as an insect, spider, or crustacean.

Bole: tree trunk.

Bottomland: low-lying land often within a floodplain.

Bundle scars: circular or barred regions within the leaf scar where bundles of vascular tissue that had connected the leaf and the stem broke off.

Cambium layer: a cell layer in the trunk where growth occurs.

Calyx: part of the flower that surrounds the growing bud.

Canopy: the total area of the tree or trees where the leaves and outermost branches extend.

Clay loam: clay is the dominant soil in the loam mixture.

Coefficient of wetness: estimated probability for which a species is likely to occur in wetland soils. Negative values indicate an affinity for wetlands.

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

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

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

1 = critically imperiled
2 = imperiled
3 = vulnerable
4 = apparently secure
5 = secure
NR = not yet ranked

Crown: the total of an individual plant's aboveground parts, including stems, leaves and reproductive structures.

Diameter at Breast Height (DBH): a standard method of expressing the diameter of the trunk or bole of a standing tree. Typically measured at 1.35 m from the highest point of ground at the tree’s base.

Dioecious: having the male and female reproductive organs in separate individuals.

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.

Entire: smooth leaf margins.

Epicormic shoot: a shoot growing from normally-dormant buds underneath the bark of some trees on their trunk, stem, or branches.

Estuary: water where saltwater tide and river outflow meet.

Frass: faeces of insect larvae. Commonly associated with wood boring species as evidence of insect activity within a piece of wood.

Genetic transformation: the transfer and incorporation of foreign DNA into a host genome.

Hypocotyl: the part of the stem of an embryo plant beneath the stalks of the seed leaves and directly above the root.

iNaturalist: citizen science website/application where the public can report observations.

Instar: a phase between two periods of molting in the development of an insect larva.

In vitro: outside the living body and in an artificial environment.

Lanceolate: shaped like the head of a lance, narrow oval with a tapered point.

Leaf scar: mark left by a leaf where the petiolules attached, after falling from the twig.

Loam: soil composed of clay, silt and sand.

Mesic: habitat or soil with moderate and balanced moisture.

Micropropagation: the propagation of plants by growing plantlets in tissue culture and then planting them out.

Muck: soil made up of 20 to 80 percent organic matter.

National Tree Seed Centre (NTSC): the primary centre for long-term seed storage for Canada's trees and shrubs for conservation purposes. The NTSC is part of the Canadian Forest Service.

Natural Heritage Information Centre (NHIC): the 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.

OCAP®: the First Nations principles of ownership, control, access, and possession assert that First Nations have control over data collection processes, and that they own and control how this information can be used.

Obligate wetland species: occurs in wetlands under natural conditions greater than 99 percent of the time.

Parasitoid: an organism that lives in close association with its host at the hosts expense, eventually resulting in the death of the host.

Peat: surface layer of a soil consisting of partially decomposed organic material.

Petiolule: stalks of leaflets.

Phloem: the tissue in vascular plants that conducts food from the leaves and other photosynthetic tissues to other plant parts.

Phytosanitary: measures for the control of plant diseases especially in agricultural crops.

Pinnate: having leaflets arranged on either side of the stem, typically in pairs opposite each other.

Samara: a winged nut containing one seed.

Sapwood: the outer, living layers of a tree’s trunk below the bark, which engage in the transport of water and nutrients through the tree.

Scion: a detached living portion of a plant (such as a bud or shoot) joined to a stock in grafting.

Silt Loam: silt is the dominant soil in the loam mixture, soil containing not less than 70 percent silt and clay and not less than 20 percent sand.

Slough: a swamp with deep mud.

Species at Risk Act, 2002 (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 Schedules 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 (Ontario Regulation 230/08).

Subpopulation: geographically or otherwise distinct groups within the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less).

Wig-wam: semi-permanent domed or tepee-like structure used by First Nations groups such as the Ojibwe. Usually covered in bark.

Windthrow: the uprooting of trees by wind.

List of abbreviations

COSEWIC: Committee on the Status of Endangered Wildlife in Canada
COSSARO: Committee on the Status of Species at Risk in Ontario
CFIA: Canadian Food Inspection Agency
CFS: Canadian Forest Service
CRZ: Critical Rooting Zone
DBH: Diameter at Breast Height
ELC: Ecological Land Classification
ESA: Ontario's *Endangered Species Act, 2007*
GLSE: Great Lakes Shoreline Ecosystem inventory
ISBN: International Standard Book Number
MECP: Ministry of the Environment, Conservation and Parks
NHIC: Natural Heritage Information Centre
NTSC: National Tree Seed Centre
OCAP®: Ownership, Control, Access, and Possession
SARA: Canada's *Species at Risk Act*
SARO List: Species at Risk in Ontario List
USDA: United States Department of Agriculture

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Personal communications

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